

Nutritional disease

Nutritional disease, any of the nutrient-related diseases and conditions that cause illness in humans. They may include deficiencies or excesses in the diet, obesity and eating disorders, and chronic diseases such as cardiovascular disease, hypertension, cancer, and diabetes mellitus. Nutritional diseases also include developmental abnormalities that can be prevented by diet, hereditary metabolic disorders that respond to dietary treatment, the interaction of foods and nutrients with drugs, food allergies and intolerances, and potential hazards in the food supply. All of these categories are described in this article. For a discussion of essential nutrients, dietary recommendations, and human nutritional needs and concerns throughout the life cycle, see nutrition, human.

TABLE OF CONTENTS

- Introduction
- Nutrient deficiencies
- Nutrient toxicities
- Diet and chronic disease
- Food-drug interactions
- Food allergies and intolerances
- Toxins in foods
- Foodborne illnesses
- Botanicals and functional foods

Nutrient deficiencies

Although the so-called diseases of civilization—for example, heart disease, stroke, cancer, and diabetes—will be the focus of this article, the most significant nutrition-related disease is chronic undernutrition, which plagues more than 925 million people worldwide. Undernutrition is a condition in which there is insufficient food to meet energy needs; its main characteristics include weight loss, failure to thrive, and wasting of body fat and muscle. Low birth weight in infants, inadequate growth and development in children, diminished mental function, and increased susceptibility to disease are among the many consequences of chronic persistent hunger, which affects those living in poverty in both industrialized and developing countries. The largest number of chronically hungry people live in Asia, but the severity of hunger is greatest in sub-Saharan Africa. At the start of the 21st century, approximately 20,000 people, the majority of them children, died each day from undernutrition and related diseases that could have been prevented. The deaths of many of these children stem from the poor nutritional status of their mothers, as well as the lack of opportunity imposed by poverty.

Only a small percentage of hunger deaths is caused by starvation due to catastrophic food shortages. During the 1990s, for example, worldwide famine (epidemic failure of the food supply) more often resulted from complex social and political issues and the ravages of war than from natural disasters such as droughts and floods.

Malnutrition is the impaired function that results from a prolonged deficiency—or excess—of total energy or specific nutrients such as protein, essential fatty acids, vitamins, or minerals. This condition can result from fasting and anorexia nervosa; persistent vomiting (as in bulimia nervosa) or inability to swallow; impaired digestion and intestinal malabsorption; or chronic illnesses that result in loss of appetite (e.g., cancer, AIDS). Malnutrition can also result from limited food availability, unwise food choices, or overzealous use of dietary supplements.

Selected nutrient-deficiency diseases are listed in the table.

Select nutrient-deficiency diseases		
disease (and key nutrient involved)	symptoms	foods rich in key nutrient
xerophthalmia (vitamin A)	blindness from chronic eye infections, poor growth, dryness and keratinization of epithelial tissues	liver, fortified milk, sweet potatoes, spinach, greens, carrots, cantaloupe, apricots
rickets (vitamin D)	weakened bones, bowed legs, other bone deformities	fortified milk, fish oils, sun exposure
beriberi (thiamin)	nerve degeneration, altered muscle coordination, cardiovascular problems	pork, whole and enriched grains, dried beans, sunflower seeds
pellagra (niacin)	diarrhea, skin inflammation, dementia	mushrooms, bran, tuna, chicken, beef, peanuts, whole and enriched grains
scurvy (vitamin C)	delayed wound healing, internal bleeding, abnormal formation of bones and teeth	citrus fruits, strawberries, broccoli
iron-deficiency anemia (iron)	decreased work output, reduced growth, increased health risk in pregnancy	meat, spinach, seafood, broccoli, peas, bran, whole-grain and enriched breads
goitre (iodine)	enlarged thyroid gland, poor growth in infancy and childhood, possible mental retardation, cretinism	iodized salt, saltwater fish

Source: Gordon M. Wardlaw, *Perspectives in Nutrition* (1999).

Protein-energy malnutrition

Chronic undernutrition manifests primarily as protein-energy malnutrition (PEM), which is the most common form of malnutrition worldwide. Also known as protein-calorie malnutrition, PEM is a continuum in which people—all too often children—consume too

little protein, energy, or both. At one end of the continuum is kwashiorkor, characterized by a severe protein deficiency, and at the other is marasmus, an absolute food deprivation with grossly inadequate amounts of both energy and protein.

An infant with marasmus is extremely underweight and has lost most or all subcutaneous fat. The body has a “skin and bones” appearance, and the child is profoundly weak and highly susceptible to infections. The cause is a diet very low in calories from all sources (including protein), often from early weaning to a bottled formula prepared with unsafe water and diluted because of poverty. Poor hygiene and continued depletion lead to a vicious cycle of gastroenteritis and deterioration of the lining of the gastrointestinal tract, which interferes with absorption of nutrients from the little food available and further reduces resistance to infection. If untreated, marasmus may result in death due to starvation or heart failure.

Kwashiorkor, a Ghanaian word meaning the disease that the first child gets when the new child comes, is typically seen when a child is weaned from high-protein breast milk onto a carbohydrate food source with insufficient protein. Children with this disease, which is characterized by a swollen belly due to edema (fluid retention), are weak, grow poorly, and are more susceptible to infectious diseases, which may result in fatal diarrhea. Other symptoms of kwashiorkor include apathy, hair discoloration, and dry, peeling skin with sores that fail to heal. Weight loss may be disguised because of the presence of edema, enlarged fatty liver, and intestinal parasites; moreover, there may be little wasting of muscle and body fat.

Kwashiorkor and marasmus can also occur in hospitalized patients receiving intravenous glucose for an extended time, as when recovering from surgery, or in those with illnesses causing loss of appetite or malabsorption of nutrients. Persons with eating disorders, cancer, AIDS, and other illnesses where appetite fails or absorption of nutrients is hampered may lose muscle and organ tissue as well as fat stores.

Treatment of PEM has three components. (1) Life-threatening conditions—such as fluid and electrolyte imbalances and infections—must be resolved. (2) Nutritional status should be restored as quickly and safely as possible; rapid weight gain can occur in a starving child within one or two weeks. (3) The focus of treatment then shifts to ensuring nutritional rehabilitation for the long term. The speed and ultimate success of recovery depend upon the severity of malnutrition, the timeliness of treatment, and the adequacy of ongoing support. Particularly during the first year of life, starvation may result in reduced brain growth and intellectual functioning that cannot be fully restored.

Carbohydrates

Under most circumstances, there is no absolute dietary requirement for carbohydrates—simple sugars, complex carbohydrates such as starches, and the indigestible plant

carbohydrates known as dietary fibre. Certain cells, such as brain cells, require the simple carbohydrate glucose as fuel. If dietary carbohydrate is insufficient, glucose synthesis depends on the breakdown of amino acids derived from body protein and dietary protein and the compound glycerol, which is derived from fat. Long-term carbohydrate inadequacy results in increased production of organic compounds called ketones (a condition known as ketosis), which imparts a distinctive sweet odour to the breath. Ketosis and other untoward effects of a very-low-carbohydrate diet can be prevented by the daily consumption of 50 to 100 grams of carbohydrate; however, obtaining at least half of the daily energy intake from carbohydrates is recommended and is typical of human diets, corresponding to at least 250 grams of carbohydrate (1,000 calories in a 2,000-calorie diet). A varied diet containing fruits, vegetables, legumes, and whole-grain cereals, which are all abundant in carbohydrates, also provides a desirable intake of dietary fibre.

Essential fatty acids

There is also a minimum requirement for fat—not for total fat, but only for the fatty acids linoleic acid (a so-called omega-6 fatty acid) and alpha-linolenic acid (an omega-3 fatty acid). Deficiencies of these two fatty acids have been seen in hospitalized patients fed exclusively with intravenous fluids containing no fat for weeks, patients with medical conditions affecting fat absorption, infants given formulas low in fat, and young children fed nonfat milk or low-fat diets. Symptoms of deficiency include dry skin, hair loss, and impaired wound healing. Essential fatty acid requirements—a few grams a day—can be met by consuming approximately a tablespoon of polyunsaturated plant oils daily. Fatty fish also provides a rich source of omega-3 fatty acids. Even individuals following a low-fat diet generally consume sufficient fat to meet requirements.

Vitamins

Although deficiency diseases have been described in laboratory animals and humans deprived of single vitamins, in human experience multiple deficiencies are usually present simultaneously. The eight B-complex vitamins function in coordination in numerous enzyme systems and metabolic pathways; thus, a deficiency of one may affect the functioning of others.

Vitamin A

Vitamin A deficiency is the leading cause of preventable blindness in children and is a major problem in the developing world, especially in Africa and Southeast Asia; in the poorest countries hundreds of thousands of children become blind each year due to a deficiency of the vitamin. Even a mild deficiency can impair immune function, thereby reducing resistance to disease. Night blindness is an early sign of vitamin A deficiency, followed by abnormal dryness of the eye and ultimately scarring of the cornea, a condition known as xerophthalmia. Other symptoms include dry skin, hardening of epithelial cells

elsewhere in the body (such as mucous membranes), and impaired growth and development. In many areas where vitamin A deficiency is endemic, the incidence is being reduced by giving children a single large dose of vitamin A every six months. A genetically modified form of rice containing beta-carotene, a precursor of vitamin A, has the potential to reduce greatly the incidence of vitamin A deficiency, but the use of this so-called golden rice is controversial.

Vitamin D

Vitamin D (also known as vitamin D hormone) is synthesized in the body in a series of steps, starting in the skin by the action of sunlight's ultraviolet rays on a precursor compound; thus, without adequate food sources of vitamin D, a deficiency of the vitamin can occur when exposure to sunlight is limited. Lack of vitamin D in children causes rickets, a disease characterized by inadequate mineralization of bone, growth retardation, and skeletal deformities such as bowed legs. The adult form of rickets, known as osteomalacia, results in weak muscles as well as weak bones. Inadequate vitamin D may also contribute to the thinning of bones seen in osteoporosis. Individuals with limited sun exposure (including women who completely cover their bodies for religious reasons), elderly or homebound persons, and those with dark skin, particularly those who live in northern latitudes, are at risk of vitamin D deficiency. Vitamin D is found in very few foods naturally; thus fortification of milk and other foods (e.g., margarine, cereals, and breads) with the vitamin has helped protect those populations in which sun exposure is inadequate. Supplemental vitamin D also may help protect against bone fractures in the elderly, who make and activate vitamin D less efficiently even if exposed to sunlight.

Vitamin E

Vitamin E deficiency is rare in humans, although it may develop in premature infants and in people with impaired fat absorption or metabolism. In the former, fragility of red blood cells (hemolysis) is seen; in the latter, where deficiency is more prolonged, neuromuscular dysfunction involving the spinal cord and retina may result in loss of reflexes, impaired balance and coordination, muscle weakness, and visual disturbances. No specific metabolic function has been established for vitamin E; however, it is an important part of the antioxidant system that inhibits lipid peroxidation; i.e., it protects cells and their membranes against the damaging effects of free radicals (reactive oxygen and nitrogen species) that are produced metabolically or enter the body from the environment. The requirement for vitamin E is increased with increasing consumption of polyunsaturated fatty acids. People who smoke or are subjected to air pollution may also need more of the vitamin to protect against oxidative damage to the lungs.

Vitamin K

Vitamin K is necessary for the formation of prothrombin and other blood-clotting factors in the liver, and it also plays a role in bone metabolism. A form of the vitamin is produced by bacteria in the colon and can be utilized to some degree. Vitamin K deficiency causes impaired clotting of the blood and internal bleeding, even without injury. Due to poor transport of vitamin K across the placenta, newborn infants in developed countries are routinely given the vitamin intramuscularly or orally within six hours of birth to protect against a condition known as hemorrhagic disease of the newborn. Vitamin K deficiency is rare in adults, except in syndromes with poor fat absorption, in liver disease, or during treatment with certain anticoagulant drugs, which interfere with vitamin K metabolism. Bleeding due to vitamin K deficiency may be seen in patients whose gut bacteria have been killed by antibiotics.

Thiamin

Prolonged deficiency of thiamin (vitamin B₁) results in beriberi, a disease that has been endemic in populations where white rice has been the staple. Thiamin deficiency is still seen in areas where white rice or flour constitutes the bulk of the diet and thiamin lost in milling is not replaced through enrichment. Symptoms of the form known as dry beriberi include loss of appetite, confusion and other mental symptoms, muscle weakness, painful calf muscles, poor coordination, tingling and paralysis. In wet beriberi there is edema and the possibility of an enlarged heart and heart failure. Thiamin deficiency can also occur in populations eating large quantities of raw fish harbouring intestinal microbes that contain the enzyme thiaminase. In the developed world, thiamin deficiency is linked primarily to chronic alcoholism with poor diet, manifesting as Wernicke-Korsakoff syndrome, a condition with rapid eye movements, loss of muscle coordination, mental confusion, and memory loss.

Riboflavin

Riboflavin (vitamin B₂) deficiency, known as ariboflavinosis, is unlikely without the simultaneous deficiency of other nutrients. After several months of riboflavin deprivation, symptoms include cracks in the skin at the corners of the mouth, fissures of the lips, and an inflamed, magenta-coloured tongue. Because riboflavin is readily destroyed by ultraviolet light, jaundiced infants who are treated with light therapy are administered the vitamin. Milk, milk products, and cereals, major sources of riboflavin in the diet, are packaged to prevent exposure to light.

Niacin

Symptoms of pellagra develop about two months after niacin is withdrawn from the diet. Pellagra is characterized by the so-called three Ds—diarrhea, dermatitis, and dementia—and, if it is allowed to progress untreated, death ensues. Pellagra was common in areas of the southern United States in the early 1900s and still occurs in parts of India, China, and

Africa, affecting people who subsist primarily on corn. The niacin in corn and other cereal grains is largely in bound form, unable to be absorbed well. Soaking corn in lime water, as practiced by Native American populations for centuries, frees bound niacin and thus protects against pellagra. In addition, unlike other cereals, corn is low in the amino acid tryptophan, which can be converted in part to niacin. Sufficient high-quality protein (containing tryptophan) in the diet can protect against niacin deficiency even if intake of niacin itself is inadequate.

Vitamin B₆

Vitamin B₆ (pyridoxine and related compounds) is essential in protein metabolism, the synthesis of neurotransmitters, and other critical functions in the body. Deficiency symptoms include dermatitis, microcytic hypochromic anemia (small, pale red blood cells), impaired immune function, depression, confusion, and convulsions. Although full-blown vitamin B₆ deficiency is rare, marginal inadequacy is more widespread, especially among the elderly, who may have a reduced ability to absorb the vitamin. People with alcoholism, especially those with the liver diseases cirrhosis and hepatitis, are at risk of deficiency. A number of drugs, including the tuberculosis drug isoniazid, interfere with vitamin B₆ metabolism.

Folic acid

Vitamin B₁₂ and folic acid (folate) are two B vitamins with many closely related functions, notably participation in DNA synthesis. As a result, people with deficiencies of either vitamin show many of the same symptoms, such as weakness and fatigue due to megaloblastic anemia, a condition in which red blood cells, lacking sufficient DNA for cell division, are large and immature. Deficiency of folic acid also causes disruption of cell division along the gastrointestinal tract, which results in persistent diarrhea, and impaired synthesis of white blood cells and platelets. Inadequate intake of the vitamin in early pregnancy may cause neural tube defects in the fetus. Thus, women capable of becoming pregnant are advised to take 400 micrograms (µg) of folic acid daily from supplements, fortified foods (such as fortified cereals), or both—in addition to consuming foods rich in folic acid such as fresh fruits and vegetables (especially leafy greens) and legumes. The cancer drug methotrexate interferes with folic acid metabolism, causing side effects such as hair loss and diarrhea. Folic acid deficiency may also result from heavy use of alcohol, which interferes with absorption of the vitamin.

Vitamin B₁₂

Deficiency of vitamin B₁₂ (cobalamin), like folic acid, results in megaloblastic anemia (large, immature red blood cells), due to interference with normal DNA synthesis.

Additionally, vitamin B₁₂ maintains the myelin sheath that protects nerve fibres; therefore, an untreated deficiency of the vitamin can result in nerve degeneration and eventually paralysis. Large amounts of folic acid (over 1,000 µg per day) may conceal, and possibly even exacerbate, an underlying vitamin B₁₂ deficiency. Only animal foods are reliable sources of vitamin B₁₂. Vegans, who eat no foods of animal origin, are at risk of vitamin B₁₂ deficiency and must obtain the vitamin through fortified food or a supplement. For people who regularly eat animal products, deficiency of the vitamin is unlikely, unless there is a defect in absorption. In order to be absorbed, vitamin B₁₂ must be bound to intrinsic factor, a substance secreted by the stomach. If intrinsic factor is absent (due to an autoimmune disorder known as pernicious anemia) or if there is insufficient production of hydrochloric acid by the stomach, absorption of the vitamin will be limited. Pernicious anemia, which occurs most often in the elderly, can be treated by injections or massive oral doses (1,000 µg) of vitamin B₁₂.

Pantothenic acid

Pantothenic acid is so widespread in foods that deficiency is unlikely under normal circumstances. Deficiency has been seen only in individuals fed semisynthetic diets deficient in the vitamin or in subjects given a pantothenic acid antagonist. Symptoms of deficiency include fatigue, irritability, sleep disturbances, abdominal distress, and neurological symptoms such as tingling in the hands. Deficiency of the vitamin was suspected during World War II when prisoners of war in Asia who exhibited “burning feet” syndrome, characterized by numbness and tingling in the toes and other neurological symptoms, responded only to the administration of pantothenic acid.

Biotin

Deficiency of biotin is rare, and this may be due in part to synthesis of the vitamin by bacteria in the colon, although the importance of this source is unclear. Biotin deficiency has been observed in people who regularly eat large quantities of raw egg white, which contains a glycoprotein (avidin) that binds biotin and prevents its absorption. A rare genetic defect that renders some infants unable to absorb a form of biotin in food can be treated with a supplement of the vitamin. Long-term use of certain anticonvulsant drugs may also impair biotin absorption. Symptoms of deficiency include skin rash, hair loss, and eventually neurological abnormalities.

Vitamin C

Vitamin C, also known as ascorbic acid, functions as a water-soluble antioxidant and as a cofactor in various enzyme systems, such as those involved in the synthesis of connective tissue components and neurotransmitters. Symptoms of scurvy, a disease caused by vitamin C deficiency, include pinpoint hemorrhages (petechiae) under the skin, bleeding

gums, joint pain, and impaired wound healing. Although rare in developed countries, scurvy is seen occasionally in people consuming restricted diets, particularly those containing few fruits and vegetables, or in infants fed boiled cow's milk and no source of vitamin C. Scurvy can be prevented with relatively small quantities of vitamin C (10 milligrams [mg] per day), although recommended intakes, which aim to provide sufficient antioxidant protection, are closer to 100 mg per day. Disease states, environmental toxins, drugs, and other stresses can increase an individual's vitamin C needs. Smokers, for example, may require an additional 35 mg of the vitamin daily to maintain vitamin C levels comparable to nonsmokers.

Minerals

Iron

Iron deficiency is the most common of all nutritional deficiencies, with much of the world's population being deficient in the mineral to some degree. Young children and premenopausal women are the most vulnerable. The main function of iron is in the formation of hemoglobin, the red pigment of the blood that carries oxygen from the lungs to other tissues. Since each millilitre of blood contains 0.5 mg of iron (as a component of hemoglobin), bleeding can drain the body's iron reserves. When iron stores are depleted a condition arises known as microcytic hypochromic anemia, characterized by small red blood cells that contain less hemoglobin than normal. Symptoms of severe iron deficiency anemia include fatigue, weakness, apathy, pale skin, difficulty breathing on exertion, and low resistance to cold temperatures. During childhood, iron deficiency can affect behaviour and learning ability as well as growth and development. Severe anemia increases the risk of pregnancy complications and maternal death. Iron deficiency anemia is most common during late infancy and early childhood, when iron stores present from birth are exhausted and milk, which is poor in iron, is a primary food; during the adolescent growth spurt; and in women during the childbearing years, because of blood loss during menstruation and the additional iron needs of pregnancy. Intestinal blood loss and subsequent iron deficiency anemia in adults may also stem from ulcers, hemorrhoids, tumours, or chronic use of certain drugs such as aspirin. In developing countries, blood loss due to hookworm and other infections, coupled with inadequate dietary iron intake, exacerbates iron deficiency in both children and adults.

Iodine

Iodine deficiency disorders are the most common cause of preventable brain damage, which affects an estimated 50 million people worldwide. During pregnancy, severe iodine deficiency may impair fetal development, resulting in cretinism (irreversible mental retardation with short stature and developmental abnormalities) as well as in miscarriage and stillbirth. Other more pervasive consequences of chronic iodine deficiency include lesser cognitive and neuromuscular deficits. The ocean is a dependable source of iodine,

but away from coastal areas iodine in food is variable and largely reflects the amount in the soil. In chronic iodine deficiency the thyroid gland enlarges as it attempts to trap more iodide (the form in which iodine functions in the body) from the blood for synthesis of thyroid hormones, and it eventually becomes a visible lump at the front of the neck known as a goitre. Some foods, such as cassava, millet, sweet potato, certain beans, and members of the cabbage family, contain substances known as goitrogens that interfere with thyroid hormone synthesis; these substances, which are destroyed by cooking, can be a significant factor in persons with coexisting iodine deficiency who rely on goitrogenic foods as staples. Since a strategy of universal iodization of salt was adopted in 1993, there has been remarkable progress in improving iodine status worldwide. Nonetheless, millions of people living in iodine-deficient areas, primarily in Central Africa, Southeast and Central Asia, and even in central and eastern Europe, remain at risk.

Zinc

A constituent of numerous enzymes, zinc plays a structural role in proteins and regulates gene expression. Zinc deficiency in humans was first reported in the 1960s in Egypt and Iran, where children and adolescent boys with stunted growth and undeveloped genitalia responded to treatment with zinc. Deficiency of the mineral was attributed to the regional diet, which was low in meat and high in legumes, unleavened breads, and whole-grain foods that contain fibre, phytic acid, and other factors that inhibit zinc absorption. Also contributing to zinc deficiency was the practice of clay eating, which interferes with the absorption of zinc, iron, and other minerals. Severe zinc deficiency has also been described in patients fed intravenous solutions inadequate in zinc and in the inherited zinc-responsive syndrome known as acrodermatitis enteropathica. Symptoms of zinc deficiency may include skin lesions, diarrhea, increased susceptibility to infections, night blindness, reduced taste and smell acuity, poor appetite, hair loss, slow wound healing, low sperm count, and impotence. Zinc is highest in protein-rich foods, especially red meat and shellfish, and zinc status may be low in protein-energy malnutrition. Even in developed countries, young children, pregnant women, the elderly, strict vegetarians, people with alcoholism, and those with malabsorption syndromes are vulnerable to zinc deficiency.

Calcium

Almost all the calcium in the body is in the bones and teeth, the skeleton serving as a reservoir for calcium needed in the blood and elsewhere. During childhood and adolescence, adequate calcium intake is critical for bone growth and calcification. A low calcium intake during childhood, and especially during the adolescent growth spurt, may predispose one to osteoporosis, a disease characterized by reduced bone mass, later in life. As bones lose density, they become fragile and unable to withstand ordinary strains; the resulting fractures, particularly of the hip, may cause incapacitation and even death.

Osteoporosis is particularly common in postmenopausal women in industrial societies. Not a calcium-deficiency disease per se, osteoporosis is strongly influenced by heredity; risk of the disease can be lessened by ensuring adequate calcium intake throughout life and engaging in regular weight-bearing exercise. Sufficient calcium intake in the immediate postmenopausal years does appear to slow bone loss, although not to the same extent as do bone-conserving drugs.

Fluoride

Fluoride also contributes to the mineralization of bones and teeth and protects against tooth decay. Epidemiological studies in the United States in the 1930s and 1940s revealed an inverse relationship between the natural fluoride content of waters and the rate of dental caries. In areas where fluoride levels in the drinking water are low, prescription fluoride supplements are recommended for children older than six months of age; dentists also may apply fluoride rinses or gels periodically to their patients' teeth. Fluoridated toothpastes are an important source of fluoride for children and also for adults, who continue to benefit from fluoride intake.

Sodium

Sodium is usually provided in ample amounts by food, even without added table salt (sodium chloride). Furthermore, the body's sodium-conservation mechanisms are highly developed, and thus sodium deficiency is rare, even for those on low-sodium diets. Sodium depletion may occur during prolonged heavy sweating, vomiting, or diarrhea or in the case of kidney disease. Symptoms of hyponatremia, or low blood sodium, include muscle cramps, nausea, dizziness, weakness, and eventually shock and coma. After prolonged high-intensity exertion in the heat, sodium balance can be restored by drinking beverages containing sodium and glucose (so-called sports drinks) and by eating salted food. Drinking a litre of water containing two millilitres (one-third teaspoon) of table salt also should suffice.

Chloride is lost from the body under conditions that parallel those of sodium loss. Severe chloride depletion results in a condition known as metabolic alkalosis (excess alkalinity in body fluids).

Potassium

Potassium is widely distributed in foods and is rarely deficient in the diet. However, some diuretics used in the treatment of hypertension deplete potassium. The mineral is also lost during sustained vomiting or diarrhea or with chronic use of laxatives. Symptoms of potassium deficiency include weakness, loss of appetite, muscle cramps, and confusion. Severe hypokalemia (low blood potassium) may result in cardiac arrhythmias. Potassium-

rich foods, such as bananas or oranges, can help replace losses of the mineral, as can potassium chloride supplements, which should be taken only under medical supervision.

Water deficiency (dehydration)

Water is the largest component of the body, accounting for more than half of body weight. To replace fluid losses, adults generally need to consume 2 to 4 litres of fluid daily in cool climates, depending on degree of activity, and from 8 to 16 litres a day in very hot climates. Dehydration may develop if water consumption fails to satisfy thirst; if the thirst mechanism is not functioning properly, as during intense physical exercise; or if there is excessive fluid loss, as with diarrhea or vomiting. By the time thirst is apparent, there is already some degree of dehydration, which is defined as loss of fluid amounting to at least 1 to 2 percent of body weight. Symptoms can progress quickly if not corrected: dry mouth, sunken eyes, poor skin turgor, cold hands and feet, weak and rapid pulse, rapid and shallow breathing, confusion, exhaustion, and coma. Loss of fluid constituting more than 10 percent of body weight may be fatal. The elderly (whose thirst sensation may be dulled), people who are ill, and those flying in airplanes are especially vulnerable to dehydration. Infants and children with chronic undernutrition who develop gastroenteritis may become severely dehydrated from diarrhea or vomiting. Treatment is with an intravenous or oral solution of glucose and salts.

Nutrient toxicities

The need for each nutrient falls within a safe or desirable range, above which there is a risk of adverse effects. Any nutrient, even water, can be toxic if taken in very large quantities. Overdoses of certain nutrients, such as iron, can cause poisoning (acute toxicity) and even death. For most nutrients, habitual excess intake poses a risk of adverse health effects (chronic toxicity). Sustained overconsumption of the calorie-yielding nutrients (carbohydrate, fat, and protein) and alcohol increases the risk of obesity and specific chronic diseases (see below), and use of isolated amino acids can lead to imbalances and toxicities. However, for most individuals, the risk of harm due to excess intake of vitamins or minerals in food is low.

In 1997 the U.S. Institute of Medicine established a reference value called the Tolerable Upper Intake Level (UL) for selected nutrients, which is also being used as a model for other countries. The UL is the highest level of daily nutrient intake likely to pose no risk of adverse health effects for almost all individuals in the general population and is not meant to apply to people under medical supervision. Discussed below as “safe intakes” for adults, most ULs for infants, children, and adolescents are considerably lower.

Tolerable upper intake level (UL) for selected nutrients for adults

nutrient	UL per day
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nutrient	UL per day
calcium	2,500 milligrams
copper	10 milligrams
fluoride	10 milligrams
folic acid*	1,000 micrograms
iodine	1,100 micrograms
iron	45 milligrams
magnesium**	350 milligrams
manganese	11 milligrams
niacin*	35 milligrams
phosphorus	4 grams
selenium	400 micrograms
vitamin A***	3,000 micrograms (10,000 IU)
vitamin B ₆	100 milligrams
vitamin C	2,000 milligrams
vitamin D	50 micrograms (2,000 IU)
vitamin E*	1,000 milligrams
zinc	40 milligrams

*The UL for vitamin E, niacin, and folic acid applies to synthetic forms obtained from supplements or fortified foods.

**The UL for magnesium represents intake from a pharmacological agent only and does not include food or supplements.

***As preformed vitamin A only (does not include beta-carotene).

Source: National Academy of Sciences, Dietary Reference Intakes (1997, 1998, 2000, 2001, and 2002).

Vitamins

Because they can be stored in the liver and fatty tissue, fat-soluble vitamins, particularly vitamins A and D, have more potential for toxicity than do water-soluble vitamins, which, with the exception of vitamin B₁₂, are readily excreted in the urine if taken in excess.

Nonetheless, water-soluble vitamins can be toxic if taken as supplements or in fortified food.

Symptoms of acute vitamin A poisoning, which usually require a dose of at least 15,000 µg (50,000 IU) in adults, include abdominal pain, nausea, vomiting, headache, dizziness, blurred vision, and lack of muscular coordination. Chronic hypervitaminosis A, usually resulting from a sustained daily intake of 30,000 µg (100,000 IU) for months or years, may

result in wide-ranging effects, including loss of bone density and liver damage. Vitamin A toxicity in young infants may be seen in a swelling of the fontanelles (soft spots) due to increased intracranial pressure. Large doses of vitamin A taken by a pregnant woman also can cause developmental abnormalities in a fetus, especially if taken during the first trimester; the precise threshold for causing birth defects is unknown, but less than 3,000 µg (10,000 IU) daily appears to be a safe intake. Although most vitamins occurring naturally in food do not cause adverse effects, toxic levels of vitamin A may be found in the liver of certain animals. For example, early Arctic explorers are reported to have been poisoned by eating polar bear liver. High beta-carotene intake, from supplements or from carrots or other foods that are high in beta-carotene, may after several weeks impart a yellowish cast to the skin but does not cause the same toxic effects as preformed vitamin A.

High intake of vitamin D can lead to a variety of debilitating effects, notably calcification of soft tissues and cardiovascular and renal damage. Although not a concern for most people, young children are especially vulnerable to vitamin D toxicity. Individuals with high intakes of fortified milk or fish or those who take many supplements may exceed the safe intake of 50 µg (2,000 IU) per day.

Because of its function as an antioxidant, supplementation with large doses (several hundred milligrams per day) of vitamin E in hopes of protecting against heart disease and other chronic diseases has become widespread. Such doses—many times the amount normally found in food—appear safe for most people, but their effectiveness in preventing disease or slowing the aging process has not been demonstrated. Daily intakes greater than 1,000 mg are not advised because they may interfere with blood clotting, causing hemorrhagic effects.

Large doses of niacin (nicotinic acid), given for its cholesterol-lowering effect, may produce a reddening of the skin, along with burning, tingling, and itching. Known as a “niacin flush,” this is the first indicator of niacin excess, and this symptom is the basis for the safe daily intake of 35 mg. Liver toxicity and other adverse effects have also been reported with several grams of niacin a day.

Large doses of vitamin B₆ have been taken in hopes of treating conditions such as carpal tunnel syndrome and premenstrual syndrome. The most critical adverse effect seen from such supplementation has been a severe sensory neuropathy of the extremities, including inability to walk. A daily intake of up to 100 mg is considered safe, although only 1 to 2 mg are required for good health.

Use of vitamin C supplements has been widespread since 1970, when chemist and Nobel laureate Linus Pauling suggested that the vitamin was protective against the common cold. Some studies have found a moderate benefit of vitamin C in reducing the duration

and severity of common-cold episodes, but numerous studies have failed to find a significant effect on incidence. The most common side effect of high vitamin C intake is diarrhea and other gastrointestinal symptoms, likely due to the unabsorbed vitamin traversing the intestine. The safe intake of 2,000 mg a day is based on the avoidance of these gastrointestinal symptoms. Although other possible adverse effects of high vitamin C intake have been investigated, none has been demonstrated in healthy people.

Minerals

A desirable dietary intake of the minerals generally falls in a fairly narrow range. Because of interactions, a high intake of one mineral may adversely affect the absorption or utilization of another. Excessive intake from food alone is unlikely, but consumption of fortified foods or supplements increases the chance of toxicity. Furthermore, environmental or occupational exposure to potentially toxic levels of minerals presents additional risks for certain populations.

Widespread calcium supplementation, primarily by children who do not drink milk and by women hoping to prevent osteoporosis, has raised concerns about possible adverse consequences of high calcium intake. A major concern has been kidney stones (nephrolithiasis), the majority of which are composed of a calcium oxalate compound. For years, a low-calcium diet was recommended for people at risk of developing kidney stones, despite disappointing effectiveness and a fair amount of research challenging the approach. However, a recent study has provided strong evidence that a diet relatively low in sodium and animal protein with normal amounts of calcium (1,200 mg per day) is much more effective in preventing recurrent stone formation than was the traditional low-calcium diet. In fact, dietary calcium may be protective against kidney stones because it helps bind oxalate in the intestine. Constipation is a common side effect of high calcium intake, but daily consumption of up to 2,500 mg is considered safe for adults and for children at least one year old.

The use of magnesium salts in medications, such as antacids and laxatives, may result in diarrhea, nausea, and abdominal cramps. Impaired kidney function renders an individual more susceptible to magnesium toxicity. Excess magnesium intake is unlikely from foods alone.

High-dose iron supplements, commonly used to treat iron deficiency anemia, may cause constipation and other gastrointestinal effects. A daily iron intake of up to 45 mg presents a low risk of gastrointestinal distress. Acute toxicity and death from ingestion of iron supplements is a major poisoning hazard for young children. In people with the genetic disorder hereditary hemochromatosis, a disease characterized by the overabsorption of iron, or in those who have repeated blood transfusions, iron can build up to dangerous levels, leading to severe organ damage, particularly of the liver and heart. It is considered

prudent for men and postmenopausal women to avoid iron supplements and high iron intakes from fortified foods. Toxicity from dietary iron has been reported in South Africa and Zimbabwe in people consuming a traditional beer with an extremely high iron content.

Excess zinc has been reported to cause gastrointestinal symptoms such as nausea and vomiting. Chronic intake of large amounts of zinc may interfere with the body's utilization of copper, impair immune response, and reduce the level of high-density lipoprotein cholesterol (the so-called good cholesterol). A safe intake of 40 mg of zinc daily is unlikely to be exceeded by food alone, although it may be exceeded by zinc lozenges or supplements, which are widely used despite a lack of data about their safety or efficacy.

Selenium is toxic in large amounts. Selenosis (chronic selenium toxicity) results in symptoms such as gastrointestinal and nervous system disturbances, brittleness and loss of hair and nails, a garliclike odour to the breath, and skin rash. There also have been reports of acute toxicity and death from ingestion of gram quantities of the mineral. Excess selenium can be harmful whether ingested as selenomethionine, the main form found in food, or in the inorganic forms usually found in supplements. A daily intake of up to 400 µg from all sources most likely poses no risk of selenium toxicity.

Impaired thyroid gland function, goitre, and other adverse effects may result from high intakes of iodine from food, iodized salt, or pharmaceutical preparations intended to prevent or treat iodine deficiency or other disorders. Although most people are unlikely to exceed safe levels, individuals with certain conditions, such as autoimmune thyroid disease, are particularly sensitive to excess iodine intake.

While the teeth are developing and before they erupt, excess fluoride ingestion can cause mottled tooth enamel; however, this is only a cosmetic effect. In adults, excess fluoride intake is associated with effects ranging from increased bone mass to joint pain and stiffness and, in extreme cases, crippling skeletal fluorosis. Even in communities where water supplies naturally provide fluoride levels several times higher than recommended, skeletal fluorosis is extremely rare.

High intakes of phosphorus (as phosphate) may affect calcium metabolism adversely and interfere with the absorption of trace elements such as iron, copper, and zinc. However, even with the consumption of phosphate additives in a variety of foods and in cola beverages, exceeding safe levels is unlikely. Manganese toxicity, with central nervous system damage and symptoms similar to Parkinson disease, is a well-known occupational hazard of inhaling manganese dust, but again, it is not likely to come from the diet. Similarly, copper toxicity is unlikely to result from excessive dietary intake, except in individuals with hereditary or acquired disorders of copper metabolism.

Alcohol

The acute effects of a large intake of alcohol are well known. Mental impairment starts when the blood concentration is about 0.05 percent. A concentration of alcohol in the blood of 0.40 percent usually causes unconsciousness, and 0.50 percent can be fatal. Accidents and violence, which are often alcohol-related, are major causes of death for young persons. Women who drink during pregnancy risk physical and mental damage to their babies (fetal alcohol syndrome). Alcohol also can interact dangerously with a variety of medications, such as tranquilizers, antidepressants, and pain relievers.

Although numerous studies have confirmed that light to moderate drinkers have less heart disease and tend to live longer than either nondrinkers or heavy drinkers, increasing chronic alcohol consumption carries with it significant risks as well: liver disease; pancreatitis; suicide; hemorrhagic stroke; mouth, esophageal, liver, and colorectal cancers; and probably breast cancer. In alcoholics, nutritional impairment may result from the displacement of nutrient-rich food as well as from complications of gastrointestinal dysfunction and widespread metabolic alterations. Thiamin deficiency, as seen in the neurological condition known as Wernicke-Korsakoff syndrome, is a hallmark of alcoholism and requires urgent treatment.

Diet and chronic disease

The relationship between diet and chronic disease (i.e., a disease that progresses over an extended period and does not resolve spontaneously) is complicated, not only because many diseases take years to develop but also because identifying a specific dietary cause is extremely difficult. Some prospective epidemiologic studies attempt to overcome this difficulty by following subjects for a number of years. Even then, the sheer complexity of the diet, as well as the multifactorial origins of chronic diseases, makes it difficult to prove causal links. Furthermore, many substances in food appear to act in a synergistic fashion—in the context of the whole diet rather than as individual agents—and single-agent studies may miss these interactive effects.

The concept of “risk factors” has been part of the public vocabulary for several decades, ever since the landmark Framingham Heart Study, begun in 1948, first reported in the early 1960s that cigarette smoking, elevated blood cholesterol, and high blood pressure were predictors of one’s likelihood of dying from heart disease. Other studies confirmed and further elucidated these findings, and an extensive body of research has since shown that particular conditions or behaviours are strongly associated with specific diseases. Not all individuals with a risk factor eventually develop a particular disease; however, the chance of developing the disease is greater when a known risk factor is present and increases further when several risk factors are present. Certain risk factors—such as diet, physical activity, and use of tobacco, alcohol, and other drugs—are modifiable, although it is often difficult to effect such change, even if one is facing possible disability or premature death. Others, including heredity, age, and sex, are not. Some risk factors are

modifiable to varying degrees; these include exposure to sunlight and other forms of radiation, biological agents, and chemical agents (e.g., air and water pollution) that may play a role in causing genetic mutations that have been associated with increased risk of certain diseases, particularly cancer.

Cardiovascular disease

Cardiovascular disease, a general term that encompasses diseases of the heart and blood vessels, is the leading cause of death in developed countries. Coronary heart disease (CHD), also known as coronary artery disease or ischemic heart disease, is the most common—and the most deadly—form of cardiovascular disease. CHD occurs when the arteries carrying blood to the heart, and thereby oxygen and nutrients, become narrow and obstructed. This narrowing is usually the result of atherosclerosis, a condition in which fibrous plaques (deposits of lipid and other material) build up on the inner walls of arteries, making them stiff and less responsive to changes in blood pressure. If blood flow is interrupted in the coronary arteries surrounding the heart, a myocardial infarction (heart attack) may occur. Restriction of blood flow to the brain due to a blood clot or hemorrhage may lead to a cerebrovascular accident, or stroke, and narrowing in the abdominal aorta, its major branches, or arteries of the legs may result in peripheral arterial disease. Most heart attacks and strokes are caused not by total blockage of the arteries by plaque but by blood clots that form more readily where small plaques are already partially blocking the arteries.

Although atherosclerosis typically takes decades to manifest in a heart attack or stroke, the disease may actually begin in childhood, with the appearance of fatty streaks, precursors to plaque. The deposition of plaque is, in essence, an inflammatory response directed at repairing injuries in the arterial wall. Smoking, hypertension, diabetes, and high blood levels of low-density lipoprotein (LDL) cholesterol are among the many factors associated with vessel injury. Infection by certain bacteria or viruses may also contribute to inflammation and vessel damage. Particularly vulnerable to premature CHD are middle-aged men, especially those with a family history of the disease, and individuals with hereditary conditions such as familial hypercholesterolemias.

Diet and weight loss are influential in modifying four major risk factors for CHD: high levels of LDL cholesterol, low levels of high-density lipoprotein (HDL) cholesterol, hypertension, and diabetes. However, the role of diet in influencing the established risk factors is not as clear as the role of the risk factors themselves in CHD. Furthermore, dietary strategies are most useful when combined with other approaches, such as smoking cessation and regular exercise. Drug therapy may include cholesterol-lowering drugs such as statins, bile acid sequestrants, and niacin, as well as aspirin or anticoagulants to prevent formation of blood clots and antihypertensive medication to lower blood pressure. Although endogenous estrogen (that produced by the body) is

thought to confer protection against CHD in premenopausal women, recent studies call into question the value of hormone therapy in reducing CHD risk in women who have gone through menopause.

Blood lipoproteins

Because lipids such as cholesterol, triglycerides, and phospholipids are nonpolar and insoluble in water, they must be bound to proteins, forming complex particles called lipoproteins, to be transported in the watery medium of blood. Low-density lipoproteins, which are the main transporters of cholesterol in the blood, carry cholesterol from the liver to body cells, including those in the arteries, where it can contribute to plaque. Multiple lines of evidence point to high levels of LDL cholesterol as causal in the development of CHD, and LDL is the main blood lipoprotein targeted by intervention efforts. Furthermore, clinical trials have demonstrated that LDL-lowering therapy reduces heart attacks and strokes in people who already have CHD.

High-density lipoproteins, on the other hand, are thought to transport excess cholesterol to the liver for removal, thereby helping to prevent plaque formation. HDL cholesterol is inversely correlated with CHD risk; therefore intervention efforts aim to increase HDL cholesterol levels. Another blood lipoprotein form, the very-low-density lipoprotein (VLDL), is also an independent CHD risk factor, but to a lesser extent than LDL and HDL. As the major carrier of triglyceride (fat) in the blood, VLDL is particularly elevated in people who are overweight and in those with diabetes and metabolic syndrome.

Although LDL cholesterol is popularly referred to as “bad” cholesterol and HDL cholesterol is often called “good” cholesterol, it is actually the lipoprotein form—not the cholesterol being carried in the lipoprotein—that is related to CHD risk. Total cholesterol levels, which are highly correlated with LDL cholesterol levels, are typically used for initial screening purposes, although a complete lipoprotein evaluation is more revealing. A desirable blood lipid profile is a total cholesterol level below 200 milligrams per decilitre (mg/dl), an HDL cholesterol level of at least 40 mg/dl, a fasting triglyceride level of less than 150 mg/dl, and an LDL cholesterol level below 100, 130, or 160 mg/dl, depending on degree of heart attack risk.

Dietary fat

It is widely accepted that a low-fat diet lowers blood cholesterol and is protective against heart disease. Also, a high-fat intake is often, although not always, linked to obesity, which in turn can increase heart disease risk. Yet, the situation is complicated by the fact that different fatty acids have differing effects on the various lipoproteins that carry cholesterol. Furthermore, when certain fats are lowered in the diet, they may be replaced by other components that carry risk. High-carbohydrate diets, for example, may actually increase cardiovascular risk for some individuals, such as those prone to metabolic syndrome or

type 2 diabetes. Heredity also plays a role in an individual's response to particular dietary manipulations.

In general, saturated fatty acids, which are found primarily in animal foods, tend to elevate LDL and total blood cholesterol. However, the most cholesterol-raising saturated fatty acids (lauric, myristic, and palmitic acids) can come from both plant and animal sources, while stearic acid, derived from animal fat as well as from cocoa butter, is considered neutral, neither raising nor lowering blood cholesterol levels.

When saturated fatty acids are replaced by unsaturated fatty acids—either monounsaturated or polyunsaturated—LDL and total blood cholesterol are usually lowered, an effect largely attributed to the reduction in saturated fat. However, polyunsaturated fatty acids tend to lower HDL cholesterol levels, while monounsaturated fatty acids tend to maintain them. The major monounsaturated fatty acid in animals and plants is oleic acid; good dietary sources are olive, canola, and high-oleic safflower oils, as well as avocados, nuts, and seeds. Historically, the low mortality from CHD in populations eating a traditional Mediterranean diet has been linked to the high consumption of olive oil in the region, although the plentiful supply of fruits and vegetables could also be a factor. Olive oil consumption is also associated with decreased levels of amyloid-beta plaque formation and a reduction of inflammation in the brain; such plaques and inflammation are indicative of Alzheimer disease. Studies in animals suggest that a diet rich in olive oil helps preserve memory and learning ability.

The two types of polyunsaturated fatty acids found in foods are omega-3 fatty acids and omega-6 fatty acids. Linoleic acid, the primary omega-6 fatty acid in most diets, is widespread in foods; the major source is vegetable oils such as sunflower, safflower, and corn oils. Low cardiovascular disease rates in Eskimo populations eating traditional diets high in omega-3 fatty acids initially provoked the speculation that these fatty acids may be protective against CHD. The primary lipid-altering effect of omega-3 fatty acids is the reduction of blood triglycerides. Omega-3 fatty acids may also protect the heart and blood vessels by lowering blood pressure, reducing blood clotting, preventing irregular heart rhythms, and acting as anti-inflammatory agents. The long-chain omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are derived from alpha-linolenic acid, a shorter-chain member of the same family. Fatty fish such as salmon, herring, sardines, mackerel, and tuna are high in both EPA and DHA. Flaxseed is an excellent source of alpha-linolenic acid, which the body can convert to the long-chain omega-3 fatty acids. Other sources of omega-3 fatty acids include walnuts, hazelnuts, almonds, canola oil, soybean oil, dark green leafy vegetables such as spinach, and egg yolk. A diet high in polyunsaturated fatty acids may increase LDL lipid oxidation and thereby accelerate atherosclerosis; therefore, it should be accompanied by increased intakes of vitamin E, an antioxidant. Fish oil supplements are not advised without medical supervision because of possible adverse effects, such as bleeding.

The safety of *trans* (as opposed to naturally occurring *cis*) unsaturated fatty acids has been called into question because *trans*-fatty acids in the diet raise LDL cholesterol to about the same extent as do saturated fatty acids, and they can also lower HDL cholesterol. *Trans*-fatty acids are found naturally in some animal fats, such as beef, butter, and milk, but they are also produced during the hydrogenation process, in which unsaturated oils are made harder and more stable. Certain margarines, snack foods, baked goods, and deep-fried products are major food sources of *trans*-fatty acids.

Dietary cholesterol

Cholesterol in food and cholesterol in the blood are distinct entities, and they are often confused. Dietary cholesterol is found only in foods of animal origin, and it is particularly high in egg yolk and organ meats. Cholesterol in the diet raises LDL cholesterol but not as much as saturated fatty acids do. If dietary cholesterol is already high, consuming even more cholesterol may not increase blood cholesterol levels further because of feedback control mechanisms. Also, there is great individual variation in response to dietary cholesterol. For healthy people, a cholesterol intake averaging less than 300 mg daily is recommended; however, because cholesterol is synthesized by the body, none is required in the diet.

Other dietary factors

Ingestion of soluble fibre, a component of dietary fibre (indigestible plant material), lowers LDL and total blood cholesterol levels and has been linked to decreased mortality from cardiovascular disease. Sources of soluble fibre include whole oats, barley, legumes, some vegetables, and fruits, particularly apples, plums, apricots, blueberries, strawberries, and citrus fruits; psyllium and other fibre supplements may also be recommended. The mechanism whereby soluble fibre lowers cholesterol levels is unclear, although it is probably related to its ability to bind with cholesterol and bile acids in the gut, thereby removing them from circulation. Other factors may contribute as well, such as fermentation of fibre by bacteria in the colon, resulting in compounds that inhibit cholesterol synthesis.

Light to moderate alcohol intake (up to two drinks per day for men and one drink per day for women) is associated with reduced CHD risk, primarily because of its ability to raise HDL cholesterol levels and possibly because it helps prevent blood clot formation. Alcohol intake may help explain the so-called French paradox: heart disease rates in France are low despite a CHD risk profile comparable to that in the United States, where rates are relatively high. Wine also contains antioxidant compounds, such as resveratrol from grape skins, that may inhibit LDL oxidation, but the beneficial effect of these substances is likely far less than that of alcohol itself.

Mortality from stroke and heart disease is significantly associated with dietary sodium (salt) intake, but only in overweight individuals, who may have an increased sensitivity to dietary sodium. Sodium intake also appears to have a direct effect on risk of stroke beyond its effect on blood pressure, which itself influences stroke risk. On the other hand, diets rich in potassium are linked to reduced risk of stroke.

Soy foods are associated with decreased LDL and total blood cholesterol levels, as well as other vascular effects associated with reduced CHD risk. Tofu, tempeh, miso, soy flour, soy milk, and soy nuts are among the soy foods that contain isoflavones, estrogen-like compounds that are thought to be responsible for these beneficial cardiovascular effects.

Antioxidant substances found in food and taken as dietary supplements include vitamin C, vitamin E, and beta-carotene (a plant precursor to vitamin A). Dietary antioxidants may lower CHD risk, although clinical trials have not yet supported this notion.

Other factors

For blood pressure that is equal to or greater than the “prehypertension” level of 120/80 millimetres of mercury (mm Hg), the more elevated the blood pressure, the greater the risk of heart disease. Hypertension (140/90 mm Hg and above) and atherosclerosis are mutually reinforcing: hypertension injures artery walls, thereby encouraging plaque formation; and once plaque has formed and arteries are less elastic, hypertension is aggravated. If hypertension is treated, the incidence of CHD, stroke, and congestive heart failure decreases.

Diabetes—often accompanied by hypertension, high blood triglyceride levels, and obesity—is an important risk factor for heart disease and also warrants aggressive intervention. Furthermore, for people with diabetes who have a heart attack, there is an unusually high death rate, immediately or in the ensuing years. If blood glucose levels are strictly controlled, vascular complications will be decreased.

Obesity is also an important factor in cardiovascular disease, primarily through its influence on other simultaneously present risk factors. Obese individuals often have an abnormal glucose tolerance and diabetes, hypertension, and blood lipoprotein abnormalities, including higher triglyceride levels and lower HDL cholesterol levels. Fat accumulation around the waist (the so-called apple shape) puts one at greater risk for premature heart disease than does fat accumulation around the hips (pear shape). A waist circumference greater than 102 cm (40 inches) for men or 88 cm (35 inches) for women is considered a high risk. Besides helping to control weight, regular exercise is thought to decrease CHD risk in several ways: slowing the progression of atherosclerosis, increasing the blood supply to the heart muscle, increasing HDL cholesterol, reducing VLDL levels, improving glucose tolerance, and reducing blood pressure. At a minimum, 30

minutes of moderate aerobic activity, such as brisk walking, on most days is recommended.

A newly described constellation of CHD risk factors called metabolic syndrome is marked by abdominal obesity, low HDL cholesterol, elevated blood triglycerides, high blood pressure, and insulin resistance. First named Syndrome X in 1988 by American endocrinologist Gerald Reaven, this condition is exacerbated when susceptible people eat high-carbohydrate diets. Individuals with metabolic syndrome benefit from regular physical activity and weight reduction, along with a diet lower in carbohydrates and saturated fat and higher in unsaturated fat.

Individuals with the genetic disease hereditary hemochromatosis excessively absorb iron, which can build up to dangerously high levels and damage the heart, liver, and other organs. Approximately 1 in 9 people of European descent are carriers (i.e., have one of two possible genes) for the disease and have an increased risk of heart disease. However, studies examining the possible role of dietary iron in heart disease risk for those who lack the gene for hemochromatosis have been inconclusive.

The amino acid homocysteine, when present in elevated amounts in blood, may damage arteries and promote atherosclerosis. Inadequate intake of vitamin B₆, vitamin B₁₂, or folic acid can increase blood homocysteine levels, although folic acid deficiency is the most common cause. While elevated homocysteine is not yet an established risk factor for CHD, it is prudent to ensure adequate intake of folic acid.

Dietary recommendations

Although plaque formation starts in childhood, infants or children under two years of age should not have any dietary restriction placed on cholesterol and fat. After age two, dietary recommendations to reduce CHD risk generally focus on controlling intake of total fat, saturated and *trans*-fatty acids, and dietary cholesterol, combined with physical activity and weight management. Since atherosclerosis is so common, such diets are considered useful not only for the general public but also for people with high LDL cholesterol or other CHD risk factors. A preventive diet for adults might include 20 to 35 percent of kilocalories as dietary fat, with low intake of saturated and *trans*-fatty acids (no more than 10 percent of kilocalories), and cholesterol intake below 300 mg daily. A therapeutic diet, which should be managed by a registered dietitian or other qualified nutrition professional, is even more restrictive. Practical suggestions include reducing intake of fatty spreads, organ meats, fatty meats, egg yolks, full-fat dairy products, baked goods and fried foods; removing skin from poultry; and carefully reading food labels to reduce hidden fats in processed foods. An emphasis on oats and other whole grains, vegetables, and fruits—with the inclusion of nonfat or low-fat dairy products, fish,

legumes, poultry, and lean meats—is likely to benefit not only cardiovascular health but also overall health.

Hypertension

Hypertension, or high blood pressure, is one of the most common health problems in developed countries. It is an important risk factor for other diseases, such as coronary heart disease, congestive heart failure, stroke, aneurysm, and kidney disease. Most people with high blood pressure have essential, or primary, hypertension, for which no specific cause can be determined. Heredity plays a role in the development of the disease, but so do modifiable factors such as excess weight, physical inactivity, high alcohol intake, and diets high in salt. For reasons that are not entirely clear, African Americans have among the highest rates of hypertension in the world.

Hypertension is usually defined as a blood pressure equal to or greater than 140/90 mm Hg, i.e., equivalent to the pressure exerted by a column of mercury 140 mm high during contraction of the heart (systole) and 90 mm high during relaxation (diastole); either systolic or diastolic blood pressure, or both, may be elevated in hypertension. Individuals with hypertension can be asymptomatic for years and then suddenly experience a fatal stroke or heart attack. Prevention and management of hypertension can significantly decrease the chance of complications. Early identification of hypertension is important so that lifestyle modification can begin as early as possible.

Overweight people, especially those with excess abdominal fat, have a much greater risk of developing hypertension than do lean people. Weight loss alone, sometimes as little as 4.5 kg (10 pounds), can be extremely effective in reducing high blood pressure. Increasing physical activity can, of course, help with weight control, but it also appears to lower blood pressure independently.

Large studies examining salt intake and blood pressure in communities around the world have clearly established that blood pressure is positively related to dietary intake of sodium (salt). Primitive societies in which sodium intake is low have very little hypertension, and the increase in blood pressure that typically occurs with age in industrialized societies fails to occur. On the other hand, in countries with extremely high salt consumption, hypertension is common and stroke is a leading cause of death. Furthermore, experimental studies indicate that decreasing sodium intake can reduce blood pressure.

Some people appear to be genetically sensitive to salt. Although salt restriction may only help lower blood pressure in those who are salt sensitive, many individuals consume more salt than is needed. Dietary recommendations typically encourage the general population to limit sodium intake to no more than 2,400 mg daily, which amounts to a little more than a teaspoon of salt. This level can be achieved by restricting salt used in cooking, not

adding salt at the table, and limiting highly salted foods, processed foods (many of which have hidden sodium), and so-called fast foods. Canned vegetables, breakfast cereals, and luncheon meats are particularly high in sodium.

Heavy alcohol consumption (more than two drinks a day) is associated with hypertension. Vegetarians, and particularly vegans (who consume no foods of animal origin, including milk and eggs) tend to have lower blood pressure than do meat eaters. The diet recommended for reducing blood pressure, which will also benefit cardiovascular health, emphasizes fruits, vegetables, and low-fat dairy products; includes whole grains, poultry, fish, and nuts; and contains only small amounts of red meat and sugary foods and beverages. Reducing salt intake should further increase the effectiveness of the diet.

A variety of drugs is used to treat hypertension, some of which have nutritional repercussions. Thiazide diuretics, for example, increase potassium loss from the body, usually necessitating the intake of additional potassium, which is particularly plentiful in foods such as bananas, citrus fruits, vegetables, and potatoes. Use of potassium-based salt substitutes is not advised without medical supervision.

Cancer

Second only to cardiovascular disease as a cause of death in much of the world, cancer is a major killer of adults ages 45 and older. The various types of cancer differ not only in location in the body and affected cell type but also in the course of the disease, treatments, and suspected causal or contributory factors.

Studies of identical twins reveal that, even for those with an identical genetic makeup, the risk for most cancers is still largely related to environmental factors. Another line of evidence supporting the limited role of heredity in most cancers is studies of migrant populations, in which cancer rates tend to grow more like a group's adopted country with each passing generation. For example, rates of breast and colorectal cancers in individuals who migrate from rural Asia to the United States gradually increase to match the higher cancer rates of the United States. On the other hand, risk of stomach cancer gradually decreases after Japanese migrants move to the United States. Nutrition is among the critical environmental and lifestyle factors investigated in migration studies, although identifying specific dietary components that affect the changing disease rates has been more elusive. A number of cancer organizations around the world have estimated that 30 to 40 percent of all cases of cancer could be prevented by appropriate dietary means.

Most cancer-causing substances (carcinogens) probably enter the body through the alimentary canal in food and beverages. Although some foodborne toxins, pesticides, and food additives may be carcinogenic if taken in sufficient quantity, it is primarily the foodstuffs themselves that are associated with cancer. Some dietary patterns or components may promote cancer, while others may inhibit it.

Substances in the diet, or other environmental factors, can act anywhere along the multistage process of cancer development (carcinogenesis): initiation, in which DNA, the genetic material in a cell, is altered; promotion, in which cells with altered DNA multiply; and progression, in which cancer cells spread to surrounding tissue and distant sites (metastasis).

Studies attempting to relate total fat or specific types of fat to various cancers have been inconsistent. High intake of dietary fat may promote cancer, but this could be due at least in part to the extra energy (calories) that fat provides. Obesity is associated with several types of cancer, including colorectal, prostate, uterine, pancreatic, and breast cancers. A possible mechanism for this effect is the higher circulating levels of estrogen, insulin, and other hormones that accompany increased body fat. Furthermore, regular exercise has been shown in a number of studies to reduce the risk of breast and colon cancers. In laboratory animals, restricting energy intake is the most effective method for reducing cancer risk; chronic underfeeding inhibits the growth of many spontaneous tumours and most experimentally induced tumours.

High alcohol consumption is another factor that has been implicated in the development of various cancers, especially of the mouth, throat, liver, and esophagus (where it acts synergistically with tobacco) and probably of the breast, colon, and rectum. The fact that moderate use of alcohol has a beneficial effect on cardiovascular disease underscores how complex and potentially confusing is the connection between food and health.

Foods also contain substances that offer some protection against cancer. For example, fresh fruits and vegetables, and specifically vitamins C and E, eaten at the same time as nitrate-containing foods (such as ham, bacon, sausages, frankfurters, and luncheon meats), inhibit nitrosamine production and thus help protect against stomach cancer. Several hundred studies have found a strong association between diets high in vegetables and fruits and lower risk for various cancers, although identifying specific protective factors in such diets has been more difficult. Vitamin C, vitamin E, carotenoids such as beta-carotene (a plant precursor of vitamin A), and the trace mineral selenium act in the body's antioxidant systems to help prevent DNA damage by reactive molecules known as free radicals. Specific vegetables, notably the cruciferous vegetables (broccoli, cauliflower, Brussels sprouts, kale, and other members of the cabbage family), contain sulforaphane and other compounds known as isothiocyanates, which induce enzymes that detoxify carcinogens and have been demonstrated to protect against cancer in animal studies. Dietary fibre in plant foods may also be protective: it dilutes potential carcinogens, binds to them, and speeds up transit time through the gut, thereby limiting exposure. Fruits and vegetables are rich in phytochemicals (biologically active plant substances), which are currently being investigated for potential anticarcinogenic activity. Animal studies suggest that antioxidant compounds known as polyphenols, which are found in both black and green tea, may be protective against the growth of cancer.

Regular consumption of tea, especially in Japan and China, where green tea is the preferred type, has been associated with a decreased risk of various cancers, especially stomach cancer, but the evidence has been conflicting.

The dietary approach most likely to reduce cancer risk is one that is rich in foods from plant sources, such as fruits, vegetables (especially cruciferous ones), whole grains, beans, and nuts; has a limited intake of fat, especially animal fat; includes a balance of energy intake and physical activity to maintain a healthy body weight; and includes alcohol in moderation, if at all. Intake of carcinogenic compounds can also be reduced by trimming fat and removing burned portions from meat before eating.

Colorectal cancer

Consumption of meat, particularly red meat and processed meat, is associated with a modest increase in risk of colorectal cancer. However, it is unclear whether this effect is related to a specific component of meat; to the fact that other nutrients, such as fibre, may be in short supply in a high-meat diet; or to carcinogenic substances, such as heterocyclic amines and polycyclic aromatic hydrocarbons, which are produced during high-temperature grilling and broiling, particularly of fatty muscle meats. High alcohol consumption and low intakes of calcium and folic acid have also been linked to an increased rate of colorectal cancer.

Although fibre-rich foods also appear to be protective against colorectal cancer in many studies, attempts to demonstrate a specific protective effect of dietary fibre, distinct from the nonfibre constituents of vegetables and fruits, have been inconclusive. Obesity is an important risk factor for colorectal cancer in men and premenopausal women, and mild or moderate physical activity is strongly associated with a decreased risk of colon cancer.

Prostate cancer

There is a growing body of evidence that a diet low in fat and animal products and rich in fruits and vegetables, including the cruciferous type, is protective against prostate cancer. This protection may be partially explained by a fibre found in fruits and vegetables called pectin, which has been shown to possess anticancer properties. Lower prostate cancer risk has been associated with the consumption of tomatoes and tomato products, which are rich sources of the carotenoid antioxidant lycopene. Prostate cancer rates are low in countries such as Japan where soy foods are consumed regularly, but there is no direct evidence that soy protects against the disease. The possible protective effect against prostate cancer of vitamin E and the mineral selenium is under investigation.

Breast cancer

The relationship between diet and breast cancer is unclear. High-fat diets have been suspected of contributing to breast cancer, based on international correlations between fat intake and breast cancer rates, as well as animal studies. However, large prospective studies have not confirmed this connection, even though a diet high in fat may be inadvisable for other reasons. Similarly, a diet high in fruits and vegetables is certainly healthful but provides no known protection against breast cancer. Alcohol intake is associated with breast cancer, but the increased risk appears related only to heavy drinking. Lifelong regular exercise may be protective against breast cancer, possibly because it helps to control weight, and obesity is associated with increased risk of postmenopausal breast cancer. Heredity and levels of estrogen over the course of a lifetime are the primary established influences on breast cancer risk.

Enthusiasm for soy foods and soy products as protection against breast cancer has been growing in recent years in the industrialized world. Although Japanese women, who have low breast cancer rates, have a lifelong exposure to high dietary soy, their situation is not necessarily comparable to midlife supplementation with soy isoflavones (estrogen-like compounds) in Western women. Isoflavones appear to compete with estrogen (e.g., in premenopausal women), and thereby blunt its effect; when in a low-estrogen environment (e.g., in postmenopausal women) they exert weak estrogenic effects. There is as yet no consistent evidence that soy in the diet offers protection against breast cancer or any other cancer; and the effects of dietary soy once cancer has been initiated are unknown (estrogen itself is a cancer promoter). Ongoing research on the benefits of soy is promising, and consumption of soy foods such as tofu is encouraged, but consumption of isolated soy constituents such as isoflavones, which have unknown risks, is not warranted.

Diabetes mellitus and metabolic disorders

Diabetes mellitus is a group of metabolic disorders of carbohydrate metabolism characterized by high blood glucose levels (hyperglycemia) and usually resulting from insufficient production of the hormone insulin (type 1 diabetes) or an ineffective response of cells to insulin (type 2 diabetes). Secreted by the pancreas, insulin is required to transport blood glucose (sugar) into cells. Diabetes is an important risk factor for cardiovascular disease, as well as a leading cause of adult blindness. Other long-term complications include kidney failure, nerve damage, and lower limb amputation due to impaired circulation.

Type 1 diabetes (formerly known as juvenile-onset or insulin-dependent diabetes) can occur at any age but often begins in late childhood with the pancreas failing to secrete adequate amounts of insulin. Type 1 diabetes has a strong genetic link, but most cases are the result of an autoimmune disorder, possibly set off by a viral infection, foreign protein, or environmental toxin. Although elevated blood sugar is an important feature of diabetes, sugar or carbohydrate in the diet is not the cause of the disease. Type 1 diabetes

is managed by injections of insulin, along with small, regularly spaced meals and snacks that spread glucose intake throughout the day and minimize fluctuations in blood glucose.

Type 2 diabetes (formerly known as adult-onset or non-insulin-dependent diabetes) is the more common type of diabetes, constituting 90 to 95 percent of cases. With this condition, insulin resistance renders cells unable to admit glucose, which then accumulates in the blood. Although type 2 diabetes generally starts in middle age, it is increasingly reported in childhood, especially in obese children. Genetic susceptibility to this form of diabetes may not be expressed unless a person has excess body fat, especially abdominal obesity. Weight loss often helps to normalize blood glucose regulation, and oral antidiabetic agents may also be used. Lifestyle intervention (e.g., diet and exercise) is highly effective in delaying or preventing type 2 diabetes in high-risk individuals.

Migration studies have shown that urbanization and adoption of a Western diet and habits can dramatically increase the rate of type 2 diabetes. For example, a high prevalence of the disorder is seen in the Pima Indians of Arizona, who are sedentary and eat a high-fat diet, whereas prevalence is low in a closely related group of Pimas living a traditional lifestyle—physically active, with lower body weight and a diet that is lower in fat—in a remote, mountainous region of Mexico. Type 2 diabetes is a serious health problem among Native Americans and other ethnic minorities in the United States. Worldwide, the prevalence of type 2 diabetes has increased sharply, along with the rise in obesity.

Specific treatment plans for diabetics are designed after individual medical assessment and consultation with a registered dietitian or qualified nutrition professional. The therapeutic diet, which has changed considerably over the years, focuses on complex carbohydrates, dietary fibre (particularly the soluble type), and regulated proportions of carbohydrate, protein, and fat. Because heart disease is the leading cause of death among diabetics, saturated fatty acids and *trans*-fatty acids are also restricted, and physical activity and weight control are strongly encouraged. Older dietary recommendations restricted sugar in the diabetic diet, but recent guidelines allow a moderate intake of sugars, so long as other carbohydrates are reduced in the same meal. Diet and exercise are also used to manage a condition known as gestational diabetes, which develops in a small percentage of pregnant women and usually resolves itself after delivery, though such women are subsequently at increased risk of developing type 2 diabetes.

Research in the 1990s led to the development of a new tool, the glycemic index, which reflects the finding that different carbohydrate foods have effects on blood glucose levels that cannot be predicted on the basis of their chemical structure. For example, the simple sugars formed from digestion of some starchy foods, such as bread or potatoes, are absorbed more quickly and cause a faster rise in blood glucose than does table sugar (sucrose), fruit, or milk. In practical terms, however, if a carbohydrate food is eaten as part

of a mixed meal, its so-called glycemic effect is less consequential. The glycemic index may prove to be a useful option for planning diabetic diets, but it in no way obviates the need for other established therapeutic practices, such as limiting total carbohydrate intake and managing body weight.

The trace element chromium is a cofactor for insulin and is important for glucose tolerance. Malnourished infants with impaired glucose tolerance have been shown to benefit from additional chromium, but there is no evidence that most people with diabetes are deficient in chromium or in need of chromium supplementation.

If a diabetic injects too much insulin, blood glucose may drop to dangerously low levels; the irritability, shakiness, sweating, headache, and confusion that ensue are indicative of low blood sugar, known as hypoglycemia. Severe hypoglycemia, if untreated, can lead to seizures, coma, and even death. Reactive hypoglycemia of nondiabetic origin is a distinct disorder of carbohydrate metabolism in which blood glucose falls unduly (below 50 mg/dl) after an overproduction of the body's own insulin in response to a meal high in simple sugars; symptoms of hypoglycemia occur simultaneously. However, this condition is uncommon.

Numerous inherited metabolic disorders, also known as inborn errors of metabolism, respond to dietary treatment. Most of these relatively rare disorders are inherited as autosomal recessive traits (i.e., both parents must be carriers) and result in a specific enzyme or cofactor that has reduced activity or is absent altogether. Biochemical pathways of amino acid, carbohydrate, or fatty acid metabolism may be affected, each having a number of possible enzyme defects. In some cases, newborn screening programs, and even prenatal diagnosis, allow for early identification and successful intervention. Without prompt and aggressive treatment, most of these disorders have a poor prognosis, resulting in severe intellectual disability and other forms of illness. Phenylketonuria (PKU), a condition in which the amino acid phenylalanine is not properly metabolized to the amino acid tyrosine, is the most recognized of these disorders. Treatment involves lifelong restriction of phenylalanine in the diet and supplementation with tyrosine. With early detection and meticulous management, normal growth and intellectual functioning are possible.

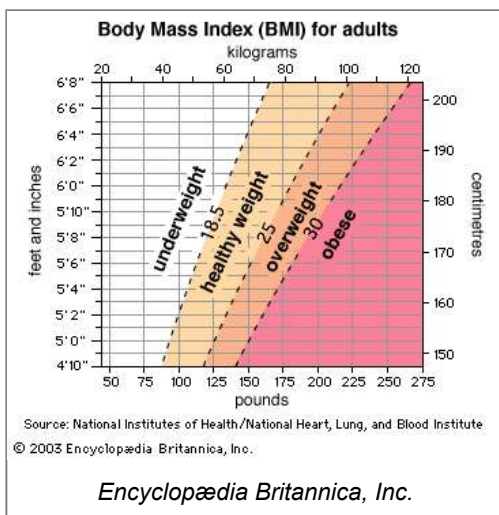
Obesity and weight control

The World Health Organization (WHO) has recognized obesity as a worldwide epidemic affecting more than 500 million adults and paradoxically coexisting with undernutrition in both developing and industrialized countries. There also have been reports of an alarming increase in childhood obesity worldwide. Obesity (excess body fat for stature) contributes to adverse health consequences such as high blood pressure, blood lipid abnormalities, coronary heart disease, congestive heart failure, ischemic stroke, type 2 diabetes,

gallbladder disease, osteoarthritis, several common cancers (including colorectal, uterine, and postmenopausal breast cancers), and reduced life expectancy. Genes play a significant role in the regulation of body weight. Nevertheless, environmental factors such as calorie-rich diets and a sedentary lifestyle can be instrumental in determining how an individual's genetic heritage will unfold.

Dietary carbohydrates are not the problem in obesity. In some Asian cultures, for example, where carbohydrate foods such as rice are the predominant food, people are relatively thin and heart disease and diabetes rates are lower than they are in Western cultures. What matters in weight control is the ratio of food energy (calories) consumed to energy expended, over time.

Height-weight tables as a reference for healthy weights have been supplanted by the parameter known as the body mass index (BMI). The BMI estimates total body fat, although it is less sensitive than using a skinfold caliper or other method to measure body fat indirectly. The BMI is defined as weight in kilograms divided by the square of the height in metres: $\text{weight} \div \text{height}^2 = \text{BMI}$. In 1997 the WHO recommended international adoption of the definition of a healthy BMI for adult women and men as between 18.5 and 24.9. A BMI lower than 18.5 is considered underweight, while a BMI of 25 to 29.9 denotes overweight and 30 or higher indicates obesity. Definitions of overweight and obesity are more difficult to quantify for children, whose BMI changes with age.



A healthful eating plan for gradual weight loss in adults will likely contain about 1,200 to 1,500 kilocalories (kcal) per day, probably accompanied by a balanced vitamin and mineral supplement. A desirable weight loss is about one pound per week from fat stores (as opposed to lean tissue), which requires an energy deficit of 3,500 kcal, or about 500 kcal per day. Consuming less than 1,000 kcal per day is not recommended; a preferred approach would be to increase physical activity, which has the added benefit of helping to maintain lean tissue. Individuals

who are severely obese and unable to lose weight may, after medical consultation, consider weight-loss medications that suppress appetite or decrease nutrient absorption or even surgery to reduce the volume of the stomach or bypass it altogether.

Carbohydrate-restricted diets, very-low-fat diets, and novelty diets—those in which one food or food group is emphasized—may result in weight loss but generally fail to establish the good dietary and exercise practices necessary to maintain the desired weight, and weight is often regained shortly after the diet is stopped.

A successful approach to long-term weight management requires establishing new patterns: eating healthfully, but eating less; engaging in regular physical activity; and changing behaviour patterns that are counterproductive, such as eating while watching television. Limiting intake of fatty foods, which are more energy-rich, is also helpful, as is eating smaller portions and drinking water instead of calorie-containing drinks. Low-fat foods are not always low in total calories, as the fat may be replaced by sugars, which themselves provide calories. Individuals who use artificial or nonnutritive sweeteners do not necessarily reduce their total calorie intake.

Research with genetically obese laboratory animals led to the discovery of the *ob* gene in mice and humans. Under the direction of this gene, adipose (fat) tissue cells secrete leptin, a protein hormone. When fat stores increase, leptin sends a signal to the hypothalamus (a regulatory centre in the brain) that stimulates one to eat less and expend more energy. Certain genetic mutations result in insufficient production of functional leptin or in a failure to respond to the leptin signal. Treatment with leptin may prove useful for the small percentage of obese persons who have a defect in the *ob* gene, although it is not yet known whether leptin therapy will induce weight loss in those who are leptin-resistant or who do not have mutations in the *ob* gene.

Eating disorders

Eating disorders such as anorexia nervosa and bulimia nervosa are serious health problems reflecting an undue concern with body weight. Girls and young women are most vulnerable to the pressures of society to be thin, although boys and men can also fall prey to these disorders, which have lifelong consequences and can even be fatal. The incidence of eating disorders has risen during the last 50 years, particularly in the United States and western Europe.

Anorexia nervosa is characterized by low body weight, propensity for drastic undereating, intense fear of gaining weight or becoming fat (despite being underweight), and a distorted body image. Consequences include impaired immunity, anemia, and diminished digestive function. Without intervention, a state of semi-starvation similar to marasmus may occur, requiring hospitalization and even force-feeding to prevent death. Treatment usually requires a coordinated approach, with the participation of a physician, psychiatrist, dietitian, and possibly other health professionals.

Bulimia nervosa is thought to be more prevalent than anorexia nervosa, and both disorders may even occur in the same person. In bulimia nervosa recurrent episodes of "binge eating" are followed by a form of purging, such as self-induced vomiting, fasting, excessive exercise, or the use of laxatives, enemas, or diuretics. Treatment usually involves a structured eating plan.

Young athletes often restrict energy intakes to meet weight guidelines and body-image expectations of their sport. Females are most affected, but male athletes, such as gymnasts, wrestlers, boxers, and jockeys, are also vulnerable. Intense training among young female athletes, coupled with food energy restriction, often results in amenorrhea (failure to menstruate for at least three consecutive months) and bone loss similar to that at menopause. Calcium supplementation may be required.

Tooth decay

Dental caries (tooth decay) is an oral infectious disease in which bacteria, primarily *Streptococcus mutans*, in the dental plaque metabolize simple sugars and other fermentable carbohydrates into acids that dissolve tooth enamel. Dental plaque (not to be confused with the lipid-containing plaque found in arteries) is a mass of bacteria and sticky polymers that shield the tooth from saliva and the tongue, thereby facilitating decay. All dietary forms of sugar, including honey, molasses, brown sugar, and corn syrup, can cause tooth decay; fermentable carbohydrates in crackers, breads, cereals, and other grain products, as well as milk, fruits, and fruit juices, also have cariogenic (decay-causing) potential. Eating sugary or starchy foods between meals, especially sticky foods that stay on the teeth longer, increases the time that teeth are exposed to destructive acids. Artificial sweeteners are not cariogenic, and xylitol, a sugar alcohol used in some chewing gums, is even cariostatic, i.e., it reduces new tooth decay by inhibiting plaque and suppressing decay-causing bacteria. Putting an infant to sleep with a bottle, especially one containing juice or other sweetened beverages, milk, or infant formula can lead to a condition called "baby bottle tooth decay."

Fluoride is extremely effective at protecting tooth enamel from decay, especially while enamel is being formed in the jaws before the permanent teeth erupt. Fluoridation of water in communities where fluoride is not naturally high is a safe and effective public health measure. Water with approximately one part per million of fluoride protects against dental caries without causing the mottling of teeth that can occur at higher levels. In areas without fluoridated water, fluoride supplements are recommended for children. Brewed tea, marine fish consumed with bones, and seaweed are significant food sources of fluoride.

Regular brushing and flossing of the teeth and gums, as well as rinsing the mouth after meals and snacks, are important measures that protect against periodontal (gum) disease as well as dental caries. Gum health also depends on a properly functioning immune system and good overall nutrition. Key nutrients include vitamin C, which helps protect against gingivitis (inflamed gums), and calcium and vitamin D, which help ensure a strong jawbone and teeth.

Heartburn and peptic ulcer

When gastric contents, containing hydrochloric acid, flow backward from the stomach, the lining of the esophagus becomes inflamed, leading to the burning sensation known as heartburn. Occasional heartburn (also known as acid indigestion) is a common occurrence, typically precipitated by eating certain foods. However, some people experience heartburn regularly, a condition known as gastroesophageal reflux disease (GERD). Individuals with GERD are advised to limit their intake of alcohol and caffeine, which relax the lower esophageal sphincter and actually promote reflux, as well as their intake of fat, which delays gastric emptying. Chocolate, citrus fruit and juices, tomatoes and tomato products, spearmint and peppermint oils, and certain spices may aggravate heartburn, but these foods do not appear to cause the condition.

For overweight or obese individuals with GERD, weight loss may have a beneficial effect on symptoms. Eating smaller meals, chewing food thoroughly, eating more slowly, avoiding tight-fitting clothes, not smoking, and not lying down before about three hours after eating are among the factors that may improve the condition. Without medical supervision, drugs such as antacids and acid controllers should be used only infrequently.

It is now known that a peptic ulcer (a sore on the lining of the stomach or duodenum) is not caused by stress or eating spicy foods, as was once thought; rather, most peptic ulcers are caused by the infectious bacterial agent *Helicobacter pylori* and can be treated by a simple course of antibiotics. However, stress and dietary factors—such as coffee, other caffeinated beverages, and alcohol—can aggravate an existing ulcer.

Bowel conditions and diseases

Constipation, a condition characterized by the difficult passage of relatively dry, hardened feces, may arise from insufficient dietary fibre (roughage) or other dietary factors, such as taking calcium or iron supplements, in addition to daily routines that preclude relaxation. Straining during defecation can also contribute to diverticulosis, small outpouchings in the colonic wall, which may become inflamed (diverticulitis) and present serious complications. Another possible consequence of straining is hemorrhoids, swollen veins of the rectum and anus that typically lead to pain, itching, and bleeding. Constipation can usually be treated by eating high-fibre foods such as whole-grain breads and cereals, drinking sufficient amounts of water, and engaging in regular exercise. By drawing water into the large intestine (colon), fibre—especially the insoluble type—helps form a soft, bulky stool. Eating dried fruits such as prunes, which contain a natural laxative substance (dihydroxyphenyl isatin) as well as being high in fibre, also helps stimulate the bowels. Although laxatives or enemas may be helpful, frequent use may upset fluid, mineral, and electrolyte (salt) balances and interfere with vitamin absorption. Any persistent change in bowel habits should be evaluated by a physician.

In contrast to constipation, diarrhea—loose, watery stools, and possibly an increased frequency of bowel movements—can be a cause for immediate concern. Acute diarrhea of bacterial origin is relatively common and often self-limiting. Other common causes of acute diarrhea include viral infections, parasites, food intolerances or allergies, medications, medical or surgical treatments, and even stress. Regardless of cause, drinking fluids is important for treating a temporary bout of diarrhea. However, if severe and persisting, diarrhea can lead to potentially dangerous dehydration and electrolyte imbalances and requires urgent medical attention, especially in infants and children. Prolonged vomiting presents similar risks.

Inflammatory bowel disease (IBD), such as Crohn disease (regional ileitis) or ulcerative colitis, results in impaired absorption of many nutrients, depending upon which portion of the gastrointestinal tract is affected. Children with IBD may fail to grow properly. Treatment generally includes a diet low in fat and fibre, high in protein and easily digestible carbohydrate, and free of lactose (milk sugar). Increased intakes of certain nutrients, such as iron, calcium, and magnesium, and supplementation with fat-soluble vitamins may also be recommended, along with additional fluid and electrolytes to replace losses due to diarrhea.

Irritable bowel syndrome (IBS) is a common gastrointestinal disorder characterized by a disturbance in intestinal peristalsis. Symptoms include excessive gas, abdominal discomfort, and cramps, as well as alternating diarrhea and constipation. Although it can be extremely uncomfortable, IBS does not cause intestinal damage. Dietary treatment involves identifying and avoiding “problem” foods, notably legumes and other gas-producing vegetables and dairy products, and possibly reducing caffeine consumption. For most people with IBS, a low-fat diet, smaller meals, and a gradual increase in fibre intake are helpful.

Food-drug interactions

Drugs may interfere with or enhance the utilization of nutrients, sometimes leading to imbalances. A common example is the increased loss of potassium that results from the use of certain diuretics to treat high blood pressure. Nutrient absorption can also be affected by drugs that change the acidity of the gastrointestinal tract, alter digestive function, or actually bind to nutrients. For example, regular use of laxatives, antacids, or mineral oil can reduce nutrient absorption and over time may lead to deficiency. Elderly individuals who take multiple medicines are particularly at risk of impaired nutritional status.

On the other hand, foods can alter drug absorption or interact with drugs in undesirable ways, resulting in drug ineffectiveness or toxicity. For example, protein and vitamin B₆ interfere with the effectiveness of levodopa, used to treat Parkinson disease. Tyramine, an

amino-acid derivative found in certain aged cheeses and red wines, may cause hypertension in individuals being treated for depression with monoamine oxidase (MAO) inhibitors. Grapefruit juice contains unique substances that can block the breakdown of some drugs, thereby affecting their absorption and effectiveness. These drugs include certain cholesterol-lowering statins, calcium channel blockers, anticonvulsant agents, estrogen, antihistamines, protease inhibitors, immunosuppressants, antifungal drugs, and psychiatric medications. Eating grapefruit or drinking grapefruit juice within a few hours or even a few days of taking these medications could result in unintended consequences.

Vitamin and mineral supplements and herbal products can also interact with medicines. For example, one or more of the supplemental antioxidants studied—vitamin C, vitamin E, beta-carotene, and selenium—may blunt the effectiveness of certain drugs (e.g., high-dose niacin, when used in combination with statins) in raising HDL cholesterol levels and improving cardiovascular health. Also, the herbal supplement St. John's wort can alter the metabolism of drugs such as protease inhibitors, anticlotting drugs, and antidepressants, and it can reduce the effectiveness of oral contraceptives.

Food allergies and intolerances

A true food allergy involves an abnormal immunologic response to an otherwise harmless food component, usually a protein. In the case of antibody-mediated (immediate hypersensitivity) food allergies, within minutes or hours of exposure to the allergen, the body produces specific immunoglobulin E antibodies and releases chemical mediators such as histamine, resulting in gastrointestinal, skin, or respiratory symptoms ranging from mild to life-threatening. Much less common are cell-mediated (delayed hypersensitivity) food allergies, in which a localized inflammatory process and other symptoms may not start for up to a day. Adverse food reactions that do not involve the immune system, aside from foodborne infection or poisoning, are called food intolerances or sensitivities. Most common of these is lactose intolerance, which is a genetically determined deficiency of the enzyme lactase that is needed to digest the milk sugar, lactose.

Milk allergy and lactose intolerance are distinct conditions that are often confused. Only about 1 percent of the population has a true allergy to the protein in cow's milk. Milk allergy is found most often in infants, whose immune and digestive systems are immature. On the other hand, much of the world's population, except those of northern European descent, is to some degree lactose intolerant after early childhood. Undigested lactose reaching the large intestine can cause abdominal discomfort, flatulence, and diarrhea. Lactose-intolerant individuals can often handle with little or no discomfort small quantities of dairy products, especially yogurt or other milk products containing the bacterium *Lactobacillus acidophilus*; alternatives are the use of lactose-hydrolyzed milk products or lactase tablets or drops, which convert lactose to simple, digestible sugars.

Celiac disease (also known as celiac sprue, nontropical sprue, or gluten-sensitive enteropathy) is a hereditary disorder in which consumption of wheat gluten and related proteins from rye and barley is not tolerated. Recent studies indicate that oats may be safe if not contaminated with wheat. Celiac disease, which may be a type of cell-mediated food allergy, affects primarily individuals of European descent and rarely those of African or Asian descent. It is characterized by inflammatory damage to the mucosal cells lining the small intestine, leading to malabsorption of nutrients and such symptoms as diarrhea, fatigue, weight loss, bone pain, and neurological disturbances. Multiple nutritional deficiencies may ensue and, in children, growth is impaired. The disorder is often associated with autoimmune conditions, particularly autoimmune thyroid disease and type 1 diabetes. Although celiac disease can be life-threatening if untreated, patients can recover if gluten is eliminated from the diet.

Other adverse reactions to foods or beverages may be drug effects, such as those caused by caffeine or alcohol. Certain foods, such as ripened cheese, chocolate, red wine, and even ice cream, trigger headaches in some individuals. Food additives that can cause reactions in susceptible people include sulfite preservatives, used in some wines, dried fruits, and dried potato products; nitrate and nitrite preservatives, used in processed meats; certain food colorants, particularly tartrazine (also known as FD&C Yellow #5); and the flavour enhancer monosodium glutamate (MSG). Some adverse reactions to food are purely psychological and do not occur when the food is served in a disguised form.

Nearly any food has allergenic potential, but foods that most commonly cause antibody-mediated allergic reactions are cow's milk, eggs, wheat, fish, shellfish, soybeans, peanuts, and tree nuts (such as almonds, walnuts, and cashews). Depending on processing methods, edible oils and other products derived from these foods may still contain allergenic protein residues. Severely allergic people may react to extremely small amounts of an offending food, even inhaled vapours.

Studies differ significantly as to the percentage of adults and children who have true food allergies. However, most seem to agree that few adults (about 2 to 5 percent) and slightly more children (roughly 3 to 8 percent) are affected. Most children outgrow food allergies, particularly if the offending food is avoided for a year or two. However, food allergies can develop at any time, and some allergies, such as those to peanuts, tree nuts, and shellfish, may be lifelong. Common symptoms of antibody-mediated food allergy include tightening of the throat, swelling of the lips or tongue, itchy lips, wheezing, difficulty breathing, headache, nasal congestion, skin rash (eczema), hives, nausea, vomiting, stomach cramps, diarrhea and, in severe cases, life-threatening anaphylactic shock. People susceptible to anaphylaxis are advised to carry a syringe loaded with epinephrine at all times and to seek emergency medical care if an allergic reaction begins.

Food allergies are often hard to document, even by physicians trained in allergy and immunology. Blood tests for antibodies to specific allergens, skin tests, and even an elimination diet, in which suspect foods are eliminated from the diet and then added back one at a time, may not be definitive. The most conclusive diagnostic test is a so-called double-blind food challenge, in which neither doctor nor patient knows whether a suspect food or a harmless placebo is being given; however, these controlled clinical tests are expensive and time-consuming.

Labels are important for identifying hidden ingredients in packaged foods, although they are often imprecise and cannot be relied on naively. For example, even if a product is labeled as nondairy, a listing of casein, caseinate, or whey indicates the presence of milk protein. Peanuts may be found in unlikely foods, such as chili, stew, processed meats, oils, flours, cream substitutes, and desserts.

Research has indicated that, at least in some instances, the severity of an allergy may be reduced through desensitization, in which a person is exposed over time to increasing amounts of the antigen to which he or she is allergic. Methods of desensitization differ; for example, allergy shots involve the injection of antigens, whereas sublingual immunotherapy involves small doses of antigen given as drops under the tongue. Sublingual immunotherapy in particular is considered a safe and effective means of building tolerance to food allergens.

Toxins in foods

Edible skins of fruits and vegetables are rich in vitamins, minerals, and fibre; however, pesticide residues and other environmental contaminants are typically more plentiful in the outer layers of these foods. Pesticides also tend to accumulate in the fat and skin of animals. Intake of toxic substances is reduced by consuming a wide variety of foods; washing fruits and vegetables carefully; and trimming fat from meat and poultry and removing skin from poultry and fish. Even organic produce requires thorough washing: it may not have synthetic chemicals, but mold, rot, fecal matter or other natural substances can contaminate it at any point from field to market. Peeling helps reduce these unwanted chemicals and microbes, although valuable nutrients will be lost as well.

A greenish tinge on potatoes, although merely the harmless substance chlorophyll, indicates that the natural toxicant solanine may be present. Solanine builds up when a potato is handled roughly, exposed to light or extremes of temperature, or is old. Symptoms of solanine poisoning include diarrhea, cramps, and headache, although many damaged potatoes would have to be eaten to cause serious illness. Peeling away green areas or removing sprouts or the entire skin (despite its high nutrient content) reduces solanine intake.

Swordfish and shark, as well as tuna steaks, may contain high levels of methylmercury (which remains after cooking) and should be avoided by pregnant women. Nonbacterial toxins in seafood include scombrototoxin (histamine) in spoiled fish, which can result in a severe allergic reaction when eaten; dinoflagellates (microscopic algae), associated with the so-called red tide, which can cause paralytic shellfish poisoning when consumed; and ciguatera, found in certain warm-water reef fish.(See *also* fish poisoning; shellfish poisoning.)

Natural toxins in some species of mushrooms cause symptoms ranging from gastrointestinal upset to neurological effects, even hallucinations. Most mushroom fatalities are due to consumption of amatoxins in *Amanita phalloides*, the mushroom species known as the death cap, which, if not lethal, can cause lasting liver and kidney damage. As there are no antidotes for mushroom poisoning, and identification of mushroom species by inexperienced mushroom pickers is often imprecise, consumption of wild mushrooms is not advised.

Foodborne illnesses

Contamination of foods or beverages with disease-causing organisms—bacteria, viruses, fungi, and parasites—can result in symptoms ranging from mild stomach upset, headache, muscle aches, and fever to abdominal cramps, vomiting, and diarrhea. Severe cases can result in dangerous dehydration, nerve damage, paralysis, kidney failure, and death. Symptoms may develop within hours or days after eating contaminated food, and they are not always easy to distinguish from influenza or other illnesses. Drinking clear liquids (such as chicken broth, juices, and water) helps replace fluids and electrolytes lost during a mild infection, but immediate medical attention is required when symptoms are severe. Most susceptible are infants and young children, pregnant women, the elderly, and people with weakened immune systems or certain chronic diseases. Particularly risky foods include raw or undercooked meat, poultry, eggs, seafood, and unpasteurized (raw) milk products and juices.

Some common foodborne illnesses are listed in the table.

Common food-borne illnesses			
illness (and causative organism)	common food sources	symptoms	symptom onset
illnesses caused by bacteria			

illness (and causative organism)	common food sources	symptoms	symptom onset
botulism (Clostridium botulinum)	canned foods, honey (for infants)	nausea, vomiting, headache, dizziness, difficulty swallowing and speaking, muscle weakness and paralysis, fatigue, blurred or double vision	18–36 hours
campylobacteriosis (Campylobacter jejuni)	raw or undercooked chicken, unpasteurized milk, non-chlorinated water	watery or bloody diarrhea, vomiting, fever, nausea, muscle pain, abdominal cramps	2–5 days
cholera (Vibrio cholerae)	shellfish, contaminated water	abdominal cramps, diarrhea, vomiting, dehydration, coma, cardiovascular collapse	6 hours–5 days
E. coli infection (Escherichia coli O157:H7 and other strains)	undercooked beef (especially ground), unpasteurized milk and fruit juices, dry-cured salami, alfalfa sprouts, contaminated water, raw fruits and vegetables	watery or bloody diarrhea, abdominal cramps, acute kidney failure	12–72 hours
listeriosis (Listeria monocytogenes)	unpasteurized milk, soft cheeses	fever, nausea, vomiting, diarrhea, encephalitis, blood infection, miscarriage or stillbirth in pregnant women, headache	gastrointestinal symptoms, more than 12 hours; serious symptoms, 3 days–3 weeks
perfringens food poisoning (Clostridium perfringens)	improperly cooked or stored meat products	diarrhea, abdominal cramps	8–24 hours
salmonellosis (non-typhoid Salmonella species)	raw or undercooked eggs, poultry, meat, or fish; unpasteurized milk	nausea, abdominal cramps, diarrhea, fever, chills, vomiting, headache	6–48 hours

illness (and causative organism)	common food sources	symptoms	symptom onset
shigellosis (Shigella)	salads (potato, shrimp, macaroni, chicken), raw vegetables, dairy products, poultry, contaminated water	watery or bloody diarrhea, abdominal cramps, vomiting	5–50 hours
staphylococcal food poisoning (Staphylococcus aureus)	meat, eggs, poultry, tuna, potato and macaroni salads, cream-filled pastries	nausea, vomiting, abdominal cramps, headache, muscle cramping, fatigue	2–6 hours
typhoid (Salmonella typhi)	sewage-contaminated water, shellfish, raw fruits and vegetables, dairy products	fever, chills, headache, abdominal pain, constipation, enlarged spleen, rash, intestinal perforation or hemorrhage	1–3 weeks
Vibriosis (Vibrio parahaemolyticus and Vibrio vulnificus)	raw, undercooked, or recontaminated seafood	gastroenteritis, bloody or watery diarrhea, fever, blood infection, abdominal pain, chills, weakness	4–96 hours
yersiniosis (Yersinia enterocolitica)	raw vegetables and meat, water, unpasteurized milk	fever, abdominal pain, diarrhea, vomiting, headache, nausea, malaise	24–48 hours

illnesses caused by viruses

hepatitis A (hepatitis A virus)	contaminated water, shellfish, salads	fever, malaise, nausea, anorexia, abdominal discomfort, jaundice	10–50 days
norovirus infection (Norwalk virus or Norwalk-like virus)	shellfish, contaminated water, salad ingredients	vomiting, diarrhea, nausea, abdominal pain	24–48 hours

illnesses caused by parasitic protozoans and worms

amebiasis (Entamoeba histolytica)	contaminated water, raw fruits or vegetables, unpasteurized dairy products	gastrointestinal distress, bloody diarrhea, abdominal cramps, intestinal ulcers	1–4 weeks
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illness (and causative organism)	common food sources	symptoms	symptom onset
cryptosporidiosis (Cryptosporidium parvum)	contaminated water, raw fruits and vegetables	diarrhea, abdominal cramps, fever	2–10 days
cyclosporiasis (Cyclospora cayetanensis)	contaminated water, Guatemalan raspberries	diarrhea, vomiting, muscle pain, fatigue	1 week
giardiasis (Giardia lamblia)	contaminated water	diarrhea, abdominal pain, bloating, heartburn, anorexia, nausea, vomiting	5–25 days
trichinosis (Trichinella spiralis)	raw or undercooked pork and wild game	fever, abdominal symptoms, joint and muscle pain, headache, facial swelling, painful breathing, muscle weakness	abdominal symptoms, 1–2 days; further symptoms, 2–8 weeks

illnesses caused by natural toxins

ciguatera fish poisoning (dinoflagellates)	warm-water fishes, typically grouper, snapper, amberjack, and barracuda	numbness and tingling, nausea, vomiting, diarrhea, respiratory paralysis, muscle pain, heart abnormalities	within 6 hours
scombroid poisoning	spoiled fish, such as tuna, mackerel, or mahimahi	nausea, vomiting, headache, thirst, hives, diarrhea, itchiness, tingling of the mouth and throat	immediate to 30 minutes
shellfish poisoning, paralytic	oysters, clams, mussels, scallops	paralysis, tingling and numbness, dry throat, incoordination, incoherent speech, respiratory paralysis	30 minutes–2 hours

Most cases of foodborne illness are caused by bacteria and the toxins they produce. *Campylobacter jejuni*, found in raw or undercooked foods of animal origin, especially poultry, is responsible for more diarrheal illness throughout the world than any other bacterium. Travelers' diarrhea is often caused by specific types of *Escherichia coli* bacteria,

while other *E. coli* types cause much of the diarrhea in infants, particularly during weaning, in developing countries. Other common foodborne infections are caused by various strains of *Salmonella* bacteria and the Norwalk family of viruses.

Smoking, drying, fermenting, and the adding of sugar or salt are traditional methods used to preserve food and keep it safe. During the 20th century public health advances such as disinfection of water supplies, pasteurization of milk, safe canning, widespread use of refrigeration, and improved food-safety practices eliminated typhoid fever, tuberculosis, and cholera, for example, as common foodborne diseases. However, others have taken their place. New causes of foodborne illness continue to be discovered or described. A recently characterized microscopic parasite, *Cyclospora cayetanensis*, was the cause of outbreaks of diarrheal illness in the United States and Canada starting in 1996. Guatemalan raspberries, contaminated with *Cyclospora* via the water supply, were the suspected source of infection. Another recently described parasite, *Cryptosporidium parvum*, contaminates water supplies and foods and is an important cause of diarrhea throughout the world, particularly in children and in persons with HIV.

In 1993, undercooked hamburgers emerged in the United States as a potential source of *E. coli* O157:H7, a deadly strain of a normally harmless bacterium found in the human digestive tract. Subsequently, this microbe has also been found in unpasteurized fruit juice, such as fresh-pressed apple cider, and other foods possibly contaminated with animal feces. The bacterium produces a potent toxin that may result in bloody diarrhea; hemolytic uremic syndrome, a possible complication, is a major cause of acute kidney failure in children. *E. coli* O157:H7 infection, which can be spread by persons who unknowingly incubate the bacterium in their intestines and transmit it through poor toilet hygiene, appears to be on the rise worldwide, particularly in North America and western Europe.

Certain other bacteria also produce a toxin, which then causes a poisoning or intoxication rather than a bacterial infection per se. For example, *Clostridium botulinum*, found in improperly canned foods, produces the lethal neurotoxin that causes botulism. The toxin responsible for staphylococcal food poisoning is produced by *Staphylococcus aureus* typically after contamination from nasal passages or cuts on the skin.

Many molds (fungi) on food are harmless and, in fact, are flavour enhancing, such as those used to ripen certain cheeses. However, some molds—particularly those on grains, nuts, fruits, and seeds—produce poisons known as mycotoxins. The mycotoxins of greatest concern are aflatoxins, which can infect nuts, peanuts, corn, and wheat. Prolonged low-level exposure to aflatoxins, as seen in regions of Asia and Africa, is suspected of contributing to liver cancer. Discarding nuts that are discoloured, shriveled, or moldy helps reduce the risk.

Eating raw shellfish, sushi, or undercooked fish puts one at risk for parasites, such as tapeworms, as well as for bacteria and viruses, all of which are killed by proper cooking. The great majority of seafood-related illness is caused by the consumption of raw bivalve mollusks. Clams, mussels, and scallops, which are usually served cooked, are of less public health concern than oysters, which are often eaten raw.

Bovine spongiform encephalopathy (BSE), commonly known as mad cow disease, was first seen in British cattle in the 1980s. However, it was not linked to human disease until 1996, when 10 young adults in the United Kingdom died of variant Creutzfeldt-Jakob disease, a fatal brain-wasting disease thought to have been transmitted by consumption of meat containing brain or spinal tissue from BSE-infected cattle. It is suspected that the diseased cattle had been infected by eating the ground remains of sheep with the neurodegenerative disease scrapie. BSE appears to be caused by infectious protein particles called prions, which kill brain cells and leave holes in the brain. Details of disease transmission are still unclear, as is the potential risk from cosmetics, dietary supplements, gelatin, or vaccines containing bovine ingredients, or from blood transfusions. Ground beef, sausages, and frankfurters are more likely to be contaminated with nervous-system tissue than are whole cuts of beef. Dairy products are considered safe, even if they come from BSE-infected cows.

Good personal hygiene and food safety practices are important in protecting against foodborne illness. The main source of contamination is fecal matter, which is reduced by frequently washing hands with soap and hot water, especially before preparing food. Thorough washing also decontaminates towels, surfaces, cutting boards, utensils, and other equipment that has touched uncooked meat. Other food safety guidelines include keeping cold foods cold, keeping hot foods hot, and refrigerating leftovers quickly.

Growth of microorganisms, parasites, and insects on certain foods (such as meat, poultry, spices, fruits, and vegetables) can be controlled by low-dose irradiation, which has been approved for specific uses in a number of countries, such as Japan, France, Italy, Mexico, and the United States. Food irradiation technology—which does not make foods radioactive—is considered safe by the World Health Organization and various health agencies, but it has yet to receive wide consumer acceptance.

Botanicals and functional foods

Many herbal products show sufficient promise in preventing or treating disease that they are being tested in rigorous scientific studies, including clinical trials. However, the “botanicals” currently on the market in many countries are untested with regard to safety and efficacy, and consumers should approach their use in an informed and cautious way. Just as with pharmaceuticals, herbal products can have mild to severe side effects, and “natural” does not mean “safe.” Furthermore, the amounts of active ingredients in

supplements can vary widely and, according to laboratory analyses, the potency specified on labels is often inaccurate. Some preparations even contain none of the active ingredients listed on the label or may have unwanted contaminants.

Potentially dangerous herbal products include comfrey and kava, which can cause liver damage, and ephedra (ma huang), which has caused fatal reactions in some people, especially those with high blood pressure or heart disease. Because of possible complications, patients scheduled to undergo surgery or other medical procedures may be advised to discontinue certain supplements for days or even weeks before surgery. Safety and efficacy concerns also need to be addressed, as “designer foods” fortified with herbs and bioactive substances continue to proliferate.

The distinction between foods, dietary supplements, and drugs is already being blurred by the burgeoning market in so-called functional foods (such as cholesterol-lowering margarine), which aim to provide health benefits beyond mere nutrient value. Moreover, recent advances in molecular biology offer the possibility of using genetic profiles to determine unique nutrient requirements, thereby providing customized dietary recommendations to more effectively delay or prevent disease.

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