TABLE 8.1 Trends in China's Population Growth

MEASURE	1950	1970	1990	2015
Total fertility rate	5.8	5.8	2.2	1.7
Rate of natural increase (% per year)	1.9	2.6	1.4	0.5
Doubling time (years)	37	27	49	140
Population (billions)	0.56	0.83	1.15	1.37

Data from China Population Information and Research Center; and Population Reference Bureau, *2015 World population data sheet.*

For most of the past 2000 years, China's population was relatively stable. The first significant increases resulted from enhanced agricultural production and a powerful government during the Qing Dynasty in the 1800s. Population growth began to outstrip food supplies by the 1850s, and quality of life for the average Chinese peasant began to decline. Over the next 100 years, China's population grew slowly, at about 0.3% per year, amid food shortages and political instability. Population growth rates rose again following Mao's establishment of the People's Republic in 1949, and they have declined since the advent of the one-child policy (TABLE 8.1).

In recent decades, falling growth rates in many countries have led to an overall decline in the global growth rate (FIGURE 8.14). This decline has come about, in part, from a steep drop in birth rates. Note, however, that although the rate of growth is slowing, the absolute size of the population continues to increase. Even though our percentage increases are getting smaller year by year, these are percentages of ever-larger numbers, so we continue to add more than 88 million people to the planet each year.

Immigration and emigration play increasingly important roles in population change in our modern, international world. People regularly relocate from one nation to another to improve their economic opportunities or to flee conflict or environmental degradation in their home nation. Such migration can have significant effects on population growth in nations, such as the United States, that accept large numbers of immigrants.

Total fertility rate influences population growth

One key statistic demographers calculate to examine a population's potential for growth is the **total fertility rate (TFR),** the average number of children born per woman during her lifetime. **Replacement fertility** is the TFR that keeps the size of a population stable. For humans, replacement fertility roughly equals a TFR of 2.1. (Two children replace the mother and father, and the extra 0.1 accounts for the risk of a child dying before reaching reproductive age.) If the TFR drops below 2.1, population size in a given country (in the absence of immigration) will shrink.

Factors such as industrialization, improved women's rights (pp. 199–204), and quality health care have driven the TFR downward in many nations in recent years. All these factors have come together in Europe, where the TFR has dropped from 2.6 to 1.4 in the past half-century. Nearly every European nation now has a fertility rate below the replacement level, and populations are declining in 15 of 45 European nations. In 2015, Europe's overall annual **rate of natural increase** (also called the *natural rate of population change*)—change due to birth and death rates alone, excluding migration—was between 0.0% and 0.1%. Worldwide by 2015, 84 countries had fallen below the replacement fertility of 2.1. These low-fertility countries make up a sizeable portion of the world's population and include China (with a TFR of 1.7). TABLE 8.2 shows total fertility rates of major continental regions.

Many nations are experiencing the demographic transition

Many nations with lowered birth rates and TFRs are experiencing a common set of interrelated changes. In countries with good sanitation, effective health care, and reliable food supplies, more people than ever are living long lives. As a result, over the past 50 years the life expectancy for the average person globally has increased from 46 to 71 years as the

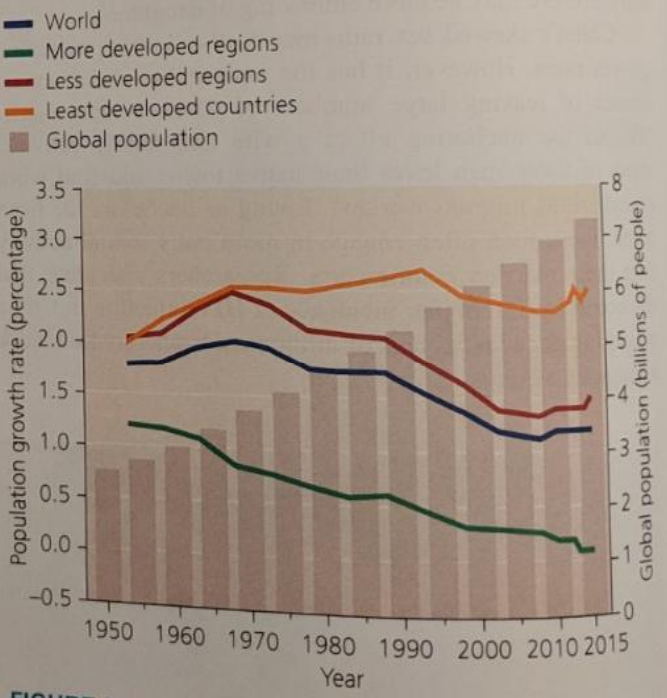

FIGURE 8.14 The annual growth rate of the global human population peaked in the late 1960s and has declined since then. Growth rates of developed nations have fallen since 1950, whereas those of developing nations have fallen since the global peak in the late 1960s. For the world's least developed nations, growth rates began to fall in the 1990s. Although growth rates are declining, global population size is still growing about the same amount each year, because smaller percentage increases of ever-larger numbers produce roughly equivalent additional amounts. *Data from Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2011.* World population prospects: The 2010 revision. *esa.un.org/unpd/wpp.* © *United Nations, 2011. Data updates for 2011–2015 from Population Reference Bureau, 2011–2015 World population data sheets.*

TABLE 8.2 Total Fertility Rates for Major Continental Regions

REGION	TOTAL FERTILITY RATE (TFR)
Africa	4.7
Australia and South Pacific	2.5
Latin America and Caribbean	2.1
Asia	2.2
North America	1.8
Europe	1.4

Data from Population Reference Bureau, *2015 World population data sheet.*

worldwide death rate has dropped from 20 deaths per 1000 people to 8 deaths per 1000 people. **Life expectancy** is the average number of years that an individual in a particular age group is likely to continue to live, but often people use this term to refer to the average number of years a person can expect to live from birth. Much of the increase in life expectancy is due to reduced rates of infant mortality. Societies going through these changes are generally those that have undergone urbanization and industrialization and have generated personal wealth for their citizens.

To make sense of these trends, demographers developed a concept called the **demographic transition.** This is a model of economic and cultural change first proposed in the 1940s and 1950s by demographer Frank Notestein to explain the declining death rates and birth rates that have occurred in Western nations as they industrialized. Notestein argued that nations move from a stable pre-industrial state of high birth and death rates to a stable post-industrial state of low birth and death rates (FIGURE 8.15). Industrialization, he proposed, causes these rates to fall by first decreasing mortality and then lessening the need for large families. Parents thereafter choose to invest in quality of life rather than quantity of children. Because death rates fall before birth rates fall, a period of net population growth results. Thus, under the demographic transition model, population growth is seen as a temporary phenomenon that occurs as societies move from one stage of development to another.

weighing the ISSUES

What Are the Consequences of Low Fertility?

In the United States, Canada, and almost every European nation, the total fertility rate is now at or below the replacement fertility rate (although some of these nations are still growing because of immigration). What economic or social consequences do you think might result from below-replacement fertility rates? Would you rather live in a society with a growing population, a shrinking population, or a stable population? Why?

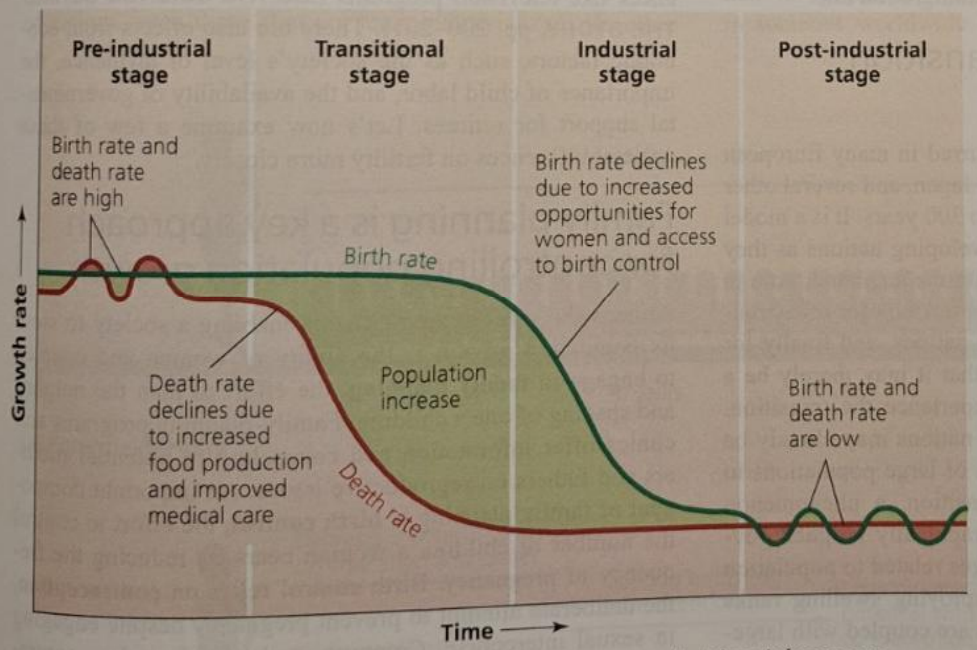

FIGURE 8.15 The demographic transition models a process that has taken some populations from a pre-industrial stage of high birth rates and high death rates to a post-industrial stage of low birth rates and low death rates. In this diagram, the wide green area between the two curves illustrates the gap between birth and death rates that causes rapid population growth during the middle portion of this process. *Adapted from Kent, M., and K. Crews, 1990. World population: Fundamentals of growth. By permission of the Population Reference Bureau.*

DATA
- In which stage of the demographic transition does population increase the most?
- Is growth greatest at the beginning or end of this stage?

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The pre-industrial stage

The first stage of the demographic transition model is the **pre-industrial stage,** characterized by conditions that have defined most of human history. In pre-industrial societies, both death rates and birth rates are high. Death rates are high because disease is widespread, medical care is rudimentary, and food supplies are unreliable and difficult to obtain. Birth rates are high because people must compensate for infant mortality by having several children and because effective methods of preventing pregnancy are not available. In this stage, children are valuable as workers who can help meet a family's basic needs. Populations within the pre-industrial stage are not likely to experience much growth, which is why the human population grew relatively slowly until the industrial revolution.

or more, as did Brazil, Canada, Colombia, Costa Rica, Cuba, Micronesia, New Zealand, Nicaragua, Paraguay, Puerto Rico, South Korea, Thailand, and Uruguay. At the other end of the spectrum, 12 African nations had rates at or below 10%.

Low usage rates for contraceptives in some societies are caused by limited availability, especially in rural areas. In others, low usage may be due to religious doctrine or cultural influences that hinder family planning, denying counseling and contraceptives to people who might otherwise use them. This can result in family sizes that are larger than the parents desire and lead to elevated rates of population growth.

In a physiological sense, access to family planning (and the civil rights to demand its use) gives women control over their **reproductive window,** the period of their life, beginning with sexual maturity and ending with menopause, in which they may become pregnant. A healthy woman can potentially bear up to 25 children within this window (**FIGURE 8.16a**), but she may choose to delay the birth of her first child to pursue education and employment. She may also use contraception to delay her first child, space births within the window, and "close" her reproductive window after achieving her desired family size (**FIGURE 8.16b**).

Family-planning programs are working around the world

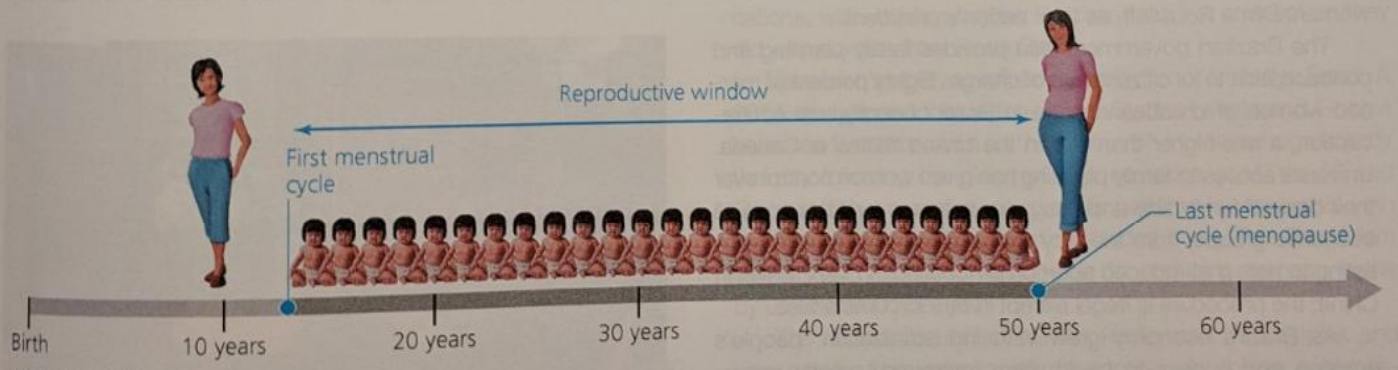
Data show that funding and policies that encourage family planning can lower population growth rates in all types of nations, even those that are least industrialized. No other nation has pursued a sustained population control program as intrusive as China's, but some rapidly growing nations have implemented programs that are less restrictive.

India was the first nation to implement population control policies. However, when some policymakers in India introduced forced sterilization in the 1970s, the resulting outcry brought down the government. Since then, India's efforts have been more modest and far less coercive, focusing on family planning and reproductive health care. This has greatly reduced rates of growth in India, but India will nonetheless likely overtake China and become the world's most populous nation in several decades because of China's more aggressive population initiatives.

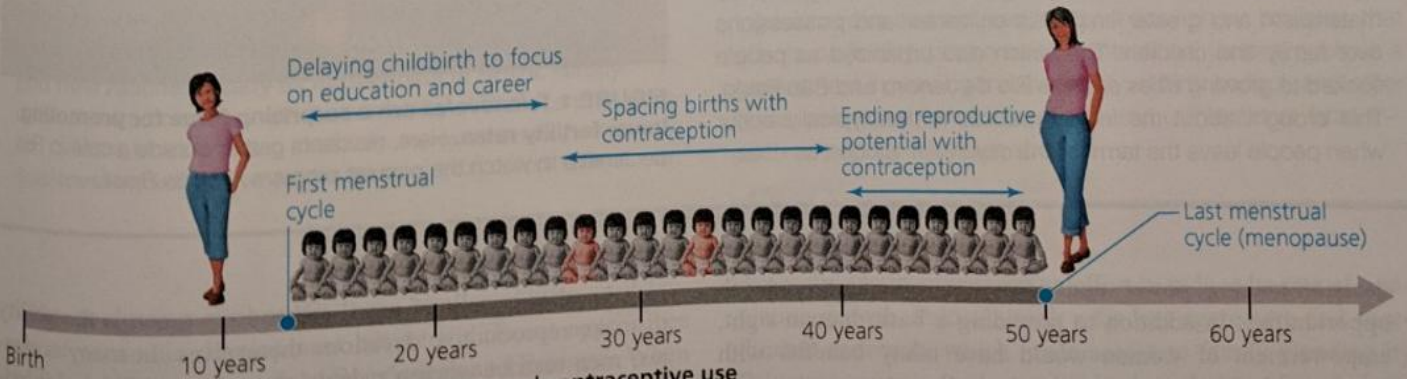
The government of Thailand has reduced birth rates and slowed population growth as well. In the 1960s, Thailand's growth rate was 2.3%, but in 2015 it was 0.4%. This decline was achieved without a one-child policy, resulting instead from an education-based approach to family planning and the increased availability of contraceptives. Brazil, Cuba, Iran, Mexico, and many other developing countries have instituted active programs to reduce their population growth; these entail setting targets and providing incentives, education, contraception, and reproductive health care.

Empowering women reduces fertility rates

Today, many social scientists and policymakers recognize that for population growth to slow and stabilize, women in societies worldwide should be granted equality in both



(a) Potential fertility



(b) Fertility reductions by delaying childbirth and contraceptive use

FIGURE 8.16 Women can potentially have very high fertility within their "reproductive window" but can choose to reduce the number of children they bear. They may do this by delaying the birth of their first child, or by using contraception to space pregnancies or to end their reproductive window at the time of their choosing.

Industrialization and falling death rates Industrialization initiates the second stage of the demographic transition, known as the **transitional stage.** This transition from the pre-industrial stage to the industrial stage is generally characterized by declining death rates due to increased food production and improved medical care. Birth rates in the transitional stage remain high, however, because people have not yet grown used to the new economic and social conditions. As a result, population growth surges.

The industrial stage and falling birth rates The third stage in the demographic transition is the **industrial stage.** Industrialization increases opportunities for employment outside the home, particularly for women. Children become less valuable, in economic terms, because they do not help meet family food needs as they did in the pre-industrial stage. If couples are aware of this, and if they have access to birth control, they may choose to have fewer children. Birth rates fall, closing the gap with death rates and reducing population growth.

The post-industrial stage In the final stage, the **post-industrial stage,** both birth and death rates have fallen to low and stable levels. Population sizes stabilize or decline slightly. The society enjoys the fruits of industrialization without the threat of runaway population growth. The United States is an example of a nation in this stage, although the U.S. population is growing faster than most other post-industrial nations because of a relatively high immigration rate.

Is the demographic transition a universal process?

The demographic transition has occurred in many European countries, the United States, Canada, Japan, and several other developed nations over the past 200 to 300 years. It is a model that may or may not apply to all developing nations as they industrialize now and in the future. On the one hand, note in Figure 8.14 (p. 196) how growth rates fell first for industrialized nations, then for less developed nations, and finally for least developed nations, suggesting that it may merely be a matter of time before all nations experience the transition. On the other hand, some developing nations may already be suffering too much from the impacts of large populations to replicate the developed world's transition, a phenomenon called **demographic fatigue.** Demographically fatigued governments face overwhelming challenges related to population growth, including educating and employing swelling ranks of young people. When these stresses are coupled with large-scale environmental degradation or disease epidemics, the society may never complete the demographic transition.

Many nations in sub-Saharan Africa are experiencing such challenges today, given their large populations and the stunningly high prevalence of HIV/AIDS. Because it removes young and productive members of society, AIDS undermines the ability of poorer nations to develop. Nations lose billions of dollars in productivity when large numbers of its citizens are battling the disease, and treatment puts a huge burden on health care systems. Children orphaned by AIDS further strain social safety nets, requiring interventions to prevent the cycle of poverty and disease from claiming yet another generation. Improved public health efforts (including sex education, contraceptives, and intravenous drug abuse policies) have slowed HIV transmission rates in many nations, however, offering hope that these nations may escape the "trap" of demographic fatigue.

Although increased prosperity for all people is a noble goal, it does come with environmental cost. Environmental scientists estimate that for people of all nations to attain the material standard of living that North Americans now enjoy, we would need the natural resources of four-and-a-half more planet Earths. Hence, whether developing nations (which include the vast majority of the planet's people) pass through the demographic transition is one of the most important and far-reaching questions for the future of our civilization and Earth's environment.

Population and Society

Demographic transition theory links the quantitative study of how populations change with the societal factors that influence (and are influenced by) population dynamics. There are many factors that affect fertility in a given society. They include public health issues, such as people's access to contraceptives and the rate of infant mortality. They also include cultural factors—such as the level of women's rights, the relative acceptance of contraceptive use, and even cultural influences like television programs (see THE SCIENCE BEHIND THE STORY, pp. 200–201). There are also effects from economic factors, such as the society's level of affluence, the importance of child labor, and the availability of governmental support for retirees. Let's now examine a few of these societal influences on fertility more closely.

Family planning is a key approach for controlling population growth

Perhaps the greatest single factor enabling a society to slow its population growth is the ability of women and couples to engage in **family planning,** the effort to plan the number and spacing of one's children. Family-planning programs and clinics offer information and counseling to potential mothers and fathers on reproductive issues. An important component of family planning is **birth control,** the effort to control the number of children a woman bears by reducing the frequency of pregnancy. Birth control relies on **contraception,** the deliberate attempt to prevent pregnancy despite engaging in sexual intercourse. Common methods of modern contraception in use today include condoms, spermicides, hormonal treatments (birth control pill/hormone injection), intrauterine devices (IUDs), and permanent sterilization through tubal ligation or vasectomy. Many family-planning organizations aid clients by offering free or discounted contraceptives.

Worldwide in 2015, 56% of women aged 15–49 reported using modern contraceptives, with rates of use varying widely among nations. China and the United Kingdom, at 84%, had the highest rate of contraceptive use of any nations. Eight European nations showed rates of contraceptive use of 70%

THE SCIENCE behind the story

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Did Soap Operas Reduce Fertility in Brazil?

Eliana La Ferrara, Bocconi University

Over the past 50 years, the South American nation of Brazil experienced the second-largest drop in fertility among developing nations with large populations—second only to China. In the 1960s, the average woman in Brazil had six children. Today, Brazil's total fertility rate is 1.9 children per woman, which is lower than that of the United States. Brazil's drastic decrease in fertility is interesting because, unlike China, it occurred without intrusive governmental policies to control its citizens' reproduction.

Brazil accomplished this, in part, by providing women equal access to education and opportunities to pursue careers outside the home. Women now make up 40% of the workforce in Brazil and graduate from college in greater numbers than men. In 2010, Brazilians elected a woman, Dilma Rousseff, as their nation's president.

The Brazilian government also provides family planning and contraception to its citizens free of charge. Eighty percent of married women of childbearing age in Brazil currently use contraception, a rate higher than that in the United States or Canada. Universal access to family planning has given women control over their desired family size and has helped reduce fertility across all economic groups, from the very rich to the very poor. It is interesting to note that induced abortion is not used in Brazil as it is in China; the procedure is illegal except in rare circumstances.

As Brazil's economy grew with industrialization, people's nutrition and access to health care improved, greatly reducing infant mortality rates. Increasing personal wealth promoted materialism and greater emphasis on career and possessions over family and children. The nation also urbanized as people flocked to growing cities such as Río de Janeiro and São Paulo. This brought about the fertility reductions that typically occur when people leave the farm for the city.

It turns out, however, that Brazil may also have had a rather unique influence affecting its fertility rates over the past several decades—soap operas (**FIGURE 1**). Brazilian soap operas, called *telenovelas* or *novelas*, are a cultural phenomenon and are watched religiously by people of all ages, races, and incomes. Each *novela* follows the activities of several fictional families, and these TV shows are wildly popular because they have characters, settings, and plot lines with which everyday Brazilians can identify.

Telenovelas do not overtly address fertility issues, but they do promote a vision of the "ideal" Brazilian family. This family is typically middle- or upper-class, materialistic, individualistic, and full of empowered women. By challenging existing cultural and religious values through their characters, *novelas* had, and continue to have, a profound impact on Brazilian society. In essence, these programs provided a model family for Brazilians to emulate—with small family sizes being a key characteristic.

In a 2012 paper in the *American Economic Journal: Applied Economics*, a team of researchers from Bocconi University in Italy, George Washington University, and the Inter-American Development Bank (based in Washington, D.C.) analyzed various parameters to investigate statistical relationships between

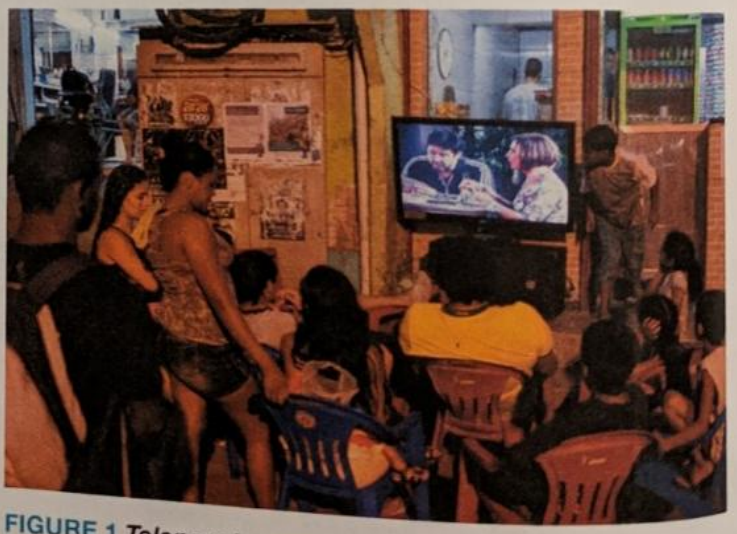

FIGURE 1 *Telenovelas* are a surprising force for promoting lower fertility rates. Here, residents gather outside a café in Río de Janeiro to watch the popular program *Avenida Brasil*.

decision-making power and access to education and job opportunities. In addition to providing a basic human right, empowerment of women would have many benefits with respect to fertility rates: Studies show that where women are freer to decide whether and when to have children, fertility rates fall, and children are better cared for, healthier, and better educated.

Another benefit of equal rights for women is the ability to make reproductive decisions themselves. In many societies, men restrict women's decision-making abilities, including decisions about how many children a woman will bear. Fertility rates have dropped most noticeably in nations where women have gained improved access to contraceptives and to family planning education. These differences are seen

telenovelas and fertility patterns in Brazil from 1965 to 2000. Rede Globo, the network that has a virtual monopoly on the most popular *novelas*, increased the number of areas that received its signal in Brazil over those 35 years (**FIGURE 2**), and it now reaches 98% of Brazilian households. By combining data on Rede Globo broadcast range with demographic data, the researchers were able to compare changes in fertility patterns over time in areas of Brazil that received access to *novelas* with areas of Brazil that did not.

The team, led by Dr. Eliana La Ferrara, found that women in areas that received the Globo signal had significantly lower fertility than those in areas not served by Rede Globo. They also found that fertility declines were age-related, with substantial reductions in fertility occurring in women aged 25–44, but not in younger women (**FIGURE 3**). The authors hypothesized that this effect was likely due to the fact that women between 25 and 44 were closer in age to the main female characters in *novelas*, who typically had no children or only a single child. The depressive effect on fertility among women in areas served by Globo was therefore attributed to wider spacing of births and earlier ending of reproduction by women over 25, rather than to younger women delaying the birth of their first child.

The researchers determined that access to television alone did not depress fertility. For example, comparisons of fertility rate in areas with access to a different television network, Sistema Brasileiro de Televisão, found no relationship. The study authors concluded that this was likely due to the reliance of Sistema Brasileiro de Televisão on programming imported from other nations, with which everyday Brazilians did not connect as they did with *novelas* from Rede Globo.

FIGURE 2 The Globo television network expanded over time and now reaches nearly all households in Brazil. Fertility declines were correlated with the availability of Globo, and its *novelas*, over the time periods in the study. *Source: La Ferrara, E., et al., 2012. Soap operas and fertility: Evidence from Brazil.* Am. Econ. J. Appl. Econ. *4: 1–31.*

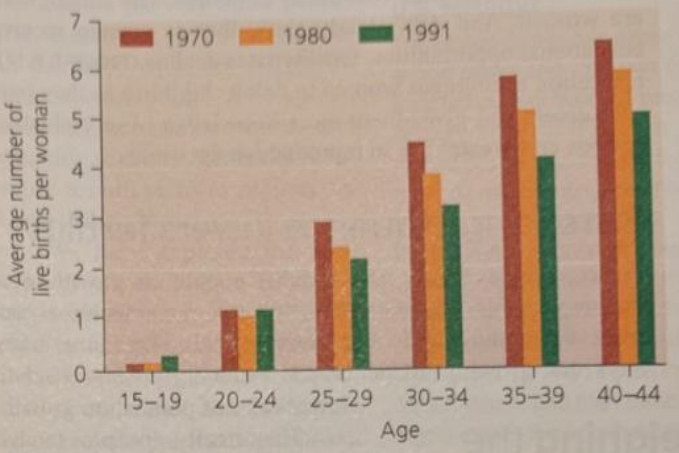

FIGURE 3 Fertility declines among Brazilian women between 1970 and 1991 were most pronounced in later age classes. The authors attribute some of this decline to women in those age classes emulating the low fertility of lead female characters in *novelas*. *Source: La Ferrara, E., et al., 2012. Soap operas and fertility: Evidence from Brazil.* Am. Econ. J. Appl. Econ. *4: 1–31.*

Television's ability to influence fertility is not limited to Brazil. A 2014 study found that in the United States, tweets and Google searches for terms such as "birth control" increased significantly the day following the airing of new episodes of MTV's *16 and Pregnant*. By correlating geographic patterns in viewership with fertility data, the study authors concluded that MTV's *Teen Mom* series may have been responsible for reducing teenage births by up to 20,000 per year.

The factors that affect human fertility can be complex and vary greatly from one society to another. As this is a correlative study (p. 13), it does not prove causation between watching *telenovelas* and reduced fertility. It does show, however, that effects on fertility can come from intentional factors, such as a government increasing the availability of birth control, and other times can come from unexpected and unintentional factors—such as popular television shows.

when comparing nations that have similar cultures and levels of economic development but very different approaches to family planning—such as Bangladesh and Pakistan. When both nations were faced with rapid population growth due to high fertility in the 1970s (with TFR in both nations hovering around 7), Bangladesh instituted a government-supported program to improve access to contraception and reproductive counseling to its citizens in an effort to reduce its rate of population growth. Pakistan took a far less aggressive and coordinated approach, which made access to family planning by Pakistani women far less reliable than that for Bangladeshi women. After 40 years of differing approaches to reproductive issues, the results are striking. While Bangladesh's TFR in 2015 had fallen to 2.3, Pakistan's TFR was 3.8 children per

woman—one of the highest in southern Asia. Expanding educational opportunities for women is an important component of equal rights. In many nations girls are discouraged from pursuing an education or are kept out of school altogether. Worldwide, more than two-thirds of people who cannot read are women. And data clearly show that as women receive educational opportunities, fertility rates decline (FIGURE 8.17). Education encourages women to delay childbirth as they pursue careers and gives them more knowledge of reproductive options and greater say in reproductive decisions.

Increasing affluence lowers fertility

Poorer societies tend to show higher population growth rates than do wealthier societies (FIGURE 8.18), as one would expect given the demographic transition model. There are many ways that growing affluence and reducing poverty lead to lower rates of population growth.

Historically, people tended to conceive many children, which helped ensure that at least some would survive. Today's improved medical care in wealthy nations has reduced infant mortality rates, making it less necessary to bear multiple children. Increasing urbanization has also driven TFR down; whereas rural families need children to contribute to farm labor, in urban areas children are usually excluded from the labor market, are required to go to school, and impose significant economic costs on their families. Moreover, if a government provides some form of social security, parents need fewer children to support them in their old age. Finally, with greater educational opportunities and changing roles in society, women tend to move into the labor force. When women are able to focus on their careers, this often acts to delay the birth of their first child until later in life or enables them to choose to not have children.

Economic factors are tied closely to population growth. Poverty exacerbates population growth, and rapid population growth worsens poverty. This connection is important because a great majority of the next billion people to be added to the global population will be born into nations in Africa, Asia, and Latin America that have emerging,

weighing the ISSUES

Should the U.S. Abstain from International Family Planning?

Over the years, the United States has joined 180 other nations in providing millions of dollars to the United Nations Population Fund (UNFPA), which advises governments on family planning, sustainable development, poverty reduction, reproductive health, and AIDS prevention in many nations, including China. From 2002 to 2008 the George W. Bush administration withheld funds from UNFPA, saying that U.S. law prohibits funding any organization that "supports or participates in the management of a program of coercive abortion or involuntary sterilization," and maintaining that the Chinese government has been implicated in both. Many nations criticized the U.S. decision, and the European Union offered UNFPA additional funding to offset the loss of U.S. contributions. Once President Obama came to office, he reinstated funding to the program. What do you think U.S. policy should be? Should the United States fund family-planning efforts in other nations? What conditions, if any, should it place on the use of such funds?

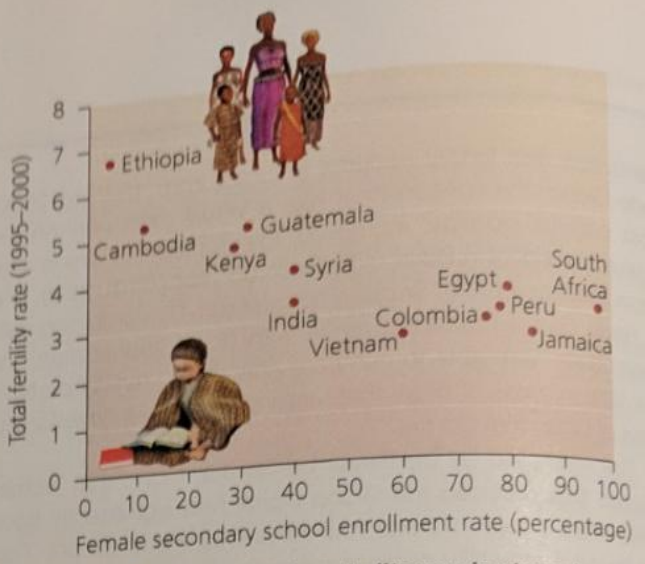

FIGURE 8.17 Increasing female literacy is strongly associated with reduced birth rates in many nations. *Data from McDonald, M., and D. Nierenberg, 2003.* Linking population, women, and biodiversity. State of the world 2003. *Washington, D.C.: Worldwatch Institute.*

DATA Is the relationship between total fertility rate and the rate of enrollment of girls in secondary school positive (as variable 1 increases, so does variable 2), negative (as variable 1 increases, variable 2 decreases), or is there no obvious relationship (increases in variable 1 are not correlated with changes in variable 2)?

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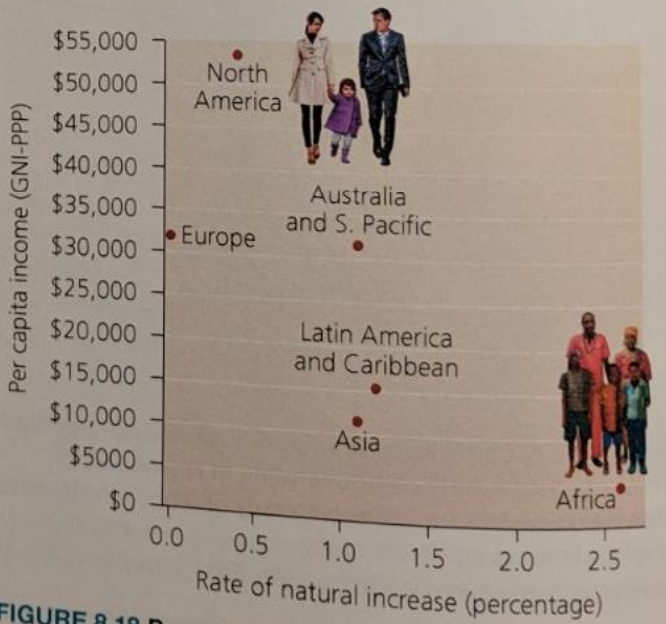

FIGURE 8.18 Poverty and population growth show a fairly strong correlation, despite the influence of many other factors. Regions with the lowest per capita incomes tend to have the most rapid population growth. Per capita income is here measured in GNI PPP, or "gross national income in purchasing power parity." GNI PPP is a measure that standardizes income among nations by converting it to "international" dollars, which indicate the amount of goods and services one could buy in the United States with a given amount of money. *Data from Population Reference Bureau, 2015 World population data sheet.*

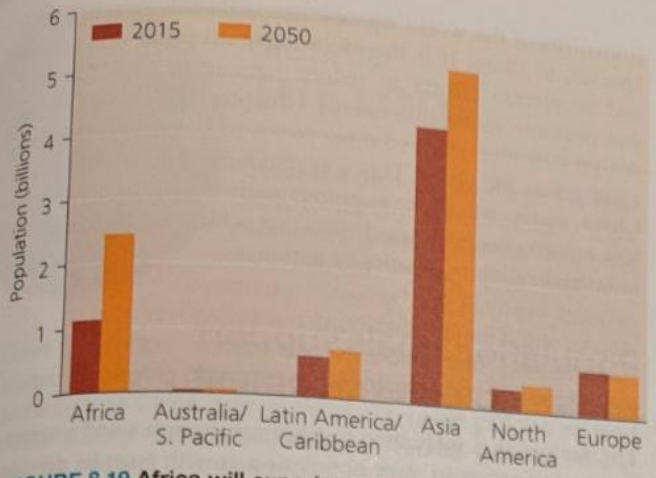

FIGURE 8.19 Africa will experience the greatest population growth of any region in coming decades. The vast majority of future population growth will occur in developing regions. The highly industrialized regions of Europe and North America are predicted to experience only minor population change. *Data from Population Reference Bureau, 2015 World population data sheet.*

DATA

- Which region will add the most people between 2015 and 2050?
- Which will increase by the greatest percentage during this time period?
- Which regions will experience very little population growth during this period?
- Propose one explanation for why the fastest-growing region will increase faster than other regions.

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developing economies (**FIGURE 8.19**). This is unfortunate from a social standpoint, because in some cases these countries, many of which already are strained by rapid population growth, will be unable to provide for them. It is also unfortunate from an environmental standpoint, because poverty often results in environmental degradation. People who depend on agriculture and live in areas of poor farmland, for instance, may need to farm even if doing so degrades the soil and is not sustainable. Poverty also drives people to cut forests and to deplete biodiversity. For example, impoverished settlers and miners hunt large mammals for "bush meat" in Africa's forests, including the great apes that are now heading toward extinction.

Expanding wealth can increase the environmental impact per person

Poverty can lead people into environmentally destructive behavior, but ironically wealth can produce even more severe and far-reaching environmental impacts. The affluence of a society such as the United States, Japan, or France is built on levels of resource consumption unprecedented in human history. Much of this chapter has dealt with numbers of people rather than with the amount of resources each member of the population consumes or the amount of waste each member produces. The environmental impact of human activities, however, depends not only on the number of people involved but also on the way those people live. Recall the *A* (for affluence) in the IPAT equation. Affluence and consumption are spread unevenly across the world, and wealthy societies generally consume resources from regions far beyond their own.

We have explored the concept of the ecological footprint, the cumulative amount of Earth's surface area required to provide the raw materials a person or population consumes and to dispose of or recycle the waste produced. Individuals from affluent societies leave considerably larger per capita ecological footprints (see Figure 1.12, p. 15). In this sense, the addition of 1 American to the world has as much environmental impact as the addition of 3.4 Chinese, 8 Indians, or 14 Afghans. This fact reminds us that the "population problem" does not lie solely with nations in the developing world but is relevant to people everywhere.

As population is rising, so is consumption, and some environmental scientists have calculated that we are already living beyond the planet's means to support us sustainably. One recent analysis concludes that humanity's global ecological footprint surpassed Earth's capacity to support us in 1971 and that our species is now living 50% beyond its means (**FIGURE 8.20**, p. 204). This is what is known as our overshoot (see Figure 1.5, p. 6). In this analysis, our ecological footprint can be compared to the amount of biologically productive land and sea available to us—an amount termed **biocapacity.** For any given area, if the footprint is greater than the biocapacity, there is an "ecological deficit." If the footprint is less than the biocapacity, there is an "ecological reserve." Because our footprint exceeds our biocapacity by 50% worldwide, we are running a global ecological deficit, gradually draining our planet of its natural capital and its long-term ability to support our civilization.

FAQ

How have societal and economic factors affected U.S. fertility?

The United States has experienced peaks and valleys in its total fertility rate over the past century. In 1913, TFR in the United States was around 3.5 children per woman, and then plunged to around 2.2 during the trying economic times of the Great Depression in the 1930s. Fertility climbed as the nation pulled out of the Great Depression, leveled off during World War II, and then climbed again during the economically prosperous period following the war (the post-war "baby boom"), peaking at 3.7 in 1957. Fertility remained high for several years and then began falling sharply in the mid-1960s, as modern contraception became widely available and women enjoyed increased opportunities to pursue higher education and employment outside the home.

Fertility rates have been largely stable around replacement level (2.1) since 1970, but may soon fall. A 2015 report by the Urban Institute found that U.S. women born after the early 1980s (the "millennial" generation) are having children at the lowest rate in American history. Surveys find that millennial women value children as much as previous generations did at their age, but many are delaying marriage and childbirth due to financial insecurity. That is, many young people state that they'd like to marry and have children but simply can't afford to do so when faced with uncertain employment prospects and relatively high levels of debt from college.

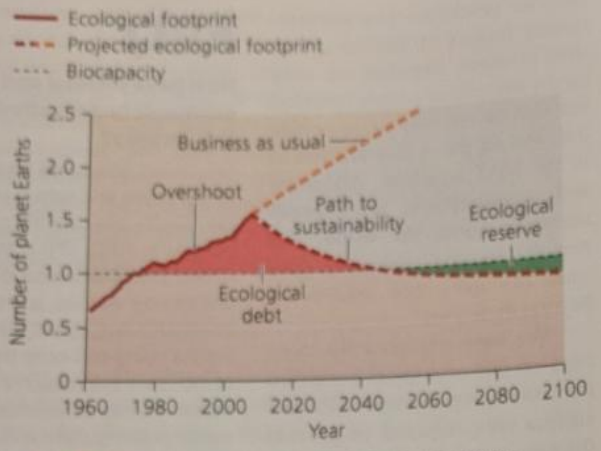

FIGURE 8.20 The global ecological footprint of the human population is estimated to be 50% greater than what Earth can bear. If population and consumption continue to rise (**orange dashed line**), we will increase our ecological deficit, or degree of overshoot, until systems give out and populations crash. If, instead, we pursue a path to sustainability (**red dashed line**), we can eventually repay our ecological debt and sustain our civilization. *Adapted from WWF, 2008.* Living planet report 2008. *Gland, Switzerland: WWF International.*

The richest one-fifth of the world's people possesses more than 80 times the income of the poorest one-fifth (FIGURE 8.21). The richest one-fifth also uses 86% of the world's resources. That leaves only 14% of global resources—energy, food, water, and other essentials—for the remaining four-fifths of the world's people, and all of the planet's other species, to share. It is therefore imperative that we continue and accelerate efforts to reduce human uses of resources, and promote renewable energy (Chapter 21), "smart" urban design (Chapter 13), and other forms of sustainable development across the globe. This way, the rapid industrialization of China, India, and other populous nations can occur with far less environmental impact than that which accompanied the industrialization of developed nations.

Population goals support sustainable development

The factors that influence fertility are complex and interacting, so initiatives to slow population growth must be diverse, flexible, and culturally specific. This call for a multifaceted approach was echoed at the milestone 1994 United Nations conference on population and development in Cairo, Egypt. The conference marked a transition away from older notions of top-down command-and-control (p. 177) population policy geared toward pushing contraception and lowering populations to preset targets. Instead, the conference organizers urged governments to offer better education and health care and to address social needs that affect population from the bottom up (such as alleviating poverty, disease, and sexism). Although nations learn from one another how to deal with rising (or shrinking) populations, it has become clear that there is no "one size fits all" solution to population issues, and programs must be as unique as the nations they are serving.

(a) A family living in the United States

(b) A family living in India

FIGURE 8.21 Material wealth varies widely from nation to nation. A typical U.S. family **(a)** may own a large house with a wealth of material possessions. A typical family in a developing nation such as India **(b)** may live in a much smaller home with far fewer material possessions. Compared with the average resident of India, the average U.S. resident shares in 10 times more economic activity, has an ecological footprint 8 times higher, and emits 10 times more carbon dioxide. Economic activity is calculated by dividing the gross national income (GNI) of each country by its population. One hectare = 2.471 acres. *Data for ecological footprints are for 2012 and are from Global Footprint Network, www.footprintnetwork.org; data for economic activity and carbon dioxide emissions are from World Bank, 2015, data.worldbank.org.*

central
CASE STUDY

Will China's New "Two-Child Policy" Defuse Its Population "Time Bomb"?

We don't need adjustments to the family-planning policy. What we need is a phaseout of the whole system.
Gu Baochang, Chinese demographer at People's University, Beijing, referring to the nation's "one-child" policy in 2013

As you improve health in a society, population growth goes down. Before I learned about it, I thought it was paradoxical.
Bill Gates, Founder, Microsoft Corporation

The People's Republic of China is the world's most populous nation, home to one-fifth of the more than 7 billion people living on Earth. It is also the site of one of the most controversial social experiments in history.

When Mao Zedong founded the country's current regime six decades ago, roughly 540 million people lived in a mostly rural, war-torn, impoverished nation. Mao's policies encouraged population growth, and by 1970 improvements in food production, food distribution, and public health allowed China's population to swell to 790 million people. At that time, Chinese women gave birth to an average of 5.8 children in their lifetimes.

However, the country's burgeoning population and its industrial and agricultural development were eroding the nation's soils, depleting its water, and polluting its air. Realizing that the nation might not be able to continue to feed its people, Chinese leaders decided in 1970 to institute a population control program that prohibited most Chinese couples from having more than one child.

The program began with outreach efforts encouraging people to marry later and have fewer children. Along with these efforts, the Chinese government increased the accessibility of contraceptives and abortion. Fertility declined with these initiatives, and by 1975 China's annual population growth rate had dropped from 2.8% to 1.8%.

In 1979, the government began rewarding one-child families with government jobs and better housing, medical care, and access to schools. Families with more than one child, meanwhile, were subjected to costly monetary fines, employment discrimination, and social scorn. The one-child program applied mostly to families in urban areas. Many farmers and ethnic minorities in rural areas were exempted, because success on the farm often depends on having multiple children. The experiment was a success in slowing population growth: The nation's growth rate is now down to 0.5%, and Chinese women now have only an average of 1.7 children in their lifetimes.

However, the one-child policy also produced a population with a shrinking labor force, increasing numbers

Will the two-child policy balance China's skewed sex ratio? ▲

Upon completing this chapter, you will be able to:

- Describe the scope of human population growth
- Discuss divergent views on population growth
- Explain how human population, affluence, and technology affect the environment
- Explain the fundamentals of demography
- Describe the concept of demographic transition
- Explain how family planning, the status of women, and affluence affect population growth

Crowded street in Shanghai, one of China's largest cities

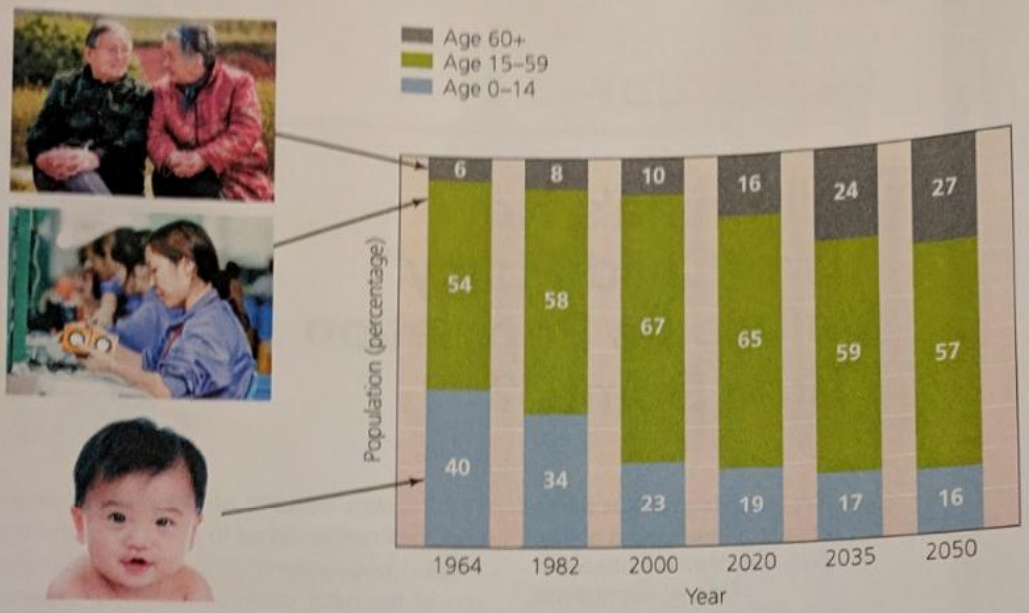

FIGURE 8.1 China's restrictive reproductive policies are leading to a shrinking workforce and rising numbers of older citizens. Values in the figure represent the percentage of the Chinese population in each age group. *Data from Population Reference Bureau, 2004.* China's Population: New Trends and Challenges.

of older people, and too few women. These unintended consequences led some demographers to question whether China's one-child policy simply traded one population problem—overpopulation—for other population problems.

The rapid reduction in fertility that resulted from this policy drastically changed China's age structure. Once consisting predominantly of young people, China's population has shifted, such that the numbers of children and older people are more even (**FIGURE 8.1**). This means there will be relatively fewer workers for China's growing economy and proportionately larger numbers of older people relying on governmental support and services.

The shrinking workforce caused by the one-child policy may now slow the growth of the thriving Chinese economy it helped to produce. Many employers in China are struggling to find workers and must pay wages up to 35% higher than they did a few years ago to keep their employees. Although this is a welcome development for workers, it threatens China's ability to produce goods as cheaply as it once did, which may induce companies to relocate from China to other nations where labor costs are lower.

The growing number of older Chinese individuals poses problems because the Chinese government lacks the resources to fully support them. And because tradition dictates that Chinese sons care for their parents and grandparents in old age, this puts a heavy economic burden on the millions of only children produced under the one-child policy.

Modern China also has too few women. Chinese culture has traditionally valued sons because they carry on the family name, assist with farm labor in rural areas, and care for aging parents. Daughters, in contrast, will most likely marry and leave their parents, as the traditional culture dictates. Thus, when faced with being limited to just one child, many Chinese couples preferred a son to a daughter. Tragically, this has led in some instances to selective abortion and the killing of female infants. This has caused a highly unbalanced ratio of young men and women in China, leading to the social instability that arises when large numbers of young men are unable to find brides and remain longtime bachelors.

Until recently, Chinese authorities attempted to address this looming population "time bomb" of an aging population with skewed ratios of men and women by occasionally loosening the one-child policy and giving some citizens greater control of their reproductive choices. For example, Chinese authorities announced in 2013 that if either member of a married couple is an only child, the couple would be allowed to have a second child—but only 1.5 million of the 11 million citizens eligible for this exemption applied for it. Faced with the prospect of continued population issues, the Chinese government announced in October 2015 that the former one-child policy would immediately become a two-child policy, and couples would be permitted to have two children without penalty.

It is unclear, however, if Chinese couples, used to the material wealth and urban lifestyle many enjoy, will embrace the opportunity to grow their families—and accept the costs of raising a second child—now that it is allowed. In 2015, 60% of Chinese women of childbearing age were over 35, so many may not wish to (or be able to) conceive a second child. In fact, an earlier survey from 2008 by China's family-planning commission reported that only 19% of the people they surveyed wished to have a second child. It may therefore be that China's relaxing of the one-child policy came too late to defuse the pending time bomb the nation may experience as China's population grays in the midst of its rapid industrialization.

China's reproductive policies have long elicited intense criticism worldwide from people who oppose government intrusion into personal reproductive choices, and such intrusion continues today, albeit with a higher allowable family size. The policy, however, has proven highly effective in slowing population growth rates and aiding the economic rise of modern China. As other nations become more crowded and they seek to emulate China's economic growth, might their governments also feel forced to turn to drastic policies that restrict individual freedoms? In this chapter, we examine human population dynamics in China and worldwide, consider their causes, and assess their consequences for the environment and human society.

Our World at Seven Billion

China receives a great deal of attention on population issues because of its unique reproductive policies and its status as the world's most populous nation. But China is not alone in dealing with population issues. India, China's neighbor, is also a population powerhouse, and is only slightly less populous than China. India lacks China's stringent reproductive policies, though, and soon will overtake China and possess the world's largest population (**FIGURE 8.2**).

Many of the world's poorer nations continue to experience substantial population growth. Some of these nations are ill-equipped to handle such growth, and this leads to stresses on society, the environment, and people's well-being. In our world of more than 7.3 *billion* people, one of our greatest challenges in this century is finding ways to slow human population growth without requiring measures such as those used in China, but rather by establishing conditions for all people that lead them to desire to have fewer children.

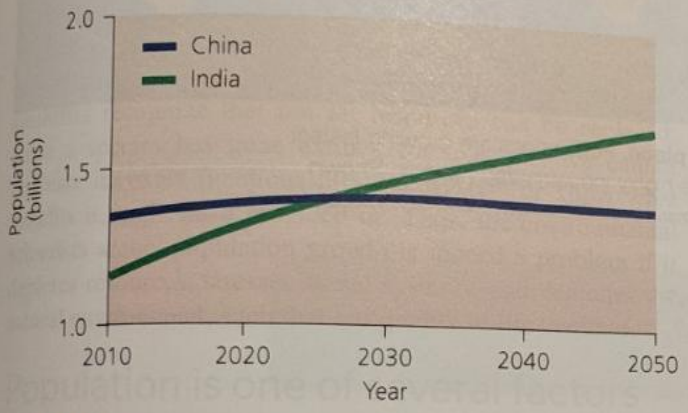

FIGURE 8.2 India will likely soon surpass China as the most populous nation. China's rate of growth is now lower than India's as a result of China's aggressive population policies. *Data from U.S. Census Bureau International Database, www.census.gov/population/international/data/idb/.*

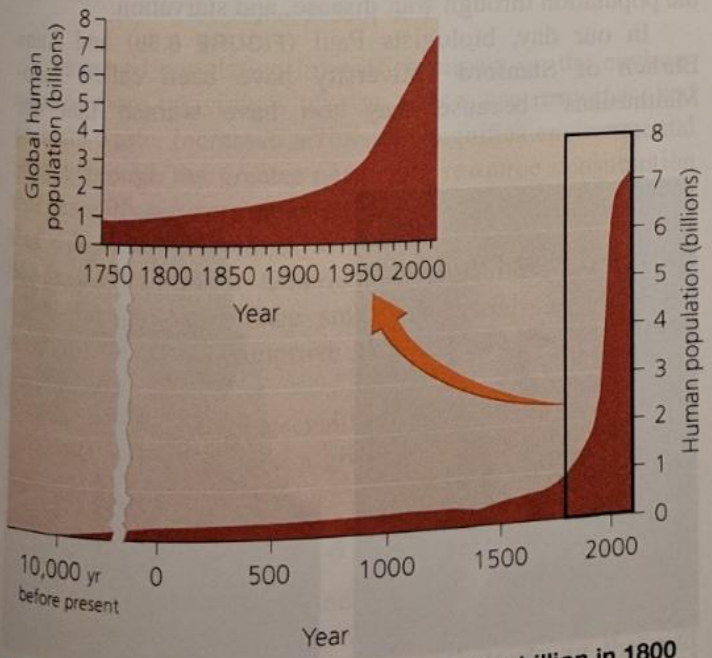

FIGURE 8.3 We have risen from fewer than 1 billion in 1800 to more than 7.3 billion today. Viewing global human population size over a long timescale **(bottom graph)** and growth since the industrial revolution **(inset top graph)** shows that nearly all growth has occurred in just the past 200 years. *Data from U.S. Census Bureau.*

The human population is growing rapidly

Our global population grows by more than 88 million people each year. This means that we add 2.8 people to the planet *every second*. Take a look at **FIGURE 8.3** and note just how recently and suddenly this increase came about.

It took until after 1800—which is recent when viewed in terms of human history—for our population to reach 1 billion. Yet we reached 2 billion by 1930 and 3 billion in just 30 more years. Our population added its next billion in just 15 years, and it has taken only 12 years to add each of the next three installments of a billion people. It is expected that the globe will be home to more than 9.7 billion people by 2050.

What accounts for our unprecedented growth? As you may recall, exponential growth—the increase in a quantity by a fixed percentage per unit time—accelerates increase in population size, just as compound interest accrues in a savings account (Chapter 3; p. 64). The reason for this pattern is that a fixed percentage of a small number makes for a small increase, but that the same percentage of a large number produces a large increase. Thus, even if the growth *rate* remains steady, population *size* will increase by greater increments with each successive generation.

For much of the 20th century, the growth rate of the human population rose from year to year. This rate peaked at 2.1% during the 1960s and has declined to 1.2% since then. Although 1.2% may sound like a small percentage of increase, exponential growth endows small numbers with large consequences. A hypothetical population starting with one man and one woman that grows at 1.2% gives rise to a population of 2939 after 40 generations and 112,695 after just 60 generations. Note that this 1.2% rate is the global average, and rates of

FAQ

How big is a billion?

Human beings have trouble conceptualizing huge numbers. As a result, we often fail to recognize the true magnitude of a number such as 7 billion. Although we know that a billion is bigger than a million, we tend to view both numbers as impossibly large and therefore similar in size. For example, guess (without calculating) how long it would take a banker to count out $1 million if she did it at a rate of a dollar a second for 8 hours a day, 7 days a week. Now guess how long it would take to count $1 billion at the same rate. The difference between your estimate and the answer may surprise you. Counting $1 million would take a mere 35 days, whereas counting $1 billion would take 95 years! Living 1 million seconds takes only 12 days, while living for 1 billion seconds requires more than 31 years. You couldn't live for 7 billion seconds—that would take 221 years. Examples like these can help us appreciate the *b* in *billion*.

closing THE LOOP

China has demonstrated that it is possible to rapidly and drastically slow population growth, but its one-child policy created demographic problems by rapidly "graying" the Chinese population and raised important human rights issues. China's neighbor India, also a population powerhouse, started employing population control initiatives at roughly the same time as China, and its initial draconian policies caused public outcry. India's subsequent relaxed policies, along with the societal changes brought about by industrialization, have acted to reduce fertility rates, but not to the extent of its neighbor to the north—which means that India will soon surpass China as the world's most populous nation.

Today's human population is larger than at any time in the past. Our growing population and our growing consumption affect the environment and our ability to meet the needs of all the world's people. However, there are at least two reasons to be encouraged. First, although global population is still rising, the rate of growth has decreased nearly everywhere, and some countries are even seeing population declines. Most developed nations have passed through the demographic transition, showing that it is possible to lower death rates while stabilizing population and creating more prosperous societies. Second, progress has been made in expanding rights for women worldwide. Although there is still a long way to go, women are obtaining better education, more economic independence, and more ability to control their reproductive decisions. Aside from the clear ethical progress these developments entail, they are also helping to slow population growth.

Human population cannot continue to rise forever. The question is how it will stop rising. Will it be through the gentle and benign process of the demographic transition as is happening in India, through restrictive governmental intervention such as China's policies, or through the miserable Malthusian checks of disease and social conflict caused by overcrowding and competition for scarce resources? How we answer this question today will determine not only the quality of the world in which we live but also the quality of the world we leave to our children and grandchildren.

REVIEWING Objectives

You should now be able to:

Describe the scope of human population growth

The human population currently stands at more than 7 billion and increases by 1.2% annually. It is predicted to rise to around 9.7 billion people by 2050. (pp. 185–188)

Discuss divergent views on population growth

Because growing populations can deplete resources, strain food supplies, and stress social systems, Thomas Malthus and Paul Ehrlich warned that overpopulation could greatly harm humanity. The contrasting Cornucopian view holds that innovation will replace consumed resources and thus that population growth can continue. (pp. 188–189)

Explain how human population, affluence, and technology affect the environment

The IPAT model summarizes how environmental impact (I) results from interactions among population size (P), affluence (A), and technology (T): $I = P \times A \times T$. Rising population and rising affluence may each increase consumption and environmental impact. Technology has frequently worsened environmental degradation, but it can also help lessen our impacts. (p. 189)

Explain the fundamentals of demography

Demography applies principles of population ecology to the statistical study of human populations. Demographers study size, density, distribution, age structure, and sex ratios of populations, as well as rates of birth, death, immigration, and emigration. (pp. 189–196)

Describe the concept of demographic transition

The demographic transition model explains why population growth slows as nations experience the process of industrialization. Economic and societal factors in agrarian societies that favored large family sizes are replaced with those that favor smaller families with industrialization and urbanization. The demographic transition may or may not proceed to completion in all of today's developing nations. (pp. 196–198)

Explain how family planning, the status of women, and affluence affect population growth

Family-planning programs, reproductive education, and access to modern contraceptives have reduced population growth in many nations. Fertility rates also tend to fall in societies that grant women equal rights to men, as women delay childbirth to pursue education and employment. Poorer societies tend to show faster population growth than do wealthier societies (pp. 198–204)

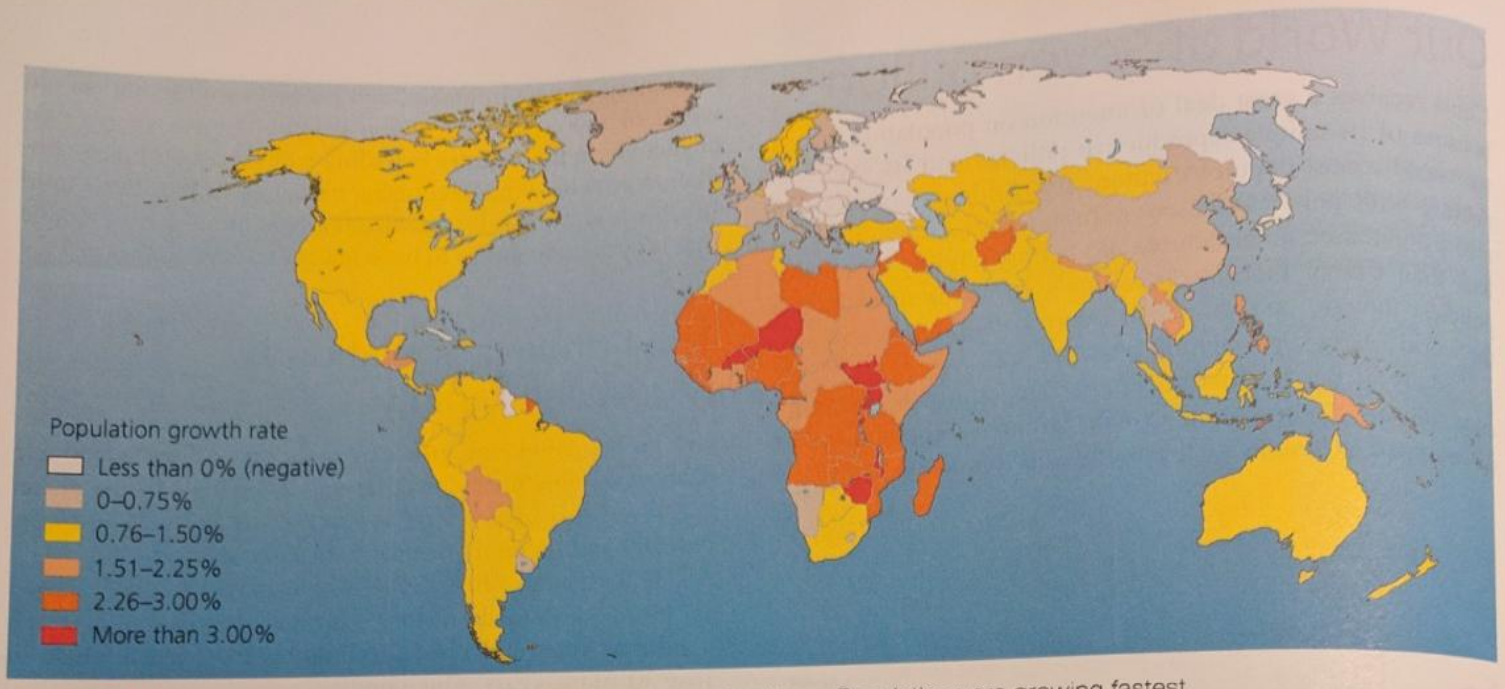

FIGURE 8.4 Population growth rates vary greatly from place to place. Populations are growing fastest in poorer nations, while populations are beginning to decrease in some highly industrialized nations. Shown are rates of natural increase as of 2015. *Data from U.S. Census Bureau International Database, www.census.gov/population/international/data/idb/.*

DATA
- Which world region has the highest population growth rates?
- Which world region has the lowest population growth rates?

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annual growth vary greatly from region to region (FIGURE 8.4) and are typically higher in developing nations.

At a 1.2% annual growth rate, a population doubles in size in just 58 years. We can roughly estimate doubling times with a handy rule of thumb. Just take the number 70 and divide it by the annual percentage growth rate: 70/1.2 = 58.3. Had China not instituted its original one-child policy, and had its growth rate remained at 2.8%, it would have taken only 25 years to double in size.

Is population growth a problem?

Our spectacular growth in numbers has resulted largely from technological innovations, improved sanitation, better medical care, increased agricultural output, and other factors that have brought down death rates. These improvements have been particularly successful in reducing **infant mortality rates,** the frequency of children dying in infancy. Birth rates have not declined as much, so births have outpaced deaths for many years now. Thus, our population explosion has arisen from a very good thing—our ability to keep more of our fellow human beings alive longer! Why, then, do so many people view population growth as a problem?

Let's start with a bit of history. At the outset of the industrial revolution (p. 5), population growth was universally regarded as a good thing. For parents, high birth rates meant more children to support them in old age. For society, it meant a greater pool of labor for factory work. However, British economist **Thomas Malthus** (1766–1834) had a different view. Malthus (FIGURE 8.5a) argued that unless population growth were controlled by laws or other social strictures, the number of people would eventually outgrow the available food supply. Malthus's most influential work, *An Essay on the Principle of Population,* published in 1798, argued that if society did not limit births (through abstinence and contraception, for instance), then rising death rates would reduce the population through war, disease, and starvation.

In our day, biologists Paul (FIGURE 8.5b) and Anne Ehrlich of Stanford University have been called "neo-Malthusians" because they too have warned that our

(a) Thomas Malthus

(b) Paul Ehrlich

FIGURE 8.5 Thomas Malthus and Paul Ehrlich each argued that runaway population growth would surpass food supply and lead to disaster.

THE SCIENCE behind the story

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Can We Map Our Population's Environmental Impact?

Dr. Helmut Haberl of Austria's Institute for Social Ecology

Burgeoning numbers of people are making heavy demands on Earth's natural resources and ecosystem services. How can we quantify and map the environmental impacts our expanding population is exerting?

One way is to ask the following question: "Of all the biomass that Earth's plants can produce, what proportion do human beings use (for food, clothing, shelter, etc.) or otherwise prevent from growing?" To answer this question, nine environmental scientists led by Helmut Haberl of the Institute for Social Ecology in Austria teamed up to measure our consumption of net primary production (NPP; p. 111), the net amount of energy stored in plant matter as a result of photosynthesis. NPP was seen as a useful measure of human impact, because our overuse of NPP diminishes resources for other species; alters habitats, communities, and ecosystems; and threatens our future ability to derive ecosystem services.

Haberl's team began with a well-established model that maps how vegetation varies with climate across the globe and used it to produce a detailed world map of "potential NPP"—vegetation that would exist if there were no human influence. The team then gathered data for the year 2000 on crop harvests, timber harvests, grazing pressure, and other human uses of vegetation from various global databases from the United Nations Food and Agriculture Organization (FAO) and other sources. They also gathered data on how people affect vegetation indirectly, such as through fires, erosion and soil degradation, and other changes due to land use. To calculate the proportion of NPP that people appropriate, the researchers divided the amounts used up in these impacts by the total "potential" amount.

When all the data crunching was done, Haberl's group concluded that people harvest 12.5% of global NPP and that our modifications associated with land use reduce it 9.6% further and fires 1.7% further still (**FIGURE 1**). This makes us responsible for using up fully 23.8% of the planet's NPP—a staggeringly large amount for just a single species! Half of this use occurred on farmed land, where 83.5% of NPP was used. In urban areas, 73.0% of NPP was consumed; on grazing land, 19.4%; and in forests, 6.6%.

To determine how human use of NPP varies across regions of the world, Haberl's group layered the data sets atop one another in a geographic information systems (GIS) approach (p. 115). Again, they calculated the proportion of NPP

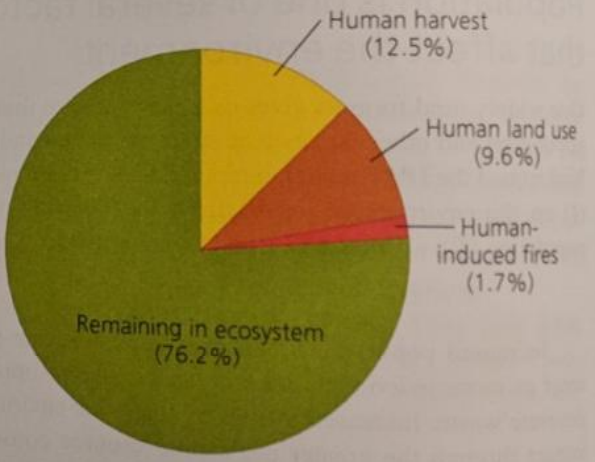


FIGURE 1 Humanity uses or causes Earth to lose 23.8% of the planet's net primary production. Direct harvesting (of crops, timber, etc.) accounts for most of this, and land use impacts and fire also contribute. *Data from Haberl, H., et al., 2007. Quantifying and mapping the human appropriation of net primary production in Earth's terrestrial ecosystems. Proc. Natl. Acad. Sci. U.S.A. 104: 12942–12947, Table 1.*

Earth has a carrying capacity for us

Environmental factors set limits on our population growth (Chapter 3), and the environment has a carrying capacity (p. 65) for our species, just as it does for every other. From an evolutionary standpoint, we happen to be a particularly successful species, however, and so we have repeatedly increased this carrying capacity by developing technology to overcome the natural limits on our population growth.

Environmental scientists who have tried to pin a number to the human carrying capacity have come up with wildly differing estimates. The most conservative estimates range from 1 to 2 billion people living prosperously in a healthy environment to 33 billion living in extreme poverty in a degraded

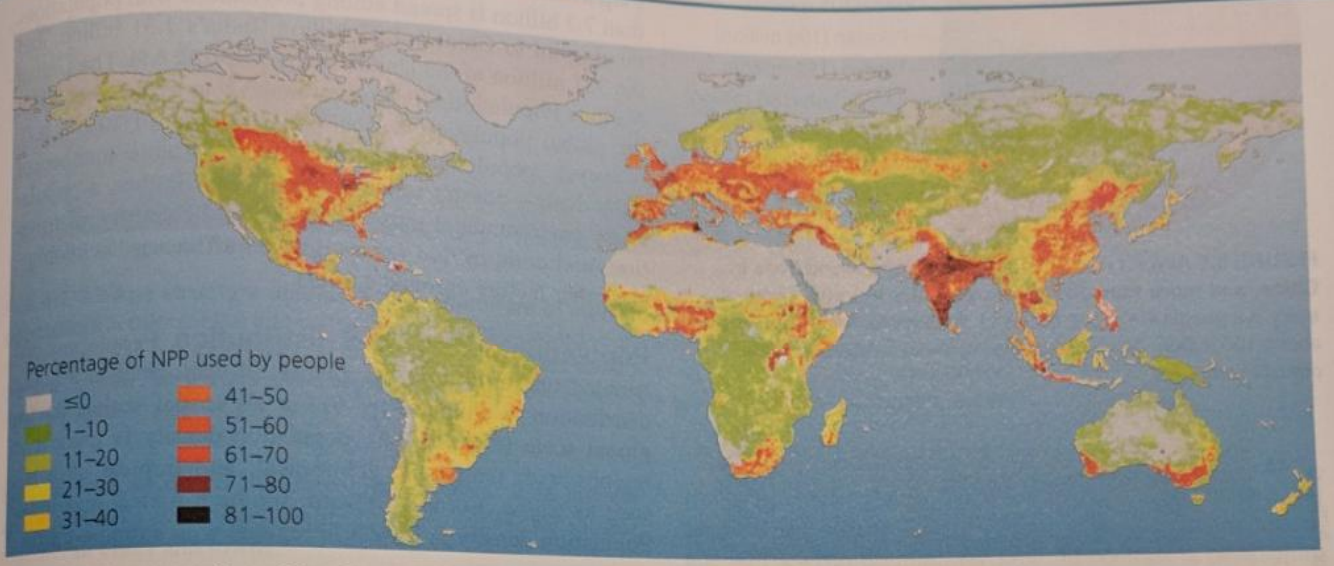


FIGURE 2 The proportion of Earth's net primary production that people appropriate varies from region to region. Regions that are densely populated or intensively farmed exert the heaviest impact. *Source: Haberl, H., et al., 2007. Quantifying and mapping the human appropriation of net primary production in Earth's terrestrial ecosystems. Proc. Natl. Acad. Sci. U.S.A. 104: 12942–12947, Fig 1b. © 2007 National Academy of Sciences, U.S.A. By permission.*

that we appropriate and produced a global map (**FIGURE 2**). The researchers published their results in 2007 in the *Proceedings of the National Academy of Sciences of the USA*.

In their global map of NPP consumption, densely populated and heavily farmed regions such as India, eastern China, and Europe show the greatest proportional use of NPP. The influence of population is clear. For instance, although people in southern Asia consume very little per capita, dense populations here result in a 63% use of NPP. In contrast, in sparsely inhabited regions of the world (such as the boreal forest, Arctic tundra, Himalayas, and Sahara Desert), humans consume almost no NPP. In North America, NPP use is heaviest in the East, Midwest, and Great Plains. In general, the map shows heavy appropriation of NPP in areas where population is dense relative to the area's vegetative production.

The map does not fully show the effects of resource consumption due to affluence. Wealthy societies tend to import food, fiber, energy, and products from other places, and this consumption can drive environmental degradation in poorer regions. For instance, North Americans and Europeans import timber logged from the Amazon basin, as well as soybeans and beef grown in areas where Amazonian forest was cleared. Through global trade, we redistribute the products we gain from the planet's NPP. As a result, the environmental impacts of our consumption are often felt far from where we consume products.

By showing areas of high and low impact, maps like the one produced in this project can help us to make better decisions and minimize our impacts on ecosystems and ecosystem services. Environmental scientists who have commented on the published paper agree and say the team's data should give us pause. As Jonathan Foley of the University of Wisconsin and his colleagues put it, "Ultimately, we need to question how much of the biosphere's productivity we can appropriate before planetary systems begin to break down. 30%? 40%? 50%? More? . . . Or have we already crossed that threshold?"

world of intensive cultivation and without wild natural areas. As our population climbs well beyond 7 billion, we may yet continue to find ways to increase our carrying capacity and preserve at least some of our current quality of life. Given our knowledge of population ecology and logistic growth (p. 65), however, we have no reason to assume that human numbers on Earth can keep growing indefinitely.

Demography is the study of human population

Just as population ecologists study such characteristics in other organisms, **demographers** study population size; density; distribution; age structure; sex ratio; and rates of birth, death, immigration, and emigration of people. Each of these

population may grow faster than our ability to produce and distribute food. In his best-selling 1968 book, *The Population Bomb*, Paul Ehrlich predicted that population growth would unleash famine and conflict that would consume civilization by the end of the 20th century.

Although human population quadrupled in the past 100 years—the fastest rate at which it has ever grown (see Figure 8.3)—Ehrlich's forecasts have not fully materialized. This is due, in part, to the way we have intensified food production in recent decades (pp. 237–238). Population growth has indeed contributed to famine, disease, and conflict—but as we shall see, enhanced prosperity, education, and increasing gender equality have also helped to reduce birth rates.

Does this mean we can disregard the concerns of Malthus and Ehrlich? Some Cornucopians (p. 144) say yes. Under the Cornucopian view that many economists hold, population growth poses no problem if new resources can be found or created to replace depleted ones. In contrast, environmental scientists recognize that not all resources can be replaced. Once a species has gone extinct, for example, we cannot replicate its exact functions in an ecosystem or know what benefits it might have provided us. Thus, the environmental scientists argue, population growth is indeed a problem if it depletes resources, stresses social systems, and degrades the natural environment, such that our quality of life declines.

Population is one of several factors that affect the environment

One widely used formula gives us a handy way to think about population and other factors that affect environmental quality. Nicknamed the **IPAT model,** it represents how our total impact (I) on the environment results from the interaction among population (P), affluence (A), and technology (T):

$$I = P \times A \times T$$

Increased population intensifies impact on the environment as more individuals take up space, use resources, and generate waste. Increased affluence magnifies environmental impact through the greater per capita resource consumption that generally has accompanied enhanced wealth. Technology that enhances our abilities to exploit minerals, fossil fuels, old-growth forests, or fisheries generally increases impact, but technology to reduce smokestack emissions, harness renewable energy, or improve manufacturing efficiency can decrease impact.

We might also add a sensitivity factor (S) to the equation to denote how vulnerable a given environment is to human pressures:

$$I = P \times A \times T \times S$$

For instance, the arid lands of western China are more sensitive to human disturbance than the moist regions of southeastern China. Plants grow more slowly in the arid west, making the land more vulnerable to deforestation and soil degradation. Thus, adding an additional person to western China has more environmental impact than adding one to southeastern China.

We could refine the IPAT equation further by adding terms for the effects of social institutions such as education, laws and their enforcement, stable and cohesive societies, and ethical standards that promote environmental well-being. Such factors all affect how population, affluence, and technology translate into environmental impact.

Impact can be thought of in various ways, but we can generally boil it down either to pollution or to resource consumption. The depletion of resources by ever-larger populations has been a focus of scientists and philosophers since Malthus's time. Today, researchers calculate that humanity is appropriating for its own use nearly one-quarter of Earth's terrestrial net primary production (see THE SCIENCE BEHIND THE STORY, pp. 190–191)—an extraordinary percentage for one species among the millions on Earth.

One reason our population has kept growing, despite limited resources, is that repeatedly we have developed technology—the T in the IPAT equation—to increase efficiency, alleviate our strain on resources, and allow the human population to expand further. For instance, we have used technological advances to increase global agricultural production faster than our population has risen (p. 237).

Modern-day China shows how all elements of the IPAT formula can combine to cause tremendous environmental impact in little time. China is the world's fastest-growing economy over the past two decades, and is "demonstrating what happens when large numbers of poor people rapidly become more affluent," in the words of Earth Policy Institute president Lester Brown. Although millions of Chinese people are increasing their material wealth and their resource consumption, the country is battling unprecedented environmental challenges brought about by its rapid economic development. Intensive agriculture has expanded into western China, and farming in this arid region has caused farmland to erode and blow away, much like the Dust Bowl tragedy that befell the U.S. heartland in the 1930s (pp. 223–224). China has overpumped aquifers and has drawn so much water for irrigation from the Yellow River that the once-mighty waterway now dries up in many stretches. Although China is reducing its air pollution from industry and charcoal-burning homes, the country faces new threats to air quality from rapidly rising numbers of automobiles. The air in Beijing is so polluted, for example, that simply breathing it on a daily basis damages the lungs to the same extent as smoking 40 cigarettes. As the world's other industrializing countries strive to attain the material prosperity that industrialized nations enjoy, they too may soon face many of the same challenges as China.

Demography

We exist within our environment as one species out of many. As such, all the principles of population ecology (Chapter 3) that apply to birds, frogs, and passenger pigeons apply to humans as well. The application of principles from population ecology to the study of statistical change in human populations is the focus of **demography.**

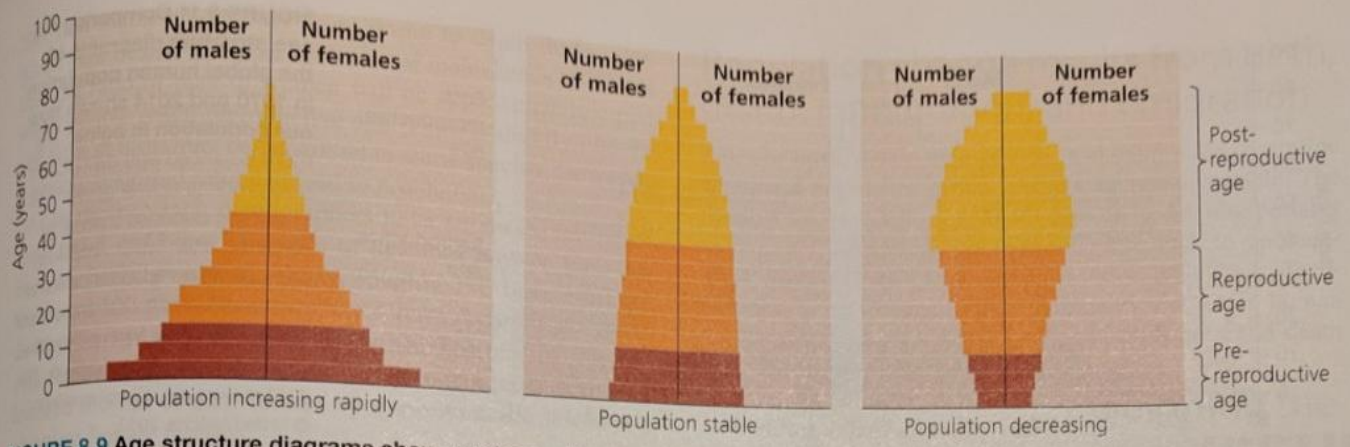


FIGURE 8.9 Age structure diagrams show numbers of individuals of different age classes in a population. A diagram like that on the left is weighted toward young age classes, indicating a population that will grow quickly. A diagram like that on the right is weighted toward old age classes, indicating a population that will decline. Populations with balanced age structures, like the one shown in the middle diagram, will remain relatively stable in size.

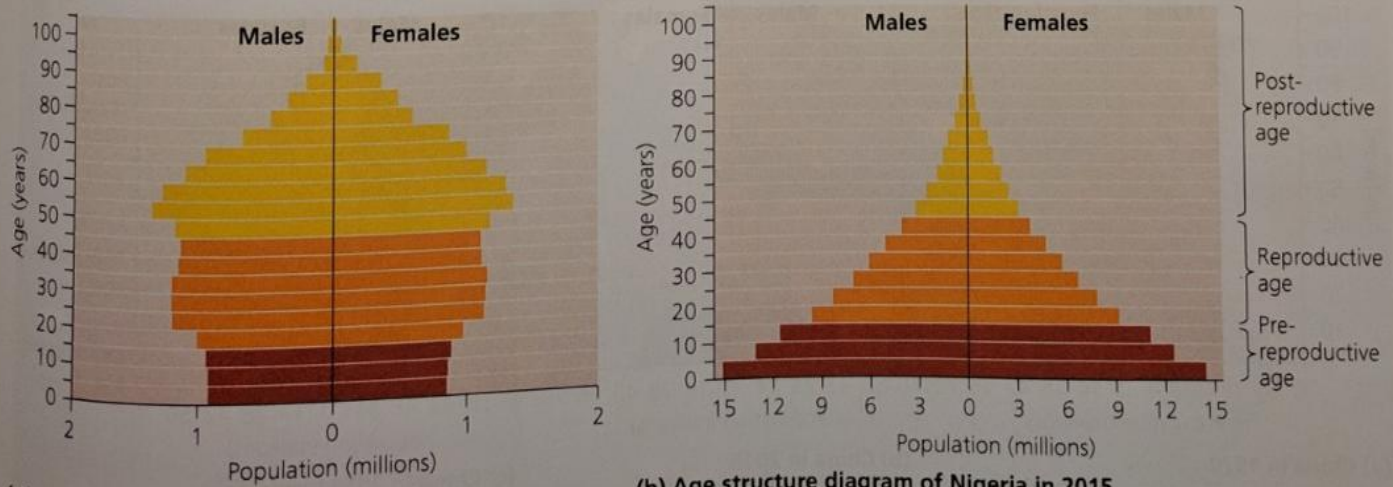
biomes, such as desert, rainforest, and tundra. It is highest along seacoasts and rivers. At more local scales, we cluster together in cities and towns.

This uneven distribution means that certain areas bear more environmental impact than others. Just as the Yellow River experiences pressure from Chinese cities and farms, the world's other major rivers, from the Nile to the Danube to the Ganges to the Mississippi, all receive greater impact because of the accompanying high population density. At the same time, some areas with low population density are sensitive (a high S value in our revised IPAT model) and thus especially vulnerable to impact. Deserts and arid grasslands, for instance, are easily degraded by development that commandeers too much water.

Age structure Age structure (p. 64) describes the relative numbers of individuals of each age class within a population. Data on age structure are especially valuable to demographers trying to predict future dynamics of human populations. A population made up mostly of individuals past reproductive age will tend to decline over time. In contrast, a population with many individuals of reproductive age or pre-reproductive age is likely to increase. A population with an even age distribution will likely remain stable as births keep pace with deaths.

Age structure diagrams, often called population pyramids, are visual tools scientists use to illustrate age structure (FIGURE 8.9). The width of each horizontal bar represents the number of people in each age class. A pyramid with a wide base denotes a large proportion of people who have not yet reached reproductive age—and this indicates a population soon capable of rapid growth. In this respect, a wide base of a population pyramid is like an oversized engine on a rocket—the bigger the booster, the faster the increase.

As an example, compare age structures for the nations of Canada and Nigeria (FIGURE 8.10). Nigeria's large concentration of individuals in young age groups portends a great deal



(a) Age structure diagram of Canada in 2015

(b) Age structure diagram of Nigeria in 2015

FIGURE 8.10 Canada (a) shows a fairly balanced age structure, whereas Nigeria (b) shows an age distribution heavily weighted toward young people. Nigeria's population growth rate (2.5%) is over six times greater than Canada's (0.4%). *Data from U.S. Census Bureau International Database, www.census.gov/population/international/data/idb/.*

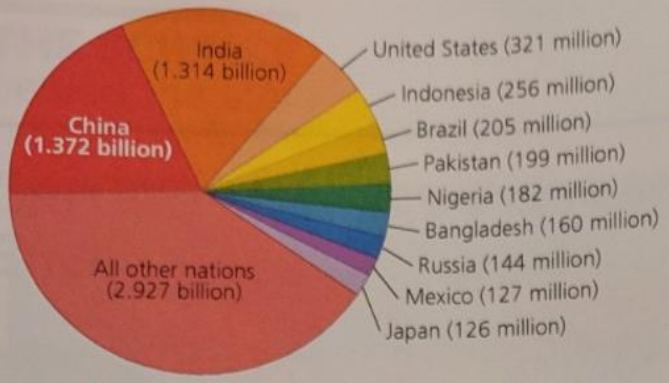
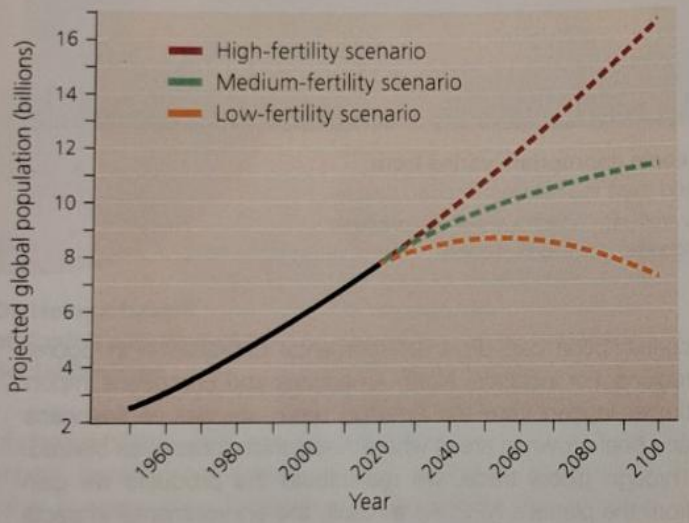


FIGURE 8.6 Almost one in five people in the world lives in China, and more than one of every six live in India. Three of every five people live in one of the 11 nations that have populations above 100 million. *Data from Population Reference Bureau,* 2015 World population data sheet.



characteristics is useful for predicting population dynamics and environmental impacts.

Population size Our global human population of more than 7.3 billion is spread among 200 nations with populations ranging up to China's 1.37 billion, India's 1.31 billion, and the 321 million of the United States (FIGURE 8.6). The United Nations Population Division estimates that by the year 2050, the global population will surpass 9.7 billion (FIGURE 8.7). However, population size alone—the absolute number of individuals—doesn't tell the whole story. Rather, a population's environmental impact depends on its density, distribution, and composition (as well as on affluence, technology, and other factors outlined earlier).

Population density and distribution People are distributed unevenly over our planet. In ecological terms, our distribution is clumped (p. 61) at all spatial scales. At the global scale (FIGURE 8.8), population density is highest in regions with temperate, subtropical, and tropical climates, such as China, Europe, Mexico, southern Africa, and India. Population density is lowest in regions with extreme-climate

FIGURE 8.7 The United Nations predicts world population growth. In the latest projection, population is estimated to reach 9.7 billion for 2050 and around 10.5 billion in 2100 using a medium-fertility scenario. In the high-fertility scenario, women on average have 0.5 child more than in the medium scenario. In the low-fertility scenario, women have 0.5 child fewer than in the medium scenario. *Adapted by permission from Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2015.* World population prospects: The 2015 revision. *esa.un.org/unpd/wpp, © United Nations, 2015.*

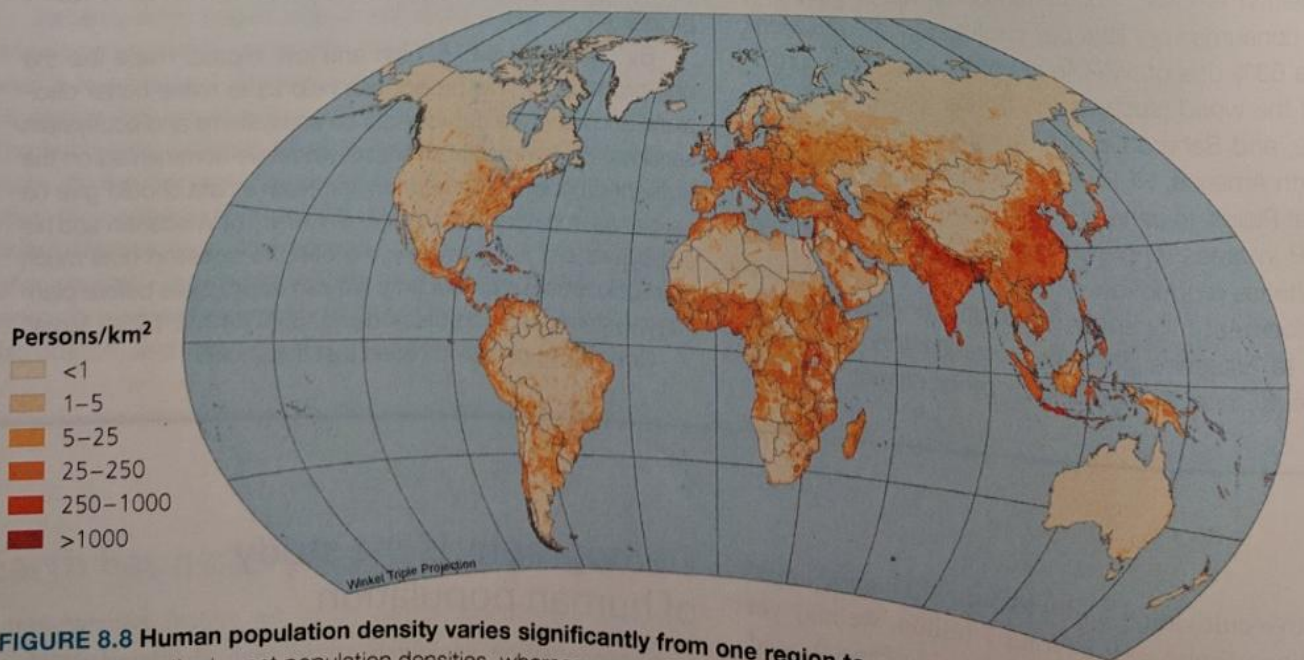


FIGURE 8.8 Human population density varies significantly from one region to another. Arctic and desert regions have the lowest population densities, whereas areas of India, Bangladesh, and eastern China have the densest populations. *Source: Center for International Earth Science Information Network–CIESIN–Columbia University, 2015.* Gridded Population of the World, Version 4 (GPWv4): Population Density. *Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC).*

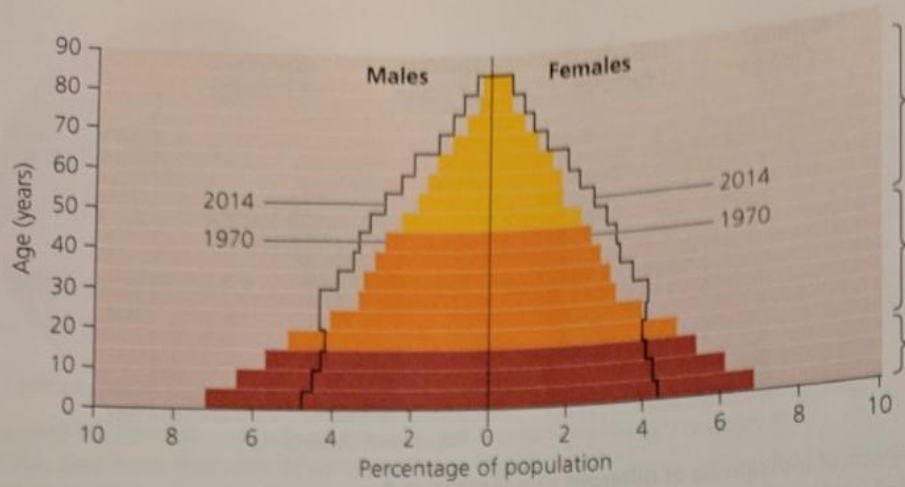


FIGURE 8.11 Comparing the age structure diagrams of the global human population in 1970 and 2014 shows how our population is aging. The more balanced age distribution also predicts slower growth in coming decades than what occurred after 1970. *Adapted by permission from Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2013. World population prospects: The 2012 revision. esa.un.org/unpd/wpp/, © United Nations, 2013.*

of reproduction. This is one of several reasons why Nigeria's population growth rate is much greater than Canada's.

Today, populations are aging in many nations, and the global population is "grayer" than in the past (FIGURE 8.11). The global median age today is 28, but it is predicted to be 38 by the year 2050. Population aging is pronounced in the United States, where the "baby boom" generation is now beginning to reach retirement age. Changing age distributions have caused concerns in some nations that have declining numbers of workers and strong social welfare programs for retirees (which are supported by current workers), such as the Social Security program in the United States. Despite the long-term benefits associated with smaller populations, many policymakers find it difficult to let go of the notion that population growth increases a nation's economic, political, and military strength. So while China and India struggle to get their population growth under control, some national governments are offering financial and social incentives that encourage their own citizens to have more children. These incentives include extended maternity and paternity leave, subsidized child care, and tax breaks for larger families.

By causing dramatic reductions in the number of children born since 1970, China's former one-child policy virtually guaranteed that the nation's population age structure would change. Indeed, in 1970 the median age in China was 20; by 2050 it is predicted to be 45. Today there are 130 million Chinese people older than 65, but that number is expected to triple by 2050 (FIGURE 8.12). Although graying populations have benefits–such as increased charitable contributions to society by retirees–the dramatic shift in age structure will challenge China's economy, health care system, families, and military forces because fewer working-age people will be available to support social programs to assist the rising number of older people.

Sex ratios The ratio of males to females also can affect population dynamics. Note that population pyramids give data on sex ratios by representing numbers of males and females on opposite sides of each diagram. The naturally occurring sex ratio at birth in human populations features a slight preponderance of males; for every 100 female infants born, about 106 male infants are born. This phenomenon is likely an evolutionary adaptation (p. 49) to account for the

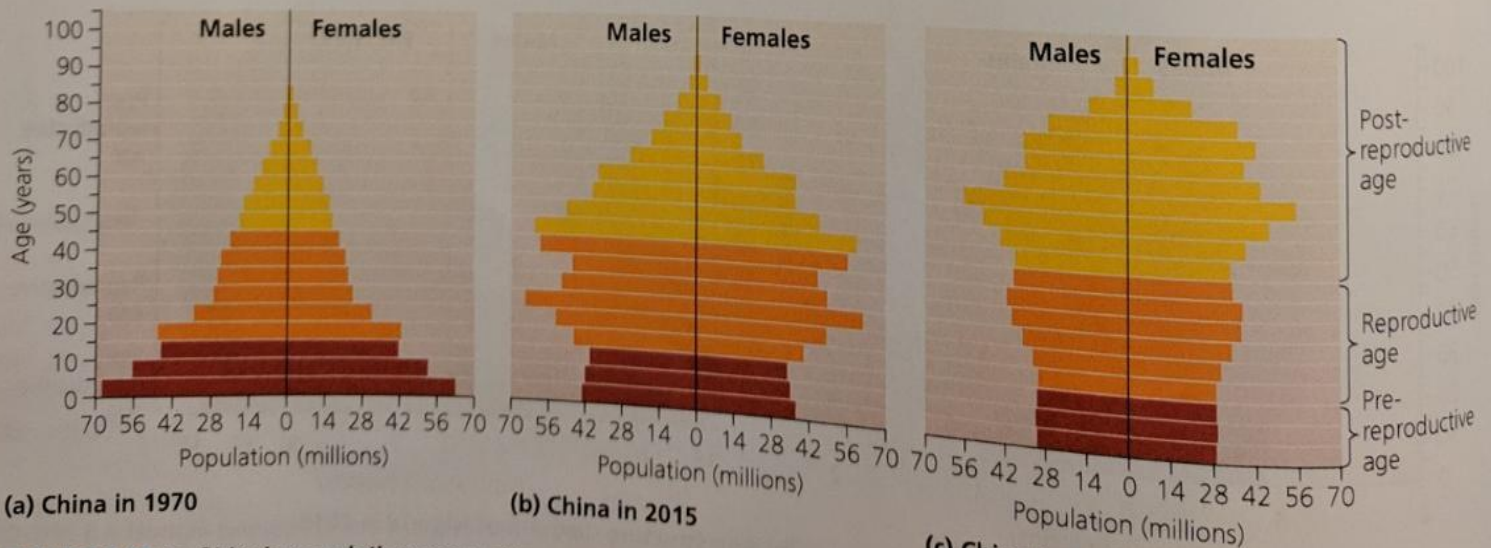


FIGURE 8.12 As China's population ages, older people will outnumber the young. China's "one child" policy was highly successful in reducing birth rates but also in significantly changing China's age structure. Population pyramids show the predicted graying of the Chinese population from **(a)** 1970 to **(b)** 2015 to **(c)** what is predicted for 2050. *Data from U.S. Census Bureau International Database, www.census.gov/population/international/data/idb.*

fact that males are slightly more prone to death during any given year of life. A higher birth rate of males tends to ensure that the ratio of men to women will be approximately equal when people reach reproductive age. Thus, a slightly uneven sex ratio at birth may be beneficial to some species. However, a greatly distorted ratio can lead to problems.

In recent years, demographers have witnessed an unsettling trend in China: The ratio of newborn boys to girls has become heavily skewed. Today, roughly 116 boys are born for every 100 girls. Some provinces have reported sex ratios as high as 138 boys for every 100 girls. The leading hypothesis for these unusual sex ratios is that many parents, having learned the sex of their fetuses by ultrasound, are selectively aborting female fetuses.

Recall that Chinese culture has traditionally valued sons over daughters. Sociologists maintain that this cultural gender preference, combined with the government's one-child policy, has led some couples to selectively abort female fetuses or to abandon or kill female infants. The Chinese government reinforced this gender discrimination when, in 1984, it exempted rural peasants from the one-child policy if their first child was a girl but not if the first child was a boy. Chinese authorities are hoping that the liberalization of their reproductive policies instituted in 2015 may help combat this skewed sex ratio, as parents will no longer be constrained to having only one child and therefore may be more embracing of daughters.

China's skewed sex ratio may further lower population growth rates. However, it has the undesirable social consequence of leaving large numbers of Chinese men single. Without the anchoring effect a wife and family provide, many of these men leave their native towns and find work elsewhere as migrant workers. Living as bachelors far from home, these men often engage in more risky sexual activity than their married counterparts. Researchers speculate that this could lead to higher incidence of HIV infection in China in coming decades, as tens of millions of bachelors find work as migrant workers.

Population change results from birth, death, immigration, and emigration

Rates of birth, death, immigration, and emigration determine whether a population grows, shrinks, or remains stable. The formula for measuring population growth (p. 64) also pertains to people: Birth and immigration add individuals to a population, whereas death and emigration remove individuals. Technological advances have led to a dramatic decline in human death rates, widening the gap between birth rates and death rates and resulting in the global human population expansion.

Falling infant mortality rates have played an especially large role in population growth. Throughout much of human history, parents needed to have larger families as insurance against the likelihood that one or more of their children would die during infancy. Poor nutrition, disease, exposure to hostile elements, and limited medical care claimed the lives of many infants in their first year of life. As societies have industrialized and become more affluent, infant mortality rates have plummeted as a result of better nutrition, prenatal care, and the presence of medically trained practitioners during birth.

As shown in **FIGURE 8.13**, infant mortality rates vary widely around the world and are closely tied to a nation's level of industrialization. China, for example, saw its infant mortality rate drop from 47 children per 1000 live births in 1980 to 16 children per 1000 live births in 2013 as the nation industrialized and prospered. Many other industrializing nations enjoyed similar success in reducing infant mortality during this time period.

weighing the ISSUES

China's Reproductive Policy

Consider the benefits as well as the problems associated with a reproductive policy such as China's. Do you think a government should be able to enforce strict penalties for citizens who fail to abide by such a policy? If you disagree with China's policy, what alternatives can you suggest for dealing with the resource demands of a rapidly growing population?

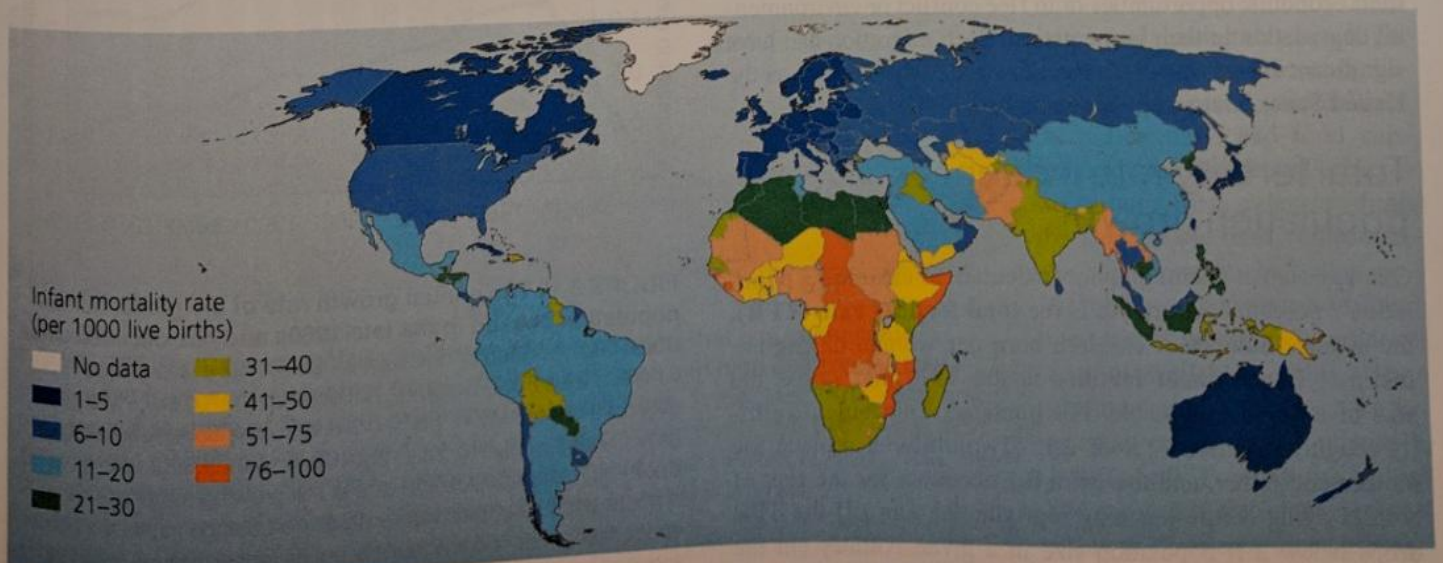


FIGURE 8.13 Infant mortality rates are highest in poorer nations, such as in sub-Saharan Africa, and lowest in wealthier nations. Industrialization brings better nutrition and medical care, which greatly reduce the number of children dying in their first year of life. *Data from Population Reference Bureau,* 2015 World population data sheet.