5

Population Ecology

As we mentioned in Chapter 1, about 10–15 percent of the exam will be about population. In other words, you'll definitely see some questions on the topics in this chapter, so learn the bold terms if you don't already know them. You should also go back to your textbook as you read through the chapter for more information on any topics that are frighteningly unfamiliar to you.

In this chapter, we'll start by discussing some important characteristics of populations and then lead you through a short section on how and why populations grow. Next we'll get to the heart of the topic, in a section specifically devoted to human population growth. Remember to use the techniques you learned in Chapter 2 as you complete the drills—the more practice you have using those techniques, the better prepared you'll be on test day! Let's begin.

SOME IMPORTANT TERMS USED TO DESCRIBE POPULATIONS

A **population** is defined as a group of organisms of the same species that inhabits a defined geographic area at the same time. Individuals in a population generally breed with one another, rely on the same resources to live, and are influenced by the same factors in their environment.

Two important characteristics of populations are the density of the population and how the population is dispersed. **Population density** refers to the number of individuals of a population that inhabit a certain unit of land or water area. An example of population density would be the number of squirrels that inhabit a particular forest. **Population dispersion** is a little more complicated; this term refers to how individuals of a population are spaced within a region. There are three main ways in which populations of species can be dispersed, and you should know all of them for the test! We've listed them below.

- **Random:** The position of each individual is not determined or influenced by the other members of the population. An example is seen in species of plants that are interspersed in fields or forests—the location of their growth is random, and relative to other species, not their population. This type of dispersion is relatively uncommon.
- **Clumping:** The most common dispersion pattern for populations. In this type of dispersion, individuals "flock together." This makes sense for many species—certain plants will all grow together in a region that suits their requirements for life; fish swim in schools to avoid predation; and birds and many other animals migrate in groups.
- **Uniform:** The members of the population are uniformly spaced throughout their geographic region. This is seen in forests, in which trees are uniformly distributed so that each receives adequate light and water, for example. Uniform dispersion is often the result of competition for resources in an ecosystem.

Got it? Now let's look at how populations grow (and shrink!).

POPULATION GROWTH

So, we know what populations are and how they're dispersed, but how do populations grow? What determines if they will or will not grow? When they grow, *how* do they grow? These are all questions that you'll need to be able to answer on test day. Let's review the basic proponents of population size and growth before we get into a more specific discussion of how human population growth occurs.

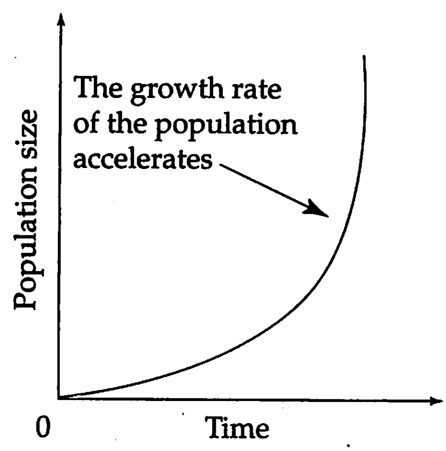
The **biotic potential** of a population is the amount that the population would grow if there were unlimited resources in its environment. This is not a practical model for population growth simply because in reality the amount of resources in the environments of populations are limited.

As we reviewed in the last chapter, in every ecosystem, members of a population compete for space, light, air, water, and food. The **carrying capacity (K)** of a particular region is defined as the maximum population size that can sustainably be supported by the available resources in the region. As you might expect, geographic regions have different carrying capacities for populations of different species—because different species have different requirements for life. For example, in a given area, you would expect a population of bacteria to be quite a bit larger—in terms of the number of individuals—than a population of zebras. This is because individual bacteria are much smaller than individual zebras; thus, each bacterium requires fewer resources to live than each zebra.

POPULATION GROWTH GRAPHS

If we looked at the growth of a population of bacteria in a Petri dish with plenty of food, the curve produced by plotting the increase in their number over time would be in the shape of a J, because the bacteria would grow exponentially. The exponential growth curve is shown below.

Exponential (unrestricted) growth

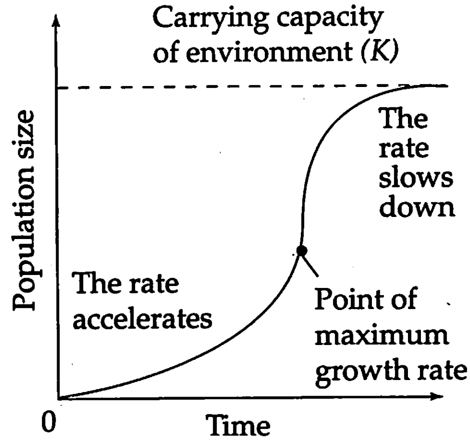


J-Curve

Now we said that this exponential growth rate is seen in populations in which resources are unlimited, but in nature these ideal settings are rare and fleeting. In a more realistic model for population growth, after the initial burst in population, the growth rate generally drops and the curve ultimately resembles a flattened S.

This type of growth, which is a much better model for what exists in natural settings, is called logistic population growth. The logistic growth model basically says that when populations are well below the size dictated by the carrying capacity of the region they live in, they will grow exponentially, but as they approach the carrying capacity, their growth rate will decrease and the size of the population will eventually become stable. This logistic growth is shown in the graph below.

Logistic (restricted) growth



S-Curve

We can predict long-term population growth rates using a model called the Rule of 70. The **Rule of 70** says that the time it takes for a population to double can be approximated by dividing 70 by the current growth rate of the population. For example, if the growth rate of a population is 5 percent, then the population will double in 14 years ($\frac{70}{5}$ percent = 14 years).

Not surprisingly, the rate of growth of a population depends on the species that makes up the population. Species can be divided into two groups based on their reproductive strategies: the *r*-selected pattern or the *K*-selected pattern. ***r*-selected organisms** reproduce early in life and often, and have a high capacity for reproductive growth. Some examples of *r*-selected species are bacteria, algae, and protozoa. In these species, little or no care is given to the offspring, but due to the sheer numbers of offspring in the population, enough of the offspring will survive to enable the population to continue. On the other hand, **K-selected organisms** reproduce later in life, produce fewer offspring, and devote significant time and energy to the nurturing of their offspring. For these species, it is important to preserve as many members of the offspring as possible because they produce so few; parents have a tremendous investment in each individual offspring. Some examples of *K*-selected species are humans, lions, and cows. Many species lie on the continuum between these two strategies, but the groups are useful for broad comparisons.

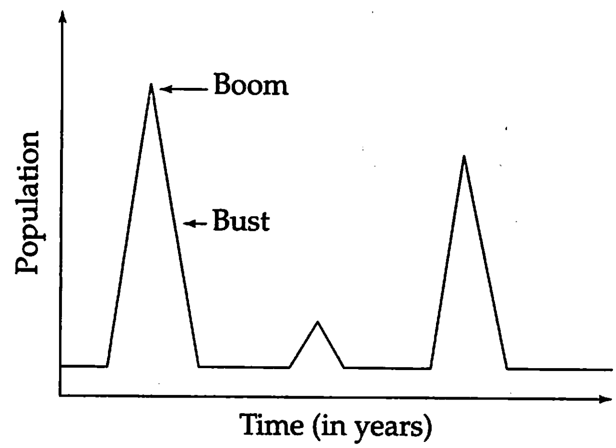
Population Cycles

When we observe populations in their natural habitats there are two distinct patterns that occur. These are the **boom-and-bust cycle** and the **predator-prey cycle**. Lets look at both of them, as they are important for the exam.

Boom-and-Bust Cycle

The boom-and-bust cycle is very common among *r*-strategists. In this type of cycle there is a rapid increase in the population and then an equally rapid drop off. These rapid changes may be linked to predictable cycles in the environment (temperature or nutrient availability, for example). When the conditions are good for growth, the population increases rapidly. When the population's conditions worsen, its numbers rapidly decline. You might say that their strategy is "get it while the getting's good." Study the graph below so you can see this type of cycle in action.

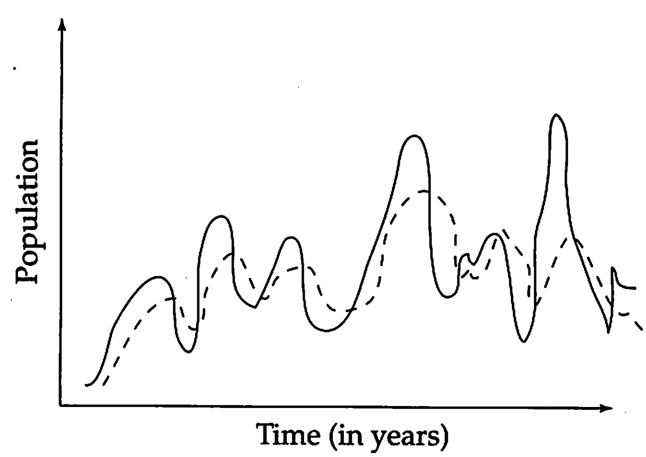
Boom-Bust Cycle



Predator-Prey Cycle

Remember the rabbit and coyote populations from the last chapter? We discussed how in a year of relatively high rainfall, rabbits have plenty of food, which enables them to reproduce very successfully. In turn, because the coyote is a predator of the rabbit, coyotes would also have plenty of food, and their populations would also rise rapidly. However, if the rainfall is below average a few years later, then there would be less grass; the population of rabbits would decline, and the coyote population would decline in turn. The graph of the predator-prey relationship looks like this:

Predator-Prey cycle



—— = Population of rabbits (prey)

- - - - = Population of coyotes (predator)

Something important to notice in this graph: the population of the coyote does not change at exactly the same time as the rabbit population. The coyote population actually rises *after* the rabbit population does. That is because the rabbit population has to have time to build up to fairly high levels before the coyotes can find enough to eat. When there is enough food, the coyote mothers have enough energy to give birth to and feed their pups. Only then can the coyote population increase.

The predator-prey cycle also plays a role in understanding why many endangered species are large carnivores. Large predator populations can suffer directly if humans alter their natural habitats, but they can also suffer indirectly if humans kill off their prey. If the prey population falls so low that the predator cannot find food, then the predator population will decline, sometimes to the point of extinction.

Factors Influencing Population Growth

There are population-limiting factors that are purely the result of the size of the population itself. For example, in many populations of species in nature, birth and death rates are influenced by the density of the population. Other **density-dependent** factors that influence population size are increased predation (which occurs because there are more members of the population to attract predators); competition for food or living space; disease (which can spread more rapidly in overcrowded populations); and the buildup of toxic materials.

Some population-limiting factors operate independently of the population size. These **density-independent** factors will change the population's size regardless of whether the population is large or small. Independent factors include fire, storms, earthquakes, and other catastrophic events.

Now that you have a basic understanding of how and why populations change in size, let's move on to discuss human populations more specifically.

HUMAN POPULATIONS

You might have heard something about human population growth as you read the news or studied biology and earth science in school. But do you know how many humans are on the planet now? Do you know how fast the human population is growing? You'll need to know for test day.

How Many People Are There in the World?

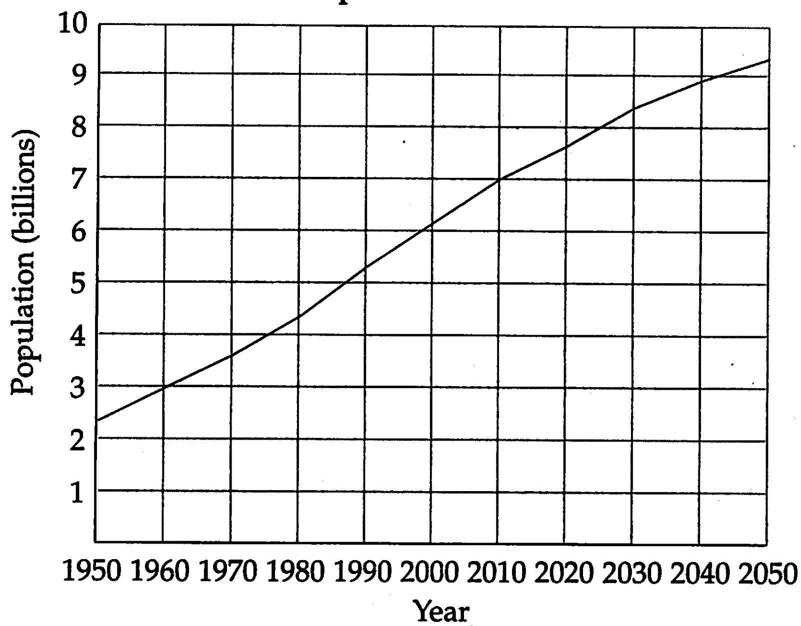
According to the U.S. Census Bureau, the world population as of June 2008 is estimated to be 6,673,355,091. The birth rate has actually fallen in the United States and worldwide, but the world population is still increasing. Take a look at the following table, which shows estimated populations of some major countries as of the summer of 2008.

Country	Estimated Population (Spring 2007)
United States	303,824,646 (303 million)
Japan	127,288,419 (127 million)
China	1,330,044,605 (1.3 billion)
Russia	140,702,094 (140 million)
Australia	20,600,856 (20 million)
Canada	33,212,696 (33 million)
Mexico	109,955,400 (110 million)
South Africa	43,786,115 (43 million)
India	1,147,995,898 (1.1 billion)
United Kingdom	60,943,912 (61 million)

Source: U.S. Census Bureau, International Data Base

The following graph shows how the overall world population of humans has increased since 1950.

World Population: 1950–2050



Source: U.S. Census Bureau, International Data Base, April 2005 version.

The population of many of the countries shown in the table is currently increasing in size. We can determine the rate of population change of a country by using a simple formula, if we only consider the contributions of births and deaths to changes in population size.

$$\text{Actual Growth Rate (\%)} = \frac{\text{birth rate} - \text{death rate}}{10}$$

The birth rate (the **crude birth rate**) is equal to the number of live births per 1,000 members of the population in a year, and the death rate (or **crude death rate**) is equal to the number of deaths per 1,000 members of the population in a year.

Here's the same table of countries from the previous page, but this one shows their growth rates.

Country	Growth Rate % Per Year	Birth Rate Per 1,000	Death Rate Per 1,000
United States	0.883	14.6	8.27
Japan	0.139	7.87	9.26
China	0.629	13.71	7.03
Russia	–0.474	11.03	16.06
Australia	0.801	11.90	7.62
Canada	0.830	10.29	7.61
Mexico	1.142	20.04	4.78
South Africa	–0.501	17.71	22.70
India	1.578	22.22	6.40
United Kingdom	0.276	10.65	10.05

Source: U.S. Census Bureau, International Data Base

How Do Human Populations Change?

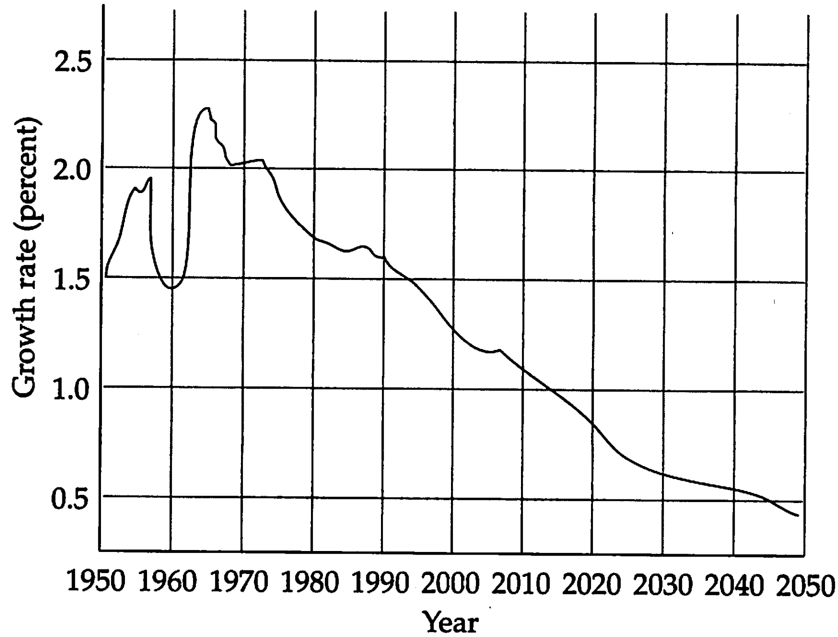
Populations can also change in number as a result of migration into and out of the population. Two important vocabulary words to describe human migration are **emigration,** which is the movement of people out of a population, and **immigration,** which is the movement of people into a population. Keep in mind that, in general, emigration and immigration are only small factors in the changes in size of human populations.

The most significant additions to human populations are due to births, plain and simple. The term **total fertility rate** is used to describe the number of children a woman will bear during her lifetime, and this information is based on an analysis of data from preceding years in the population in question. Total fertility rates are predictions that provide a rough estimate, but they can't be depended on because they assume that the conditions of the past will be the conditions of the future.

The **replacement birth rate** of a human population refers to the number of children a couple must have in order to replace themselves in a population. While you might automatically think that the answer is always two, in reality it is slightly higher to compensate for the deaths of children, the existence of non-child bearing females in the population, and other factors. In developing countries, the replacement birth rate can be as high as 2.5!

As we mentioned earlier, despite the relatively recent drop in total fertility rates worldwide, the world's population is still increasing. This is because many members of the human population are future parents, so even if they only reproduce at a replacement rate, there will be an overall increase in the total population. Now, let's look at a graph of how the overall world population growth rate has changed and is projected to change from 1950–2050.

World Projected Population Growth Rate: 1950–2050



Source: U.S. Census Bureau, International Data Base, April 2005 version.

Though not shown on this graph, the human population has actually been growing exponentially for more than three centuries. But what did we learn earlier in this chapter? That no population can grow exponentially indefinitely… we'll talk more about that in a bit. For now, let's discuss some factors that affect the growth rates of human populations.

Not surprisingly, a number of factors affect the total fertility rates in a population, and as a result, the population's birth rate. Among these are

- The availability of birth control
- The demand for children in the labor force
- The base level of education for women
- The existence of public and/or private retirement systems
- The population's religious beliefs, culture, and traditions

As you can see, perhaps not surprisingly, there is a strong empirical correlation between the education level of women and the growth rate of populations. Additionally, the reason that religion and culture are predictors of birth rates is that in some countries, certain groups have a proclivity toward reproduction for religious reasons. This is seen in Mormons (the world population of Mormons has now surpassed the population of Jewish people!), as well as several other religious and ethnic groups.

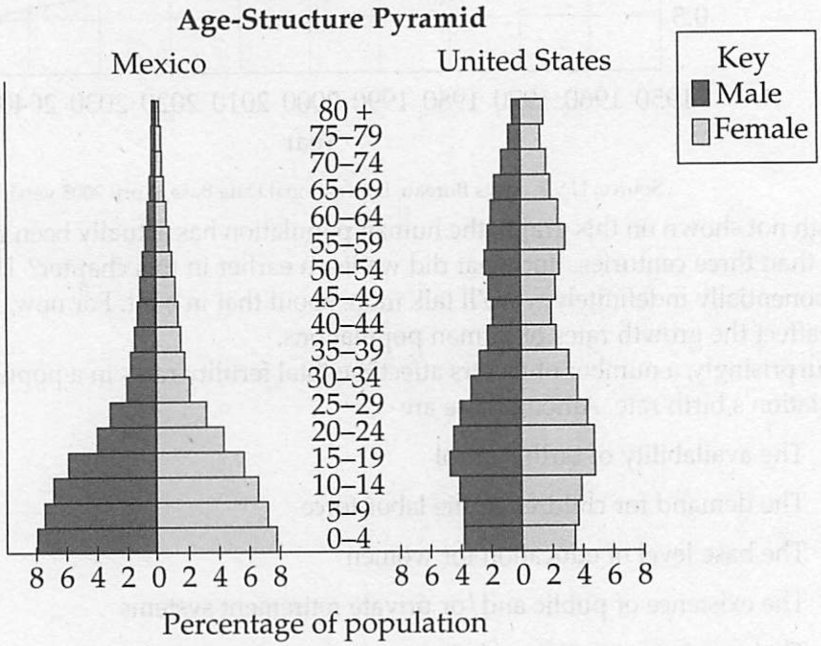
The reason that the world's population has grown so considerably, especially in the past 100 years, is not because of an increased number of births, but because of the significant drop in the world death rate. People are living longer lives, and there are far fewer infant deaths today than there were 100 years ago. This is due, in large part, to the Industrial Revolution, which improved the standard of living for millions living in industrialized nations. Other causes of the extension of the human life span are the development of clean water sources and better sanitation, the creation of dependable food supplies, and better health care. In general, the overall health of a population can be estimated by examining the expected life span of individuals and the mortality rate of infants.

Life-span information leads us right into our next topic: age-structure pyramids.

AGE-STRUCTURE PYRAMIDS

Age-structure pyramids (also called **age-structure diagrams**) are useful for graphically representing populations. Some age-structure diagrams group humans into three categories by age: those who are **pre-reproductive** (0–14), those who are **reproductive** (15–44), and those who are **post-reproductive** (45 and older). Age pyramids, such as the one shown below, group members of the population strictly by age, with each decade representing a different group.

We can use age-structure pyramids to predict population trends; for example, when the majority of a population is in the post-reproductive category, the population size will decrease in the future because most of its members are incapable of reproducing. The opposite is true if the majority of a population is in the pre-reproductive category; these populations will increase in size as time goes on. Take a look at the age-structure diagram for Mexico and the United States, below. As you can see, Mexico has a large number of pre-reproductive and reproductive members in its population, while the United States has a fairly even distribution. From this, we can see that the population of Mexico should increase significantly over time, while the population of the United States should grow more slowly.



THE DEMOGRAPHIC TRANSITION MODEL

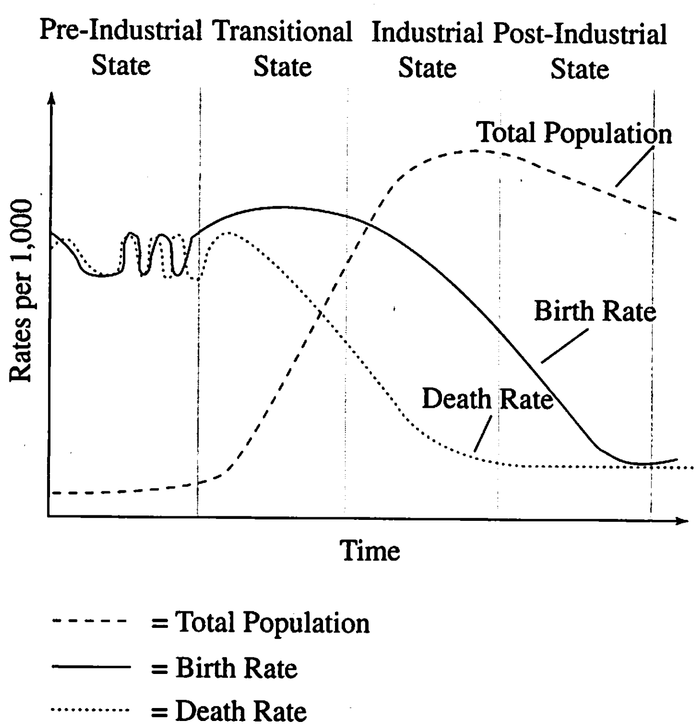
The **demographic transition model** is used to predict population trends based on the birth and death rates of a population. In this model, a population can experience zero population growth via two different means: as a result of high birth rates and high death rates; or as a result of low birth rates and low death rates. When a population moves from the first state to the second state, the process is called **demographic transition.** The four states that exist during this transition are:

1. The **pre-industrial state:** In this state, the population exhibits a slow rate of growth and has a high birth rate and high death rate because of harsh living conditions. Harsh living conditions can be considered **environmental resistance,** an umbrella term for conditions that slow a population's growth.

2. The **transitional state:** In this second state, birth rates are high, but due to better food, water, and health care, death rates are lower. This allows for rapid population growth.
3. The **industrial state:** In the third state, population growth is slow and the birth rate drops, becoming similar to the death rate. Many developing countries are currently in the industrial state.
4. The **postindustrial state:** In the final state, the population approaches and reaches a zero growth rate. Populations may also drop below the zero growth rate (as we saw in Russia, South Africa, and Japan, in the table of growth rates).

Check out a graph to better understand the demographic transition model.

Demographic Transition Model



You will most likely see questions that will ask you specifically to describe the demographic transition model, or apply it to hypothetical or real population states, so make sure you understand this material—and if you don't, go back to your textbook for further explanation!

THE IMPACT OF HUMANS ON EARTH

As you're probably well aware, humans have the greatest impact on the environment of any living species on Earth, and the increase in our population over the last few centuries has seriously and dramatically changed the face of the earth.

Three of the most significant factors that have contributed to the increase in the world human population are: the availability of clean water, newly implemented systems for sanitary waste disposal, and better medical care.

Another very significant factor has been the increase in food production. Almost half of Earth's land surface is currently devoted to various ways of producing food for humans; specifically, 12 percent of the Earth's land is composed of farms, 11 percent is composed of forests planted by humans, and 26 percent is used for grazing livestock! As we mentioned earlier, this enormous amount of food production takes its toll on the land, and we now face excessive and harmful erosion, in addition to a variety of environmental problems that have resulted due to the wide-scale use of irrigation. Finally, the widespread use of pesticides and fertilizers for increased crop yields leaves large amounts of harmful chemical residues in the soil and water.

In response to these problems, the agricultural industry is continuing to invent and promote soil conservation techniques, organic farming, more efficient irrigation methods, and genetically modified crops. However, these new techniques will need to be implemented in all countries in order to be effective globally. In many cases, new techniques introduce new problems—for example, crop sizes may increase, but pesticides must then be used in order to protect the larger crops.

What Happens When There Aren't Enough Resources?

Our bodies need certain nutrients to keep them healthy and to help resist disease. Some nutrients, or **macronutrients,** are needed in large amounts. These include proteins, carbohydrates, and fats. Other nutrients are needed in smaller amounts, these are also called **micronutrients**. These include vitamins, iron, and minerals such as calcium. When people are deprived of food, one result is the onset of hunger. Technically speaking, **hunger** occurs when insufficient calories are taken in to replace those that are being expended. **Malnutrition** is poor nutrition that results from an insufficient or poorly balanced diet; those whose diets lack essential vitamins and other components often suffer from it. A third term used to describe those who aren't receiving sufficient resources is **undernourished.** Undernourished people have not been provided with sufficient quantity or quality of nourishment to sustain proper health and growth.

According to the Food and Agriculture Organization, or FAO, 840 million people on Earth are hungry. Some 799 million of these people are living in developing countries, but, perhaps surprisingly, the remaining 41 million are living in developed nations. On the other hand, 30 percent of the total population of the United States is considered obese (which means that they are more than 30 lbs. overweight) and globally, 1.2 billion people are overweight. Why does this dichotomy exist?

While the reasons for hunger are many and complex, the simplest answer to this question is: poverty. Our planet produces sufficient food to feed today's world population, but many people lack the money to buy food or the resources to produce it.

All over the world, human communities are trapped in a cycle of poverty, resource degradation, and high fertility. For example, in the first third of the twentieth century, Asia, Africa, and Latin America produced enough grain that it was not necessary for them to import it from other countries. However, because of their constantly increasing populations, all of these countries are now importing grain; this is an ominous sign of impending problems with hunger in these countries.

Encouragingly, China, Thailand, and Indonesia are working hard to implement government reforms that will increase the quality of life for their citizens. In China, for example, as a result of reform and development in rural areas, the number of people in the country without enough food and clothing has decreased from 250 million in 1978, to 29 million in 2004.

Hunger in America

Despite its high obesity rate, there are hungry people even in the United States, one of the richest countries in the world—lots of hungry people. In fact, the number of hungry people in the United States is greater now than it was when international leaders set hunger-cutting goals at the 1996 World Food Summit. At this summit, government leaders pledged to cut the number of Americans living in hunger from 30.4 million to 15.2 million by 2010, but this goal has not nearly been met. Today more than 35 million Americans are considered "food insecure." Additionally, at least four in ten people in the United States who are between the ages of 20 and 65 rely on food stamps. That's nearly half of all citizens of the United States!

But why are American people hungry when they live in a nation that's known as the world's breadbasket? Again, the main reason is poverty.

In the mid-1990s, a call for welfare reform resulted in the passing of the Personal Responsibility and Work Opportunity Reconciliation Act (PRWORA). The premise of this welfare reform, according to its proponents, was that people who are able to work should be encouraged to find employment, so that they will not remain dependent on government assistance. The act limited the number of people who qualified for food stamps—and also limited the duration that people could receive food stamps and public support.

While at the time it was generally agreed that welfare reform was necessary, many families are now reaching their deadline for public assistance. Since the implementation of this act, and in the future, it will be of crucial importance for state and local groups to find ways to support the truly needy.

In the United States, there are a number of charitable agencies that provide food at no or low cost to those in need. One example is **Second Harvest**, which makes use of food that would otherwise go to waste. Second Harvest receives food from foods processors and distributors and redistributes it via food banks. Recent federal legislation called the Charity, Aid, Recovery, Empowerment Act of 2003 (the CARE Act), has supported Second Harvest and other food distribution charities by allowing farmers, ranchers, and restaurant owners to deduct the cost of the foods they donate.

Global Hunger Policies — For Good or Ill

While social reform is a viable solution to the problem of hunger in the United States, often the only solution in developing countries is to enable communities to become self-sufficient in food procurement. These destitute communities either need monetary resources that will allow them to purchase necessary food supplies, or the resources that would enable them to produce their own food.

Another issue that must be dealt with in the struggle against global hunger is that many countries just can't produce the food they need in order to feed their citizens. In these cases, the first viable solution mentioned above—that of providing monetary resources to people so they can purchase food—is rendered irrelevant.

The World Trade Organization (WTO) controls the policies of international trade. Unfortunately for smaller, poorer nations, the economically strong nations of the world have more influence over the creation of policies by the WTO. Oftentimes, trade policies undercut prices for developing nations, which makes it difficult for them to enter the world market.

Another problem for developing countries is that a trade imbalance exists between them and developed nations. In many poorer nations, national resources have been degraded in an effort to reduce the national debt. The people in these poverty-stricken nations have nothing to export—except labor. Relatively recently, companies in the United States and other developed nations have begun outsourcing jobs to developing countries. Many Americans are appalled at the terrible conditions under which these overseas laborers work—their hours are abnormally long and they are paid almost nothing. Despite these conditions, the competition between poor communities to secure contracts with companies overseas is fierce because often the alternative is continued poverty.

So, Where Do All These People Live?

Most people who live on Earth do not live in a wilderness. The majority of humans live in some type of community, and the largest percentage of the human population lives in relatively large communities and urban centers.

Since the development of ancient civilizations, humans have lived together in large centralized communities, or cities. A couple of ancient cities that you may be familiar with are Rome (in Italy) and Athens (in Greece). However, never before have the urban centers of the world grown as quickly as they are growing now. If we traced the growth of urban areas in the United States, we would find that before the Civil War (around the 1850s), only about 15 percent of the population lived in a city. Around the time of World War I (1920), that number grew to encompass about 50 percent of the total population of the United States, and today it hovers around 75 percent.

Globally, almost half of the world's population today lives in an urban area. In the United States, this is partly due to the fact that our aging population has largely moved into the cities to have greater access to health services, employment opportunities, and cultural activities.

When considering those who live in urban areas, we also count those who reside in satellite communities, or **suburbs.** In recent times, with lower oil prices making it easier for people to afford gasoline to commute to and from their jobs in cars, people have moved out of city centers in order to have more living space. Interestingly, people who live in the suburbs, on average, occupy eleven times more space than do those who live in the city. One of the advantages of living in the suburbs is that people have their own land space—a backyard—which they need not share with others.

The term used to describe the emigration of people out of the city and into the suburbs is **urban sprawl.** In some areas of the United States, urban sprawl takes over vast tracts of land. In Colorado, for example, population growth has resulted in a number of new communities between Denver and Boulder; when traveling between the two cities, it is now difficult to determine where the Denver metro area ends and the city of Boulder begins.

When urban areas grow too large and become too dense, providing water to all of their citizens becomes increasingly difficult. Coupled with this is the strain on the water supply—more people means more water use. In many of these newly crowded areas, water shortages have led to the implementation of restrictions on water usage.

Another problem that results from the increase in the populations of cities is what to do with all of the waste that's created. When you think about it, almost all human activities create waste—when you go to your local coffee shop and get a cup of coffee, you probably don't think much of it. However, if you get a cup of coffee every morning in a paper cup, five days a week for the 52 weeks of the year, then at the end of the year you've accumulated more than 250 cups! That's a significant pile of garbage. Another waste problem arises because of the sheer amount of human sewage created. We'll discuss this more in the chapter on pollution, later in the book.

Transportation Alternatives

While many people find the suburbs a pleasant place to live, ecologists and city planners have recently come to realize that this urban sprawl may reduce quality of life for all urban dwellers. One major concern of policy makers and citizens in metro areas is what to do about transportation. Ideally, people would be encouraged to use mass transit or participate in car pools rather than drive separately in private cars. Having fewer cars on the road decreases the amount of air pollution from automobile emissions and also results in less congestion on roadways.

Other environmentally conscious or "green" modes of transportation include bicycles, motor scooters, and electric bikes. Larger cities often opt to build subway systems, but they are extremely expensive to develop and are only cost-effective when there are enough people who will pay to use them. However, city buses are an option for both large and small cities; fleets of buses are less expensive than subways to create and maintain, and although they contribute to road congestion, they decrease congestion by having more people per vehicle.

Rapid-rail or light rail systems are more common in Japan and Western Europe than the United States, but as of recently they're being considered as an option for cities that lack subways. Rapid rail systems work by magnetic levitation; suspended above a track, a train moves along as a result of strong attractive and repulsive magnetic forces.

Building Sustainable Cities

In order for cities to be sustainable, city planners and developers must build and manage cities to work with, and within, their natural settings, instead of merely placing buildings and structures in these settings.

There are certain cities in the United States and elsewhere in the world that are setting examples of progressive thinking in conservation and ecology. For example, the city of Boulder, Colorado has long been recognized for its forward-thinking, green policies. Bicycle paths cover the city, allowing cyclists to move freely from one area of the community to another. Buses move around the city and in and out of Denver and the surrounding communities, which enables people to commute to work without using their cars and creating more emissions. For those who need to drive to work, the city encourages carpools and provides parking areas for those who carpool. Additionally, the city's strong recycling programs help reduce the amount of material that's added to land fills. The city is ringed by open spaces that can be used by the city population for recreation. These areas are leased to local ranchers for grazing cattle. Unbelievably, Boulder's citizens have voted to tax themselves to pay for the purchase of additional communal green space for the city!

Other cities that have been held up as models for city planning are Curitiba, Brazil and Portland, Oregon. Curitiba has an excellent mass transport system, as well as bicycle paths and pedestrian walk ways. The city provides recycling programs, job training, health care, and environmental education for its citizens. Likewise, in the 1970s the state of Oregon became determined to head off urban sprawl, and the city of Portland established statewide zoning policies and restrictive growth policies for urban areas. City developers were encouraged to invest in established neighborhoods rather than develop undisturbed areas. The city of Portland established Metro, a regional body that deals with land use, city planning, and the development of natural areas. Light rail systems were developed, and Metro began to encourage neighborhood self-sufficiency in order to keep the number of people who need to commute for food or other supplies to a minimum.

Now and in the future, it will be important for city planners to deal with new problems created as a result of urban sprawl. City planners and developers must take environmental concerns into consideration; providing green spaces and transportation alternatives, and planning for the supply of water are all relatively new challenges for those involved in building cities.

Big Cities in Less Developed Countries

So far we've made it sound like the cities of the world are dealing quite well with the boom in their population, but this is not true globally. In less developed countries, the increase in the population size of major cities has many very negative effects. Among the worst effects is a deficiency of housing or habitable areas for the burgeoning population. As a result, people are homeless, become "squatters," or make their homes in areas that are completely undeveloped—areas that have no water or electricity, or stable, durable housing.

Some of the reasons people in less developed countries are moving to cities are similar to those people in developed countries, for example, more opportunities for employment. However, these people often have other motivations that drive them out of the country, such as war, religious or cultural persecution, or the degradation of their environment.

Ecological Footprint

One concept that you should definitely be familiar with for this exam is that of the ecological footprint. An **ecological footprint** is used to describe the environmental impact of a population. It is defined as the amount of the Earth's surface that's necessary to supply the needs of, and dispose of the waste of, a particular population. Americans have one of the largest ecological footprints; we require about 9.7 hectares per capita (per person). One hectare is 10,000 square meters, or about 2.5 acres. America's amount is comparatively enormous—the ecological footprint of Indonesia is only 1.1 hectares per capita. In general, affluent populations have a much higher ecological footprint than non-affluent ones.

We can use a mathematical model to describe the impact that humans have on the environment. Nicknamed the IPAT model, it is written as

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

In the model, I = the total impact, P = population size, A = affluence, and T = level of technology.

While you probably won't be asked to calculate the impact of populations on this exam, it's a good idea to know this formula exists, and that the variables of population size, affluence, and level of technology all influence the impact a population has on its environment.

Threatened and Endangered Species

Another way humans impact the Earth is through their interaction with animals. Human activities have caused or contributed to the **extinction** of many species. Some species are **threatened**, meaning the number of individuals of a species is quite low, or they are **endangered**, meaning the species is in imminent danger of going extinct. The World Conservation Union estimates that in 2004 there were approximately 15,500 worldwide species that were endangered, ranging from 12% of the bird species to 42% of the tortoises. Plants and organisms living in marine and freshwater ecosystems face similar problems. The United Nations estimates that one in five species in coral reefs (or 200,000 species) are in danger of becoming extinct in the next 40 years. Extinctions have happened throughout Earth's history—this natural rate of extinction is called the **background extinction rate.** Knowledgeable scientists estimate that today the extinction rate is between 50 and 500 times higher than in the past, probably due to human influence. Extinctions can happen anywhere in the world but the rates are particularly high in the tropics (mostly mountains and islands).

The species that are most endangered have several factors in common: they require large ranges of habitat to survive, have low reproductive rates, have specialized feeding habits, and have low population numbers.

Humans play a major role in the extinction of species because of our destruction of animal and plant **habitats.** Poverty and rapid population growth cause people to use destructive practices, such as slash and burn farming, that destroy species' habitats. When we build roads or cities, habitats are lost or **fragmented** (broken into smaller pieces). Finally, we cause habitat **degradation** by adding pollutants to the environment. Other factors that can contribute to extinction are invasive species and direct hunting or **overexploitation** for animal products. Dr. Norman Myers coined the term **biodiversity hot spot** to describe a highly diverse region that faces severe threats and has already lost 70 percent of its original vegetation.

There are things we can do to reduce the rate of extinction. Living sustainably and conserving resources helps lower the demand that destroys habitats. Making it illegal to trade in specific organisms means that those organisms will not be hunted or collected. We can also help organisms on a species-by-species approach. Zoos and other institutions have captive breeding programs in which endangered species are bred under human control until their populations are high enough to be reintroduced into the wild. We can conserve habitats by requiring that large tracts of land be set aside and protected from human activity. In these protected habitats, organisms will find their niche and survive without risk of human interference. National parks and animal sanctuaries are two examples of protected habitats.

There are many United States laws that have been passed to reduce the rates of extinctions and protect specific organisms. Three very important ones are:

Date	Law	What It Did
1972	Marine Mammal Protection Act	This act protected marine mammals from falling below their optimum sustainable population levels.
1973	Endangered Species Act Program for the protection of threatened plants and animals and their habitats	The act prohibited the commerce of those species considered to be endangered or threatened.
1973	Convention on International Trade in Endangered Species of Wild Flora and Fauna (**CITES**)	This agreement bans the capture, exportation, or sale of endangered and threatened species.

Now you're ready for the key terms review and the following drills. Remember to use our techniques as you go through them!

KEY TERMS

Know these terms backward and forward so that you can spout them in your sleep.

Population Growth

- population density
- population dispersion: random, clumping, uniform
- biotic potential
- carrying capacity
- logistic population growth
- Rule of 70
- *r*-selected, *K*-selected
- density-dependent and independent factors
- boom-and-bust cycle
- predator-prey cycle

Human Populations

- crude birth rate
- crude death rate
- emigration
- immigration
- total fertility rate
- replacement birth rate
- age-structure pyramids
- pre-reproductive, reproductive, post-reproductive
- demographic transition
- environmental resistance
- malnourished
- macronutrient
- micronutrient
- suburbs
- urban sprawl
- ecological footprint

Threatened and Endangered Species

- extinction
- threatened
- endangered
- background extinction rate
- fragmented habitat
- habitat degradation
- overexploitation
- biodiversity hot spot
- CITES

CHAPTER 5 QUIZ

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case.

1. Populations have all the following characteristics EXCEPT

   (A) density
   (B) dispersion
   (C) habitat
   (D) gene pool
   (E) size

2. Which of the following describes individuals leaving a population?

   (A) Birth rate
   (B) Carrying capacity
   (C) Immigration
   (D) Emigration
   (E) Environmental resistance

3. A population has a growth rate of 2 percent per year. How long will it take for this population to double?

   (A) 70 years
   (B) 40 years
   (C) 35 years
   (D) 15 years
   (E) 2 years

4. An age-structure pyramid is used to

   (A) study the immigration rates in a population
   (B) calculate the doubling time of a population
   (C) study the carrying capacity of a habitat
   (D) determine what the density-dependent factors are for a population
   (E) study the number and ages of people in a country

5. Which of the following are exhibited by *k*-select organisms?

   I. Slow maturation
   II. Many small offspring
   III. Reproduction occurs late in life

   (A) I only
   (B) II only
   (C) III only
   (D) I and II only
   (E) I and III only

6. A population cycle that is marked by regular increases and decreases in its numbers is correctly said to be

(A) boom-and-bust
(B) irruptive
(C) stable
(D) logistic
(E) irregular

7. The demographic transition model is used to study the

(A) effects of migration patterns
(B) influence of industrialization on population growth or decline
(C) location of large population centers
(D) benefits of mass transportation projects
(E) negative effects of pollution on the habitat

8. Which disease is having a severe negative impact on the population in sub-Saharan Africa today?

(A) Lung cancer
(B) Heart disease
(C) HIV/AIDS
(D) Alzheimer's
(E) Down syndrome

9. Which of the numbers below is closest to the population of India?

(A) 1 billion
(B) 900 million
(C) 300 million
(D) 50 million
(E) 2 million

10. Which of the following is a density independent population factor?

(A) Number of parasites in the population
(B) Number of predators in the population
(C) Competition for resources
(D) Disease
(E) Habitat destruction

11. When a population encounters environmental resistance it is most likely to

(A) continue its high growth rate
(B) mutate to form and continue growing
(C) slow down its growth rate
(D) move to a higher growth rate
(E) have no effect on the growth rate

12. A population's growth can best be calculated using which of the following?

(A) Births + immigration – deaths + emigration
(B) Immigration + emigration
(C) Emigration + births
(D) Births + emigration – deaths + immigration
(C) Immigration – emigration

13. Overexploitation of a species can happen by all of the following EXCEPT

(A) excessive hunting
(B) use of a species for food
(C) use of species as a pet
(D) habitat destruction
(E) habitat conservation

Directions: Each set of lettered choices below refers to the numbered questions or statements immediately following it. Select the one lettered choice that best answers each questions or best fits each statement. A choice may be used once, more than once, or not at all in each set.

Questions 14-18 refer to the following characteristics of populations.

(A) birth rate
(B) total fertility rate
(C) mortality rate
(D) life expectancy
(E) replacement birth rate

14. The number of people who die per 1,000 in the population

15. The average number of years a person can be expected to live

16. The average number of offspring a woman is expected to have

17. The number of individuals born per 1,000 in the population

18. The number of children a couple must have to replace themselves

19. Poverty can affect population in all of the following ways EXCEPT

(A) causing premature deaths
(B) increasing total fertility rate
(C) decreasing total fertility rate
(D) forcing the use of resources in unsustainable ways
(E) emigration

20. In comparison to the surrounding rural areas, cities are

(A) cooler than the rural area
(B) the same temperature as the rural area
(C) hotter than the rural area
(D) incomparable to the surrounding areas as far as temperatures
(E) more likely to have snowfall than the surrounding area

Free-Response Question

1. A habitat's carrying capacity imposes limits on the growth of populations and their consumption of resources.

   (a) Define the term "carrying capacity." Give two examples of how carrying capacity can impose limits on a population.

   (b) Explain how a population's consumption of natural resources might be controlled. Give two examples of how nature slows down the consumption of natural resources by a population.

   (c) Describe one human activity that can raise a habitat's carrying capacity for humans.

ANSWERS AND EXPLANATIONS

Multiple-Choice Answers

1. **C** Remember that with EXCEPT questions, you're looking for the answer that does not fit the statement. If you read through them, you'll see that choice (C) is the only factor that does not measure some characteristic of populations. Habitat is important in determining a population's size, but it is not a way to measure a population.

2. **D** Emigration refers to the movement of individuals that are leaving, or emigrating from, a population. Birth rate is the number of births per thousand; carrying capacity is the maximum number that can live sustainably in a habitat; immigration is the movement of individuals into a population; and environmental resistance is all of the factors in a habitat that limit a population's growth.

3. **C** To do this problem, remember the rule of 70, which approximates the time it takes for a population to double (called its doubling time). Take the rate of change (2 percent), and divide that number into 70. So, $\frac{70}{2} = 35$ the number of years that it will take this population to double in size.

4. **E** Age-structure pyramids are often constructed using data about the number and gender of various age groups in a population. Generally, the female population is shown on the right side of the pyramid, and the male population is situated on the left side. The length of each age group indicates how the total number of individuals in that age group compares to the other age groups, and the population as a whole.

5. **E** *k*-selected organisms reproduce later in life, produce fewer offspring, and devote significant time and energy to the nurturing of their offspring. For these species, it is important to preserve as many members of the offspring as possible because they produce so few; parents have a tremendous investment in each individual offspring. Some examples of *k*-selected species are humans, lions, and cows.

6. A Organisms like the hare and the lynx (predator and prey) exhibit regular changes in their population (every 10 years) in a pattern known as boom-and-bust. For the other choices, an irruptive population is very large and then very small; an irregular population behaves in a chaotic manner; a logistic population doubles in a short time; and a stable population varies only slightly above and below its carrying capacity over time.

7. B The demographic transition model is used to study countries' transitions from one type of economy to another; specifically, how the transition affects the population. The four stages of the transition are pre-industrial (high birth and death rates), transitional (high birth rates and low death rates), industrial (declining birth and death rates), and finally postindustrial (very low birth and death rates).

8. C HIV / AIDS is correct. The other diseases are seen more commonly in Western Europe and North America. HIV / AIDS spreads very rapidly because it is caused by an easily transmittable virus; the other diseases listed are not communicable—they cannot be passed from person to person.

9. A One billion is the figure that is closest to the current population in India.

10. E (E) is the only answer choice that lists a factor that is density independent. Destruction by humans (or natural event) would occur whether the population density was low or high. Density dependent factors only influence a population when the density is high. You might have thought that this answer choice was incorrect because you reasoned that, as a population increases in size, it could get so large that it would degrade its environment. However, remember carrying capacity! Habitats only tolerate the existence of a certain number of individuals in a population.

11. C Environmental resistance factors such as competition, parasites, or a lack of reources are factors that slow a population's growth. Factors might include competition, parasites, or a lack of resources.

12. A Births and immigration add individuals to a population whereas deaths and emigration remove individuals. The difference between gain and loss is the growth.

13. E Habitat conservation is the only factor that promotes species growth. All other factors cause a population to decline.

14. C The number of people who die per 1,000 in the population is known as the mortality rate of the population.

15. D The life expectancy of a person in a population is defined as the average number of years a person can be expected to live.

16. **B** The total fertility rate is used to describe the number of children a woman will bear during her lifetime, and this information is based on an analysis of data from preceding years in the population in question. Total fertility rates are predictions that provide a rough estimate, but they can't be depended on because they assume that the conditions of the past will be the conditions of the future.

17. **A** The birth rate of a population is the number of individuals born per 1,000 in the population.

18. **E** The replacement birth rate of a human population refers to the number of children a couple must have in order to replace themselves in a population. While you might automatically think that the answer is always two, in reality it is slightly higher to compensate for the deaths of children, the existence of non-child-bearing females in the population, and other factors.

19. **C** In developing countries experiencing poverty, women tend to have more children than women in developed nations. While this is in part the result of a lack of available birth control, this cultural phenomenon is also the result of the need for these children to go to work and provide an economic "safety net" for families. Also, at poverty level, infant mortality rates are higher, which means that women must have more children to even attain replacement rate.

20. **C** Urban heat islands are created because of the presence of buildings, highways, factories, and automobiles, and the use of lights warm the surrounding air. This can cause the formation of clouds and can trap pollution near the Earth and prevent it from being diluted.

Free-Response Answer

1. **(a)** The carrying capacity is the maximum number of individuals that a habitat can sustain for a long period of time. If a population exceeds the carrying capacity, there will be a die-off of individuals until the population dips below the carrying capacity. When the population is lower than the carrying capacity, the population can begin to increase. Factors that can limit population in a habitat are physical factors (temperature, nutrient availability, amounts of light, amount of dissolved oxygen, or pH) and biotic factors (parasites, predators, competitors).
(4 points maximum—2 for definition and 1 for each correct example)

(b) One example of how nature limits consumption is competition that occurs between two populations for the same habitat. For example, if two different species of animals prey on the same species in the same habitat, they are said to be in direct competition. Sooner or later, the population of prey would be small enough that one predator in the population would not have enough resources. This might cause them to become extinct, to leave that area, or to switch to another food source, thus ending the competition. Some examples of competition are two raptor birds that compete for mice or fish; hunting cats like cheetahs and lions, which compete for grazing animals; or two species of birds that compete for insects.
(4 points maximum—2 points for correctly explaining how competition is avoided and 1 point each for two correct examples)

(c) Human activities that violate the limits of population growth can include examples of how we harvest natural resources to help grow food; this affects the habitat of certain plant and animal species. Examples of harvesting more natural resources might include: irrigation to increase water availability; fertilizers to overcome a lack of certain minerals in the soil; or turning the natural biome into farmland to raise more food crops. We eliminate competitors for our food supply and we use medicines to kill parasites. There are numerous possible correct answers to this question.
(2 points maximum—1 point for each correct explanation of how humans remove competition and exploit resources)