Biology Lesson 8: Communities and Populations

If you saw the movie *Finding Nemo,* then you probably recognize this fish. It's known as a clownfish, and it's swimming near the tentacles of an animal called a sea anemone. The sea anemone kills prey by injecting poison with its tentacles. For some reason, the anemone doesn't harm the clownfish, perhaps because the fish has a coating of mucus that helps disguise it. But why does the clownfish "hang out" with the sea anemone? One reason is for the food. The clownfish eats the remains of the anemone's prey after it finishes feeding. Another reason is safety. The clownfish is safe from predators when it's near the anemone. Predators are scared away by the anemone's poison tentacles. In return, the clownfish helps the anemone catch food by attracting prey with its bright colors. Its feces also provide nutrients to the anemone. The clownfish and anemone are just one example of the diverse ways that living things may help each other in nature. You will learn more about species interactions such as this when you read this chapter.

Section 1: Community Interactions

Section Objectives

- Define community as the term is used in ecology.
- Describe predation and its effects on population size and evolution.
- Explain why interspecific competition leads to extinction or greater specialization.
- Compare and contrast mutualism, commensalism, and parasitism.
- Outline primary and secondary succession, and define climax community.

Vocabulary

- climax community
- commensalism
- ecological succession
- host
- interspecific competition
- intraspecific competition
- keystone species
- mutualism
- parasite
- parasitism
- pioneer species
- predation
- predator
- prey
- primary succession
- secondary succession
- specialization

Introduction

Biomes as different as deserts and wetlands share something very important. All biomes have populations of interacting species. Species also interact in the same basic ways in all biomes. For example, all biomes have some species that prey on others for food. The focus of study of species interactions is the community.

What Is a Community?

A community is the biotic part of an ecosystem. It consists of all the populations of all the species in the same area. It also includes their interactions. Species interactions in communities are important factors in natural selection. They help shape the evolution of the interacting species. There are three major types of community interactions: predation, competition, and symbiosis.

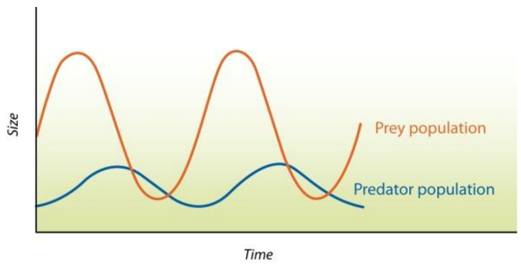
Predation

Predation is a relationship in which members of one species (the **predator**) consume members of another species (the **prey**). The lions and buffalo in **Figure** below are classic examples of predators and prey. In addition to the lions, there is another predator in this figure. Can you spot it? The other predator is the buffalo. Like the lion, it consumes prey species, in this case species of grass. However, unlike the lions, the buffalo does not kill its prey. Predator-prey relationships such as these account for most energy transfers in food chains and food webs.

Predators and Their Prey. Two lions feed on the carcass of a South African cape buffalo.

Predation and Population

A predator-prey relationship tends to keep the populations of both species in balance. This is shown by the graph in **Figure** below. As the prey population increases, there is more food for predators. So, after a slight lag, the predator population increases as well. As the number of predators increases, more prey are captured. As a result, the prey population starts to decrease. What happens to the predator population then?



Predator-Prey population Dynamics. As the prey population increases, why does the predator population also increase?

Keystone Species

Some predator species are known as keystone species. A **keystone species** is one that plays an especially important role in its community. Major changes in the numbers of a keystone species affect the populations of many other species in the community. For example, some sea star species are keystone species in coral reef communities. The sea stars prey on mussels and sea urchins, which have no other natural predators. If sea stars were removed from a coral reef community, mussel and sea urchin populations would have explosive growth. This, in turn, would drive out most other species. In the end, the coral reef community would be destroyed.

Adaptations to Predation

Both predators and prey have adaptations to predation that evolve through natural selection. Predator adaptations help them capture prey. Prey adaptations help them avoid predators. A common adaptation in both predator and prey is camouflage. Several examples are shown in **Figure** below. Camouflage in prey helps them hide from predators. Camouflage in predators helps them sneak up on prey.

Competition

Competition is a relationship between organisms that strive for the same resources in the same place. The resources might be food, water, or space. There are two different types of competition:

1. **Intraspecific competition** occurs between members of the same species. For example, two male birds of the same species might compete for mates in the same area. This type of competition is a basic factor in natural selection. It leads to the evolution of better adaptations within a species.
2. **Interspecific competition** occurs between members of different species. For example, predators of different species might compete for the same prey.

Interspecific Competition and Extinction

Interspecific competition often leads to extinction. The species that is less well adapted may get fewer of the resources that both species need. As a result, members of that species are less likely to survive, and the species may go extinct.

Interspecific Competition and Specialization

Instead of extinction, interspecific competition may lead to greater specialization. **Specialization** occurs when competing species evolve different adaptations. For example, they may evolve adaptations that allow them to use different food sources. **Figure** below describes an example.

Specialization in Anole Lizards. Specialization lets different species of anole lizards live in the same area without competing.

Symbiotic Relationships

Symbiosis is a close relationship between two species in which at least one species benefits. For the other species, the relationship may be positive, negative, or neutral. There are three basic types of symbiosis: mutualism, commensalism, and parasitism.

Mutualism

Mutualism is a symbiotic relationship in which both species benefit. An example of mutualism involves goby fish and shrimp (see **Figure** below). The nearly blind shrimp and the fish spend most of their time together. The shrimp maintains a burrow in the sand in which both the fish and shrimp live. When a predator comes near, the fish touches the shrimp with its tail as a warning. Then, both fish and shrimp retreat to the burrow until the predator is gone. From their relationship, the shrimp gets a warning of approaching danger. The fish gets a safe retreat and a place to lay its eggs.

The multicolored shrimp in the front and the green goby fish behind it have a mutualistic relationship.

Commensalism

Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected. One species typically uses the other for a purpose other than food. For example, mites attach themselves to larger flying insects to get a “free ride.” Hermit crabs use the shells of dead snails for homes.

Parasitism

Parasitism is a symbiotic relationship in which one species (the **parasite**) benefits while the other species (the **host**) is harmed. Many species of animals are parasites, at least during some stage of their life. Most species are also hosts to one or more parasites. Some parasites live on the surface of their host. Others live inside their host. They may enter the host through a break in the skin or in food or water. For example, roundworms are parasites of mammals, including humans, cats, and dogs (see **Figure** below). The worms produce huge numbers of eggs, which are passed in the host’s feces to the environment. Other individuals may be infected by swallowing the eggs in contaminated food or water.

Canine Roundworm. The roundworm above, found in a puppy's intestine, might eventually fill a dog

Some parasites kill their host, but most do not. It’s easy to see why. If a parasite kills its host, the parasite is also likely to die. Instead, parasites usually cause relatively minor damage to their host.

Ecological Succession

Communities are not usually static. The numbers and types of species that live in them generally change through time. This is called **ecological succession**. Important cases of succession are primary and secondary succession.

Primary Succession

Primary succession occurs in an area that has never before been colonized. Generally, the area is nothing but bare rock. This type of environment may come about when

- lava flows from a volcano and hardens into rock.

- a glacier retreats and leaves behind bare rock.
- a landslide uncovers an area of bare rock.

The first species to colonize a disturbed area such as this are called **pioneer species** (see **Figure** below) They change the environment and pave the way for other species to come into the area. Pioneer species are likely to include bacteria and lichens that can live on bare rock. Along with wind and water, they help weather the rock and form soil. Once soil begins to form, plants can move in. At first, the plants include grasses and other species that can grow in thin, poor soil. As more plants grow and die, organic matter is added to the soil. This improves the soil and helps it hold water. The improved soil allows shrubs and trees to move into the area.

Primary Succession. On an island near New Zealand, bare rocks from a volcanic eruption are slowly being colonized by pioneer species.

Secondary Succession

Secondary succession occurs in a formerly inhabited area that was disturbed. The disturbance could be a fire, flood, or human action such as farming. This type of succession is faster because the soil is already in place. In this case, the pioneer species are plants such as grasses, birch trees, and fireweed. Organic matter from the pioneer species improves the soil. This lets other plants move into the area. An example of this type of succession is shown in **Figure** below.

Secondary Succession. This formerly plowed field in Poland is slowly changing back to forest.

Climax Communities

Many early ecologists thought that a community always goes through the same series of stages during succession. They also assumed that succession always ends with a final stable stage. They called this stage the **climax community**. Today, most ecologists no longer hold these views. They believe that continued change is normal in most ecosystems. They think that most communities are disturbed too often to become climax communities.

Section Summary

- A community is the biotic part of an ecosystem. It consists of all the populations of all the species that live in the same area. It also includes their interactions.

- Predation is a relationship in which members of one species (the predator) consume members of another species (the prey). A predator-prey relationship keeps the populations of both species in balance.
- Competition is a relationship between organisms that strive for the same resources in the same place. Intraspecific competition occurs between members of the same species. It improves the species' adaptations. Interspecific competition occurs between members of different species. It may lead to one species going extinct or both becoming more specialized.
- Symbiosis is a close relationship between two species in which at least one species benefits. Mutualism is a symbiotic relationship in which both species benefit. Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected. Parasitism is a symbiotic relationship in which one species (the parasite) benefits while the other species (the host) is harmed.
- Ecological succession is the process in which a community changes through time. Primary succession occurs in an area that has never before been colonized. Secondary succession occurs in a formerly inhabited area that was disturbed.

Extra Practice

1. In 1980, a massive volcanic eruption of Mount St. Helen's in Washington State covered a large area with lava and ash. By 2010, plants were growing in the area, including some small trees. What type of ecological succession had occurred? How do you know? Describe how living things colonized the bare rock.

2. Compare and contrast the evolutionary effects of intraspecific and interspecific competition.

3. Explain why most parasites do not kill their host. Why is it in their own best interest to keep their host alive?

Points to Consider

Communities consist of populations of different species. The size and growth of populations in a community are influenced by species interactions. For example, predator-prey relationships control the growth of both predator and prey populations.

- How might populations grow without these influences? What other factors do you think might affect population growth?
- What factors do you think may have affected the growth of the human population?

Section 2: Characteristics of Populations

Section Objectives

- Define population size, density, and dispersion.
- Relate population pyramids and survivorship curves to population structure.
- Identify factors that determine population growth rate.
- Compare and contrast exponential and logistic growth.

Vocabulary

- age-sex structure
- carrying capacity (K)
- dispersal
- emigration
- exponential growth
- immigration
- *K*-selected
- logistic growth
- migration
- population density
- population distribution
- population growth rate (r)
- population pyramid
- *r*-selected
- survivorship curve

Introduction

Communities are made up of populations of different species. In biology, a population is a group of organisms of the same species that live in the same area. The population is the unit of natural selection and evolution. How large a population is and how fast it is growing are often used as measures of its health.

Population Size, Density, and Distribution

Population size is the number of individuals in a population. For example, a population of insects might consist of 100 individual insects, or many more. Population size influences the chances of a species surviving or going extinct. Generally, very small populations are at greatest risk of extinction. However, the size of a population may be less important than its density.

Population Density

Population density is the average number of individuals in a population per unit of area or volume. For example, a population of 100 insects that live in an area of 100 square meters has a density of 1 insect per square meter. If the same population lives in an area of only 1 square meter, what is its density? Which population is more crowded? How might crowding affect the health of a population?

Population Distribution

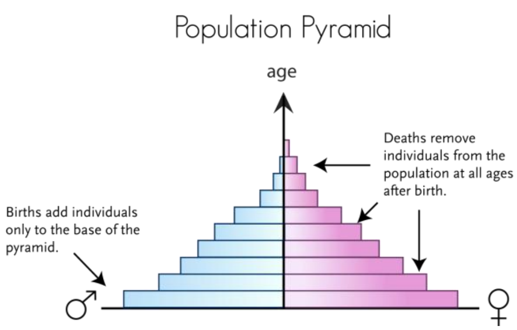
Population density just gives the average number of individuals per unit of area or volume. Often, individuals in a population are not spread out evenly. Instead, they may live in clumps or some other pattern (see **Figure** below). The pattern may reflect characteristics of the species or its environment. **Population distribution** describes how the individuals are distributed, or spread throughout their habitat.

Population Structure

An important factor in population growth is **age-sex structure**. This is the number of individuals of each sex and age in the population. The age-sex structure influences population growth. This is because younger people are more likely to reproduce, while older people have higher rates of dying.

Population Pyramids

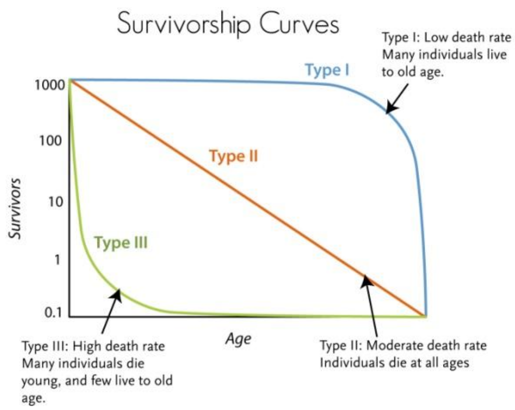
Age-sex structure is represented by a **population pyramid**. This is a bar graph, like the one **Figure** below. In this example, the bars become narrower from younger to older ages. Can you explain why?



Population Pyramid. A population pyramid represents the age-sex structure of a population.

Survivorship Curves

Another way to show how deaths affect populations is with **survivorship curves**. These are graphs that represent the number of individuals still alive at each age. Examples are shown in **Figure** below.



Survivorship Curves. Survivorship curves reflect death rates at different ages.

The three types of curves shown in the figure actually represent different strategies species use to adapt to their environment:

- Type I: Parents produce relatively few offspring and provide them with a lot of care. As a result, most of the offspring survive to adulthood so they can reproduce. This pattern is typical of large animals, including humans.
- Type II: Parents produce moderate numbers of offspring and provide some parental care. Deaths occur more uniformly throughout life. This pattern occurs in some birds and many asexual species.
- Type III: Parents produce many offspring but provide them with little or no care. As a result, relatively few offspring survive to adulthood. This pattern is typical of plants, invertebrates, and many species of fish.

The type I strategy occurs more often in stable environments. The Type III strategy is more likely in unstable environments. Can you explain why?

Population Growth

Populations gain individuals through births and immigration. They lose individuals through deaths and emigration. These factors together determine how fast a population grows.

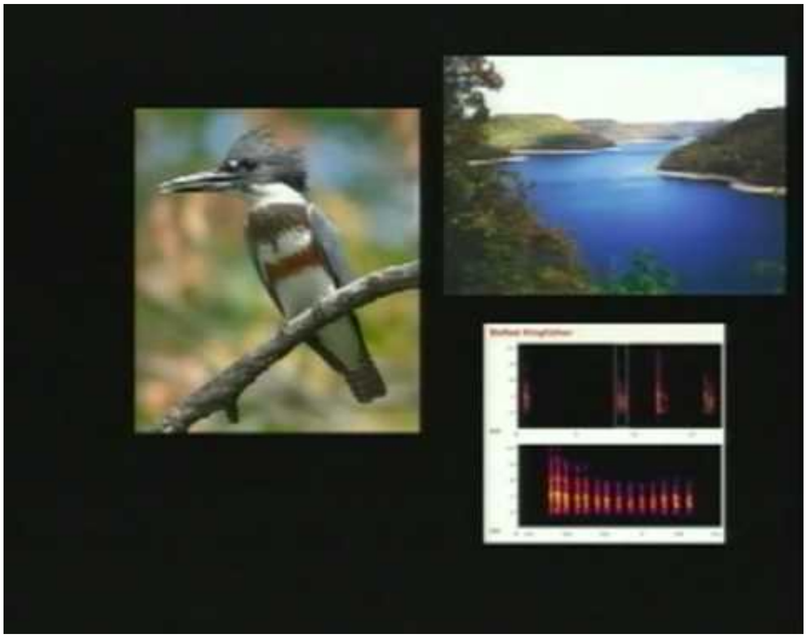
Population Growth Rate

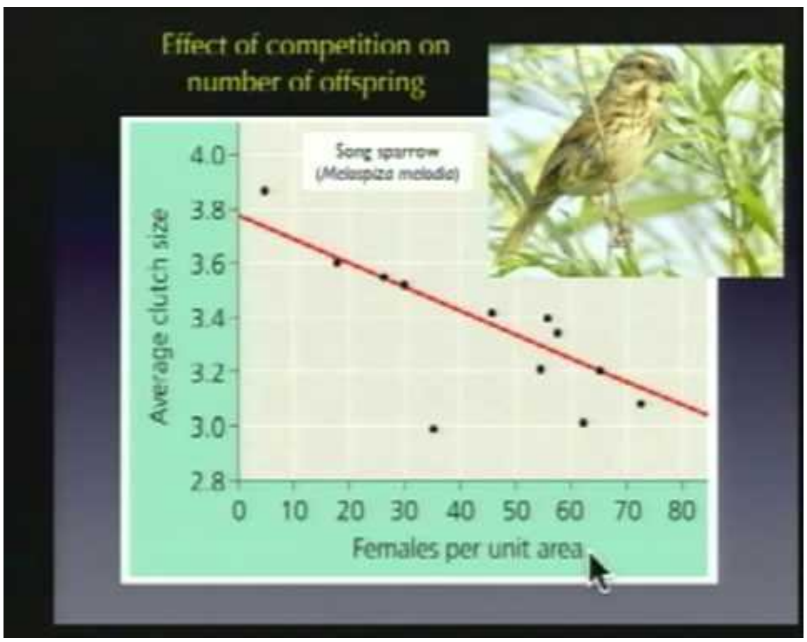
Population growth rate (*r*) is how fast a population changes in size over time. A positive growth rate means a population is increasing. A negative growth rate means it is decreasing. The two main factors affecting population growth are the birth rate (*b*) and death rate (*d*). Population growth may also be affected by people coming into the population from somewhere else (**immigration**, *i*) or leaving the population for another area (**emigration**, *e*). The formula for population growth takes all these factors into account.

$r = (b + i) - (d + e)$

- r = population growth rate
- b = birth rate
- i = immigration rate
- d = death rate
- e = emigration rate

Two lectures on demography are available at **(6c)** http://www.youtube.com/watch?v=3diw1Hu3auk (50:36) and **(6c)** http://www.youtube.com/watch?v=Wg3ESbyKbic (49:38).





Dispersal and Migration

Other types of movements may also affect population size and growth. For example, many species have some means of **dispersal**. This refers to offspring moving away from their parents. This prevents the offspring from competing with the parents for resources such as light or water. For example, dandelion seeds have "parachutes." They allow the wind to carry the seeds far from the parents (see **Figure** below).

Dandelion Seeds. These dandelion seeds may disperse far from the parent plant. Why might this be beneficial to both parents and offspring?

Migration is another type of movement that changes population size. **Migration** is the regular movement of individuals or populations each year during certain seasons. The purpose of migration usually is to find food, mates, or other resources. For example, many Northern Hemisphere birds migrate thousands of miles south each fall. They go to areas where the weather is warmer and more resources are available (see **Figure** below). Then they return north in the spring to nest. Some animals, such as elk, migrate vertically. They go up the sides of mountains in spring as snow melts. They go back down the mountain sides in fall as snow returns.

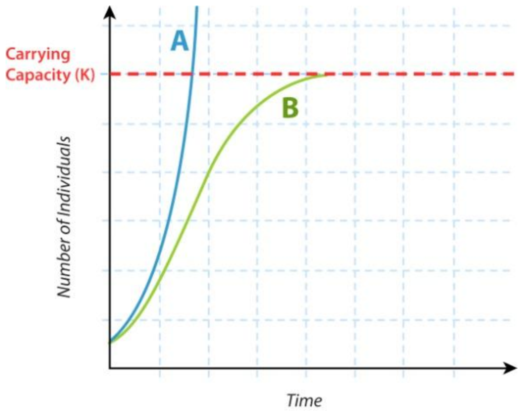
Swainson

Patterns of Population Growth

Populations may show different patterns of growth. The growth pattern depends partly on the conditions under which a population lives.

Exponential Growth

Under ideal conditions, populations of most species can grow at exponential rates. Curve A in **Figure** below represents **exponential growth**. The population starts out growing slowly. As population size increases, the growth rate also increases. The larger the population becomes, the faster it grows.



Exponential and Logistic Growth. Curve A shows exponential growth. Curve B shows logistic growth.

Logistic Growth

Most populations do not live under ideal conditions. Therefore, most do not grow exponentially. Certainly, no population can keep growing exponentially for very long. Many factors may limit growth. Often, the factors are density dependent. These are factors that kick in when the population becomes too large and crowded. For example, the population may start to run out of food or be poisoned by its own wastes. As a result, population growth slows and population size levels off. Curve B in **Figure** above represents this pattern of growth, which is called **logistic growth**.

At what population size does growth start to slow in the logistic model of growth? That depends on the population's carrying capacity (see **Figure** above). The **carrying capacity (K)** is the largest population size that can be supported in an area without harming the environment. Population growth hits a ceiling at that size in the logistic growth model.

K-Selected and *r*-Selected Species

Species can be divided into two basic types when it comes to how their populations grow.

- Species that live in stable environments are likely to be ***K*-selected**. Their population growth is controlled by density-dependent factors. Population size is generally at or near the carrying capacity. These species are represented by curve B in **Figure** above.
- Species that live in unstable environments are likely to ***r*-selected**. Their potential population growth is rapid. For example, they have large numbers of offspring. However, individuals are likely to die young. Thus, population size is usually well below the carrying capacity. These species are represented by the lower part of curve A in **Figure** above.

Section Summary

- Population size is the number of individuals in a population. Population density is the average number of individuals per unit of area or volume. The pattern of spacing of individuals in a population may be affected by characteristics of a species or its environment.
- The age-sex structure of a population is the number of individuals of each sex and age in the population. Age-sex structure influences population growth. It is represented by a population pyramid. The number of survivors at each age is plotted on a survivorship curve.
- Population growth rate is how fast a population changes in size over time. It is determined by rates of birth, death, immigration, and emigration.
- Under ideal conditions, populations can grow exponentially. The growth rate increases as the population gets larger. Most populations do not live under ideal conditions and grow logistically instead. Density-dependent factors slow population growth as population size nears the carrying capacity.

Extra Practice

1. A population of 820 insects lives in a 1.2-acre area. They gather nectar from a population of 560 flowering plants. The plants live in a 0.2-acre area. Which population has greater density, the insects or the plants?

2. Assume that a population pyramid has a very broad base. What does that tell you about the population it represents?

3. What can you infer about a species that has a random pattern of distribution over space? A uniform pattern?

4. Compare and contrast Type I and Type III survivorship curves.

Points to Consider

Human populations have an interesting history that you will read about in the next Section. You just read about population dispersion and growth. Make some predictions about dispersion and growth in human populations:

- Do you think human populations have a clumped, random, or uniform dispersion?
- How fast do human populations grow? What might limit their growth?

Section 3: Human Population Growth

Section Objectives

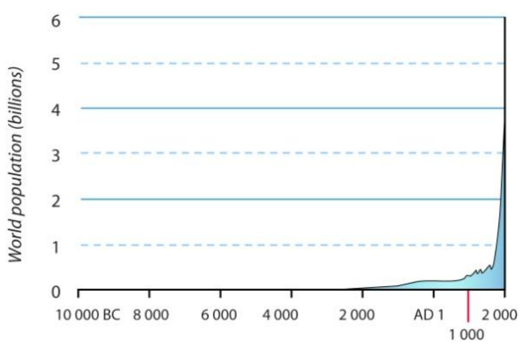
- Describe early human population growth.
- Outline the stages of the demographic transition.
- Explain trends in recent human population growth.
- Summarize the human population problem and possible solutions to the problem.

Vocabulary

- demographic transition

Introduction

Humans have been called the most successful “weed species” Earth has ever seen. Like weeds, human populations are fast growing. They also disperse rapidly. They have colonized habitats from pole to pole. Overall, the human population has had a pattern of exponential growth, as shown in **Figure** below. The population increased very slowly at first. As it increased in size, so did its rate of growth.



Growth of the Human Population. This graph gives an overview of human population growth since 10,000 BC. It took until about 1800 AD for the number of humans to reach 1 billion. It took only a little over 100 years for the number to reach 2 billion. Today, the human population is rapidly approaching the 7 billion mark! Why do you think the human population began growing so fast?

Early Population Growth

Homo sapiens arose about 200,000 years ago in Africa. Early humans lived in small populations of nomadic hunters and gatherers. They first left Africa about 40,000 years ago. They soon moved throughout Europe, Asia, and Australia. By 10,000 years ago, they had reached the Americas. During this long period, birth and death rates were both fairly high. As a result, population growth was slow. Humans invented agriculture about 10,000 years ago. This provided a bigger, more dependable food supply. It also let them settle down in villages and cities for the first time. The death rate increased because of diseases associated with domestic animals and crowded living conditions. The birth rate increased because there was more food and settled life offered other advantages. The combined effect was continued slow population growth.

Demographic Transition

Major changes in the human population first began during the 1700s in Europe and North America. First death rates fell, followed somewhat later by birth rates.

Death Rates Fall

Several advances in science and technology led to lower death rates in 18th century Europe and North America:

- New scientific knowledge of the causes of disease led to improved water supplies, sewers, and personal hygiene.
- Better farming techniques and machines increased the food supply.
- The Industrial Revolution of the 1800s led to new sources of energy, such as coal and electricity. This increased the efficiency of the new agricultural machines. It also led to train transport, which improved the distribution of food.

For all these reasons, death rates fell, especially in children. This allowed many more children to survive to adulthood, so birth rates increased. As the gap between birth and death rates widened, the human population grew faster.

Birth Rates Fall

It wasn't long before birth rates started to fall as well in Europe and North America. People started having fewer children because large families were no longer beneficial for several reasons.

- As child death rates fell and machines did more work, farming families no longer needed to have as many children to work in the fields.

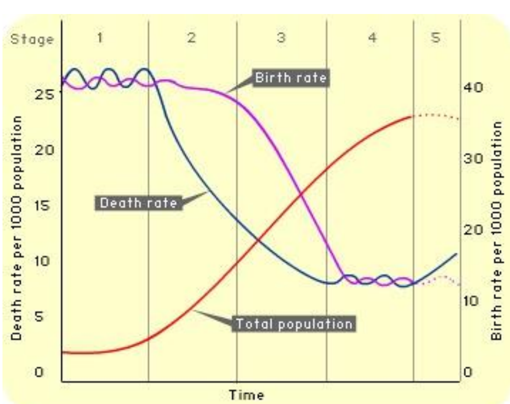
- Laws were passed that required children to go to school. Therefore, they could no longer work and contribute to their own support. They became a drain on the family's income.

Eventually, birth rates fell to match death rates. As a result, population growth slowed to nearly zero.

Stages of the Demographic Transition

These changes in population that occurred in Europe and North America have been called the **demographic transition**. The transition can be summarized in the following four stages, which are illustrated in **Figure** below:

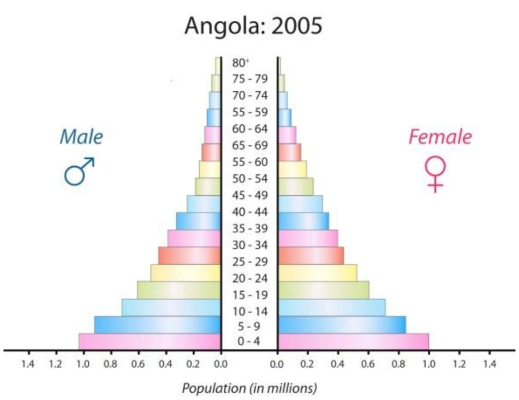
- Stage 1—High birth and death rates lead to slow population growth.
- Stage 2—The death rate falls but the birth rate remains high, leading to faster population growth.
- Stage 3—The birth rate starts to fall, so population growth starts to slow.
- Stage 4—The birth rate reaches the same low level as the death rate, so population growth slows to zero.



Stages of the Demographic Transition. In the demographic transition, the death rate falls first. After a lag, the birth rate also falls. How do these changes affect the rate of population growth over time?

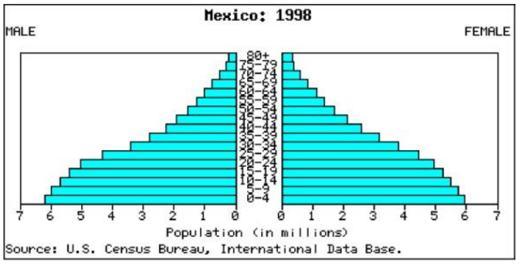
Recent Population Growth

At one time, scientists predicted that all human populations would pass through the same demographic transition as Europe and North America. Now, they are not so sure. Death rates have fallen throughout the world. No country today remains in Stage 1 of the transition. However, birth rates are still high in many poor countries. These populations seem to be stuck in Stage 2. An example is the African country of Angola. Its population pyramid for 2005 is shown in **Figure** below. The wide base of the pyramid base reflects the high birth rate of this population.



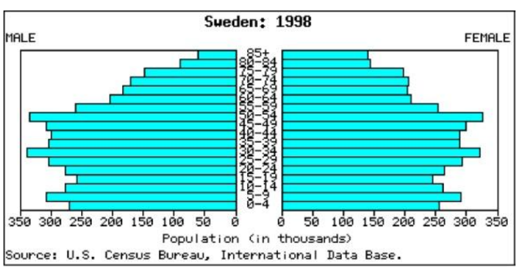
Angola

Many other countries have shifted to Stage 3 of the transition. Birth rates have started to fall. As a result, population growth is slowing. An example is Mexico. Its population pyramid for 1998 is shown in **Figure** below. It reflects a recent fall in the birth rate.



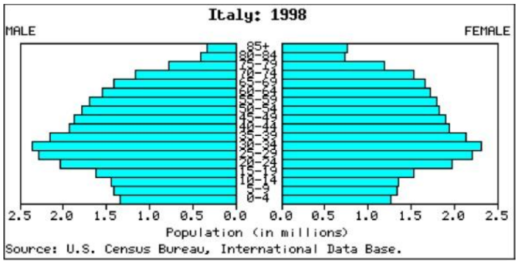
Mexico

Most developed nations have entered Stage 4. Sweden is an example (see **Figure** below). The birth rate has been low for many years in Sweden. Therefore, the rate of population growth is near zero.



Sweden

In some countries, birth rates have fallen even lower than death rates. As result, their population growth rates are negative. In other words, the populations are shrinking in size. These populations have top-heavy population pyramids, like the one for Italy shown in **Figure** below. This is a new stage of the demographic transition, referred to as Stage 5. You might think that a negative growth rate would be a good thing. In fact, it may cause problems. For example, growth-dependent industries decline. Supporting the large aging population is also a burden for the shrinking younger population of workers.



This 1998 population pyramid for Italy represents a Stage 5 population.

Future Population Growth

The human population is now growing by more than 200,000 people a day. At this rate, there will be more than 9 billion people by 2050. The human population may well be close to its carrying capacity. It has already harmed the environment. An even larger human population may cause severe environmental problems. This could lead to outbreaks of disease, starvation, and global conflict. There are three potential solutions:

1. Use technology to make better use of resources to support more people.
2. Change behaviors to reduce human numbers and how much humans consume.
3. Distribute resources more fairly among all the world's people.

Which solution would you choose?

Section Summary

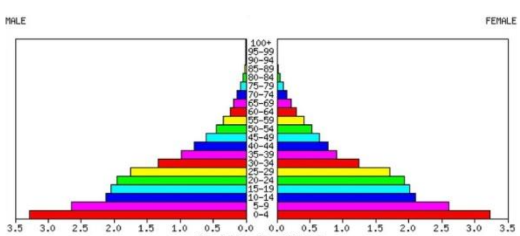
- Early humans lived in small populations of nomadic hunters and gatherers. Both birth and death rates were fairly high. As a result, human population growth was very slow.

The invention of agriculture increased both birth and death rates. The population continued to grow slowly.

- Major changes in the human population first began during the 1700s. This occurred in Europe and North America. First, death rates fell while birth rates remained high. This led to rapid population growth. Later, birth rates also fell. As a result, population growth slowed.
- Other countries have completed a similar demographic transition. However, some countries seem stalled at early stages. They have high birth rates and rapidly growing populations.
- The total human population may have to stop growing eventually. Even if we reduce our use of resources and distribute them more fairly, at some point the carrying capacity will be reached.

Extra Practice

1. Which stage of the demographic transition is represented by the population pyramid below?



2. Assume you will add a line to the graph in **Figure** above to represent the population growth rate (r). Describe what the line would like.

3. Evaluate how well the original demographic transition model represents human populations today.

4. What is the human population problem? What are some potential solutions? Which solution do you think is best? Present a logical argument to support your choice.

Points to Consider

The human population may already be larger than its carrying capacity.

- What evidence might show that there are too many people on Earth today?
- How does human overpopulation affect the environment? How does it affect the populations of other species?

Section 4: The Biodiversity Crisis

Section Objectives

- Define biodiversity.
- Identify economic benefits and ecosystem services of biodiversity.
- Relate human actions to the sixth mass extinction.

Vocabulary

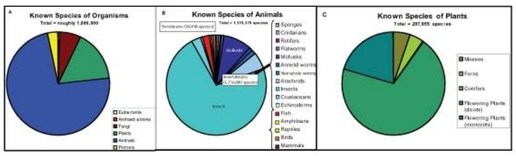
- exotic species
- habitat loss
- sixth mass extinction

Introduction

One of the effects of human overpopulation is the loss of other species. The rapidly growing human population has reduced Earth's biodiversity.

What Is Biodiversity?

Biodiversity refers to the variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur. Scientists have identified about 1.9 million species alive today. They are divided into the six kingdoms of life shown in **Figure** below. Scientists are still discovering new species. Thus, they do not know for sure how many species really exist today. Most estimates range from 5 to 30 million species.



Known species represent only a fraction of all species that exist on Earth.

A discussion of biodiversity is available at **(6a)** http://www.youtube.com/watch?v=vGxJArebKoc (6:12).

Why Is Biodiversity Important?

Human beings benefit in many ways from biodiversity. Biodiversity has direct economic benefits. It also provides services to entire ecosystems.

Economic Benefits of Biodiversity

The diversity of species provides humans with a wide range of economic benefits:

- Wild plants and animals maintain a valuable pool of genetic variation. This is important because domestic species are genetically uniform. This puts them at great risk of dying out due to disease.
- Other organisms provide humans with many different products. Timber, fibers, adhesives, dyes, and rubber are just a few.
- Certain species may warn us of toxins in the environment. When the peregrine falcon nearly went extinct, for example, it warned us of the dangers of DDT.
- More than half of the most important prescription drugs come from wild species. Only a fraction of species have yet been studied for their medical potential.
- Other living things provide inspiration for engineering and technology. For example, the car design in **Figure** below was based on a fish.

Ecosystem Services of Biodiversity

Biodiversity generally increases the productivity and stability of ecosystems. It helps ensure that at least some species will survive environmental change. It also provides many other ecosystem services. For example:

- Plants and algae maintain the atmosphere. During photosynthesis, they add oxygen and remove carbon dioxide.

- Plants help prevent soil erosion. They also improve soil quality when they decompose.
- Microorganisms purify water in rivers and lakes. They also return nutrients to the soil.
- Bacteria fix nitrogen and make it available to plants. Other bacteria recycle the nitrogen from organic wastes and remains of dead organisms.
- Insects and birds pollinate flowering plants, including crop plants.
- Natural predators control insect pests. They reduce the need for expensive pesticides, which may harm people and other living things.

Human Actions and the Sixth Mass Extinction

Over 99 percent of all species that ever lived on Earth have gone extinct. Five mass extinctions are recorded in the fossil record. They were caused by major geologic and climatic events. Evidence shows that a **sixth mass extinction** is occurring now. Unlike previous mass extinctions, the sixth extinction is due to human actions.

Some scientists consider the sixth extinction to have begun with early hominids during the Pleistocene. They are blamed for over-killing big mammals such as mammoths. Since then, human actions have had an ever greater impact on other species. The present rate of extinction is between 100 and 100,000 species per year. In 100 years, we could lose more than half of Earth's remaining species.

Causes of Extinction

The single biggest cause of extinction today is **habitat loss**. Agriculture, forestry, mining, and urbanization have disturbed or destroyed more than half of Earth's land area. In the U.S., for example, more than 99 percent of tall-grass prairies have been lost. Other causes of extinction today include:

- **Exotic species** introduced by humans into new habitats. They may carry disease, prey on native species, and disrupt food webs. Often, they can out-compete native species because they lack local predators. An example is described in **Figure** below.

- Over-harvesting of fish, trees, and other organisms. This threatens their survival and the survival of species that depend on them.
- Global climate change, largely due to the burning of fossil fuels. This is raising Earth’s air and ocean temperatures. It is also raising sea levels. These changes threaten many species.
- Pollution, which adds chemicals, heat, and noise to the environment beyond its capacity to absorb them. This causes widespread harm to organisms.
- Human overpopulation, which is crowding out other species. It also makes all the other causes of extinction worse.

How You Can Help Protect Biodiversity

There are many steps you can take to help protect biodiversity. For example:

- Consume wisely. Reduce your consumption wherever possible. Re-use or recycle rather than throw out and buy new. When you do buy new, choose products that are energy efficient and durable.
- Avoid plastics. Plastics are made from petroleum and produce toxic waste.
- Go organic. Organically grown food is better for your health. It also protects the environment from pesticides and excessive nutrients in fertilizers.
- Save energy. Unplug electronic equipment and turn off lights when not in use. Take mass transit instead of driving.

Section Summary

- Biodiversity refers to the number of species in an ecosystem or the biosphere as a whole.

- Biodiversity has direct economic benefits. It also provides services to entire ecosystems.
- Evidence shows that a sixth mass extinction is occurring. The single biggest cause is habitat loss caused by human actions. There are many steps you can take to help protect biodiversity. For example, you can use less energy.

Extra Practice

1. Create a poster that conveys simple tips for protecting biodiversity.

2. Why might the brown tree snake or the peregrine falcon serve as “poster species” for causes of the sixth mass extinction?37. Predict what would happen to other organisms in an ecosystem in which all the decomposers went extinct?

3. Describe a hypothetical example showing how rising sea levels due to global warming might cause extinction.

Points to Consider

All species depend on the environment to provide them with the resources they need. As populations grow, resources may be used up. Just using the resources can create more problems.

- What resources do you depend on?
- Does using the resources pollute the environment? Are the resources running out?

Section 4: Natural Resources and Climate Change

Section Objectives

- Distinguish between renewable and nonrenewable resources.
- Describe threats to soil and water resources.
- Identify the causes and effects of air pollution.
- Explain global climate change.

Vocabulary

- acid rain
- air pollution
- algal bloom
- dead zone
- global warming
- greenhouse effect
- natural resource
- nonrenewable resource
- ozone hole
- renewable resource
- soil
- sustainable use

Introduction

A **natural resource** is something supplied by nature that helps support life. When you think of natural resources, you may think of minerals and fossil fuels. However, ecosystems and the services they provide are also natural resources. Biodiversity is a natural resource as well.

Renewable and Nonrenewable Resources

From the human point of view, natural resources can be classified as renewable or nonrenewable.

Renewable Resources

Renewable resources can be replenished by natural processes as quickly as humans use them. Examples include sunlight and wind. They are in no danger of being used up (see **Figure** below). Metals and other minerals are renewable too. They are not destroyed when they are used and can be recycled.

Wind is a renewable resource. Wind turbines like this one harness just a tiny fraction of wind energy.

Living things are considered to be renewable. This is because they can reproduce to replace themselves. However, they can be over-used or misused to the point of extinction. To be truly renewable, they must be used sustainably. **Sustainable use** is the use of resources in a way that meets the needs of the present and also preserves the resources for future generations.

Nonrenewable Resources

Nonrenewable resources are natural resources that exist in fixed amounts and can be used up. Examples include fossil fuels such as petroleum, coal, and natural gas. These fuels formed from the remains of plants over hundreds of millions of years. We are using them up far faster than they could ever be replaced. At current rates of use, petroleum will be used up in just a few decades and coal in less than 300 years. Nuclear power is also considered to be a nonrenewable resource because it uses up uranium, which will sooner or later run out. It also produces harmful wastes that are difficult to dispose of safely.

Soil and Water Resources

Theoretically, soil and water are renewable resources. However, they may be ruined by careless human actions.

Soil

Soil is a mixture of eroded rock, minerals, partly decomposed organic matter, and other materials. It is essential for plant growth, so it is the foundation of terrestrial ecosystems. Soil is important for other reasons as well. For example, it removes toxins from water and breaks down wastes.

Although renewable, soil takes a very long to form—up to hundreds of millions of years. So, for human purposes, soil is a nonrenewable resource. It is also constantly depleted of nutrients through careless use and eroded by wind and water. For example, misuse of soil caused a huge amount of it to simply blow away in the 1930s during the Dust Bowl (see **Figure** below). Soil must be used wisely to preserve it for the future. Conservation practices include contour plowing and terracing. Both reduce soil erosion. Soil also must be protected from toxic wastes.

Water

Water is essential for all life on Earth. For human use, water must be fresh. Of all the water on Earth, only 1 percent is fresh, liquid water. Most of the rest is either salt water in the ocean or ice in glaciers and ice caps.

Although water is constantly recycled through the water cycle, it is in danger. Over-use and pollution of freshwater threaten the limited supply that people depend on. Already, more than 1 billion people worldwide do not have adequate freshwater. With the rapidly growing human population, the water shortage is likely to get worse.

Too Much of a Good Thing

Water pollution comes from many sources. One of the biggest sources is runoff. Runoff picks up chemicals such as fertilizer from agricultural fields, lawns, and golf courses. It carries the chemicals to bodies of water. The added nutrients from fertilizer often cause excessive growth of algae, creating **algal blooms** (see **Figure** below). The algae use up oxygen in the water so that other aquatic organisms cannot survive. This has occurred over large areas of the ocean, creating **dead zones**, where low oxygen levels have killed all ocean life. A very large dead zone exists in the Gulf of Mexico. Measures that can help prevent these problems include cutting down on fertilizer use. Preserving wetlands also helps because wetlands filter runoff.

Algal Bloom. Nutrients from fertilizer in runoff caused this algal bloom.

The Atmosphere

The atmosphere plays an important part in maintaining Earth's freshwater supply. It is part of the water cycle. It refills lakes and rivers with precipitation. The atmosphere also provides organisms with gases needed for life. It contains oxygen for cellular respiration and carbon dioxide for photosynthesis.

Air Pollution

Earth's atmosphere is vast. However, it has been seriously polluted by human activities. **Air pollution** consists of chemical substances and particles released into the atmosphere, mainly by human actions. The major cause of outdoor air pollution is the burning of fossil fuels. Power plants, motor vehicles, and home furnaces all burn fossil fuels and contribute to the problem (see **Table** below). Ranching and using chemicals such as fertilizers also cause air pollution. Erosion of soil in farm fields and construction sites adds dust particles to the air as well. Fumes from building materials, furniture, carpets, and paint add toxic chemicals to indoor air.

Pollutant	Example/Major Source	Problem
Sulfur oxides (SO_x)	Coal-fired power plants	Acid Rain
Nitrogen oxides (NO_x)	Motor vehicle exhaust	Acid Rain
Carbon monoxide (CO)	Motor vehicle exhaust	Poisoning
Carbon dioxide (CO_2)	All fossil fuel burning	Global Warming
Particulate matter (smoke, dust)	Wood and coal burning	Respiratory disease, Global Dimming
Mercury	Coal-fired power plants, medical waste	Neurotoxicity
Smog	Coal burning	Respiratory problems; eye irritation
Ground-level ozone	Motor vehicle exhaust	Respiratory problems; eye irritation

Table 12.6 The burning of fossil fuels adds many different pollutants to air. Ways to reduce air pollution from fossil fuels include switching to nonpolluting energy sources (such as solar energy) and using less energy. What are some ways you could use less energy?

In humans, air pollution causes respiratory and cardiovascular problems. In fact, more people die each year from air pollution than automobile accidents. Air pollution also affects ecosystems worldwide by causing acid rain, ozone depletion, and global warming.

Acid Rain

All life relies on a relatively narrow range of pH, or acidity. That's because protein structure and function is very sensitive to pH. Air pollution can cause precipitation to become acidic. Nitrogen and sulfur oxides—mainly from motor vehicle exhaust and coal burning—create acids when they combine with water in the air. The acids lower the pH of precipitation, forming **acid rain**. If acid rain falls on the ground, it may damage soil and soil organisms. If it falls on plants, it may kill them (see **Figure** below). If it falls into lakes, it lowers the pH of the water and kills aquatic organisms.

Effects of Acid Rain. These trees in a European forest were killed by acid rain.

Ozone Depletion

There are two types of ozone. You can think of them as bad ozone and good ozone. Both are affected by air pollution.

- Bad ozone forms near the ground when sunlight reacts with pollutants in the air. Ground-level ozone is harmful to the respiratory systems of humans and other animals.
- Good ozone forms in a thin layer high up in the atmosphere, between 15 and 35 kilometers above Earth's surface. This ozone layer shields Earth from most of the sun's harmful UV radiation. It plays an important role in preventing mutations in the DNA of organisms.

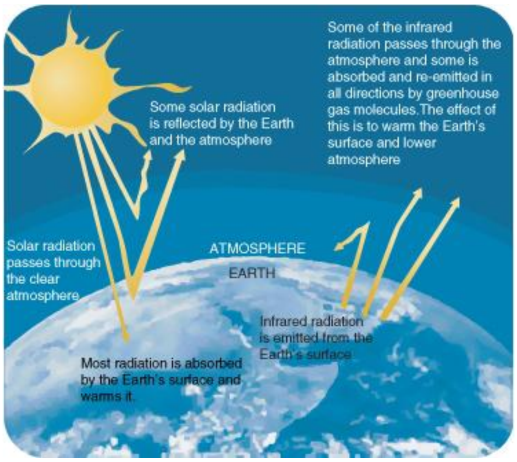
Unfortunately, the layer of good ozone is being destroyed by air pollution. The chief culprits are chlorine and bromine gases. They are released in aerosol sprays, coolants, and other products. Loss of ozone has created an **ozone hole** over Antarctica. Ozone depletion results in higher levels of UV radiation reaching Earth. In humans, this increases skin cancers and eye cataracts. It also disturbs the nitrogen cycle, kills plankton, and disrupts ocean food webs. The total loss of the ozone layer would be devastating to most life. It's rate of loss has slowed with restrictions on pollutants, but it is still at risk.

Global Climate Change

Another major problem caused by air pollution is global climate change. Gases such as carbon dioxide from the burning of fossil fuels increase the natural greenhouse effect. This raises the temperature of Earth's surface.

What Is the Greenhouse Effect?

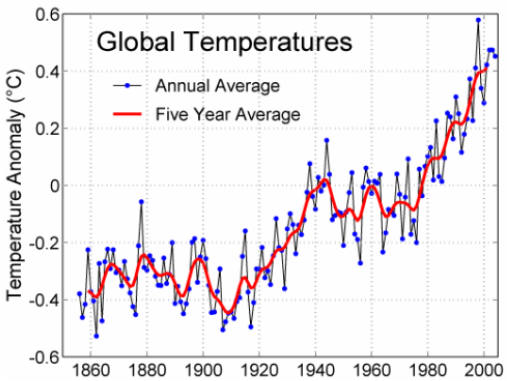
The **greenhouse effect** is a natural feature of Earth's atmosphere. It occurs when gases in the atmosphere radiate the sun's heat back down to Earth's surface (see **Figure** below). Otherwise, the heat would escape into space. Without the greenhouse effect, Earth's surface temperature would be far cooler than it is. In fact, it would be too cold to support life as we know it.



The Greenhouse Effect. Without greenhouse gases, most of the sun

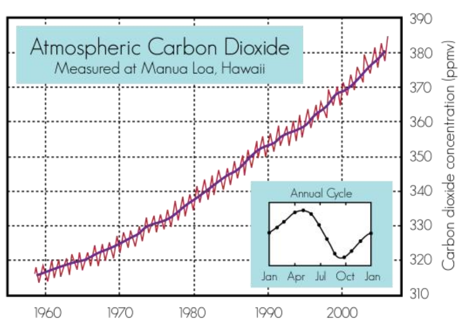
Global Warming

Global warming refers to a recent increase in Earth's average surface temperature (see **Figure** below). During the past century, the temperature has risen by almost 1°C (about 1.3°F). That may not seem like much. But consider that just 10°C is the difference between an ice-free and an ice-covered Earth.



The average annual temperature on Earth has been rising for the past 100 years.

Most scientists agree that global warming is caused by more carbon dioxide in the atmosphere (see **Figure** below). This increases the greenhouse effect. There is more carbon dioxide mainly because of the burning of fossil fuels. Destroying forests is another cause. With fewer forests, less carbon dioxide is removed from the atmosphere by photosynthesis.



This graph shows the recent trend in carbon dioxide in the atmosphere.

Effects of Climate Change

How has global warming affected Earth and its life? Some of its effects include:

- Decline in cold-adapted species such as polar bears.
- Melting of glaciers and rising sea levels.
- Coastal flooding and shoreline erosion.
- Heat-related human health problems.
- More droughts and water shortages.
- Changing patterns of precipitation.
- Increasing severity of storms.
- Major crop losses.

These two videos discuss some of the consequences from changes in ecosystems: **(6b)** http://www.youtube.com/watch?v=jHWgWxDWhsA (7:47) and http://www.youtube.com/watch?v=5qblwORXwrg (2:26).

What Can Be Done?

Efforts to reduce future global warming mainly involve energy use. We need to use less energy, for example, by driving more fuel-efficient cars. We also need to switch to energy sources that produce less carbon dioxide, such as solar and wind energy. At the same time, we can increase the amount of carbon dioxide that is removed from air. We can stop destroying forests and plant new ones.

Section Summary

- Renewable resources can be replaced by natural processes as quickly as humans use them. Examples include sunlight and wind. Nonrenewable resources exist in fixed amounts. They can be used up. Examples include fossil fuels such as coal.
- Soil and water are renewable resources but may be ruined by careless human actions. Soil can be depleted of nutrients. It can also be eroded by wind or water. Over-use and pollution of freshwater threaten the limited supply that people depend on.
- Air pollution consists of chemical substances and particles released into the air, mainly by human actions. The major cause of outdoor air pollution is the burning of fossil fuels. Indoor air can also be polluted. Air pollution, in turn, causes acid rain, ozone depletion, and global warming.

- Gases such as carbon dioxide from the burning of fossil fuels increase the natural greenhouse effect. This is raising the temperature of Earth's surface, and is called global warming.

Extra Practice

1. How could you create a three-dimensional model of the greenhouse effect? What processes would you demonstrate with your model? What materials would you use?

2. Apply Section concepts to explain the relationship between the graphs in **Figure** above and **Figure** above

3. Infer factors that determine whether a natural resource is renewable or nonrenewable.

4. Why would you expect a dead zone to start near the mouth of a river, where the river flows into a body of water?

5. Explain how air pollution is related to acid rain and ozone depletion.

Points to Consider

Microorganisms such as bacteria are important living resources in all ecosystems. They recycle nutrients and other matter.

- What do you know about microorganisms? Besides bacteria, are there other types of microorganisms?
- Are viruses microorganisms? Are they living things?

Lesson Review Questions (Submit answers for grading)

1. List the three major types of community interactions.

2. Describe the relationship between a predator population and the population of its prey.

3. What is a keystone species? Give an example.

4. Define mutualism and commensalism.

5. What is a climax community?

6. Summarize how ideas about ecological succession and climax communities have changed.

7. What is population density?

8. Define immigration and emigration.

9. What is migration? Give an example.

10. Write the formula for the population growth rate. Identify all the variables.

11. State why dispersal of offspring away from their parents might be beneficial.

12. Describe exponential population growth.

13. What are K-selected and r-selected species?

14. How did the invention of agriculture affect human birth and death rates? How did it affect human population growth?

15. Outline the four stages of the demographic transition as it occurred in Europe and North America.

16. State two reasons why death rates fell in Europe and North America, starting in the 1700s.

17. Why did birth rates fall in Europe and North America during the demographic transition?

18. Why was a fifth stage added to the demographic transition model? Describe a population at this stage.

19. What is biodiversity?

20. List three economic benefits of biodiversity.

21. Identify ecosystem services of biodiversity.

22. How is human overpopulation related to the sixth mass extinction?

23. Define natural resource.

24. Distinguish between renewable and nonrenewable resources and give examples.

25. Summarize the environmental effects of burning fossil fuels.