year in one country. GDP is made up of four types of economic activity: consumer spending, investments, government spending, and exports minus imports. A country's per capita GDP often correlates with its pollution levels. At very low levels of per capita GDP, industrial activity is too low to produce much pollution: the country uses very little fossil fuel and generates relatively little waste. Many developing countries fit this pattern.

As GDP increases, a nation begins to be able to afford to burn fossil fuels, especially coal, which, although relatively inexpensive, emits a substantial amount of pollution. The country may also rely on rudimentary, inefficient equipment that emits large amounts of pollutants. It is at this point in its development that a country emits pollution at the highest levels. The United States fit this pattern during the twentieth century. China, which is going through a similar rapid industrialization, currently relies on coal as its primary energy source. Many people view this shift as a trade off that occurs as a country's GDP increases: Breathing dirty air poses a different risk to human health than poverty. Although it is not always a more desirable risk, many people would choose dirty air over poverty.

As a nation's GDP increases further, it may reach a turning point. It can afford to purchase equipment that burns fossil fuels more efficiently and cleanly, which helps to reduce the amounts and types of pollution generated. People may also be willing to expend resources and support government efforts to regulate polluting industries. Wealthier societies are also able to afford better policing and enforcement mechanisms that ensure environmental regulations are being followed. Western European countries and the United States fit this scenario today. We will explore this turning point in more depth in Chapter 20.

Some environmental scientists argue that increasing the GDP of developing nations is the best way to save the environment, for at least two reasons. First, as we have seen, rising income generally correlates with falling birth rates, and a reduced population size should lead to a reduction in environmental impact. Second, wealthier countries can afford to make environmental improvements and increase their efficiency of resource use.

Local versus Global Impacts, and Urban Impacts

Impacts on the environment may occur locally—within the borders of a region, city, or country—or they may be global in scale. The scale of impact depends on the nature of the economy and the degree to which the society has developed. For example, a person may create a local impact by using products created within the country's borders. That same person may create a global impact by using materials that are imported. In addition to local and global impacts, some impacts are specific to people who live in urban environments.

FIGURE 23.9 **Deforested land in Brazil.** Clearing forests and grasslands for agriculture can lead to erosion, soil degradation, and habitat loss. This photo shows erosion caused by clear-cutting in Brazil. *(Publiphoto/Science Source)*

Local versus Global

In general, highly localized impacts are typical of rural, agriculturally based societies. Most of the materials consumed in developing countries are produced locally. While this may benefit the local economy, it can lead to regional overuse of resources and environmental degradation. Chapter 3 described deforestation in Haiti as an example of such overuse.

Two commonly overused local resources are the land itself and woody biomass from trees and other plants. A growing population requires increasing amounts of food. In developing countries that do not import their food, local demand for agricultural land increases with population size. To put more land into cultivation, farmers may convert forests or natural grasslands into cropland.

Brazil provides an example of land overuse in a developing nation. The United Nations Food and Agriculture Organization estimates that in Brazil, approximately 3 million hectares (7.4 million acres) were cleared per year during the peak years between 2000 and 2005. Some of this land was used for small-scale agriculture and some for industrial production of soybeans, sugarcane, and corn. The local environmental impacts of converting land to agricultural use include erosion, soil degradation, and habitat loss (**FIGURE 23.9**). Agriculture has global as well as local impacts, whether it occurs in developed or developing countries. Conversion of land to agriculture reduces the total amount of atmospheric carbon dioxide uptake by plants, which affects the global carbon cycle.

In addition, an increase in the use of fertilizers made from fossil fuels increases the release of greenhouse gases into the atmosphere.

Global impacts are more common in affluent or urban societies because they tend to specialize production in the industrial and high technology sectors. For example, more than half the ecological footprint of the United States comes from its use of fossil fuels, of which approximately 50 percent are imported. China's ecological footprint has more than doubled since 1970, and its ratio of local to global impact has shifted. Most of its ecological footprint was previously driven by demand for food, fiber crops such as cotton, hemp, and flax, and woody biomass. However, in recent years, China's demand for fossil fuels has increased dramatically.

Families in suburban areas of developed countries such as the United States consume far fewer local resources than rural families in developing countries, but they have a much greater impact on the global environment. In general, populations with large global impacts tend to deplete more environmental resources. Much of the impact comes from consumption of imported energy sources such as oil and other imported resources such as food. When people are affluent, they are more likely to purchase imported bananas, fish, and coffee from other countries, drive long distances in automobiles that were manufactured in factories hundreds or thousands of miles away, and live in homes surrounded by lawns that require large quantities of water, fertilizer, and pesticides.

Urban Impacts

Urban populations represent one-half of the human population but consume three-fourths of Earth's resources. While definitions vary by country, an **urban area,** according to the U.S. Census Bureau, contains more than 386 people per square kilometer (1,000 people per square mile). New York City is the most densely populated city in the United States, with 10,400 people per square kilometer (27,000 people per square mile). Mumbai, India, is the most densely populated city in the world, with 23,000 people per square kilometer (60,000 people per square mile).

More than 75 percent of people in developed countries live in urban areas, as **FIGURE 23.10** shows, and that number is expected to increase slightly over approximately the next 20 years. In developing countries, 44 percent of people live in urban areas, but that

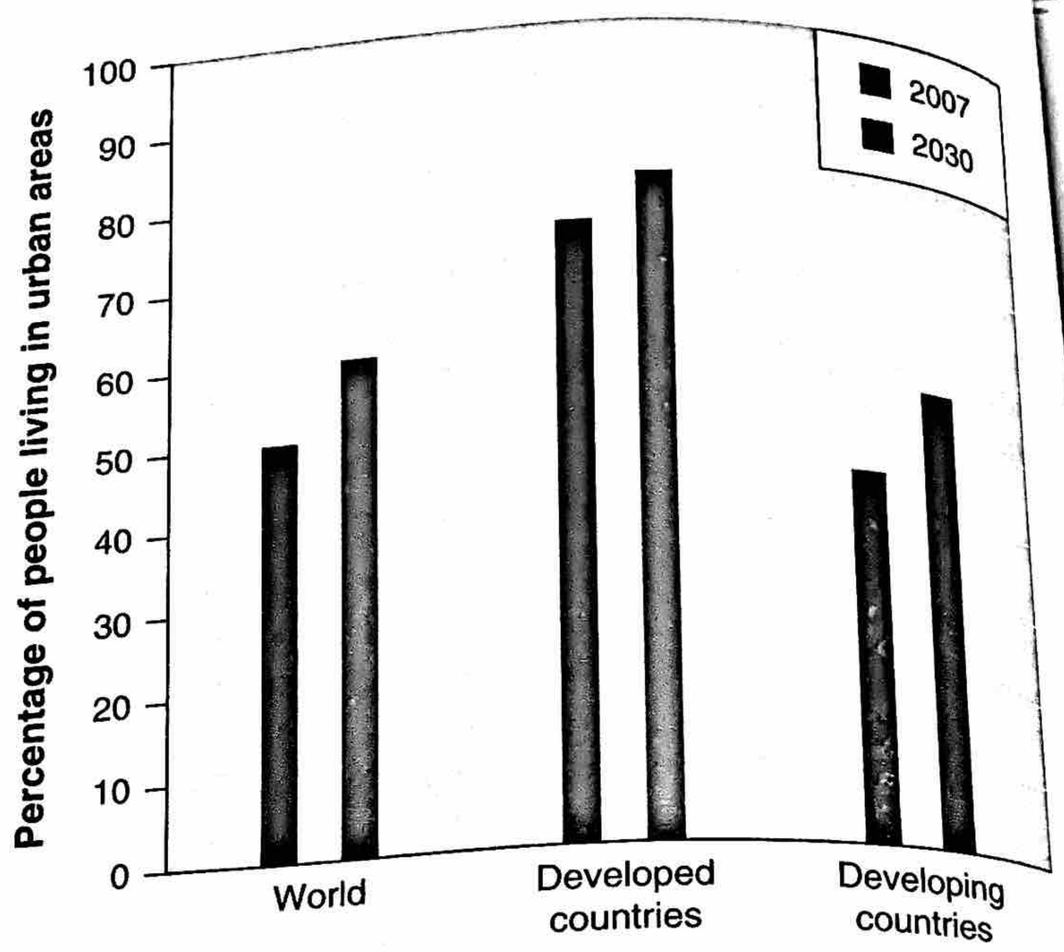


FIGURE 23.10 Urban growth. More than one-half of the world's population will live in urban settings by 2030. *(Data from United Nations Population Fund)*

number is increasing more rapidly than in developed countries and will probably reach 56 percent by 2030. **TABLE 23.1** shows that, of the 20 largest cities in the world, 16 are in developing countries. Worldwide, almost 5 billion people are expected to live in urban areas by 2030.

Urban living in both developed and developing countries presents environmental challenges. Most developed countries employ city planning to some degree. As urban areas expand, experts design and install public transportation facilities, water and sewer lines, and other municipal services. In addition, while urban areas produce greater amounts of solid waste, pollution, and carbon dioxide emissions than suburban or rural areas, they tend to have smaller per capita ecological footprints. There are many reasons for this difference, including greater access to public transportation and services that are nearby, such as shopping.

In developing countries, the relatively affluent portions of urban areas have safe drinking water, sewage treatment systems, and systems for disposal of household solid waste to minimize their impact on the surrounding environment. However, many less-affluent urban residents have no access to these services. Rapid urbanization in the developing world often results in an influx of the very poor who often cannot afford permanent housing and instead construct temporary shelters with whatever materials they find available, including mud, cardboard, or plastic. Whether they are squatter settlements, shantytowns, or slums, these overcrowded and underserved living situations are a common fact of life in

Urban area An area that contains more than 385 people per square kilometer (1,000 people per square mile).

TABLE 23.1 The largest 20 urban areas in the world

Rank	City, Country	Population (millions)
1	Tokyo, Japan	37.2
2	Delhi, India	22.7
3	Mexico City, Mexico	20.4
4	New York-Newark, United States	20.4
5	Shanghai, China	20.2
6	São Paulo, Brazil	19.9
7	Mumbai, India	19.7
8	Beijing, China	15.6
9	Dhaka, Bangladesh	15.4
10	Kolkata, India	14.4
11	Karachi, Pakistan	13.9
12	Buenos Aires, Argentina	13.5
13	Los Angeles-Long Beach-Santa Ana, United States	13.4
14	Rio de Janeiro, Brazil	12.0
15	Manila, Philippines	11.9
16	Moscow, Russia	11.6
17	Osaka-Kobe, Japan	11.5
18	Istanbul, Turkey	11.3
19	Lagos, Nigeria	11.2
20	Cairo, Egypt	11.2

Source: United Nations Population Division.
Note: Data are from 2011 and contain the areas defined by the United Nations as "urban agglomerations." Other agencies agglomerate urban areas differently and obtain slightly different results.

most cities in the developing world. The United Nations organization UN-HABITAT estimates that 1 billion people live in squatter settlements and other similar areas throughout the world. Most residents live in housing structures without flooring, safe walls and ceilings, or such basic amenities as water, sanitation, or health care (FIGURE 23.11).

Sustainable development is a common, if elusive, goal

We have seen that economic development and advancement improve human well-being, but it also has a strong influence on the environmental impact of a society. While many people believe that we cannot have both economic development and environmental protection, a growing number of social and natural scientists maintain that, in fact, sustainable economic development is possible.

As we saw in Chapter 1, sustainable development goes beyond economic development to meet the essential needs of people in the present without compromising the ability of future generations to meet their needs. In other words, sustainable development strives to improve standards of living—which involves greater expenditures of energy and

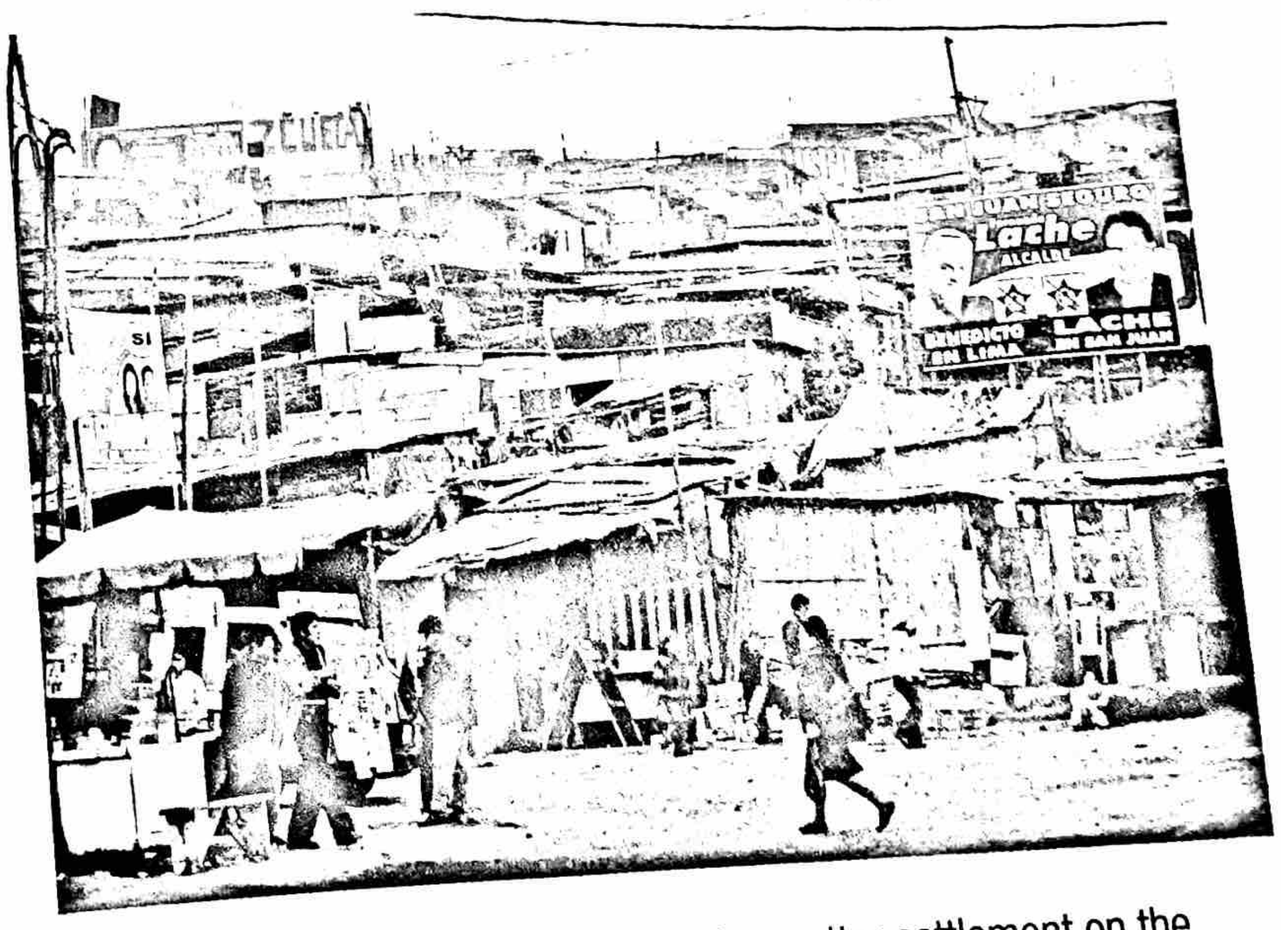


FIGURE 23.11 Shantytowns. A squatter settlement on the outskirts of Lima, Peru. Such shantytowns expand outward from the urban center. *(Reuters/Mariana Bazo/Landov)*

resources—without causing additional environmental harm. Many cities in Scandinavia have achieved something close to sustainable development. For example, Övertorneå, a Swedish town of 5,600 people, recently revived the local economy by focusing its economic activities on renewable energy, free public transportation, organic agriculture, and land preservation. The city still has an ecological footprint, of course, but it is much smaller, and thus much more sustainable, than it was previously.

How can sustainable development be achieved? There are no simple answers to that question, nor is there a single path that all people must follow. The Millennium Ecosystem Assessment project, completed in 2005, offers some insights. This project's reports constitute a global analysis of the effects of the human population on ecosystem services such as clean water, forest products, and natural resources. They are also a blueprint for sustainable development. The reports, prepared at the request of the United Nations, concluded that human demand for food, water, lumber, fiber, and fuel has led to a large and irreversible loss of biodiversity. The Millennium Ecosystem Assessment drew several other conclusions:

- Ecosystem sustainability will be threatened if the human population continues along its current path of resource consumption around the globe.
- The continued alterations to ecosystems that have improved human well-being (greater access to food, clean water, suitable housing) will also exacerbate poverty for some populations.
- If we establish sustainable practices, we may be able to improve the standard of living for a large number of people.

The project's reports state that "human actions are depleting Earth's natural capital, putting such strain on the environment that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted." They further suggest that sustainability, as well as sustainable development, will be achieved only with a broader and accelerated understanding of the connections between human systems and natural systems. This means that governments, nongovernmental organizations, and communities of people will have to work together to raise standards of living while understanding the impacts of those improvements on the local, regional, and global environments.

module 23

REVIEW

In this module we examined the theory of the demographic transition, which states that in some countries, the process of industrialization causes a reduction in the population growth rate. Slower population growth is typical of many countries that have industrialized and become wealthier. Some nations that have slowed in population growth have not industrialized. Those countries that have industrialized typically increase their consumption of resources, with adverse impacts on the environment. Impacts can occur locally and globally. Some locations are beginning to take on the challenge of fostering industrialization and economic development in a sustainable manner.

Module 23 AP® Review Questions

1. According to the theory of demographic transition, countries move through growth phases in which order?
   (a) Stable growth, rapid growth, slow growth, declining growth
   (b) Rapid growth, slow growth, stable growth, declining growth
   (c) Slow growth, declining growth, rapid growth, stable growth
   (d) Slow growth, rapid growth, stable growth, declining growth
   (e) Stable growth, rapid growth, declining growth, slow growth

2. Which of the following have contributed to increased family planning worldwide?
   I. Women's education
   II. Increased income
   III. Advertising campaigns

(a) I and II only
(b) I and III only
(c) II and III only
(d) I and III only
(e) I, II, and III

3. Which of the following is NOT a factor in gross domestic product?
(a) Consumer spending
(b) Cost of environmental damage
(c) Government spending
(d) Imports and exports
(e) Investments

4. The IPAT equation was developed to estimate
(a) the affluence of a country's population.
(b) the rate of demographic transition.
(c) the impact of human lifestyles on Earth.
(d) the gross domestic product of a country.
(e) the effect of urbanization on resource use.

5. Approximately what percentage of the population of developed countries lives in urban areas?
(a) 20%
(b) 44%
(c) 50%
(d) 75%
(e) 86%

working toward **sustainability**

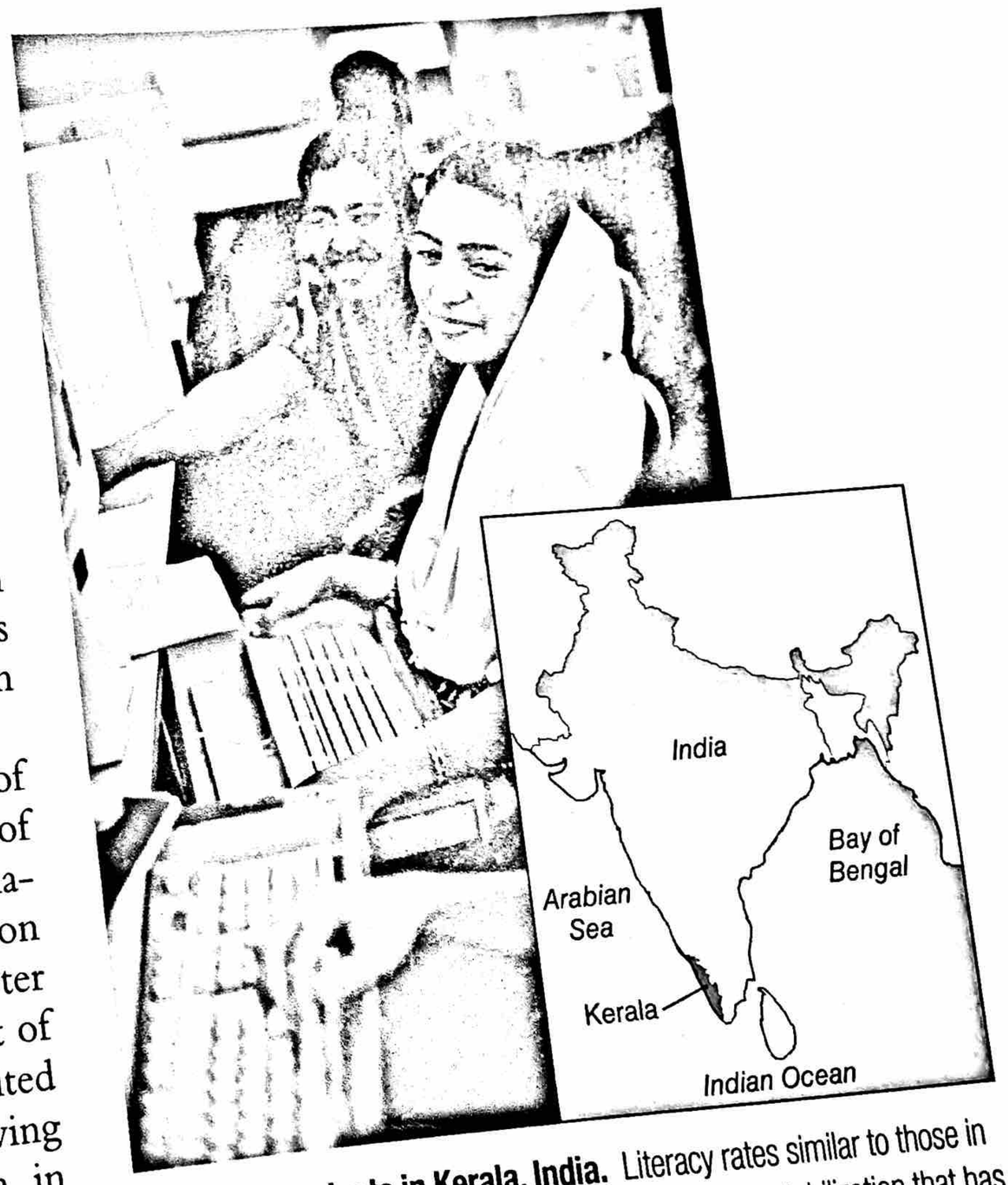
Gender Equity and Population Control in Kerala

India is the world's second most populous country and will probably overtake China as the most populous before 2030. Since the 1950s, India has tried various methods of population control, steadily reducing its growth rate to the current 1.5 percent. Although this growth rate would suggest below-replacement-level fertility, India's population will continue to increase for some time because of its large number of young people. The Population Reference Bureau estimates that India's population will not stabilize until after 2050.

In the 1960s, India attempted to enforce nationwide population control through sterilization, but massive protests against this coercive approach led to changes in policy. Since the 1970s, India has emphasized family planning and reproductive health, although each Indian state chooses its own approach to population stabilization. Some states have had tremendous success in lowering growth rates. Kerala, in southwestern India, is one of those states.

The state of Kerala is about twice the size of Connecticut. But Connecticut has a population of roughly 3.5 million people while Kerala has a population of more than 30 million. Kerala's population density is about 820 people per square kilometer (2,100 people per square mile), almost 3 times that of India as a whole, and 25 times that of the United States. Until 1971, Kerala's population was growing even faster than the population in the rest of India, in large part because the state government had implemented an effective health care system that decreased infant and adult mortality rates.

Since 1971, Kerala's birth rate, like its mortality rate, has fallen to levels similar to those in North America and other industrialized countries. The current total



Computer students in Kerala, India. Literacy rates similar to those in developed countries may be a factor in the population stabilization that has occurred in the state of Kerala, India. *(Owen Franken/Corbis)*

fertility rate in Kerala is about 2.0—lower than the U.S. TFR of 2.1 and much lower than the TFR of 2.7 for India as a whole. As a result, Kerala's population has stabilized. How did the state's population stabilize despite its poverty?

A special combination of social and cultural factors seems to be responsible for Kerala's sustainable population growth. Kerala has emphasized "the three Es" in its approach: education, employment, and equality. In addition to its accessible health care system, Kerala has good schools that support a literacy rate of over 90 percent, the highest in India. Furthermore, unlike rates in the rest of India, male and female literacy rates in Kerala are almost identical. In other parts of India and in most other developing countries, women attend school, on average, only half as long as men do. As we have learned, higher education levels for women lead to greater female empowerment and increased use of family planning. In Kerala, 63 percent of women use contraceptives, compared with 48 percent in the rest of India, and many women delay childbirth and join the workforce before deciding to start families. Kerala has a strong matriarchal tradition in which women are highly valued and their education is encouraged. Education and empowerment allow these women to be in a better position to make decisions regarding family size.

The World Bank estimates that if the rest of the developing world had followed Kerala's lead 30 years ago and equalized education for men and women, current TFR throughout the developing world would be close to replacement-level fertility. Evidence for this view can be found in the reduced fertility rates of other relatively poor countries where women and men have equal status, such as Sri Lanka and Cuba. In fact, gender equity was made a cornerstone of an international program to control population growth at the 1994 Third International Conference on Population and Development in Cairo, Egypt.

Critical Thinking Questions

1. Name some typical ways countries have tried to lower birth rates.
2. What are some other innovative ways to lower birth rates?
3. Can achieving replacement-level fertility sometimes cause difficulties? If so, describe some problems that might occur.
4. What is preventing the model used to promote slower population growth in Kerala from being used elsewhere in the world?

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chapter

7 REVIEW

Throughout this chapter, we have examined the ways in which the human population changes in response to natural biological factors and in response to other factors that are specifically human in nature. Together, these factors determine the carrying capacity of Earth, the total number of human beings that the world can support. People in the developed world are currently exhibiting very different behavior from those in the developing world. In the developed world, population growth has almost stopped while consumption of resources is still quite high. In the developing world, growth rates, while slowing, are still high, and consumption of resources is still rather low. As the world becomes more urban, and the impacts of development and consumption from larger numbers of people increase, the challenge is to achieve sustainable growth while also promoting the improvement of living conditions in the developing world.

Key Terms

Demography
Demographer
Immigration
Emigration
Crude birth rate (CBR)
Crude death rate (CDR)
Doubling time
Total fertility rate (TFR)
Replacement-level fertility
Developed country
Developing country
Life expectancy
Infant mortality
Child mortality
Net migration rate
Age structure diagram
Population pyramid
Population momentum
Theory of demographic transition
Family planning
Affluence
IPAT equation
Gross domestic product (GDP)
Urban area

Learning Objectives Revisited

Module 22 Human Population Numbers

- **Explain factors that may potentially limit the carrying capacity of humans on Earth.**

Scientists disagree about the size of Earth's carrying capacity for humans. Some scientists believe we have already exceeded that carrying capacity. Others believe that innovative approaches and new technologies will allow the human population to continue to grow beyond the environmental limits currently imposed by factors such as the supply of food, water, and natural resources.

- **Describe the drivers of human population growth.**

The human population is currently 7.2 billion people, and it is growing at a rate of about a million people every 5 days. If we think of the human population—as a whole or in individual countries—as a system, there are more inputs—births and immigration—than outputs—deaths and emigration. To understand changes in population size, demographers measure crude birth rate, crude death rate, total fertility rate, replacement-level fertility, life expectancy, infant and child mortality, age structure, and net migration rate.

- **Read and interpret an age structure diagram**

Age structure diagrams are visual representations of age structures for males and females. Each horizontal bar in the diagram represents an age group. The total area of all the bars in the diagram represents the size of the whole population. A country with more younger people than older people has an age structure diagram that is widest at the bottom and narrowest at the top. This is often called a population pyramid and is typical of developing countries. Developed countries tend to have closer to an even age distribution and their age structure diagrams are more vertical or column-like.

Module 23 Economic Development, Consumption, and Sustainability

- **Describe how demographic transition follows economic development.**

A number of countries have undergone a demographic transition as their economies have modernized. Economic development generally leads to increased affluence, increased education, less need for children to help their families generate subsistence income, and increased family planning. These factors have reduced the average size of families in developed countries, which leads to slower population growth. Eventually, population size may even decline.

- **Explain how relationships among population size, economic development, and resource consumption influence the environment.**

Most population growth today is occurring in developing countries. Only one-fifth of the global population lives in developed countries, but those countries consume more than half the world's energy and resources. The IPAT equation states that the environmental impact of a population is a result of population size, affluence, and technology. A relatively small population can have a high environmental impact if its affluence leads to high consumption and extensive use of destructive technology. However, an affluent nation can more easily take measures to reduce its environmental impact through the use of technology that counters pollution and increases the efficiency of resource use.

- **Explain why sustainable development is a common but elusive goal.**

Sustainable development attempts to raise standards of living without increasing environmental impact. The Millennium Ecosystem Assessment is a blueprint for sustainable development.

Chapter 7 AP® Environmental Science Practice Exam

Section 1: Multiple-Choice Questions

Choose the best answer for questions 1–12.

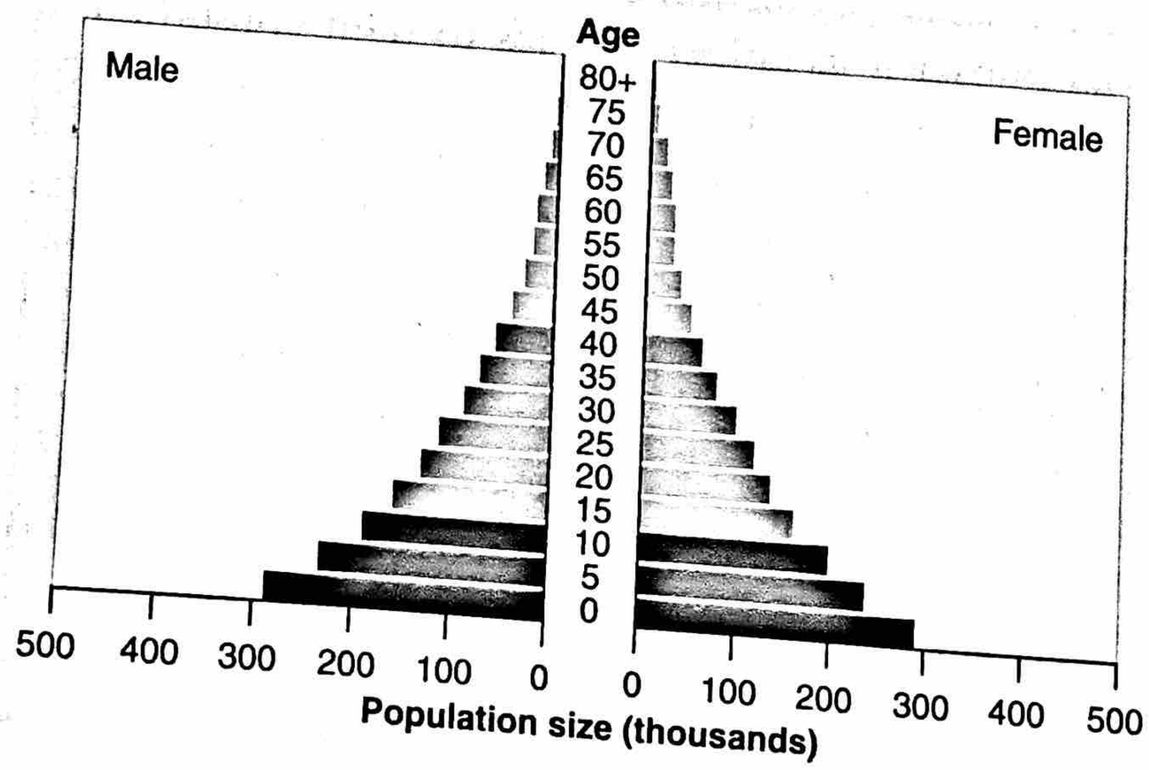
1. Which of the following does NOT support the theory that humans can devise ways to expand their carrying capacity on Earth?
   (a) The development of CFCs for use in refrigeration
   (b) The development of hydraulic fracturing to reach natural gas reserves
   (c) The use of arrows for hunting animals
   (d) The use of horse-driven plows
   (e) The use of waste methane from landfills for electricity generation

2. A metropolitan region of 100,000 people has 2,000 births, 500 deaths, 200 emigrants, and 100 immigrants over a 1-year period. Its population growth rate is
   (a) 1.2 percent.
   (b) 1.4 percent.
   (c) 1.6 percent.
   (d) 1.8 percent.
   (e) 2.0 percent.

3. Which of the following pairs of indicators best reflects the availability of health care in a country?
   (a) Crude death rate and growth rate
   (b) Crude death rate and crude birth rate
   (c) Growth rate and life expectancy
   (d) Infant mortality rate and crude death rate
   (e) Infant mortality rate and life expectancy

4. In 2013, the population of Earth was about _____ billion, with about _____ billion living in China.
   (a) 6.1/1.1
   (b) 6.1/1.2
   (c) 6.3/1.4
   (d) 7.1/1.2
   (e) 7.1/1.4

Use the following age structure diagram to answer question 5.



5. A country with an age structure diagram like the one shown is most likely experiencing
   (a) a high life expectancy.
   (b) slow population growth.
   (c) a short doubling time.
   (d) a low infant mortality rate.
   (e) replacement-level fertility.

6. Which statement about total fertility rate is correct?
   (a) TFR is equal to the crude birth rate minus the crude death rate.
   (b) TFR is the average number of children each woman must have to replace the current population.
   (c) TFR is generally higher in developed countries than in developing countries.
   (d) TFR is equal to the growth rate of a country.
   (e) TFR is the average number of children each woman will give birth to during her childbearing years.

7. Even if a country reduces its birth rate and maintains replacement-level fertility, its population will still continue to grow for several decades because of
   (a) lower death rates.
   (b) increased income.
   (c) population momentum.
   (d) better health care.
   (e) increased life expectancy.

8. At current growth rates, which country will probably be the most populous in the world after 2050?
   (a) China
   (b) Brazil
   (c) India
   (d) Indonesia
   (e) United States

9. Which characteristics are typical of developed countries?
   I. High technology use
   II. Low GDP
   III. Small-scale sustainable agriculture

   (a) I only
   (b) II only
   (c) I and III only
   (d) II and III only
   (e) I, II, and III

10. What percentage of the world's population lives in developing countries?
    (a) 34
    (b) 50
    (c) 66
    (d) 82
    (e) 98

11. Which country best exemplifies phase 4 of a demographic transition?
    (a) Argentina
    (b) China
    (c) India
    (d) Japan
    (e) Mexico

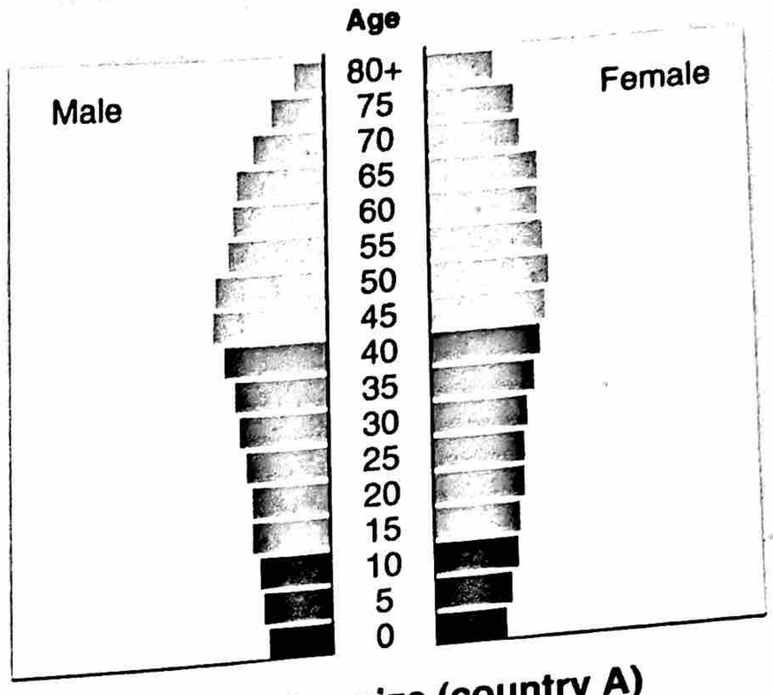
12. As Brazil has become more developed and industrialized, its population growth has stabilized. At the same time, the use of technology and raw materials has increased to meet the demands of a wealthier and more prosperous population. This increased consumption is predicted by
    (a) Thomas Malthus.
    (b) the Millennium Ecosystem Assessment.
    (c) the theory of demographic transition.
    (d) the IPAT equation.
    (e) population momentum.

Section 2: Free-Response Questions

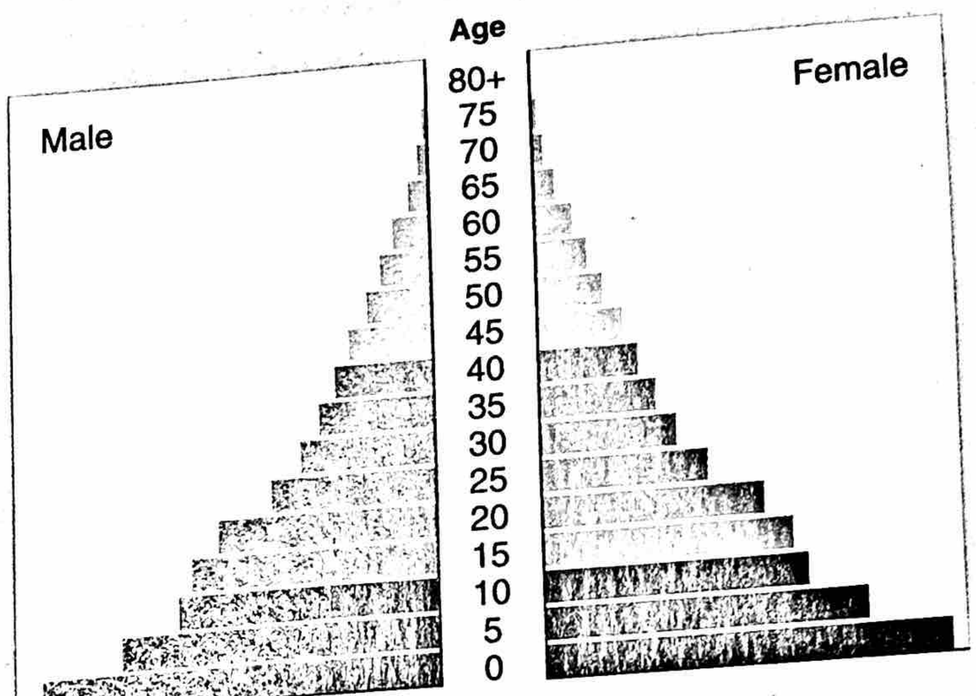
Write your answer to each part clearly. Support your answers with relevant information and examples. Where calculations are required, show your work.

1. Answer the following questions about the theory of demographic transition.
    (a) Draw a fully labeled diagram that shows how birth and death rates change as a country undergoes the four phases of a demographic transition. (3 points)
    (b) For each of the phases labeled in your diagram, explain the changes occurring in each phase and describe what is causing them. (3 points)
    (c) Describe a strategy that a government might implement to slow its population growth that could be utilized by a country undergoing a demographic transition. Explain how your proposed strategy would work, and describe one potential drawback to its implementation. (4 points)

2. Look at the age structure diagrams for country A and country B below and answer the following questions.



Population size (country A)



Population size (country B)

    (a) What observations and educated predictions can you make about the following characteristics of country A?
        (i) The age structure of its population (1 point)
        (ii) The total fertility rate of the country (1 point)
        (iii) The life expectancy of the population (1 point)
        (iv) The growth rate and doubling time of the population (2 points)
    (b) Describe one socioeconomic feature of country A. (2 points)
    (c) Explain how country B differs from country A in terms of
        (i) the age structure of its population. (1 point)
        (ii) its infant mortality rate. (1 point)
        (iii) its rate of population growth. (1 point)

Unit 3 AP® Environmental Science Practice Exam

Section 1: Multiple-Choice Questions

Choose the best answer for questions 1–20.

1. Which of the following is NOT true regarding limiting resources?
   (a) A limiting resource is an important density-independent factor.
   (b) A limiting resource is common to all members of a population.
   (c) Foraging territory is an example of a limiting resource.
   (d) The number of reproducing individuals in a population is not a limiting resource.
   (e) A population at carrying capacity has consumed all limiting resources.

2. Which of the following is most likely to result in a random population distribution?
   (a) Clumping of individuals around limiting resources
   (b) Competition among individuals
   (c) Density-independent factors
   (d) Variable carrying capacities among populations within a metapopulation
   (e) An age structure biased toward younger individuals

3. The common reed (*Phragmites australis*) is a perennial grass found throughout temperate and tropical regions of the world. Researchers recently discovered that many North American populations of the reed are composed entirely of genetically identical clones. Which is most likely true of these populations?
   (a) The age structure is unlikely to vary among populations.
   (b) Evolution by natural selection occurs very slowly in the absence of seed dispersal among populations.
   (c) Density-dependent factors will be more important than density-independent factors in regulating population densities.
   (d) Density-dependent factors will be less important than density-independent factors in regulating population densities.
   (e) Individual populations will not reach carrying capacity.

4. Species with a type III survivorship curve are likely to exhibit
   I. fast population growth rate.
   II. large amounts of parental care.
   III. density-independent population regulation.
   (a) I only
   (b) II only
   (c) III only
   (d) I and II
   (e) I and III

5. In an experimental grassland plot, researchers planted 20 seeds of a wildflower species that exhibits exponential growth with an intrinsic growth rate of 0.60. Approximate the maximum population size after 10 years.
   (a) 20×0.60
   (b) $20 \div 0.60$
   (c) $e^{0.60 \times 10}$
   (d) $e^{0.60 \times 11}$
   (e) $20 \times e^{0.60 \times 10}$

6. Which of the following is NOT a likely consequence of resource niche partitioning?
   (a) Predator-prey interactions
   (b) Clumped species distributions
   (c) Morphological variation within species
   (d) Competition within a species
   (e) Coexistence among species

7. Mycorrhizal fungi are commonly found attached to plant roots. The fungi are more efficient than plants at extracting nutrients from the soil. In exchange for nutrients, plants provide the fungi with sugars made through photosynthesis. However, when nutrients in the soil are abundant, researchers have found that plant growth increases if mycorrhizal fungi are removed. This phenomenon suggests that
   (a) mycorrhizae have switched from being mutualists to parasites.
   (b) mycorrhizae have switched from being mutualists to predators.
   (c) mycorrhizae have switched from being mutualists to commensalists.
   (d) mycorrhizae have ceased to act as a keystone species.
   (e) mycorrhizae are not able to partition resources as well as plants.

Given two islands of the same size, the theory of island biogeography suggests that the _____ island should have a higher _____.
(a) farther/extinction rate
(b) closer/speciation rate
(c) farther/species diversity
(d) closer/species richness
(e) closer/population size

9. Ecological succession
(a) begins with primary succession, followed by secondary succession, and ends with a climax stage.
(b) begins with either primary or secondary succession and ends with a climax stage.
(c) cannot occur if there are no species initially present at a site.
(d) starts with bare soil and ends with a climax forest.
(e) does not end with a climax stage.

10. The theory of island biogeography does not apply to
(a) protected wildlife areas.
(b) islands very far away from the mainland.
(c) metapopulations.
(d) mountaintop communities.
(e) bacterial communities.

11. Which may lead to an increase in the carrying capacity of the global human population?
I. Niche partitioning
II. Technological advancement
III. Reduction in per-capita consumption rate

(a) I only
(b) II only
(c) I and II
(d) II and III
(e) I, II, and III

12. In Vietnam, there were 16 births and 6 deaths out of every 100 people in the year 2011. Using the rule of 70, estimate the doubling time for Vietnam's population.
(a) 0.7 years
(b) 7 years
(c) 0.14 years
(d) 1.4 years
(e) 14 years

13. Which is NOT likely to describe a population in a developing country?
(a) Replacement level fertility is higher than 2.1.
(b) Infant mortality is 10 percent or more.
(c) Immigration is relatively low or nonexistent.
(d) The age structure will be shaped like an inverted pyramid.
(e) Per capita ecological footprint is much lower than in developed countries.

14. World Bank records indicate that in 2010, the total fertility rate in Puerto Rico was 1.6 and population size was 4,000,000. If net migration rate was −1.0, then the best estimate of the population in 2012 is
(a) 2,500,000.
(b) 3,700,000.
(c) 4,000,000.
(d) 4,500,000.
(e) 4,600,000.

15. A developing country with a total fertility rate of 4.0 and a net migration rate of −3.5 is likely to have an age structure
(a) shaped like a pyramid.
(b) shaped like an inverted pyramid.
(c) shaped like a column.
(d) that is variable depending on the demographic.
(e) shaped like a diamond.

16. Which is NOT a factor that determines population growth under the theory of demographic transition?
(a) Improved sanitation and health care leads to rapid population growth.
(b) Population momentum holds birth rates stable while death rates decline.
(c) Density independent factors slow economic growth.
(d) Education reduces a population growth rate.
(e) A burgeoning proportion of elderly people slows advancement.

17. Increasing the gross domestic product of a nation can be associated with
I. an increase in pollution.
II. a decrease in pollution.
III. an increase in population size.

(a) I only
(b) II only
(c) III only
(d) I and II
(e) I, II, and III

Questions 18 and 19 refer to the following table:

Country	Ecological footprint (km^2)	Average monthly salary	Number of coal burning plants	Population growth rate (%)
Argentina (119)	1,000,000	1,100	1	0.98
Colombia (108)	800,000	700	4	1.10
Philippines (64)	1,100,000	300	9	1.84
Brazil (133)	5,500,000	800	7	0.83
Panama (89)	100,000	800	1	1.38

Sources: Global Energy Observatory, *http://www.globalenergyobservatory.org;* United Nations International Labour Organization, *http://www.ilo.org;* World Bank, *http://data.worldbank.org.*

18. Based solely on the IPAT equation, _____ is likely to have the greatest population size and _____ is likely to have smallest population size.
    (a) Argentina/Colombia
    (b) Colombia/Philippines
    (c) Philippines/Panama
    (d) Brazil/Panama
    (e) Brazil/Argentina

19. Which country is most likely to be in the second phase of demographic transition?
    (a) Argentina
    (b) Colombia
    (c) Philippines
    (d) Brazil
    (e) Panama

20. If everyone moved to urban areas, it is likely that
    (a) the global ecological footprint would decrease.
    (b) the global ecological footprint would increase.
    (c) the global ecological footprint would remain the same.
    (d) global sustainability would be achieved.
    (e) global population increase would cease.

Section 2: Free-Response Questions

Write your answer to each part clearly. Support your answers with relevant information and examples. Where calculations are required, show your work.

1. *Wolbachia* is one of the world's most common parasitic microbes. It infects an enormous number of species, including many insects. Estimates indicate that as many as 70 percent of all insect species are infected with *Wolbachia,* including mosquitoes, spiders, and mites. The bacteria reproduce inside a host and are transmitted directly from mother to offspring or when infected males mate with uninfected females. After infection, *Wolbachia* consume host resources, which leaves the host with fewer resources for reproduction. As a result, infected females often have fewer offspring.
    (a) What is a possible limiting resource for *Wolbachia,* aside from the amount of resources within the host? (2 points)
    (b) Describe the population trajectory of *Wolbachia* inside of a host. (2 points)
    (c) Describe the population trajectory of *Wolbachia* in a population of hosts. (2 points)
    (d) Based on your answer for the previous question, what is one possible way that natural selection is altering the interaction between *Wolbachia* and its hosts? (2 points)
    (e) Discuss how the presence of nearby host populations might alter the spread of *Wolbachia.* (2 points)

2. China's one-child policy has drastically reduced total fertility rate to 1.4, and has led to a reduction in population growth rate to 0.50 percent in 2012. One problem associated with this is the development of an inverted population pyramid. Care for the elderly requires a substantial amount of energy, resources, and manpower. Chinese elderly primarily rely on their families for health care.
    (a) Given China's one-child policy, provide two examples of how China's growing elder population will affect future population growth. (3 points)
    (b) Describe one potential benefit and one potential problem associated with the emigration of elderly individuals from rural to urban areas. (2 points)
    (c) The total population size of China was 1,400,000,000 in 2012, with a crude birth rate of 12 births per 1,000 individuals. The number of individuals that emigrated from China was 700,000 and the number of individuals that immigrated to China was 200,000. Calculate the crude death rate. (3 points)
    (d) What would the total fertility rate be if all families in China obeyed the one-child policy rule? (1 point)