

The doubling time for the human population is easily calculated by dividing the number 70 by the annual rate of increase. Thus, at a 1 percent rate of annual increase, the population will double in 70 years (70/1). At a 2 percent rate of annual increase, the human population will double in 35 years (70/2). The current worldwide annual increase of about 1.2 percent will double the world human population in about 58 years.

HUMAN POPULATION CHARACTERISTICS AND IMPLICATIONS

The human population dilemma is very complex. To appreciate it, we must understand current population characteristics and how they are related to social, political, and economic conditions.

ECONOMIC DEVELOPMENT

The world can be divided into two segments based on the state of economic development of the countries. The **more-developed countries** of the world typically have a per capita income that exceeds US \$10,000; they include all of Europe, Canada, the United States, Australia, New Zealand, and Japan, with a combined population of about 1.2 billion people. The remaining countries of the world are referred to as **less-developed countries** and typically have a per capita income of less than US \$5000. The population

of these countries totals almost 5.5 billion people, nearly 3 billion of whom live on less than US \$2 per day. While these definitions constitute an oversimplification and some countries are exceptions, basically this means that the majority of Asian, Latin American, and African citizens are much less well off economically than those who live in the more-developed countries. Collectively, the more-developed countries of the world have relatively stable populations and are expected to grow by about 5 percent between 2008 and 2050. The less-developed regions of the world, however, have high population growth rates and are expected to grow by about 47 percent between 2008 and 2050. (See figure 7.12.) If these trends continue, the total population of the less-developed world will increase from the current 5.5 billion to over 8 billion by 2050, when this region will contain over 86 percent of the world's people.

MEASURING THE ENVIRONMENTAL IMPACT OF A POPULATION

Human population growth is tied to economic development and is a contributing factor to nearly all environmental problems. Current population growth has led to

1. famine in areas where food production cannot keep pace with increasing numbers of people;
2. political unrest in areas with great disparities in the availability of resources (jobs, goods, food);
3. environmental degradation (erosion, desertification, strip mining, oil spills, groundwater mining) caused by poor agricultural

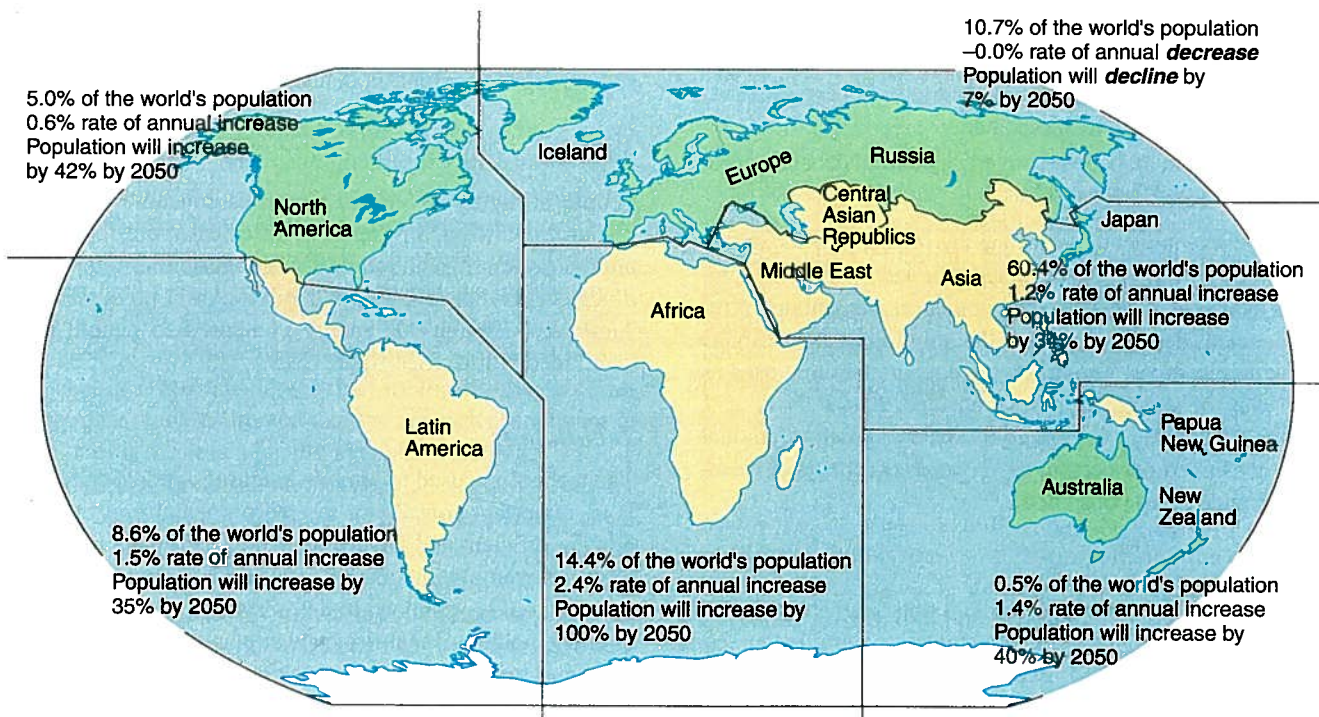


FIGURE 7.12 Population Growth and Economic Development (2008) The population of the world is not evenly distributed. It can be divided into the economically more-developed and less-developed nations. The more-developed nations are indicated in green and the less-developed in tan. Currently, about 33 percent of the world's population is in the less-developed nations of Latin America, Africa, and Asia. These areas also have the highest rates of population increase. Because of the high birthrates, they are likely to remain less developed and will constitute about 86 percent of the world's population by the year 2050.

CASE STUDY 7.1

THOMAS MALTHUS AND HIS ESSAY ON POPULATION

In 1798, Thomas Robert Malthus, an Englishman, published an essay on human population. In it, he presented an idea that was contrary to popular opinion. His basic thesis was that human population increased in a geometric or exponential manner (2, 4, 8, 16, 32, 64, etc.), while the ability to produce food increased only in an arithmetic manner (1, 2, 3, 4, 5, 6, etc.). The ultimate outcome of these different rates would be that population would outgrow the ability of the land to produce food. He concluded that wars, famines, plagues, and natural disasters would be the means of controlling the size of the human population. His predictions were hotly debated by the intellectual community of his day. His assumptions and conclusions were attacked as erroneous and against the best interest of society. At the time he wrote the essay, the popular opinion was that human knowledge and "moral constraint" would be able to create a world that would supply all human needs in abundance. One of Malthus's basic postulates was that "commerce between the sexes" (sexual intercourse) would continue unchanged,



Thomas Robert Malthus

while other philosophers of the day believed that sexual behavior would take less procreative forms and human population would be limited. Only within the past 50 years, however, have really effective conception-control mechanisms become widely accepted and used, and they are used primarily in developed countries.

Malthus did not foresee the use of contraception, major changes in agricultural production techniques, or the exporting of excess people to colonies in the Americas, Australia, and other parts of the world. These factors, as well as high death rates, prevented the most devastating of his predictions from coming true. However, in many parts of the world today, people are experiencing the forms of population control (famine, epidemic disease, wars, and natural disasters) predicted by Malthus in 1798. Many people feel that his original predictions were valid—only his timescale was not correct—and that we are seeing his predictions come true today.

practices and the destructive effects of exploitation of natural resources;

4. water pollution caused by human and industrial waste;
5. air pollution caused by the human need to use energy for personal and industrial applications; and
6. extinctions caused by people converting natural ecosystems to managed agricultural ecosystems.

Several factors interact to determine the impact of a society on the resources of its country. These include the land and other natural resources available, the size of the population, the amount of resources consumed per person, and the environmental damage caused by using resources. The following equation is often used as a shorthand way of stating these relationships: $I = P \times A \times T$ (Impact on the environment = Population size \times Affluence (amount of resources consumed per person) \times Technology (effects of methods used to provide items consumed)).

Population

As the population of a country increases, it puts a greater demand on its resources. Some countries have abundant natural resources, such as good agricultural land, energy resources, or mineral resources. Others are resource poor. Thus, some countries can sustain high populations while others cannot.

Population density, the number of people per unit of land area, relates the size of the population to the resources available. A million people spread out over the huge area of the Amazon

Basin have much less impact on resources than that same million people in a small island country because the impact is distributed over a greater land surface. Countries with abundant resources can sustain higher population densities than resource-poor countries.

Affluence

People in highly developed countries consume huge amounts of resources. Citizens of these countries eat more food, particularly animal protein, which requires larger agricultural inputs than does a vegetarian diet. They have more material possessions and consume vast amounts of energy compared to people in the less-developed world. (See figure 7.13.)

Technology

The technology used to provide the things people consume and use is an important contributor to environmental impact. Some methods are efficient and have minor impacts; others are very damaging. For example, the use of firewood to heat homes and provide fuel for cooking can lead to deforestation. Similarly, the use of inefficient, polluting, coal-fired power plants has a high environmental impact. More efficient power plants or the use of wind or solar energy to provide energy lowers environmental impact.

The affluence and technology components of this equation are very difficult to tease apart. Often the per-capita energy consumption is used as a measure of the combined effects of affluence and technology.



Possessions of an Indian family



Possessions of an American family

FIGURE 7.13 Differences in Affluence These two families have greatly different numbers of possessions. Those with more possessions have a greater ecological footprint.

THE ECOLOGICAL FOOTPRINT CONCEPT

The environmental impact of the developed world is often underestimated because the population in these countries is relatively stable and local environmental conditions are good. However, developed countries purchase goods and services from other parts of the world, often degrading environmental conditions in less-developed countries. Thus, the environmental impact of highly developed regions such as North America, Japan, Australia, New Zealand, and Europe is often felt in distant places, while the impact on resources in the developed region may be minimal.

This has led to the development of the concept of the ecological footprint of a society. The **ecological footprint** is a measure of the land area required to provide the resources and absorb the wastes of a population. Most of the more-developed countries of the world have a much larger ecological footprint than is represented by their land area. For example, Japan has a highly developed economy but few resources. Thus, it must import most of the materials it needs. One study calculated that the ecological impact of Japan is nearly five times larger than its locally available resources. The same study estimated that the ecological footprint of the United States is 1.5 times locally available resources.

It is clear that as the world human population continues to increase, it will become more difficult to limit the environmental degradation that accompanies it. Since much of the population growth will occur in the less-developed areas of the world that have weak economies, the money to invest in pollution control, health programs, and sustainable agricultural practices will not be present.

While controlling world population growth would not eliminate all environmental problems, it could reduce the rate at which environmental degradation is occurring. It is also generally believed that the quality of life for many people in the world would improve if their populations grew less rapidly. Why, then, does the human population continue to grow at such a rapid rate?

FACTORS THAT INFLUENCE HUMAN POPULATION GROWTH

Human populations are subject to the same biological factors discussed earlier in this chapter. There is an ultimate carrying capacity for the human population. Eventually, limiting factors will cause human populations to stabilize. However, unlike other kinds of organisms, humans are also influenced by social, political, economic, and ethical factors. We have accumulated knowledge that allows us to predict the future. We can make conscious decisions based on the likely course of events and adjust our lives accordingly. Part of our knowledge is the certainty that as populations continue to increase, death rates and birthrates will become equal. This can happen by allowing the death rate to rise or by choosing to limit the birthrate. Controlling human population would seem to be a simple process. Once people understand that lowering the birthrate is more humane than allowing the death rate to rise, they should make the “correct” decision and control their birthrates; however, it is not quite that simple.

BIOLOGICAL FACTORS

The scientific study of human populations, their characteristics, how these characteristics affect growth, and the consequences of that growth is known as **demography**. Demographers can predict the future growth of a population by looking at several biological indicators.

Birthrate and Death Rate

Currently, in most countries of the world, the birthrate exceeds the death rate. Therefore, the size of the population must increase. (See table 7.2.) Some countries that have high birthrates and high

TABLE 7.2 Population Characteristics of the 20 Most Populous Countries, 2008

Country	Current Population (Millions)	Births per 1000 Individuals	Deaths per 1000 Individuals	Infant Mortality Rate (Deaths per 1000 Live Births)	Total Fertility Rate (Children per Woman per Lifetime)	% Married Women Using Birth Control	Rate of Natural Increase (Annual %)	Projected Population Changes 2008–50 (%)
World	6705	21	8	49	2.6	62	1.2	39
Russia	141.9	12	15	9	1.4	67	(-0.3)	(-22)
Germany	82.2	8	10	3.9	1.3	75	(-0.2)	(-13)
Japan	127.7	9	9	2.8	1.3	52	0.0	(-25)
China	1324.7	12	7	23	1.6	90	0.5	8
Thailand	66.1	13	8	16	1.6	72	0.5	4
United States	304.5	14	8	6.6	2.1	73	0.6	44
Vietnam	86.2	17	5	16	2.1	78	1.2	31
Turkey	74.8	19	6	23	2.2	71	1.2	19
Brazil	195.1	20	6	24	2.3	76	1.3	33
Iran	72.2	20	5	32	2.1	79	1.4	39
Indonesia	239.9	21	6	34	2.6	61	1.5	43
India	1149.3	24	8	57	2.8	31	1.6	53
Mexico	107.7	20	5	19	2.3	71	1.6	22
Bangladesh	147.8	24	7	52	2.7	56	1.7	46
Egypt	74.9	27	6	33	3.1	59	2.0	57
Philippines	90.5	26	5	25	3.3	51	2.1	66
Pakistan	172.8	31	8	75	4.1	30	2.2	71
Nigeria	148.1	43	18	100	5.9	12	2.5	91
Ethiopia	79.1	40	15	77	5.3	15	2.5	87
Democratic Republic of Congo	66.5	44	13	92	6.5	21	3.1	185

Source: Population Reference Bureau, 2008 Population Data Sheet.

death rates—with birthrates greatly exceeding the death rates—will grow rapidly (Nigeria and Ethiopia). Such countries usually have an extremely high mortality rate among children because of disease and malnutrition; but because the birthrate still greatly exceeds the death rate, the populations will grow rapidly.

Some countries have high birthrates and low death rates and will grow rapidly (Mexico and Indonesia). Infant mortality rates are moderately high in these countries. Other countries have low birthrates and death rates that closely match the birthrates; they will grow slowly (Japan and the United States). These and other more-developed countries typically have very low infant mortality rates. The disruption caused by the political upheaval in the former Soviet Union and Eastern Europe has resulted in several countries (e.g., Russia and Germany) having death rates that are equal to or exceed birthrates, causing their populations to decline. Because of these countries and the generally low rates of growth in the rest of Europe, the European region as a whole has a declining population.

Total Fertility Rate

The most important determinant of the rate at which human populations grow is related to how many women in the population are

having children and the number of children each woman will have. The **total fertility rate** of a population is the number of children born per woman in her lifetime. A total fertility rate of 2.1 is known as **replacement fertility**, since parents produce 2 children who will replace the parents when they die. Eventually, if the total fertility rate is maintained at 2.1, population growth will stabilize. A rate of 2.1 is used rather than 2.0 because some children do not live very long after birth and therefore will not contribute to the population for very long. When a population is not growing, and the number of births equals the number of deaths, it is said to exhibit **zero population growth**.

For several reasons, however, a total fertility rate of 2.1 will not necessarily immediately result in a stable population with zero growth. First, the death rate may fall as living conditions improve and people live longer. If the death rate falls faster than the birthrate, there will still be an increase in the population even though it is reproducing at the replacement rate.

Age Distribution

The **age distribution**, the number of people of each age in the population, also has a great deal to do with the rate of population

growth. If a population has many young people who are raising families or who will be raising families in the near future, the population will continue to increase even if the families limit themselves to two children. Depending on the number of young people in a population, it may take 20 years to a century for the population of a country to stabilize so that there is no net growth.

SOCIAL FACTORS

It is clear that populations in economically developed countries of the world have low fertility rates and low rates of population growth and that the less-developed countries have high fertility rates and high population growth rates. It also appears obvious that reducing fertility rates would be to everyone's advantage; however, not everyone in the world feels that way. Several factors influence the number of children a couple would like to have. Some are religious, some are traditional, some are social, and some are economic.

Culture and Traditions

The major social factors that determine family size are the status and desires of women in the culture. In many male-dominated cultures, the traditional role of women is to marry and raise children. Often this role is coupled with strong religious input as well. Typically, little value is placed on educating women, and early marriage is encouraged. In these cultures, women are totally dependent on their husbands and children in old age. Because early marriage is encouraged, fertility rates are high, since women are exposed to the probability of pregnancy for more of their fertile years. Lack of education reduces options for women in these cultures. They do not have the option to not marry or to delay marriage and thus reduce the number of children they will bear.

By contrast, in much of the developed world, women are educated, delay marriage, and have fewer children. It has been said that the single most important activity needed to reduce the world population growth rate is to educate women. Whenever the educational level of women increases, fertility rates fall. Figure 7.14 compares total fertility rates and educational levels of women in the 20 most populous countries of the world. The educational level of women is strongly correlated with the total fertility rate and economic well-being of a population.

Data on the age at which women marry and have children are strongly correlated with total fertility rate. Early marriage results in women being exposed to the probability of pregnancy for a longer period of their lives and results in a higher total fertility rate. Table 7.3 compares the age of marriage and total fertility rate.

Even childrearing practices have an influence on population growth rates. In countries where breast feeding is practiced, several benefits accrue. Breast milk is an excellent source of nutrients for the infant as well as a source of antibodies against some diseases. Furthermore, since many women do not return to a normal reproductive cycle until after they have stopped nursing, during the months a woman is breast

feeding her child, she is less likely to become pregnant again. Since in many cultures, breast feeding may continue for one to two years, it serves to increase the time between successive births. Increased time between births results in a lower mortality among women of childbearing age.

Attitudes Toward Birth Control

As women become better educated and obtain higher-paying jobs, they become financially independent and can afford to marry later and consequently have fewer children. Better-educated women are also more likely to have access to and use birth control. In economically advanced countries, a high proportion of women typically use contraception. In the less-developed countries, contraceptive use is much lower—about 28 percent in Africa, about 71 percent in Latin America, and about 67 percent in Asia (about 56 percent if China is excluded).

It is important to recognize that access to birth control alone will not solve the population problem. What is most important is the desire of women to limit the size of their families. In developed countries, the use of birth control is extremely important in regulating the birthrate. This is true regardless of religion and previous historical birthrates. For example, Italy and Spain are both traditionally Catholic countries and have low total fertility rates (Spain 1.4 and Italy 1.3). The average for the developed countries of the world is 1.6. Obviously, women in these countries make use of birth control to help them regulate the size of their families. By contrast, Mexico, which is also a traditionally Catholic country, has a total fertility rate of 2.3, which is somewhat less than 2.8, which is typical for the less-developed world regardless of religious tradition.

Women in the less-developed world typically have more children than they think is ideal, and the number of children they have is higher than the replacement fertility rate of 2.1 children. Access to birth control will allow them to limit the number of children they have to their desired number and to space their children at more convenient intervals, but they still desire more children than the 2.1 needed for replacement. Why do they desire large families? There are several reasons. In areas where infant mortality is high, it is traditional to have large families, since several of a woman's children may die before they reach adulthood. This is particularly important in the less-developed world, where there is

TABLE 7.3 Age of Marriage, Births to Young Mothers, and Total Fertility Rate (2007)

	Africa	Latin America	Asia Excluding China	Asia	Developed World
% women 15–19 years old who have married	23	17	24	15	3
% of women 15–19 years old who give birth in any year	11	8	8	5	2
Total Fertility Rate	5.0	2.5	2.8	2.4	1.6

	Total Fertility Rate (2008)	% Female Literacy (2005)	GNI PPP/Capita US\$ (2007)
Germany	1.3	99	\$33,820
Japan	1.3	99	\$34,600
Russia	1.4	99	\$14,400
China	1.6	86.5	\$5,770
Thailand	1.6	90.5	\$7,880
Vietnam	2.1	86.9	\$2,550
U.S.	2.1	99	\$45,850
Iran	2.1	76.8	\$10,800
Turkey	2.2	79.6	\$12,090
Brazil	2.3	88.8	\$9,370
Mexico	2.3	90.2	\$12,580
Indonesia	2.6	86.6	\$3,580
Bangladesh	2.7	40.8	\$1,340
India	2.8	47.8	\$2,740
Egypt	3.1	59.4	\$5,400
Philippines	3.3	93.6	\$3,730
Pakistan	4.1	35.4	\$1,040
Ethiopia	5.3	22.8	\$780
Nigeria	5.9	60.1	\$1,770
Dem. Republic of Congo	6.5	54.1	\$290

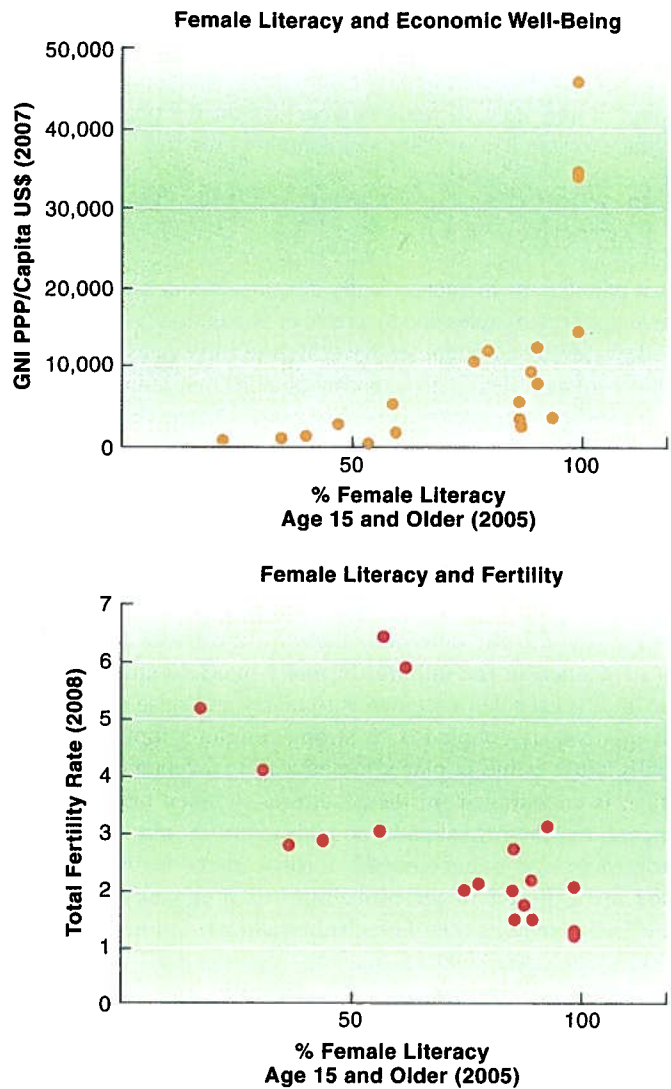


FIGURE 7.14 Female Literacy, Total Fertility Rate, and Economic Well-Being These graphs show the relationship among female literacy, total fertility, and economic well-being of the 20 most populous countries of the world. In general the higher the female literacy rate the lower the total fertility rate and the higher the per capita income.

Source: Data from Population Reference Bureau, 2008 Data Sheet, and *Human Development Report 2007/2008*, United Nations Development program.

no government program of social security. Parents are more secure in old age if they have several children to contribute to their needs when they become elderly and can no longer work.

ECONOMIC FACTORS

In less-developed countries, the economic benefits of children are extremely important. Even young children can be given jobs that contribute to the family economy. They can protect livestock from predators, gather firewood, cook, or carry water. In the developed world, large numbers of children are an economic drain. They are prevented by law from working, they must be sent to school at great expense, and they consume large amounts of the family income. Many parents in the developed world make an economic decision about having children in the same way they buy a house

or car: “We are not having children right away. We are going to wait until we are better off financially.”

POLITICAL FACTORS

Two other factors that influence the population growth rate of a country are government policies on population growth and immigration.

Government Population Policy

Many countries in Europe have official policies that state their population growth rates are too low. As their populations age and there are few births, they are concerned about a lack of working-age people in the future and have instituted programs that are

meant to encourage people to have children. For example, Hungary, Sweden, and several other European countries provide paid maternity leave for mothers during the early months of a child's life and the guarantee of a job when the mother returns to work. Many countries provide childcare facilities and other services that make it possible for both parents to work. This removes some of the economic barriers that tend to reduce the birthrate. The tax system in many countries, such as the United States, provides an indirect payment for children by allowing a deduction for each child. Canada pays a bonus to couples on the birth of a child.

By contrast, most countries in the developing world publicly state that their population growth rates are too high. To reduce the birthrate, they have programs that provide information on maternal and child health and on birth control. The provision of free or low-cost access to contraceptives is usually a part of their population-control effort as well.

China and India are the two most populous countries in the world, each with over a billion people. China has taken steps to control its population and now has a total fertility rate of 1.6 children per woman while India has a total fertility rate of 2.8. This difference between these two countries is the result of different policy decisions over the last 50 years. The history of China's population policy is an interesting study of how government policy affects reproductive activity among its citizens. When the People's Republic of China was established in 1949, the official policy of the government was to encourage births, because more Chinese would be able to produce more goods and services, and production was the key to economic prosperity. The population grew from 540 million to 614 million between 1949 and 1955, while economic progress was slow. Consequently, the government changed its policy and began to promote population control.

Since 1955 China has had a series of family-planning programs all aimed at reducing the number of births. Although many believe these programs include human rights violations, the birthrate has fallen steadily, and the current total fertility rate is 1.6, well below the replacement rate. Ninety percent of couples use contraception; the most commonly used forms are male and female sterilization and the intrauterine device. Abortion is also an important aspect of this program, with a ratio of over 600 abortions per 1000 live births.

By contrast, during the same 50 years, India has had little success in controlling its population. In 2000, a new plan was unveiled that had the goal of bringing the total fertility rate from 3.1 children per woman to 2 (replacement rate) by 2010. (In 2008, the total fertility rate was 2.8, so it is highly unlikely that the goal will be met.) In the past, the emphasis of government programs was on meeting goals of sterilization and contraceptive use, but this has not been successful. Today, about 55 percent of couples use contraceptives.

This new plan emphasizes improvements in the quality of life of the people. The major thrusts are to reduce infant and maternal death, immunize children against preventable disease, and encourage girls to attend school. It is hoped that improved health will remove the perceived need for large numbers of births. Currently, less than 50 percent of the women in India can read and write. The

emphasis on improving the educational status of women is related to the experiences of other developing countries. In many other countries, it has been shown that an increase in the education level of women is linked to lower fertility rates.

Immigration

The immigration policies of a country also have a significant impact on the rate at which the population grows. Birthrates are currently so low in several European countries, Japan, and China that these countries will likely have a shortage of working-age citizens in the near future. One way to solve this problem is to encourage immigration from other parts of the world.

The developed countries are under tremendous pressure to accept immigrants. The standard of living in these countries is a tremendous magnet for refugees or people who seek a better life than is possible where they currently live. In the United States, approximately one-third of the population increase experienced each year is the result of immigration. Canada encourages immigrants and has set a goal of accepting 300,000 new immigrants each year. This is about 1 percent of its current population.

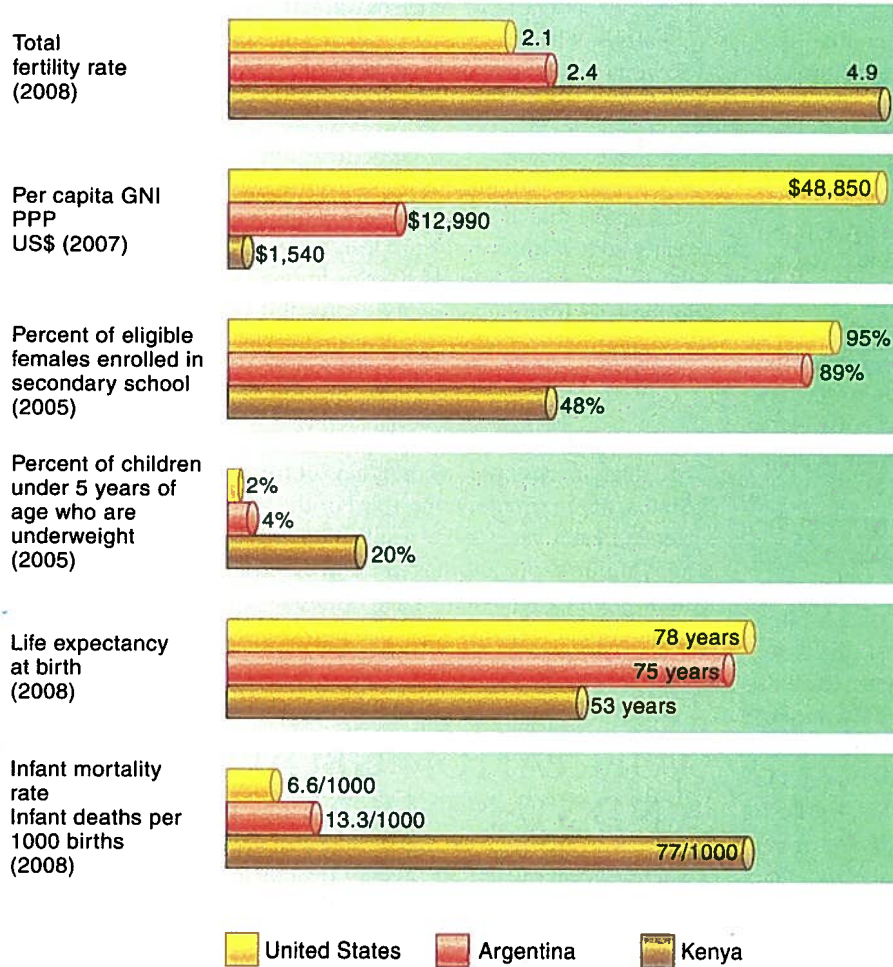
POPULATION GROWTH RATES AND STANDARD OF LIVING

There appears to be an inverse relationship between the rate at which the population of a country is growing and its standard of living. The **standard of living** is an abstract concept that attempts to quantify the quality of life of people. Standard of living is a difficult concept to quantify, since various cultures have different attitudes and feelings about what is desirable. However, several factors can be included in an analysis of standard of living: economic well-being, health conditions, and the ability to change one's status in the society. Figure 7.15 lists several factors that are important in determining standard of living and compares three countries with very different standards of living (the United States, Argentina, and Kenya). One important economic measure of standard of living is the average purchasing power per person. One index of purchasing power is the **gross national income (GNI)**. The GNI is an index that measures the total goods and services generated within a country as well as income earned by citizens of the country who are living in other countries. Since the prices of goods and services vary from one country to another, a true comparison of purchasing power requires some adjustments. Therefore, a technique used to compare economic well-being across countries is a measure called the GNI PPP (gross national income purchasing power parity). Finally, the GNI PPP can be divided by the number of people in the country to get a per capita (per person) GNI PPP. As you can see from figure 7.15, a wide economic gap exists between economically advanced countries and those that are less developed. Yet the people of less-developed countries aspire to the same standard of living enjoyed by people in the developed world.

FIGURE 7.15 Standard of Living and Population Growth in Three Countries

Standard of living is a measure of how well one lives. It is not possible to get a precise definition, but when we compare the United States, Argentina, and Kenya, it is obvious that there are great differences in how the people in these countries live. Kenya has a high population growth rate, a low life expectancy, a high infant mortality rate, and many people without adequate food. Furthermore, their incomes are low and they are poorly educated. The United States has a low population growth rate, a high life expectancy, a low infant mortality rate, and many people who eat too much. People in the United States have high educational levels and high incomes. Argentina is intermediate in all of these characteristics.

Source: Data from The Population Reference Bureau, 2008 Population Data Sheet; and Human Development Report 2007/2008, United Nations Development Program.



Health criteria reflect many aspects of standard of living. Access to such things as health care, safe drinking water, and adequate food are reflected in life expectancy, infant mortality, and growth rates of children. The United States and Argentina have similar life expectancies (over 75 years) and adequate nutrition. Kenya has a low life expectancy (53 years), many undernourished children (20 percent are underweight), and a high infant mortality rate (77 per 1000). The United States has a low infant mortality rate (6.6 per 1000). Argentina has an intermediate infant mortality rate (13.3 per 1000).

Finally, the educational status of people determines the kinds of jobs that are available and the likelihood of being able to improve one's status. In general, men are more likely to receive an education than women, but the educational status of women has a direct bearing on the number of children they will have and, therefore, on the economic well-being of the family. In Argentina and the United States over 89 percent of girls of high school age attend high school but only 48 percent do so in Kenya. Obviously, tremendous differences exist in the standard of living among these three countries. What the average U.S. citizen would consider poverty level would be considered a luxurious life for the average person in Kenya.

HUNGER, FOOD PRODUCTION, AND ENVIRONMENTAL DEGRADATION

As the human population increases, the demand for food rises. People must either grow food themselves or purchase it. Most people in the developed world purchase what they need and have more than enough food to eat. Most people in the less-developed world must grow their own food and have very little money to purchase additional food. Typically, these farmers have very little surplus. If crops fail, people starve. Even in countries with the highest population (China and India), the majority of the people live on the land and farm. (Fifty-five percent of Chinese and 72 percent of Indians live in rural areas.)

ENVIRONMENTAL IMPACTS OF FOOD PRODUCTION

The human population can increase only if the populations of other kinds of plants and animals decrease. Each ecosystem has a maximum biomass that can exist within it. There can be

CASE STUDY 7.2

THE GRAMEEN BANK AND MICROCREDIT

Poverty and environmental degradation go together. Today, more than half of the people of the world live on less than US \$2 a day. Impoverished people do not worry about the environmental impacts of their actions when they are trying to provide food and other basic necessities for themselves and their families. Therefore, the easing of poverty can have a positive effect on environmental conditions. Typically, the poor are unable to get loans from traditional sources and must go to moneylenders who charge extremely high rates of interest. This locks them into a cycle of poverty.

The Grameen Bank is a creation of Muhammad Yunus, a professor of economics at Chittagong University in Bangladesh, that provides an alternative source of credit for poor people. It is an outgrowth of an experiment during the late 1970s that showed that it was possible to make loans to the poor with a high rate of repayment and that the loans would improve the standard of living of the borrowers. In 1983, the Bangladeshi government established the Grameen Bank (*grameen* means village or rural in the Bengali language) as an independent bank. The bank provides tiny loans without any collateral (most are for less than US \$200) to the rural poor to begin a variety of businesses that can generate income that will raise the standard of living of the people. About 90 percent of the borrowers are women. The large proportion of loans to women is based on several factors. Unmarried women (widows, divorced, abandoned) are the poorest segments of society and have the greatest need. In addition, lenders feel that women are more likely to use the money to improve the conditions of their families and to repay the loan.

One of the primary reasons the bank has been successful is that the borrowers are helped to manage the repayment of their loans. Many of the conditions of the loans may be considered intrusive, but the system works. Some of the loan conditions are:

1. There is close supervision by bank personnel.
2. Borrowers must become members of a small group of their peers that advises the borrower and supervises the repayment of loans. Because most decisions about loans are made in meetings with other borrowers present, peer pressure is strong to use the loan wisely.
3. Loans are paid back on a weekly basis, which means that loans must be for activities that provide a quick return on investment and rely on skills already possessed by the borrower.
4. Compulsory saving is required of those who receive loans. This reduces the likelihood that poor decisions by the borrower will result

in squandering of the new income generated by the business started with the aid of the loan.

Today, the Grameen Bank is owned by the rural poor whom it serves. Borrowers own 90 percent of the bank's shares, while the Bangladeshi government owns the remaining 10 percent. Through its loans, about 5 percent of its borrowers come out of poverty every year. In 2006, Muhammad Yunus was awarded the Nobel Peace Prize for his efforts to help the world's poor.

The success of the Grameen Bank has led to replication of the concept in other countries. In 1997, a Microcredit Summit was held in Washington, D.C., that attracted 2900 delegates from 137 countries. They adopted a goal of reaching 100 million of the world's poorest families with microcredit and other financial services, preferably through the women in those families, by 2005. By the end of 2004, about 2500 microcredit institutions existed in nearly 100 countries. They had served over 92 million clients, over 83 percent of whom were women. The year 2005 was declared the International Year of Microcredit by the United Nations. The goal of reaching 100 million people with microcredit by the end of 2005 was not met. But by the end of 2007, 133 million people had been reached with microcredit worldwide.



shifts within ecosystems to allow an increase in the population of one species, but this always adversely affects certain other populations because they are competing for the same basic resources.

When humans need food, they convert natural ecosystems to artificially maintained agricultural ecosystems. The natural mix of plants and animals is destroyed and replaced with species useful to humans. If these agricultural ecosystems are mismanaged, the region's total productivity may fall below that

of the original ecosystem. The desertification in Africa and destruction of tropical rainforests are well-known examples. In countries where food is in short supply and the population is growing, pressure is intense to convert remaining natural ecosystems to agriculture. Typically, these areas are the least desirable for agriculture and will not be productive. However, to a starving population, the short-term gain is all that matters. The long-term health of the environment is sacrificed for the immediate needs of the population.

THE HUMAN ENERGY PYRAMID

A consequence of the basic need for food is that people in less-developed countries generally feed at lower trophic levels than do those in the developed world. (See figure 7.16.) Converting the less-concentrated carbohydrates of plants into more nutritionally valuable animal protein and fat is an expensive process. During the process of feeding plants to animals and harvesting animal products, approximately 90 percent of the energy in the original plants is lost. (See chapter 5.) Although many modern agricultural practices in the developed world obtain better efficiencies than this, most of the people in the developing world are not able to use such sophisticated systems. Thus, their conversion rates approach the 90 percent loss characteristic of natural ecosystems. Therefore, in terms of economics and energy, people in less-developed countries must consume the plants themselves rather than feed the plants to animals and then consume the animals. In most cases, if the plants were fed to animals, many people would starve to death. On the other hand, a lack of protein in diets that consist primarily

ECONOMICS AND POLITICS OF HUNGER

of plants can lead to malnutrition. It is possible to get adequate protein from a proper mixture of plant foods. In regions where food is in short supply, however, the appropriate mixture of foods is often not available. Thus, many people in the less-developed world suffer from a lack of adequate protein, which stunts their physical and mental development.

In contrast, in most of the developed world, meat and other animal protein sources are important parts of the diet. Many people suffer from overnutrition (they eat too much); they are "malnourished" in a different sense. About 66 percent of North Americans are overweight and 30 percent are obese. The ecological impact of one person eating at the carnivore level is about 10 times that of a person eating at the herbivore level. If people in the developed world were to reduce their animal protein intake, they would significantly reduce their demands on world resources. Almost all of the corn and soybeans grown in the United States are used as animal feed or to produce biofuels. Instead, if these grains were used to feed people, less grain would have to be grown and the impact on farmland would be reduced.

In countries where food is in short supply, agricultural land is already being exploited to its limit, and there is still a need for more food. This makes the United States, Canada, Australia, Argentina, New Zealand, and the European Union net food exporters. Many countries, such as India and China, are able to grow enough food for their people but do not have any left for export. Others, including many nations of the former Soviet Union, are not able to grow enough to meet their own needs and, therefore, must import food. Improved plant varieties, irrigation, and improved agricultural methods have dramatically increased food production in some parts of the world. In recent years, India, China, and much of southern Asia have moved from being food importers to being self-sufficient and, in some cases, food exporters.

A country that is a net food importer is not necessarily destitute. Japan and some European countries are net food importers but have enough economic assets to purchase what they need. Hunger occurs when countries do not produce enough food to feed their people and cannot obtain food through purchase or humanitarian aid.

The current situation with respect to world food production and hunger is very complicated. It involves the resources needed to produce food, such as arable land, labor, and machines; appropriate crop selection; and economic incentives. It also involves the

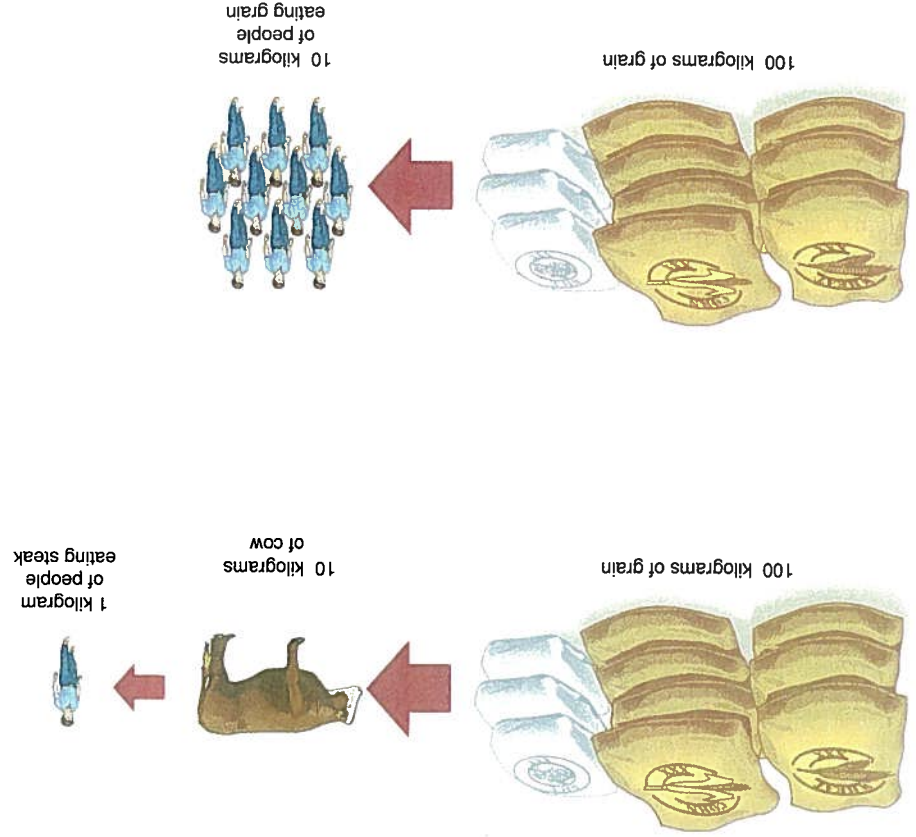


FIGURE 7.16 Population and Trophic Levels The larger a population, the more energy it takes to sustain the population. Every time one organism is eaten by another organism, approximately 90 percent of the energy is lost. Therefore, when countries are densely populated, they usually feed at the herbivore trophic level because they cannot afford the 90 percent energy loss that occurs when plants are fed to animals. The same amount of grain can support 10 times more people at the herbivore level than at the carnivore level.

maldistribution of food within countries. This is often an economic problem, since the poorest in most countries have difficulty finding the basic necessities of life, while the rich have an excess of food and other resources. In addition, political activities often determine food availability. War, payment of foreign debt, corruption, and poor management often contribute to hunger and malnutrition.

The areas of greatest need are in sub-Saharan Africa. Africa is the only major region of the world where per capita grain production has decreased over the past few decades. People in these regions are trying to use marginal lands for food production, as forests, scrubland, and grasslands are converted to agriculture. Often, this land is not able to support continued agricultural production. This leads to erosion and desertification.

SOLVING THE PROBLEM

What should be done about countries that are unable to raise enough food for their people and are unable to buy the food they need? This is not an easy question. A simple humanitarian solution to the problem is for the developed countries to supply food. Many religious and humanitarian organizations do an excellent service by taking food to those who need it and save many lives. However, the aim should always be to provide temporary help and insist that the people of the country develop mechanisms for solving their own problem. Often, emergency

food programs result in large numbers of people migrating from their rural (agricultural) areas to cities, where they are unable to support themselves. They become dependent on the food aid and stop working to raise their own food, not because they do not want to work but because they need to leave their fields to go to the food distribution centers. Many humanitarian organizations now recognize the futility of trying to feed people with gifts from the developed world. They try to provide food aid in local villages rather than in large cities and support projects that provide incentives for improving the local agricultural economy. The emphasis must be on self-sufficiency.

THE DEMOGRAPHIC TRANSITION CONCEPT

Clearly there is a relationship between the standard of living and the population growth rate. Countries with the highest standard of living have the lowest population growth rate, and those with the lowest standard of living have the highest population growth rate. This has led many people to suggest that countries naturally go through a series of stages called **demographic transition**.

THE DEMOGRAPHIC TRANSITION MODEL

The demographic transition model is based on the historical, social, and economic development of Europe and North America. In a demographic transition, the following four stages occur (see figure 7.17):

1. Initially, countries have a stable population with a high birthrate and a high death rate. Death rates often vary because of famine and epidemic disease.
2. Improved economic and social conditions (control of disease and increased food availability) bring about a period of rapid population growth as death rates fall. Birthrates remain high.
3. As countries develop an industrial economy, birthrates begin to drop because people desire smaller families and use contraceptives.
4. Eventually, birthrates and death rates again become balanced. However, the population now has *low* birthrates and *low* death rates.

This is a very comfortable model because it suggests that if a country can develop a modern industrial economy, then social, political, and economic processes will naturally cause its population to stabilize.

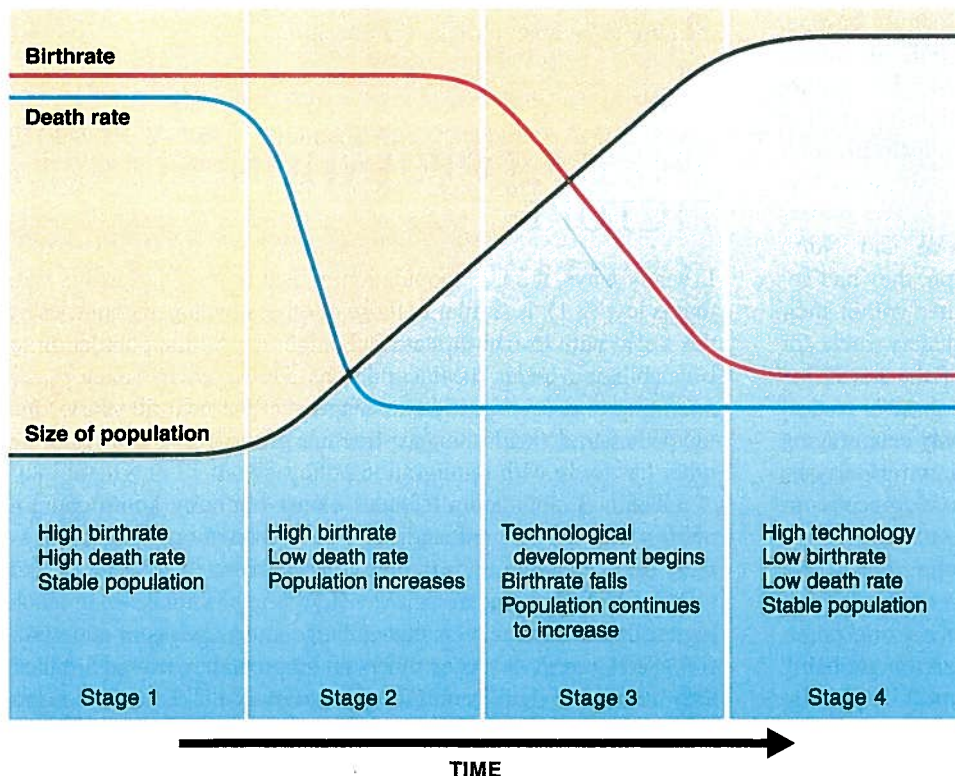


FIGURE 7.17 Demographic Transition The demographic transition model suggests that as a country develops technologically, it automatically experiences a drop in the birthrate. This certainly has been the experience of the developed countries of the world. However, the developed countries make up less than 20 percent of the world's population. It is doubtful whether the less-developed countries can achieve the kind of technological advances experienced in the developed world.

CAMPUS SUSTAINABILITY INITIATIVE



AUBURN UNIVERSITY'S WAR ON HUNGER INITIATIVE

The United Nations World Food Program (WFP) selected Auburn University in Auburn, Alabama, to be the lead academic partner in a student-based "War on Hunger" campaign. The WFP is the emergency food-aid arm of the United Nations and is the largest humanitarian organization in the world. Each year the agency provides food to an average 90 million people, including 56 million children. WFP also uses food aid as a tool to encourage long-term economic development and sustainability through programs focused on school feeding and mother/child nutrition.

Leadership for the Auburn/WFP "War on Hunger" is in the hands of Auburn students who are collectively known as the Committee of 19. The group's name is derived from the 19 cents a day it takes the World Food

Program to feed a hungry school child in the developing world. Representing every school, college, and major student organization on the Auburn campus, the Committee of 19 is addressing the pressing issues of world hunger and malnutrition. The committee members are responsible for the organization of hunger task forces within the individual units they represent.

Campus and community leaders, including representatives from the regional food bank, city council, and public school system, comprise the Steering Committee. Its purpose is to lend vision to the "War on Hunger" and advise on specific issues related to the implementation of the model.

APPLYING THE MODEL

However, the model leads to some serious questions. Can the historical pattern exhibited by Europe and North America be repeated in the less-developed countries of today? Europe, North America, Japan, and Australia passed through this transition period when world population was lower and when energy and natural resources were still abundant. It is doubtful whether these supplies are adequate to allow for the industrialization of the major portion of the world currently classified as less developed.

Furthermore, when the countries of Europe and North America passed through the demographic transition, they had access to large expanses of unexploited lands, either within their boundaries or in their colonies. This provided a safety valve for expanding populations during the early stages of the transition. Without this safety valve, it would have been impossible to deal adequately with the population while simultaneously encouraging economic development. Today, less-developed countries may be unable to accumulate the necessary capital to develop economically, since they do not have uninhabited places to which their people can migrate and an ever-increasing population is a severe economic drain.

A second concern is the time element. With the world population increasing as rapidly as it is, industrialization probably cannot occur fast enough to have a significant impact on population growth. As long as people in less-developed countries are poor, there is a strong incentive to have large numbers of children. Children are a form of social security because they take care of their elderly parents. Only people in developed countries can save money for their old age. They can choose to have children, who are expensive to raise, or to invest money in some other way.

Today, most people feel that this model provides important insight into why some populations stabilize, but that most countries will require assistance in the form of economic development funds, education, and birth control information and technology if they are to be able to make the transition.

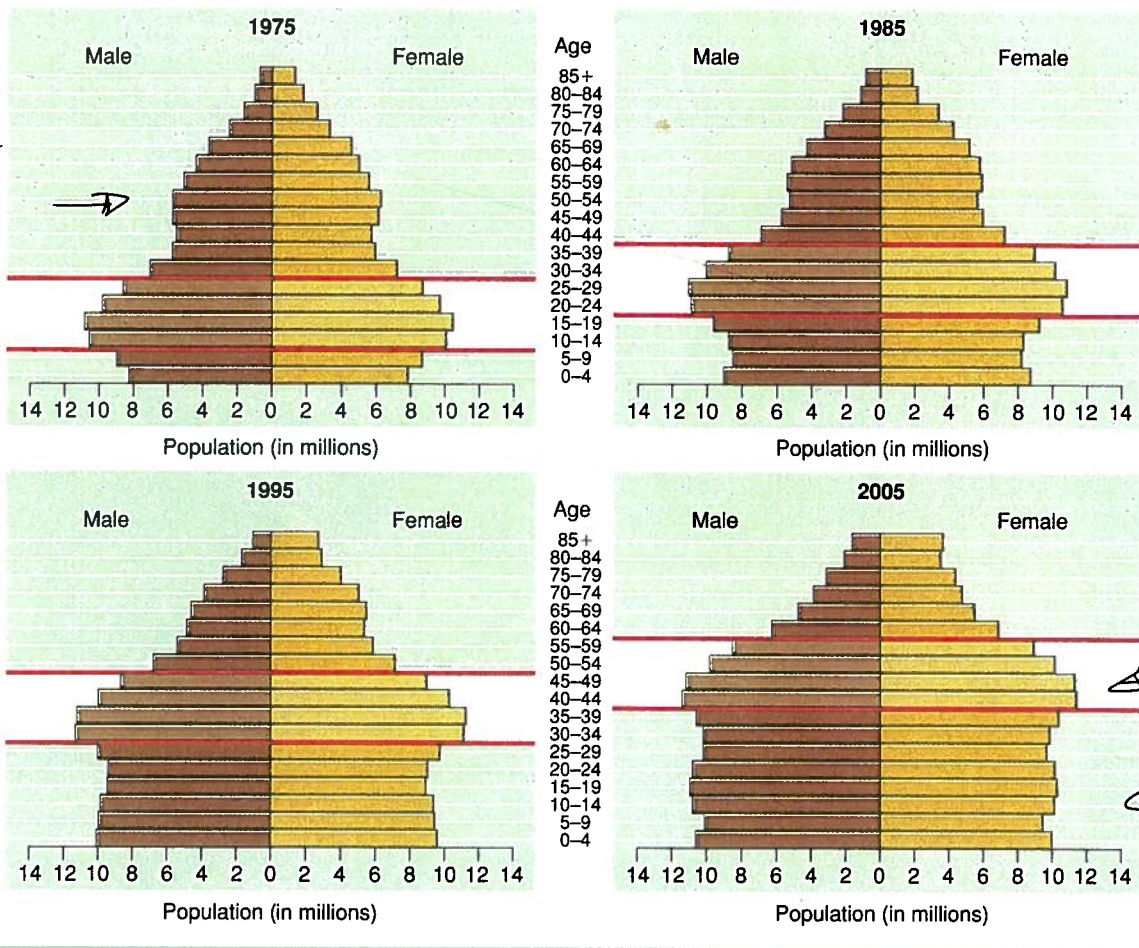
THE U.S. POPULATION PICTURE

In many ways, the U.S. population, which has a total fertility rate that is low (2.1), is similar to those of other developed countries of the world with low birthrates. One might expect the population to be stabilizing under these conditions. However, two factors are operating to cause significant change over the next 50 years. One factor has to do with the age structure of the population, and the other has to do with immigration policy.

The U.S. population includes a **postwar baby boom** component, which has significantly affected population trends. These baby boomers were born during an approximately 15-year period (1947–61) following World War II, when birthrates were much higher than today, and constitute a bulge in the age distribution profile. (See figure 7.18.) As members of this group have raised families, they have had a significant influence on how the U.S. population has grown. As this population bulge ages and younger people limit their family size, the population will gradually age. By 2030, about 20 percent of the population will be 65 years of age or older.

Both legal and illegal immigration significantly influence future population growth trends. Even with the current total fertility rate of 2.0 children per woman, the population is still growing by about 1.1 percent per year. About 0.6 percent is the result of

Post
WWII
boom



boom
"boom
echo"

FIGURE 7.18 Changing Age Distribution of U.S. Population (1975–2005) These graphs show the number of people in the United States at each age level. Notice that in the year 2005 a bulge begins to form at age 40 to 44 and ends at about age 55 to 59. These people represent the “baby boom” that followed World War II. As you compare the age distribution for 1975, 1985, and 1995 with 2005, you can see that this group of people moves through the population. As this portion of the population has aged, it has had a large impact on the nature of the U.S. population. In the 1970s and 1980s, baby boomers were in school. In the 1990s, they were in their middle working years. In 2005, some of them were beginning to retire, and many more will do so throughout the decade.
Source: Data from the U.S. Department of Commerce, U.S. Census Bureau, International Data Base.

natural increases due to the difference between birthrates and death rates. The remainder is the result of immigration into the United States. The U.S. Census Bureau projects that immigration will increase significantly and will account for 50 percent of population growth by the year 2050.

Current immigration policy in the United States is difficult to characterize. Strong measures are being taken to reduce illegal immigration across the southern border. This is in part due to pressures placed on Congress by states that receive large numbers of illegal immigrants. Illegal immigrants add to the education and health care costs that states must fund. At the same time, some segments of the U.S. economy (agriculture, tourism) maintain that they are unable to find workers to do certain kinds of work. Consequently, special guest workers are allowed to enter the country for limited periods to serve the needs of these segments of the economy. There is also a consistent policy of allowing immigration that reunites families of U.S. residents. Obviously, the families that fall into this category are likely to include U.S. citizens who were recent immigrants themselves. Most immigration policy is

the result of political decisions rather than decisions that relate to population policy or a concern about the rate at which the U.S. population is growing.

Projections based on the 2000 census indicate that the population will continue to grow and does not seem to be moving toward zero growth despite the fact that the total fertility rate is at the replacement rate of 2.1. Two reasons account for this. Immigration adds about a million people per year, and new immigrants typically are young and have larger numbers of children than nonimmigrants. This is likely to result in an increase from about 305 million people in 2008 to about 438 million by 2050.

Differences in family size exist between different segments of the U.S. population. The Hispanic and Asian-American portions of the population tend to have larger families. Furthermore, many of the people in these groups are recent immigrants, so these portions of the population will grow rapidly, and the caucasian portion will decline. Thus, the U.S. population will be much more ethnically diverse in the future.

Water Connections

DRINKING WATER: A BASIC RIGHT?

Death rates in many countries of the developing world are directly related to sanitation and access to safe drinking water. Target 10 of the United Nations Millennium Development Goals recognizes this connection and states that the goal is to

Halve by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation.

As of the year 2004—the latest year for which there are data—about one-sixth of the world's population (over 1.1 billion people) did not have access to safe drinking water. Those who live in rural areas are least likely to have access to safe drinking water. The regions with the greatest need to improve safe drinking water access are Sub-Saharan Africa, East Asia (China, North and South Korea, and Taiwan), and South Asia (India, Pakistan, and Bangladesh). Even those who did have access to safe drinking water typically did not have access in their homes. Someone from the household—usually women or children—must walk to a safe water source and carry water back to their homes. If people must walk more than 30 minutes round trip to get water, they are not likely to get enough water to satisfy the basic needs of washing, cooking, and drinking—about 20 liters/person/day (about 5 gallons/person/day).

Diarrheal diseases caused by bacteria, viruses, or protozoa in drinking water or contaminated food cause about 2.2 million deaths a year and nearly 90 percent of these cases are attributable to a lack of safe drinking

water. Most of these deaths occur in children under 5 years of age. Children who are subject to repeated bouts of severe diarrhea are also likely to suffer from malnutrition because they are unable to absorb nutrients during their illness.



Children in India obtaining water from an unsafe source.

WHAT DOES THE FUTURE HOLD?

Humans are subject to the same limiting factors as other species. We cannot increase beyond our ability to acquire raw materials and energy and safely dispose of our wastes. We also must remember that interactions with other species and with other humans will help determine our carrying capacity. Furthermore, when we think about the human population and carrying capacity, we need to distinguish between the biological carrying capacity, which describes how many people the Earth can support, and a cultural carrying capacity, which describes how many people the Earth can support with a reasonable standard of living. Regardless of which of these two concepts we are thinking about, the same four basic factors are involved. Let us look at these four factors in more detail.

AVAILABLE RAW MATERIALS

Many of us think of raw materials simply as the amount of food available. However, we have become increasingly dependent on technology, and our lifestyles are directly tied to our use of

other kinds of resources, such as irrigation water, genetic research, and antibiotics. Food production is becoming a limiting factor for some segments of the world's human population. Malnutrition is a serious problem in many parts of the world because sufficient food is not available. Currently, about 1 billion people (one-sixth of the world's population) suffer from a lack of adequate food.

AVAILABLE ENERGY

The second factor, available energy, involves problems similar to those of raw materials. Essentially, all species on Earth are ultimately dependent on sunlight for their energy. Currently, the world's human population depends on fossil fuels to raise food, modify the environment, and move from place to place. When energy prices increase, much of the world's population is placed in jeopardy because incomes are not sufficient to pay the increased costs for energy and other essentials. New, less disruptive methods of harnessing this energy must be developed to support an increasing population. Increases in the efficiency with which energy is used could reduce demands on fossil fuels. In addition, the development of more efficient solar and wind energy conversion systems could reduce the need for fossil fuels.

CASE STUDY 7.3

NORTH AMERICA—POPULATION COMPARISONS

The three countries that make up North America (Canada, the United States, and Mexico) interact politically, socially, and economically. The characteristics of their populations determine how they interact. Canada and the United States are both wealthy countries with similar age structures and low total fertility rates. The United States has a total fertility rate of 2.1, and Canada has a total fertility rate of 1.6. Both countries have a relatively small number of young people (20 percent or less of the population is under 15 years of age) and a relatively large number of older people (about 13 to 14 percent are 65 or older). Without immigration, these countries would have stable or falling populations. Therefore, they must rely on immigration to supply additional people to fill the workplace. This is particularly true for jobs with low pay. The United States currently receives about 1 million immigrants per year. Canada currently receives about 230,000 immigrants per year but is planning to increase that to about 300,000 in the future.

Mexico, on the other hand, has a young, rapidly growing population. About 31 percent of the population is under 15 years of age, and the total fertility rate is 2.6. At that rate, the population will double in about 32 years. Furthermore, the average Mexican has a purchasing power about 36 percent of that in Canada and about 27 percent of that in the United States. These conditions create a strong incentive for individuals to migrate from Mexico to other parts of the world. The United States is the usual country of entry. The number is hard to evaluate, since many enter the United States illegally or as seasonal

workers and eventually plan to return to Mexico. Current estimates are that about 250,000 people enter the United States from Mexico each year.

In response to the large number of illegal immigrants from Mexico, the United States has erected fences and increased surveillance. In 2008, about 725,000 people were apprehended attempting to cross the border from Mexico to the United States. Thus, instead of crossing at normal points of entry, illegal immigrants are likely to cross the border in remote desert areas, which has resulted in numerous deaths due to exposure.

The economic interplay between Mexico and the United States has several components. Working in the United States allows Mexican immigrants to improve their economic status. Furthermore, their presence in the United States has a significant effect on the economy of Mexico, since many immigrants send much of their income to Mexico to support family members. The North American Free Trade Agreement (NAFTA) allows for relatively free exchange of goods and services among Canada, the United States, and Mexico. Consequently, many Canadian, U.S., and European businesses have built assembly plants in Mexico to make use of the abundant inexpensive labor, particularly along the U.S.-Mexican border. Labor leaders in Canada and the United States are concerned about the effect access to low-cost labor will have on their membership and complain that many high-paying jobs have been moved to Mexico, where labor costs are lower.

Country	Population Size 2008 (Millions)	Birthrate per 1000	Death Rate per 1000	Rate of Natural Increase	Total Fertility Rate (Children per woman per lifetime)	Life Expectancy (Years)	Infant Mortality Rate (Deaths per 1000 births)	Per Capita GNI PPP 2007 US\$	% Under 15 Years of Age	% Over 65 Years of Age	Annual Immigration/Emigration (Estimate)
Canada	33.3	11	7	0.3	1.6	80	5.4	35,310	17	14	+230,000
United States	304.5	14	8	0.6	2.1	78	6.6	45,850	20	13	+1,000,000
Mexico	107.7	20	5	1.9	2.3	75	19	12,580	32	6	-650,000

Source: Population Reference Bureau, 2008 Population Data Sheet.

WASTE DISPOSAL

Waste disposal is the third factor determining the carrying capacity for humans. Most pollution is, in reality, the waste product of human activity. Lack of adequate sewage treatment and safe drinking water causes large numbers of deaths each year. Some people are convinced that disregard for the quality of our environment will be a major limiting factor. In any case, it makes good sense to control pollution and to work toward cleaning our environment.

INTERACTION WITH OTHER ORGANISMS

The fourth factor that determines the carrying capacity of a species is interaction with other organisms. We need to become aware that we are not the only species of importance. When we convert land to meet our needs, we displace other species from their habitats. Many of these displaced organisms are not able to compete with us successfully and must migrate or become extinct. Unfortunately, as humans expand their domain, the areas available to these displaced

organisms become rarer. Parks and natural areas have become tiny refuges for the plants and animals that once occupied vast expanses of land. If these refuges fall to the developer's bulldozer or are converted to agricultural use, many organisms will become extinct. What today seems like an unimportant organism, one that we could easily do without, may someday be seen as an important link to our very survival. It is also important to recognize that many organisms provide services that we enjoy without thinking about them. Forest trees release water and moderate temperature changes, bees and other insects pollinate crops, insect predators eat pests, and decomposers recycle dead organisms. All of these activities illustrate how we rely on other organisms. Eliminating the services of these valuable organisms would be detrimental to our way of life.

SOCIAL FACTORS INFLUENCE HUMAN POPULATION

Human survival depends on interaction and cooperation with other humans. Current technology and medical knowledge are available to control human population growth and to improve the health of the people of the world. Why, then, does the population continue to increase, and why do large numbers of people continue to live in poverty, suffer from preventable diseases, and endure malnutrition? Humans are social animals who have freedom of choice and frequently do not do what is considered "best" from an unemotional, uninvolved, biological point of view. People make decisions based on history, social situations, ethical and religious considerations, and personal desires. The biggest obstacles to controlling human population are not biological but are the province of philosophers, theologians, politicians, and sociologists. People in all fields need to understand that the cause of the population problem has both biological and social components if they are to successfully develop strategies for addressing it.

ULTIMATE SIZE LIMITATION

The human population is subject to the same biological constraints as are other species of organisms. We can say with certainty that

our population will ultimately reach its carrying capacity and stabilize. There is disagreement about how many people can exist when the carrying capacity is reached. Some people suggest we are already approaching the carrying capacity, while others maintain that we could more than double the population before the carrying capacity is reached. Furthermore, uncertainty exists about what the primary limiting factors will be and about the quality of life the inhabitants of a more populous world would have. If the human population continues to grow at its current rate of 1.2 percent per year, the population will reach 9.4 billion by 2050.

As with all K-strategist species, when the population increases, density-dependent limiting factors will become more significant. Some people suggest that a lack of food, a lack of water, or increased waste will ultimately control the size of the human population. Still others suggest that, in the future, social controls will limit population growth. These social controls could be either voluntary or involuntary. In the economically developed portions of the world, families have voluntarily lowered their birthrates to fewer than two children per woman. Most of the poorer countries of the world have higher birthrates. What kinds of measures are needed to encourage them to limit their populations? Will voluntary compliance with stated national goals be enough, or will enforced sterilization and economic penalties become the norm? Others are concerned that countries will launch wars to gain control of limited resources or to simply eliminate people who compete for the use of those resources.

It is also important to consider the age structure of the world population. In most of the world, there are many reproductive and prereproductive individuals. Since most of these individuals are currently reproducing or will reproduce in the near future, even if they reduce their rate of reproduction, there will be a sharp increase in the number of people in the world in the next few years.

No one knows what the ultimate human population size will be or what the most potent limiting factors will be, but most agree that we are approaching the maximum sustainable human population. If the human population continues to increase, eventually the amount of agricultural land available will not be able to satisfy the demand for food.

The Lesser Snow Goose—A Problem Population

Lesser snow geese use breeding grounds in the Arctic and subarctic regions of Canada and wintering grounds on salt marshes of the Gulf of Mexico, California, and Mexico. (See map.) One population of the lesser snow goose has breeding grounds around Hudson Bay and wintering grounds on the Gulf of Mexico. Because these birds migrate south from Hudson Bay through the central United States west of the Mississippi River to the west coast of the Gulf of Mexico, they are called the midcontinent population. Populations of the midcontinent lesser snow goose have grown from about 800,000 birds in 1969 to an estimated 4.5 million in 2005. (Some experts believe the number may be closer to 6 million.) These numbers are so large that the nesting birds are destroying their breeding habitat.

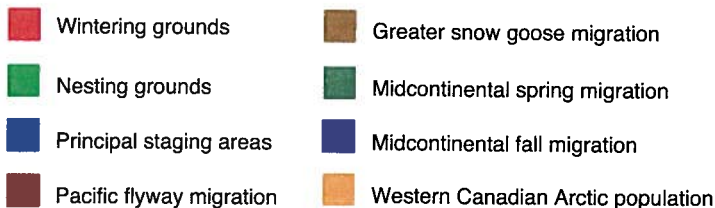
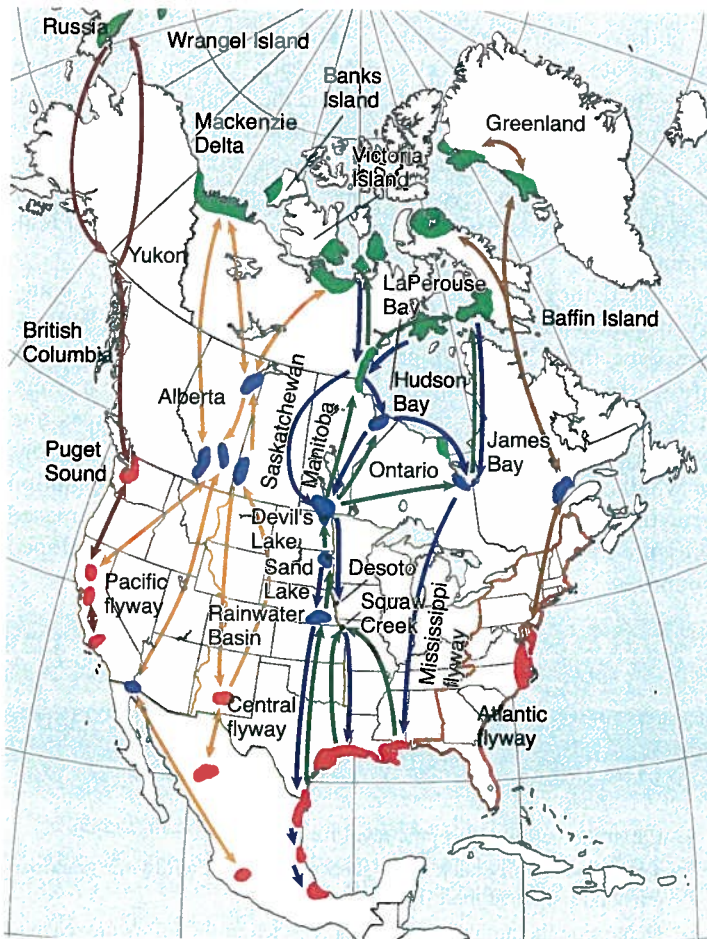
What has caused this drastic population increase? A primary reason appears to be a change in feeding behavior. Originally, during the winter snow geese fed primarily on the roots and tubers of aquatic vegetation in

the salt marshes of the Gulf of Mexico. Since this habitat and the food source it provided is limited, there was a natural control on the size of the population. However, many of these wetland areas have been destroyed. Simultaneously, agriculture (particularly rice farming) in the Gulf Coast region provided an alternative food source. As the geese began to use agricultural areas for food, they had an essentially unlimited source of food during the winter months, which led to very high winter survival. Furthermore, concerns about erosion have resulted in farmers using no-till and reduced tillage practices in the grain fields along the geese's flyway. The fields provided food for the fall migration that improved the survival of young snow geese. During the spring migration, geese used the same resources to store food as body fat that they took with them to their northern breeding grounds. Other factors that may have played a role are the decline in the number of people who hunt geese and a warming of the climate that leads to greater breeding success on the cold northern breeding grounds. The large goose population is causing habitat destruction on their Canadian breeding grounds.

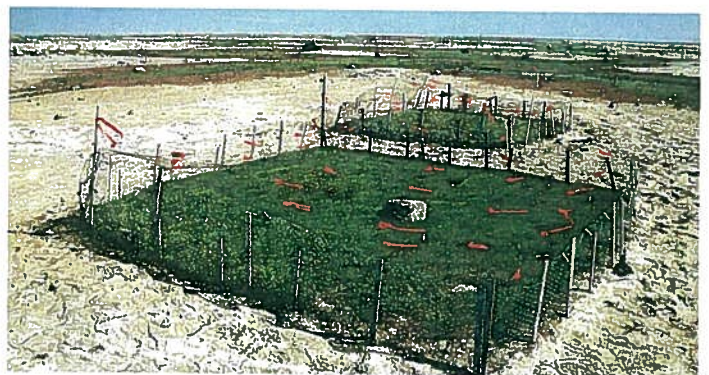
Habitat destruction occurring in Canada is a result of several factors. Snow geese feed by ripping plants from the ground, and they nest in large colonies. Therefore, they can have a powerful local impact on the vegetation. This coupled with a huge increase in the breeding population has resulted in the destruction of large areas of the coastal vegetation around Hudson Bay. (See photo.)

What can be done to control the snow goose population and protect their breeding habitat? There are two possibilities: let nature take its course or use population management tools. If nothing is done, the geese will eventually destroy so much of their breeding habitat that they will be unable to breed successfully, and the population will crash. It could take decades for the habitat to recover, however. The alternative is to use population management tools to try to resolve the problem. Several management activities have been instituted. These include allowing hunters to kill more geese, increasing the length of the hunting season, allowing hunts during the spring as well as the fall migration seasons, and allowing more harvest by Canadian native communities. In recent years, the harvest in the United States and Canada has increased, varying between 1 million and 1.5 million geese killed. Preliminary evidence suggests that the increased harvest is starting to have an effect. It will take several more years, however, to determine if the population can be controlled.

- Do you think the killing of geese is justified to protect the coastal habitat of Hudson Bay?
- Do you think it is better to have the population crash as a result of natural forces or to reduce the size of the population by increasing the harvest?



The map shows the migration routes between the traditional nesting and wintering areas of different snow goose populations.



This photo shows the kind of damage done by geese. The enclosures were established by Dawn R. Bazely and Robert L. Jefferies of the Hudson Bay Project.

SUMMARY

A population is a group of organisms of the same species that inhabits an area. The birthrate (natality) is the number of individuals entering the population by reproduction during a certain period. The death rate (mortality) measures the number of individuals that die in a population during a certain period. Population growth is determined by the combined effects of the birthrate and death rate.

The sex ratio of a population is a way of stating the relative number of males and females. Age distribution and the sex ratio have a profound impact on population growth. Most organisms have a biotic potential much greater than that needed to replace dying organisms.

Interactions among individuals in a population, such as competition, predation, and parasitism, are also important in determining population size. Organisms may migrate into (immigrate) or migrate out of (emigrate) an area as a result of competitive pressure.

A typical population growth curve shows a lag phase followed by an exponential growth phase, a deceleration phase, and a stable equilibrium phase at the carrying capacity. The carrying capacity is determined by many limiting factors that are collectively known as environmental resistance. The four major categories of environmental resistance are available raw materials, available energy, disposal of wastes, and interactions among organisms. Some populations experience a death phase following the stable equilibrium phase.

K-strategists typically are large, long-lived organisms that reach a stable population at the carrying capacity. Their population size is usually controlled by density-dependent limiting factors. Organisms that are r-strategists are generally small, short-lived organisms that reproduce very quickly. Their populations do not generally reach a carrying capacity but crash because of some density-independent limiting factor.

Currently, the world's population is growing very rapidly. The causes for human population growth are not just biological but

also social, political, philosophical, and theological. Many of the problems of the world are caused or made worse by an increasing human population. Most of the growth is occurring in the less-developed areas of the world (Africa, Asia, and Latin America), where people have a low standard of living. The more-developed regions of the world, with their high standard of living, have relatively slow population growth and, in some instances, declining populations.

Demography is the study of human populations and the things that affect them. Demographers study the sex ratio and age distribution within a population to predict future growth. Population growth rates are determined by biological factors such as birthrate, which is determined by the number of women in the population and the age of the women, and death rate. Sociological and economic conditions are also important, since they affect the number of children desired by women, which helps set the population growth rate. In more-developed countries, women usually have access to jobs. Couples marry later, and they make decisions about the number of children they will have based on the economic cost of raising children. In the less-developed world, women marry earlier, and children have economic value as additional workers, as future caregivers for the parents, and as status for either or both parents.

The demographic transition model suggests that as a country becomes industrialized, its population begins to stabilize. However, there is little hope that the Earth can support the entire world's population in the style of the industrialized nations. It is doubtful whether there are enough energy resources and other natural resources to develop the less-developed countries or whether there is enough time to change trends of population growth. Highly developed nations should anticipate increased pressure in the future to share their wealth with less-developed countries.

THINKING GREEN

1. Participate in a local effort to eliminate alien species.
2. Make a donation to an organization devoted to improving living conditions in the developing world.
3. Express your views on population policy to your congressional representatives.
4. Eat at the herbivore trophic level for one week.
5. Trace your family back three generations. Start with your grandparents and list all of their descendants.
6. Determine the number of siblings for each of the following: each of your grandparents, each parent, you.

WHAT'S YOUR TAKE?

Like much of the developed world, the United States has an aging population and would cease to grow without immigration. Immigrants (both legal and illegal) have larger families than non-immigrants. Immigrants often take low-paying jobs that the rest of the population does not want. Illegal immigrants from Mexico constitute a major problem, and the United States spends over a billion dollars each year to try to control illegal immigration.

Consequently, many people support a guest-worker program in which immigrants could enter the country for specific time periods but must eventually return to their home countries. Choose to support or oppose the concept of a guest-worker program, and develop arguments to support your point of view.

REVIEW QUESTIONS

1. How is biotic potential related to the rate at which a population will grow?
2. List three characteristics populations might have.
3. Why do some populations grow? What factors help to determine the rate of this growth?
4. Under what conditions might a death phase occur?
5. List four factors that could determine the carrying capacity of an animal species.
6. How do the concepts of birthrate and population growth differ?
7. How does the population growth curve of humans compare with that of bacteria on a petri dish?
8. How do K-strategists and r-strategists differ?
9. As the human population continues to increase, what might happen to other species?
10. All successful organisms overproduce. What advantage does this provide for the species? What disadvantages may occur?
11. What is demography?
12. What is demographic transition? What is it based on?
13. What does the age distribution of a population mean?
14. List 10 differences between your standard of living and that of someone in a less-developed country.
15. Why do people who live in overpopulated countries use plants as their main source of food?
16. Which three areas of the world have the highest population growth rate? Which three areas of the world have the lowest standard of living?
17. What role does the status of women play in determining population growth rates?
18. Describe three reasons why women in the less-developed world might desire more than two children.

CRITICAL THINKING QUESTIONS

1. Why do you suppose some organisms display high natality and others display lower natality? For example, why do cottontail rabbits show high natality and wolves relatively low natality? Why wouldn't all organisms display high natality?
2. Consider the differences between K-strategists and r-strategists. What costs are incurred by adopting either strategy? What evolutionary benefits does each strategy enjoy?
3. Do you think it is appropriate for developed countries to persuade less-developed countries to limit their population growth? What would be appropriate and inappropriate interventions, according to your ethics? Now imagine you are a citizen of a less-developed country. What might be your reply to those who live in more-developed countries? Why?
4. Population growth causes many environmental problems. Identify some of these problems. What role do you think technology will play in solving these problems? Are you optimistic or pessimistic about these problems being solved through technology? Why?
5. Do you think that demographic transition will be a viable option for world development? What evidence leads you to your conclusions?
6. What role should the developed countries play in the current demographic transition of developing countries? Why?
6. Imagine a debate between an American and a Sudanese person about human population and the scarcity of resources. What perspectives do you think the American might bring to the debate? What perspectives do you think the Sudanese would bring? What might be their points of common ground? On what might they differ?
7. Many people in developing countries hope to achieve the standard of living of those in the developed world. What might be the effect of this pressure on the environment in developing countries? On the political relationship between developing countries and already developed countries? What ethical perspective do you think should guide this changing relationship?
8. The demographic changes occurring in Mexico have an influence on the United States. What problems does Mexico face regarding its demographics? Should the United States be involved in Mexican population policy?