ECOLOGICAL CONCEPTS

Ecology is the study of how organisms interact with one another and their nonliving surroundings. Ecologists study the ways in which organisms have adapted to their surroundings, how they make use of their surroundings, and how an area is altered by the presence and activities of organisms.

Ecosystems

Even though ecosystems are a complex network of interrelationships between organisms, all ecosystems have two main components:

1. *Abiotic factors* are "non-living" factors such as physical or chemical conditions within an environment. For example, in a salt marsh ecosystem, the abiotic factors would include climate, weather, water temperature, salinity, pH, soil composition, and oxygen content of the water and mud.

2. *Biotic factors* are "living" factors, including all the living organisms within an ecosystem. In a salt marsh ecosystem, the biotic factors would include marsh grass, shrubs, and all plant life; fish, worms, insects, shellfish, crabs, and birds; and microorganisms such as bacteria and plankton.

Biotic factors can be organized into a hierarchy from the lowest level to the highest level:

1. *Organisms:* Individual life forms. For example, in a salt marsh, some organisms are marsh grass, flounder, and fiddler crabs.

2. *Species:* A population of organisms potentially capable of reproducing naturally among themselves to produce offspring that can also reproduce. All members of a species share similar behaviors, genetic structure, and appearance. For example, fiddler crabs are one species that inhabit salt marshes.

3. *Population:* A group of the same species living in the same geographic region at the same time. For example, the fiddler crabs living in a salt marsh in Maryland would be a separate population from fiddler crabs living in a salt marsh in Delaware.

4. *Community:* All of the interacting populations of different species that live in a given area at the same time. In a salt marsh ecosystem, fiddler crabs, fish, birds, and plants all form a community.

Noting the above information, it is easy to see that an ecosystem is a community of different species that interact with one another and with surrounding abiotic factors. The interaction of both biotic and abiotic factors allows an ecosystem to respond to changes in the environment.

Global Ecology

Global ecology is a field of ecology that deals with the relationship of organisms with one another and their environment on a global rather than local scale. Ecologists look at interactions among Earth's ecosystems, land, atmosphere, and oceans in an attempt to understand Earth's systems and predict future changes. All aspects of ecosystems are examined to fully understand global environmental issues. The global environment is very complex, with countless organisms and diverse processes interacting from the microscopic scale to the continental scale. New instruments, models, and theories are continuously developed to address fundamental questions about the way the systems work together.

Role of Organisms

Each species in an ecosystem has a specific role, or job, within the community. Examining the roles of species can help determine how they might interact. The functional role of each species in an ecosystem is its niche. A niche consists of all the physical, chemical, and biological conditions that a particular species requires in order to survive and reproduce within a given ecosystem. A description of an organism's niche always includes all the ways in which it affects other organisms and how it may modify its physical surroundings.

Ecologists have identified three general types of organism-to-organism interactions that take place in all ecosystems:

1. *Predation:* One organism known as the predator kills and eats another organism known as the prey. The predator benefits from this relationship, and the prey is harmed. To succeed, predators have adapted several strategies, such a speed, stealth, or the ability to build a trap for their prey. At the same time, many prey species have adapted characteristics that help them to avoid predation. These characteristics include keen senses, the ability to camouflage, and the ability to remain motionless to avoid detection.

2. *Competition:* Within an ecosystem, many species compete for limited resources such as food, water, sunlight, and territory. Competition is classified as intraspecific if it occurs between members of the same species, and interspecific if it occurs between members of different species. Whichever organism is less harmed by the competition is the winner. One organism may win out over another by one of two ways:
   a. *Interference:* One organism limits the access of another species to a resource.
   b. *Exploitation:* Two or more organisms have equal access to a resource, but one uses it more quickly and efficiently than the other.

   The competitive exclusion principle states that no two species can occupy the same ecological niche in the same place at the same time. The more similar two species are, the fiercer their competition will become.

3. *Symbiosis:* A close, long-lasting physical relationship between two species. The two species are in close physical contact, and at least one of them derives some benefit from the relationship. There are three different categories of symbiotic relationships:
   a. *Parasitism:* A relationship in which one organism, the parasite, lives in or on another organism, the host. The parasite generally derives nourishment from the host, and the host is harmed, or even eventually killed, by the parasite.
   b. *Commensalism:* A relationship between organisms in which one organism benefits and the other is not affected.
   c. *Mutualism:* A relationship between organisms that is beneficial to both organisms. In many cases of mutualism, the species cannot live without each another.

Ecologists divide organisms into four broad categories:

1. *Producers:* Organisms that are able to use sources of energy to make complex, organic molecules from simple inorganic substances in their environment. In almost all ecosystems, energy supplied by the sun is used to carry out photosynthesis in plants, algae, or phytoplankton. All other organisms rely on producers as a food source, either directly or indirectly.

2. *Consumers:* Organisms that require organic matter as a food source. They consume organic matter to obtain energy and organic materials that will help to build and maintain their own bodies. Consumers can be further divided based on what they eat:
   a. *Primary Consumers:* These are organisms that eat producers and are also known as herbivores. Ecosystems generally have a large number of herbivores.
   b. *Secondary Consumers:* These are organisms that eat other consumers and are also known as carnivores. Some carnivores primarily eat herbivores, while others consume carnivores and herbivores.
   c. *Teritairy Consumers*: A carnivore that feeds only on secondary consumers.
3. *Omnivores:* These include both producers (plants) and consumers (animals) in their diet.
4. *Decomposers:* These are organisms that use nonliving organic matter as a source of energy and material to build their bodies. When an organism sheds, excretes waste products, or dies, it provides a source of food for decomposers.

Biodiversity and Stability

"Biodiversity" is a term used to describe the diversity (variations) of genes, species, and ecosystems within a region. "Genetic diversity" is a term used to describe the number of different kinds of genes that are present in a given population. A high genetic diversity means there is a large amount of variation in structure and function among a population, and a low genetic diversity indicates that the population is almost all uniform in its traits. Genetic diversity is dependent on chromosomal mutations, migration of individuals or a population, sexual reproduction, population size, and selective breeding.

Species diversity is a measure of the number of various species within a given area. Some localities have high species diversity (a large number of species) and others have low species diversity. Factors that affect species diversity are the size of the area, human activities, and evolutionary and geological history of an area.

Ecosystem diversity is a measure of the number of different kinds of ecosystems present in a given area. Even if areas appear to have general similarities (for example, all deserts have low rainfall), there are specific organisms that live in each ecosystem that create diversity.

Trophic Levels

All ecosystems are stable, self-regulating units, but they are continually changing. The organisms within an ecosystem are continually growing, reproducing, dying, and decaying. Ecosystems must have a continuous input of energy to remain stable. This energy is usually provided by the sun. Producers obtain energy from a source like the sun, and this energy is then passed through the producers to consumers and decomposers. Each step in the flow of energy through an ecosystem is known as a trophic level.

Producers occupy the first trophic level. Herbivores occupy the second trophic level. The third trophic level consists of carnivores that eat herbivores, and the fourth trophic level consists of carnivores that eat other carnivores.

Omnivores, parasites, and scavengers occupy a different trophic level depending on what they are eating at any given time. For example, if you eat a salad, you occupy the second trophic level, and

if you eat a steak, you occupy the third trophic level. Decomposers process food from all trophic levels. The available energy decreases as the trophic level increases.

Food Chains and Food Webs

A food chain describes the relationship of organisms in an ecosystem in terms of who eats whom. Members of a food chain occupy different trophic levels, and energy passes from one organism to another as they are eaten. For example, the leaves on a tree growing beside a lake would take energy from the sun and provide a food source for insects. These insects are a food source for spiders living in the tree. If a spider falls from the tree into the pond, it can then be eaten by a frog. In turn, this frog may be eaten by a bass that is then caught by a fisherman. In the next step of this food chain, the fish is then consumed by humans.

The typical order in a five-step food chain is as follows: producer → primary consumer → secondary consumer → tertiary consumer → decomposers.

Because most consumers eat two or more types of organisms at different trophic levels, multiple food chains can overlap and intersect to form a food web. Complex food webs are more stable than simple food chains, but in this network of interactions, several organisms would be affected if one key organism is reduced in number.

Biogeochemical Cycling

As matter flows through an ecosystem, it gets recycled. Many chemicals that are important to sustain life and the growth of organisms cycle between organisms, the atmosphere, the oceans, and Earth's crust. These chemicals include carbon, nitrogen, oxygen, phosphorus, sulfur, and water. The cycles of these chemicals are called biogeochemical cycles. Biogeochemical cycles involve multiple ecosystems and have global effects.

- *Carbon Cycle:* Carbon is the main element in all living organisms. It is also found in the atmosphere as carbon dioxide and in the oceans and rocks as carbonates. The carbon cycle includes processes and pathways that capture inorganic carbon-based molecules and convert them into organic carbon-based molecules that can be used by organisms. The same carbon atoms are used over and over. Carbon dioxide is fixed into plants and microorganisms through photosynthesis. Carbon passes through the food chains and webs as consumers eat. Fixed carbon in food and waste is broken down through respiration. Carbon from decomposing matter gets released back into soil. Carbon dioxide from the atmosphere moves into oceans. Sediment contains carbonate and compresses over time to form sedimentary rocks. Geological forces such as earthquakes and volcanoes return carbon from rocks back into the atmosphere. Human activity such as burning fossil fuels and raising farm animals like pigs and cattle also releases large quantities of carbon dioxide into the atmosphere.
- *Nitrogen Cycle:* The major source of nitrogen is Earth's atmosphere. It is 78 percent nitrogen gas. Living organisms cannot utilize nitrogen gas, so it must first be converted to another chemical form, such a nitrates or nitrites. The chemical conversions in the nitrogen cycle are made by bacteria and other microorganisms. There are five important steps in the nitrogen cycle:
    1. Nitrogen gas must be made into a chemically usable form by the process known as nitrogen fixation. Nitrogen-fixing bacteria can convert nitrogen gas from the atmosphere into am-

monia, which contains nitrogen, in the soil. Nitrifying bacteria in the soil convert ammonia to nitrates and nitrates. This process is called nitrification.

2. Plants take up nitrates from the soil and incorporate them into amino acids. Animals eat the plants and incorporate the ingested nitrogen from plant amino acids into their own amino acids, proteins, nucleic acids, and other nitrogen-containing organic molecules. This process is called assimilation.
3. After animals and plants die, decomposers convert their nitrogen-containing organic molecules back into ammonia and return it to the soil. This process is called ammonification.
4. The ammonia can be used directly by many types of plants. Nitrifying bacteria in the soil are able to convert ammonia to nitrite and nitrate. Under conditions where oxygen is absent, denitrifying bacteria are able to convert nitrite to nitrogen gas. This process is called denitrification.
5. The nitrogen gas is eventually released back into the atmosphere, where it can then reenter the nitrogen cycle.

- *Phosphorus Cycle:* Phosphorus is another element that is common to living organisms. It is present in many important biological molecules, such as DNA and cell membranes. Phosphorus-containing ATP and ADP are important molecules for storing and utilizing energy in living organisms. Many enzymes require a phosphate group for activation or inactivation. Unlike carbon and nitrogen, phosphorus is not present in the atmosphere, so the phosphorus cycle is limited to soil and water. The major form of phosphorus is the mineral apatite, which is found in rocks and phosphate deposits. The weathering of phosphate rocks leaches phosphate into soil. Then plants take up phosphorus from the soil and incorporate it into their tissue. Animals eat the plants and take up the phosphate. When plants and animals die, decomposers release phosphate back into the soil. Animal excretion also contains phosphate that is released back into the soil.

- *Sulfur Cycle:* Sulfur is important for the production of proteins because the amino acids cysteine and cystine contain sulfur. Sulfur is mainly found in rocks and soil as sulfate minerals. There is also sulfur in the atmosphere in the form of hydrogen sulfide. Weathering exposes sulfates from rocks, which are deposited into soil and aquatic ecosystems. Plants and other photosynthetic organisms take up and assimilate the sulfates into their tissue. Then animals eat plants and assimilate sulfates into their tissue. Death and decomposition of plants and animals convert organic sulfates into inorganic sulfates. Animal excretions also add sulfates to water and soil. Inorganic sulfates are then recycled. During decomposition in both soil and water, sulfates are converted into hydrogen sulfide gas that can escape into the atmosphere, water, soil, and marine sediment. Hydrogen sulfide gas can also come from volcanoes and power plant emissions.

- *Oxygen Cycle:* Molecular oxygen is critical for all living things. It is a by-product of photosynthesis and a necessary reactant for cellular respiration. Biological and chemical processes help to recycle oxygen on Earth. The main supply of oxygen is our atmosphere. Oxygen cycles through the atmosphere, living organisms, and Earth's crust. Oxygen is removed from the atmosphere by chemically reacting with rocks and minerals exposed to weathering. Oxygen is also removed from the atmosphere through respiration of living organisms. Sunlight breaks down water into hydrogen and oxygen, and oxygen is released into the atmosphere. Photosynthesis also breaks down water into hydrogen and oxygen, releasing oxygen into the atmosphere.

- *Hydrologic Cycle:* Water cycles between the atmosphere and Earth's surface and underground, and it exists in three states: (1) solid, (2) liquid, and (3) gas. This cycle is primarily driven by the sun's energy. Water is stored in the atmosphere as water vapor (gas), on Earth's surface as a liquid (lakes, oceans, rivers, streams) or a solid (ice, glaciers), and in the ground as a liquid (groundwater) or a solid (ice in the form of permafrost). Energy from the sun is the source of power that drives the water cycle. Water can move between all these sites in six different ways. (1) Water moves from its liquid or solid state on Earth's surface to the atmosphere into its gaseous state through evaporation and sublimation. (2) Groundwater moves into the atmosphere through plants during the process of transpiration, a part of photosynthesis. (3) Thermal energy from the sun is absorbed by Earth's surface and snow and ice melt into liquid water. This water either flows into lakes, oceans, rivers, or streams or is absorbed as groundwater. (4) Energy released by water vapor in the atmosphere causes precipitation, and liquid water returns to Earth's surface. (5) Once on Earth's surface, water flows through porous surfaces and into liquid groundwater storage. (6) Liquid groundwater can also flow back to Earth's surface and into streams, lakes, rivers, and oceans.

Humans significantly impact the flow of all the biogeochemical cycles through (1) the burning of fossil fuels, (2) the conversions of natural ecosystems to agricultural land, (3) agricultural runoff, and (4) industrialization.

Natural Selection and Evolution

Natural selection is the process that determines which individuals within a species will survive and reproduce, thereby passing their genes on to the next generation. Changes observed over time in the physical appearance or behavior of a species are due to the process of evolution. Individuals in a species who are best adapted to a certain environment will survive best and reproduce more offspring, thus changing the characteristics of a given species over a long period of time. Therefore, natural selection is the mechanism that causes the evolution of a species.

There are several factors involved in the process of natural selection. Individuals within a species have genetic variation; some of the variations are useful, and some are not. Organisms reproduce at such a rate that many more offspring are produced than are needed to replace the parent generation, but most of the offspring die. The excess number of offspring results in a shortage of food supplies and other resources. However, because there is a genetic variation among individuals of a species, some have a greater chance of obtaining the necessary food and resources and, therefore, are more likely to survive and reproduce. Over time, each generation is subjected to the same process of natural selection, so that the percentage of individuals with favorable variations will increase, and the number of individuals with unfavorable variations will decrease.

Therefore, over time, there is a considerable change in the type of species present and their characteristics. Some changes can take place in a few generations, whereas others have taken thousands or millions of years. The process of natural selection plays a key role in evolution, and through the study of fossil records, it is obvious to see that some new species evolve, while others die out.

- *Speciation* is the development of a new species from a previously existing species. In general, speciation occurs as two subpopulations adapt to different conditions and eventually are unable to interbreed because they are so different.

- *Polyploidy* is a condition in plants in which there is an increase in the number of chromosomes in the cells, and this can also lead to the development of a new species that cannot interbreed with the original species.
- *Extinction* is the loss of an entire species and is a common feature in evolutionary history. In general, extinction comes about due to changes in a species' environment or from human intervention.
- *Coevolution* is the idea that two or more species of organisms can influence the evolutionary path of the other. This is a common pattern since all organisms within an ecosystem influence one another.

Succession

Ecosystems respond to environmental challenges through succession. Succession is a series of recognizable and predictable changes over time to maintain the stability of the community. Succession occurs because the activities of a given species cause changes to the environment that make it now suitable for other species. Succession proceeds until a stable climax community is reached. There are two general types of succession:

1. *Primary succession* in new life is colonized in an environment that has a complete lack of life form and minimal water. Primary succession can occur in areas where volcanic activity wipes out life forms in an ecosystem. Primary succession takes a very long time to establish.
2. *Secondary succession* occurs when a portion of an ecosystem is disturbed by an event such as a forest fire. In this case, the area is eventually restored through succession, and it is a much more rapid process than primary succession because soil and water are usually already present.

Regardless of whether succession is primary or secondary, the process occurs in basically the same manner. First, new land is exposed. This land is either devoid of life (primary succession) or disturbed in some way (secondary succession). Next, pioneer species take root. Pioneer species are generally fast-growing plants that can thrive in exposed conditions and have a short-life span. These are usually lichen or mosses, and they begin to modify the ecosystem for the growth of other species. The collection of organisms at this stage is known as the pioneer community. Eventually, as a thin layer of soil is established, longer-lived plants are established.

Each step in the sequence from the pioneer community to the climax community is a successional or seral stage. The entire sequence of stages is known as a sere. At each seral stage, species either replace or coexist with previously existing species, and the ecosystem continues to be further modified at each stage, until the climax community is attained.

In a climax community, long-living plants and animals are sustained by the environment. The difference between a climax community and a successional (seral) community is that climax communities maintain their diversity of species for a long time, and successional communities are temporary. The organisms in a climax community maintain specialized niches, recycle nutrients, and maintain a relatively constant biomass, whereas successional communities do not. The general trend in succession is toward increasing complexity and efficiency.

With respect to aquatic ecosystems, with the exception of the oceans, most aquatic ecosystems are temporary. All aquatic systems receive a continuous input of soil and organic matter, and eventually

bodies of water are filled in. This may take thousands of years, but it is a continual process. The successional stages of aquatic ecosystems are often called "wet meadow" stages and mark the transition of an aquatic community to a terrestrial community.

Biomes and Productivity

Biomes are terrestrial climax communities that have a wide geographic distribution. In general, the structure of ecosystems in a biome and the kinds of niches and habitats in those ecosystems are similar. However, it is important to recognize that although the concept of a biome is useful for discussing overall patterns and processes, different communities within a given type of biome show differences in the exact species present.

There are two major nonbiological factors that have an impact on the kind of climax community that develops in a given part of the world: precipitation pattern and temperature range. The aspects of precipitation that are most important are (1) the total amount of precipitation per year, (2) the form of precipitation (rain, snow, sleet), and (3) its seasonal distribution.

Temperature patterns vary greatly throughout regions of the world. Some regions, like tropical areas near the equator or areas near the poles, have a relatively consistent temperature throughout the year, whereas other areas are more evenly divided between cold and warm temperatures. Each type of biome is dependent in large part on precipitation and temperature.

Desert

Deserts are one type of biome in which there are generally less than 25 centimeters of precipitation per year. The form of precipitation varies for each desert. Although deserts are typically thought to be hot and dry (Sahara and the desert of the Southwest United States), there are some desert biomes in which temperatures are quite cool for a major part of the year (Gobi Desert and the deserts of the northwestern United States).

Many species populate a desert biome, but there are usually a low number of individuals of each species. In the past, humans had little impact on desert biomes in part because the hot arid conditions did not allow for agriculture. Hunter-gatherer societies were most common in deserts. However, modern technology allows for water to be transported into deserts, cities have developed in some desert biomes, and there is also limited agriculture.

Grassland

Temperate grassland biomes such as prairies or steppes are widely distributed in temperate regions of Earth. Grasslands generally receive 25–75 centimeters of rain annually. In general, grassland biomes are windy with hot summers and cold winters. In many grassland biomes, fire is an important factor in releasing nutrients from dead plants into the soil and for preventing the invasion of trees.

Between 60 and 90 percent of the vegetation is grass. Primary consumers eat the grasses, and there are often large herds of migratory animals such as bison living in grasslands. Carnivores also inhabit grasslands. Most of the moist grasslands throughout the world have been converted to agriculture. Drier grasslands have been converted to grazing for domestic grazers such as cattle, sheep, and goats. There is very little undisturbed grassland left.

Savanna

Savannas are found in tropical parts of Africa, South America, and Australia. They are characterized by extensive grasslands and occasional patches of trees. These biomes typically have a rainy season in which 50 to 150 centimeters of rain fall, followed by a drought period. Plants and animals time their reproductive activities to coincide with the rainy season, when food and water are more abundant.

Savannas have been heavily impacted by agriculture. Farming is possible in moister regions, and animal grazing is found in drier regions. Irrigation is essential because of the long periods of drought.

Mediterranean Shrublands (Chaparral)

Mediterranean shrublands are located near oceans and are dominated by low shrubs. The climate varies from wet, cool winters to hot, dry summers. Rainfall is 40 to 100 centimeters per year. Vegetation is dominated by woody shrubs, and the types of animals vary widely. Very little shrubland exists that has not been impacted by humans. There are many major cities in this type of biome and also a large amount of agriculture.

Tropical Dry Forest

Tropical dry forests are heavily influenced by seasonal rainfall. This type of biome is found in parts of Central and South America, Australia, Africa, and Asia. Many tropical dry forests have monsoon seasons, and rainfall ranges from 50 to 200 centimeters. There are generally high human populations in tropical dry forests, and wood is harvested from them for fuel and building materials.

Tropical Rain Forest

Tropical rain forests are located near the equator in Central and South America, Africa, Southeast Asia, and some islands in the Caribbean Sea and Pacific Ocean. The temperature is warm and relatively constant, and it rains nearly every day, 200 to 500 centimeters a year. There is extensive vegetation, but soils are generally poor because all of the nutrients are taken up by plants. Tropical rain forests have a greater diversity of species than any other biome. Today, tropical rainforests are under intense pressure from logging and agricultural industries, although agriculture is generally not successful in the long term because of generally poor soil conditions.

Temperate Deciduous Forest

Temperate deciduous forests have changes of seasons, and trees lose their leaves in fall and regrow leaves in spring. This forest is typical in the eastern half of the United States, parts of south central and southeastern Canada, southern Africa, and many areas of Europe and Asia. Winters are generally mild, and plants actively grow for about six months. There are generally 75 to 100 centimeters of precipitation per year distributed evenly. Each region of the world has certain species of trees and other organisms. Most of the temperate deciduous forests have been heavily impacted by human activity. Much has been cleared for agriculture and logging and to develop major population areas.

Taiga, Northern Coniferous Forest, or Boreal Forest

The evergreen coniferous forests found throughout southern Canada, parts of northern Europe, and Russia are known as taiga, northern coniferous forests, or Boreal forests. These biomes have

short, cool summers and long, harsh winters, lasting up to six months. There are about 25 to 100 centimeters of precipitation per year, and there is a great deal of snowmelt in spring contributing to humid climates. These regions have many lakes, ponds, and bogs, and conifers are the most common organisms in these biomes. Humans have a less severe impact on these biomes because of low population density. Logging and herding of reindeer are common activities.

Tundra

Tundra is the area north of taiga biomes. It is an extremely cold region with permanently frozen subsoil (permafrost), which means there are no trees. Tundra biomes experience ten months of winter. Less than 25 centimeters of precipitation fall each year, but summer months see generally wet soil conditions due to snow melt. Water is not absorbed into the soil because of the permafrost subsoil layer. Therefore, many shallow ponds and waterlogged areas exist in summer.

Also in summer months, there is a variety of small plants and swarms of insects that are a food source for migratory birds and waterfowl. Tundra is also home to a few hardy mammals such as reindeer and arctic hare. Many species of birds and large mammals migrate during summer months using the scattered patches of small communities known as alpine tundra. Very few people live in tundra biomes, but any damage to this ecosystem is slow to heal because of the very short growing season. Tundra land must be handled with care.

Aquatic Ecosystems

Aquatic ecosystems are shaped by (1) the ability of the sun's energy to penetrate the water, (2) the depth of the water, (3) the nature of the bottom of the body of water, (4) the water temperature, and (5) the amount of salts dissolved in the water. Freshwater ecosystems have little dissolved salt, and marine ecosystems have a high salt content.

Oceans are defined as pelagic marine ecosystems and have many organisms that float or actively swim. Plankton are very small, weak organisms that are carried by currents. Phytoplankton are plankton-like organisms that carry out photosynthesis. Most phytoplankton, such as algae, live in the upper layers of the ocean where the sun's rays penetrate. This region is the euphotic zone. Zooplankton are small, weak swimming animals that feed on phytoplankton. These species swim to the euphotic zone to feed, then are eaten by larger animals such as fish and shrimp at lower depths, which, in turn, are then eaten by larger animals.

- *Bethnic Marine Ecosystems:* Organisms that live on the bottom of oceans are part of bethnic marine ecosystems. The substrate material on the ocean bottom is important in determining which species live in a particular bethnic ecosystem. Temperature also has an impact on bethnic ecosystems. An abyssal ecosystem is a bethnic ecosystem that is situated in great depths of the ocean. No light reaches these ecosystems, so animals must depend on the fall of organic matter from the euphotic zones.
- *Coral Reef Ecosystems:* These are produced by coral animals that build up around themselves cup-shaped external skeletons. The skeletons of corals provide a surface upon which many other species live. Coral reef systems require warm water and are, therefore, found only near the equator.

- *Mangrove Swamp Ecosystems:* These are tropical forest ecosystems found in shallow waters near the shore of marine ecosystems and an adjacent landmass. These ecosystems are dominated by trees that can tolerate the high salt content of the water and excrete salt from their leaves. Seeds of these trees germinate on the tree itself, and then fall into the water and are buried in mud where they take root. These trees have extensive root systems that extend above water to take in oxygen. Mangroves are found in south Florida, the Caribbean, Southeast Asia, and Africa, as well as other parts of the world where there are tropical mudflats.
- *Estuary Ecosystems:* An estuary is an ecosystem consisting of shallow water and a partially enclosed area where fresh water runs into the ocean. The salt content of water in estuaries changes with the tide and the inflow and outflow of the rivers. Organisms in this type of ecosystem have adapted to these changing conditions. An estuary is a productive ecosystem because the shallow regions allow light to penetrate the water, and rich nutrients are dumped from rivers into the basin of an estuary.
- *Freshwater Ecosystems:* These have a much lower salt content than marine ecosystems and have a large range of water temperature. Freshwater ecosystems consist of either relatively stationary water, such as lakes, ponds, or reservoirs, or moving water, such as streams or rivers.

If a lake is deep enough, it has similar characteristics to an ocean ecosystem: There is a euphotic zone at the top, and there are many kinds of phytoplankton and zooplankton. Emergent plants grow near the shores and shallower regions of lakes. They are rooted to the bottom of the lakes and their leaves can float on the surface (water lily) or stick out above the water's surface (cattail). Submerged plants are rooted below the surface, but do not protrude above the surface (Elodea and Chara). The regions of a lake with rooted vegetation are called the littoral zone, and regions where vegetation is not rooted are called the limnetic zone.

The productivity of a lake is dependent upon water temperature and depth. (1) Oligotrophic lakes are deep, clear, cold and have a low nutrient content. There is low productivity in this type of lake. (2) On the other hand, eutrophic lakes are shallow, murky, warm, and nutrient-rich. Productivity is higher in these lakes.

The dissolved oxygen content of water is also important to ecosystems. It determines the kind of organisms that inhabit a lake. When organic molecules enter water, bacteria and fungi break them down. The amount of oxygen used by these decomposers to break down a specific amount of organic matter is known as the biochemical oxygen demand (BOD).

In streams and rivers, water is moving, so organisms like algae attach to rocks. The collection of algae and fungi in streams and rivers is called periphyton. Most streams are shallow, and light can penetrate to the bottom, but because the water is fast-moving, photosynthetic organisms do not accumulate enough essential nutrients for growth. Therefore, most streams are not very productive. Most of the nutrients come from organic matter that falls into streams. In rivers, the water is deeper, and there is less light penetration. Organisms must rely on nutrients flowing in from streams. Rivers tend to be larger than streams with warmer, slower-moving water. Therefore, there is less oxygen in rivers, and different species occupy rivers and streams.

Swamps and marshes delineate the transition from terrestrial ecosystems into freshwater ecosystems. Swamps are wetlands that contain trees that withstand the flooded conditions. Marshes are wetlands dominated by grasses and reeds.

Most freshwater ecosystems have been heavily impacted by human activity. Activity on land affects freshwater systems because there is runoff from land into lakes, rivers, and streams. Agricultural runoff, sewage, and trash affect freshwater ecosystems. Human impact on marine ecosystems comes in the form of overfishing, oil pollution from transportation, oil spills, and trash dumping.

Population Biology

Population biology is a branch of environmental science that is concerned with characterizing the make-up and growth of populations and their impact on the environment and its organisms. A population is a group of individuals of one species that inhabits a given area. Population dynamics focus on the growth and limitations of a population and how that population interacts with its environment with respect to its growth and stability. Population genetics addresses the frequency and distribution of specific genes in a population and how these frequencies might change over time. Population genetics is also concerned with mutation rates within a given population.

Different populations of the same species have different characteristics such as birthrate, mortality, sex ratio, age distribution, growth rate, migration rate, spatial distribution, and density. Demography describes the vital statistics of a given population.

- *Birthrate:* The number of individuals added to a population over a particular time period, through reproduction of the species. Asexual reproduction is the process in which an organism such as bacteria divides to form new individuals. Sexual reproduction is the most common type of reproduction. Most species produce many more offspring than are needed to replace the parent generation. The birthrate in humans is usually described as the number of offspring produced by 1,000 individuals in a given year.
- *Death Rate or Mortality Rate:* The number of deaths in a population over a given time period. For most species, mortality rates are high, but in humans, it is relatively low. One way to study mortality is with a survivorship curve, which shows the proportion of individuals likely to survive at each age. The death rate in humans is referred to as the number of people in 1,000 that die per year. For a population to grow, the birthrate must exceed the death rate in a given year.
- *Sex Ratio:* The relative number of males and females in a given population. The number of females has a bigger effect on the number of offspring produced in a population. However, the typical ratio approximates 1:1.
- *Age Distribution:* The number of individuals in each age range in a population. Age distribution has a large influence on population growth rates. Among humans, different societies see vastly different age distributions, but in general, a large reproductive population will cause future population growth.
- *Population Density:* The number of organisms within a species in a given area. Movement from a densely populated region is called dispersal. Dispersal relieves overcrowding in a given area. The migration of individuals is referred to as emigration. Some organisms may leave their population to become members of a different population. This is called migration, or immigration.

Biological ability to produce offspring is a species' biotic potential. Because most species have a high biotic potential, there is a natural tendency for populations to increase. In general, there is an

exponential growth in populations for a given period. There is often a pattern of growth that includes (1) a lag phase in which the population grows more slowly, (2) an exponential growth phase, (3) a declaration phase in which population growth slows due to equal birth and death rates, which leads to (4) a stabile equilibrium phase in which there is a stable population size.

There are several main environmental factors that limit population size. Factors from outside a population are known as (1) extrinsic limiting factors. Factors regulated within a population are called (2) intrinsic limiting factors. As the population increases, (3) density-dependent limiting factors are important. (4) Density-independent limiting factors are influences that control population, but they are not dependent on limiting factors. Limiting factors can be divided into four main categories: (1) availability of raw materials, (2) availability of energy, (3) accumulation of waste products, and (4) interaction between organisms.

The carrying capacity is the maximum population that is able to be sustained in a given area. The carrying capacity is determined by a set of limiting factors. Environmental changes such as forest fires or floods can change the carrying capacity of an area.

A given species has a particular reproduction strategy.

- *K-strategists* are organisms that tend to reach a stable population as the carrying capacity is reached. These species tend to occupy a stable environment and tend to be large organisms that have a long lifespan, produce few offspring, and expend a lot of energy to care for their offspring. These populations tend to be limited by density-dependent limiting factors.
- *R-strategists* tend to be small organisms that have a short lifespan, produce many offspring, do not reach the carrying capacity, and live in unstable environments. These organisms produce many offspring, but do not expend energy to care for them. These species tend to be limited by density-independent limiting factors.

In northern regions of the world, many species follow a population cycle in which periods of large populations are followed by periods of small populations. In general, this occurs because of the nature of ecosystems in this part of the world. Ecosystems are relatively simple with few organisms affecting one another.

Atmospheric Structure

The atmosphere is composed of 78.1 percent nitrogen, 20.9 percent oxygen, and 1 percent of a mixture of other gases, including carbon dioxide, methane, and water vapor. The atmosphere is composed of four layers.

1. *Troposphere:* Extends from Earth's surface to about 10 kilometers above Earth. The actual depth of the troposphere depends on the position of Earth and the season. The temperature of the troposphere decreases by about 6 degrees Celsius for every kilometer above Earth's surface.
2. *Stratosphere:* Extends about 50 kilometers above the top of the troposphere. The stratosphere contains most of the ozone, which is a band between 15 and 30 kilometers above Earth's surface that absorbs sunlight. Since the ozone absorbs sunlight, the upper layers of the stratosphere are warmer than the lower layers.
3. *Mesosphere:* Extends above the stratosphere from 50 to 80 kilometers above Earth's surface with decreasing temperature

4. *Thermosphere:* Extends from 80 to 300 kilometers above Earth's surface and is a layer with increasing temperatures

Gravitational pull keeps air near Earth, but air is not static. As it absorbs heat, it expands and rises, and as air cools, it becomes denser and falls back towards Earth's surface. Therefore, air circulates vertically because of heating and cooling and circulates horizontally because of Earth's rotation. The combination of air movements creates wind and weather patterns.

ENVIRONMENTAL IMPACTS

In order for individuals to survive, they must expend energy. However, some energy sources used by humans in industrialized societies can cause damage to the environment. An ever-growing population must be aware of the impact of population growth and its choice of energy sources on our environment.

Human Population Growth

Human population has been steadily increasing since the modern era, mostly because of the longer life span of populations. Developed countries have an increase in food production and better methods of controlling disease. All of this can be shared with the rest of the world, resulting in an improved quality of life overall. The world population is currently increasing at a rate of 1.2 percent annually. At this rate, the world population is expected to double in about 58 years. Several factors must be taken into consideration to fully understand human population growth. Economic development plays a huge role in population growth. More developed countries have a relatively stable population growth, and less developed countries do not.

Several factors interact to determine the impact of a society's population growth on the resources of a country. These factors include (1) land, (2) natural resources, (3) size of a population, (4) quantity of natural resources consumed, and (5) environmental damage caused by using resources. The relationship of all these factors can be expressed in the equation:

Impact on the Environment = Population × Affluence × Damage Due to Technology ($I = P \times A \times T$)

Population density relates the size of a population to available resources. People in highly developed countries tend to have a greater impact on the environment because of technological development. The ecological footprint of a population is a measure of the land area required to provide resources and absorb waste.

Demography is the study of human populations, their characteristics, and the consequences of growth. Demographers can predict future population growth by looking at biological factors, including the total fertility rate and age distribution. A total fertility rate of 2.1 is a replacement fertility rate whereby parents will be replaced by offspring when they die. If the number of births equals the number of deaths, there is zero population growth.

Social factors that influence population growth are aspects like culture, traditions, and attitudes towards birth control. Political factors also influence human population growth. Developed countries often have low rates of population growth and try to promote more births, whereas countries like China have taken measures to control growth. Immigration also has an impact on the rate of growth in a population. A human population can increase only if populations of other animals and plants

decrease. When humans need food, they convert ecosystems into agricultural systems. In some cases, the long-term health of the environment is sacrificed to feed a population.

Countries with the highest standard of living seem to have the lowest rate of population growth, and those with the lowest standard of living have the highest population growth rate. This leads to the demographic transition model that occurs in four stages. (1) Initially, countries have a stable population with a high birthrate and death rate. (2) Improved economic and social conditions cause a decrease in the death rate, so there is a period of rapid population growth. (3) As countries develop an industrial economy, birthrates drop and population growth rates fall. (4) Eventually, birthrates and death rates are balanced again, but this time there is a low birthrate and low death rate.

Pollution

Pollution is any matter or energy that harms the environment, and human actions are the major cause of air pollution. Air pollution is directly related to the population of a given area. There are several categories of air pollutants on Earth. (1) Primary air pollutants are released into the atmosphere in unmodified forms. These pollutants include carbon monoxide, volatile organic compounds (hydrocarbons), particulate matter, sulfur dioxide, and oxides of nitrogen. (2) Secondary air pollutants are primary pollutants that can interact with other compounds in the presence of sunlight to form new compounds such as ozone. (3) The U.S. Environmental Protection Agency (EPA) has a category of air pollutants called criteria air pollutants. These include nitrogen dioxide, ozone, sulfur dioxide, particulate matter, carbon monoxide, and lead.

Water pollution is the result of population growth and industrial growth. (1) A source of water pollution that is readily identifiable because it has a definite point where it enters the water is called a point source. (2) Diffuse pollutants such as those that come from agricultural runoff, urban roadways, and acid rain are nonpoint sources of water pollution. Types of water pollution include municipal, agricultural, industrial, thermal, marine oil, and groundwater pollution.

Ozone Layer

Ozone is a molecule that consists of three oxygen atoms bound to each other. Ground-level ozone is an extremely reactive molecule that can cause irritation to respiratory tissue and damage to lungs. Ozone is a secondary pollutant formed as a component of photochemical smog. However, there is also a necessary layer of ozone in the atmosphere that shields Earth from the harmful effects of ultraviolet (UV) radiation from the Sun. This ozone layer is slowly being depleted as a result of pollutants, especially chlorofluorocarbons (CFC), in the atmosphere. Less ozone in the upper atmosphere results in more UV light reaching Earth's surface. This can lead to increased risks of skin cancer, cataracts, and mutations.

Greenhouse Effect

Energy from the sun enters the atmosphere, but not all of that energy reaches Earth's surface. Clouds and gases high in the atmosphere reflect back about 25 percent of the sun's energy. Another 25 percent are absorbed by gases in the atmosphere, such as ozone, carbon dioxide, methane, and water vapor. Of the 50 percent of the energy that reach Earth's surface, some is reflected back into the atmosphere by rain, snow, ice, and sand. The rest is absorbed by Earth's surface.

As this energy is rereleased into the atmosphere, it is absorbed by gases in the atmosphere known as greenhouse gases. The greenhouse effect actually is necessary to keep the surface of Earth warm enough to sustain life; however, too much of a greenhouse effect due to the accumulation of large quantities of carbon dioxide, chlorofluorocarbons, methane, and nitrous oxide (greenhouse gases) can be harmful to the environment and can lead to global warming and climate change.

Environmental Risk Assessment

Risk to the environment from human activities can be determined through identifying potential hazards and the consequences of these hazards. The magnitude and probability of the consequences also need to be considered when assessing risk. Finally, there needs to be an evaluation of the risk, also known as risk characterization. A concept frequently used in environmental risk assessment is that of source-pathway-receptor. The pathway between a hazard (source) and a receptor (i.e., ecosystem) is investigated. If no pathway exists, then there is no risk to the environment. If a pathway links a source to a receptor, then the consequences need to be assessed.

Industrial and Agricultural Revolutions

The Industrial Revolution, beginning in the mid-1700s, was brought about by the use of coal as a major fuel source in England. It involved the invention of the steam engine and the development of machines to mass produce goods. The steam engine also made large-scale coal mining possible. During the Industrial Revolution and afterwards, energy consumption increased, economies grew, and populations became more prosperous. An increase in coal use also caused an increase in air pollution. Within the span of 200 years, energy consumption increased eightfold, and pollution became a serious problem in some countries.

Early civilizations obtained food by hunting and gathering. The development of agriculture involved manipulating plants and soil to grow desired foods. The increase in yield of food grown allowed for an increase in populations. With the advent of the Industrial Revolution, agriculture was also mechanized. To operate effectively, new machines required large tracts of relatively flat land planted with a single crop, a practice known as monoculture. Although these methods produce abundant crops of food, the clearing of large tracts of land also leads to soil erosion. Because of erosion problems, many farmers now use methods that reduce the time a field is left fallow.

Currently, the most rapid industrial development takes place in emerging nations. This development leads to a disproportionate amount of ecosystem degradation (deforestation, desertification, eutrophication), and loss of biodiversity in those countries. The damage to the environment in these nations can actually increase poverty instead of promoting wealth.

Deforestation

To clear land for agriculture, farmers clear large tracts of forestland, a process called deforestation. Deforestation is mainly used for agricultural purposes, but in some countries, forests are still cleared for wood to be used as a fuel source or for building materials. Removal of trees in tropical regions removes biomass, which contains most of the nutrients in the soil. The soil that is left is poor and not ideal for agriculture. In addition, deforestation leads to erosion of soil.

Deforestation causes carbon dioxide to stay in the atmosphere because there are fewer trees to take it in, which contributes to global warming. Evapotranspiration through the leaves of trees returns water to the atmosphere as part of the hydrologic cycle, but deforestation reduces this process and disrupts the hydrologic cycle. Deforestation also disrupts ecosystems and species that live in forests. (1) Patchwork clear cutting, (2) reforestation, and (3) selective harvesting are methods used to try to avoid deforestation.

Desertification

The conversion of dry arid or semiarid land into desert-like ecosystems is a process called desertification. Desertification is most prevalent in northern Africa and parts of Asia where there is irregular or unpredictable rainfall. In many of these areas, there are populations of nomadic herders or subsistence farmers that are under pressure to provide food for their families, even at a cost to the environment. Overgrazing and over-farming lead to desertification in these areas.

Eutrophication

The excessive growth of algae and other aquatic plants in water with added nutrients is a process called eutrophication. When phosphates or nitrates are added to the surface of a body of water from sources such as organic waste from agriculture or industries, they can act as a fertilizer and cause excessive growth of algae. This undesirable algae growth can interfere with the use of the water. Also, as the algae dies, there is a decrease in oxygen levels in the water, and fish and other aquatic life die.

ENVIRONMENTAL MANAGEMENT AND CONSERVATION

Environmental management and conservation involve a number of highly contentious political issues.

Nonrenewable Resources

Natural resources are those that humans can use for their own purposes, but that they cannot create. Soil, wind, and water are all examples of natural resources. A renewable resource can be formed or regenerated by natural processes, so that it is not used up. However, nonrenewable resources are not replaced by natural processes. Fossil fuels and mountain ranges are nonrenewable on a human time scale.

The energy sources most commonly used by industrialized nations are fossil fuels: oil, coal, and natural gas. They constitute 76 percent of the world's energy sources and are all nonrenewable resources. Nuclear energy accounts for another 6 percent of the energy used. Humans are using up nonrenewable energy sources at a much faster rate than they can be replaced, which eventually will exhaust Earth's supply of these sources.

The mining and processing of fossil fuels takes a toll on the environment as well. (1) Coal can be extracted by surface, or strip, mining, which involves removing the overburden material on top of a vein of coal to get to the coal below the surface. This method is efficient, but it disrupts the landscape. The damage can be minimized by reclaiming the land, but it is rarely restored to its original condition. (2) Underground mining extracts coal that is buried deep beneath Earth's surface. The method poses many safety concerns and health hazards for miners, but it doesn't disturb the above-ground

landscape. However, underground mining still raises environmental issues such as subsidence, or sinking of the land, and the accumulation of large waste heaps.

Coal mining and coal transport generates a lot of dust in the atmosphere, and there is also sulfur associated with coal that causes acid mine drainage and air pollution. Burning of coal causes acid deposition in the atmosphere, which is a cause of acid rain. The release of carbon dioxide from coal has become a greater concern with respect to the potential for global warming.

Oil extraction causes less environmental damage, is a more efficient source of energy than coal, and creates less pollution. Liquid oil is more easily transported than solid coal; however, there are major problems associated with oil spills and leaks from oil pipelines. The processing of natural gas is the least disruptive to the environment.

Renewable Resources

Only 18 percent of the world's energy comes from renewable energy sources: 11 percent from biomass, 4.5 percent from hydroelectric power, and only 1.5 percent from a combination of geothermal, wind, and solar energy.

- *Biomass* is the primary source of energy for developing countries. All biomass is produced by green plants that convert sunlight into plant material through photosynthesis. Major types of biomass include wood, municipal and industrial wastes, agricultural crop residue, animal waste, and energy plantations. However, using biomass fuels can create air pollution.
- *Hydroelectric power* relies on water to generate electricity. The construction of reservoirs, however, can cause environmental and social issues. One possible impact is that dams can cause flooding of land around them. Damming a river can prevent the proper flow of water in a river downstream of the dam.
- *Tidal power* can also supply a renewable energy source, but this can result in negative impacts on shorelines.
- *Geothermal power* is linked to geologically active regions where thermal energy from Earth can reach the surface through thin layers of Earth's crust. Geothermal energy creates steam that contains hydrogen sulfide, which causes air pollution.
- *Wind power* is another source of energy, but it is dependent on the variability of winds. Places such as the Dakotas in the United States have the strongest winds, but because they are remote from large energy-using population centers, there would be a loss in electricity as it was transferred to distant areas of the country. The moving blades of wind generators can pose a hazard to birds, depending on where the turbines are located. They can also produce noise that bothers nearby residents.
- *Solar energy* is a renewable energy source that can be collected through means of passive solar or active solar systems.

The Green Revolution

The Green Revolution brought about the introduction of new varieties of plants and farming methods in the 1950s, '60s, and '70s. Both developed and developing countries benefitted from the Green Revolution, and it has caused a significant increase in food production. The Green Revolution

came about as a cooperative venture between Western countries to increase productivity and relieve hunger in Mexico and India. High-yield varieties of wheat were developed that were more resistant to pests and diseases. These new crops along with irrigation techniques and chemicals (fertilizers, pesticides, and herbicides) increased food production; however, many farmers in Mexico and India still remained poor.

Over time, more high-yield crops such as rice, sorghum, corn, and beans were introduced. Intensive farming methods to relieve hunger in Latin America and Asia were created. The Green Revolution has not been successful in parts of the world where the climate is arid and irrigation is not possible, such as sub-Saharan Africa. The Green Revolution also made crops more dependent on chemicals, which caused environmental concerns. The crop yield has increased as a result of the Green Revolution, but it has not solved the problems of world hunger.

Agricultural Practices

The basic unit of agriculture is the farm, where farmers must clear land, plant seed, grow crops, and harvest them. Resources like land, water, soil, and seeds must be managed and conserved. There are several different types of agricultural methods practiced throughout the world.

- *Shifting agriculture* is practiced in many areas of the world where soil conditions are poor and human populations are low. It involves the cutting down and burning of trees in small area forests. Once the nutrients in the soil are depleted, the site is abandoned. In some parts of the world with poor soil conditions, such as tropical forests, this method is still used successfully.
- *Labor-intensive agriculture* is practiced in areas of the world with better soil conditions. It is still practiced in much of the world today, and it involves the extensive use of manual labor. This allows for high yields, but low use of fossil fuels. In developing countries, the cost of manual labor is low compared to the cost of mechanized farming equipment.
- *Mechanized agriculture* developed after the beginning of the Industrial Revolution. This type of farming requires large tracts of mostly level land so the machines can operate, and the same crop is planted in large areas to maximize efficiency. In this type of farming, machines and fossil fuels have replaced human labor.

Fertilizers are used to increase crop yields. They can be valuable because they replace nutrients in the soil that are removed by plants. Macronutrients are the three primary soil nutrients: (1) nitrogen, (2) phosphorus, and (3) potassium. Other micronutrients are also present in fertilizers (zinc, boron, manganese). Chemical fertilizers replace inorganic nutrients, but not organic materials in soil. The decomposition of organic matter returns organic nutrients to the soil.

Alternative agriculture methods include sustainable agriculture, which does not deplete soil, water wildlife, or human resources; organic agriculture, which prohibits the use of pesticides and fertilizers; and other alternative agriculture practices that include all nontraditional methods such as hydroponics.

Precision agriculture is a technique of farming that addresses the concerns of conventional agricultural practices, such as fertilizer runoff in water supplies, pesticides accumulating in food chains, and groundwater contaminated by fertilizers. Computer technology allows farmers to vary the amount of fertilizers applied to different places in a crop. Thus, farmers use less chemicals overall more effectively.

Pesticides and Pest Control

In addition to fertilizers, modern mechanized farming practices require other chemicals such as pesticides, insecticides, fungicides, denticides, and herbicides. These chemicals can cause damage to the environment and many species. The use of persistent pesticides, such as DDT, has been mostly banned because of the bioaccumulation and biomagnification effects on species. For example, higher and higher trophic levels feed on lower-level organisms, so the concentration of DDT accumulates and can be up to 2,000 times the original concentration in the highest-trophic-level species.

Another problem with pesticides is that pest populations such as insects, weeds, rodents, and fungi can become resistant to the chemicals. Over 500 species of insects have developed resistance to pesticides. Most pesticides are not specific to a particular organism and end up killing beneficial species as well as harmful ones.

There are also health concerns to humans who either apply pesticides or ingest foods with pesticide residues. For most people, the most critical health problems are related to exposure to small quantities over a long period of time. Many pesticides cause mutations, cancer, and abnormal offspring in experimental animals. Despite this, pesticide use in many countries continues to increase because more food can be produced with the use of pesticides, fewer crops are lost to pests, and less money is lost by farmers.

Soil Conservation and Land Use Practices

Erosion is the wearing away of soil by water, wind, or ice, which is a natural process that has been accelerated by agricultural methods. Soil erosion takes place everywhere in the world, but some areas are more exposed and have a higher degree of erosion than others. Erosion occurs mostly in regions where vegetation has been removed. Deforestation and desertification leave land open to erosion.

In order to maintain the proper soil and nutrients for crop growth, land converted to agricultural use must experience only minimal soil erosion. Therefore, many techniques are used to protect soil from eroding and to minimize the loss of topsoil. Some soil quality management components include (1) enhancement of organic matter, (2) avoidance of excess tillage, (3) efficient management of pests and soil nutrients, (4) prevention of soil compaction, (5) keeping the ground covered so soil is not exposed, and (6) diversifying cropping systems.

Several land use practices can also help to control soil erosion.

- *Contour farming,* or tilling at right angles to the slope of the land, is a simple method of preventing soil erosion and is useful on gentle slopes. Each ridge produced at right angles to the slope acts as a dam to prevent water from running down the slope. Therefore, more water soaks into the soil and less soil is washed away.
- *Strip farming* helps prevent erosion on longer or steeper slopes. Strips of closely sown crops are alternated with strips of row crops. The closely sown crops such as hay or wheat slow down the flow of water, reducing soil erosion.
- *Terracing* is a method of preventing soil erosion on steep land. Terraces are constructed at right angles to the slope.

- *Waterways* are depressions of land on sloped ground where water collects. Instead of allowing the land to remain bare, it should be properly maintained with a sod covering. Then, the speed of water flow is reduced and erosion is decreased.
- *Windbreaks* should be established to stop wind from eroding soil. Windbreaks are plantings of trees or other plants that protect soil from wind.

Methods of tilling the land, such as reduced tillage and conservation tillage, also help to reduce the amount of soil erosion. There are several variations of conservation tillage, including (1) mulch tillage, (2) strip tillage, (3) ridge tillage, and (4) no-farm tilling.

Air Pollution Control

Because humans produce air pollution, it can be controlled by changes in human activity. Motor vehicles are the primary cause of air pollution, including carbon monoxide, volatile organic compounds, and nitrogen oxides. Ozone is a secondary pollutant of motor vehicle use. Even though newer cars emit less nitrogen oxides, the mileage that people drive each year has increased, so NO_x emissions have stayed the same. Almost all other air pollutants have been reduced significantly.

Particulate matter emissions come from industrial activities, mining, farming, and the transfer of grain and coal. Improper land use is also a major source of airborne particulates, as is the burning of fossil fuels and wood. Devices are used by industries to trap particulate matter so it does not escape from smokestacks, but smaller particles that form sulfur dioxide and nitrogen oxides can still escape.

Power plant emissions of sulfur dioxide are also a cause of air pollution. Switching to the use of low-sulfur coal decreases emissions by about 66 percent. Switching to oil, natural gas, or nuclear fuels reduces emissions even more. It is also possible to reduce the sulfur in coal before it is used, but this process is costly and would drive up the cost of electricity.

The accumulation of acid-forming particles on a surface is known as acid deposition. Acid-forming particles are dissolved in rain, sleet, snow, and fog and can also be deposited as dry particles. All forms of precipitation that contain acid-forming particles are known as acid rain. Acid rain is a worldwide problem that stems from natural causes, such as vegetation, volcanoes, and lightening, and human activities, including burning of fossil fuels and the use of the internal combustion engine. The combination of sulfur dioxide or oxides of nitrogen with an oxidizing agent like ozone, hydroxide ions, or hydrogen peroxide, along with water, forms sulfuric and nitric acid in the atmosphere. Acid rain is suspected of causing the death of many forests, and it also causes damage to human-made structures, especially those made of limestone. Sulfuric acid converts limestone to gypsum, which then erodes away. There are also effects of acid rain on aquatic ecosystems, including a progressive loss of organisms as the acidity of the water increases.

Drinking Water Quality and Supply

Drinking water supplies in the United States come mainly from municipal sources. About 37 percent of municipal water comes from wells, and the rest is surface water contained in reservoirs. In rural area, residents obtain water from private wells.

To ensure water quality safety, water is treated by the following processes: (1) raw water is filtered through sand or other substrates to remove particulate matter; (2) chemicals are added to remove

dissolved particles; (3) water is disinfected with chlorine, ozone, or UV light to remove organisms. When freshwater is scarce, saltwater can be treated through desalination processes and made suitable for drinking.

Wastewater Treatment

Wastewater consists of storm water runoff, waste from industry, and domestic wastewater. Domestic waste consists primarily of organic matter from food preparation; garbage; washing clothes, dishes, and cars; and human waste. All wastewater must be cleaned before it is released, and, therefore, most municipalities and industries have wastewater treatment facilities.

Sewage treatment is classified as (1) primary, (2) secondary, and (3) tertiary.

- *Primary sewage treatment* is a physical process that removes larger particles by filtering water through large screens and smaller particles by allowing them to settle out of the water as it sits in large tanks or lagoons. Water is removed from above the settled particles and is either released back into the environment or to another treatment stage.
- *Secondary sewage treatment* involves the holding of wastewater until all of the organic matter dissolved in the water is degraded by bacteria and other microorganisms. To promote the growth of microorganisms during this treatment stage, wastewater is mixed with highly oxygenated water, or it is aerated directly with a trickling filter system. Microorganisms eventually settle out of the water in the form of sewage sludge. Water and sludge are separated, and the water is disinfected, usually with chlorine, before it is released.
- *Tertiary treatment* involves techniques to remove inorganic nutrients such as phosphorus and nitrogen in the water that could potentially increase aquatic plant growth.

Solid and Hazardous Waste

Solid waste is made up of objects and particles that accumulate at the site where they are produced or where they are disposed. Solid wastes are produced by agriculture, mining, manufacturing, and municipalities. Nations with high standards of living generally produce more solid waste than less developed nations.

There are several ways that humans dispose of solid waste. Landfills have been the primary means of solid waste disposal. Municipal solid waste landfills are constructed above impermeable clay layers lined with impermeable membranes. Each layer of garbage is covered with fresh soil to keep it from blowing away and to discourage scavengers. Contaminated water is trapped by leachate bottom layers.

Burning refuse in incinerators is another disposal method. Most incinerators are designed to capture thermal energy to make steam that is then used to produce electricity. Organic solid waste can be mulched or composted, and then reused in enriching soils or landscaping. Most municipalities now have composting facilities.

Hazardous wastes are certain by-products of industrial, business, or domestic activities that cannot be disposed of by normal measures. Waste is defined as hazardous if it causes or contributes to an increase in mortality or serious illness, or if it poses a serious threat to human health or the environment. Hazardous waste ranges from waste containing dioxins and heavy metals to organic wastes. Hazardous waste can be liquid or in the form of batteries, computer parts, or CFL light bulbs.

Once a hazardous material has been identified, government agencies such as the Food and Drug Administration (FDA) and Occupational Safety and Health Administration (OSHA) determine acceptable exposure limits to the materials. Hazardous wastes can enter the environment, for example, by evaporating into the atmosphere or leaking through faulty pipes or improper disposal. Industries are now required to report the level of hazardous toxic water released into the atmosphere. Management of hazardous waste materials has become part of industrial processes, but the best way to deal with it is not to produce hazardous waste materials in the first place.

The two most common methods of disposing of hazardous waste are (1) incineration and (2) land disposal, with land disposal being the primary disposal method. Land disposal is carried out in four different ways: (1) deep-well injection, (2) discharge of treated and untreated liquids into sewers or waterways, (3) placement of liquid or sludge in surface pits or lagoons, and (4) storage of solid waste in specially designed landfills. In 1980, Congress developed the Superfund Act to identify hazardous waste sites and clean them up on a priority basis.

Recycling and Resource Recovery

In 2001, recycling efforts, including composting of organic materials, diverted about 30 percent of waste from landfills and incinerators. This was about a twofold increase in waste reduction as compared to 1990. Container laws set in 1972 have provided an economic incentive to recycle. These laws include a two- to five-cent deposit on all recyclable beverage containers. This law reduced beverage container litter by almost 50 percent. Mandatory recycling laws are in effect in many cities and states. Municipalities often provide recycling containers and curbside recycling to assist residents.

Although recycling programs have been successful at reducing waste, there are some economic and technical problems associated with recycling. For example, plastics are recyclable, but each type of plastic requires different recycling methods, and, therefore, all plastics cannot be recycled together. Also, recycling of materials has produced an overabundance of those materials, especially in developing nations. To help reduce waste, people can (1) buy materials that last, (2) have goods repaired instead of discarding them, (3) buy items that are reusable or recyclable, (4) buy beverages in reusable glass containers, (5) use plastic or metal lunchboxes instead of paper bags, (6) use rechargeable batteries, (7) reduce the use of disposable bags, (8) separate recyclables from trash, (9) recycle all recyclable materials, (10) choose items with minimal packaging, (11) compost organic materials, and (12) use electronic sources as opposed to paper sources.

Industrial Ecology

During the mid-1990s, a concept that links industrial production to environmental quality emerged. This concept, called industrial ecology, models methods of industrial production on biological production. It forces industries to manage and account for their waste. Industrial ecology forces industries to view pollution and waste in a new way and ensures that good environmental practices translate to good economics. Businesses have become more environmentally responsible.

POLITICAL PROCESSES AND THE FUTURE

Environmental policy consists of laws, rules, and regulations aimed at preventing or correcting an environmental problem. These policies are developed, implemented, and enforced by government agencies.

Environmental Laws, Policies, and Ethics

The publication of Rachel Carson's *Silent Spring* is considered the beginning of the modern environmental movement. In 1970, with the advent of Earth Day and mounting public concern for the environment, the United States began to address some of the most obvious and pressing environmental problems. Over the last 45 years, important environmental laws, like the Clean Air Acts, Clean Water Acts, Resource Conservation and Recovery Act, Energy Policy Act, Compensation and Liability Act (Superfund), wildlife conservation acts, and land use conservation acts, have helped to protect the environment, wildlife species, and human populations.

Until 1970, most federal agencies acted within their authority without considering the environment, but the National Environmental Policy Act (NEPA) was designed to institutionalize within the federal government a concern for the environment. As a result of NEPA, many states have instituted stronger state environmental policy acts (SEPA). Congress established the Environmental Protection Agency (EPA) in 1970. The EPA helps to shape environmental laws and controls the daily operations of industries and regulates the agencies authorized to protect the environment.

International Policy

Environmental concerns are a growing factor in international relations. Policies related to health, environmental, and natural resource concerns are beginning to enter the mainstream of political policies. There are many international institutions that address the global environment by gathering and evaluating environmental data, helping to develop international treaties, and providing funding and loans to developing countries. Perhaps the most influential organization that has helped shape environmental policy is the United Nations (UN). The UN has 21 agencies that deal with environmental issues. Organizations formed under the UN include the UN Environmental Programme (UNEP), the World Health Organization (WHO), the UN Development Programme (UNDP), and the Food and Agriculture Organization (FAO). However, some agencies fail to make significant progress because they are controlled by members with competing interests. Other institutions don't succeed because they are unable to address issues in their totality. For example, the World Bank can only address issues of air pollution and biodiversity for development projects that rely on funds from the World Bank.

Other organizations that influence environmental decisions are the Global Environment Facility (GEF) and the World Conservation Union (IUNC). All of these and other organization have played a role in the following: (1) expanding the understanding of environmental issues, (2) gathering and evaluating environmental data, (3) developing international environmental treaties, (4) providing funds for sustainable economic development in an attempt to reduce poverty, and (5) helping over 100 nations develop environmental laws and regulations.

The International Organization for Standardization (ISO) was established in 1947 in Geneva to promote the development of voluntary standards for international trade. The ISO is a nongovernmental

organization (NGO) that has developed over 10,000 standards that govern products. In the early 1990s, ISO began to work on standards for environmental management. These standards aim to (1) improve the understanding of the environmental impact of activities, (2) have businesses comply with environmental regulations, (3) prevent pollution, (4) audit performance of businesses, and (5) set the standard of disclosing information about a business' environmental policy to the public.

Despite tensions between domestic concerns, international relations, and environmental issues, there have been several successful international conventions and treaties that deal with the environment. In 1987, the Montreal Protocol helped to start a decrease in CFCs in the atmosphere. The Earth Summit in 1992 aimed to develop better integration of national environmental goals with their economic goals. This summit accomplished the following: (1) development of 27 principles to guide the behavior of nations toward better environmentally sustainable patterns, (2) adoption of *Agenda 21,* and (3) a statement of principles for a global consensus on the management, conservation, and sustainable development of all types of forests. Later conferences have been less successful, with the major developing nations of China and India as well as the United States refusing to sign the Kyoto Protocol of 1997.

The European Union also works to maintain strict environmental standards for European countries. By 2000, more than 12 countries had adopted the policy of providing consumers with informational labels that enable them to be "green" consumers.

Differing Cultural and Societal Values

Many people, either within the same culture or in different cultures, differ in their views about the environment. People with widely different worldviews can examine the same data and arrive at different conclusions because they view the problem with different assumptions and values. Some environmental worldviews are human-centered, whereas others are life-centered.

According to the human-centered worldview, humans are the most important species and should manage Earth to their benefit, no matter how it might affect other species. Another human-centered view is the stewardship worldview, in which it is believed that humans have the responsibility to care for and manage the Earth. According to this view, we are borrowing resource from the Earth and have the ethical responsibility to leave the Earth in at least as good a condition as we now enjoy. Those with a life-centered worldview believe we have an ethical responsibility—not just for humans, but for all species—not to degrade Earth's ecosystems, biodiversity, and biosphere.

Future Issues

The message of environmentalism for the future should be one of hope. It calls for a commitment to overcoming today's challenges regarding the environment with respect to world population, pollution, energy sources, and food supplies. The environmental revolution that many environmental scientists hope to achieve in this century has the following components: (1) a biodiversity protection revolution, (2) an efficiency revolution, (3) a sufficiency revolution, (4) an energy revolution, (5) a pollution prevention revolution, (6) a demographic revolution, and (7) an economic and political revolution.

SUMMING IT UP

- Ecosystems are a complex network of interrelationships between abiotic and biotic factors.
- A community consists of all interacting populations of various species living in a given area at the same time.
- There are three types of organisms in organism relationships: (1) predation, (2) competition, and (3) symbiosis. There are three broad categories of organisms: (1) producers, (2) consumers, and (3) decomposers.
- All organisms occupy one or more trophic levels, and available energy decreases as the trophic level increases.
- A food chain or food web describes the relationship of organisms within an ecosystem.
- Biogeochemical cycling is the process by which the most fit and best adapted members of a species survive and reproduce.
- Succession is a series of changes that ecosystems go through in order to maintain the stability of a community.
- Biomes are climax communities that are distributed around the world. In general, the structure of ecosystems within a given type of biome is similar.
- Aquatic ecosystems are shaped by the ability of the sun's energy to reach organisms below the water's surface, the depth to the bottom, the water's temperature, the amount of salts dissolved in the water, and the nature of the body of water.
- Population biology is concerned with the characterization of the make-up, growth, and impact of a population on the environment and its organisms.
- Earth's atmosphere is 78.1 percent nitrogen, 20.9 percent oxygen, and 1 percent other gases, including carbon dioxide, methane, and water vapor.
- There are four layers in Earth's atmosphere: (1) troposphere, (2) stratosphere, (3) mesosphere, and (4) thermosphere.
- Human population growth has a significant impact on the environment and a country's resources. Developed countries tend to have low rates of population growth, and developing countries tend to have higher rates of population growth.
- Pollution is a form of matter or energy that harms the environment.
- The ozone layer is necessary to block harmful UV light, but it is slowly being depleted by human activities.
- The greenhouse effect is necessary to keep Earth's temperature warm enough to sustain life, but too much greenhouse effect can harm the environment.
- The Industrial Revolution brought about the use of coal as a fuel source and the advent of machines, all of which caused a significant increase in pollution.

- The agricultural revolution developed techniques of growing larger quantities of food, especially after the invention of mechanized farm equipment. Agricultural practices can lead to deforestation and desertification, especially in developing countries. Agricultural and industrial runoff can lead to the process of eutrophication in aquatic environments.
- Nonrenewable energy sources constitute 86.5 percent of the world's energy consumption, and only 13.5 percent of our energy comes from renewable sources.
- The Green Revolution introduced new, faster growing and hardier plant varieties and improved farming methods. High yields were achieved through the use of chemical fertilizers, pesticides, and herbicides.
- Agricultural practices are dependent on soil type, land conditions, and economic conditions. Fertilizers increase crop yield, but they cause problems to the environment. Pesticides increase crop yield, but they are harmful to the environment and to human and other species. Alternative agricultural methods aim to preserve the environment by using less or no chemicals.
- Erosion is a natural process, but some land use practices can help to control erosion.
- Human activity produces air pollution, but humans can help to control air pollution by changing activities and practices.
- Water treatment techniques are used to provide safe, clean drinking water and to clean up wastewater before it is released back into the environment. Solid and hazardous waste is disposed of in landfills or incinerated.
- Recycling helps to reduce the amount of solid waste, but there are some technical and economic problems associated with recycling.
- Environmental policy consists of laws, rules, and regulations developed by government organizations to solve environmental problems. International environmental policies are established by the United Nations and other world organizations.
- People either view environmental issues as human-centered or life-centered issues.
- An environmental revolution can address concerns for the environment and Earth's population.