ENVIRONMENTAL HEALTH

What is health? The WHO defines **health** as a state of complete physical, mental, and social well-being, not merely the absence of disease or infirmity. By that definition, we all are ill to some extent. Likewise, we all can improve our health to live happier, longer, more productive, and more satisfying lives if we think about what we do.

What is disease? A **disease** is an abnormal change in the body's condition that impairs important physical or psychological functions. Diet and nutrition, infectious agents, toxic substances, genetics, trauma, and stress all play roles in **morbidity** (illness) and **mortality** (death). **Environmental health** focuses on external factors that cause disease, including elements of the natural, social, cultural, and technological worlds in which we live.

Figure 8.2 shows some major environmental disease agents as well as the media through which we encounter them. Ever since the publication of Rachel Carson's *Silent Spring* in 1962, the discharge, movement, fate, and effects of synthetic chemical toxins have been a special focus of environmental health. Later in this chapter, we'll study these topics in detail. First, however, let's look at some of the major causes of illness worldwide.

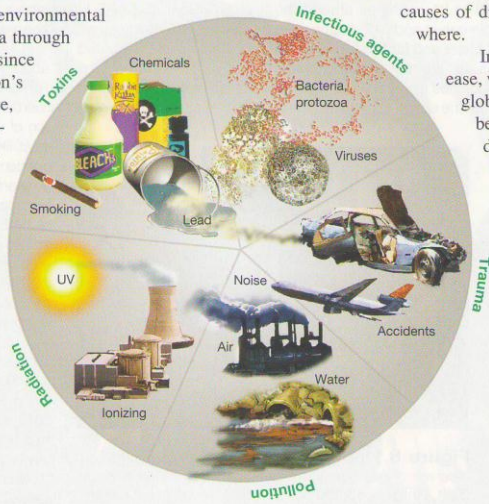

Figure 8.2 Major sources of environmental health risks.

The global disease burden is changing

In the past, health organizations have focused on the leading causes of death as the best summary of world health. Mortality data, however, fail to capture the impacts of nonfatal outcomes of disease and injury, such as dementia or blindness, on human well-being. When people are ill, work isn't done, crops aren't planted or harvested, meals aren't cooked, and children can't study and learn. Health agencies now calculate **disability-adjusted life years (DALYs)** as a measure of disease burden. DALYs combine premature deaths and loss of a healthy life resulting from illness or disability. This is an attempt to evaluate the total cost of disease, not simply how many people die. Clearly, many more years of expected life are lost when a child dies of neonatal tetanus than when an 80-year-old dies of pneumonia. Similarly, a teenager permanently paralyzed by a traffic accident will have many more years of suffering and lost potential than will a senior citizen who has a stroke. According to the WHO, chronic diseases now account for nearly 60 percent of the 56.5 million total deaths worldwide each year and about half of the global d ease burden.

The world is now undergoing a dramatic epidemiologi transition. Chronic conditions, such as cardiovascular disease a cancer, no longer afflict only wealthy people. Marvelous progr in eliminating communicable diseases, such as smallpox, pol and malaria, is allowing people nearly everywhere to live long As chapter 7 points out, over the past century the average l expectancy worldwide has risen by about two-thirds. In some poo countries, like India, life expectancies nearly tripled in the twer eth century. Although the traditional killers in developing cou tries—infections, maternal and perinatal (birth) complicatio and nutritional deficiencies—still take a terrible toll, diseases su as depression and heart attacks that once were thought to occ only in rich countries are rapidly becoming the leadi causes of disability and premature death eve where.

In 2020, the WHO predicts heart d ease, which was fifth in the list of causes global disease burden a decade ago, w be the leading source of disability a deaths worldwide (table 8.1). Most that increase will be in the poo parts of the world where people rapidly adopting the lifestyles a diet of the richer countries. Sir larly, global cancer rates w increase by 50 percent. By 20 it's expected that 15 million pe ple will have cancer and 9 milli will die from it.

Ask American women wh disease they're most afraid and a majority will probably a swer breast cancer. What ma don't realize is that cardiovasc lar disease is the leading cause death among U.S. women. Wh focusing on the 40,000 wom who die each year from bre cancer we aren't aware of t 500,000 who die in that same time from heart attacks and strok For reasons we don't fully understand, women are far more like than men to be disabled or die as a result of heart attack or strok Forty-six percent of women are seriously disabled by their fi heart attack, for instance, compared to only 22 percent of m Smoking, diabetes, high blood pressure, high cholesterol, exc weight, and lack of physical activity increase cardiovascular d ease risks in both women and men, but women are less likely th men to be aware of the importance of these health factors.

Taking disability as well as death into account in our a sessment of disease burden reveals the increasing role of me tal health as a worldwide problem. WHO projections sugg that psychiatric and neurological conditions could increa

TABLE 8.1

Leading Causes of Global Disease Burden

Rank	1990	Rank	2020
1	Pneumonia	1	Heart disease
2	Diarrhea	2	Depression
3	Perinatal conditions	3	Traffic accidents
4	Depression	4	Stroke
5	Heart disease	5	Chronic lung disease
6	Stroke	6	Pneumonia
7	Tuberculosis	7	Tuberculosis
8	Measles	8	War
9	Traffic accidents	9	Diarrhea
10	Birth defects	10	HIV/AIDS
11	Chronic lung disease	11	Perinatal conditions
12	Malaria	12	Violence
13	Falls	13	Birth defects
14	Iron anemia	14	Self-inflicted injuries
15	Malnutrition	15	Respiratory cancer

Source: World Health Organization, 2002.

their share of the global burden from 10 percent currently to 15 percent of the total load by 2020. Again, this isn't just a problem of the developed world. Depression is expected to be the second largest cause of all years lived with disability worldwide, as well as the cause of 1.4 percent of all deaths. For women in both developing and developed regions, depression is the leading cause of disease burden, while suicide, which often is the result of untreated depression, is the fourth largest cause of female deaths.

Notice in table 8.1 that diarrhea, which was the second leading cause of disease burden in 1990, is expected to be ninth on the list in 2020, while measles and malaria are expected to drop out of the top 15 causes of disability. Tuberculosis, which is becoming resistant to antibiotics and is spreading rapidly in many areas (especially in the former Soviet Union), is the only infectious disease whose ranking is not expected to change over the next 20 years. Traffic accidents are now soaring as more people drive. War, violence, and self-inflicted injuries similarly are becoming much more important health risks than ever before.

Chronic obstructive lung diseases (e.g., emphysema, asthma, and lung cancer) are expected to increase from eleventh to fifth in disease burden by 2020. A large part of the increase is due to rising use of tobacco in developing countries, sometimes called "the tobacco epidemic." Every day about 100,000 young people—most of them in poorer countries—become addicted to tobacco. At least 1.1 billion people now smoke, and this number is expected to increase at least 50 percent by 2020. If current patterns persist, about 500 million people alive today will eventually be killed by

Figure 8.3 At least 3 million children die every year from easily preventable diseases. This billboard in Guatemala encourages parents to have their children vaccinated against polio, diphtheria, TB, tetanus, pertussis (whooping cough), and scarlet fever.

tobacco. This is expected to be the biggest single cause of death worldwide (because illnesses such as heart attack and depression are triggered by multiple factors). In 2003, the World Health Assembly adopted a historic tobacco-control convention that requires countries to impose restrictions on tobacco advertising, establish clean indoor air controls, and clamp down on tobacco smuggling. Dr. Gro Harlem Brundtland, former director-general of the WHO, predicted that the convention, if passed, could save billions of lives.

Think About It

What changes could you make in your lifestyle to lessen your risks from the diseases in table 8.1? What would have the greatest impact on your future well-being?

Infectious diseases are still important threats

Although the ills of modern life have become the leading killers almost everywhere in the world, communicable diseases still are responsible for about one-third of all disease-related mortality. Diarrhea, acute respiratory illnesses, malaria, measles, tetanus, and a few other infectious diseases kill about 11 million children under age five every year in the developing world. Better nutrition, clean water, improved sanitation, and inexpensive inoculations could eliminate most of those deaths (fig. 8.3).

A wide variety of **pathogens** (disease-causing organisms) afflict humans including viruses, bacteria, protozoans (single-celled

endangered by mass social instability, the spread of pathogens across borders, and the spread of other ills such as terrorism and drug trafficking caused by social problems. Sachs also argues that reducing disease burden would help reduce population growth. When parents believe their offspring will survive, they have fewer children and invest more in food, health, and education for smaller families.

The United States is the least generous of the world's rich countries, donating only about 12 cents per $100 of GDP on international development aid. Could the U.S. do better? During a time of fear of terrorism and rising anti-American feelings around the globe, it's difficult to interest legislators in international aid, and yet, helping to reduce disease might win the United States more friends and make the nation safer than buying more bombs and bullets. Improved health care in poorer countries may also help prevent the spread of emergent diseases like SARS in a globally interconnected world.

At the 2003 meeting of the Global Health Council, epidemiologists noted that almost all of the 2.2 billion people expected to be added to the world population in the next 30 years will live in megacities of the developing world. The economic and environmental conditions in those cities will have a profound impact on global disease burden. Madagascar President Marc Ravalomanana urged conference attendees—and the world—to address the "lethal disease of poverty." More discussion of urban areas and their problems is presented in chapter 22.

Think About It

If you were making a case for greater U.S. funding for international health care, what points would you stress? Do we have a moral obligation to help others?

TOXICOLOGY

Toxicology is the study of **toxins** (poisons) and their effects, particularly on living systems. Because many substances are known to be poisonous to life (whether plant, animal, or microbial), toxicology is a broad field, drawing from biochemistry, histology, pharmacology, pathology, and many other disciplines. Toxins damage or kill living organisms because they react with cellular components to disrupt metabolic functions. Because of this reactivity, toxins often are harmful even in extremely dilute concentrations. In some cases billionths, or even trillionths of a gram can cause irreversible damage.

All toxins are hazardous, but not all hazardous materials are toxic. Some substances, for example, are dangerous because they're flammable, explosive, acidic, caustic, irritants, or sensitizers. Many of these materials must be handled carefully in large doses or high concentrations, but can be rendered relatively innocuous by dilution, neutralization, or other physical treatment. They don't react with cellular components in ways that make them poisonous at low concentrations.

Environmental toxicology or ecotoxicology specifically deals with the interactions, transformation, fate, and effects of natural and synthetic chemicals in the biosphere including individual

TABLE 8.2

Top 20 Toxic and Hazardous Substances

1. Arsenic
2. Lead
3. Mercury
4. Vinyl Chloride
5. Polychlorinated Biphenyls (PCBs)
6. Benzene
7. Cadmium
8. Benzo(a)pyrene
9. Polycyclic aromatic hydrocarbons
10. Benzo(b)fluoranthene
11. Chloroform
12. DDT
13. Aroclor 1254
14. Aroclor 1260
15. Trichloroethylene
16. Dibenz(a,h)anthracene
17. Dieldrin
18. Chromium, Hexavalent
19. Chlordane
20. Hexachlorobutadiene

Source: U.S. EPA, 2003.

organisms, populations, and whole ecosystems. In aquatic s
tems the fate of the pollutants is primarily studied in relatio
mechanisms and processes at interfaces of the ecosystem com
nents. Special attention is devoted to the sediment/water, wa
organisms, and water/air interfaces. In terrestrial environments,
emphasis tends to be on effects of metals on soil fauna commu
and population characteristics.

Table 8.2 lists the top 20 toxins compiled by the U.S. Env
mental Protection Agency from the 275 substances regulated
the Comprehensive Environmental Response, Compensation,
Liability Act (CERCLA), commonly known as the Superfund
These materials are listed in order of assessed importance in te
of human and environmental health.

How do toxins affect us?

Allergens are substances that activate the immune system. So
allergens act directly as **antigens;** that is, they are recognize
foreign by white blood cells and stimulate the production of s
cific antibodies (proteins that recognize and bind to foreign cell
chemicals). Other allergens act indirectly by binding to and cha
ing the chemistry of foreign materials so they become antige
and cause an immune response.

Formaldehyde is a good example of a widely used chem
that is a powerful sensitizer of the immune system. It is dire

allergenic and can also trigger reactions to other substances. Widely used in plastics, wood products, insulation, glue, and fabrics, formaldehyde concentrations in indoor air can be thousands of times higher than in normal outdoor air. Some people suffer from what is called **sick building syndrome:** headaches, allergies, chronic fatigue, and other symptoms caused by poorly vented indoor air contaminated by mold spores, carbon monoxide, nitrogen oxides, formaldehyde, and other toxins released from carpets, insulation, plastics, building materials, and other sources (fig. 8.10). The Environmental Protection Agency estimates that poor indoor air quality may cost the nation $60 billion a year in absenteeism and reduced productivity.

Immune system depressants are pollutants that suppress the immune system rather than activate it. Little is known about how this occurs or which chemicals are responsible. Immune system failure is thought to have played a role, however, in widespread deaths of seals in the North Atlantic and of dolphins in the Mediterranean. These dead animals generally contain high levels of pesticide residues, polychlorinated biphenyls (PCBs), and other contaminants that are suspected of disrupting the immune system and making it susceptible to a variety of opportunistic infections.

Endocrine disrupters are chemicals that disrupt normal hormone functions. Hormones are chemicals released into the blood stream by cells in one part of the body to regulate development and function of tissues and organs elsewhere in the body (fig. 8.11). You undoubtedly have heard about sex hormones and their powerful effects on how we look and behave, but these are only one example of the many regulatory hormones that rule our lives. Some other powerful hormones include thyroxin, insulin, adrenalin, and endorphins.

We now know that some of the most insidious effects of persistent chemicals such as dioxins and PCBs are that they interfere with normal growth, development, and physiology of a variety of animals—including humans—at very low doses. In some cases, picogram concentrations (trillionths of a gram per liter) may be enough to cause developmental abnormalities in sensitive organisms. Because these

Figure 8.10 Some sources of toxic and hazardous substances in a typical home.

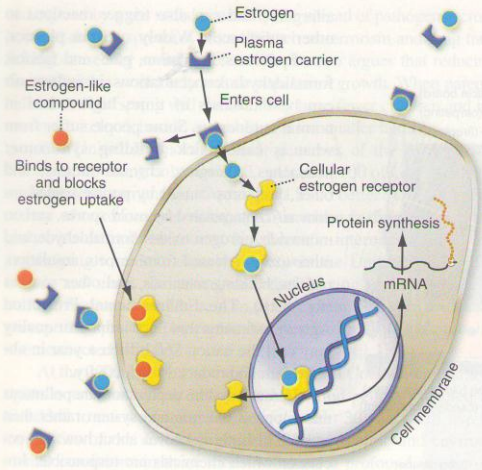

Figure 8.11 Steroid hormone action. Plasma hormone carriers deliver regulatory molecules to the cell surface, where they cross the cell membrane. Intracellular carriers deliver hormones to the nucleus, where they bind to and regulate expression of DNA. Estrogen-like compounds bind to receptors and either block uptake of endogenous hormone, or act as a substitute hormone to disrupt gene expression.

chemicals often cause sexual dysfunction (reproductive health problems in females or feminization of males, for example), these chemicals are sometimes called environmental estrogens or androgens. They are just as likely, however, to disrupt functions of other important regulatory molecules as they are to obstruct sex hormones.

Neurotoxins are a special class of metabolic poisons that specifically attack nerve cells (neurons). The nervous system is so important in regulating body activities that disruption of its activities is especially fast-acting and devastating. Different types of neurotoxins act in different ways. Heavy metals such as lead and mercury kill nerve cells and cause permanent neurological damage. Anesthetics (ether, chloroform, halothane, etc.) and chlorinated hydrocarbons (DDT, Dieldrin, Aldrin) disrupt nerve cell membranes necessary for nerve action. Organophosphates (Malathion, Parathion) and carbamates (carbaryl, zeneb, maneb) inhibit acetylcholinesterase, an enzyme that regulates signal transmission between nerve cells and the tissues or organs they innervate (for example, muscle). Most neurotoxins are both extremely toxic and fast-acting.

Mutagens are agents, such as chemicals and radiation, that damage or alter genetic material (DNA) in cells. This can lead to birth defects if the damage occurs during embryonic or fetal growth. Later in life, genetic damage may trigger neoplastic (tumor) growth. When damage occurs in reproductive cells, the results can be passed on to future generations. Cells have repair mechanisms to detect and restore damaged genetic material, but some changes may be hidden, and the repair process itself can be flawed. It is generally accepted that there is no "safe" threshold for exposure to mutagens. Any exposure has some possibility of causing damage.

Teratogens are chemicals or other factors that specifically cause abnormalities during embryonic growth and development. Some compounds that are not otherwise harmful can cause tragic problems in these sensitive stages of life. Perhaps the most prevalent teratogen in the world is alcohol. Drinking during pregnancy can lead to **fetal alcohol syndrome**—a cluster of symptoms including craniofacial abnormalities, developmental delays, behavioral problems, and mental defects that last throughout a child's life. Even one alcoholic drink a day during pregnancy has been associated with decreased birth weight.

By some estimates, between 300,000 and 600,000 children born every year in the United States are exposed in the womb to unsafe levels of mercury. The effects are subtle, but include reduced intelligence, attention deficit, and behavioral problems. The total cost of these effects is estimated to be $8.7 billion per year.

Carcinogens are substances that cause **cancer**, invasive, out-of-control cell growth that results in malignant tumors. Cancer rates rose in most industrialized countries during the twentieth century, and cancer is now the second leading cause of death in

What Can You Do?

Tips for Staying Healthy

- Eat a balanced diet with plenty of fresh fruits, vegetables, legumes, and whole grains. Wash fruits and vegetables carefully, they may well have come from a country where pesticide and sanitation laws are lax.
- Use unsaturated oils such as olive or canola rather than hydrogenated or semisolid fats such as margarine.
- Cook meats and other foods at temperatures high enough to kill pathogens; clean utensils and cutting surfaces; store food properly.
- Wash your hands frequently. You transfer more germs from hand to mouth than any other means of transmission.
- When you have a cold or flu, don't demand antibiotics from your doctor—they aren't effective against viruses.
- If you're taking antibiotics, continue for the entire time prescribed—quitting as soon as you feel well is an ideal way to select for antibiotic-resistant germs.
- Practice safe sex.
- Don't smoke and avoid smoky places.
- If you drink, do so in moderation. Never drive when your reflexes or judgment are impaired.
- Exercise regularly: walk, swim, jog, dance, garden. Do something you enjoy that burns calories and maintains flexibility.
- Get enough sleep. Practice meditation, prayer, or some other form of stress reduction.
- Make a list of friends and family who make you feel more alive and happy. Spend time with one of them at least once a week.

States, killing more than half a million people in 2002. ...ording to the American Cancer Society, 1 in 2 males and 1 in 3 ...s in the United States will have some form of cancer in their ...time. Some authors blame this cancer increase on toxic syn... chemicals in our environment and diet. Others argue that it is ...ributable mainly to lifestyle (smoking, sunbathing, alcohol) or ...ply living longer. The U.S. EPA estimates that 200 million U.S. ...idents live in areas where the combined lifetime cancer risk ...m environmental carcinogens exceeds 1 in 100,000, or ten ...es the risk normally considered acceptable.

Case Study: Poisoning Bhopal Just after midnight on December 3, 1984, a thick, acrid, gas cloud rolled through ...quiet streets of the industrial city of Bhopal, in central India. ...the still night air, the poisonous fog crept along the ground and ...iently seeped into houses where families lay asleep on mats. Peo... awakened coughing, gasping for air, and rubbing their burning ...s. As they emerged from their houses, they joined a panicked ...wd surging through the narrow streets trying to escape the toxic ...ors. Some never made it beyond their doorstep. Others col...sed in the street and died where they lay. Hospitals overflowed ...h terrified, suffering victims, many of whom were children and ...r people.

The noxious gas blanketing the city was methylisocyanate ...MIC), a component of the pesticide Temik, which was being ...ade at the Union Carbide plant in Bhopal. Water had gotten into ...k containing about 40 tons of MIC and set off a chemical ...tion that resulted in an explosive eruption of the toxic cloud. ...trol panels that should have detected rising temperatures and ...ssures had been shut down for repairs. Safety equipment that ...s designed to neutralize or incinerate the escaping gas had ...ed. Workers blamed management for cutting corners and creat... unsafe conditions. Management blamed the staff, claiming that ...r must have been put in the tank by a disgruntled worker.

Morning revealed a horrifying sight. Human bodies, along ...h those of dogs, cats, cows, and birds, littered the streets. Whole ...ilies perished. Hardest hit was the crowded shantytown of ...prakash Ngar, which lay just outside the Union Carbide fence. ...ctly how many people were killed by the poison gas will never ...known; many corpses were disposed of in emergency mass ...ials or cremations without documentation. Amnesty Interna... estimates that at least 15,000 people died immediately, while ...,000 suffered medical problems, including chronic obstructive ...g disease, eye injuries, immune system dysfunction, nerve dam..., memory loss, cancer, miscarriages, birth defects, and im...ed mental health. Families needing medical care, but without ...adult able to work, were plunged even more deeply into poverty ...misery.

More than 20 years after this catastrophe, which was probably ...greatest industrial disaster in history, no one has been punished. ...st of the $470 million in compensation that Union Carbide paid ...the Indian government has yet to be distributed to the victims. ...Bhopal tragedy has, however, served to alert us to the environ... health effects of air pollution and the risks inherent in man...facture, storage, and use of highly toxic industrial chemicals.

TABLE 8.3

National Health Recommendations and Diet Goals

1. Balance the food you eat with physical activity to maintain or improve your weight.
2. Choose a diet with plenty of grain products, vegetables, and fruits.
3. Choose a diet low in fat, saturated fat, and cholesterol.
4. Eat a variety of foods.
5. Choose a diet moderate in salt and sodium.
6. Choose a diet moderate in sugars.
7. If you drink alcoholic beverages, do so in moderation.

Source: U.S. Department of Health and Human Services, 1995.

Diet affects health

Diet also has an important effect on health. For instance, there is a strong correlation between cardiovascular disease and the amount of salt and animal fat in one's diet.

Fruits, vegetables, whole grains, complex carbohydrates, and dietary fiber (plant cell walls) often have beneficial health effects. Certain dietary components, such as pectins; vitamins A, C, and E; substances produced in cruciferous vegetables (cabbage, broccoli, cauliflower, brussels sprouts); and selenium, which we get from plants, seem to have anticancer effects.

Eating too much food is a significant dietary health factor in developed countries and among the well-to-do everywhere. Sixty percent of all U.S. adults are now considered overweight, and the worldwide total of obese or overweight people is estimated to be over 1 billion. Every year in the United States, 300,000 deaths are linked to obesity.

The U.S. Centers for Disease Control in Atlanta warn that one in three U.S. children will become diabetic unless many more people start eating less and exercising more. The odds are worse for Black and Hispanic children: nearly half of them are likely to develop the disease. And among the Pima tribe of Arizona, nearly 80 percent of all adults are diabetic. Some goals for reducing obesity and other diet-related problems are shown in table 8.3. More information about food and its health effects is available in chapter 9.

MOVEMENT, DISTRIBUTION, AND FATE OF TOXINS

There are many sources of toxic and hazardous chemicals in the environment and many factors related to each chemical itself, its route or method of exposure, and its persistence in the environment, as well as characteristics of the target organism (table 8.4), that determine the danger of the chemical. We can think of both individuals and an ecosystem as sets of interacting compartments between which chemicals move, based on molecular size, solubility,