CHAPTER 8 Environmental Hazards and Human Health

Chapter Outline

FIGURE 8.1

Bayee Waqo (12) was named after her grandmother Bayee Chumee (82). When her son and his wife both died of AIDS, Chumee took on the care of their daughter who was just two years old. Some years later, after repeated illness, the young girl was diagnosed HIV positive, and she has been on treatment since. At 82, Chumee is getting too weak for all the household chores, so her granddaughter helps by collecting firewood, fetching water, making coffee and baking bread.

Legesse, T. (2013). Bayee Chumee and Bayee Waqo. [JPG]. Retrieved from https://commons.wikimedia.org/wiki/Category:AIDS_in_Africa#/media/File:12._Bayee_Chumee_and_Bayee_Waqo_(10995486103).jpg

Learning Outcomes

After studying this chapter, you should be able to:

- Define environmental health
- Categorize environmental health risks
- Explain the concept of emerging diseases
- Summarize the principles of environmental toxicology
- Classify environmental contaminants

8.1 The Impacts of Environmental Conditions

When environmental conditions are degraded such that the range of tolerance is exceeded, there will be a significant impact on human health. Our industrialized society dumps huge amounts of pollutants and toxic wastes into the earth's biosphere without fully considering the consequences. Such actions seriously degrade the health of the earth's ecosystems, and this degradation ultimately affects the health and well-being of human populations (University of California College Prep, 2012).

For most of human history, **biological agents** were the most significant factor in health. These included pathogenic (disease causing) organisms such as bacteria, viruses, protozoa, and internal parasites. In modern times, cardiovascular diseases, cancer, and accidents are the leading killers in most parts of the world. However, infectious diseases still cause about 22 million deaths a year, mostly in undeveloped countries. These diseases include: tuberculosis, malaria, pneumonia, influenza, whooping cough, dysentery and Acquired Immune Deficiency Syndrome (AIDS). Most of those affected are children. Malnutrition, unclean water, poor sanitary conditions and lack of proper medical care all play roles in these deaths. Compounding the problems of infectious diseases are factors such as drug-resistant pathogens, insecticide resistant carriers and overpopulation. Overuse of antibiotics have allowed pathogens to develop a resistance to drugs. For example, tuberculosis (TB) was nearly eliminated in most parts of the world, but drug-resistant strains have now reversed that trend. Another example is malaria. The insecticide DDT (Dichlorodiphenyltrichloroethane) was widely used to control malaria-carrying mosquito populations in tropical regions. However, after many years the mosquitoes developed a natural resistance to DDT and again spread the disease widely. Anti-malarial medicines were also over-prescribed, which allowed the malaria pathogen to become drug-resistant.

ENVIRONMENTAL PERSISTENCE OF DDT

The pesticide DDT was widely used for decades. It was seen as an ideal pesticide because it is inexpensive and breaks down slowly in the environment. Unfortunately, the latter characteristic allows it to biomagnify through the food chain. Populations of bird species at the top of the food chain, e.g., eagles and pelicans, are greatly affected by DDT in the environment. When these birds have sufficient levels of DDT, the shells of their eggs are so thin that they break, making reproduction impossible. After DDT was banned in the United States in 1972, affected bird populations made noticeable recoveries.

In our industrialized society, **chemical agents** also have significant effects on human health. Toxic heavy metals, dioxins, pesticides, and endocrine disrupters are examples of these chemical agents. Heavy metals (mercury, lead, cadmium, bismuth, selenium, chromium, thallium) are typically produced as by-products of mining and manufacturing processes. All of them biomagnify (become more concentrated in species with increasing food chain level). Mercury from polluted water can accumulate in swordfish to levels toxic to humans. When toxic heavy metals get into the body, they accumulate in tissues and may eventually cause sickness or death. Studies show that people with above-average lead levels in their bones have an increased risk of developing attention deficit disorder and aggressive behavior. Lead can also damage brain cells and affect muscular coordination.

8.2 Environmental Health

Environmental health is concerned with preventing disease, death and disability by reducing exposure to adverse environmental conditions and promoting behavioral change. It focuses on the direct and indirect causes of diseases and injuries, and taps resources inside and outside the health care system to help improve health outcomes.

Underlying Determinants	Possible Adverse Health and Safety Consequences
Inadequate water (quantity and quality), sanitation (wastewater and excreta removal) and solid waste disposal, improper hygiene (hand washing)	Diarrheas and vector-related diseases, eg, malaria, schistosomiasis, dengue
Improper water resource management (urban and rural), including poor drainage	Vector-related diseases, eg, malaria, schistosomiasis
Crowded housing and poor ventilation of smoke	Acute and chronic respiratory diseases, including lung cancer (from coal and tobacco smoke inhalation)
Exposures to vehicular and industrial air pollution	Respiratory diseases, some cancers, and loss of IQ in children
Population movement and encroachment and construction, which affect feeding and breeding grounds of vectors, such as mosquitoes	Vector-related diseases, eg, malaria, schistosomiasis, and dengue fever, may also help spread other infectious diseases eg HIV/AIDS, Ebola fever
Exposure to naturally occurring toxic substances	Poisoning from, eg, arsenic, manganese, and fluorides
Natural resource degradation, eg, mudslides, poor drainage, erosion	Injury and death from mudslides and flooding
Climate change, partly from combustion of greenhouse gases in transportation, industry and poor energy conservation in housing, fuel, commerce, industry	Injury/death from: extreme heat/cold, storms, floods, fires. Indirect effects: spread of vector-borne diseases, aggravation of respiratory diseases, population dislocation, water pollution from sea level rise, etc.
Ozone depletion from industrial and commercial activity	Skin cancer, cataracts. Indirect effects: compromised food production, etc.

FIGURE 8.2

Typical Environmental Health Issues: Determinants and Health Consequences.

World Bank. (2017). Environmental health. Washington, DC: World Bank. © World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/9734/536580BRI0ENGL10Box345621B01PUBLIC1.pdf?sequence=1&isAllowed=y.

Poverty, Health and Environment

Environmental health risks can be grouped into two broad categories (World Bank, 2017). **Traditional hazards** related to poverty and lack of development affect developing countries and poor people most. Their impact exceeds that of modern health hazards by a factor of 10 in Africa, 5 in Asian countries (except for China), and 2.5 in Latin America and Middle East (see Figure 8.3). *Water-related diseases* caused by inadequate water supply and sanitation impose an especially large health burden in Africa, Asia, and the Pacific region. In India alone, over 700,000 children under 5 die annually from *diarrhea*. In Africa, *malaria* causes about 800,000 deaths annually. More than half of the world's households use unprocessed *solid fuels*, particularly biomass (crop residues, wood, and dung) for cooking and heating in inefficient stoves without proper ventilation, exposing people—mainly poor women and children—to high levels of *indoor air pollution* (IAP). IAP causes about 2 million deaths in each year.

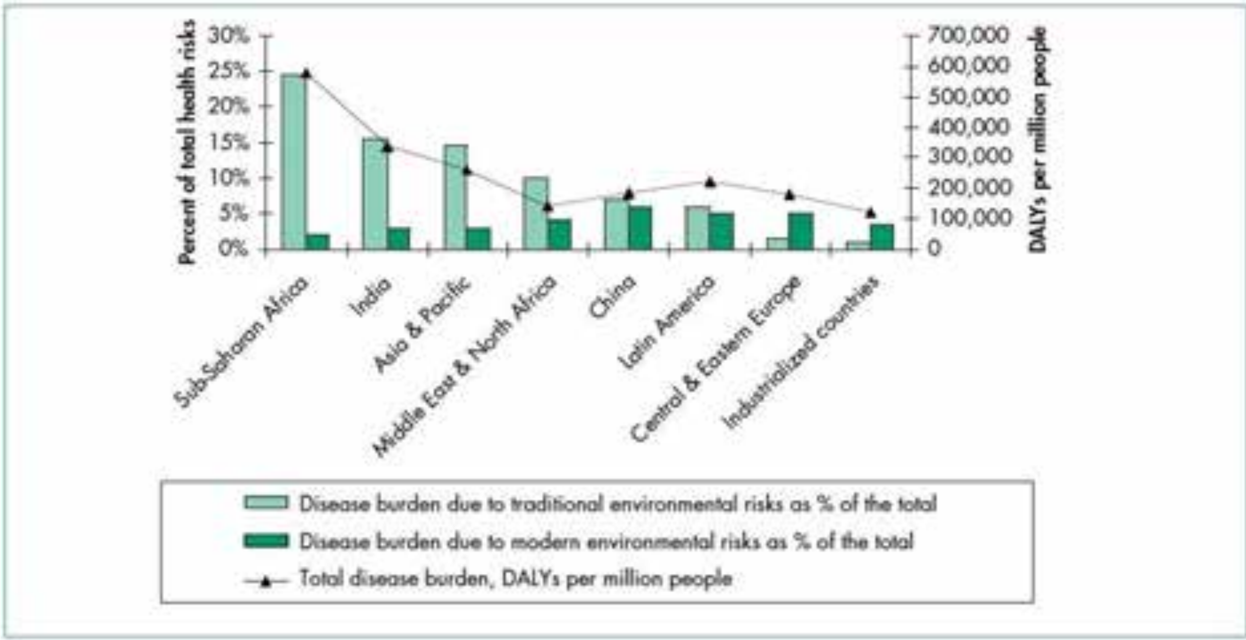


FIGURE 8.3

Traditional environmental health hazards prevail in developing countries but modern risks are also significant.

World Bank. (2017). Environmental health. Washington, DC : World Bank. © World Bank. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/9734/536580BRI0ENGL10Box345621B01PUBLIC1.pdf?sequence=1&isAllowed=y

Modern hazards, caused by development that lacks environmental safeguards, such as urban (outdoor) air pollution and exposure to agro-industrial chemicals and waste, prevail in industrialized countries, where exposure to traditional hazards is low (World Bank, 2017). But the contribution of modern environmental risks to the disease burden in most developing countries is similar to – and in quite a few countries, greater than – that in rich countries. *Urban air pollution*, for example, is highest in parts of China, India and some cities in Asia and Latin America. Poor people increasingly experience a "**double burden**" of traditional and modern environmental health risks. Their total burden of illness and death from all causes per million people is about twice that in rich countries, and the disease burden from environmental risks is 10 times greater.

Environmental Health and Child Survival

The top killers of children under five are acute respiratory infections (from indoor air pollution); diarrheal diseases (mostly from poor water, sanitation, and hygiene); and malaria (from inadequate environmental management and vector control) (World Bank, 2008, 2009). Children are especially susceptible to environmental factors that put them at risk of developing illness early in life. **Malnutrition** (the condition that occurs when body does not get enough nutrients) is an important contributor to child mortality—malnutrition and environmental infections are inextricably linked.

The World Health Organization (WHO) recently concluded that about 50 percent of the consequences of malnutrition are in fact caused by inadequate water and sanitation provision and poor hygienic practices.

FIGURE 8.4

Malnourished children in Niger, during the 2005 famine.
Bavier, J. (2001). Malnourished children in Niger, during the 2005 famine. [JPG]. Retrieved from https://en.wikipedia.org/wiki/2005%E2%80%9306_Niger_food_crisis#/media/File:Niger_childhood_malnutrition_16oct06.jpg

Poor Water and Sanitation Access

With 1.1 billion people lacking access to safe drinking water and 2.6 billion without adequate sanitation, the magnitude of the water and sanitation problem remains significant . Each year contaminated water and poor sanitation contribute to 5.4 billion cases of diarrhea worldwide and 1.6 million deaths, mostly among children under the age of five. Intestinal worms—which thrive in poor sanitary conditions—infect close to 90 percent of children in the developing world and, depending on the severity of the infection, may lead to malnutrition, anemia, or retarded growth, which, in turn, leads to diminished school performance. About 6 million people are blind from trachoma, a disease caused by the lack of water combined with poor hygiene practices.

Indoor Air Pollution (Major concerns in developing countries)

Indoor air pollution—a much less publicized source of poor health—is responsible for more than 1.6 million deaths per year and for 2.7 percent of global burden of disease (World Bank, 2008, 2009). It is estimated that half of the world's population, mainly in developing countries, uses solid fuels (biomass and coal) for household cooking and space heating. Cooking and heating with such solid fuels on open fires or stoves without chimneys lead to indoor air pollution, which, in turn, results in respiratory infections. Exposure to these health-damaging pollutants is particularly high among women and children in developing countries, who spend the most time inside the household. As many as half of the deaths attributable to indoor use of solid fuel are of children under the age of five.

Malaria

Approximately 40% of the world's people—mostly those living in the world's poorest countries—are at risk from malaria. Every year, more than 500 million people become severely ill with malaria, with most cases and deaths found in Sub-Saharan Africa. However, Asia, Latin America, the Middle East, and parts of Europe are also affected. Pregnant women are especially at high risk of malaria. Non-immune pregnant women risk both acute and severe clinical disease, resulting in fetal loss in up to 60 percent of such women and maternal deaths in more than 10 percent, including a 50 percent mortality rate for those with severe disease. Semi-immune pregnant women with malaria infection risk severe anemia and impaired fetal growth, even if they show no signs of acute clinical disease. An estimated 10,000 women and 200,000 infants die annually as a result of malaria infection during pregnancy.

Emerging Diseases

Emerging and reemerging diseases have been defined as infectious diseases of humans whose occurrence during the past two decades has substantially increased or threatens to increase in the near future relative to populations affected, geographic distribution, or magnitude of impacts. Examples include Ebola virus, West Nile virus, sudden acute respiratory syndrome (SARS); H1N1 influenza; swine and avian influenza (swine, bird flu); HIV, and a variety of other viral, bacterial, and protozoal diseases.

A variety of environmental factors may contribute to re/emergence of a particular disease, including temperature, moisture, human food or animal feed sources, etc. Disease re/emergence may be caused by the coincidence of several of these environmental and/or social factors to allow optimal conditions for transmission of the disease.

Ebola, previously known as Ebola hemorrhagic fever, is a rare and deadly disease caused by infection with one of the Ebola virus strains. Ebola can cause disease in humans and nonhuman primates (CDC, 2019). The 2014 Ebola epidemic is the largest in history (with over 28,000 cases and 11,302 deaths), affecting multiple countries in West Africa. There were a small number of cases reported in Nigeria and Mali and a single case reported in Senegal; however, these cases were contained, with no further spread in these countries.

The **HIV/AIDS** epidemic has spread with ferocious speed. Virtually unknown 20 years ago, HIV has infected more than 60 million people worldwide. Each day, approximately 14,000 new infections occur, more than half of them among young people below age 25. Over 95 percent of PLWHA (People Living With HIV/AIDS) are in low- and middle- income countries. More than 20 million have died from AIDS, over 3 million in 2002 alone. AIDS is now the leading cause of death in Sub-Saharan Africa and the fourth-biggest killer globally. The epidemic has cut life expectancy by more than 10 years in several nations.

It seems likely that a wide variety of infectious diseases have affected human populations for thousands of years emerging when the environmental, host, and agent conditions were favorable. Expanding human populations have increased the potential for transmission of infectious disease as a result of close human proximity and increased likelihood for humans to be in "the wrong place at the right time" for disease to occur (eg, natural disasters or political conflicts). Global travel increases the potential for a carrier of disease to transmit infection thousands of miles away in just a few hours, as evidenced by WHO precautions concerning international travel and health.

Antibiotic Resistance

Antibiotics and similar drugs, together called antimicrobial agents, have been used for the last 70 years to treat patients who have infectious diseases. Since the 1940s, these drugs have greatly reduced illness and death from infectious diseases. However, these drugs have been used so widely and for so long that the infectious organisms the antibiotics are designed to kill have adapted to them, making the drugs less effective. Antibiotic resistance occurs when bacteria change in a way that reduces the effectiveness of drugs, chemicals, or other agents designed to cure or prevent infections. The bacteria survive and continue to multiply, causing more harm (Figure 8.5).

New forms of antibiotic resistance can cross international boundaries and spread between continents with ease. Many forms of resistance spread with remarkable speed. Each year in the United States, at least 2 million people acquire serious infections with bacteria that are resistant to one or more of the antibiotics designed to treat those infections. At least 23,000 people die each year as a direct result of these antibiotic-resistant infections. Many more die from other conditions that were complicated by an antibiotic- resistant infection. The use of antibiotics is the single most important factor leading to antibiotic resistance around the world. Antibiotics are among the **most commonly prescribed drugs** used in human medicine, but up to 50% of all the antibiotics prescribed for people are not needed or are not optimally effective as prescribed (CDC, 2013).

During recent years, there has been growing concern over Methicillin-resistant *Staphylococcus aureus* (**MRSA**), a bacteria that is resistant to many antibiotics. In the community, most MRSA infections are skin infections. In medical facilities, MRSA causes life-threatening bloodstream infections, pneumonia and surgical site infections (CDC, 2015).

FIGURE 8.5

CDC. (2013). Antibiotic resistance threats in the United States, 2013. Retrieved from https://www.cdc.gov/drugresistance/pdf/ar-threats-2013-508.pdf. Modified from original.

8.3 Environmental Toxicology

Environmental toxicology is the scientific study of the health effects associated with exposure to **toxic chemicals** and systems occurring in the natural, work, and living environments; the management of environmental toxins and toxicity; and the development of protections for humans, animals, and plants (Table 8.1).

TABLE 8.1: The ATSDR 2013 Substance Priority List. The table below lists top 20 substances, in order of priority, which are determined to pose the most significant potential threat to human health. This priority list is not a list of "most toxic" substances, but rather a prioritization of substances based on a combination of their frequency, toxicity, and potential for human exposure at various sites.

2013 RANK	NAME
1	ARSENIC
2	LEAD
3	MERCURY
4	VINYL CHLORIDE
5	POLYCHLORINATED BIPHENYLS
6	BENZENE
7	CADMIUM
8	BENZO(A)PYRENE
9	POLYCYCLIC AROMATIC HYDROCARBONS
10	BENZO(B)FLUORANTHENE
11	CHLOROFORM
12	AROCLOR 1260
13	DDT, P,P'-
14	AROCLOR 1254
15	DIBENZO(A,H)ANTHRACENE
16	TRICHLOROETHYLENE
17	CHROMIUM, HEXAVALENT
18	DIELDRIN
19	PHOSPHORUS, WHITE
20	HEXACHLOROBUTADIENE

Routes of Exposure to Chemicals

In order to cause health problems, chemicals must enter your body. There are three main "routes of exposure," or ways a chemical can get into your body (OSHA, 2013).

- Breathing (inhalation): Breathing in chemical gases, mists, or dusts that are in the air.
- Skin or eye contact: Getting chemicals on the skin, or in the eyes. They can damage the skin, or be absorbed through the skin into the bloodstream.
- Swallowing (ingestion): This can happen when chemicals have spilled or settled onto food, beverages, cigarettes, beards, or hands.

Once chemicals have entered your body, some can move into your bloodstream and reach internal "target" organs, such as the lungs, liver, kidneys, or nervous system.

What Forms do Chemicals Take?

Chemical substances can take a variety of forms. They can be in the form of solids, liquids, dusts, vapors, gases, fibers, mists and fumes. The form a substance is in has a lot to do with how it gets into your body and what harm it can cause. A chemical can also change forms. For example, liquid solvents can evaporate and give off vapors that you can inhale. Sometimes chemicals are in a form that can't be seen or smelled, so they can't be detected.

Detecting some forms of chemicals can be difficult. Solids and liquids are easier to recognize since they can be seen. Dusts and mists may or may not be visible, depending upon their size and concentration. Fumes, vapors, and gases are usually invisible.

What Health Effects Can Chemicals Cause?

An **acute effect** of a contaminant (The term "contaminant" means hazardous substances, pollutants, pollution, and chemicals) is one that occurs rapidly after exposure to a large amount of that substance (OSHA, 2013). A chronic effect of a contaminant results from exposure to small amounts of a substance over a long period of time. In such a case, the effect may not be immediately obvious. **Chronic effect** are difficult to measure, as the effects may not be seen for years. Long-term exposure to cigarette smoking, low level radiation exposure, and moderate alcohol use are all thought to produce chronic effects.

For centuries, scientists have known that just about any substance is toxic in suffcient quantities. For example, small amounts of selenium are required by living organisms for proper functioning, but large amounts may cause cancer. The effect of a certain chemical on an individual depends on the dose (amount) of the chemical. This relationship is often illustrated by a dose-response curve which shows the relationship between dose and the response of the individual. **Lethal doses** in humans have been determined for many substances from information gathered from records of homicides and accidental poisonings.

Much of the dose-response information also comes from animal testing. Mice, rats, monkeys, hamsters, pigeons, and guinea pigs are commonly used for dose-response testing. A population of laboratory animals is exposed to measured doses under controlled conditions and the effects noted and analyzed. Animal testing poses numerous problems, however. For instance, the tests may be painful to animals, and unrelated species can react differently to the same toxin. In addition, the many differences between test animals and humans makes extrapolating test results to humans very difficult. A dose that is lethal to 50 percent of a population of test animals is called the **lethal dose-50 percent** or **LD-50**. Determination of the LD-50 is required for new synthetic chemicals in order to give a measure of their toxicity. A dose that causes 50 percent of a population to exhibit any significant response (e.g., hair loss, stunted development) is referred to as the effective dose-50 percent or ED-50. Some toxins have a threshold amount below which there is no apparent effect on the exposed population.

Some scientists believe that all toxins should be kept at a zero-level threshold because their effects at low levels are not well known. That is because of the synergy effect in which one substance exacerbates the effects of another. For example, if cigarette smoking increases lung cancer rates 20 times and occupational asbestos exposure also increases lung cancer rates 20 times, then smoking and working in an asbestos plant may increase lung cancer rates up to 400 times.

Environmental Contaminants

The contamination of the air, water, or soil with potentially harmful substances can affect any person or community. Contaminants (Table 8.2) are often chemicals found in the environment in amounts higher than what would be there naturally. We can be exposed to these contaminants from a variety of residential, commercial, and industrial sources. Sometimes harmful environmental contaminants occur biologically, such as mold or a toxic algae bloom.

TABLE 8.2: Classification of Environmental Contaminants

Contaminant	Definition
Carcinogen	An agent which may produce cancer (uncontrolled cell growth), either by itself or in conjunction with another substance. Examples include formaldehyde, asbestos, radon, vinyl chloride, and tobacco.
Suspect Carcinogen	An agent which is suspected of being a carcinogen based on chemical structure, animal research studies, or mutagenicity studies.
Confirmed Animal Carcinogen with Unknown Relevance to Humans	An agent that is carcinogenic in experimental animals at a relatively high dose, by routes of administration, at sites, or histologic types, or by mechanisms that may not be relevant to worker exposure. Available epidemiologic studies do not confirm an increased risk of cancer in exposed humans. Available evidence does not suggest that the agent is likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure.
Teratogen	A substance which can cause physical defects in a developing embryo. Examples include alcohol and cigarette smoke.
Mutagen	A material that induces genetic changes (mutations) in the DNA. Examples include radioactive substances, x-rays and ultraviolet radiation.
Neurotoxicant	A substance that can cause an adverse effect on the chemistry, structure or function of the nervous system. Examples include lead and mercury.
Endocrine disruptor	A chemical that may interfere with the body's endocrine system and produce adverse developmental, reproductive, neurological, and immune effects in both humans and wildlife. A wide range of substances, both natural and man-made, are thought to cause endocrine disruption, including pharmaceuticals, dioxin and dioxin-like compounds, arsenic, polychlorinated biphenyls (PCBs), DDT and other pesticides, and plasticizers such as bisphenol A (BPA). Endocrine disruptors may be found in many everyday products– including plastic bottles, metal food cans, detergents, flame retardants, food, toys, cosmetics, and pesticides. Research shows that endocrine disruptors may pose the greatest risk during prenatal and early postnatal development when organ and neural systems are forming.

The following are some environmental contaminants that can affect a community or an individual's health (Tox Town, 2018).

Arsenic is a naturally occurring element that is normally present throughout our environment in water, soil, dust, air, and food. Levels of arsenic can vary from place to place due to farming and industrial activity as well as natural geological processes. The arsenic from farming and smelting tends to bind strongly to soil and is expected to remain near the surface of the land for hundreds of years as a long-term source of exposure. Wood that has been treated with chromated copper arsenate (CCA) is commonly found in decks and railing in existing homes and outdoor structures such as playground equipment. Some underground aquifers are located in rock or soil that has naturally high arsenic content.

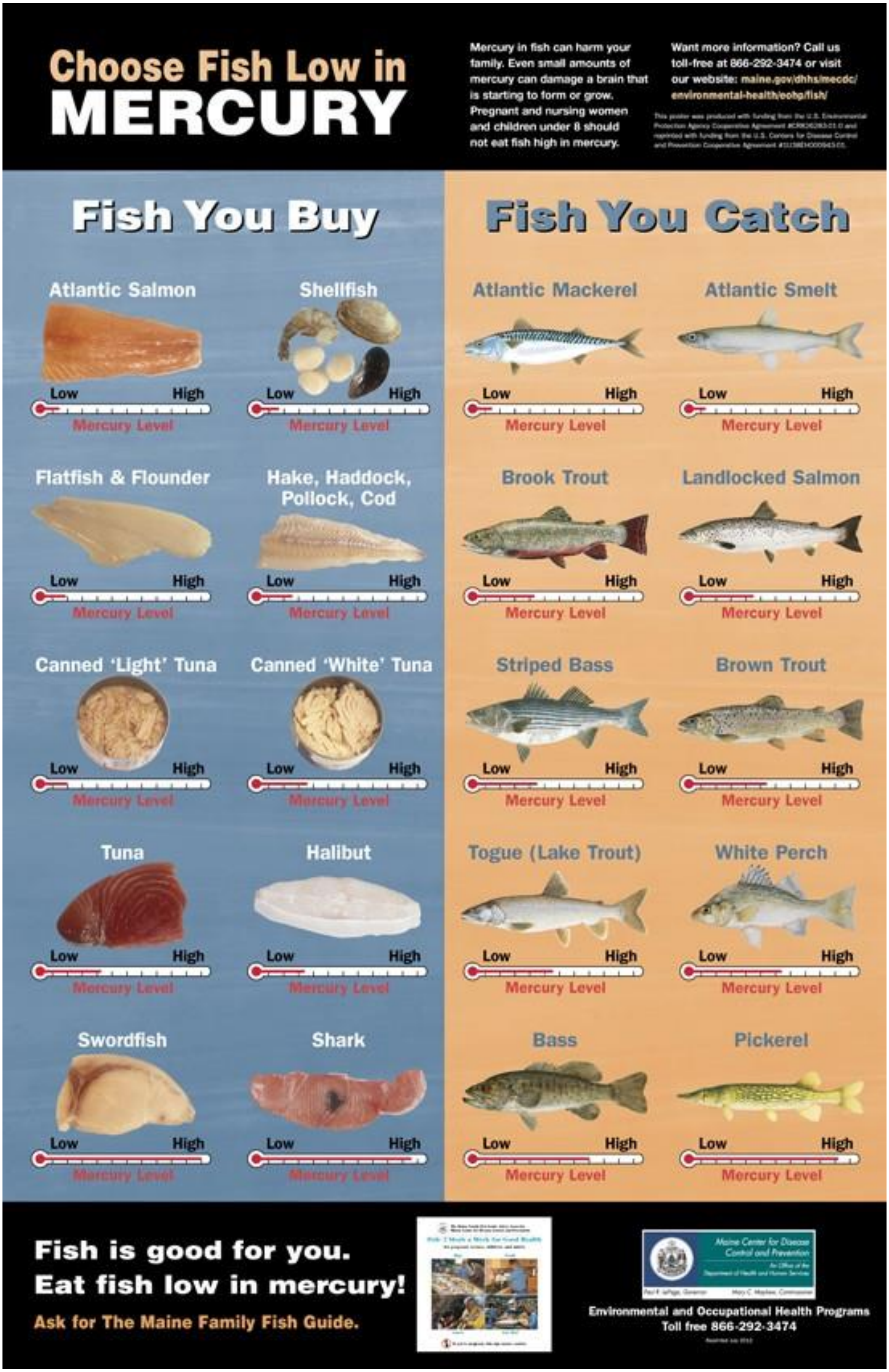
Most arsenic gets into the body through ingestion of food or water. Arsenic in drinking water is a problem in many countries around the world, including Bangladesh, Chile, China, Vietnam, Taiwan, India, and the United States. Arsenic may also be found in foods, including rice and some fish, where it is present due to uptake from soil and water. It can also enter the body by breathing dust containing arsenic, or through the skin, though this is not a major route of exposure. Researchers are finding that arsenic, even at low levels, can interfere with the body's endocrine system. In several cell culture and animal models, arsenic has been found to act as an endocrine disruptor, which may underlie many of its health effects. Arsenic is also a known human carcinogen associated with skin, lung, bladder, kidney, and liver cancer.

Polychlorinated biphenyls, commonly called PCBs, are mixtures of up to 209 chlorinated compounds that do not occur naturally. They have no taste or smell. PCBs are persistent organic pollutants (POPs) and endocrine disruptors. The manufacture of PCBs was stopped in the U.S. in 1977 because of evidence they build up in the environment and can cause harmful health effects. But, before 1977, PCBs were used as insulation, as plasticizers, and in surface coatings, sealants, fire retardants, glues, inks, pesticides, and carbonless copy paper. PCBs don't break down easily in the environment and may remain there for very long periods of time. Studies indicate that PCBs are associated with certain kinds of cancer in humans. Women who were exposed to relatively high levels of PCBs in the workplace or ate large amounts of fish contaminated with PCBs had babies that weighed slightly less than babies from women who did not have these exposures.

Mercury is a naturally occurring metal, a useful chemical in some products, and a potential health risk. Mercury exists in several forms – the types people are usually exposed to are methylmercury and elemental mercury. Elemental mercury at room temperature is a shiny, silver-white liquid, which can produce a harmful odorless vapor. Methylmercury, an organic compound, can build up in the bodies of long-living, predatory fish. To keep mercury out of the fish we eat and the air we breathe, it's important to take mercury-containing products to a hazardous waste facility for disposal. Common products sold today that contain small amounts of mercury include fluorescent lights and button-cell batteries.

Although fish and shellfish have many nutritional benefits, consuming large quantities of fish increases a person's exposure to mercury. Pregnant women who eat fish high in mercury on a regular basis run the risk of permanently damaging their developing fetuses. Children born to these mothers may exhibit motor difficulties, sensory problems and cognitive deficits. The poster 8.6 (published by the Maine Center for Disease Control & Prevention) identifies the typical (average) amounts of mercury in commonly consumed commercial and sport-caught fish.

Bisphenol A (BPA) is a chemical produced in large quantities for use primarily in the production of polycarbonate plastics and epoxy resins. Polycarbonate plastics have many applications including use in some food and drink packaging, e.g., water and infant bottles, compact discs, impact-resistant safety equipment, and medical devices. Epoxy resins are used as lacquers to coat metal products such as food cans, bottle tops, and water supply pipes. Some dental sealants and composites may also contribute to BPA exposure. The primary source of exposure to BPA for most people is through the diet. Bisphenol A can leach into food from the protective internal epoxy resin coatings of canned foods and from consumer products such as polycarbonate tableware, food storage containers, water bottles, and baby bottles. The degree to which BPA leaches from polycarbonate bottles into liquid may depend more on the temperature of the liquid or bottle, than the age of the container. BPA can also be found in breast milk.



Choose Fish Low in MERCURY
Mercury in fish can harm your family. Even small amounts of mercury can damage a brain that is starting to form or grow. Pregnant and nursing women and children under 8 should not eat fish high in mercury.
Want more information? Call us toll-free at 866-292-3474 or visit our website: maine.gov/dhhs/mecdc/environmental-health/eohp/fish/
Fish You Buy
Fish You Catch
Atlantic Salmon
Shellfish
Atlantic Mackerel
Atlantic Smelt
Flatfish & Flounder
Hake, Haddock, Pollock, Cod
Brook Trout
Landlocked Salmon
Canned 'Light' Tuna
Canned 'White' Tuna
Striped Bass
Brown Trout
Tuna
Halibut
Togue (Lake Trout)
White Perch
Swordfish
Shark
Bass
Pickerel
Low
High
Mercury Level
Fish is good for you.
Eat fish low in mercury!
Ask for The Maine Family Fish Guide.
Maine Center for Disease Control and Prevention
Environmental and Occupational Health Programs
Toll free 866-292-3474

BOX 1. What can I do to prevent exposure toBPA?

Some animal studies suggest that infants and children may be the most vulnerable to the effects of BPA. Parents and caregivers, can make the personal choice to reduce exposures of their infants and children to BPA:

- Don't microwave polycarbonate plastic food containers. Polycarbonate is strong and durable, but over time it may break down from over use at high temperatures.
- Plastic containers have recycle codes on the bottom. Some, but not all, plastics that are marked with recycle codes 3 or 7 may be made with BPA.
- Reduce your use of canned foods.
- When possible, opt for glass, porcelain or stainless steel containers, particularly for hot food or liquids.
- Use baby bottles that are BPA free.

Dioxins are a class of chemical contaminants that are formed during combustion processes such as waste incineration, forest fires, and backyard trash burning, as well as during some industrial processes such as paper pulp bleaching and herbicide manufacturing (Tox Town, 2018). The highest environmental concentrations of dioxin are usually found in soil and sediment, with much lower levels found in air and water. We are primarily exposed to dioxins by eating food contaminated by these chemicals. Studies have also shown that chemical workers who are exposed to high levels of dioxins have an increased risk of cancer. Other studies of show that dioxins can cause reproductive and developmental problems, and an increased risk of heart disease and diabetes.

Phthalates are a group of chemicals used to soften and increase the flexibility of plastic and vinyl. Polyvinyl chloride is made softer and more flexible by the addition of phthalates. Phthalates are used in hundreds of consumer products. Phthalates are used in cosmetics and personal care products, including perfume, hair spray, soap, shampoo, nail polish, and skin moisturizers. They are used in consumer products such as flexible plastic and vinyl toys, shower curtains, wallpaper, vinyl miniblinds, food packaging, and plastic wrap. Exposure to low levels of phthalates may come from eating food packaged in plastic that contains phthalates or breathing dust in rooms with vinyl miniblinds, wallpaper, or recently installed flooring that contain phthalates. We can be exposed to phthalates by drinking water that contains phthalates. Phthalates are suspected to be endocrine disruptors.

Lead is a metal that occurs naturally in the rocks and soil of the earth's crust. It is also produced from burning fossil fuels such as coal, oil, gasoline, and natural gas; mining; and manufacturing. Lead has no distinctive taste or smell. The chemical symbol for elemental lead is **Pb**. Lead is used to produce batteries, pipes, roofing, scientific electronic equipment, military tracking systems, medical devices, and products to shield X-rays and nuclear radiation. It is used in ceramic glazes and crystal glassware. Because of health concerns, lead and lead compounds were banned from house paint in 1978; from solder used on water pipes in 1986; from gasoline in 1995; from solder used on food cans in 1996; and from tin-coated foil on wine bottles in 1996. The U.S. Food and Drug Administration has set a limit on the amount of lead that can be used in ceramics.

Lead and lead compounds are listed as "reasonably anticipated to be a human carcinogen". It can affect almost every organ and system in your body. It can be equally harmful if breathed or swallowed. The part of the body most sensitive to lead exposure is the central nervous system, especially in children, who are more vulnerable to lead poisoning than adults. A child who swallows large amounts of lead can develop brain damage that can cause convulsions and death; the child can also develop blood anemia, kidney damage, colic, and muscle weakness. Repeated low levels of exposure to lead can alter a child's normal mental and physical growth and result in learning or behavioral problems. Exposure to high levels of lead for pregnant women can cause miscarriage, premature births, and smaller babies. Repeated or chronic exposure can cause lead to accumulate in your body, leading to lead poisoning.

Polyvinyl chloride (PVC) is an odorless and solid plastic. It is most commonly white but can also be colorless or amber. It can also come in the form of white powder or pellets. PVC is made from vinyl chloride. PVC is made softer and more flexible by the addition of phthalates. Bisphenol A (BPA) is also used to make PVC plastics. PVC contains high levels of chlorine. PVC is used to make pipes, pipe fittings, pipe conduits, vinyl flooring, and vinyl siding. When softened with phthalates, PVC is used to make some medical devices (including intravenous (IV) bags, blood bags, blood and respiratory tubing) and consumer products (raincoats, toys, shower curtains, furniture, carpet backing, plastic bags and credit cards). Most vinyl chloride produced in the United States is used to make PVC.

Exposure to PVC often includes exposure to phthalates, which are used to soften PVC and may have adverse health effects. Because of PVC's heavy chlorine content, dioxins are released during the manufacturing, burning, or landfilling of PVC. Exposure to dioxins can cause reproductive, developmental, and other health problems, and at least one dioxin is classified as a carcinogen. Dioxins, phthalates, and BPA are suspected to be endocrine disruptors, which are chemicals that may interfere with the production or activity of hormones in the human endocrine system.

Formaldehyde is a colorless, flammable gas or liquid that has a pungent, suffocating odor (Tox Town, 2018). It is a volatile organic compound, which is an organic compound that easily becomes a vapor or gas. It is also naturally produced in small, harmless amounts in the human body. The primary way we can be exposed to formaldehyde is by breathing air containing it. Releases of formaldehyde into the air occur from industries using or manufacturing formaldehyde, wood products (such as particle-board, plywood, and furniture), automobile exhaust, cigarette smoke, paints and varnishes, and carpets and permanent press fabrics. Nail polish, and commercially applied floor finish emit formaldehyde.

In general, indoor environments consistently have higher concentrations than outdoor environments, because many building materials, consumer products, and fabrics emit formaldehyde. Levels of formaldehyde measured in indoor air range from 0.02–4 parts per million (ppm). Formaldehyde levels in outdoor air range from 0.001 to 0.02 ppm in urban areas.

Radiation

Radiation is energy given off by atoms and is all around us. We are exposed to radiation every day from natural sources like soil, rocks, and the sun. We are also exposed to radiation from man-made sources like medical X-rays and smoke detectors. We're even exposed to low levels of radiation on cross-country flights, from watching television, and even from some construction materials. You cannot see, smell or taste radiation. Some types of radioactive materials are more dangerous than others. So it's important to carefully manage radiation and radioactive substances to protect health and the environment.

Radon is a colorless, odorless radioactive gas (Tox Town, 2018). It comes from the natural decay of uranium or thorium found in nearly all soils. It typically moves up through the ground and into the home through cracks in floors, walls and foundations. It can also be released from building materials or from well water. Radon breaks down quickly, giving off radioactive particles. Long-term exposure to these particles can lead to lung cancer. Radon is the leading cause of lung cancer among nonsmokers, according to the U.S. Environmental Protection Agency, and the second leading cause behind smoking.

8.4 Risk Assessment and Management

Risk assessment is a scientific process used by federal agencies and risk management decision-makers to make informed decisions about actions that may be taken to protect human health by ascertaining potential human health risks or health hazard associated with exposure to chemicals in the environment (EPA, 2013). Some of the real-world examples of risk assessment includes: establishment of national ambient air quality and drinking water standards for protection of public health (e.g. ozone, particulate matter in outdoor air; chromium, chloroform or benzene in water); establishment of cleanup levels for hazardous waste site remediation; development of fish consumption advisories for pregnant women and general population (e.g. PCBs, mercury); assessment of risks and benefits of different alternative fuels for sound energy policy development (e.g. oxygenated gasoline, biodiesel); and estimation of health risks associated with pesticide residues in food. The estimated risk is a function of exposure and toxicity. The regulatory risk assessment follows a four-step paradigm using qualitative and/or quantitative approaches. In quantitative risk assessment using either deterministic or probabilistic approaches, the risk estimates pertaining to an exposure scenario is particularly useful when comparing a number of exposure or risk reduction measures among one another as an optimization protocol to determine the best economically viable option for protection of public health and the environment. The four steps of risk assessment are i) hazard identification; ii) toxicity (or dose- response) assessment; iii) exposure assessment; and iv) risk characterization, which are described below in detail. The emphasis is given in documenting the resources necessary to successfully perform each step.

1. In the hazard identification step, a scientific weight of evidence analysis is performed to determine whether a particular substance or chemical is or is not causally linked to any particular health effect at environmentally relevant concentrations. Hazard identification is performed to determine whether, and to what degree, toxic effects in one setting will occur in other settings. The evidence comes from human but also animal studies.
2. Toxicity or dose-response assessment takes the toxicity data gathered in the hazard identification step from animal studies and exposed human population studies and describes the quantitative relationship between the amount of exposure to a chemical (or dose) and the extent of toxic injury or disease (or response). Generally, as the dose of a chemical increases, the toxic response increases either in the severity of the injury or in the incidence of response in the affected population.
3. The magnitude of exposure is determined by measuring or estimating the amount of an agent to which humans are exposed (i.e. exposure concentration) and the magnitude of dose (or intake) is estimated by taking the magnitude, frequency, duration, and route of exposure into account. Exposure assessments may consider past, present, and future exposures.
4. In the last step, a hazard quotient (HQ) as an indicator of risks associated with health effects other than cancer and excess cancer risk as the incremental probability of an exposed person developing cancer over a lifetime, are calculated by integrating toxicity and exposure information.

The improvement in the scientific quality and validity of health risk estimates depends on advancements in our understanding of human exposure to, and toxic effects associated with, chemicals present in environmental and occupational settings. Risk assessments are important for informed regulatory decision-making in environmental sustainability and to ensure that costs associated with different technological alternatives are scientifically justified and protest public health. Risk assessment helps federal agencies and risk management decision makers arrive at informed decisions about actions to take to protect human health from environmental hazards. Although significant uncertainties remain, this risk assessment methodology has been extensively peer-reviewed, is widely used and understood by the scientific community, and continues to expand and evolve as scientific knowledge advances.

Risk management (Figure 8.7) is distinct from risk assessment, and involves the integration of risk assessment with other considerations, such as economic, social, or legal concerns, to reach regulatory decisions regarding the need for and practicability of implementing various risk reduction activities.

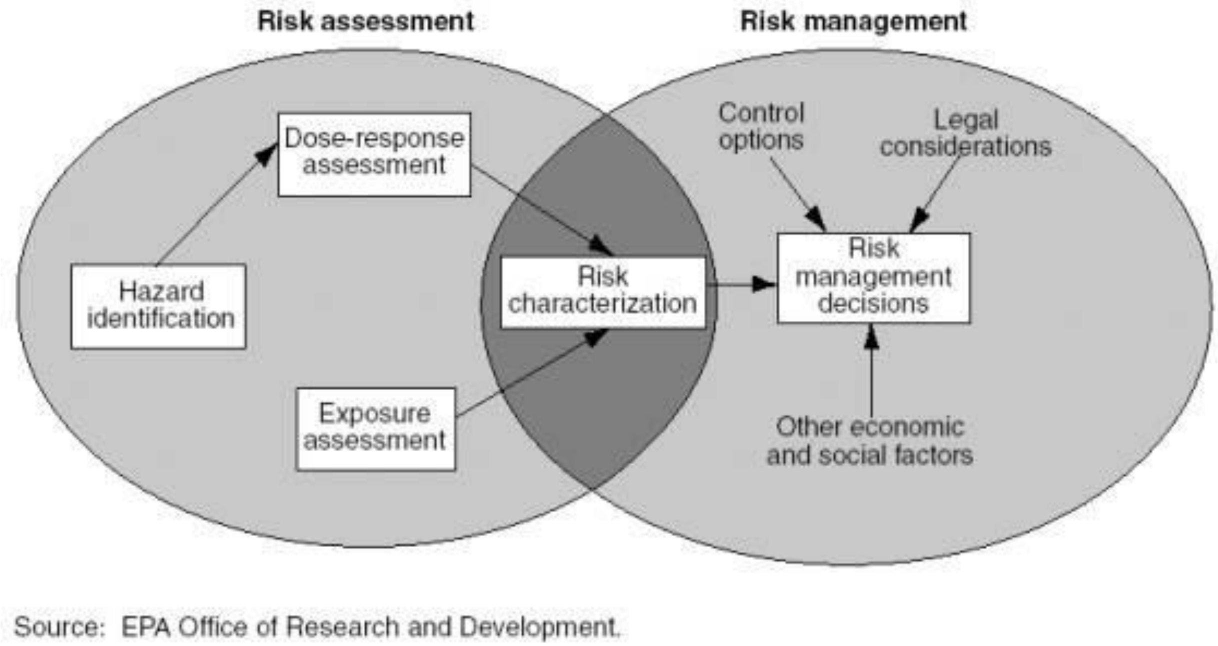


FIGURE 8.7

Risk Assessment and Management.

EPA. (2013). Attachment 6: Useful terms and definitions for explaining risk. Accessed August 31, 2019 at https://semspub.epa.gov/work/HQ/174688.pdf.

Finally, **risk communication** consists of the formal and informal processes of communication among various parties who are potentially at risk from or are otherwise interested in the threatening agent/action. It matters a great deal how a given risk is communicated and perceived: do we have a measure of control, or are we subject to powerful unengaged or arbitrary forces?

8.5 Case Study: The Love Canal Disaster

One of the most famous and important examples of groundwater pollution in the U.S. is the Love Canal tragedy in Niagara Falls, New York. It is important because the pollution disaster at Love Canal, along with similar pollution calamities at that time (Times Beach, Missouri and Valley of Drums, Kentucky), helped to create Superfund, a federal program instituted in 1980 and designed to identify and clean up the worst of the hazardous chemical waste sites in the U.S.

Love Canal is a neighborhood in Niagara Falls named after a large ditch (approximately 15 m wide, 3–12 m deep, and 1600 m long) that was dug in the 1890s for hydroelectric power. The ditch was abandoned before it actually generated any power and went mostly unused for decades, except for swimming by local residents. In the 1920s Niagara Falls began dumping urban waste into Love Canal, and in the 1940s the U.S. Army dumped waste from World War II there, including waste from the frantic effort to build a nuclear bomb. Hooker Chemical purchased the land in 1942 and lined it with clay. Then, the company put into Love Canal an estimated 21,000 tons of hazardous chemical waste, including the carcinogens benzene, dioxin, and PCBs in large metal barrels and covered them with more clay. In 1953, Hooker sold the land to the Niagara Falls school board for $1, and included a clause in the sales contract that both described the land use (filled with chemical waste) and absolved them from any future damage claims from the buried waste. The school board promptly built a public school on the site and sold the surrounding land for a housing project that built 200 or so homes along the canal banks and another 1,000 in the neighborhood During construction, the canal's clay cap and walls were breached, damaging some of the metal barrels.

Eventually, the chemical waste seeped into people's basements, and the metal barrels worked their way to the surface. Trees and gardens began to die; bicycle tires and the rubber soles of children's shoes disintegrated in noxious puddles. From the 1950s to the late 1970s, residents repeatedly complained of strange odors and substances that surfaced in their yards. City officials investigated the area, but did not act to solve the problem. Local residents allegedly experienced major health problems including high rates of miscarriages, birth defects, and chromosome damage, but studies by the New York State Health Department disputed that. Finally, in 1978 President Carter declared a state of emergency at Love Canal, making it the first human-caused environmental problem to be designated that way. The Love Canal incident became a symbol of improperly stored chemical waste. Clean up of Love Canal, which was funded by Superfund and completely finished in 2004, involved removing contaminated soil, installing drainage pipes to capture contaminated groundwater for treatment, and covering it with clay and plastic. In 1995, Occidental Chemical (the modern name for Hooker Chemical) paid $102 million to Superfund for cleanup and $27 million to Federal Emergency Management Association for the relocation of more than 1,000 families. New York State paid $98 million to EPA and the US government paid $8 million for pollution by the Army. The total clean up cost was estimated to be $275 million.

The Love Canal tragedy helped to create Superfund, which has analyzed tens of thousands of hazardous waste sites in the U.S. and cleaned up hundreds of the worst ones. Nevertheless, over 1,000 major hazardous waste sites with a significant risk to human health or the environment are still in the process of being cleaned.

8.6 Resources

Summary

Environmental health is concerned with preventing disease, death and disability by reducing exposure to adverse environmental conditions and promoting behavioral change. It focuses on the direct and indirect causes of diseases and injuries, and taps resources inside and outside the health care system to help improve health outcomes. Environmental health risks can be grouped into two broad categories. Traditional hazards related to poverty and lack of development affect developing countries and poor people most. Modern hazards, caused by development that lacks environmental safeguards, such as urban (outdoor) air pollution and exposure to agro-industrial chemicals and waste, prevail in industrialized countries, where exposure to traditional hazards is low. Each year contaminated water and poor sanitation contribute to 5.4 billion cases of diarrhea worldwide and 1.6 million deaths, mostly among children under the age of five. Indoor air pollution—a much less publicized source of poor health—is responsible for more than 1.6 million deaths per year and for 2.7 percent of global burden of disease. Emerging and reemerging diseases have been defined as infectious diseases of humans whose occurrence during the past two decades has substantially increased or threatens to increase in the near future relative to populations affected, geographic distribution, or magnitude of impacts. Antibiotic resistance is a global problem. New forms of antibiotic resistance can cross international boundaries and spread between continents. Environmental toxicology is the scientific study of the health effects associated with exposure to toxic chemicals and systems occurring in the natural, work, and living environments; the management of environmental toxins and toxicity; and the development of protections for humans, animals, and plants. Environmental contaminants are chemicals found in the environment in amounts higher than what would be there naturally. We can be exposed to these contaminants from a variety of residential, commercial, and industrial sources.

Review Questions

1. Define environmental health.
2. Define the following terms: carcinogenic, mutagenic, teratogenic, endocrine disruptor.
3. Describe the difference between acute and chronic effect.
4. Give two examples of emerging diseases.
5. Define modern hazards.
6. What are the three main routes of exposure a chemical can get into our body?
7. What are the two types of mercury people are usually exposed to?

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CHAPTER 9 Food and Hunger

Chapter Outline

FIGURE 9.1

By learning skills like composting, crop diversification, organic pesticide production, seed multiplication and agro-forestry farmers in Malawi are increasing their ability to feed their families over the long term.

Learning Outcomes

After studying this chapter, you should be able to:

- Understand the major drivers of food insecurity
- Recognize the role of women in food and nutritional security
- Classify key food and nutritional sources
- Identify benefits and risks of genetic engineering

9.1 Food Security

Progress continues in the fight against hunger, yet an unacceptably large number of people still lack the food they need for an active and healthy life (World Bank, 2009). The latest available estimates indicate that about 795 million people in the world – just over one in nine –still go to bed hungry every night, and an even greater number live in poverty (defined as living on less than $1.25 per day). Poverty—not food availability—is the major driver of food insecurity. Improvements in agricultural productivity are necessary to increase rural household incomes and access to available food but are insufficient to ensure food security. Evidence indicates that poverty reduction and food security do not necessarily move in tandem. The main problem is lack of economic (social and physical) access to food at national and household levels and inadequate nutrition (or hidden hunger). Food security not only requires an adequate supply of food but also entails availability, access, and utilization by all—men and women of all ages, ethnicities, religions, and socioeconomic levels.

From Agriculture to Food Security

Agriculture and food security are inextricably linked (World Bank, 2015). The agricultural sector in each country is dependent on the available natural resources, as well as on national and international policy and the institutional environment that governs those resources. These factors influence women and men in their choice of crops and levels of potential productivity. Agriculture, whether domestic or international, is the only source of food both for direct consumption and as raw material for refined foods. Agricultural production determines food availability. The stability of access to food through production or purchase is governed by domestic policies, including social protection policies and agricultural investment choices that reduce risks (such as droughts) in the agriculture production cycle. Yet the production of food is not the only goal of agricultural systems that also produce feed for livestock and fuel. Therefore, demand for and policies related to feed and fuel also influence food availability and access.

Staple grains are the main source of dietary energy in the human diet and are more likely to be available through national and international markets, even in developing countries, given their storage and transport characteristics. Fruits, vegetables, livestock, and aquaculture products are the key to micronutrient, that is, vitamins and minerals, sufficiency. However, most of these products are more perishable than grains, so that in the poorest countries where lack of infrastructure, such as cold storage and refrigerated transport, predicates short food chains, local agriculture determines the diversity of diets. Food security can become a reality only when the agricultural sector is vibrant.

Women's Role in Food and Nutritional Security

Agricultural interventions are most likely to affect nutrition outcomes when they involve diverse and complementary processes and strategies that redirect the focus beyond agriculture for food production and toward broader consideration of livelihoods, women's empowerment, and optimal intrahousehold uses of resources (World Bank, 2009). Successful projects are those that invest broadly in improving human capital, sustain and increase the livelihood assets of the poor, and focus on gender equality. Women are crucial in the translation of the products of a vibrant agriculture sector into food and nutritional security for their households. They are often the farmers who cultivate food crops and produce commercial crops alongside the men in their households as a source of income. When women have an income, substantial evidence indicates that the income is more likely to be spent on food and children's needs. Women are generally responsible for food selection and preparation and for the care and feeding of children. Women are the key to food security for their households. In rural areas the availability and use of time by women is also a key factor in the availability of water for good hygiene, firewood collection, and frequent feeding of small children. In sub-Saharan Africa transportation of supplies for domestic use—fetching fuelwood and water—is largely done by women and girls on foot. Changes in the availability of natural resources, due to the depletion of natural resources and/or impacts of climate change, can compromise food security by further constraining the time available to women. Water degradation and pollution can force women to travel farther to collect water, reduce the amount they collect, and compromise hygiene practices in the household. Recognizing women's needs for environmental resources, not only for crop production but also for fuel and water, and building these into good environmental management can release more time for women to use on income generation, child care, and leisure.

Food security

Food security is essentially built on four pillars: **availability**, **access**, **utilization** and **stability** (Bora, Ceccacci, Delgado & Townsend, 2011). An individual must have access to sufficient food of the right dietary mix (quality) at all times to be food secure. Those who never have sufficient quality food are **chronically food insecure**.

TABLE 9.1:

WHAT IS FOOD SECURITY?
Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets dietary needs and food preferences for an active and healthy life. It includes the following dimensions: **availability**: the availability of sufficient quantities of appropriate quality; **access**: access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet on a regular basis; **utilization**: utilization of food through adequate diet, clean water, sanitation and health care to reach a nutritional well-being where all physiological needs are met; **stability**: a population, household or individual must have access to food at all times and should not risk losing access as a consequence of sudden shocks or cyclical events. Certain groups are particularly vulnerable to food insecurity, including women (especially low income pregnant and lactating women), victims of conflict, the ill, migrant workers, low-income urban dwellers, the elderly, and children under five.

The definition of food security is often applied at varying levels of aggregation, despite its articulation at the individual level. The importance of a pillar depends on the level of aggregation being addressed. At a global level, the important pillar is **food availability** (World Bank, 2009). Does global agricultural activity produce sufficient food to feed all the world's inhabitants? The answer today is yes, but it may not be true in the future given the impact of a growing world population, emerging plant and animal pests and diseases, declining soil productivity and environmental quality, increasing use of land for fuel rather than food, and lack of attention to agricultural research and development, among other factors.

When food security is analyzed at the national level, an understanding not only of national production is important, but also of the country's **access** to food from the global market, its foreign exchange earnings, and its citizens' consumer choices. Food security analyzed at the household level is conditioned by a household's own food production and household members' ability to purchase food of the right quality and diversity in the market place. However, it is only at the individual level that the analysis can be truly accurate because only through understanding who consumes what can we appreciate the impact of sociocultural and gender inequalities on people's ability to meet their nutritional needs.

The third pillar, food **utilization**, essentially translates the food available to a household into nutritional security for its members. One aspect of utilization is analyzed in terms of distribution according to need. Nutritional standards exist for the actual nutritional needs of men, women, boys, and girls of different ages and life phases (that is, pregnant women), but these "needs" are often socially constructed based on culture. For example, in South Asia evidence shows that women eat after everyone else has eaten at a meal and are less likely than men in the same household to consume preferred foods such as meats and fish. **Hidden hunger** commonly results from poor food utilization: that is, a person's diet lacks the appropriate balance of macro- (calories) and micronutrients (vitamins and minerals). Individuals may look well nourished and consume sufficient calories but be deficient in key micronutrients such as vitamin A, iron, and iodine.

When food security is analyzed at the national level, an understanding not only of national production is important, but also of the country's access to food from the global market, its foreign exchange earnings, and its citizens' consumer choices. Food security analyzed at the household level is conditioned by a household's own food production and household members' ability to purchase food of the right quality and diversity in the market place. However, it is only at the individual level that the analysis can be truly accurate because only through understanding who consumes what can we appreciate the impact of sociocultural and gender inequalities on people's ability to meet their nutritional needs.

Malnutrition is economically costly: it can cost individuals 10 percent of their lifetime earnings and nations 2 to 3 percent of gross domestic product (GDP) in the worst-affected countries (Alderman 2005). Achieving food security is even more challenging in the context of HIV and AIDS. HIV affects people's physical ability to produce and use food, reallocating household labor, increasing the work burden on women, and preventing widows and children from inheriting land and productive resources (Izumi 2006).

Public policies, written from a human rights perspective, recognize the interrelatedness of all basic rights and assist in the identification of those whose rights are not fully realized. In this way they facilitate corrective action and appropriate strategies to enable equal protection for all. Equal representation and active engagement of both women and men in the policymaking processes are required so that their varying needs and priorities are appropriately targeted. More often than not, however, access to the legal system may be more problematic for women than men, but technical and financial support is also needed if institutions that advance and implement women's rights are to fulfill their mandate.

Recognizing the Role of Women Can Improve Food and Nutritional Security

Food security is a primary goal of sustainable agricultural development and a cornerstone for economic and social development (World Bank, 2009). Women play vital and often unacknowledged role in agriculture. Gender-based inequalities all along the food production chain "from farm to plate" impede the attainment of food and nutritional security. Maximizing the impact of agricultural development on food security entails enhancing women's roles as agricultural producers as well as the primary caretakers of their families.

Obesity

Obesity means having too much body fat. It is not the same as overweight, which means weighing too much. Obesity has become a significant global health challenge, yet is preventable and reversible. Over the past 20 years, a global overweight/obesity epidemic has emerged, initially in industrial countries and now increasingly in low- and middle-income countries, particularly in urban settings, resulting in a triple burden of undernutrition, micronutrient deficiency, and overweight/obesity. There is significant variation by region; some have very high rates of undernourishment and low rates of obesity, while in other regions the opposite is true (Figure 9.2).

However, obesity has increased to the extent that the number of overweight people now exceeds the number of underweight people worldwide. The economic cost of obesity has been estimated at $2 trillion, accounting for about 5 percent of deaths worldwide. Almost 30 percent of the world's population, or 2.1 billion people, are overweight or obese, 62 percent of whom live in developing countries.

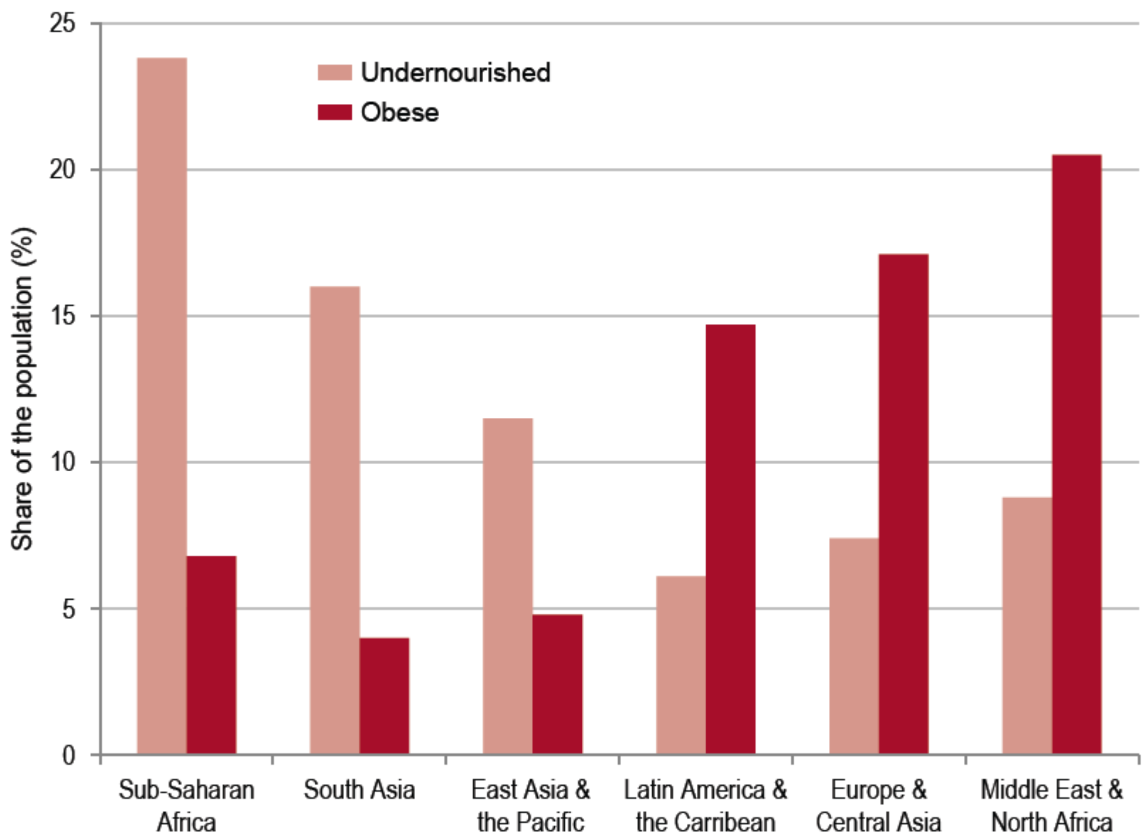


FIGURE 9.2

Obesity and undernourishment by region.

World Bank. (2015). Ending poverty and hunger by 2030: An agenda for the global food system. Wash- ington, DC. © World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/21771. Available under Creative Commons Attribution License 3.0 IGO

Obesity accounts for a growing level and share of worldwide noncommunicable diseases, including diabetes, heart disease, and certain cancers that can reduce quality of life and increase public health costs of already underresourced developing countries. The number of overweight children is projected to double by 2030. Driven primarily by increasing availability of processed, affordable, and effectively marketed food, the global food system is falling short with rising obesity and related poor health outcomes. Due to established health implications and rapid increase in prevalence, obesity is now a recognized major global health challenge, and no national success stories in curbing its growth have so far been reported. Eating a variety of healthful foods promotes good physical health and provides energy for growth and activity. Many common diseases and their symptoms can be prevented or helped with healthful eating. Knowing what your body needs can help you choose foods to meet those needs.

Nutrients, Energy, and Building Materials

Nutrients are chemical elements or compounds that the body needs for normal functioning and good health (CK12, 2009). There are six main classes of nutrients: carbohydrates, proteins, lipids, water, vitamins, and minerals. The body needs these nutrients for three basic purposes: energy, building materials, and control of body processes.

A steady supply of energy is needed by cells for all body functions. Carbohydrates, proteins, and lipids provide this energy. Chemical bonds in molecules of these nutrients contain energy. When the bonds are broken during digestion to form simpler molecules, the energy is released. Energy is measured in units called kilocalories (kcal), commonly referred to as Calories.

Molecules that make up the body are continuously broken down or used up, so they must be replaced. Some nutrients, particularly proteins, provide the building materials for this purpose. Other nutrients—including proteins, vitamins, and minerals—are needed to regulate body processes. One way is by helping to form enzymes. Enzymes are compounds that control the rate of chemical reactions in the body.

Nutrients can be classified in two groups based on how much of them the body needs:

- **Macronutrients** are nutrients that the body needs in relatively large amounts. They include carbohydrates, proteins, lipids, and water.
- **Micronutrients** are nutrients the body needs in relatively small amounts. They include vitamins and minerals.

The exact amount of a macronutrient an individual needs depends on many factors, including gender and age. Recommended daily intakes of three macronutrients for young people of both genders are shown in **Table** 9.2.

TABLE 9.2: Recommended Daily Intakes of Carbohydrates, Proteins, and Water

Gender And Age	Carbohydrates(grams/day)	Proteins(grams/day)	Water*(liters/day)
Males 9–13 years	130	34	2.4
14–18 years	130	52	3.3
Females 9–13 years	130	34	2.1
14–18 years	130	46	2.3

- Includes water in foods as well as beverages

Carbohydrates are classified as either simple or complex, based on the number of saccharides they contain.

Simple carbohydrates contain just one or two saccharides. They are all sugars. Examples of sugars in the diet include fructose, which is found in fruit, and lactose, which is found in milk. The main function of simple carbohydrates is to provide the body with energy. One gram of carbohydrate provides four kilocalories of energy. Glucose is the sugar that is used most easily by cells for energy. It circulates in the blood, providing energy to cells throughout the body. Glucose is the only source of energy used by the brain.

Complex carbohydrates, called polysaccharides, generally contain many saccharides. They include starches and fiber. Starches are found in plant foods such as vegetables and grains. They are broken down during digestion to form sugars that provide energy. Fiber consists of indigestible starches and other materials such as cellulose. It is present in all plant foods.

Fiber may be soluble or insoluble.

- Soluble fiber dissolves in water as it passes through the large intestine. It helps form substances that keep blood levels of glucose stable and blood levels of harmful lipids low (see below).
- Insoluble fiber does not dissolve but attracts water as it passes through the large intestine. This helps keep waste moist and moving easily through the intestine.

Proteins play many vital roles in the body, including:

- Making up the majority of muscle tissue.
- Regulating many body processes.
- Forming antibodies that destroy bacteria and other "foreign invaders."
- Regulating the salt-water and acid-base balance in body fluids.
- Transporting nutrients and other vital substances in the blood.

Dietary proteins are broken down during digestion to provide the amino acids that cells need to make proteins for the body. Twenty different amino acids are needed for this purpose. Ten of these amino acids can be synthesized by cells from simple components. The other ten cannot be synthesized and must be obtained from foods. They are called essential amino acids because they are essential in the diet.

Proteins that contain all ten essential amino acids are referred to as complete proteins. They are found in animal foods such as milk and meat. Proteins that are missing one or more essential amino acids are referred to as incomplete proteins. They are found in plant foods such as legumes and rice. By eating a variety of different plant foods containing incomplete proteins, you can include all ten essential amino acids in your diet.

If you eat more protein than needed for the synthesis of new proteins by cells, the excess is used for energy or stored as fat. One gram of protein provides four kilocalories of energy. This is the same amount of energy that one gram of carbohydrate provides.

Lipids, or fatty acids, are organic compounds that consist of repeating units of carbon, hydrogen, and oxygen. They provide the body with energy. The heart and skeletal muscles rely mainly on lipids for fuel. One gram of lipids provides nine kilocalories of energy, more than twice the amount provided by carbohydrates or proteins. Lipids have several other functions as well. Lipids form an insulating sheath around nerve cells that helps nerve messages travel more quickly. Lipids also help form substances that regulate blood pressure, blood clotting, and blood lipid levels. In addition, lipids make up the membranes that surround cells.

The term fat is often used interchangeably with the term lipid, but fats are actually a particular type of lipid, called **triglycerides**, in which three fatty acids are bound to a compound called glycerol. Fats are important in the body. They are the main form in which the body stores energy. Stored body fat is called adipose tissue. Stored fat not only provides an energy reserve but also cushions and protects internal organs. In addition, stored fat insulates the body and helps prevent heat loss in cold weather.

Although lipids and fats are necessary for life, they may be harmful if they are present in the blood at high levels. Both triglycerides and the lipid called cholesterol are known to damage blood vessels if their concentrations in the blood are too high. By damaging blood vessels, triglycerides and cholesterol also increase the risk of heart disease.

Lipids are classified as either saturated fatty acids or unsaturated fatty acids. This classification is based on the number of chemical bonds between carbon atoms in lipid molecules.

- **Saturated fatty acids** have only single bonds between carbon atoms. This gives them properties that make them unhealthful. Their amount in the diet should be kept as low as possible. If consumed in excess, they contribute to high blood levels of cholesterol and triglycerides. Saturated fatty acids are found in animal foods, such as meat, whole milk, and eggs.

- **Unsaturated fatty acids** have at least one double bond between carbon atoms. This gives them properties that make them more healthful. Eaten in appropriate amounts, they may help lower blood levels of cholesterol and triglycerides and decrease the risk of cardiovascular disease. They are found mainly in plant foods.

The human body can synthesize all but two of the fatty acids it needs: omega-3 fatty acids and omega-6 fatty acids. Both are unsaturated fatty acids. They are called essential fatty acids because they must be present in the diet. They are found in salmon, vegetable oil, flaxseed, eggs, and whole grains. Small amounts of these two fatty acids may help lower blood pressure as well as blood levels of harmful lipids.

Unsaturated fatty acids known as trans fatty acids (or trans fats), are manufactured from plant oils and do not occur naturally. They are added to foods to extend their shelf life. Trans fats have properties like saturated fats and may increase risk of cardiovascular disease. They should be avoided in balanced eating. Many manufacturers no longer add trans fats to food products, and their use in restaurants has been banned in some cities.

Water

You may not think of water as a food, but it is a nutrient. Water is essential to life because it is the substance within which all the chemical reactions of life take place. An adult can survive only a few days without water.

Water is lost from the body in exhaled air, sweat, and urine. Dehydration occurs when a person does not take in enough water to replace the water that is lost. Symptoms of dehydration include headaches, low blood pressure, and dizziness. If dehydration continues, it can quickly lead to unconsciousness and even death. When you are very active, particularly in the heat, you can lose a great deal of water in sweat. To avoid dehydration, you should drink extra fluids before, during, and after exercise.

Taking in too much water—especially without consuming extra salts—can lead to a condition called hyponatremia. In this condition, the brain swells with water, causing symptoms such as nausea, vomiting, headache, and coma. Hyponatremia can be fatal, so it requires emergency medical care.

Balanced Eating

Balanced eating is a way of eating that promotes good health. It includes eating several medium-sized meals regularly throughout the day. It also includes eating the right balance of different foods to provide the body with all the nutrients it needs. How much of these foods should you eat to get the right balance of nutrients? Two tools for choosing foods that provide balanced nutrition are MyPyramid and nutrition labels on food packages.

MyPyramid

MyPyramid was developed by the U.S. Food and Drug Administration. It shows how much you should eat each day of foods in different food groups. MyPyramid is shown in **Figure** 9.3. You can visit the mypyramid.gov website for more details or to customize MyPyramid for your gender, age, activity level, and other factors.

Guidelines for Using MyPyramid

1. The six colored bands represent six food groups:

- Brown = Grains—At least half should be whole grains.
- Green = Vegetables—Choose a variety of vegetables, including dark green and orange vegetables, dry beans and peas.
- Red = Fruits—Include a variety of fruits, and consume whole fruits instead of fruit juices.
- Yellow = Oils—Choose mainly unsaturated nut and vegetable oils.
- Blue = Milk—Dairy products should be low-fat or fat-free choices.
- Purple = Meat and Beans—Choose fish and low-fat meats, as well as beans, peas, nuts, and seeds.

FIGURE 9.3

MyPyramid is visual representation of how much you should eat each day of foods in different food groups.

2. The width of each colored band shows the proportion of food that should come from each food group.

3. The figure climbing stairs reminds you to balance food with exercise: 30–60 min/day of moderate-to-vigorous activity is recommended for most people.

Each food group represented by a colored band in MyPyramid is a good source of nutrients. The wider the band, the more you should eat from that food group. For example, the brown band is widest, so the largest proportion of foods should come from the grains group. The white tip of MyPyramid represents foods that should be eaten only in very small amounts or very infrequently. They include foods such as ice cream and potato chips that contain few nutrients and may contribute excess kilocalories to the diet.

The figure "walking" up the side of MyPyramid in **Figure** 9.3 represents the role of exercise in balanced eating. Daily exercise helps you burn any extra energy that you consume in foods. The more active you are, the more energy you use. Light activities, such as golfing, typically use only a few hundred kilocalories per hour. Strenuous activities, such as running, may use over 900 kilocalories per hour.

Harvard University recently developed an alternative healthy eating pyramid, which is shown in **Figure** 9.4. It differs from MyPyramid in placing more emphasis on exercise and a greater focus on eating fruits, vegetables, and healthy plant oils. It moves red meats and starchy, low-nutrient foods, such as white bread and white rice, to the category of foods to eat in very limited amounts. Some experts think that the Harvard pyramid is less confusing than MyPyramid and represents an even healthier way of eating.

MyPlate

In June 2011, the United States Department of Agriculture replaced My Pyramid with **MyPlate.** MyPlate depicts the relative portions of various food groups. See http://www.choosemyplate.gov for further information.

The following guidelines accompany MyPlate:

1. Balancing Calories

- Enjoy your food, but eat less.
- Avoid oversized portions.

2. Foods to Increase

- Make half your plate fruits and vegetables.
- Make at least half your grains whole grains.
- Switch to fat-free or low-fat (1%) milk.

FIGURE 9.4

Healthy eating pyramid.
Choosemyplate. (2019). Choose my plate. Department of agriculture. Retrieved from https://www.choosemyplate.gov/

FIGURE 9.5

MyPlate is a visual guideline for balanced eating, replacing MyPyramid in 2011.
Choosemyplate.gov. (2019). Choose my plate. Department of agriculture. Retrieved from https://www.choosemyplate.gov/

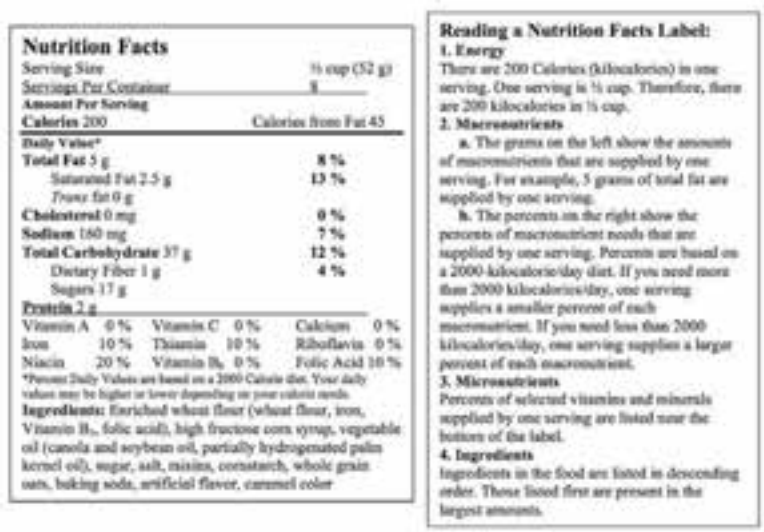
3. Foods to Reduce

- Compare sodium in foods like soup, bread, and frozen meals [U+2015] and choose the foods with lower numbers.
- Drink water instead of sugary drinks.

Food Labels

Packaged foods are required by law to carry a nutrition facts label, like the one in **Figure** 9.6, showing the nutrient content and ingredients in the food.

Reading nutrition facts labels can help you choose foods that are high in nutrients such as protein and low in nutrients such as fat. Nutrition facts labels can also help you choose foods that are nutrient dense. Nutrient density is the ratio of nutrient content, measured in grams, to total energy content in kilocalories.



Nutrition Facts
Serving Size ½ cup (52 g)
Servings Per Container 8
Amount Per Serving
Calories 200 Calories from Fat 45
Daily Value*
Total Fat 5 g **8 %**
Saturated Fat 2.5 g **13 %**
Trans fat 0 g
Cholesterol 0 mg **0 %**
Sodium 160 mg **7 %**
Total Carbohydrate 37 g **12 %**
Dietary Fiber 1 g **4 %**
Sugars 17 g
Protein 2 g
Vitamin A 0 % Vitamin C 0 % Calcium 0 %
Iron 10 % Thiamin 10 % Riboflavin 0 %
Niacin 20 % Vitamin B6 0 % Folic Acid 10 %
*Percent Daily Values are based on a 2000 Calorie diet. Your daily values may be higher or lower depending on your calorie needs.
Ingredients: Enriched wheat flour (wheat flour, iron, Vitamin B, folic acid), high fructose corn syrup, vegetable oil (canola and soybean oil, partially hydrogenated palm kernel oil), sugar, salt, raisins, cornstarch, whole grain oats, baking soda, artificial flavor, caramel color

Reading a Nutrition Facts Label:
1. Energy
There are 200 Calories (kilocalories) in one serving. One serving is ½ cup. Therefore, there are 200 kilocalories in ½ cup.
2. Macronutrients
a. The grams on the left show the amounts of macronutrients that are supplied by one serving. For example, 5 grams of total fat are supplied by one serving.
b. The percents on the right show the percents of macronutrient needs that are supplied by one serving. Percents are based on a 2000-kilocalorie/day diet. If you need more than 2000 kilocalories/day, one serving supplies a smaller percent of each macronutrient. If you need less than 2000 kilocalories/day, one serving supplies a larger percent of each macronutrient.
3. Micronutrients
Percents of selected vitamins and minerals supplied by one serving are listed near the bottom of the label.
4. Ingredients
Ingredients in the food are listed in descending order. Those listed first are present in the largest amounts.

FIGURE 9.6
Nutrition facts label.

TABLE 9.3: Consider the following two foods:

15g/300 kcal = 0.05 g/kcal	10g/120 kcal = 0.08 g/kcal
Nutrient Density:	Nutrient Density:
Energy: 300 kcal	Energy: 120 kcal
Protein: 15 g	Protein: 10 g
Food A	**Food B**

In terms of protein, Food B is more nutrient dense than Food A, because it provides more protein per kilocalorie. Eating nutrient-dense foods helps you to get enough of each nutrient without taking in too many kilocalories.

Reading the ingredients list on food labels can also help you choose healthful foods for balanced eating. At the top of the list, look for ingredients such as whole grains, vegetables, and fruits. These are foods you need the most of in a balanced diet. Avoid foods that contain processed ingredients, such as white flour or white rice. Processing removes nutrients. As a result, processed foods generally supply fewer nutrients than whole foods, even when they have been enriched or fortified with added nutrients.

Vitamins and Minerals

Unlike the major macronutrients, micronutrients—including vitamins and minerals—do not provide energy (CK12, 2009). Nonetheless, adequate amounts of micronutrients are essential for good health. The needed amounts generally can be met with balanced eating. However, many people do not eat enough of the right foods to meet their requirements. They may need vitamin or mineral supplements to increase their intake of micronutrients.

Vitamins

Vitamins are organic compounds that are needed by the body to function properly. There are 13 vitamins that humans need. They are described in **Table** 9.4, which also includes recommended daily vitamin intakes for teens.

Vitamins play many roles in good health, ranging from helping maintain vision to helping form red blood cells. Many vitamins are components of enzymes. For example, vitamin K is a component of enzymes involved in blood clotting. Several vitamins, including vitamins C and E, act as antioxidants. An antioxidant is a compound that neutralizes chemicals called free radicals. Free radicals are produced naturally during cellular activities and may cause some types of cancer. Neutralizing free radicals makes them harmless.

Some vitamins, including vitamin B_6, are produced by bacteria that normally live in the intestines, where they help digest food. Vitamin D is synthesized in the skin when it is exposed to UV radiation in sunlight. Most other vitamins must be obtained from foods because the body is unable to synthesize them. Good food sources of vitamins are listed in the table below. They include whole grains, vegetables, fruits, milk, and nuts.

Consuming inadequate amounts of vitamins can cause deficiency diseases. For example, consuming inadequate amounts of vitamin D causes soft bones. In children this is called rickets. It can cause permanent bone deformities. Consuming inadequate amounts of vitamin A may lead to blindness and visual impairment.

Consuming too much of some vitamins can also be dangerous. Overdoses of vitamins can cause problems ranging from diarrhea to birth defects and even death.

Vitamins are either fat-soluble or water-soluble. This determines whether they can accumulate in the body and lead to overdoses.

- Vitamins A, D, E, and K are fat soluble. Excess intakes of these vitamins are stored in fatty tissues of the body. Because they are stored in the body, they can build up to toxic levels, especially if they are taken improperly in supplements.
- Vitamin C and all the B vitamins are water soluble. Excess amounts of these vitamins are excreted in the urine, so they are unlikely to reach toxic levels in the body.
- Recommended daily intakes not established; figures given are adequate daily intakes.

TABLE 9.4: Vitamins

Vitamin (Chemical Name)	Functions in the Body	Good Food Sources
(Retinoids)Vitamin A	Needed for good vision, reproduction, and fetal development	Carrots, spinach, milk, eggs
(Thiamine)Vitamin B1	Helps break down macronutrients; essential for proper functioning of nerves	Whole wheat, peas, beans, fish, peanuts, meats
(Riboflavin)Vitamin B2	Helps the body process amino acids and fats; acts as antioxidant	Milk, liver, green leafy vegetables, almonds, soybeans
(Niacin)Vitamin B3	Helps release energy from macronutrients; needed for healthy skin and nerves	Beets, beef liver, pork, turkey, fish, sunflower seeds, peanuts
(Pantothenic Acid)Vitamin B5,	Helps form critical enzymes for synthesis of macronutrients	Whole grains, legumes, eggs, meat
(Pyridoxine) Vitamin B6	Forms enzymes needed for amino acid synthesis and energy storage	Cereals, yeast, liver, fish, avoca- does, nuts, green beans
(Biotin)Vitamin B7	Enables synthesis of fatty acids; helps store energy; keeps level of blood sugar stable	None
(Folate)Vitamin B9	Needed to make red blood cells	Liver, green leafy vegetables, dried beans and peas
(Cyanocobalamin)Vitamin B12	Needed for normal functioning of nervous system and formation of blood	Meat, liver, milk, shellfish, eggs

TABLE 9.4: (continued)

(Ascorbic Acid) Vitamin C	Needed to make many biological chemicals; acts as antioxidant	Citrus fruits such as oranges, red peppers, broccoli, kiwi
(Ergocalciferol and Cholecalciferol) Vitamin D	Helps maintain blood levels of calcium; needed for healthy bones and teeth	Salmon, tuna, eggs, mushrooms
(Tocopherol) Vitamin E	Acts as antioxidant; protects cell membranes from LDL cholesterol damage	Vegetable oils, nuts, green leafy vegetables, whole grains, fish
(Naphthoquinone) Vitamin K	Helps transport calcium; helps blood clot	Kale, spinach, Brussels sprouts, milk, eggs, soy products

Minerals

Dietary minerals are chemical elements that are essential for body processes. Minerals are inorganic, meaning they do not contain carbon. Minerals needed by humans in relatively large amounts (greater than 200 mg/day) are listed in **Table** below. Minerals not listed in the table are called trace minerals because they are needed in very small amounts. Trace minerals include chromium, iodine, iron, molybdenum, selenium, and zinc.

TABLE 9.5: Minerals

Mineral Name (Symbol)	Functions in the Body	Good Food Sources
(Ca) Calcium	Needed for nerve and muscle action; builds bone and teeth; helps blood clot	Milk, soy milk, green leafy vegetables, sardines
(Cl) Chloride	Helps maintain water and pH balance; helps form stomach acid	Table salt, most processed foods
(Mg) Magnesium	Needed to form several enzymes	Whole grains, green leafy vegetables, nuts, seeds
(P) Phosphorus	Component of bones, teeth, lipids, and other important molecules in the body	Meat, poultry, whole grains
(K) Potassium	Needed for muscle and nerve function; helps maintain salt-water balance in body fluids	Meats, grains, orange juice, potatoes, bananas
(Na) Sodium	Needed for muscle and nerve function; helps maintain salt-water balance in body fluids	Table salt, most processed foods
(S) Sulfur	Necessary component of many proteins	Whole grains, meats, seafood, eggs

Minerals play many important roles in the body. Most are found in the blood and cytoplasm of cells, where they control basic functions. For example, calcium and potassium regulate nerve and muscle activity. Several minerals, including zinc, are components of enzymes. Other minerals, including calcium, form the bulk of teeth and bones. Recommended daily intakes not established; figures given are adequate daily intakes.

Minerals cannot be synthesized by the body. Good food sources of minerals include dairy products, green leafy vegetables, and legumes. Mineral deficiencies are uncommon, but inadequate intakes of a few minerals may lead to health problems. For example, an inadequate intake of calcium may contribute to osteoporosis, a disease in which bones become brittle and break easily. A deficiency in iodine (necessary for the thyroid hormones that regulate growth) may lead to goiter. Iron deficiency is the primary cause of anemia.

Some minerals may be toxic in excess, but overdoses of most minerals are uncommon. Overdoses are more likely when mineral supplements are taken. Salt (sodium chloride) is added to many foods, so the intake of sodium may be too high in many people. Too much sodium in the diet can cause high blood pressure in some individuals.

Other Micronutrients

Recently, new micronutrients called phytochemicals have been found in plants. They occur primarily in colorful fruits and vegetables. Thousands of phytochemicals have been discovered, and some have already been shown to lower the risk of certain diseases. For example, the phytochemical lutein helps reduce the risk of macular degeneration, an eye disease that leads to blindness. Lutein is found in many yellow and orange fruits and vegetables. Several phytochemicals, including some found in berries and cherries, have proven to be powerful antioxidants.

9.3 Biotechnology and Genetic Engineering

Agricultural biotechnology is a range of tools, including traditional breeding techniques, that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses (USDA, 2019). Modern biotechnology today includes the tools of genetic engineering. **Genetic engineering** is the name for certain methods that scientists use to introduce new traits or characteristics to an organism (known also as **genetically modified organism** or **GMO**). For example, plants may be genetically modified to produce characteristics to enhance the growth or nutritional profile of food crops.

BENEFITS OF GENETIC ENGINEERING

Advocates of modern biotechnology and generic engineering say that the application of biotechnology in agriculture has resulted in benefits to farmers, producers, and consumers (USDA, 2019).

Enhanced nutrition. Advances in biotechnology may provide consumers with foods that are nutritionally-enriched (Figure 9.8) or longer-lasting, or that contain lower levels of certain naturally occurring toxicants present in some food plants. Developers are using biotechnology to try to reduce saturated fats in cooking oils, reduce allergens in foods, and increase disease-fighting nutrients in foods. Biotechnology may also be used to conserve natural resources, enable animals to more effectively use nutrients present in feed, decrease nutrient runoff into rivers and bays, and help meet the increasing world food and land demands.

FIGURE 9.8

White rice and Golden rice. Genetically engineered "Golden Rice" contains up to 35 μg β-carotene per gram of rice. International Rice Research Institute (IRRI). (2011). Golden Rice grain compared to white rice grain in screenhouse of Golden Rice plants. (JPG). Retrieved from https://commons.wikimedia.org/wiki/File:Golden_Rice.jpg. Available under the Creative Commons Attribution 2.0

Cheaper and more manageable production. Biotechnology may provide farmers with tools that can make production cheaper and more manageable. For example, some biotechnology crops can be engineered to tolerate specific herbicides, which make weed control simpler and more efficient. Other crops have been engineered to be resistant to specific plant diseases and insect pests, which can make pest control more reliable and effective, and/or can decrease the use of synthetic pesticides. These crop production options can help countries keep pace with demands for food while reducing production costs.

Improved pest control. Biotechnology has helped to make both insect pest control and weed management safer and easier while safeguarding crops against disease. For example, genetically engineered insect-resistant cotton has allowed for a significant reduction in the use of persistent, synthetic pesticides that may contaminate groundwater and the environment. In terms of improved weed control, herbicide-tolerant soybeans, cotton, and corn enable the use of reduced-risk herbicides that break down more quickly in soil and are non-toxic to wildlife and humans.

CONCERNS ABOUT GENETICALLY MODIFIED ORGANISMS

The complexity of ecological systems presents considerable challenges for experiments to assess the risks and benefits and inevitable uncertainties of GMOs (Maghari & Ardekani, 2011). Assessing such risks is extremely difficult, because both natural and human-modified systems are highly complex, and fraught with uncertainties that may not be clarified until long after an experimental introduction has been concluded. Critics of GMOs warn that the cultivation of GMOs, with their potential benefits and hazards to the environment, should be carefully considered within broader ecosystems.

Interbreeding with native species. When the genetically modified organisms are allowed to breed with the organisms which are not genetically engineered, then these organisms may affect the genetic of non-genetically engineered organisms. Due to this reason the whole ecological system might get affected. The main concern is that genetically modified organisms might lead the non-GM organisms to extinction and reduce biodiversity.

GM food labeling. In order to verify whether people have been harmed over the years by consuming GMF, specifically in countries like the US where people's dietary are mainly composed of such products, the law for mandatory labeling is highly required. However, the labeling is not just about health issue rather, it is about consumer rights to make an informed choice. Although a consensual system on GMO labeling is crucial, it seems unlikely that an internationally agreed labeling system can be set up in proximate future. Nevertheless, different GMO labeling schemes have been established in different countries, ranging from stringent to extremely lenient or even non existent legislations. While the EU has established strict labeling regulations, in the US, Canada and Argentina, three big producers of GMO food, such laws have been put forward but not enacted by these governments. A proper labeling represents the "GM" word, along with additional information on changed characteristics and the external source of the inserted gene. Negative labeling such as "GM free" is not suggested, because it might give the wrong impression to the consumers. The law for compulsory labeling of genetically modified food products has been established in more than 40 countries. Surveys commissioned by different organizations have shown that people across the world are seeking for transparency and consumer choice and believe that compulsory labeling scheme on GM ingredients is highly required: 88% Canadians, 92% Americans and 93% French.

Consumers right to choose. The International Federation of Organic Agriculture Movement has made stringent efforts to keep GMOs out of organic production, yet some US organic farmers have found their corn (maize) crops, including seeds, to contain detectable levels of genetically engineered DNA (Godheja, 2013). The organic movement is firm in its opposition to any use of GMOs in agriculture, and organic standards explicitly prohibit their use. The farmers, whose seed is contaminated, have been under rigid organic certification, which assures that they did not use any kind of genetically modified materials on their farms. Any trace of GMOs must have come from outside their production areas. While the exact origin is unclear at this time, it is most likely that the pollution has been caused by pollen drift from GMO-fields in surrounding areas. However, the contamination may have also come from the seed supply. Seed producers, who intended to supply GMO-free seed, have also been confronted with genetic contamination and cannot guarantee that their seed is 100% GMO-free.

Ecological long-term effects. The Bt corn produces wind-borne pollen that kills the caterpillars of the Monarch butterfly. If the life cycles of this butterfly are disrupted, the Monarch butterflies might be endangered. Agriculture might be affected as the weeds acquire the modified genes to become more competitive. The risk of the evolution of common plant viruses to become more resistant or form new strains will be greatly increased. If genetic modification is carried out extensively, new viruses with greater potential to harm humankind may evolve, and the probability of this occurring can be quite high.

Human health risk. At least some of the genes used in GMOs may not have been used in the food supply before, so GM foods may pose a potential risk for human health. Much of the GM production currently grown worldwide is destined for animal feed. The FAO has concluded that risks to human and animal health from the use of GM crops and enzymes derived from GM microorganisms as animal feed are negligible. But scientists acknowledge that little is known about the long-term safety of consuming food made from GM products. WHO recognizes the need for continued safety assessments on genetically modified foods before they are marketed to prevent risks to human health and for continued monitoring.

The potential of GM crops to be allergenic is one of the main suspected adverse health effects. Many scientific data indicate that animals fed by GMO crops have been harmed or even died. Rats exposed to transgenic potatoes or soy had abnormal young sperm; cows, goats, buffalo, pigs and other livestock grazing on Bt-maize, GM cottonseed and certain biotech corn showed complications including early deliveries, abortions, infertility and also many died. However, this is a controversial subject as studies conducted by company producing the biotech crops did not show any negative effects of GM crops on mice.

Although Agri-biotech companies do not accept the direct link between the GMOs consumption and human health problems, there are some examples given by the opponents (Maghari, B. M., & Ardekani, A. M., 2011). For example: The foodborne diseases such as soy allergies have increased over the past 10 years in USA and UK and an epidemic of Morgellons disease in the US. There are also reports on hundreds of villagers and cotton handlers who developed skin allergy in India. Recent studies have revealed that *Bacillus thuringiensis* corn expresses an allergenic protein which alters overall immunological reactions in the body. The aforementioned reports performed by independent GMO researchers have lead to a concern about the risks of GMOs and the inherent risks associated with the genetic technology.

Intellectual property rights are one of the important factors in the current debate on GMOs. The GM crops are patented by Agri-business companies leading to monopolization of the global agricultural food and controlling distribution of the world food supply (Maghari, B. M., & Ardekani, A. M., 2011). Social activists believe that the hidden reason why biotech companies are eager to produce GMO crops is because they can be privatized, unlike ordinary crops which are the natural property of all humanity. It is argued for example that to achieve this monopoly, the large Agri-biotech company, Monsanto, has taken over small seed companies in the past 10 years and has become the biggest Agri-biotech Corporation in the world. The patent right for vegetable forms of life also affect the livelihoods of family farmers as they are required to sign a contract preventing them from saving and re-planting the seeds, thus they have to pay for seeds each year.

Critics, thus advise that the risks for the introduction of a GMOs into each new ecosystem need to be examined on a case-by-case basis, alongside appropriate risk management measures, such as through the precautionary principle in the Cartagena Protocol and the IPPC's Pest Risk Assessment (PRA).

9.4 Resources

Summary

Progress continues in the fight against hunger, yet an unacceptably large number of people still lack the food they need for an active and healthy life. About 795 million people in the world still go to bed hungry every night, and an even greater number live in poverty. Poverty is the major driver of food insecurity. Improvements in agricultural productivity are necessary to increase rural household incomes and access to available food but are insufficient to ensure food security. Food security is essentially built on four pillars: availability, access, utilization and stability. Women are crucial in the translation of the products of a vibrant agriculture sector into food and nutritional security for their households. They are often the farmers who cultivate food crops and produce commercial crops alongside the men in their households as a source of income. Over the past 20 years, a global obesity epidemic has emerged. Due to established health implications and rapid increase in prevalence, obesity is now a recognized major global health challenge, and no national success stories in curbing its growth have so far been reported. Genetic engineering is the name for methods that scientists use to introduce new traits or characteristics to an organism. Advocates say that application of genetic engineering in agriculture has resulted in benefits to farmers, producers, and consumers. Critics advise that the risks for the introduction of a GMO into each new ecosystem need to be examined on a case-by-case basis, alongside appropriate risk management measures.

Review Questions

1. Explain the four dimensions of food security.
2. How are *poverty* and *food security* related?
3. Define *hidden hunger*.
4. Why is women's role in agriculture important in food security?
5. What percentage of overweight people live in developed countries?
6. Do you think that biotechnology should be used to change the genetic makeup of the plants and animals that humans consume for food? What might be the benefits and risks? Do you think the benefits outweigh the risks?

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