The spread of acquired immune deficiency syndrome (AIDS), caused by infection with the human immunodeficiency virus (HIV), is a serious global health threat. The virus itself is not deadly, but it cripples the immune system and leaves the body vulnerable to infections such as tuberculosis (TB) and rare forms of cancer such as Kaposi’s sarcoma (Figure 17-1). The virus is transmitted from one person to another by unsafe sex, sharing of needles by drug users, infected mothers who pass the virus on to their offspring before or during birth, and exposure to infected blood.

Since the HIV virus was identified in 1981, this viral infection has spread exponentially around the globe. According to the World Health Organization (WHO), in 2007, about 33 million people worldwide (1.1 million in the United States) were infected with HIV. Almost two-thirds of them were in African countries located south of the Sahara Desert (sub-Saharan Africa) (see Figure 14, p. S18, in Supplement 3).

In 2007, about 2.5 million people (58,000 to 63,000 in the United States) became infected with HIV—an average of 6,800 new cases per day—half of them between the ages of 15 and 24. Within 7–10 years, at least half of all HIV-infected people will develop AIDS. This long incubation period means that infected people often spread the virus for several years without knowing they are infected.

Currently, there is no vaccine to prevent HIV and no cure for AIDS. If you get AIDS, you will almost certainly die from it. Drugs help some infected people live longer, but 90% of those suffering from AIDS cannot afford to use these drugs.

Between 1981 and 2007, more than 25 million people (584,000 in the United States) died of AIDS-related diseases. Each year AIDS claims about 2.1 million more lives (17,000 in the United States)—a daily average of 5,750 premature deaths.

AIDS has reduced the life expectancy of the 750 million people living in sub-Saharan Africa from 62 to 47 years—40 years in the seven countries most severely affected by AIDS. The premature deaths of teachers, health-care workers, soldiers, and other young productive adults in such countries leads to diminished education and health care, decreased food production and economic development, and disintegrating families.

This means that countries like Botswana are expected to lose half of their adult populations within a decade. Such death rates drastically alter a country’s age structure (Figure 17-2). AIDS has also left more than 15 million children orphaned—roughly equal to the number of children under age 5 in the United States. Many of these orphans are forced into child labor or the sex trade.

In this chapter, we will look at connections between environmental hazards and human health and at what we can do to reduce the deadly global pandemic of AIDS and other environmental health threats from diseases and exposure to harmful chemicals.
Risks Are Usually Expressed as Probabilities

A *risk* is the *probability* of suffering harm from a hazard that can cause injury, disease, death, economic loss, or damage. It is usually expressed in terms of probability—a mathematical statement about how likely it is that harm will be suffered from a hazard. Scientists often state a probability in terms such as “The lifetime probability of developing lung cancer from smoking one pack of cigarettes per day is 1 in 250.” This means that 1 of every 250 people who smoke a pack of cigarettes every day will likely develop lung cancer over a typical lifetime (usually considered to be 70 years).

It is important to distinguish between *possibility* and *probability*. When we say that it is *possible* that a smoker can get lung cancer, we are saying that this event could happen. *Probability* gives us an estimate of the likelihood of such an event.

*Risk assessment* is the scientific process of using statistical methods to estimate how much harm a particular hazard can cause to human health or to the environment. Scientists use it to estimate the probability of a risk, to compare it with the probability of other risks, and to establish priorities for avoiding or managing risks. *Risk management* involves deciding whether or how to reduce a particular risk to a certain level and at what cost. Figure 17-3 (p. 440) summarizes how risks are assessed and managed.

A major problem is that most people are not good at understanding and comparing risks. Because of sensational news coverage about the latest scare, many people worry about the highly unlikely possibility of minor risks and ignore the significant probability of harm from major risks.

For example, some Americans worry about getting widely publicized avian flu, which by mid-2008 had killed no one in the United States, but they do not get vaccinated for the common flu, which contributes to the deaths of about 36,000 Americans each year. Thus, educating people and especially news reporters about the meaning of risk assessments and
teaching them how to make risk comparisons is an important priority.

We Face Many Types of Hazards

All of us take risks every day. Examples include choosing to drive or ride in a car instead of using a bicycle or mass transit; eating foods with a high cholesterol or fat content that contribute to heart attacks, which kill far more people each year than any other risk; drinking alcohol; smoking or being in an enclosed space with a smoker; lying out in the sun or going to a tanning parlor, which increases the risk of getting skin cancer and wrinkled skin; and living in a hurricane-prone area. The key questions are, how serious are the risks we face, and do the benefits of certain activities outweigh the risks?

We can suffer harm from five major types of hazards (Concept 17-1):

- **Biological hazards** from more than 1,400 pathogens that can infect humans. A **pathogen** is a living organism that can cause disease in another organism. Examples are bacteria, viruses, parasites, protozoa, and fungi.
- **Chemical hazards** from harmful chemicals in air, water, soil, and food.
- **Physical hazards** such as fire, earthquakes, volcanic eruptions, floods, and storms.
- **Cultural hazards** such as unsafe working conditions, unsafe highways, criminal assault, and poverty.
- **Lifestyle choices** such as smoking, eating too much, drinking too much alcohol, and having unsafe sex.

### THINKING ABOUT Hazards

Think of a hazard from each of these categories that you may have faced recently. Which one was the most threatening?

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### 17-2 What Types of Biological Hazards Do We Face?

**Concept 17-2** In terms of death rates, the most serious infectious diseases are flu, AIDS, diarrheal diseases, malaria, and tuberculosis; most of these deaths occur in developing countries.

Some Diseases Can Spread from One Person to Another

A **nontransmissible disease** is caused by something other than a living organism and does not spread from one person to another. Such diseases tend to develop slowly and have multiple causes. Examples include cardiovascular (heart and blood vessel) diseases, most cancers, asthma, diabetes, and malnutrition. As average life expectancy increases, people are more likely to suffer and die from nontransmissible diseases such as cardiovascular diseases and cancers.

An **infectious disease** is caused when a pathogen such as a bacterium, virus, or parasite invades the body and multiplies in its cells and tissues. Examples are flu, HIV (Core Case Study), malaria, tuberculosis, and measles. A **transmissible disease** (also called a **contagious** or **communicable disease**) is an infectious disease that can be transmitted from one person to another. Examples are flu, HIV, tuberculosis, and measles.

A bacterial disease such as tuberculosis spreads as the bacteria multiply. A viral disease such as flu or HIV spreads when a virus takes over a cell’s genetic machinery to copy itself. Figure 17-4 shows the percentages of deaths in the world and in the United States in 2005 caused by cardiovascular diseases (mostly heart attacks and strokes), infectious diseases, and cancers.

In 1900, infectious disease was the leading cause of death in the world and in the United States. Since then, and especially since 1950, the incidences of infectious diseases and the death rates from such diseases have been greatly reduced. This has been achieved mostly by a combination of better health care, the use of antibiotics to treat infectious diseases caused by bacteria, and the development of vaccines to prevent the spread of...
some infectious viral diseases. As a result, average life expectancy has increased in most countries, the leading cause of death has shifted to nontransmissible cardiovascular disease, and the percentage of people dying from cancers is increasing in both developed and developing countries.

Traditionally, health organizations have described the state of global and national health by focusing mainly on the leading causes of death such as those shown in Figure 17-4. But such data do not give us a picture of the nonfatal effects of disease and injury like prolonged illnesses and forms of disability like blindness, paralysis, and impaired learning ability. Health agencies now use disability-adjusted life years (DALYs) as a measure of the total disease burden in a population. A DALY is a measure designed to assess the amount of ill health, including premature death and disability due to specific diseases and injuries. However, the use of DALYs to make health care decisions has been criticized because of the shortage of reliable data on disabilities, and because of disagreements about how to evaluate the severity of various disabilities and how to apply them to different age groups.

Infectious Diseases Are Still Major Health Threats

Despite the shift in higher risk levels from transmissible to nontransmissible diseases, infectious diseases remain as serious health threats, especially in developing countries. Figure 17-5 shows major pathways for infectious diseases in humans. Such diseases can then be spread through air, water, food, and body fluids such as feces, urine, blood, and droplets sprayed by sneezing and coughing.

A large-scale outbreak of an infectious disease in an area or country is called an epidemic and a global epidemic, such as AIDS (Core Case Study) is called a pandemic. Figure 17-6 (p. 442) shows the annual

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**Figure 17-4** Major causes of death in the world and in the United States in 2005. **Questions:** Why do you think that a higher percentage of the people in the United States die of cardiovascular disease than in the world? Why do you think that a much higher percentage of people in the world die from infectious diseases than in the United States? (Data from the World Health Organization and the U.S. Centers for Disease Control and Prevention)

**Table: Major causes of death in the world and in the United States in 2005**

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>United States</th>
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<tbody>
<tr>
<td>Cardiovascular</td>
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<td>39%</td>
</tr>
<tr>
<td>disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infectious</td>
<td>30%</td>
<td>7%</td>
</tr>
<tr>
<td>diseases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cancers</td>
<td>17%</td>
<td>23%</td>
</tr>
</tbody>
</table>

**Figure 17-5** **Science:** pathways for infectious disease in humans. **Question:** Can you think of other pathways not shown here?
death toll from the world’s seven deadliest infectious diseases (Concept 17-2). The World Health Organization (WHO) is developing a Global Health Atlas, which contains a global database and maps based on health statistics, such as child mortality and the incidence of major infectious diseases in the world’s countries (see www.who.int/GlobalAtlas/).

A growing problem is that many disease-carrying bacteria have developed genetic immunity to widely used antibiotics (Science Focus, at right). Also, many disease-transmitting species of insects such as mosquitoes have become immune to widely used pesticides that once helped to control their populations.

### CASE STUDY

#### The Growing Global Threat from Tuberculosis

Since 1990, one of the world’s most underreported stories has been the rapid spread of tuberculosis (TB). According to the WHO, this highly infectious bacterial disease strikes about 9.2 million people per year and kills 1.7 million—about 84% of them in developing countries.

Many TB-infected people do not appear to be sick, and about half of them do not know they are infected. Left untreated, each person with active TB typically infects 10–15 other people.

Several factors account for the recent increase in TB incidence. One is that there are too few TB screening and control programs, especially in developing countries. Left untreated, each person with active TB typically infects 10–15 other people. The biggest killer is the influenza or flu virus (Concept 17-2), which is transmitted by the body fluids or airborne emissions of an infected person. Easily transmitted and especially potent flu viruses could spread around the world in a pandemic that could kill millions of people in only a few months (Science Focus, p. 444).

The second biggest viral killer is the human immuno-deficiency virus (HIV) (Core Case Study and Concept 17-2). On a global scale, HIV infects about 2.5 million people each year, and the resulting complications from AIDS kill about 2.1 million people annually. AIDS is a serious and growing threat, but fortunately it is not as easily spread as is the common flu.
We risk falling behind in our efforts to prevent infectious bacterial diseases because of the astounding reproductive rate of bacteria, some of which can produce well over 16 million offspring in 24 hours. This allows bacteria to become genetically resistant to an increasing number of antibiotics through natural selection (Concept 4-2A, p. 80, and Figure 4-5, p. 83). In addition, some drug-resistant bacteria can quickly transfer their resistance to nonresistant bacteria by exchanging genetic material.

Other factors play a key role in fostering such genetic resistance. One is the spread of bacteria (some beneficial and some harmful) around the globe by human travel and international trade. Another is the overuse of pesticides, which increases populations of pesticide-resistant insects and other carriers of bacterial diseases.

Yet another factor is overuse of antibiotics. According to a 2000 study by Richard Wenzel and Michael Edward, at least half of all antibiotics used to treat humans are prescribed unnecessarily. In many countries, antibiotics are available without a prescription, which promotes unnecessary use. Resistance to some antibiotics has increased because of their widespread use in livestock and dairy animals to control disease and to promote growth. Also, the growing use of antibacterial hand soaps and other cleansers is probably promoting genetic resistance.

As a result of these factors acting together, every major disease-causing bacterium now has strains that resist at least one of the roughly 160 antibiotics used to treat bacterial infections such as tuberculosis (Case Study, at left). Each year, genetic resistance to antibiotics plays a role in the deaths of at least 90,000 of the 2 million people who pick up mostly preventable infections while they are in U.S. hospitals, according to the U.S. Centers for Disease Control and Prevention. This serious problem is much worse in hospitals in many other countries.

A bacterium known as methicillin-resistant *staphylococcus aureus*, or MRSA, has become resistant to most common antibiotics. This staph infection first appears on the skin as a red, swollen pimple or boil that may be painful and have pus. Many victims think they have a spider bite that will not heal. MRSA can cause a vicious type of pneumonia, flesh-eating wounds, and a quick death if it gets into the bloodstream.

This staph germ typically thrives on the body (mostly on the skin and in the nose) in health care settings where people have open wounds and tubes. But in recent years, it has been increasingly found in the general population. It can be picked up on playgrounds, in meeting rooms, and in gyms. It can spread through skin contact, tattoo needles, and contact with poorly laundered clothing items or shared items such as towels.

In 2005, MRSA infections contributed to the premature deaths of 18,650 people in the United States (more than the 17,000 who died from AIDS).

Ways to reduce the chances of infection from MRSA include frequent, thorough washing of hands; careful cleansing of even superficial wounds with soap and water; covering all wounds with a clean, dry bandage; and not sharing towels or other linens.

Most antibiotics work by crippling key proteins inside bacteria. But bacteria often develop immunity to such chemicals by modifying their protein receptor sites in ways that prevent the antibiotic molecules from entering their cells. In 2008, University of Pennsylvania scientists developed a compound that mimics molecules they identified in frog skin that essentially stab staph bacteria to death. This has inspired a new approach toward killing harmful bacteria by poking thousands of tiny holes in the bacterium’s membranes. Ironically, at a time when chemical knowledge gained by studying amphibians could save millions of human lives, our activities are threatening many of the world’s amphibian species. (Case Study, p. 93).

**Critical Thinking**

What are three things that could be done to slow the rate at which disease-causing organisms develop resistance to antibiotics?
A Nightmare Flu Scenario

Common flu viruses kill up to 2% of the people they infect, most of them very young, old, weak, or sick. Most die from secondary infections of bacterial pneumonia. Flu viruses regularly contribute to the deaths of about 1 million people a year—36,000 of them in the United States.

Every now and then, an especially potent flu virus develops that can kill up to 80% of it victims, including healthy young adults. The result: a global flu pandemic that can kill millions of people within a few months and cause economic and social chaos. This happened in 1918 when a virus called Spanish flu spread rapidly around the globe and, within a few months, killed 20–50 million people—including 250,000–500,000 in the United States. Some people woke up healthy and were dead by nightfall.

Many health scientists believe that, sooner or later, a mass infection from a new and very potent flu virus will sweep the world again. Infected people crisscrossing the world every day in airliners would hasten its spread. Health officials project that within a few months, such a flu pandemic could infect up to one-fourth of the world’s population and kill anywhere from 51–360 million people, with the highest death tolls in South Asia, East Asia, Sub-Saharan Africa, and the Middle East. According to the U.S. Centers for Disease Control and Prevention (CDC), a worst-case pandemic could kill as many as 1.9 million and hospitalize 8.5 million Americans.

Pigs, chickens, ducks, and geese are the major reservoirs of flu viruses. As these viruses move from one animal species to another, they can mutate and exchange genetic materials with other flu viruses to create new flu viruses.

In 1997, a new HSN1 avian strain of flu virus genetically related to the 1918 killer strain emerged in Asia. This strain, commonly known as bird flu or avian flu, first showed up in chickens that were probably infected by wild bird droppings. The virus then spread to people in Hong Kong, and since then, has spread to chickens and wild birds, including migratory birds that can spread the viruses far and wide. Between 2003 and 2008, it is known to have infected 376 people in at least 61 countries and killed 238, most of them in Vietnam and Indonesia.

Only once a genetic mutation hurdle keeps this flu from becoming a pandemic: the current forms of this virus do not have the ability to spread easily from person to person. However, health officials tracking this virus say it is probably only a matter of time before strains with such an ability emerge.

Critical Thinking
What would you do to protect yourself if a global flu pandemic occurred?

RESEARCH FRONTIER
Ecological medicine. See academic.cengage.com/biology/miller.

You can greatly reduce your chances of getting infectious diseases by practicing good, old-fashioned hygiene. Wash your hands thoroughly and frequently, avoid touching your face, and stay away from people who have flu or other viral diseases. Another growing hazard is infectious diseases caused by parasites, especially malaria (see the following Case Study).

CASE STUDY
Malaria—Death by Parasite-Carrying Mosquitoes

About one of every five people in the world—most of them living in poor African countries—is at risk from malaria (Figure 17-7). This should concern anyone traveling to malaria-prone areas because there is no vaccine for this disease.
Malaria is caused by a parasite that is spread by the bites of certain mosquito species. It infects and destroys red blood cells, causing intense fever, chills, drenching sweats, anemia, severe abdominal pain, headaches, vomiting, extreme weakness, and greater susceptibility to other diseases. It kills at least 1 million and perhaps as many as 2 million people each year—an average of 2,700–5,400 deaths per day (Concept 17-2). About 90% of those dying are children younger than age 5. Many of the children who survive suffer brain damage or impaired learning ability.

Four species of protozoan parasites in the genus *Plasmodium* cause malaria. Most infections occur when an uninfected female of any of about 60 *Anopheles* mosquito species bites a person (usually at night) who is infected with *Plasmodium* parasite, ingests blood that contains the parasite, and later bites an uninfected person (Figure 17-8). *Plasmodium* parasites then move out of the mosquito and into the human’s bloodstream and liver where they multiply. Malaria can also be transmitted by blood transfusions and by drug users sharing needles.

The malaria cycle repeats itself until immunity develops, treatment is given, or the victim dies. Over the course of human history, malarial protozoa probably have killed more people than all the wars ever fought.

During the 1950s and 1960s, the spread of malaria was sharply curtailed when swamplands and marshes where mosquitoes were breeding were drained or sprayed with insecticides, and drugs were used to kill the parasites in victims’ bloodstreams. Since 1970, however, malaria has come roaring back. Most species of the *Anopheles* mosquito have become genetically resistant to most insecticides. Worse, the *Plasmodium* parasites have become genetically resistant to common antimalarial drugs. In addition, clearing and developing tropical forests (Figure 10-5, p. 218, and Figure 10-13, p. 224) leads to the spread of malaria among workers and the settlers who follow. Global warming is also...
Infectious diseases are moving from one animal species to another and from wild and domesticated animal species to humans. Examples of infectious diseases transmitted from animals to humans include avian flu (Science Focus, p. 444), HIV (Core Case Study), SARS, West Nile virus, and Lyme disease. A 2008 study by Peter Daszak and other scientists found that about 60% of 325 diseases emerging between 1940 to 2004 were transmitted from animals to humans and the majority of those came from wild animals. And most people do not realize that pets such as rabbits, hamsters and other “pocket pets,” and turtles can transfer various infectious diseases to humans.

Ecological medicine is a new interdisciplinary field devoted to tracking down these connections between wildlife and humans. Scientists in this new field are looking for ways to slow or prevent the spread of such diseases, and they have identified several human practices that encourage the spread of diseases from animals to humans.

One is the clearing of forests, which forces wild animals to move to other areas. For example, cutting down tropical rain forests has increased the spread of malaria by increasing the range of Anopheles mosquito species, which live in sunlit ponds and carry the parasite that infects humans. There is also concern that global warming will expand tropical conditions under which malaria-carrying species thrive (Figure 17-7).

Where forests have been cleared and fragmented to make way for suburbs in the eastern United States, the chances of many suburbanites becoming infected with debilitating Lyme disease have increased. The bacterium that causes this disease lives in the bodies of deer and white mice and is passed between these two animals and to humans by certain types of ticks.

Lyme disease usually starts with a red rash shaped like a bull’s-eye around the tick bite. Antibiotics can cure people of the disease if they are administered within a month after the bite. Left untreated, though, Lyme disease can cause debilitating arthritis, heart disease, and nervous disorders. A vaccine is available, but does not give full protection. The best defense against the disease is to avoid tick bites by using insect repellant and wearing light-color clothing that is tucked in.

Expanding suburbs while fragmenting woodland areas has led to greatly reduced populations of foxes and wildcats, which had kept down populations of the white-footed mouse, which carries the Lyme bacterium. The result: white-footed mouse and tick populations have exploded and more suburbanites and hikers are becoming infected. Fortunately, the Lyme bacterium does not spread from person to person.

Another practice that encourages the spread of diseases takes place in parts of Africa and Asia where local people kill monkeys and other animals for bush meat (Figure 9-22, p. 206). They come in regular contact with primate blood and can be exposed to a simian strain of the HIV virus that causes AIDS and has infected 65 million people. Some monkeys also carry dangerous viruses such as herpes B that can be transferred to humans.

Another important factor is the legal and illegal international trade in wild species. In 2005, some 210 million wild animals—from kangaroos to iguanas, kinkajous, and tropical fish—were legally imported into the United States with limited quarantining and minimal screening for disease. Each year, countless other animals, bush meats, and animal parts are smuggled illegally across U.S. borders. A backpack carried off a flight from Nigeria may contain bush meat that could harbor the lethal Ebola virus. Salted duck eggs from South Korea could carry the deadly bird flu virus. Exotic birds or monkey paws, which are often smuggled internationally, could harbor various diseases that could jump to humans.

Factory meat production and the global trade of livestock animals can also increase the spread of food-borne infectious diseases to humans. For example, a deadly form of E. coli bacteria sometimes spreads from livestock animals and animals such as wild boars to people when they eat meat contaminated by animal manure. Salmonella bacteria, found on animal hides and in poorly processed meat can also cause food-borne disease.

Finally, global trade in general contributes to the spread of diseases among species. Infectious organisms can be transferred in shipping crates and containers, agricultural products, and ship ballast water. And global travel, especially ecotourism in wilderness areas, can spread infectious organisms around the world. GREEN CAREER: Ecological medicine

Critical Thinking
Do you think that air travelers should be more carefully monitored and possibly more restricted in the face of threats such as the Ebola and bird flu viruses? Explain.
tion, before they have a chance to bite and infect a human, by exposing the mosquitoes to a hormone that dramatically increases their urination.

Another approach is to provide poor people in malarial regions with free or inexpensive, long-lasting, insecticide-treated bed nets (Figure 17-9) and window screens. Also, zinc and vitamin A supplements could be used to boost resistance to malaria in children. And we can greatly reduce the incidence of malaria by spraying the insides of homes with low concentrations of the pesticide DDT twice a year at a cost of about $10. Under an international treaty enacted in 2002, DDT and five similar pesticides are being phased out in developing countries. However, in 2006 the WHO supported the use of DDT for malaria control.

Columbia University scientist Jeffrey Sachs estimates that spending $2–3 billion a year on preventing and treating malaria might save more than a million lives a year. Sachs notes, “This is probably the best bargain on the planet.”

**RESEARCH FRONTIER**

Finding new drugs and other treatments for malaria and finding ways to hinder the mosquitoes that transmit the malaria parasite. See academic.cengage.com/biology/miller.

**CENGAGENOW** Watch through a microscope what happens when a mosquito infects a human with malaria at CengageNOW.

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**We Can Reduce the Incidence of Infectious Diseases**

*Good news.* According to the WHO, the global death rate from infectious diseases decreased by about two-thirds between 1970 and 2000 and is projected to continue dropping. Also, between 1971 and 2000, the percentage of children in developing countries immunized with vaccines to prevent tetanus, measles, diphtheria, typhoid fever, and polio increased from 10% to 84%—saving about 10 million lives each year. It costs about $30 to get a basic package of vaccines to a child—an affordable way to save a child’s life for roughly the price of a single night out at the movies in a developed country.

Figure 17-10 lists measures promoted by health scientists and public health officials to help prevent or reduce the incidence of infectious diseases—especially in developing countries. An important breakthrough has

**SOLUTIONS**

<table>
<thead>
<tr>
<th>Infectious Diseases</th>
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<tbody>
<tr>
<td>Increase research on tropical diseases and vaccines</td>
</tr>
<tr>
<td>Reduce poverty</td>
</tr>
<tr>
<td>Decrease malnutrition</td>
</tr>
<tr>
<td>Improve drinking water quality</td>
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<tr>
<td>Reduce unnecessary use of antibiotics</td>
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<tr>
<td>Educate people to take all of an antibiotic prescription</td>
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<tr>
<td>Reduce antibiotic use to promote livestock growth</td>
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<tr>
<td>Require careful hand washing by all medical personnel</td>
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<tr>
<td>Immunize children against major viral diseases</td>
</tr>
<tr>
<td>Provide oral rehydration for diarrhea victims</td>
</tr>
<tr>
<td>Conduct global campaign to reduce HIV/AIDS</td>
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</tbody>
</table>

**Figure 17-10 Solutions:** ways to prevent or reduce the incidence of infectious diseases, especially in developing countries. **Question:** Which three of these approaches do you think are the most important?
been the development of simple oral rehydration therapy to help prevent death from dehydration for victims of severe diarrhea, which causes about one-fourth of all deaths of children younger than age 5 (Concept 17-2). It involves administering a simple solution of boiled water, salt, and sugar or rice, at a cost of only a few cents per person. It has been the major factor in reducing the annual number of deaths from diarrhea from 4.6 million in 1980 to 1.9 million in 2006. Few investments have saved so many lives at such a low cost. In 2006, the WHO estimated that implementing the solutions in Figure 17-10 could save the lives of as many as 4 million children younger than age 5 each year.

Recall that more than a third of the world’s people—2.6 billion—do not have decent bathroom facilities, and more than a billion get their water for drinking, washing, and cooking from sources polluted by animal and human feces. A key to reducing sickness and premature death from infectious disease is to focus on providing people with simple latrines and access to safe drinking water. The U.N. estimates that this could be done for about $20 billion a year—about what rich countries with almost universal access to clean water spend each year on bottled water. Bad news. The WHO estimates that only 10% of global medical research and development money goes toward preventing infectious diseases in developing countries, even though more people worldwide suffer and die from these diseases than from all other diseases combined. Fortunately, the problem is getting more attention. In recent years, philanthropists including Bill and Melinda Gates and Warren E. Buffet have donated billions of dollars to improve global health, with primary emphasis on preventing infectious diseases in developing countries. GREEN CAREER: Infectious disease prevention

17-3 What Types of Chemical Hazards Do We Face?

CONCEPT 17-3 There is growing concern about chemicals that can cause birth defects and cancers and disrupt the human immune, nervous, and endocrine systems.

Some Chemicals Can Cause Cancers, Mutations, and Birth Defects,

A toxic chemical is one that can cause temporary or permanent harm or death to humans and animals. In 2004, the U.S. Environmental Protection Agency (EPA) listed arsenic, lead, mercury, vinyl chloride (used to make PVC plastics), and polychlorinated biphenyls (PCBs, Case Study, at right) as the five most toxic substances in terms of threats to human and environmental health. Note that three of them are metallic chemical elements.

There are three major types of potentially toxic agents. Carcinogens are chemicals, types of radiation, or certain viruses that can cause or promote cancer—a disease in which malignant cells multiply uncontrollably and create tumors that can damage the body and often lead to premature death.

Examples of carcinogens are arsenic, benzene, chloroform, formaldehyde, gamma radiation, nickel, PCBs, radon, certain chemicals in tobacco smoke, UV radiation, X-rays, and vinyl chloride. (For a longer list, see ntp.niehs.nih.gov/.)

Typically, 10–40 years may elapse between the initial exposure to a carcinogen and the appearance of detectable symptoms. Partly because of this time lag, many healthy teenagers and young adults have trouble believing that their smoking, drinking, eating, and other lifestyle habits today could lead to some form of cancer before they reach age 50.

The second major type of toxic agent, mutagens, includes chemicals or forms of radiation that cause mutations, or changes, in the DNA molecules found in cells, or that increase the frequency of such changes. Most mutations cause no harm but some can lead to cancers and other disorders. For example, nitrous acid (HNO₃), formed by the digestion of nitrite (NO₂⁻) preservatives in foods, can cause mutations linked to stomach cancer in people who consume large amounts of processed foods and wine with such preservatives. Harmful mutations occurring in reproductive cells can be passed on to offspring and to future generations. (For a list of mutagens see www.evol.nw.ru/~spirov/hazard/mutagen_lst.html.)

Third, teratogens are chemicals that cause harm or birth defects to a fetus or embryo. Ethyl alcohol is a teratogen. Drinking during pregnancy can lead to offspring with low birth weight and a number of physical, developmental, behavioral, and mental problems. Other teratogens are angel dust, benzene, cadmium, formaldehyde, lead, mercury, mescaline, PCBs, phthalates, thalidomide, vinyl chloride, and hundreds of other organic compounds. (For a list, see ptc1.chem.ox.ac.uk/MSDS/teratogens.html.) Between 2001 and 2006, birth defects in Chinese infants soared by nearly 40%. Officials link this to the country’s growing
pollution, especially from coal-burning power plants and industries.

**CASE STUDY**

**PCBs Are Everywhere—A Legacy from the Past**

PCBs are a class of more than 200 chlorine-containing organic compounds that are very stable and nonflammable. They exist as oily liquids or solids that can enter the air as a vapor. Between 1929 and 1977, PCBs were widely used as lubricants, hydraulic fluids, and electrical insulators in transformers and capacitors. They also became ingredients in a variety of products including paints, fire retardants in fabrics, preservatives, adhesives, and pesticides.

The U.S. Congress banned the domestic production of PCBs in 1977 after research showed that they could cause liver and other cancers in test animals and, according to the EPA, probably can cause cancers in humans. A 1996 study related exposure of fetuses to PCBs in the womb to learning disabilities in children.

Production of PCBs has also been banned in most other countries. But the potential health threats from these chemicals will be with us for a long time. For decades, PCBs entered the air, water, and soil during their manufacture, use, and disposal, as well as from accidental spills and leaks. Because PCBs breakdown very slowly in the environment, they can travel long distances in the air and be deposited far away from where they were released. Because they are fat soluble, PCBs can also be biologically magnified (Figure 9-19, p. 202) in food chains and webs.

As a result, PCBs are now found everywhere—in soil, air, lakes, rivers, fish, birds, your body, and the bodies of polar bears and penguins in the Arctic. PCBs are present even in the milk of nursing mothers, although most scientists say the health benefits of mother’s milk outweigh the risk from exposure to trace amounts of PCBs in breast milk.

According to the EPA, about 70% of all the PCBs made in the United States are still in the environment. Figure 17-11 shows potential pathways on which persistent toxic chemicals such as PCBs move through the living and nonliving environment.

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**THINKING ABOUT PCBs**

We are stuck with long-term exposure to trace amounts of PCBs with mostly unknown long-term health effects, but what environmental lesson can we learn from the widespread use of these persistent chemicals?

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**Some Chemicals May Affect Our Immune, Nervous, and Endocrine Systems**

Since the 1970s, a growing body of research on wildlife and laboratory animals, along with some studies of humans, suggest that long-term exposure to some chemicals in the environment can disrupt the body’s immune, nervous, and endocrine systems (Concept 17-3).

The immune system consists of specialized cells and tissues that protect the body against disease and harmful substances by forming antibodies that render invading agents harmless. Some chemicals such as arsenic, methylmercury, and dioxins can weaken the human immune system and leave the body vulnerable to attacks by allergens and infectious bacteria, viruses, and protozoa.

Some natural and synthetic chemicals in the environment, called neurotoxins, can harm the human nervous system (brain, spinal cord, and peripheral nerves). Effects can include behavioral changes, learning disabilities, retardation, attention deficit disorder, paralysis, and death. Examples of neurotoxins are PCBs, methyl mercury (Science Focus, pp. 450–451), arsenic, lead, and certain pesticides. For example, a 2007 study by scientists Beate Ritz and Caroline Tanner found that farm workers exposed to the widely used weed killer paraquat had two to three times the normal risk of suffering from Parkinson’s disease, a degenerative brain disease that eventually paralyzes victims.

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**Figure 17-11** Potential pathways on which toxic chemicals move through the living and nonliving environment.
Mercury (Hg) is a teratogen and a potent neurotoxin that interferes with the nervous system and brain function. This toxic metal is released into the air from rocks, soil, and volcanoes and by vaporization from the ocean. Such natural sources account for about one-third of the mercury reaching the atmosphere each year.

According to the EPA, the remaining two-thirds come from human sources—mostly coal-burning power plants, waste incinerators, and chemical manufacturing plants. Other lesser sources include gold and silver mines, metal ore smelters, and facilities that incinerate or crush products containing mercury, such as batteries, electronic switches, and relays.

Mercury is persistent and, because it is an element, cannot be degraded. Therefore this global pollutant accumulates in soil, water, and the bodies of people and other animals that feed high on food chains. This includes polar bears, toothed whales, and seals living in the Arctic, which is a global mercury hotspot.

In 2007, scientists from the EPA and Oregon State University surveyed 2,707 fish randomly collected from 626 rivers in 12 U.S. states. They found mercury in every fish and every river, but generally at levels considered safe for people to eat occasionally.

In the atmosphere, some elemental mercury is converted to more toxic inorganic and organic mercury compounds that can be deposited in aquatic environments. In acidic aquatic systems, bacteria can convert inorganic mercury compounds to highly toxic methylmercury (CH$_3$Hg$^+$), which can be biologically magnified in food chains and webs (Figure 17-A). As a result, high levels of methylmercury are often found in the tissues of predatory fishes such as large albacore (white) tuna, sharks, swordfish, king mackerel, tilefish,

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**Figure 17-A** _Science_: cycling of mercury in aquatic environments, in which mercury is converted from one form to another. The most toxic form to humans is methylmercury (CH$_3$Hg$^+$), which can be biologically magnified in aquatic food chains and webs. Some mercury is also released back into the atmosphere as mercury vapor.
before birth. Figure 17-B lists ways to prevent or control human exposure to mercury.

In its 2003 report on global mercury pollution, the U.N. Environment Programme recommended phasing out coal-burning power plants and incinerators throughout the world as rapidly as possible. In 2007, 16 U.S. states filed a lawsuit in federal court against the EPA for not requiring sharp reductions in mercury emissions from all U.S. coal-burning power plants.

Other recommended goals are to reduce or eliminate use of mercury in batteries, TVs, compact fluorescent light bulbs, and all other products unless they are recycled.

Critical Thinking
Should we phase out all coal burning and waste incineration as rapidly as possible as a way to sharply reduce mercury pollution? Explain. How might your lifestyle change if this were done?
The endocrine system is a complex network of glands that release tiny amounts of hormones into the bloodstream of humans and other vertebrate animals. Low levels of these chemical messengers turn on and turn off bodily systems that control sexual reproduction, growth, development, learning, and behavior. Each type of hormone has a unique molecular shape that allows it to attach to certain cells, using a part of the cell called a receptor, and to transmit its chemical message (Figure 17-12, left). In this “lock-and-key” relationship, the receptor is the lock and the hormone is the key.

Certain chemicals, called hormonally active agents (HAAs), can mimic hormones. Exposure to low levels of HAAs can impair reproductive systems and sexual development and cause physical and behavioral disorders. Examples of HAAs include aluminum, atrazine and several other herbicides, DDT, mercury, PCBs (Case Study, p. 449), phthalates, and bisphenol A (Science Focus, at right). Natural biological evolution has not equipped us to deal with these synthetic hormone imposters.

Some hormone mimics are chemically similar to estrogens (female sex hormones). They can disrupt the endocrine system by attaching to estrogen receptor molecules (Figure 17-12, center). Others, called hormone blockers, disrupt the endocrine system by preventing natural hormones such as androgens (male sex hormones) from attaching to their receptors (Figure 17-12, right).

Estrogen mimics and hormone blockers are sometimes called gender benders because of their possible effects on sexual development and reproduction. In males, excessive levels of female hormones can cause feminization, smaller penises, lower sperm counts, and the presence of both male and female sex organs (hermaphroditism). And there is growing concern about still another group of HAAs—pollutants that can act as thyroid disrupters—which cause growth, weight, brain, and behavioral disorders.

The harmful effects of certain phthalates (pronounced “thall-eights”) are also of concern. These chemicals are used to soften polyvinyl chloride (PVC) plastic found in a variety of products such as soft vinyl toys, teething rings, and blood storage bags, IV bags, and medical tubes used in hospitals. And they are used as solvents in many consumer products, including perfumes, cosmetics, body lotions, hair sprays, deodorants, nail polishes and shampoos. A 2008 study by Sheela Sathyanarayana and her colleagues tested urine from the diapers of 163 infants aged 2 months to 28 months. They found that 81% of the urine had measurable amounts of seven or more phthalates contained in baby lotions, baby powders, and baby shampoos.

Exposure of laboratory animals to high doses of various phthalates has caused birth defects, liver cancer, kidney and liver damage, premature breast development, immune suppression, and abnormal sexual development in these animals. The European Union and at least 14 other countries have banned phthalates. But scientists in the United States are divided on its risks to human health and reproductive systems. U.S. toy makers say that phthalates, which have been used for more than 20 years in baby items, pose no threats. In addition, they warn that substitutes could make plastic toys more brittle and subject to breaking, which could lead to harm to children.

Some scientists hypothesize that certain problems may be related to increased levels of hormone disruptors in our bodies. Such problems include sharp drops in male sperm counts and male sperm mobility occurring in 20 countries on six continents, rising rates of testicular cancer and genital birth defects in men, and increased breast cancer rates in women.

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**Figure 17-12** Hormones are molecules that act as messengers in the endocrine system to regulate various bodily processes, including reproduction, growth, and development. Each type of hormone has a unique molecular shape that allows it to attach to specially shaped receptors on the surfaces of, or inside, cells and to transmit its chemical message (left). Molecules of certain pesticides and other synthetic chemicals have shapes similar to those of natural hormones and can disrupt the endocrine systems in humans and other animals (center and right). These molecules are called hormonally active agents (HAAs). Because of the difficulty of determining the harmful effects of long-term exposure to low levels of HAAs, there is uncertainty about their effects on human health.
Other scientists disagree and point out that there have not been enough scientific studies and that we lack statistical evidence to link these medical problems to HAA levels in humans. They call for doing more research before banning or severely restricting HAAs, which could cause huge economic losses for companies that make them. Such research will take decades. Meanwhile, some scientists believe that as a precaution, we should sharply reduce our use of potential hormone disrupters.

A widely used estrogen mimic is bisphenol A (BPA). It is a chemical building block in certain plastics (especially polycarbonates) used in a variety of products including water and baby bottles, sports drink and juice bottles, microwave dishes, food storage containers, food and beverage can liners (including cans of infant formula), and dental fillings.

Studies show that this chemical can leach out of many of these products into food and water, especially when exposed to heat or acidic and basic liquids and foods. Research indicates that 95% of Americans and most of the citizens in other industrialized countries have trace levels of bisphenol A in their bodies. Ninety-four studies by independent laboratories have found a number of adverse effects on test animals from exposure to very low levels of bisphenol A. These effects include brain damage, prostate disease, breast cancer, early puberty, reduced sperm count, impaired immune function, type 2 diabetes, hyperactivity, increased aggressiveness, impaired learning, increased addiction to drugs such as amphetamines, decreased sex drive in males, and obesity in un born test animals exposed to bisphenol A. On the other hand, 12 studies funded by the chemical industry found no evidence or weak evidence for adverse effects from low-level exposure to bisphenol A on test animals. In recent years, two groups of scientists convened by the U.S. National Institutes of Health have reached opposite conclusions about whether exposure to trace amounts of BPA poses a threat to human health.

This controversy may take decades to resolve. Meanwhile, some scientists call for banning or phasing out many uses of bisphenol A (especially in baby bottles and sipping cups used by more vulnerable infants and in the plastic lining of baby formula cans) as a preventive or precautionary measure and encouraging scientists to look for less potentially harmful substitutes. Others say we need more research before taking such measures that would cause huge economic losses for the chemical industry.

Critical Thinking
Should we ban or phase out the use of BPA? Defend your choice. What beneficial or harmful effects might such a ban have on your life or on the lives of future generations?

### SCIENCE FOCUS

**Bisphenol A**

A widely used estrogen mimic is bisphenol A (BPA). It is a chemical building block in certain plastics (especially polycarbonates) used in a variety of products including water and baby bottles, sports drink and juice bottles, microwave dishes, food storage containers, food and beverage can liners (including cans of infant formula), and dental fillings.

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**Critical Thinking**
Should we ban or phase out the use of BPA? Defend your choice. What beneficial or harmful effects might such a ban have on your life or on the lives of future generations?

### How Can We Evaluate and Deal with Chemical Hazards?

**CONCEPT 17-4A** Scientists use live laboratory animals, non-animal tests, case reports of poisonings, and epidemiological studies to estimate the toxicity of chemicals, but these methods have limitations.

**CONCEPT 17-4B** Many health scientists call for much greater emphasis on pollution prevention to reduce our exposure to potentially harmful chemicals.

Many Factors Determine the Harmful Health Effects of a Chemical

We are exposed to small amounts of potentially harmful chemicals every day in the air we breathe, the water we drink, and the food we eat. **Toxicology** is the study of the harmful effects of chemicals on humans and other organisms. In effect, it is a study of poisons.

**Toxicity** is a measure of how harmful a substance is—its ability to cause injury, illness, or death to a living organism. A basic principle of toxicology is that any synthetic or natural chemical can be harmful if ingested in a large enough quantity. But the critical question is this: At
what level of exposure to a particular toxic chemical will the chemical cause harm? This is the meaning of the chapter-opening quote by the Swiss scientist Paracelsus about the dose making the poison.

This is a difficult question to answer because of the many variables involved in estimating the effects of human exposure to chemicals (Figure 17-13). A key factor is the dose, the amount of a harmful chemical that a person has ingested, inhaled, or absorbed through the skin.

The effects of a particular chemical can also depend upon the age of the person exposed to it. For example, toxic chemicals usually have a greater effect on children than on adults (Case Study, at right). Toxicity also depends on genetic makeup, which determines an individual’s sensitivity to a particular toxin. Some individuals are sensitive to a number of toxins—a condition known as multiple chemical sensitivity (MCS). Another factor is how well the body’s detoxification systems (such as the liver, lungs, and kidneys) work.

Several other factors can affect the level of harm caused by a chemical. One is its solubility. Water-soluble toxins (which are often inorganic compounds) can move throughout the environment and get into water supplies and the aqueous solutions that surround the cells in our bodies. Oil- or fat-soluble toxins (which are usually organic compounds) can penetrate the membranes surrounding cells, because the membranes allow similar oil-soluble chemicals to pass through them. Thus, oil- or fat-soluble toxins can accumulate in body tissues and cells.

Another factor is a substance’s persistence, or resistance to breakdown. Many chemicals, such as DDT and PCBs (Case Study, p. 449), have been widely used
because they are not easily broken down in the environment. This means that more people and wildlife are likely to come in contact with them and that they are more likely to remain in the body and have long-lasting harmful health effects.

Another factor is biological magnification, in which the concentrations of some potential toxins in the environment increase as they pass through the successive trophic levels of food chains and webs. Organisms at low trophic levels might ingest only small amounts of a toxin, but each animal on the next trophic level up that eats many of those organisms will take in increasingly larger amounts of that toxin (Figure 9-19, p. 202). Examples of chemicals that can be biomagnified include long-lived, fat-soluble, organic compounds, such as DDT and PCBs.

The damage to health resulting from exposure to a chemical is called the response. An acute effect is an immediate or rapid harmful reaction to an exposure—ranging from dizziness and nausea to death. A chronic effect is a permanent or long-lasting consequence (kidney or liver damage, for example) of exposure to a single dose or to repeated lower doses of a harmful substance.

**CASE STUDY**

**Protecting Children from Toxic Chemicals**

Everyone on the planet is exposed to an array of toxic chemicals whose long-term effects are largely unknown. In 2005, the Environmental Working Group analyzed umbilical cord blood from 10 randomly selected newborns in U.S. hospitals. Of the 287 chemicals detected, 180 cause cancers in humans or animals, 217 damage the brain and nervous systems in test animals, and 208 cause birth defects or abnormal development in test animals. Scientists do not know what harm, if any, might be caused by the very low concentrations of these chemicals found in infants’ blood.

But infants and young children are more susceptible to the effects of toxic substances than are adults for three major reasons. First, children generally breathe more air, drink more water, and eat more food per unit of body weight than do adults. Second, they are exposed to toxins in dust or soil when they put their fingers, toys, or other object in their mouths (as they frequently do). Third, children usually have less well-developed immune systems and body detoxification processes than adults have.

In 2003, the U.S. EPA proposed that in determining any risk, regulators should assume children face a risk 10 times higher than that faced by adults. Some health scientists contend that these guidelines are too weak. They suggest that, to be on the safe side, we should assume that this risk for children is 100 times that of adults.

**THINKING ABOUT**

**Toxic Chemical Levels for Children**

Should environmental regulations require that allowed levels of exposure to toxic chemicals for children be 100 times lower than for adults? Explain your reasoning.

**Scientists Use Live Laboratory Animals and Nonanimal Tests to Estimate Toxicity**

The most widely used method for determining toxicity is to expose a population of live laboratory animals to measured doses of a specific substance under controlled conditions. Laboratory-bred mice and rats are widely used because, as mammals, their systems function somewhat like humans, they are small, and can reproduce rapidly under controlled laboratory conditions.

Animal tests take 2–5 years, involve hundreds to thousands of test animals, and cost as much as $2 million per substance tested. Such tests can be painful to the test animals and can kill or harm them. Animal welfare groups want to limit or ban the use of test animals or ensure that they are treated in the most humane manner possible.

Scientists estimate the toxicity of a chemical by determining the effects of various doses of the chemical on test organisms and then by plotting the results in a dose-response curve (Figure 17-14). One approach is to determine the lethal dose—the amount needed to kill an animal. A chemical’s median lethal dose (LD50) is the dose that can kill 50% of the animals (usually rats and mice) in a test population within an 18-day period.

![Figure 17-14 Science: hypothetical dose-response curve showing determination of the LD50, the dosage of a specific chemical that kills 50% of the animals in a test group. Toxicologists use this method to compare the toxicities of different chemicals.](image-url)
Chemicals vary widely in their toxicity (Table 17-1). Some poisons can cause serious harm or death after a single exposure at very low dosages. Others cause such harm only at dosages so huge that it is nearly impossible to get enough into the body to cause injury or death. Most chemicals fall between these two extremes.

There are two general types of dose-response curves (Figure 17-15). With the nonthreshold dose-response model (Figure 17-15, left), any dosage of a toxic chemical causes harm that increases with the dosage. With the threshold dose-response model (Figure 17-15, right), a threshold dosage must be reached before any detectable harmful effects occur, presumably because the body can repair the damage caused by low dosages of some substances.

Establishing which model applies at low dosages is extremely difficult and controversial. To be on the safe side, scientists often assume that even a small dose will have an effect, and they choose the nonthreshold dose-response model.

In testing, scientists often use fairly high dosages to reduce the number of test animals needed, obtain results quickly, and lower costs. Otherwise, manufacturers would need to run tests on millions of laboratory animals for many years, which means they could not afford to test most chemicals. For the same reasons, scientists usually use mathematical models to extrapolate, or estimate the effects of low-dose exposures based on the measured results of high-dose exposures. Then they extrapolate these results from test organisms to humans to estimate LD50 values for acute toxicity (Table 17-1).

Some scientists challenge the validity of extrapolating data from test animals to humans because human physiology and metabolism differ from those of the test animals. Other scientists say that such tests and models work fairly well (especially for revealing cancer risks) when the correct experimental animal is chosen or when a chemical is toxic to several different test-animal species.

More humane methods for carrying out toxicity tests are available and are increasingly being used to replace live animal testing. They include computer simulations and testing with tissue cultures, chicken egg membranes, and individual animal cells, instead of with whole, live animals. High-speed robot testing devices can now measure the biological activity of more than one million compounds a day to help determine their possible toxic effects.
In 2008, U.S. government labs began making much greater use of such nonanimal testing methods because they are faster and cheaper than animals tests and because of growing public concern over animal testing. For example, government toxicity testing labs can run between 10 and 100 tests a year using live rodents such as rats and mice but can run more than 10,000 tests a day using specialized cells and computerized testing measurements.

RESEARCH FRONTIER
Computer modeling and other alternatives to animal testing. See academic.cengage.com/biology/miller.

There are several problems involved with using laboratory experiments to estimate toxicities (Concept 17-4A). In real life, each of us is exposed to a variety of chemicals, some of which can interact in ways that decrease or enhance their short- and long-term individual effects. Toxicologists already have great difficulty in estimating the toxicity of a single substance. And adding the problem of evaluating mixtures of potentially toxic substances, separating out which ones are the culprits, and determining how they can interact with one another is overwhelming from a scientific and economic standpoint. For example, just studying the interactions of three of the 500 most widely used industrial chemicals would take 20.7 million experiments—a physical and financial impossibility.

THINKING ABOUT
Animal Testing
Should laboratory-bred mice, rats, and other animals be used to determine toxicity and other effects of chemicals? Explain.

There Are Other Ways to Estimate the Harmful Effects of Chemicals

Scientists use several other methods to get information about the harmful effects of chemicals on human health. For example, case reports, usually made by physicians, provide information about people suffering adverse health effects or death after exposure to a chemical. Such information often involves accidental or deliberate poisonings, drug overdoses, homicides, or suicide attempts.

Most case reports are not reliable sources for estimating toxicity because the actual dosage and the exposed person’s health status are often unknown. But such reports can provide clues about environmental hazards and suggest the need for laboratory investigations.

Another source of information is epidemiological studies, which compare the health of people exposed to a particular chemical (the experimental group) with the health of a similar group of people not exposed to the agent (the control group). The goal is to determine whether the statistical association between exposure to a toxic chemical and a health problem is strong, moderate, weak, or undetectable.

Four factors can limit the usefulness of epidemiological studies. First, in many cases, too few people have been exposed to high enough levels of a toxic agent to detect statistically significant differences. Second, they usually take a long time. Third, conclusively linking an observed effect with exposure to a particular chemical is difficult because people are exposed to many different toxic agents throughout their lives and can vary in their sensitivity to such chemicals. And fourth, we cannot use epidemiological studies to evaluate hazards from new technologies or chemicals to which people have not yet been exposed.

Are Trace Levels of Toxic Chemicals Harmful?

Almost everyone is now exposed to potentially harmful chemicals (Figure 17-16, p. 458) that have built up to trace levels in their blood and other parts of their bodies. Trace amounts of birth control pills, blood pressure medicines, antidepressants, painkillers, and a host of other chemicals with largely unknown effects on human health are being released into waterways from sewage treatment plants or are leaching into groundwater from home septic sewage systems.

Should we be concerned about trace amounts of various synthetic chemicals in air, water, food, and our bodies? The honest answer is that, in most cases, we do not know, because there is too little data and because of the difficulty of determining the effects of low levels of these chemicals (Concept 17-4A).

Some scientists view trace amounts of such chemicals with alarm, especially because of their potential long-term effects on the human immune, nervous, and endocrine systems. Others view the risks from trace levels as minor. They point out that average life expectancy has been increasing in most countries, especially developed ones, for decades. And many industry officials contend that the concentrations of such chemicals are so low that they are harmless.

Chemists are also able to detect increasingly smaller amounts of potentially toxic chemicals in air, water, and food. This is good news, but it can give the false impression that dangers from toxic chemicals are increasing. In reality, we may simply be uncovering levels of chemicals that have been around for a long time.

RESEARCH FRONTIER
Learning more about the long-term effects of trace amounts of potentially harmful chemicals on human health. See academic.cengage.com/biology/miller.
Some people have the mistaken idea that all natural chemicals are safe and all synthetic chemicals are harmful. In fact, many synthetic chemicals, including many of the medicines we take, are quite safe if used as intended; and many natural chemicals, such as mercury and lead, are deadly.

**Why Do We Know So Little about the Harmful Effects of Chemicals?**

As we have seen, all methods for estimating toxicity levels and risks have serious limitations (Concept 17-4A). But they are all we have. To take this uncertainty into account and to minimize harm, scientists and regulators typically set allowed levels of exposure to toxic substances and ionizing radiation at 1/100 or even 1/1,000 of the estimated harmful levels.

According to risk assessment expert Joseph V. Rodricks, “Toxicologists know a great deal about a few chemicals, a little about many, and next to nothing about most.” The U.S. National Academy of Sciences estimates that only 10% of 100,000 registered synthetic chemicals in commercial use have been thoroughly screened for toxicity, and only 2% have been adequately tested to determine whether they are carcinogens, teratogens, or mutagens. Hardly any of the chemicals in commercial use have been screened for possible damage to the human nervous, endocrine, and immune systems. Because of insufficient data and the high costs of regulation, federal and state governments do not regulate about 99.5% of the commercially used chemicals in the United States.

**How Far Should We Go in Using Pollution Prevention and the Precautionary Principle?**

So where does this leave us? We do not know a lot about the potentially toxic chemicals around us and inside of us, and estimating their effects is very difficult, time-consuming, and expensive. Is there a way to deal with this problem?
Some scientists and health officials, especially those in European Union countries, are pushing for more emphasis on pollution prevention (Concept 17-4, p. 16). They say we should not release into the environment chemicals that we know or suspect can cause significant harm. This means looking for harmless or less harmful substitutes for toxic and hazardous chemicals (Individuals Matter, below). Another option is to recycle them within production processes to keep them from reaching the environment, as the U.S. companies 3M and DuPont have been doing (Concept 17-4B).

Pollution prevention is a strategy for implementing the precautionary principle (p. 210). According to this principle, when there is reasonable but incomplete scientific evidence of significant or irreversible harm to humans or to the environment from a proposed or existing chemical or technology, we should take action to prevent or reduce the risk instead of waiting for more conclusive evidence (Concept 9-4C, p. 206). Note that the precautionary principle is a general guideline that does not specify what should trigger action, or what specific action should be taken.

There is controversy over how far we should go in implementing pollution prevention based on the precautionary principle. If we applied it strictly, those proposing to introduce a new chemical or technology would bear the burden of establishing its safety. This would require two major changes in the way we evaluate risks. First, new chemicals and technologies would be assumed to be harmful until scientific studies could show otherwise. Second, existing chemicals and technologies that appear to have a strong chance of causing significant harm would be removed from the market until their safety could be established. For example, after decades of research revealed the harmful effects of lead, especially in children, lead-based paints and leaded gasoline were phased out in most developed countries.

Some movement is being made in this direction, especially in the European Union. In 2000, negotiators agreed to a global treaty that would ban or phase out use of 12 of the most notorious persistent organic pollutants (POPs), also called the dirty dozen (See www.pops.int/). The list includes DDT and eight other persistent pesticides, PCBs, dioxins, and furans. Animal studies have shown that the harmful effects of various POPS include tumors and cancers, birth defects, compromised immune systems, feminization of males and masculinization of females, abnormally functioning thyroid glands, and reproductive failure. There is also concern that some of these chemicals may play a role in malformed penises in boys, increased testicular cancers, and a 50% decline in sperm counts and sperm quality in men in a number of countries.

Although such evidence is not clear and is controversial, phasing these chemicals out could be a reasonable precaution. New chemicals will be added to the list when the harm they could potentially cause is seen as outweighing their usefulness. This treaty went into effect in 2004 but has not been ratified and implemented by the United States.

INDIVIDUALS MATTER

Ray Turner and His Refrigerator

Life as we know it could not exist on land or in the upper layers of the oceans and other bodies of water without the thin layer of ozone (O$_3$) found in the lower stratosphere (Figure 3-8, p. 56). In other words, a basic rule of sustainability relating to pollution prevention is: Do not mess with the ozone layer.

However, for decades we violated this principle of pollution prevention by releasing large amounts of chemicals such as chlorofluorocarbons (CFCs) into the troposphere. These chemicals have drifted into the stratosphere where they react with and destroy some of the ozone that protects life from harmful UV radiation.

In 1974, scientists alerted the world to this threat. After further research and lengthy debate, in 1992, most of the world’s nations signed a landmark international agreement to phase out the use of CFCs and other ozone-destroying chemicals. The discovery of these chemicals led scientists to use the principle of pollution prevention and search for less harmful alternatives.

Ray Turner, a manager at Hughes Aircraft in the U.S. state of California, was concerned about this. His company was using CFCs as cleaning agents to remove films of oxidation from the electronic circuit boards they manufactured. Turner’s concern for the environment led him to search for a cheap and simple substitute for these chemicals. He found it in his refrigerator.

Turner decided to put drops of some common kitchen substances on a corroded penny to see whether any of them would remove the film of oxidation. Then he used his soldering gun to see whether solder would stick to the surface of the penny, indicating that the film had been cleaned off.

First he tried vinegar. No luck. Then he tried some ground-up lemon peel. Another failure. Next he tried a drop of lemon juice and watched as the solder took hold. The rest, as they say, is history.

Today, Hughes Aircraft uses inexpensive, CFC-free, citrus-based solvents to clean circuit boards. This new cleaning technique has reduced circuit board defects by about 75% at the company. And Turner got a hefty bonus. Now, other companies clean computer boards and chips using acidic chemicals extracted from cantaloupes, peaches, and plums. Maybe you can find a solution to an environmental problem in your refrigerator.
In 2006, the European Union enacted new regulations that require the registration of 30,000 untested and unregulated potentially harmful chemicals. The most hazardous substances will no longer be approved for use if safer alternatives exist. And when there is no alternative, producers must present a research plan aimed at finding one. Many environmental scientists applaud this use of pollution prevention to implement the precautionary principle, but some say that the regulation does not go far enough and has too many loopholes.

Manufacturers and businesses contend that widespread application of this approach would make it too expensive and almost impossible to introduce any new chemical or technology. They argue that we can never have a risk-free society.

Proponents of increased reliance on pollution prevention agree that we can go too far, but argue we have an ethical responsibility to reduce known or potentially serious threats to human health and to our life support system (Concept 17-4B). They also point out that using the precautionary principle focuses the efforts and creativity of scientists, engineers, and businesses on finding solutions to pollution problems based on prevention rather than on cleanup. This in turn reduces health risks for employees and society, frees businesses from having to deal with pollution regulations, reduces the threat of lawsuits from harmed parties, increases profits, in some cases, from sales of safer products and innovative technologies, and improves the public image of businesses operating in this manner.

**HOW WOULD YOU VOTE?**

Should we rely more on pollution prevention to implement the precautionary principle as a way to reduce the potential risks from chemicals and technologies? Cast your vote online at [academic.cengage.com/biology/miller](academic.cengage.com/biology/miller).

### 17-5 How Do We Perceive Risks and How Can We Avoid the Worst of Them?

**CONCEPT 17-5** We can reduce the major risks we face if we become informed, think critically about risks, and make careful choices.

#### The Greatest Health Risks Come from Poverty, Gender, and Lifestyle Choices

**Risk analysis** involves identifying hazards and evaluating their associated risks (risk assessment; Figure 17-3, left), ranking risks (comparative risk analysis), determining options and making decisions about reducing or eliminating risks (risk management; Figure 17-3, right), and informing decision makers and the public about risks (risk communication).

Statistical probabilities based on past experience, animal testing, and other tests are used to estimate risks from older technologies and chemicals. To evaluate new technologies and products, risk evaluators use more uncertain statistical probabilities, based on models rather than actual experience and testing.

Figure 17-17 lists the results of a comparative risk analysis and summarizes the greatest ecological and health risks identified by a panel of scientists acting as advisers to the EPA.

The greatest risks many people face today are rarely dramatic enough to make the daily news. In terms of the number of premature deaths per year (Figure 17-18) and reduced life span (Figure 17-19, p. 462), the greatest risk by far is poverty. The high death toll ultimately resulting from poverty is caused by malnutrition, increased susceptibility to normally nonfatal infectious diseases, and often-fatal infectious diseases transmitted by unsafe drinking water.

After poverty and gender, the greatest risks of premature death mostly result from lifestyle choices that people make (Figures 17-18 and 17-19, p. 462) (Concept 17-1). The best ways to reduce one’s risk of premature death and serious health problems are to avoid smoking and exposure to smoke (Case Study, p. 462), lose excess weight, reduce consumption of foods containing cholesterol and saturated fats, eat a variety of fruits and vegetables, exercise regularly, drink little or no alcohol (no more than two drinks in a single day), avoid excess sunlight (which ages skin and can cause skin cancer), and practice safe sex (Concept 17-5). A 2005 study by Majjid Ezzati with participation by 100 scientists around the world estimated that one-third of the 7 million annual cancer deaths could be prevented if individuals followed these guidelines.
**Comparative Risk Analysis**

**Most Serious Ecological and Health Problems**

**High-Risk Health Problems**
- Indoor air pollution
- Outdoor air pollution
- Worker exposure to industrial or farm chemicals
- Pollutants in drinking water
- Pesticide residues on food
- Toxic chemicals in consumer products

**High-Risk Ecological Problems**
- Global climate change
- Stratospheric ozone depletion
- Wildlife habitat alteration and destruction
- Species extinction and loss of biodiversity

**Medium-Risk Ecological Problems**
- Acid deposition
- Pesticides
- Airborne toxic chemicals
- Toxic chemicals, nutrients, and sediment in surface waters

**Low-Risk Ecological Problems**
- Oil spills
- Groundwater pollution
- Radioactive isotopes
- Acid runoff to surface waters
- Thermal pollution

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**Figure 17-17** *Science*; comparative risk analysis of the most serious ecological and health problems, according to scientists acting as advisers to the EPA. Risks under each category are not listed in rank order. **Question:** Which two risks in each of the two high-risk problem lists do you think are the most serious? Why? (Concept 17-5) (Data from Science Advisory Board, *Reducing Risks*, Washington, D.C.: Environmental Protection Agency, 1990)

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**Figure 17-18** Global outlook: number of deaths per year in the world from various causes (Concept 17-5). Numbers in parentheses give these deaths in terms of the number of fully loaded 200-passenger jet airplanes crashing every day of the year with no survivors. Because of sensational media coverage, most people are misinformed about the largest annual causes of death. **Question:** Which three of these items are most likely to shorten your life span? (Data from World Health Organization)

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**Cause of death**

<table>
<thead>
<tr>
<th>Annual deaths</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poverty/malnutrition/disease cycle</td>
<td>11 million (150)</td>
</tr>
<tr>
<td>Tobacco</td>
<td>5.4 million (74)</td>
</tr>
<tr>
<td>Pneumonia and flu</td>
<td>3.2 million (44)</td>
</tr>
<tr>
<td>Air pollution</td>
<td>3 million (41)</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>2.1 million (29)</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>1.9 million (26)</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>1.7 million (23)</td>
</tr>
<tr>
<td>Automobile accidents</td>
<td>1.2 million (16)</td>
</tr>
<tr>
<td>Work-related injury and disease</td>
<td>1.1 million (15)</td>
</tr>
<tr>
<td>Malaria</td>
<td>1 million (14)</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>1 million (14)</td>
</tr>
<tr>
<td>Measles</td>
<td>800,000 (11)</td>
</tr>
</tbody>
</table>
Poverty hazard shortens average life span in the United States by 7–10 years.

- Born male - 7.5 years
- Smoking - 6–10 years
- Overweight (35%) - 6 years
- Unmarried - 5 years
- Overweight (15%) - 2 years
- Spouse smoking - 1 year
- Driving - 7 months
- Air pollution - 5 months
- Alcohol - 5 months
- Drug abuse - 4 months
- Flu - 4 months
- AIDS - 3 months
- Drowning - 1 month
- Pesticides - 1 month
- Fire - 1 month
- Natural radiation - 8 days
- Medical X rays - 5 days
- Oral contraceptives - 5 days
- Toxic waste - 4 days
- Flying - 1 day
- Hurricanes, tornadoes - 1 day
- Living lifetime near nuclear plant - 10 hours

Figure 17-19 Global outlook: Comparison of risks people face, expressed in terms of shorter average life span (Concept 17-5). Excepting poverty and gender, the greatest risks people face come mostly from the lifestyle choices they make. These are merely generalized relative estimates. Individual responses to these risks differ because of factors such as genetic variation, family medical history, emotional makeup, stress, and social ties and support. Question: Which three of these factors are most likely to shorten your life span? (Data from Bernard L. Cohen)

**Case Study: Death from Smoking**

What is roughly the diameter of a 30-caliber bullet, can be bought almost anywhere, is highly addictive, and kills an average of about 14,800 people every day, or about one every 6 seconds? It is a cigarette. *Cigarette smoking is the world’s most preventable major cause of suffering and premature death among adults.*

In 2007, the WHO estimated that tobacco use helped to kill 100 million people prematurely during the 20th century and could kill 1 billion people during this century unless governments act now to dramatically reduce smoking. The WHO estimates that each year, tobacco contributes to the premature deaths of at least 5.4 million people (about half from developed and half from developing countries) from 25 illnesses including heart disease, lung cancer, other cancers, bronchitis, emphysema, and stroke. By 2030, the annual death toll from smoking-related diseases is projected to reach more than 8 million—an average of 21,900 preventable deaths per day. About 80% of these deaths are expected to occur in developing countries, especially China, with 30% of the world’s smokers, and India with 11% (compared to 4.5% in the United States).

According to the CDC, smoking kills about 442,000 Americans per year prematurely—an average of 1,210 deaths per day, or nearly one every minute (Figure 17-20). This death toll is roughly equivalent to six fully loaded 200-passenger jet planes crashing every day with no survivors! Yet, this ongoing major human tragedy in the United States and throughout the world rarely makes the news.

The overwhelming consensus in the scientific community is that the nicotine inhaled in tobacco smoke is highly addictive. Only one in ten people who try to
quit smoking succeeds. Smokers suffer about the same relapse rate as do recovering alcoholics and those addicted to heroin or crack cocaine. A British government study showed that adolescents who smoke more than one cigarette have an 85% chance of becoming smokers.

*Passive smoking,* or breathing secondhand smoke, also poses health hazards for children and adults. Children who grow up with smokers are more likely to develop allergies and asthma. Among adults, nonsmoking spouses of smokers have a 30% higher risk of both heart attack and lung cancer than do spouses of nonsmokers. In 2006, the CDC estimated that each year, secondhand smoke causes an estimated 3,000 lung cancer deaths and 46,000 deaths from heart disease in the United States.

A 50-year study published in 2004 by Richard Doll and Richard Peto found that cigarette smokers die, on average, 10 years earlier than nonsmokers, but that kicking the habit—even at 50 years old—can cut a person’s risk in half. If people quit smoking by the age of 30, they can avoid nearly all the risk of dying prematurely, but again, the longer one smokes, the harder it is to quit.

Many health experts urge that a $3–5 federal tax be added to the price of a pack of cigarettes in the United States (and in other countries). Then users of tobacco products—not the rest of society—would pay a much greater share of the $158 billion per year (an average of $301,000 per minute) in health, economic, and social costs associated with smoking in the United States.

Analysts also call for classifying and regulating nicotine as an addictive and dangerous drug under the U.S. Food and Drug Administration, eliminating all federal subsidies and tax breaks to tobacco farmers and tobacco companies, and using cigarette tax revenues to finance an aggressive antitobacco adver-

![Figure 17-20](image)

**Figure 17-20** Annual deaths in the United States from tobacco use and other causes in 2004. Smoking is by far the nation’s leading cause of preventable death, causing more premature deaths each year than all the other categories in this figure combined. (Data from U.S. National Center for Health Statistics, the Centers for Disease Control and Prevention, and the U.S. Surgeon General)

Estimating Risks from Technologies Is Not Easy

The more complex a technological system and the more people needed to design and run it, the more difficult it is to estimate the risks of using the system. The system’s overall *reliability,* or the probability (expressed as a percentage) that a person or device will complete a task without failing, is the product of two factors:

\[
\text{System reliability (%) = Technological reliability \times Human reliability}
\]

With careful design, quality control, maintenance, and monitoring, a highly complex system such as a nuclear power plant or space shuttle can achieve a high degree of technological reliability. But human reliability usually is much lower than technological reliability and is almost impossible to predict: To err is human.

Suppose the technological reliability of a nuclear power plant is 95% (0.95) and human reliability is 75% (0.75). Then the overall system reliability is 71% (0.95 \times 0.75 = 0.71). Even if we could make the technology 100% reliable (1.0), the overall system reliability would still be only 75% (1.0 \times 0.75 = 0.75%). The crucial dependence of even the most carefully designed systems on unpredictable human reliability helps to
explain tragedies that were deemed almost impossible, such as the Chernobyl nuclear power plant explosion (Case Study, p. 390), the Three Mile Island nuclear power accident (Case Study, p. 390), and the Challenger and Columbia space shuttle accidents.

One way to make a system more foolproof is to move more of the potentially fallible elements from the human side to the technological side. However, chance events such as a lightning strike can knock out an automatic control system, and no machine or computer program can completely replace human judgment. Also, the parts in any automated control system are manufactured, assembled, tested, certified, and maintained by fallible human beings. In addition, computer software programs used to monitor and control complex systems can be flawed because of human error or can be deliberately caused to malfunction.

Most People Do Not Know How to Evaluate Risks

Most of us are not good at assessing the relative risks from the hazards that surround us. Many people deny or shrug off the high-risk chances of death (or injury) from voluntary activities they enjoy, such as motorcycling (1 death in 50 participants), smoking (1 in 250 by age 70 for a pack-a-day smoker), hang gliding (1 in 1,250), and driving (1 in 3,300 without a seatbelt and 1 in 6,070 with a seatbelt). Indeed, the most dangerous thing that most people in many countries do each day is to drive or ride in a car.

Yet some of these same people may be terrified about the possibility of being killed by a gun (1 in 28,000 in the United States), flu (1 in 130,000), nuclear power plant accident (1 in 200,000), West Nile virus (1 in 1 million), lightning (1 in 3 million), commercial airplane crash (1 in 9 million), snakebite (1 in 36 million), or shark attack (1 in 281 million).

Five factors can cause people to see a technology or a product as being more or less risky than experts judge it to be. First is fear. Research going back 3 decades shows that fear causes people to overestimate risks and to worry more about unusual risks than they do about common everyday risks. Studies show that people tend to overestimate the numbers of deaths caused by tornadoes, floods, fires, homicides, cancer, and terrorist attacks, and to underestimate numbers of deaths from flu, diabetes, asthma, stroke, and automobile accidents. Many people also fear a new, unknown product or technology more than they do an older, more familiar one. For example, some people fear genetically modified food and trust food produced by traditional plant-breeding techniques. Most people have a greater fear of nuclear power plants than of more familiar and highly polluting coal-fired power plants (Figure 15-22, p. 392).

A second factor is the degree of control we have. Most of us have a greater fear of things over which we do not have personal control. For example, some individuals feel safer driving their own cars over long distances and through bad traffic than they do traveling the same distance on a plane. But look at the numbers. The risk of dying in a car accident in the United States while using a seatbelt is 1 in 6,070 whereas the risk of dying in a commercial airliner crash is 1 in 9 million.

Third is whether a risk is catastrophic, not chronic. We usually are more frightened by news of a single catastrophic accident such as a plane crash than we are of a cause of death such as smoking, which has an even larger death toll spread out over time.

Fourth, some people suffer from optimism bias, the belief that risks that apply to other people do not apply to them. Some people get upset when they see someone driving erratically while talking on a cell phone. But they may believe that their own talking on the cell phone does not impair their driving ability.

A fifth factor is that many of the risky things we do are highly pleasurable and give instant gratification, while the potential harm from such activities comes later. Examples are smoking cigarettes, eating lots of ice cream, and getting a tan.

There is also concern about the unfair distribution of risks in some cases. For example, citizens are often outraged when government officials decide to put a hazardous waste landfill or incinerator in or near their neighborhood. Even when the decision is based on careful risk analysis, it is usually seen as a political, not a scientific, decision. Residents will not be satisfied by an estimate putting the lifetime risk of cancer death from the facility at no greater than, say, 1 in 100,000. Instead, they point out that living near the facility means that they will have a much higher risk of dying from cancer than will people living farther away.

Several Principles Can Help Us to Evaluate and Reduce Risk

Here are some guidelines for evaluating and reducing risk (Concept 17-5):

- Compare risks. Is there a risk of getting cancer from eating a charcoal-broiled steak once or twice a week for a lifetime? Yes, because in theory, anything can harm you. The question is whether this danger is great enough for you to worry about. In evaluating a risk, the question is not “Is it safe?” but rather “How risky is it compared to other risks?”

- Determine how much risk you are willing to accept. For most people, a 1 in 100,000 chance of dying or suffering serious harm from exposure to an environmental hazard is a threshold for changing their behavior. However, in establishing standards and reducing risk, the U.S. EPA generally assumes that a 1 in 1 million chance of dying from an environmental hazard is acceptable. People
The burden of proof imposed on individuals, companies, and institutions should be to show that pollution prevention options have been thoroughly examined, evaluated, and used before lesser options are chosen.

JOEL HIRSCHORN

REVIEW

1. Review the Key Questions and Concepts for this chapter on p. 439. Describe how an HIV/AIDS epidemic (Core Case Study) in a country can affect the age structure of its population.

2. Distinguish among risk, risk assessment, and risk management. Distinguish between possibility and probability. What is a pathogen? Give an example of a risk from each of the following: biological hazards, chemical hazards, physical hazards, cultural hazards, and lifestyle choices.

3. Distinguish among a nontransmissible disease, infectious disease, and transmissible disease and give an example of each. In terms of death rates, what are the world’s four most serious infectious diseases? Distinguish between an epidemic and a pandemic of an infectious disease. Describe the causes and possible solutions for the increasing genetic resistance in microbes to commonly used antibiotics.

4. Describe the global threat from tuberculosis. Describe the threat from flu and the effects of a global flu pandemic. Describe the health threats from the global HIV/AIDS pandemic and list six ways to reduce this threat. Describe the threats from the hepatitis B, West Nile, and SARS viruses. Describe the threat from malaria for 40% of the world’s people and how we can reduce this threat.

AIDS and Sustainability

In this chapter, we have seen that on a global basis, the greatest threat to human health is the tragic poverty-malnutrition-disease cycle, followed by the threats from smoking, pneumonia and flu, air pollution, and HIV/AIDS (Core Case Study). These five global threats prematurely kill about 24.7 million people a year (Figure 17-18)—an average of nearly 67,700 a day or 2,820 an hour—half of them children younger than age 5.

These major global health risks are largely preventable if governments, under pressure from concerned citizens, choose to make them global priorities. We can use the four scientific principles of sustainability (see back cover) to help us reduce these and other major risks to human health. One way to do this involves shifting from nonrenewable fossil fuels to renewable energy, thereby reducing pollution and the threats from global warming. Another solution is to cut down on waste of energy and matter resources by reusing and recycling them, thereby helping to provide enough resources for most people to avoid poverty. We can also emphasize the use of diverse strategies for solving environmental and health problems, and especially for reducing poverty and controlling population growth.

Is this idealistic? Sure. But if creative and caring people throughout human history had not acted to improve the world by doing things that others said were impossible or too idealistic, we would have accomplished very little on this marvelous planet. Each of us can make a difference.
5. Give three examples of problems being studied in the new field of ecological medicine. What is Lyme disease, and how can individuals reduce their chances of getting it? List five major ways to reduce the global threat from infectious diseases.

6. What is a toxic chemical? Discuss the threat from PCBs. Distinguish among mutagens, teratogens, and carcinogens, and give an example of each. Describe the toxic legacy from PCBs. Describe the human immune, nervous, and endocrine systems and give an example of a chemical that can threaten each of these systems. Describe the toxic effects of the various forms of mercury and ways to reduce these threats. What are hormonally active agents, what risks do they pose, and how can we reduce these risks? Describe the potential threats from bisphenol A.

7. Define toxicology, toxicity, dose, and response. Give three reasons why children are more vulnerable to harm from toxic chemicals. Describe how the toxicity of a substance can be estimated by using laboratory animals, and discuss the limitations of this approach. What is a dose-response curve? Describe how toxicities are estimated by case reports and epidemiological studies and discuss the limitations of these approaches. Why do we know so little about the harmful effects of chemicals? Discuss the use of pollution prevention and the precautionary principle in dealing with health threats from chemicals.

8. What is risk analysis? In terms of premature deaths, what are the three greatest threats that humans face? Describe the health threats from smoking and what can be done to reduce these threats.

9. How can we reduce the threats from the use of various technologies? What five factors can cause people to misjudge risks? List five principles that can help us evaluate and reduce risk.

10. Discuss how lessening the threats of HIV/AIDS and other major infectious diseases (Core Case Study) can be achieved by applying the four scientific principles of sustainability.

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**CRITICAL THINKING**

1. List three ways in which you could apply Concept 17-5 to make your lifestyle more environmentally sustainable while reducing the major risks you face.

2. How can changes in the age structure of a human population increase the spread of infectious diseases? How can the spread of infectious diseases such as HIV/AIDS affect the age structure of human populations (Core Case Study and Figure 17-2)?

3. What are three actions you would take to reduce the global threats to human health and life from (a) HIV/AIDS (Core Case Study), (b) tuberculosis, and (c) malaria?

4. Evaluate the following statements:
   a. We should not get worked up about exposure to toxic chemicals because almost any chemical, at a large enough dosage, can cause some harm.
   b. We should not worry much about exposure to toxic chemicals because, through genetic adaptation, we can develop immunity to such chemicals.
   c. We should not worry much about exposure to toxic chemicals because we can use genetic engineering to reduce our susceptibility to the effects of toxic chemicals.

5. Workers in a number of industries are exposed to higher levels of various toxic substances than are the general public. Should workplace levels allowed for such chemicals be reduced? What economic effects might this have?

6. Explain why you agree or disagree with the proposals for reducing the death toll and other harmful effects of smoking listed in the Case Study on p. 462. Do you believe there should be a ban on smoking indoors in all public places? Explain.

7. What are the three major risks you face from (a) your lifestyle, (b) where you live, and (c) what you do for a living? Which of these risks are voluntary and which are involuntary? List the three most important things you can do to reduce these risks. Which of these things do you plan to do?

8. Would you support legislation requiring the use of pollution prevention based on the precautionary principle in deciding what to do about risks from chemicals in the country where you live? Explain.

9. Congratulations! You are in charge of the world. List the three most important features of your program to reduce the risks from exposure to (a) infectious disease organisms and (b) toxic and hazardous chemicals.

10. List two questions that you would like to have answered as a result of reading this chapter.

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**Note:** Key Terms are in **bold** type.
The graph below shows the effects of AIDS on life expectancy at birth in Botswana from 1950 through 2000 and projects the effects to 2050. Answer the questions below.

1. **a.** By what percentage did life expectancy in Botswana increase between 1950 and 1995?
   **b.** By what percentage is life expectancy in Botswana projected to decrease between 1995 and 2015?

2. **a.** By what percentage is life expectancy in Botswana projected to increase between 2015 and 2050?
   **b.** By what percentage is life expectancy in Botswana projected to decrease between 1995 and 2050?

**LEARNING ONLINE**

Log on to the Student Companion Site for this book at academic.cengage.com/biology/miller, and choose Chapter 17 for many study aids and ideas for further reading and research. These include flash cards, practice quizzing, Weblinks, information on Green Careers, and InfoTrac® College Edition articles.

Source: Data from United Nations and U.S. Census Bureau
Question 1 refers to the projection of the Botswana population in 2020 shown below.

1. What percent of the people aged 20–29 years will be lost if they die from AIDS?
   (A) 0.36
   (B) 0.64
   (C) 36
   (D) 64
   (E) 76

2. Which of the events below is NOT one of the social ramifications of HIV infection and the resulting death of young adults?
   (A) Decreasing orphanage rates
   (B) Diminishing education
   (C) Diminishing healthcare
   (D) Decreased food production
   (E) Disintegrating families

3. Which of the factors below is a part of risk assessment?
   (A) Comparative risk analysis
   (B) Determining financial commitment
   (C) Assessing the probability of risk
   (D) Risk reduction strategy
   (E) Quantity of risk reduction needed

4. Which of the diseases below is incorrectly paired with its type of organism?
   (A) Virus–HIV
   (B) Bacteria–Severe Acute Respiratory Syndrome (SARS)
   (C) Fungi–Ringworm
   (D) Protozoan–Malaria
   (E) Prion–Creutzfeldt-Jacob Disease (Mad Cow)

5. A United Nations risk management training program reported that the risk of accidental death from playing field sports is 1 in 25,000. This means that
   (A) one out of every 25,000 people who play field sports will die from an accidental death.
   (B) people who play field sports are at equal risk of accidental death.
   (C) one out of every 25,000 people will likely die from accidental death while playing field sports.
   (D) there is a very low possibility that one who plays field sports will die from an accidental death.
   (E) accidental deaths from playing field sports are uncommon.

Questions 6 and 7 refer to the three types of chemical hazards shown below.

I. Carcinogens
II. Mutagens
III. Teratogens

6. PCBs that can cause cancer and birth defects are classified as
   (A) I only.
   (B) II only.
   (C) III only.
   (D) I and II only.
   (E) II and III only.

7. Ethyl alcohol can cause birth defects and is classified as
   (A) I only.
   (B) II only.
   (C) III only.
   (D) I and II only.
   (E) II and III only.

8. Which of the activities below is NOT a factor in the spread of infectious diseases to humans from other animals?
   (A) Clearing of forests
   (B) Expanding suburbs and fragmentation of woodlands
   (C) Limits put on the international trade of livestock animals
   (D) Legal and illegal trade in wild species
   (E) Local people utilizing monkeys and other animals for bush meat
9. One of the largest threats of infectious disease to humans next to HIV and malaria is the spread of tuberculosis (TB). This is due primarily to
   (A) the overuse of antibiotics treating people infected with TB.
   (B) increased urbanization coupled with too few screening and control programs.
   (C) identifying people with chronic coughs that may be active carriers.
   (D) quarantining people who have an incurable form of TB.
   (E) utilizing viruses as transmission vectors for gene therapy.

10. One reason that mercury (Hg) is so persistent and bioaccumulates without being broken down is that Hg is a
    (A) potent carcinogen.
    (B) radioactive element.
    (C) pervasive compound.
    (D) common molecule.
    (E) stable element.

11. A major limitation of epidemiological studies used to determine the harmful effects of chemicals is that
    (A) people have not been exposed to new technologies or chemicals.
    (B) computer simulations are not always accurate for living processes.
    (C) threshold dosages are frequently difficult to determine.
    (D) the toxicity of single substances is often difficult to sort out from multiple sources.
    (E) actual dosages from case reports are frequently unknown.

12. The LD50 of a drug or compound
    (A) depends on how much of the drug is required for biological activity.
    (B) is based on the number of days it takes to kill the test subjects.
    (C) utilizes the response times of individual cells in petri dishes to determine lethal doses.
    (D) is based on computer modeling of simulated cell responses.
    (E) is the dose that can kill 50% of the animals in a test population.