Human Population Numbers

Although it may seem surprising, environmental scientists do not know the human carrying capacity of Earth. However, we are able to discuss the factors that contribute to the carrying capacity of humans on Earth and what drives human population growth. We can also look at patterns of past human population growth to gain an understanding of what might occur in future decades.

Learning Objectives

After reading this module you should be able to

- explain factors that may potentially limit the carrying capacity of humans on Earth.
- describe the drivers of human population growth.
- read and interpret an age structure diagram.

Scientists disagree on Earth's carrying capacity

Every 5 days, the global human population increases by more than a million lives: 1.9 million infants are born and 800,000 people die. The human population has not always grown at this rate, however. As FIGURE 22.1 shows, until a few hundred years ago the human population was relatively stable: Deaths and births occurred in roughly equal numbers. This situation changed about 400 years ago, when agricultural output increased and sanitation began to improve. Better living conditions caused death rates to fall, but birth rates remained relatively high. This was the beginning of a period of rapid population growth that has brought us to the current human population of 7.2 billion people.

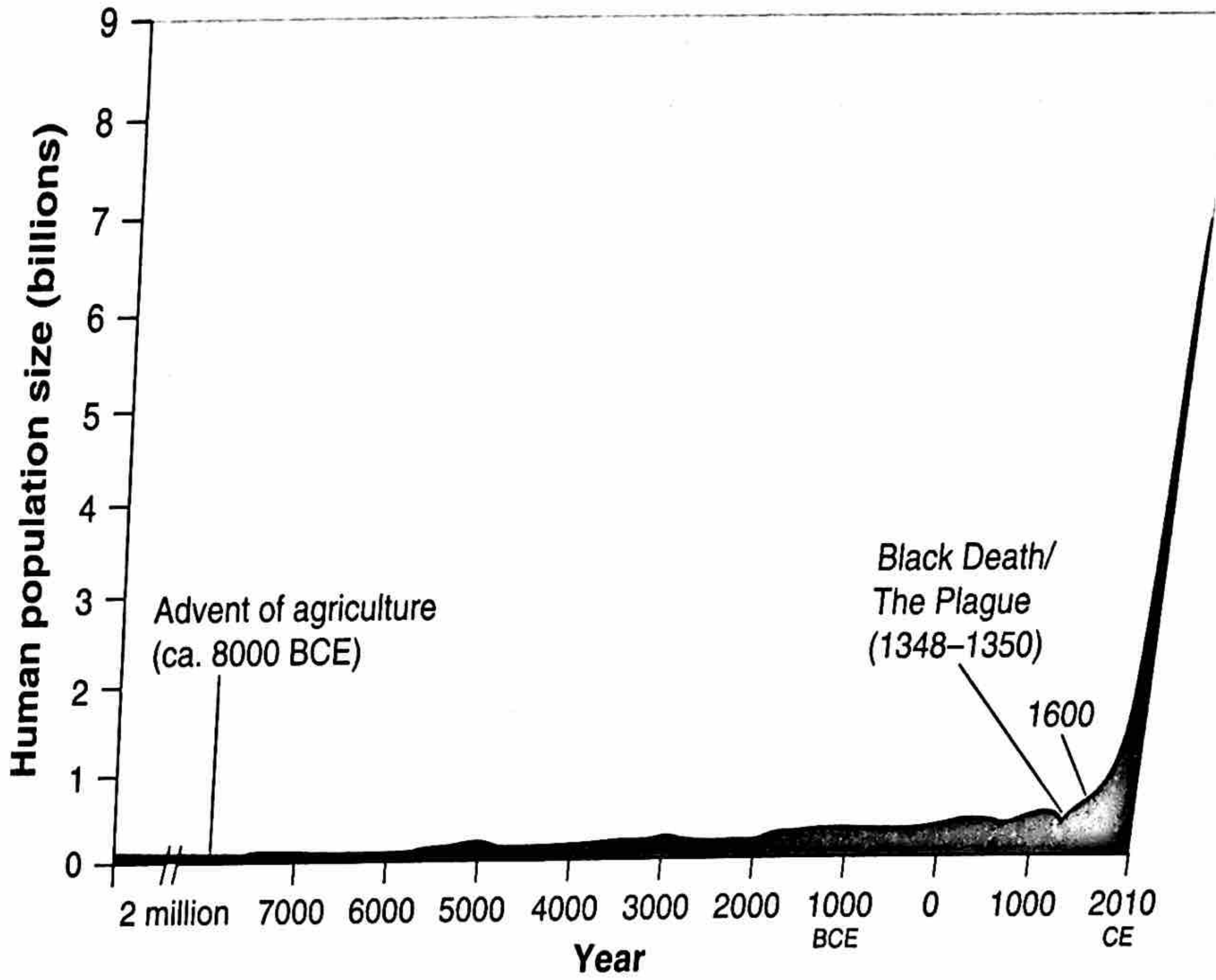

FIGURE 22.1 Human population growth. *The global human population has grown more rapidly in the last 400 years than at any other time in history.*

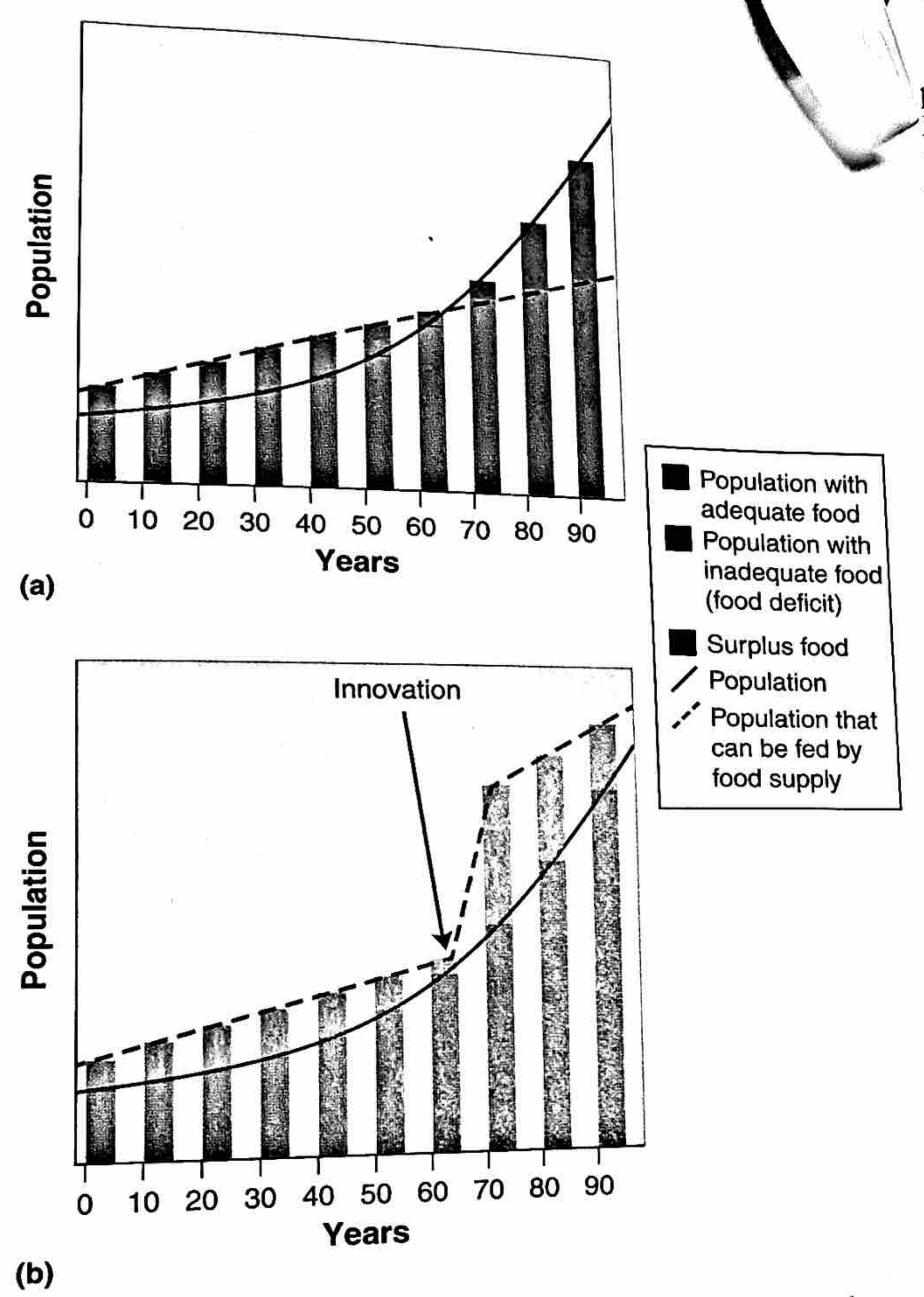

FIGURE 22.2 A theoretical model of food supply and population size. (a) In a theoretical 100-year period *without* significant improvements in agricultural technology, the human population grows exponentially, while the food supply grows linearly. Consequently, a food surplus is followed by a food deficit. (b) In a theoretical 100-year period *with* significant improvements in agricultural technology, the food supply increases suddenly. Consequently, there is a continuing food surplus.

As we saw in Chapter 6, under ideal conditions all populations grow exponentially. In most cases, exponential growth slows or stops when an environmental limit is reached. The limiting factor can be a scarcity of resources such as food or water or an increase in predators, parasites, or diseases. Limiting factors determine the carrying capacity of a habitat. Are human populations constrained by limiting factors?

Environmental scientists have differing opinions on Earth's carrying capacity for humans. Some scientists believe we have already outgrown, or eventually will outgrow, the available supply of food, water, timber, fuel, and other resources on which humans rely. One of the first proponents of the notion that the human population could exceed Earth's carrying capacity was English clergyman and professor Thomas Malthus. In 1798, Malthus observed that the human population was growing exponentially while the food supply we rely on was growing linearly. In other words, the food supply increases by a fixed amount each year, while the human population increases in proportion to its own increasing size. Malthus concluded that the human population size would eventually exceed the food supply. FIGURE 22.2a shows this projection graphically.

A number of environmental scientists today subscribe to Malthus's view that humans will eventually reach the carrying capacity of Earth, after which the rate of population growth will decline. Other scientists do not believe that Earth has a fixed carrying capacity for humans. They argue that the growing population of humans provides an increasing supply of intellect that leads to increasing amounts of innovation. Humans can alter Earth's carrying capacity by employing creativity—one of the fundamental ways in which humans differ from most other species on Earth.

For example, in the past whenever the food supply seemed small enough to limit the human population, major technological advances increased food production. This progression began thousands of years ago. The development of arrows made hunting more efficient, which allowed hunters to feed a larger number of people. Early farmers increased crop yields with hand plows and later with oxen- or horse-driven plows. More recently, mechanical harvesters made farming even more efficient. Each of these inventions increased the planet's carrying capacity for humans, as Figure 22.2b shows.

The ability of humans to innovate in the face of challenges has led some scientists to expect that we will continue to make technological advances indefinitely. This expectation is reasonable, but questions remain. Based on our history, should we assume that humans will continue to find ways to feed a growing population? Are there other limits to human population growth? And how do we know if we have exceeded Earth's carrying capacity?

Many factors drive human population growth

As we know from our study of biological populations, a variety of factors influence the growth, reproduction, and success of plant and animal species. Many of these same factors influence human populations as well. Population size, birth and death rates, fertility, life expectancy, and migration are factors that influence population size in countries. In order to understand the impact of the human population on the environment,

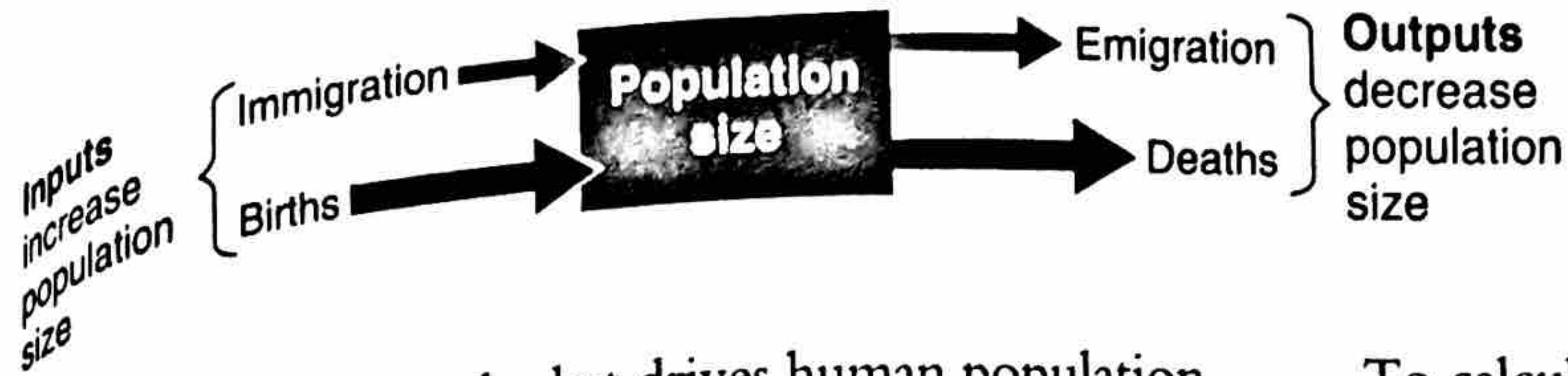

FIGURE 22.3 The human population as a system. We can think of the human population as a system, with births and immigration as inputs and deaths and emigration as outputs.

we must first understand what drives human population growth. The study of human populations and population trends is called **demography,** and scientists in this field are called **demographers.** By analyzing specific data such as changes in population size, fertility, life expectancy, and migration, demographers can offer insights—some of them surprising—into how and why human populations change and what can be done to influence rates of change.

Changes in Population Size

We can view the human population as a system with inputs and outputs, like all biological systems. If there are more births than deaths, the inputs are greater than the outputs, and the system expands. For most of human history, total births slightly outnumbered total deaths, resulting in very slow population growth. If the reverse had been true, the human population would have decreased and would have eventually become extinct.

When demographers look at population trends in individual countries, they take into account inputs and outputs. As FIGURE 22.3 shows, inputs include both births and **immigration,** which is the movement of people into a country or region from another country or region. Outputs, or decreases, include deaths and **emigration,** which is the movement of people out of a country or region. When inputs to the population are greater than outputs, the growth rate is positive. Conversely, if outputs are greater than inputs, the growth rate is negative.

Demographers use specific measurements to determine yearly birth and death rates. The **crude birth rate (CBR)** is the number of births per 1,000 individuals per year. The **crude death rate (CDR)** is the number of deaths per 1,000 individuals per year. Worldwide, there were 20 births and 8 deaths per 1,000 people in 2014. We do not factor in migration for the global population because, even though people move from place to place, they do not leave Earth. Thus, in 2014, the global population increased by 12 people per 1,000 people. This rate can be expressed mathematically as a percentage:

$$\text{Global population growth rate} = \frac{[CBR - CDR]}{10}$$

$$= \frac{[20-8]}{10}$$

$$= 1.2\%$$

We divide by 10 to arrive at the percentage because the birth and death rates are expressed per 1,000 people.

To calculate the population growth rate for a single nation, we take immigration and emigration into account:

$$\text{National population growth rate} = \frac{[(CBR + \text{immigration}) - (CDR + \text{emigration})]}{10}$$

If we know the growth rate of a population and assume that growth rate is constant, we can calculate the number of years it takes for a population to double, which is known as its **doubling time.** As a population grows rapidly, the doubling time gives us a better sense of the magnitude of the change than the growth rate alone. Because growth rates may change in future years, we can never determine a country's doubling time with certainty. Therefore, we say that a population will double in a certain number of years if the growth rate remains constant.

The doubling time can be approximated mathematically using a formula called the rule of 70:

$$\text{Doubling time (years)} = \frac{70}{\text{growth rate}}$$

Therefore, a population growing at 2 percent per year will double every 35 years:

$$\frac{70}{2} = 35 \text{ years}$$

Note that this is true of any population growing at 2 percent per year, regardless of the size of that population. At a 2 percent growth rate, a population of 50,000 people will increase by 50,000 in 35 years, and a population of 50 million people will increase by 50 million in 35 years.

Demography The study of human populations and population trends.

Demographer A scientist in the field of demography.

Immigration The movement of people into a country or region, from another country or region.

Emigration The movement of people out of a country or region.

Crude birth rate (CBR) The number of births per 1,000 individuals per year.

Crude death rate (CDR) The number of deaths per 1,000 individuals per year.

Doubling time The number of years it takes a population to double.

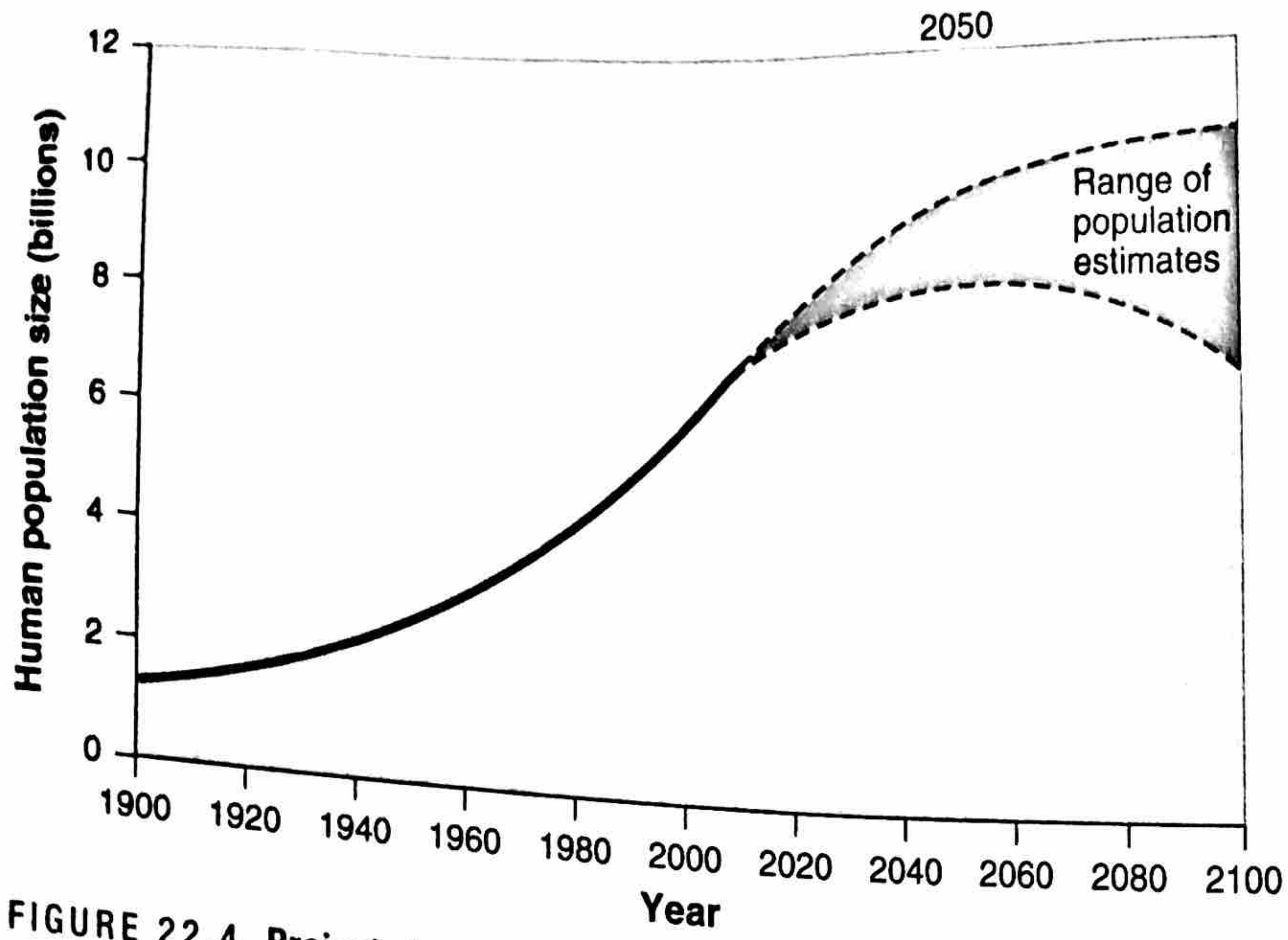

FIGURE 22.4 Projected world population growth. Demographers project that the global human population will be between 8.1 billion and 9.6 billion by 2050. By 2100, it is projected to be between 6.8 billion and 10.5 billion. The dashed lines represent estimated values. *(After Millennium Ecosystem Assessment, 2005)*

As we saw in Figure 22.1, Earth's population has doubled several times since 1600. It is almost certain, however, that Earth's population will not double again. **FIGURE 22.4** shows the current projections through the year 2100. Most demographers believe that the human population will be somewhere between 8.1 billion and 9.6 billion in 2050 and will stabilize between 6.8 billion and 10.5 billion by roughly 2100.

Fertility

To understand more about the role births play in population growth, demographers look at the **total fertility rate (TFR),** an estimate of the average number of children that each woman in a population will bear throughout her childbearing years (between the onset of puberty and menopause). For example, in the United States in 2014, the TFR was 1.9, meaning that, on average, each woman of childbearing age gave birth to just under 2 children. Note that, unlike crude birth rate and crude death rate, TFR is not calculated per 1,000 people. Instead, it is a measure of births per woman.

To gauge changes in population size, demographers also calculate **replacement-level fertility,** the TFR required to offset the average number of deaths in a population so that the current population size remains stable. Typically, replacement-level fertility is just over 2 children. Two children replace the parents who conceive them when the parents die. Replacement level fertility is higher than 2, however, because it also must account for children who die before they are able to have children or people who otherwise do not have children. As we shall see, the rate of death among children depends on a country's economic status.

In **developed countries**—countries with relatively high levels of industrialization and income—we typically see a replacement-level fertility of about 2. In **developing countries**—those with relatively low levels of industrialization and incomes of less than $3 per person per day—a TFR of greater than 2.1 is needed to achieve replacement-level fertility. Replacement level fertility is higher in developing countries because mortality among young people tends to be higher.

In a country where TFR is equal to replacement-level fertility, and where immigration and emigration are equal, the country's population is stable. A country with a TFR of less than 2.1 and no net increase from immigration is likely to experience a population decrease because that country's TFR is below replacement-level fertility. In contrast, a developed country with a TFR of more than 2.1 and no net decrease from emigration is likely to experience population growth because that country's TFR is above replacement-level fertility.

Life Expectancy

To understand more about the outputs in a human population system, demographers study the human life span. **Life expectancy** is the average number of years that an infant born in a particular year in a particular country can be expected to live, given the current average life span and death rate in that country. Life expectancy is generally higher in countries with better health care. A high life expectancy also tends to be a good predictor of high resource consumption rates and environmental impacts. **FIGURE 22.5** shows life expectancies around the world.

Total fertility rate (TFR) An estimate of the average number of children that each woman in a population will bear throughout her childbearing years.

Replacement-level fertility The total fertility rate required to offset the average number of deaths in a population in order to maintain the current population size.

Developed country A country with relatively high levels of industrialization and income.

Developing country A country with relatively low levels of industrialization and income.

Life expectancy The average number of years that an infant born in a particular year in a particular country can be expected to live, given the current average life span and death rate in that country.

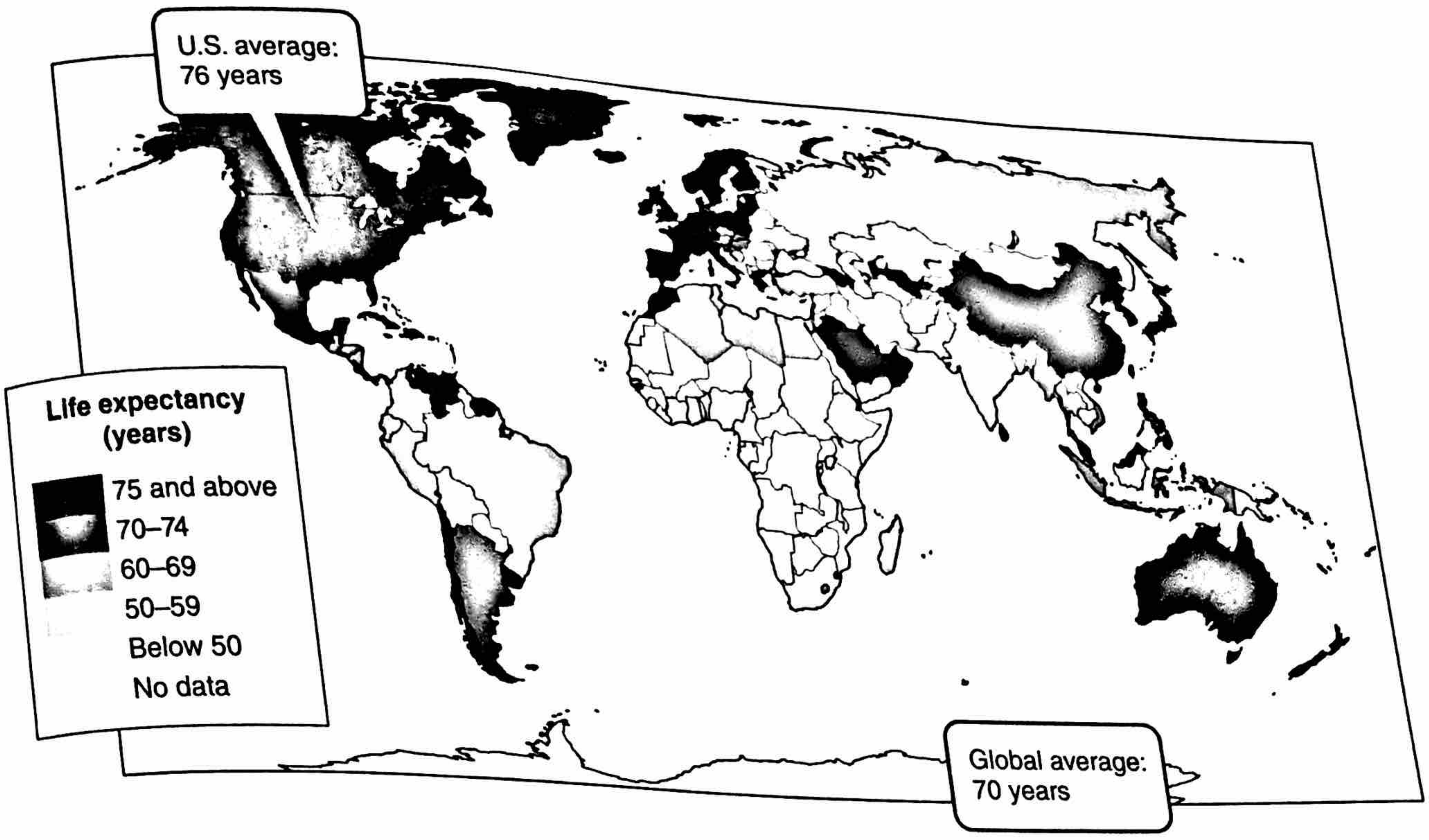

FIGURE 22.5 Average life expectancies around the world. Life expectancy varies significantly by continent and in some cases by country. *(Data from CountryWatch, http://www.countrywatch.com/facts/facts_default.aspx?type=image&img=LEAG; data from http://www.worldlifeexpectancy.com/world-life-expectancy-map)*

Life expectancy is often reported in three different ways: for the overall population of a country, for males only, and for females only. For example, in 2014, global life expectancy was 70 years overall, 68 years for men, and 72 years for women. In the United States, life expectancy was 76 years overall, 73 years for men, and 81 years for women. In general, human males have higher death rates than human females, leading to a shorter life expectancy for men. In addition to biological factors, men have historically tended to face greater dangers in the workplace, made more hazardous lifestyle choices, and been more likely to die in wars. Cultures have changed over time, however, and as more and more women enter the workforce and the armed forces, the life expectancy gap between men and women will probably decrease.

Infant and Child Mortality

The availability of health care, access to good nutrition, and exposure to pollutants are all factors in life expectancy, *infant mortality*, and *child mortality*. The **infant mortality** rate is defined as the number of deaths of children under 1 year of age per 1,000 live births. The **child mortality** rate is defined as the number of deaths of children under age 5 per 1,000 live births. FIGURE 22.6 shows infant mortality rates around the world.

If a country's life expectancy is relatively high and its infant mortality rate is relatively low, it is likely that the country has a high level of available health care, an adequate food supply, potable drinking water, good sanitation, and a moderate level of pollution. Conversely, if its life expectancy is relatively low and its infant mortality rate is relatively high, it is likely that the country's population does not have sufficient health care or sanitation and that potable drinking water and food are in limited supply. Pollution and exposure to other environmental hazards may also be high. In 2014, the global infant mortality rate was 41. In the United States, the infant mortality rate was 5.9. In other developed countries, such as Sweden (2.6) and France (3.3), the infant mortality rate was even lower. Availability of prenatal care is an important predictor of the infant mortality rate. For example, the infant mortality rate is 63 in Liberia and 40 in Bolivia, both countries where many women do not have good access to prenatal care.

Sometimes, life expectancy and infant mortality in a given sector of a country's population differ widely from life expectancy and infant mortality in the country as a whole. In this case, even when the overall numbers seem to indicate a high level of health care throughout the country, the reality may be starkly different for a portion of its population. For example, whereas the infant mortality rate for the U.S. population as a whole is 6.0, it is 12.4 for African Americans, 8.5 for Native Americans, and 5.3 for Caucasians. This variation in infant mortality rates is probably related to socioeconomic status and varying degrees of access to adequate nutrition and health care. These differences are often issues of environmental justice, a topic we discuss in more detail in Chapter 20.

Infant mortality The number of deaths of children under 1 year of age per 1,000 live births.

Child mortality The number of deaths of children under age 5 per 1,000 live births.

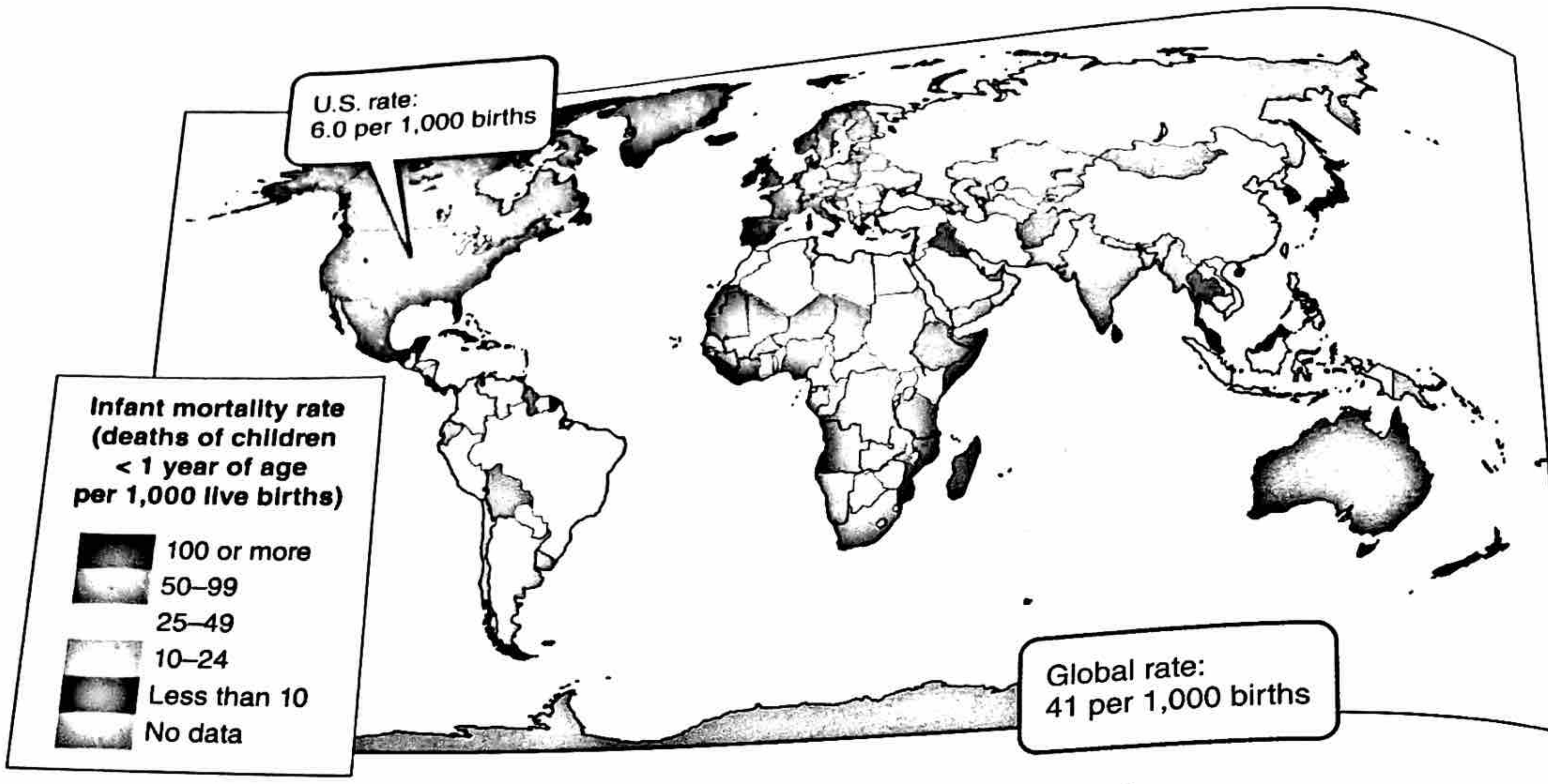

FIGURE 22.6 Infant mortality around the world. Infant mortality rates are lower in developed countries and higher in developing countries. *(Data from http://www.mapsofworld.com/infant-mortality-rate-map.htm#bot)*

Aging and Disease

Even with a high life expectancy and a low infant mortality rate, a country may have a high crude death rate, in part because it has a large number of older individuals. The United States, for example, has a higher standard of living than Mexico, which is consistent with the higher life expectancy and lower infant mortality rate in the United States. At the same time, the United States has a much higher CDR, at 8 deaths per 1,000 people on average, than Mexico, which has 5 deaths per 1,000 people on average. This higher CDR results from the much larger elderly population in the United States, with 13 percent of its population aged 65 years or older, compared with the 6 percent of the population aged 65 or older in Mexico.

Disease is an important regulator of human populations. According to the World Health Organization, infectious diseases—those caused by microbes that are transmissible from one person to another—are the second biggest killer worldwide after heart disease. In the past, tuberculosis and malaria were two of the infectious diseases responsible for the greatest number of human deaths. Today, the human immunodeficiency virus (HIV), which causes acquired immune deficiency syndrome (AIDS), is responsible for more deaths annually than either tuberculosis or malaria. Between 1990 and 2012, AIDS-related illnesses killed more than 28 million adults and children. Because HIV disproportionately infects people aged 15 to 49—the most productive years in a person's life span—HIV has had a more disruptive effect on society than other illnesses that affect the very young and the very old.

HIV has a significant effect on infant mortality, child mortality, population growth, and life expectancy. In Lesotho, in southern Africa, where 23 percent of the adult population is infected with HIV, life expectancy fell from 63 years in 1995 to 40 years in 2009. It has since been increasing and is now approximately 48.

As **FIGURE 22.7** shows, approximately 34 million people were living with HIV in 2011, 22 million of

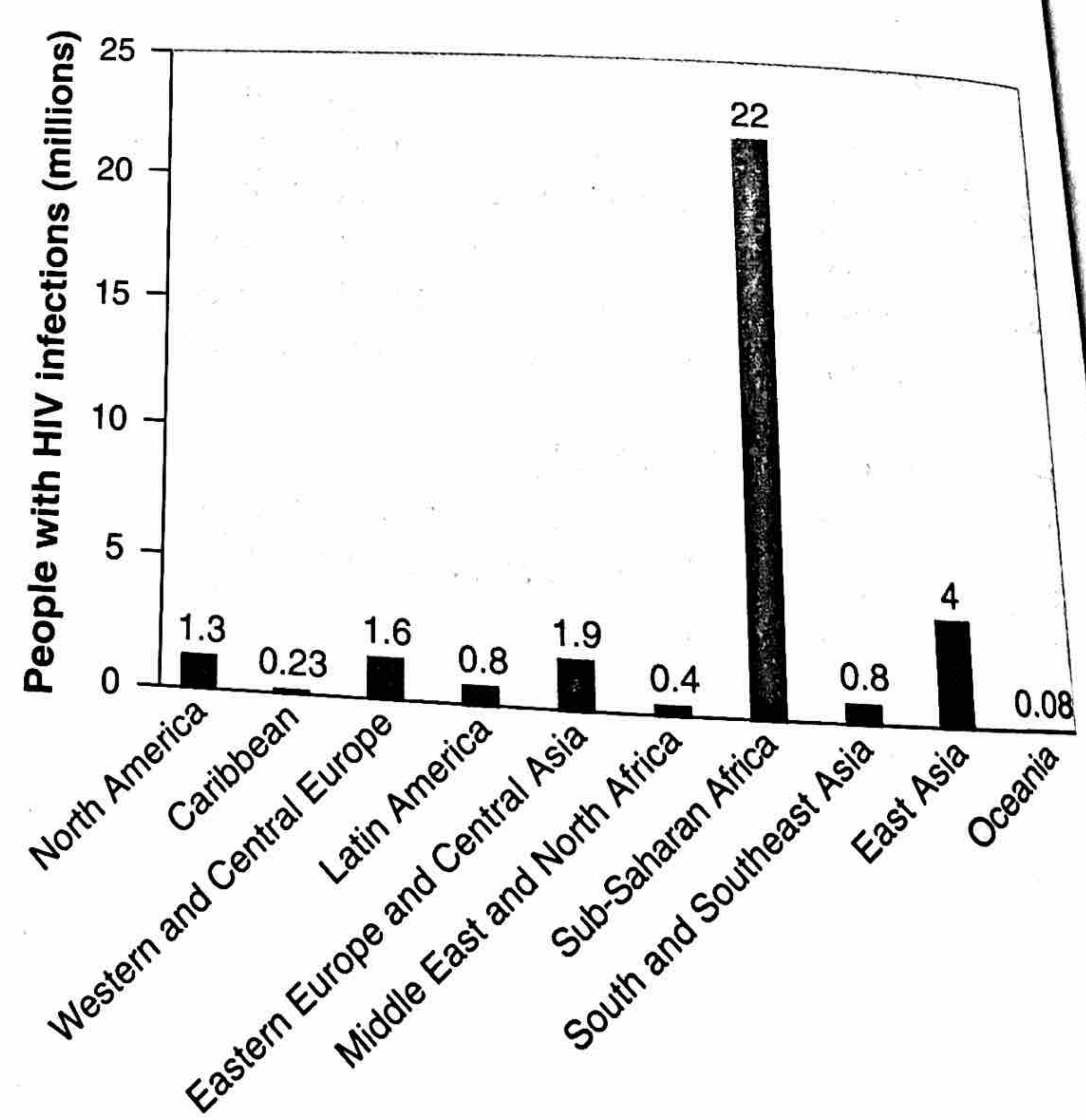

FIGURE 22.7 HIV infection worldwide. Worldwide, about 33 million people are living with HIV, two-thirds of them in sub-Saharan Africa. *(Data from World Health Organization, UNAIDS)*

do the math

Calculating Population Growth

In 2012, New Zealand had a population of 4.3 million people, a TFR of 2.1, and a net migration rate of 2 per 1,000. How many people will New Zealand gain in the following year as a result of immigration? If the TFR stays the same for the next century, and the net migration rate stays the same as well, when will the population of New Zealand double?

$$\text{Net migration rate} = \frac{\text{number of immigrants/year}}{\text{number of people in the population}}$$

A TFR of 2.1 for a developed country suggests that the country is at replacement-level fertility and, therefore, the population is stable. The migration rate suggests that

$$\frac{2}{1{,}000} = \frac{x}{4{,}300{,}000}$$

and therefore that

$$x = 8{,}600 \text{ people/year}$$

So, 8,600 people are added to New Zealand each year by migration. If there is no growth due to biological replacement, then the rate of increase is

$$\frac{8{,}600 \text{ people/year}}{4{,}300{,}000 \text{ people}} = 0.2\%/\textit{year}$$

Your Turn How many years will it take for the New Zealand population to double if the population increases due to migration only? Recall that to calculate doubling time, we use the rule of 70:

$$\text{Doubling time (years)} = \frac{70}{\text{growth rate}}$$

them in sub-Saharan Africa. The annual number of deaths due to AIDS reached a peak of 2.1 million in 2005 but has decreased since then. We will talk more about AIDS and other infectious diseases in Chapter 17.

Migration

Regardless of its birth and death rates, a country may experience population growth, stability, or decline as a result of migration. **Net migration rate** is the difference between immigration and emigration in a given year per 1,000 people in a country. A positive net migration rate means there is more immigration than emigration, and a negative net migration rate means the opposite. For example, approximately 1 million people immigrate to the United States each year, and only a small number emigrate. With a U.S. population of 315 million, these rates are equal to 3.2 immigrants per 1,000 people.

A country with a relatively low CBR but a high immigration rate may still experience population growth. For example, the United States has a TFR of 1.9, but it has a high net migration. As a result, the U.S. population will probably increase by 30 percent by 2050. Canada has a net migration rate of 0.7 per 1,000 and a TFR of 1.6, which is well below replacement-level fertility. Therefore, both the United States and Canada will experience net population growth over the next few decades, but the growth will come from immigration rather than from births originating within the existing population. "Do the Math: Calculating Population Growth" shows how this can happen.

In countries with a negative net migration rate and a low TFR, the population actually decreases over time. Very few countries fit this model. One is the country of Georgia, in western Asia. It has a growth rate of 0.2 percent, a TFR of 1.7, and a net migration rate of −5 per 1,000. Georgia is projected to have a 20 percent population decrease by 2050.

Net migration rate The difference between immigration and emigration in a given year per 1,000 people in a country.

We have noted that although the movement of people around the world does not affect the total number of people on the planet, migration is still an important issue in environmental science. The movement of people displaced because of disease, natural disasters, environmental problems, or conflict can create crowded, unsanitary conditions, and shortages of food and water. In some cases people are moved into refugee camps where they have little opportunity to improve their conditions through employment or emigration. All of these situations can easily become humanitarian and environmental health issues. The movement of people from developing countries to developed countries tends to increase the ecological footprint of those people because, over time, immigrants typically adopt the lifestyle and consumption habits of their new country. A person who migrates from Mexico to the United States, for example, is likely to use more resources as a U.S. resident than as a resident of Mexico because the United States typically has a more affluent lifestyle.

Age structure diagrams describe how populations are distributed across age ranges

Demographers use data on age to predict how rapidly a population will increase and what its size will be in the future. The age structure of a population describes how its members are distributed across age ranges, usually in 5-year increments. **Age structure diagrams,** examples of which are shown in FIGURE 22.8, are visual representations of the number of individuals within specific age groups for a country, typically expressed for males and females. Each horizontal bar of the diagram represents a 5-year age group. The total area of all the bars in the diagram represents the size of the whole population.

Age structure diagram A visual representation of the number of individuals within specific age groups for a country, typically expressed for males and females.

Population pyramid An age structure diagram that is widest at the bottom and smallest at the top, typical of developing countries.

Population momentum Continued population growth after growth reduction measures have been implemented.

While every nation has a unique age structure, we can group countries very broadly into three categories. A country with many more younger people than older people has an age structure diagram that is widest at the bottom and narrowest at the top, as shown in Figure 22.8a. This type of age structure diagram, called a **population pyramid,** is typical of developing countries, such as Venezuela and India. The wide base of the graph compared with the levels above it indicates that the population will grow because a large number of females aged 0 to 15 have yet to bear children. Even if each one of these future potential mothers has only two children, the population will grow simply because there are increasing numbers of women able to give birth.

The population pyramid can also be used to illustrate how long a time it takes for changes to affect a growing population. **Population momentum** is continued population growth after growth reduction measures have been implemented. It occurs because there are relatively large numbers of individuals at reproductive maturity in the population. Population momentum has been compared with the momentum of a long, heavy freight train, which takes longer to stop than a shorter, lighter freight train. It is the reason why a population keeps on growing after birth control policies or voluntary birth reductions have begun to lower the CBR of a country. Eventually, over several generations, those actions will bring the population to a more stable growth rate but the momentum of all the individuals who have recently reached child-bearing age will carry the population forward for a number of years.

A country with little difference between the number of individuals in younger age groups and in older age groups has an age structure diagram that looks more like a column from age 0 through age 50, as shown in Figure 22.8b. If a country has few individuals in the younger age classes, we can deduce that it has slow population growth or is approaching no growth at all. The United States, Canada, Australia, Sweden, and many other developed countries have this type of age structure diagram. A number of developing countries that have recently lowered their growth rates should begin to show this pattern within the next 10 to 15 years.

A country with a greater number of older people than younger people has an age structure diagram that resembles an inverted pyramid. Such a country has a total fertility rate below 2.1 and a decreasing number of females within each younger age range. Such a population will continue to shrink. Italy, Germany, Russia, and a few other developed countries display this pattern, seen in Figures 22.8c and 22.8d. China is in the very early stages of showing this pattern

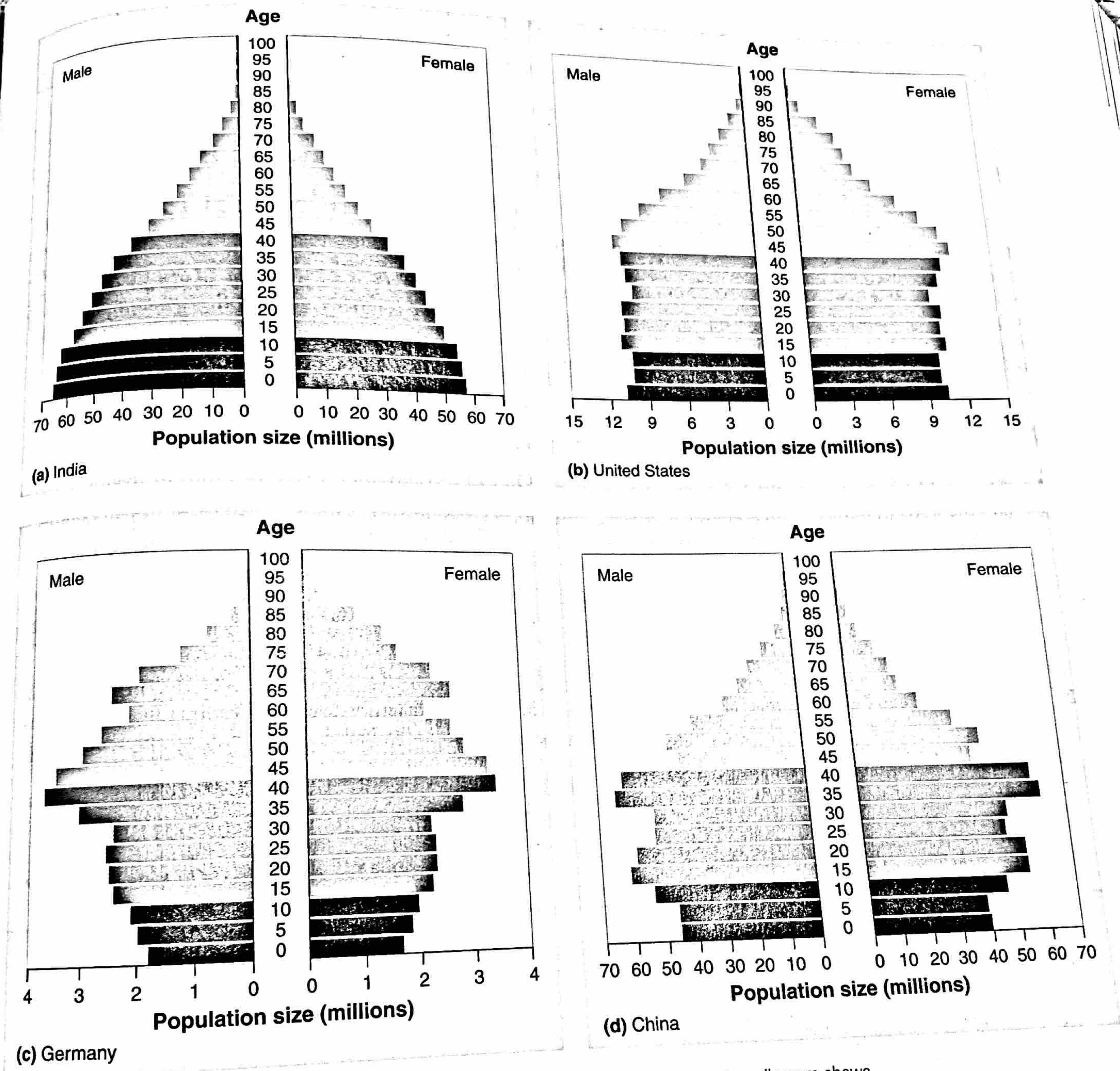

FIGURE 22.8 Age structure diagrams in 2010. The horizontal axis of the age structure diagram shows the population size in millions for males and females in each 5-year age group shown on the vertical axis. (a) A population pyramid illustrates a rapidly growing population. (b) A column-shaped age structure diagram indicates population stability. (c) In some developed countries, the population is declining. (d) China's population control measures will eventually lead to a population decline. *(Data from http://www.census.gov/ipc/www/idb/pyramids.html)*

module

23

Economic Development, Consumption, and Sustainability

Human populations undergo change as a variety of natural and societal conditions in those populations change over time. Some of these changes occur with specific patterns that can be described and explained. In this module we will look at demographic transitions, the effect of these transitions on the environment, and the relationship between economic development and sustainability.

Learning Objectives

After reading this module you should be able to

- describe how demographic transition follows economic development.
- explain how relationships among population size, economic development, and resource consumption influence the environment.
- describe why sustainable development is a common but elusive goal.

Demographic transition follows economic development

As we saw in Module 22, populations in different countries change over time and the population of Earth has also fluctuated. Demographers are interested in understanding the reasons behind fluctuations in population growth in the past and whether they apply to contemporary or future demographic issues. We will begin this module by looking at an important theory of how populations change. We will also look at family planning because it is an important component of demographic transition.

The Theory of Demographic Transition

Historically, nations that have gone through similar processes of economic development have experienced similar patterns of population growth. Scientists who studied the population growth patterns of European countries in the early 1900s described a four-phase process they referred to as a demographic transition. The **theory of demographic transition** says that as

Theory of demographic transition The theory that as a country moves from a subsistence economy to industrialization and increased affluence it undergoes a predictable shift in population growth.

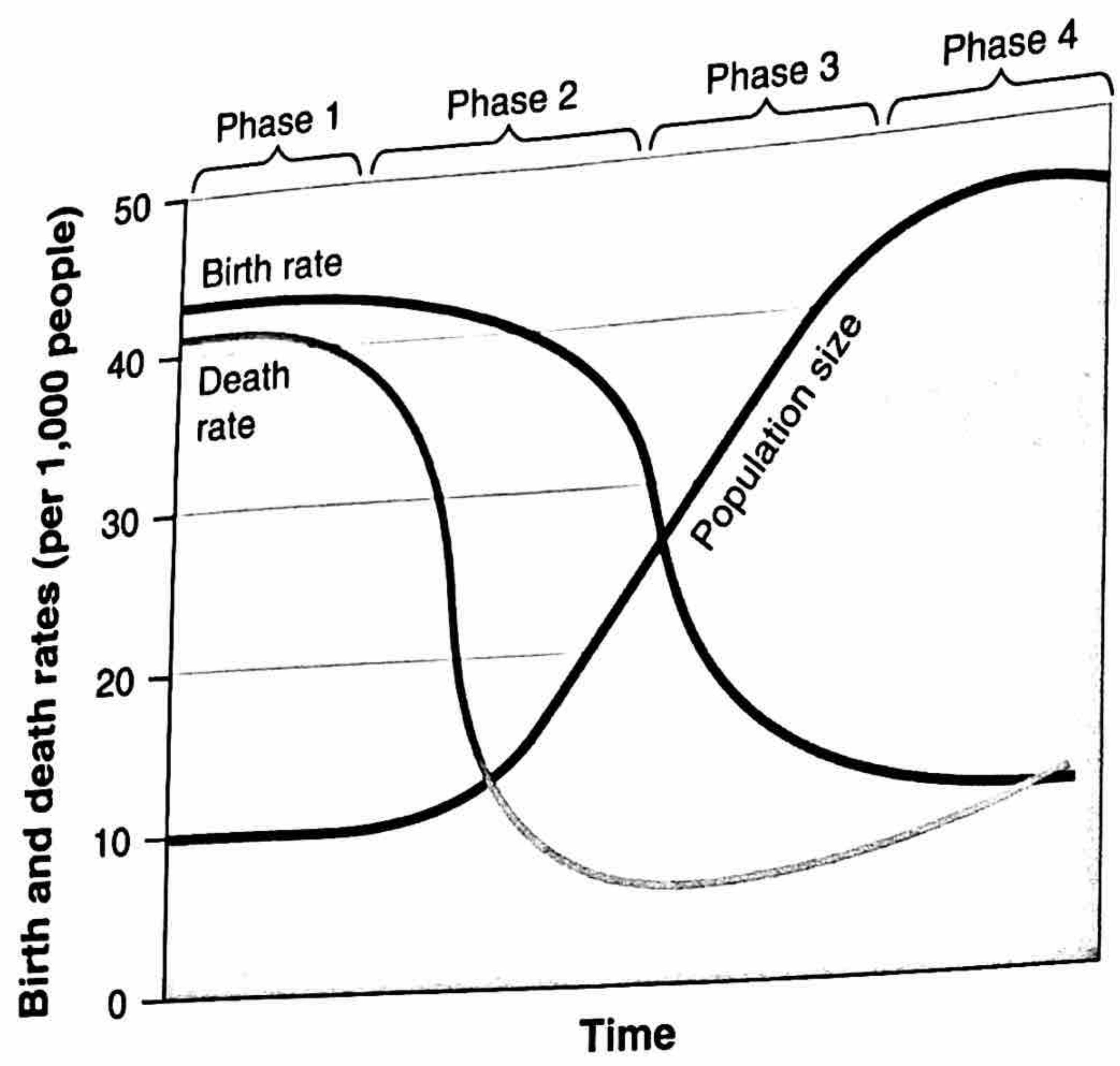

FIGURE 23.1 Demographic transition. The theory of demographic transition models the way that birth, death, and growth rates for a nation change with economic development. Phase 1 is a preindustrial period characterized by high birth rates and high death rates. In phase 2, as the society begins to industrialize, death rates drop rapidly, but birth rates do not change. Population growth is greatest at this point. In phase 3, birth rates decline for a variety of reasons. In phase 4, the population stops growing and sometimes begins to decline as birth rates drop below death rates.

a country moves from a subsistence economy to industrialization and increased affluence, it undergoes a predictable shift in population growth. The four phases of a demographic transition are shown in **FIGURE 23.1**.

The theory of demographic transition, while helpful as a learning tool, does not adequately describe the population growth patterns of some developing countries either today or during the last quarter-century. Both birth and death rates have declined rapidly in a number of developing countries because of a variety of factors that are not yet entirely understood. In some developing countries governments have taken measures to improve health care and sanitation and promote birth control, in spite of the country's poverty.

Despite the limitations of the theory of demographic transition, it is worth examining in more detail because it allows us to understand the way some countries influence the environment as they undergo growth and development.

Phase 1: Slow Population Growth

Phase 1 represents a population that is nearly at steady state. The size of the population will not change very quickly because high birth rates and high death rates offset one another. In other words, CBR equals CDR. This pattern is typical of countries before they begin to modernize. In these countries, life expectancy for adults is relatively short due to difficult and often dangerous working conditions. The infant mortality rate is also high because of disease, lack of health care, and poor sanitation. In a subsistence economy, where most people are farmers, having numerous children is an asset. Children can do jobs such as collecting firewood, tending crops, watching livestock, and caring for younger siblings. With no social security system, parents also count on having many children to care for them when they become old.

Western Europe and the United States were in phase 1 before the Industrial Revolution, which began in the late eighteenth century. Today, crude birth rates exceed crude death rates in almost every country, so even the poorest nations have moved beyond phase 1. However, an increase in crude death rates due to war, famine, and diseases such as AIDS has pushed some countries back in the direction of phase 1. For example, a decade ago, Lesotho (CBR= 26, CDR = 28 in 2005) moved back into phase 1 as a result of its high death rate.

Affluence The state of having plentiful wealth including the possession of money, goods, or property.

Phase 2: Rapid Population Growth

In phase 2, death rates decline while birth rates remain high and, as a result, the population grows rapidly. As a country modernizes, better sanitation, clean drinking water, increased access to food and goods, and access to health care, including childhood vaccinations, all reduce the infant mortality rate and CDR. However, the CBR does not markedly decline. Couples continue to have large families because it takes at least one generation, if not more, for people to notice the decline in infant mortality and adjust to it. This is another example of population momentum. It also takes time to implement educational systems and birth control measures.

A phase 2 country is in a state of imbalance: Births outnumber deaths. India is in phase 2 today. The United States population exhibited a phase 2 population pyramid in the early twentieth century when there were high birth rates, low death rates, and a large total fertility rate.

Phase 3: Stable Population Growth

A country enters phase 3 as its economy and educational system improve. In general, as family income increases, people have fewer children, as **FIGURE 23.2** shows. As a result, the CBR begins to fall. Phase 3 is typical of many developed countries, including the United States and Canada.

Why do people produce fewer children as their income increases? As societies transition from subsistence farming to more complex economic specializations, having large numbers of children may become a financial burden rather than an economic benefit. Relative **affluence**, more time spent pursuing education, and the

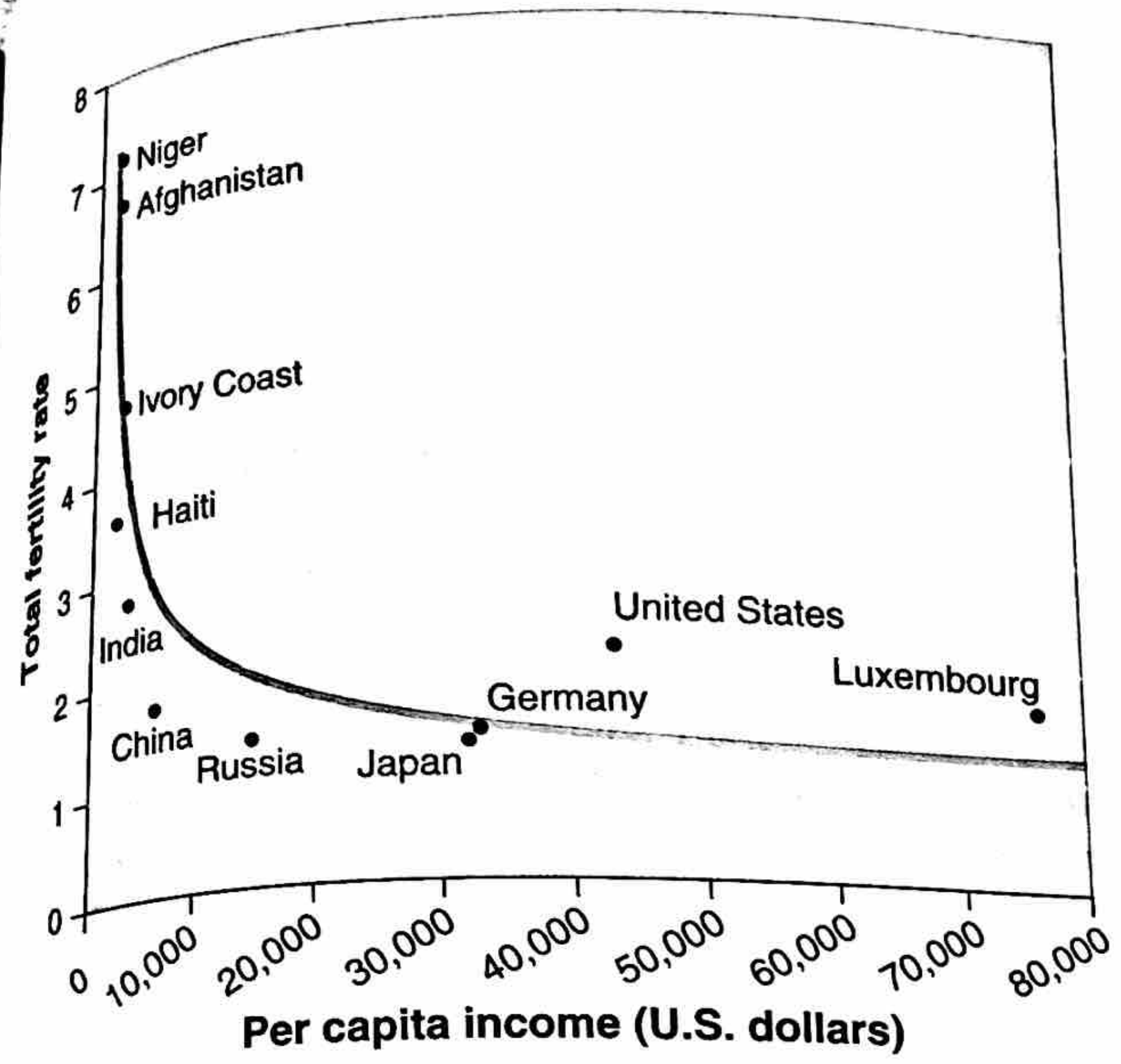

FIGURE 23.2 **Total fertility rate and per capita income.** Wealthier nations tend to have lower total fertility rates. *(Data from http://www.gapminder.org)*

availability of birth control increase the likelihood that people will choose to have smaller families. However, it is important to note that cultural, societal, and religious norms may also play a role in birth rates.

As birth rates and death rates decrease in phase 3, the system returns to a steady state. Population growth levels off during this phase, and population size does not change very quickly, because low birth rates and low death rates cancel each other out.

Phase 4: Declining Population Growth

Phase 4 is characterized by declining population size and often by a relatively high level of affluence and economic development. Japan, the United Kingdom, Germany, Russia, and Italy are phase 4 countries, with the CBR well below the CDR.

The declining population in phase 4 means fewer young people and a higher proportion of elderly people (FIGURE 23.3). This demographic shift can have important social and economic effects. With fewer people in the labor force and more people retired or working part-time, the ratio of dependent elderly to wage earners increases, and the costs of pension programs and social security services will increase the tax burden on each wage earner. There may be a shortage of health care workers to care for an aging population. Governments may encourage immigration as a source of additional workers. In some countries, such as Japan, the government provides economic incentives to encourage families to have more children in order to offset the demographic shift.

Recent studies on demographic shifts in highly developed countries suggest that the TFR actually increases after reaching a low point between 1.2 and 1.5. The reasons for this increase are unclear, but it appears that when a population becomes affluent and well educated, it becomes somewhat easier for women to raise children, and they choose to do so in slightly greater numbers. Such a pattern is occurring in Norway, Italy, the United States, and other developed nations.

FIGURE 23.3 **Elderly populations.** Some countries have very large elderly populations. Here, men and women gather at a senior residence home in San Diego, California. *(Stockbroker/Alamy Images)*

Family Planning

We have already observed that as family income increases, people tend to have fewer children. In fact, there is a link between higher levels of education and affluence among females, in particular, and lower birth rates. As the educational levels of women increase and women enter the workplace, fertility generally decreases. Even in developed countries where the TFR has increased slightly after hitting its apparent low point, women have fewer children than those in developing countries. Educated and working women tend to have fewer children than other women, and many delay having children because of the demands of school and work. Having a first child at an older age means that a woman is likely to have fewer children in her lifetime.

Women with more education and income also tend to have more access to information about methods of birth control, they are more likely to interact with their partners as equals, and they may choose to practice *family planning* with or without the consent of their partners. **Family planning** is regulation of the number or spacing of offspring through the use

Family planning The practice of regulating the number or spacing of offspring through the use of birth control.

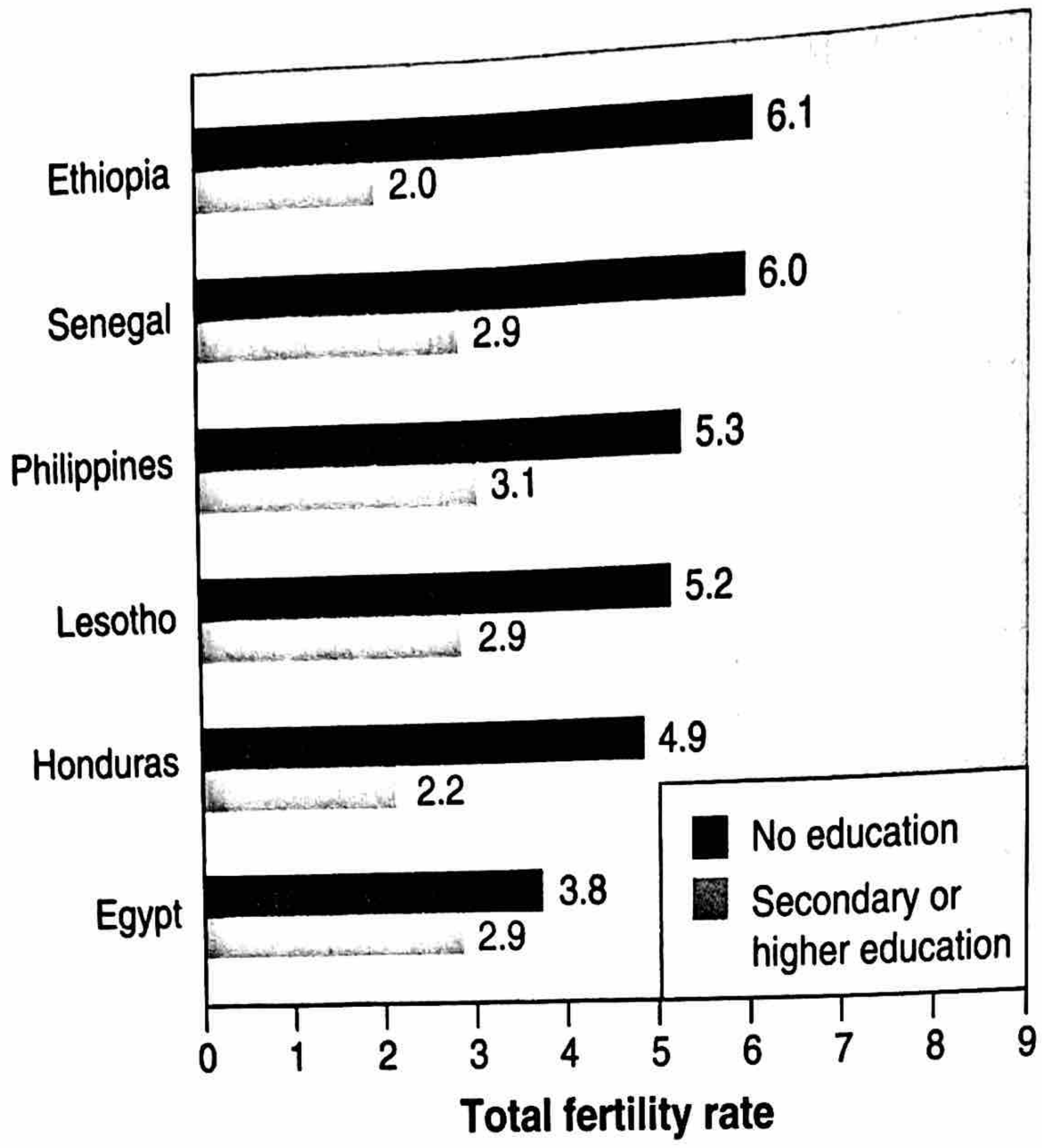

FIGURE 23.4 Total fertility rates for educated and uneducated women in six countries. Fertility is strongly related to female education in many developing countries. *(Data from Population Reference Bureau, 2007 World Population Data Sheet, http://www.prb.org/pdf07/07WPDS_Eng.pdf)*

of birth control. When women have the option to use family planning, crude birth rates tend to drop. FIGURE 23.4 shows how female education levels correlate with crude birth rates. In Ethiopia, for instance, women with a secondary school education or higher have a TFR of 2.0, whereas the TFR among uneducated women is 6.1.

There have been many examples of effective family planning campaigns in the last few decades. In the 1980s, Kenya had one of the highest population growth rates in the world, and its TFR was almost 8. By 1990, its TFR was about 4—one-half of the previous rate. Kenya's government achieved these dramatic results by implementing an active family planning campaign. The campaign, which began in the 1970s, encouraged smaller families. Advertising directed toward both men and women emphasized that overpopulation led to both unemployment and harm to the natural environment. The ads also promoted condom use.

Thailand also successfully used family planning campaigns to lower its growth rate and TFR. Beginning in 1971, national population policy encouraged married couples to use birth control. Contraceptive use increased from 15 to 70 percent, and within 15 years the population growth rate fell from 3.2 to 1.6 percent. Today, Thailand's growth rate is 0.6 percent, among the lowest in Southeast Asia. Some of the credit for this hugely successful reduction in the growth rate is given to a creative and charismatic government official who gained a great deal of attention, in part by handing out condoms in public places.

Population size, economic development, and consumption interact to influence the environment

Both population size and the amount of resources each person uses are critical factors that determine the impact of humans on Earth. Every human exacts a toll on the environment by eating, drinking, generating waste, and consuming products. Even relatively simple foods such as beans and rice require energy, water, and mineral resources to produce and prepare. Raising and preparing meat requires even more resources: Animals require crops to feed them as well as water and energy resources. Building homes, manufacturing cars, and making clothing and consumer products all require energy, water, wood, steel, and other resources. These and many other human activities contribute to environmental degradation.

Both population and economic development contribute to the consumption of resources and to human impact on the environment. In this section we will examine how relationships among population size, economic development, and resource consumption influence the environment. We will then look more closely at local, urban, and global impacts.

Resource Use

In Module 22 we described developing countries as those with relatively low levels of industrialization and incomes of less than $3 per person per day. In contrast, developed nations have relatively high levels of both industrialization and income. Of Earth's 7.2 billion human inhabitants, roughly 6.0 billion live in developing countries, and 1.2 billion live in developed countries. As FIGURE 23.5 shows, 9 of the 12 most populous nations on Earth are developing countries. FIGURE 23.6 charts the relationship between economic development and population growth rate for developing nations. Populations in developing parts of the world have continued to grow relatively rapidly, at an average rate of 1.4 percent per year. At the same time, populations in the developed world have almost leveled off, with an average growth rate of 0.1 percent per year. Impoverished countries are increasing their populations more rapidly than are affluent countries.

Differences in resource use are striking in terms of how population and wealth affect the environment. Calculating the per capita ecological footprint for a country provides a way to measure the effect of affluence—the state of having plentiful wealth that includes the possession of money, goods, or property—and consumption on the planet. Although affluence tends to be associated with higher consumption, it is possible to be affluent without having a large ecological footprint. FIGURE 23.7 shows some examples of

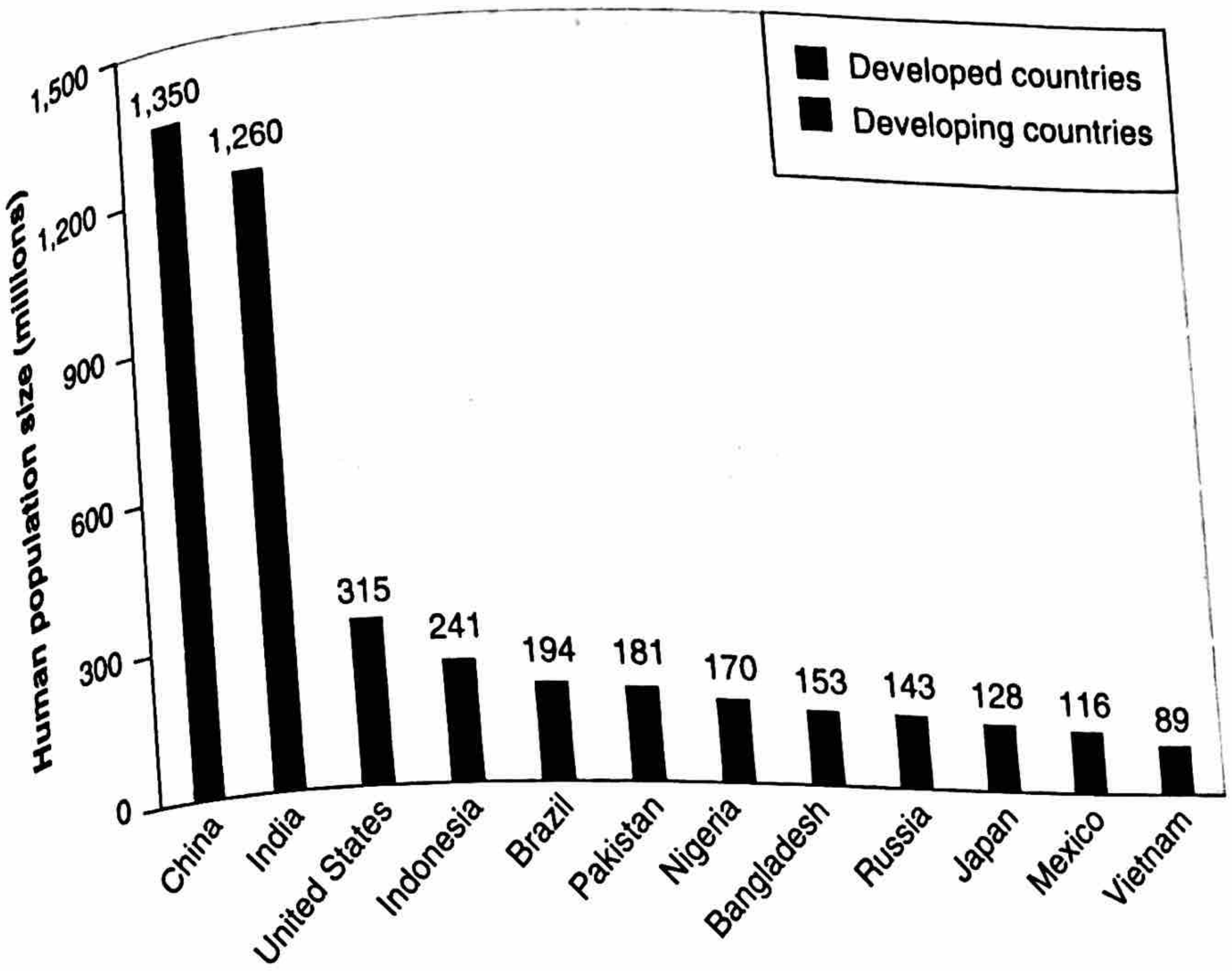

FIGURE 23.5 The 12 most populous countries in the world. China and India are by far the largest nations in the world. Only 3 of the 12 most populous countries are developed nations. *(Data from Population Reference Bureau, 2012 data)*

ecological footprints for selected countries. The world average ecological footprint is 2.7 ha (6.7 acres) per capita. The United States has the largest ecological footprint of any nation, at 9.0 ha (22 acres) per capita. China's footprint is 1.8 ha (4.5 acres) per capita. Haiti, the poorest country in the Western Hemisphere, has a footprint of 0.5 ha (1.2 acres) per capita. In other words, a person living in the United States has more than 5 times the environmental impact of a person living in China and 18 times that of a person living in Haiti.

In addition to looking at data on a per capita basis, it is useful to examine the footprints of entire countries. We can do this by multiplying the per capita ecological footprint of a country by the number of people in the country. We find that the United States has a footprint of 2,810 million hectares (6,944 million acres). China's footprint is 2,790 million hectares (6,894 million acres), and Ivory Coast (in western Africa) has a footprint of 18.6 million hectares (46.0 million acres). Looked at another way, the United States, with only one-fourth the population of China, has an ecological

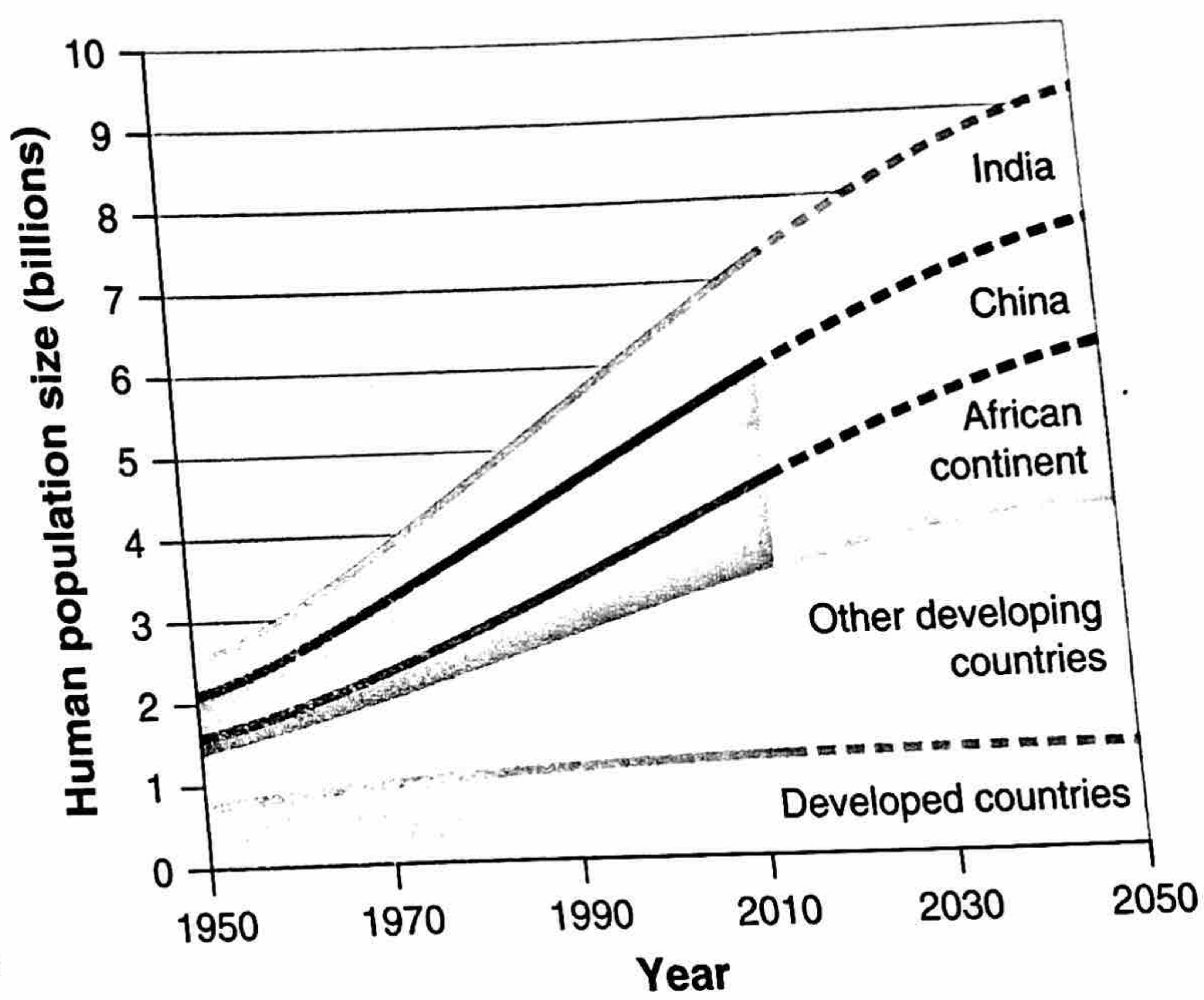

FIGURE 23.6 Population growth past and future. Population growth in developed countries has mostly ceased, while that in developing countries is slowing, but is expected to continue beyond 2050. *(Data from United Nations Population Division)*

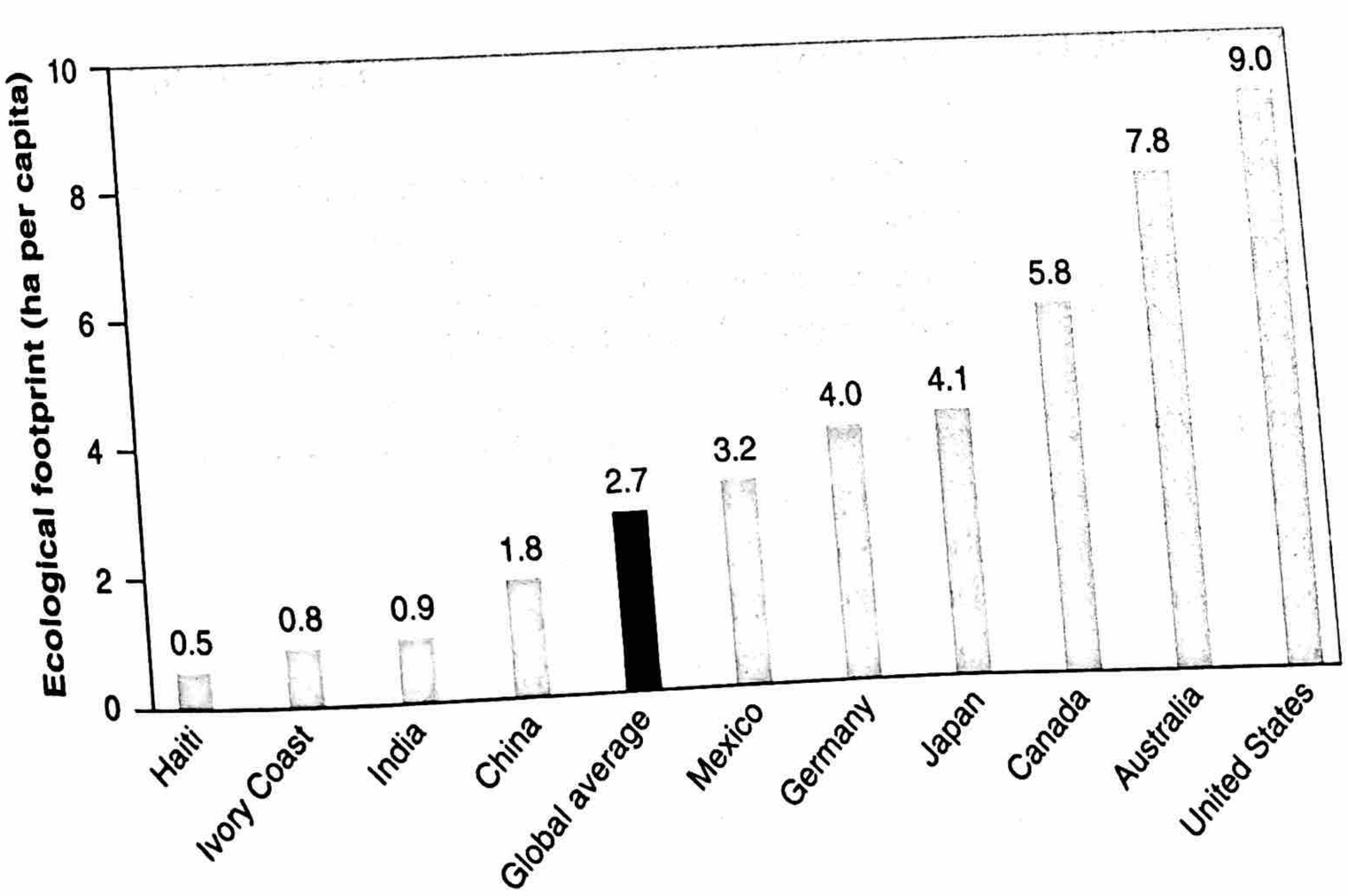

FIGURE 23.7 Per capita ecological footprints. Many countries exceed the global average footprint of 2.7 ha per capita. *(Data from Global Footprint Network, 2009 Data Sheet)*

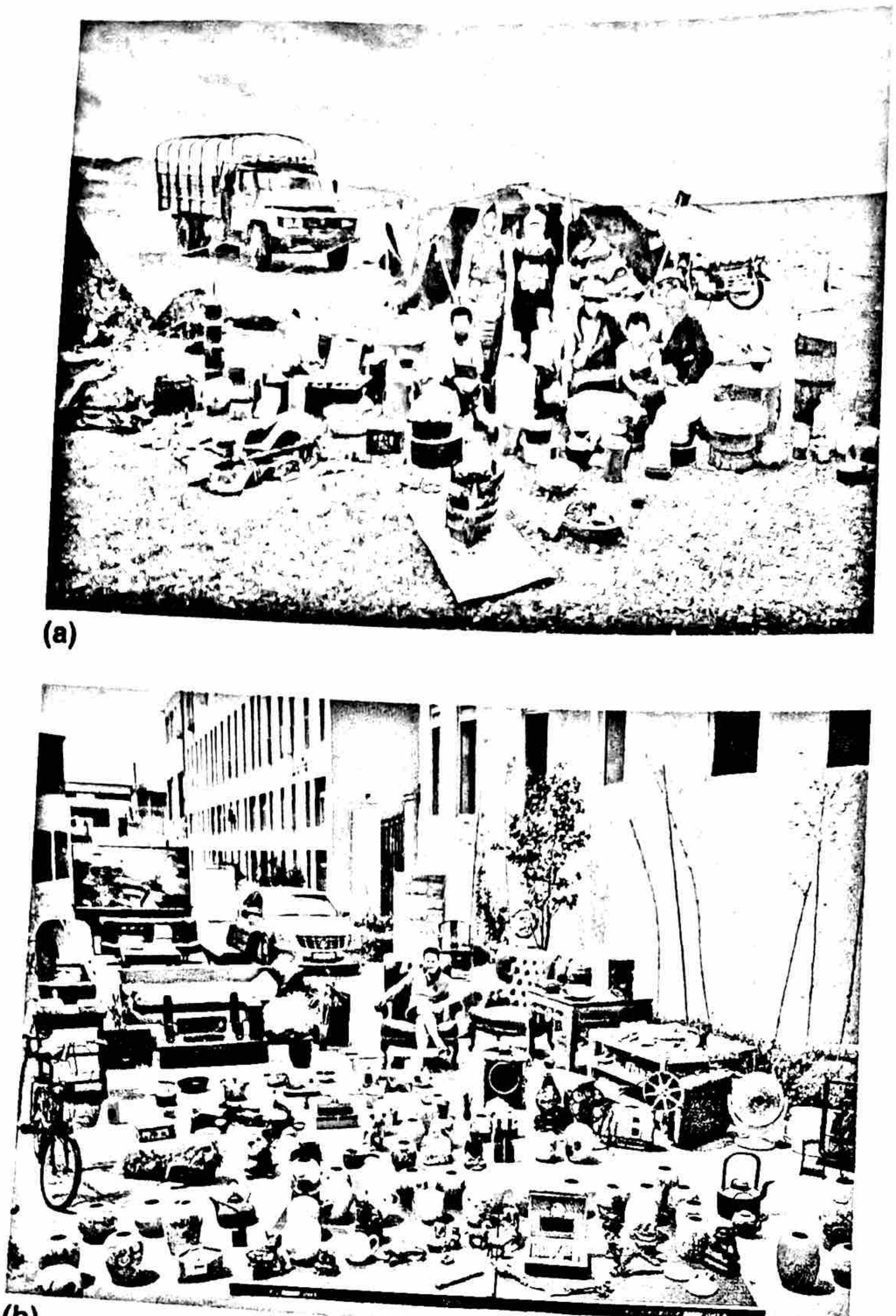

FIGURE 23.8 Material possessions. Most families in developing countries have few possessions compared with their counterparts in developed countries. In each of these photos, members of a family are shown outside their homes with all their possessions. (a) A family in a rural region of Tibet. (b) An individual in an urban part of China, where more development has occurred. *(Huang Qingjun [http://www.huangqingjun.com/])*

footprint comparable to that of China because of its high levels of consumption. However, China's rapid development, as described at the beginning of this chapter, means that its ecological footprint is likely to continue to grow in the coming years.

The IPAT Equation

The total environmental impact of 7.2 billion people is hard to appreciate and even more difficult to quantify. Some people consume large amounts of resources and have a negative impact on environmental systems, while others live much more lightly on the land (FIGURE 23.8). Living lightly can be intentional, as when people in the developed world make an effort to live "green," or sustainably. But it can also be unintentional, as when poverty prevents people from acquiring material possessions or building homes.

To estimate the impact of human lifestyles on Earth, environmental scientists Barry Commoner, Paul Ehrlich, and John Holdren developed the **IPAT equation**:

$$\text{impact} = \text{population} \times \text{affluence} \times \text{technology}$$

Although it is written mathematically, the IPAT equation is a conceptual representation of the three major factors that influence environmental impact. Impact in this context is the overall environmental effect of a human population multiplied by affluence, multiplied by technology. It is useful to look at each of these factors individually.

Population has a straightforward effect on impact. All else being equal, two people consume twice as much as one. Therefore, when we compare two countries with similar economic circumstances, the one with more people is likely to have a larger impact on the environment.

Affluence is created by economic opportunity and does not have as simple a relationship to impact as population does. One person in a developed country can have a greater impact than two or more people in a developing country. A family of four in the United States that owns two large sport utility vehicles and lives in a spacious home with a lawn and swimming pool uses a much larger share of Earth's resources than a Bangladeshi family of four living in a two-room apartment and traveling on bicycles and buses. The more affluent a society or individual is, the higher the environmental impact.

The effect of technology is even more complicated. Technology can both degrade the environment and create solutions to minimize our impact on the environment. For example, the manufacturing of chlorofluorocarbons (CFCs) resulted in safe and effective refrigeration and air conditioning that was beneficial to human health, yet CFCs led to ozone destruction in the stratosphere. In contrast, the hybrid electric car helps to reduce the impact of the automobile on the environment because it has greater fuel efficiency than a conventional internal combustion vehicle. The IPAT equation originally used the term *technology*, but some scientists now use the term *destructive technology* to differentiate it from beneficial technologies such as the hybrid electric car.

The Impact of Affluence

To help gauge a country's wealth and its potential impact on the environment, environmental scientists often turn to the most commonly used measure of a nation's wealth. **Gross domestic product (GDP)** is the value of all products and services produced in one

IPAT equation An equation used to estimate the impact of the human lifestyle on the environment: Impact = population × affluence × technology.

Gross domestic product (GDP) A measure of the value of all products and services produced in one year in one country.