Chapter 52: An Introduction to Ecology and the Biosphere

**YOU MUST KNOW**
- The role of abiotic factors in the formation of biomes.
- How biotic and abiotic factors affect the distribution of biomes.
- How changes in these factors may alter ecosystems.

**Concept 52.1** Earth's climate varies by latitude and season and is changing rapidly

- **Ecology** is the scientific study of the interactions between organisms and the environment.
- **Climate** is the long-term prevailing weather conditions in a given area. The major components that make up the climate are temperature, precipitation, sunlight, and wind. Climate patterns can be described on two scales: macroclimate and microclimate.
  - **Macroclimate** patterns work at the global, regional, or local level.
  - The changing angle of the sun over the year, bodies of water, and mountains exert seasonal, regional, and local effects on macroclimate.
  - **Microclimate** is determined by fine-scale variations, such as sunlight and temperature under a log.
  - Increasing greenhouse gas concentrations in the air are warming Earth and altering the distributions of many species. Some species will not be able to shift their ranges quickly enough to survive.

**Concept 52.2** The structure and distribution of terrestrial biomes are controlled by climate and disturbance

- **Biomes** are the major types of ecosystems that occupy very broad geographic regions.
- The importance of climate, especially precipitation and temperature, are reflected in the climograph for the major biomes of North America featured in Figure 10.1.
STUDY TIP Why are some biomes rich in species abundance? Why is productivity higher in some ecosystems? You will not be expected to know the names of specific biomes, but you may be expected to predict and justify how alteration of a factor such as moisture, or light availability, or soil nutrients would impact the system. Always look for the big picture! Think why? What if? (Species abundance is related to primary productivity, which provides energy resources, and numerous niches. Productivity is higher in ecosystems that have abundant light energy, warmer temperatures, and longer growing seasons.)

- **Savannas** are characterized by grasses and also some trees. The dominant herbivores are insects, such as ants and termites. Fire is a dominant abiotic factor, and many plants are adapted for fire. Plant growth is quite substantial during the rainy season, but large grazing mammals must migrate during regular seasons of drought.
- **Desert** is marked by sparse rainfall, and desert plants and animals are adapted to conserve and store water. Deserts contain many CAM plants and plants with adaptations that prevent animals from consuming them, such as the spines on cacti. Temperature (either hot or cold) is usually extreme.
- **Chaparral** is dominated by dense, spiny, evergreen shrubs. These are coastal areas with mild rainy winters and long, hot, dry summers. Plants are adapted to fires.
- **Temperate grassland** is marked by seasonal drought with occasional fires and by large grazing mammals. All these factors prevent the significant growth of trees. Grassland soil is rich in nutrients, making these areas good for agriculture.
Temperate broadleaf forest is marked by dense stands of deciduous trees that require sufficient moisture. These forests are more open than (and not as tall as) rain forests. They are stratified—the top layer contains one or two strata of trees; beneath that are shrubs; and under that is an herbaceous stratum. Canopy refers to the upper layers of trees in a forest. These trees drop their leaves in fall, and many mammals enter hibernation. Many birds migrate to warmer climates.

Coniferous forest is dominated by cone-bearing trees such as pine, spruce, and fir. The conical shape of conifers prevents much snowfall from accumulating on—and breaking—these trees' branches.

Tundra is marked by permafrost (permanently frozen layer of soil), very cold temperatures, high winds, and little rainfall. Tundra supports no trees or tall plants. It accounts for about 20% of Earth's terrestrial surface.

Tropical forest has pronounced vertical stratification. The canopy is so dense that little light breaks through. These forests are marked by epiphytes, which are plants that grow on other plants instead of the soil. Rainfall is varied. Biodiversity is greatest of all the terrestrial biomes.

**Concept 52.3 Aquatic biomes are diverse and dynamic systems that cover most of Earth**

Aquatic biomes make up the largest part of the biosphere, because water covers roughly 75% of Earth's surface. These biomes are classified into freshwater biomes and marine biomes.

All aquatic biomes display vertical stratification, which forms the following ecologically unique areas:

- The **photic zone**, in which there is enough light for photosynthesis to occur, and an **aphotic zone**, where very little light penetrates.
- The **benthic zone** is located at the bottom of the biome, where it is made up of sand, inorganic matter, and organic sediments. Organic sediments also include **detritus**, which is dead organic matter.
- **Thermoclines** are narrow layers of fast temperature change that separate a warm upper layer of water and cold deeper waters.

The two types of freshwater biomes are standing bodies of water, such as lakes and wetlands, and moving bodies of water, such as streams and rivers.

- In lakes, communities are distributed according to the water's depth. The **littoral zone** (well-lit shallow waters near the shore) contains rooted and floating aquatic plants, whereas the **limnetic zone** (well-lit open surface waters farther from shore) is occupied by phytoplankton.
- **Oligotrophic lakes** are deep lakes that are nutrient-poor and oxygen-rich and contain sparse phytoplankton. **Eutrophic lakes** are shallower, and they have higher nutrient content and lower oxygen content with a high concentration of phytoplankton.
- The prominent physical attribute of **streams and rivers** is current. Organisms are distributed in vertical zones and from the headwaters to the mouth.
- **Estuaries** are areas where freshwater streams or rivers merge with the ocean.
TIP FROM THE READERS
What biome do you live in? Focus on it as an illustrative example of a biome. Know the typical species found there, and reasons for their distribution.

Marine biomes include the following:

- The **intertidal zone**, where land meets the water, is periodically submerged and exposed by the twice-daily tides.
- The **neritic zone**, beyond the intertidal zone, is the shallow water over the continental shelves.
- The **pelagic zone** is a vast realm of open blue water found past the continental shelves.
- A **coral reef** is a biome created by a group of cnidarians that secrete hard calcium carbonate shells, which vary in shape and support the growth of other corals, sponges, and algae. Coral reefs are among the most productive ecosystems on Earth.

**Concept 52.4 Interactions between organisms and the environment limit the distribution of species**

- The ecological study of species involves biotic (living) and abiotic (nonliving) influences.

  - **Biotic factors** may include behaviors as well as interactions with other species. Population and community ecology (Chapters 53 and 54) will explore many of the interactions between organisms.
  - The **abiotic components** of an environment are the nonliving, chemical, and physical components. Some important abiotic factors include temperature, water, salinity, sunlight, and soil.

**Chapter 53: Population Ecology**

**YOU MUST KNOW**

- How density, dispersion, and demographics can describe a population.
- The differences between exponential and logistic models of population growth.
- How density-dependent and density-independent factors can control population growth.

**SCIENCE PRACTICES: CAN YOU ...**

- Pose scientific questions and apply mathematical routines to analyze interactions among community components?
- Predict and justify the effect of a change in one of the components on the interactions within the community and matter and energy flow?
Concept 53.1 Dynamic biological processes influence population density, dispersion, and demographics

A population is a group of individuals of a single species living in the same general area. Population ecology explores how biotic and abiotic factors influence the density, distribution, size, and age structure of populations.

Three fundamental characteristics of the organisms in a population follow:

- **Density** is the number of individuals per unit area or volume. The density of a population increases by births or immigration and decreases by deaths or emigration.
- **Dispersion** is the pattern of spacing among individuals within the boundaries of the population.
  - The most common pattern of dispersion is *clumped*, with individuals in patches, usually around a required resource. *Example*: cottonwood trees along a stream in the arid Southwest.
  - A *uniform* dispersion pattern is often the result of antagonistic interactions. Animals that defend territories often show a uniform pattern. *Example*: red-winged blackbirds during mating season.
  - *Random* dispersion shows unpredictable spacing. This is not a common spacing in nature, as there is usually a reason for a pattern of spacing.
- **Demography** is the study of vital statistics of a population, especially birth and death rates. A graphic way to show birth and death rates in a population is survivorship curves. Three types are shown in Figure 10.2.
  - **Type I** shows low death rates during early and midlife; then the death rate increases sharply in older age groups.
  - **Type II** shows a constant death rate over the organism's life span.
  - **Type III** shows very high early death rates early, then a flat rate for the few surviving to older age groups.

![Figure 10.2 Survivorship curves: types I, II, and III](image-url)
Concept 53.2 The exponential model describes population growth in an idealized, unlimited environment

- **Exponential population** growth refers to population growth under ideal conditions. Figure 10.3 shows a graph of population growth as predicted by the exponential model. Any species, regardless of its life history, is capable of exponential growth if resources are abundant.
- Exponential population growth is shown by the equation \( \frac{dN}{dt} = r_{max}N \).

![Graph of population growth predicted by the exponential model](image)

Figure 10.3 Population growth predicted by the exponential and logistic model

Concept 53.3 The logistic model describes how a population grows more slowly as it nears its carrying capacity

- The **carrying capacity** of a population is defined as the maximum population size that a certain environment can support at a particular time with no degradation of the habitat.
- If immigration and emigration are ignored, a population's growth rate (per capita increase) equals birth rate minus death rate: \( \frac{dN}{dt} = B - D \).
- In the **logistic growth model**, the per capita rate of increase declines as carrying capacity is reached. Figure 10.3 shows a graph of population growth as predicted by the logistic growth model.
- We construct the logistic model by starting with the exponential model and adding an expression that reduces per capita rate of increase as \( N \) approaches \( K \): \( \frac{dN}{dt} = r_{max}N \frac{(K - N)}{K} \).

**TIP FROM THE READERS**

You will be given a formula sheet to use on the AP exam. The formulas for population growth, exponential growth, and logistic growth rate are included. You will need to practice using each of these! There is a practice problem at the end of this section.
Concept 53.4 Life history traits are products of natural selection

- Traits that affect an organism's schedule of reproduction and survival make up its life history. Life histories entail three variables: How early? How often? How many?
  - How early in the life cycle does reproduction begin?
  - How often does the organism reproduce? Some organisms save their resources for one big reproductive event (big-bang reproduction), whereas others produce offspring in repeated reproduction.
  - How many offspring per reproductive event?

- Life history traits are evolutionary outcomes, not conscious decisions by organisms.
- Selection of life history traits that are sensitive to population density and carrying capacity are known as K-selection. K-selection operates in populations living close to the density imposed by the carrying capacity. By contrast, selection for life history traits that maximize reproductive success is called r-selection.
- The logistic growth model is sometimes associated with K-selection, whereas the exponential growth model is often associated with r-selection. Both K-selection and r-selection are two ends of a continuum of life history strategies.

Concept 53.5 Many factors that regulate population growth are density dependent

- A death rate that rises as population density rises and a birth rate that falls as population density rises are density-dependent factors. Examples of factors that reduce birth rates or increase death rates include the following:
  - Competition for resources. As population density increases, competition for resources intensifies. This might include competition for food, space, or essential nutrients.
  - Territoriality. Available space for territories or nesting may be limited, thus controlling the population.
  - Disease. Increasing densities allow for easier transmission of diseases.
  - Predation. As prey populations increase, predators may find the prey more easily.

- When a death rate does not change with increase in population density, it is said to be density independent. Natural disasters are examples of density-independent factors.
- All populations exhibit some size fluctuations. Many populations undergo regular boom-and-bust cycles that are influenced by complex interactions between biotic and abiotic factors.

Concept 53.6 The human population is no longer growing exponentially but is still increasing rapidly

- The exponential growth model in Figure 10.3 approximates the population explosion of humans over the last four centuries. However, since about 1970 the rate of growth has fallen by nearly 50%.
- One reason for falling human population growth is demographic transition. Demographic transition occurs when a population goes from high birth rates
and high death rates to low birth rates and low death rates. Demographic transition may regularly take 150 years to complete. First, death rates fall, usually due to increased medical care and sanitation; however, falling birth rates take much longer, thus delaying transition.

**Age-structure pyramids** show the relative number of individuals of each age in a population, and can be used to predict and explain many demographic patterns. Study Figure 10.4. Why is Afghanistan poised for rapid growth? Why might economic growth in Italy be predicted to slow?

![Figure 10.4 Age structure pyramids](image)

Global carrying capacity for humans is not known. A concept termed the **ecological footprint** examines the total land and water area needed for all the resources a person consumes in a population. Currently, 1.7 hectares per person is considered sustainable. A typical person in the United States has a footprint of 10 hectares.

**Practice problem:** Can you use and apply a formula to calculate population growth rate? Use the table below to calculate the population growth rate of a hypothetical population where the carrying capacity \( K = 1,500 \) individuals and \( r_{max} \) is 1.0. See page 280 for the solution to the problem.

<table>
<thead>
<tr>
<th>Population Size ( (N) )</th>
<th>Maximum Rate of Increase ( (r_{max}) )</th>
<th>( \frac{K - N}{K} )</th>
<th>Per Capita Rate of Increase ( r_{max} \left(\frac{K - N}{K}\right) )</th>
<th>Population Growth Rate ( r_{max}N\left(\frac{K - N}{K}\right) )</th>
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</thead>
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</table>
Chapter 54: Community Ecology

YOU MUST KNOW

- The difference between a fundamental niche and a realized niche.
- The role of competitive exclusion in interspecific competition.
- The symbiotic relationships of parasitism, mutualism, and commensalism.
- The impact of keystone species on community structure.
- The difference between primary and secondary succession.

Concept 54.1  Community interactions are classified by whether they help, harm, or have no effect on the species involved

A community is a group of populations of different species living close enough to interact. **Interspecific interactions** may be positive for one species (+), negative (−), or neutral (0) and include **competition**, predation, and symbioses.

**STUDY TIP** The prefix *inter-* means between different groups, whereas *intra-* means within the same group. **Intraspecific competition** is competition within the same species, like two males fighting over a territory. **Interspecific competition** is competition between two different species for resources, like food. Pay attention to the prefix! You could be asked to write about either type of competition in an essay.

**Interspecific competition** for resources occur when resources are in short supply. Competition is a −/− interaction between the species involved. Central to the idea of competition and community structure are these two concepts:

- The **competitive exclusion principle** states that when two species are vying for a resource, eventually the one with the slight reproductive advantage will eliminate the other.
- An organism's **ecological niche** is the sum total of biotic and abiotic resources that the species uses in its environment. A species' **fundamental niche**, the niche potentially occupied by the species, is often different from the **realized niche**, the portion of the fundamental niche the species actually occupies.

**Predation** is a +/− interaction between two species in which one species (the **predator**) eats the other species (the **prey**). Defenses for predators include the following:

- **Cryptic coloration**, in which the animal is camouflaged by its coloring.
- **Aposematic, or warning coloration**, in which a poisonous animal is brightly colored as a warning to other animals.
- **Batesian mimicry** refers to a situation in which a harmless species has evolved to mimic the coloration of an unpalatable or harmful species. In **Müllerian mimicry**, two bad-tasting species resemble each other, ostensibly so that predators will learn to avoid them equally.
**Herbivory** is also a +/- interaction in which an herbivore eats part of a plant or alga. It is advantageous for an animal to be able to distinguish toxic from nontoxic plants. A plant’s main protective devices are chemical toxins, spines, and thorns.

**Symbiosis** occurs when individuals of two or more species live in direct contact with one another.

- **Parasitism** is a +/- symbiotic interaction in which the parasite derives its nourishment from its host. Parasites may have a significant effect on the survival, reproduction, and density of their host population.
- **Mutualism** is an interspecific interaction that benefits both species (+/+). Both pollinators and flowering plants benefit from their relationship.
- **Commensalism** benefits one of the species but neither harms nor helps the other species. A fern growing in the shade of another plant could be a commensal relationship.

**Concept 54.2 Diversity and trophic structure characterize biological communities**

- **Species diversity** measures the number of different species in a community (species richness) and the relative abundance of each species. A community with an even species abundance is more diverse than one in which one or two species are abundant and the remainder are rare.

- The **trophic structure** of a community refers to the feeding relationships among the organisms. **Trophic levels** are the links in the trophic structure of a community.

- The transfer of food energy from plants through herbivores through carnivores through decomposers (from one trophic level to another) is referred to as a **food chain**. **Food webs** consist of two or more food chains linked together.

- **Dominant species** in a community have the highest **biomass** (the sum weight of all the members of a population) or are the most abundant.

- **Keystone species** exert control on community structure by their important ecological niches. Notice in Figure 10.5 the impact of the keystone predator **Pisaster** (a sea star) on the diversity of species present in a tidal pool.

**Concept 54.3 Disturbance influences species diversity and composition**

- A disturbance—storm, fire, flood, drought, or human activity—changes a community by removing organisms or changing resource availability.

![Figure 10.5 Impact of keystone predator on species diversity](image)
Disturbance is not necessarily bad for a community. The intermediate disturbance hypothesis states that moderate levels of disturbance create conditions that foster greater species diversity than low or high levels of disturbance.

Ecological succession refers to transitions in species composition in a certain area over ecological time.

- In primary succession, plants and animals gradually invade a region that was virtually lifeless where soil has not yet formed. The gradual colonization of a newly formed volcanic island would be an example.
- Secondary succession occurs when an existing community has been cleared by a disturbance that leaves the soil intact. An abandoned farm will show secondary succession as it starts with the soil intact.

Concept 54.4 Biogeographic factors affect community diversity

Two biogeographic contributions are especially important in community diversity:

- The latitude of the community. Plant and animal life is generally more abundant and diverse in the tropics, becoming less so moving toward the poles.
- The area of the community. If all other factors are held equal, the larger the geographic area of a community is, the more species it has.

Because of their isolation and limited size, islands are natural laboratories for studying biogeographic factors. In addition to actual islands, this idea also pertains to islands of land, like national parks surrounded by development.

Island biogeography is primarily influenced by two factors:

- Rates of immigration and extinction are influenced primarily by the size of the island and the distance of the island from the mainland. The greater the sizes of the island, the higher the immigration rates and the lower the rates of extinction.
- As the distance from the mainland increases, the rate of immigration falls, whereas extinction rates increase.

Chapter 55: Ecosystems and Restoration

Ecology

YOU MUST KNOW

- How energy flows through the ecosystem by understanding the terms in bold that relate to food chains and food webs.
- The difference between gross primary productivity and net primary productivity.
- The carbon and nitrogen biogeochemical cycles.
- Biogeochemical cycles such as the carbon and nitrogen cycles, and how they may impact individual organisms and/or populations and ecosystems.
Concept 55.1 Physical laws govern energy flow and chemical cycling in ecosystems

- An ecosystem is the sum of all the organisms living within its boundaries (biotic community) and all the abiotic factors with which they interact. Ecosystem ecology involves two unique processes: energy flow and chemical cycling.
- The flow of energy can be traced through the feeding or trophic levels in food chains and food webs. Energy cannot be recycled; therefore, energy must be constantly supplied to an ecosystem—in most cases by the sun.
  - Primary producers in an ecosystem are the autotrophs ("self-feeders"). They support all other organisms in the ecosystem.
  - Organisms that are in trophic levels above primary producers cannot make their own food and are therefore consumers or heterotrophs ("other-feeders").
  - Herbivores eat primary producers and are called primary consumers.
  - Carnivores that eat herbivores are called secondary consumers, whereas carnivores that eat secondary consumers are termed tertiary consumers.
  - Detritivores, or decomposers, are consumers that get their energy from detritus, which is nonliving organic material such as the remains of dead organisms, feces, dead leaves, and wood. Detritivores convert organic materials from all trophic levels to inorganic compounds that can be used by producers. In this way nutrients cycle through ecosystems.
- It is not uncommon for a species to feed at more than one trophic level. An animal's diet might consist of berries and fish or algae and insects. The feeding level may also change as the stage in a species' life cycle changes.

Concept 55.2 Energy and other limiting factors control primary production in ecosystems

- The amount of light energy converted to chemical energy by autotrophs is an ecosystem's primary production. The amount of all photosynthetic production sets the spending limit for the energy budget of the entire ecosystem.
  - Total primary production in an ecosystem is known as that system's gross primary production (GPP).
  - GPP is not the amount of energy available to consumers, however. Some of the fuel molecules made by the producers must be used as fuel for their own cellular respiration. Net primary production (NPP) is equal to gross primary production minus the energy used by the primary producers for their "autotrophic respiration" ($R_a$):

\[
NPP = GPP - R_a
\]

- Primary production in aquatic ecosystems is affected primarily by light availability and nutrient availability. In the photic zone, light—and therefore photosynthesis—decreases with depth. The nutrient most often limiting marine production is either nitrogen or phosphorus. A lake that is nutrient-rich and that supports a vast array of algae is said to be eutrophic.
- Temperature and moisture are the key factors controlling primary production in terrestrial ecosystems. A measure of the amount of water transpired by plants and evaporated from the landscape, termed evapotranspiration, combines both key terrestrial factors.
Concept 55.3  Energy transfer between trophic levels is typically only 10% efficient
- Energy is lost at each level of transfer as heat, or for movement or reproduction or any of the many life processes that consume energy.
- If 10% of energy is transferred from primary producer to primary consumer to secondary consumer, only 1% of the net primary production (10% of 10%) is available to secondary consumers. The loss of energy from trophic level to trophic level is one of the factors that keeps food chains so short.
- Ecological pyramids can give insight into food chains. Try to sketch and explain each of these: a biomass pyramid, an energy pyramid, and a pyramid of numbers.

Concept 55.4  Biological and geochemical processes cycle nutrients and water in ecosystems
- Biogeochemical cycles are nutrient cycles that contain both biotic and abiotic components. Understanding these cycles allows scientists to trace how nutrients flow through ecosystems and how humans may have altered the flow.
- The carbon cycle is a balance between the amount of CO$_2$ removed from ecosystems by photosynthesis and added by cellular respiration. The burning of fossil fuels has added significant amounts of additional CO$_2$ to the atmosphere. Examine Figure 10.6 to see the generalized flow of carbon while also considering the effects of CO$_2$ on global warming.

**TIP FROM THE READERS**
Remember this:
Matter cycles!
Energy does not cycle!

*Figure 10.6  The carbon cycle*
The nitrogen cycle moves nitrogen from the atmosphere through the living world. Nitrogen is a common limiting factor for plant growth, making its movement through ecosystems especially important. Note the important role of bacteria in the nitrogen cycle while tracing nitrogen flow through Figure 10.7.

**Figure 10.7** The terrestrial nitrogen cycle

- Most of Earth's nitrogen is in the form of N₂, which is unusable by plants. The major pathway for nitrogen to enter an ecosystem is nitrogen fixation, the conversion of N₂ by bacteria to forms that can be used by plants. Earlier we noted this relationship between plants that are legumes and the bacterium *Rhizobium* as an example of mutualism.

- **Nitrification** is the process by which ammonium (NH₄⁺) is oxidized to nitrite and then nitrate (NO₃⁻) by bacteria. Two inorganic nitrogen forms can be absorbed by plants: nitrates and ammonium.

- **Denitrification** by bacteria releases nitrogen to the atmosphere.

- Other important nutrient cycles involve water and phosphorus.

TIP FROM THE READERS

Work through each figure verbally. You need to be able to explain how a change in the amount of nitrogen or carbon dioxide or another factor would impact an ecosystem. To understand the impact of acid rain, or fertilizer runoff, or global warming, you need to understand these cycles!
Concept 55.5 Restoration ecologists help return degraded ecosystems to a more natural state

- **Bioremediation** is the use of organisms, usually prokaryotes, fungi, or plants, to detoxify polluted ecosystems. It has been used to restore areas degraded by mining, or to remove oil or radioactive elements.

- **Bioaugmentation** is the introduction of desirable species such as nitrogen fixers to add essential nutrients.

Chapter 56: Conservation Biology and Global Change

**YOU MUST KNOW**

- The value of biodiversity, and the major human threats to it.
- How human activity is changing the Earth.

Concept 56.1 Human activities threaten Earth’s biodiversity

- **Biodiversity**—short for biological diversity—can be considered at three main levels: genetic diversity, species diversity, and ecosystem diversity.

- Four major threats to biodiversity are habitat loss, introduced species, over-harvesting, and global change.

Concept 56.2 Population conservation focuses on population size, genetic diversity, and critical habitat

- When a population drops below a minimum viable population (MVP) size, its loss of genetic variation due to nonrandom mating and genetic drift can trap it in an extinction vortex. One key factor is the loss of genetic variation necessary to enable evolutionary responses to environmental change, such as the appearance of new strains of pathogens.

Concept 56.3 Landscape and regional conservation help sustain biodiversity

- The structure of a landscape can strongly influence biodiversity. As habitat fragmentation increases and edges become more extensive, biodiversity tends to decrease. Movement corridors can promote dispersal and help sustain populations.

- A **biodiversity hot spot** is a relatively small area with an exceptional concentration of endemic species and a large number of endangered and threatened species. Biodiversity hot spots are also hot spots of extinction and thus prime candidates for protection.

Concept 56.4 Earth is changing rapidly as a result of human actions

- Nutrient cycling is altered by human activities, particularly agriculture. For example, soil nitrogen is often depleted by crops. Excess nitrogen enters aquatic ecosystems as a result of livestock activities and can lead to eutrophication.
Acid precipitation is defined as rain, snow, or fog with a pH less than 5.2. The burning of wood and fossil fuels releases sulfur oxides and nitrogen oxides into the atmosphere. These oxides react with water, forming sulfuric acid and nitric acid.

In biological magnification, toxins become more concentrated in successive trophic levels of a food web. The toxins cannot be broken down biologically by normal chemical means, so they magnify in concentration as they move through the food chain.

The greenhouse effect refers to the absorption of heat the Earth experiences due to certain atmospheric gases. Carbon dioxide and water vapor intercept and absorb much reflected infrared radiation, re-reflecting some back toward Earth.

Because of the burning of fossil fuels, CO₂ levels have been steadily increasing. One effect of this increase is that Earth is being warmed significantly (global warming).

The ozone layer reduces the amount of UV radiation penetration from the sun through the atmosphere. Chlorine-containing compounds used by humans are eroding the ozone layer, allowing more DNA-damaging UV radiation to penetrate to the surface of the Earth.

Solution to practice problem on page 272:

Using a population size of 1,600 as an example,

\[
\frac{dN}{dt} = r_{max} \frac{(K - N)}{K} = 1 \left(1,600 \right) \left(1,500 - 1,600 \right) \frac{1}{1,500}
\]

and the population “growth” rate is -107 individuals per year. The population shrinks even faster when N is farther from the carrying capacity; when N equals 1,750 and 2,000 individuals, the population shrinks by 292 and 667 individuals per year, respectively.

<table>
<thead>
<tr>
<th>Population Size (N)</th>
<th>Maximum Rate of Increase (r_{max})</th>
<th>(\frac{K - N}{K})</th>
<th>Per Capita Rate of Increase (r_{max} \left(\frac{K - N}{K}\right))</th>
<th>Population Growth Rate (r_{max}N \left(\frac{K - N}{K}\right))</th>
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<td>1.0</td>
<td>(1,500 - 1,600)/1,500 = -0.067)</td>
<td>1(-0.067) = (-0.067)</td>
<td>(-0.067)(1,600) = -107</td>
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<td>1,750</td>
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<td>(-0.25)(2,000) = -500</td>
</tr>
</tbody>
</table>
Level 1: Knowledge/Comprehension Questions

1. All of the following statements about Earth’s ozone layer are false EXCEPT
   (A) it is composed of O₂.
   (B) it decreases the amount of ultraviolet radiation that reaches Earth.
   (C) it is thinning as a result of widespread use of certain chlorine-containing compounds.
   (D) it is a result of widespread burning of fossil fuels.
   (E) it allows green light in but screens out red light.

2. Which of the following is the major primary producer in a savanna ecosystem?
   (A) lion
   (B) gazelle
   (C) grass
   (D) snake
   (E) diatom

3. The carrying capacity of a population is defined as
   (A) the amount of time the parents in the population spend rearing and nurturing their offspring.
   (B) the maximum population size that a certain environment can support at a particular time.
   (C) the amount of vegetation that a certain geographic area can support.
   (D) the number of different types of species a biome can support.
   (E) the number of different genes a population can carry at a particular time.

4. Which of the following terms is used to describe major types of ecosystems that occupy broad geographic regions?
   (A) biome
   (B) community
   (C) chaparral
   (D) trophic level
   (E) photic zone

5. A lake that is nutrient-rich and that supports a vast array of algae is said to be
   (A) oligotrophic.
   (B) abyssal.
   (C) littoral.
   (D) eutrophic.
   (E) limnetic.

6. Which of the following best describes an estuary?
   (A) an area that is periodically flooded, causing its soil to be consistently damp
   (B) an area where a river changes course after being diverted from its original course by an obstacle
   (C) the area where a freshwater river merges with the ocean
   (D) the area where a mass of cold water and a mass of warm water meet in the pelagic zone
   (E) an outshoot of land that extends into the ocean

7. Which of the following is the term that refers to the layer of light penetration in aquatic ecosystems?
   (A) littoral zone
   (B) limnetic zone
   (C) photic zone
   (D) benthic zone
   (E) aphotic zone

Directions: The group of questions below consists of five lettered choices followed by a list of numbered phrases or sentences. For each numbered phrase or sentence, select the one choice that is most closely related to it. Each choice may be used once, more than once, or not at all.

Questions 8–12
   (A) Temperate grassland
   (B) Tropical forest
   (C) Temperate broadleaf forest
   (D) Tundra
   (E) Desert
8. Characterized by permafrost and few large plants

9. Characterized by epiphytes, a significant canopy, and abundant rainfall

10. Characterized by an understory of shrubs and trees that lose their leaves in the fall

11. Characterized by occasional fires, nutrient-rich soil, and large grazing animals

12. Characterized by sparse rainfall and extreme daily temperature fluctuations

13. A bacterial colony that exists in an environment displaying ideal conditions will undergo
   (A) logistic growth.
   (B) intrinsic growth.
   (C) hyperactive growth.
   (D) exponential growth.
   (E) unbounded growth.

14. A species' specific use of the biotic and abiotic factors in an environment is collectively called the species' 
   (A) habitat.
   (B) trophic level.
   (C) ecological niche.
   (D) placement.
   (E) partitioning.

15. In which type of camouflaging does a non-toxic animal mimic the appearance of a toxic animal?
   (A) Müllerian mimicry
   (B) cryptic coloration
   (C) aposematic coloration
   (D) Batesian mimicry
   (E) parasitoidism

16. The dominant species in a community is the one that
   (A) has the greatest number of genes per individual.
   (B) is at the top of the food chain.
   (C) has the largest biomass.
   (D) eats all other members of the community.
   (E) bears the most offspring in each mating.

17. Which statement best describes energy transfer in a food web?
   (A) Energy is transferred to consumers, which convert it to nitrogen compounds and use it to synthesize amino acids.
   (B) Energy from producers is converted into oxygen and transferred to consumers.
   (C) Energy from the sun is stored in green plants and transferred to consumers.
   (D) Energy is transferred to consumers that use it to synthesize food.
   (E) Energy moves from autotrophs to heterotrophs to decomposers, which convert it to a form producers can use again.

18. A fire cleared a large area of forest in Yellowstone National Park in the 1980s. When the first plants pioneered this burned area, this was an example of
   (A) primary succession.
   (B) secondary succession.
   (C) biological evolution.
   (D) a keystone species.
   (E) the top-down model.

19. In the nitrogen cycle, the process by which nitrogen in the atmosphere is made available for use by plants is known as
   (A) ammonification.
   (B) denitrification.
   (C) nitrogen fixation.
   (D) nitrogen cycling.
   (E) nitrogenation.
20. The process in which CO₂ in the atmosphere intercepts and absorbs reflected infrared radiation and re-reflects it back to Earth is known as  
(A) global warming.  
(B) atmospheric insulation.  
(C) stratospheric insulation.  
(D) biological magnification.  
(E) the greenhouse effect.

21. A Type I survivorship curve is level at first, with a rapid increase in mortality in old age. This type of curve is  
(A) typical of many invertebrates that produce large numbers of offspring.  
(B) typical of human and other large mammals.  
(C) found most often in r-selected populations.  
(D) almost never found in nature.  
(E) typical of all species of birds.

22. Which of the following would not be a density-dependent factor limiting a population's growth?  
(A) increased predation by a predator  
(B) a limited number of available nesting sites  
(C) a stress syndrome that alters hormone levels  
(D) a very early fall frost  
(E) intraspecific competition

Level 2: Application/Analysis/Synthesis Questions
After reading the paragraphs, answer the question(s) that follow.

The largest estuary in the United States is the Chesapeake Bay, which extends through six states, including Maryland, Virginia, and Pennsylvania. The bay is one of the most productive natural areas in the world. It is home to thousands of plants and animals, including many commercially important species.

23. The human population is growing at such an alarmingly fast rate because  
(A) technology has increased our carrying capacity.  
(B) the death rate has greatly decreased since the Industrial Revolution.  
(C) the age structure of many countries is highly skewed toward younger ages.  
(D) fertility rates in many developing countries are above the 2.1 children per female replacement level.  
(E) all of the above are true.

24. When one species was removed from a tide pool, the species richness became significantly reduced. The removed species was probably  
(A) a strong competitor.  
(B) a potent parasite.  
(C) a resource partitioner.  
(D) a keystone species.  
(E) the species with the highest relative abundance.

25. Which of the following interspecific interactions is not an example of a +/- interaction?  
(A) ectoparasite and host  
(B) herbivore and plant  
(C) honeybee and flower  
(D) pathogen and host  
(E) carnivore and prey

The water of the bay is relatively shallow. Many areas are no more than 10 feet deep, with an average depth of 30 feet. Light penetrates the shallow water and supports the submerged plants that provide food and shelter for the many species living in the bay ecosystem. However, like many estuaries, the bay receives large amounts of fertilizer runoff from farms, lawns, and wastewater treatment facilities. This runoff introduces large amounts of nutrients.
1. Which of the following is the most probable sequence of events when fertilizer runoff reaches the bay?
   (A) submerged vegetation increases, more food for fish and shellfish, fish and shellfish populations increase
   (B) phytoplankton population increases, more food for fish and shellfish, fish and shellfish populations increase
   (C) phytoplankton population increases, sunlight blocked to submerged vegetation, submerged vegetation dies, fish and shellfish populations decrease
   (D) submerged vegetation decreases, fish and shellfish feed on decaying plants, phytoplankton feed on fish and shellfish, commercial fisheries decline

2. Which of the following pairs of nutrients would have the greatest effect on growth of phytoplankton?
   (A) carbon and hydrogen
   (B) oxygen and carbon dioxide
   (C) nitrogen and phosphorus
   (D) sulfur and magnesium

3. According to this graph of the population growth of fur seals, in what year did the population first reach its carrying capacity?

   ![Graph of population growth of fur seals](image)

   (A) 1925
   (B) 1930
   (C) 1940
   (D) 1950

4. The formula \( \frac{dN}{dt} = r_{\text{max}}N(K - N)/K \) describes the pattern of growth for the graph. Which of the following is true concerning the formula and the graph it describes in 1945?
   (A) \( K = N \)
   (B) \( r_{\text{max}}N \)
   (C) The variable \( N \) is constantly changing.
   (D) \( (K - N)/K = 9,000 \)

5. When snakeheads enter aquatic ecosystems, biodiversity in these ecosystems would most likely
   (A) increase, since another species has been added to the environment.
   (B) decrease, since the snakehead will prey on native species.
   (C) remain the same, since local species will prey on the snakeheads and remove them.
   (D) remain the same, because the snakeheads will merge without problems into established communities.
6. Based on the characteristics of the snakehead described, which of the following is most likely to be a productive strategy to reduce the spread of this species?
(A) extending the fishing season for prey fishes
(B) introducing a natural predator to feed on juvenile snakeheads
(C) introducing a fungus that prevents fish eggs from hatching
(D) introducing algae and photosynthetic bacteria to reduce nutrient levels in the water

7. The age-structure data for Nigeria shows that the country has many more individuals under the age of 15 than over the age of 40. What does this imply about the future population of Nigeria?
(A) The population will probably remain stable.
(B) The population will probably decrease.
(C) The population will probably grow rapidly.
(D) The number of older people will probably increase rapidly.

8. Based on the age structure of the country, which of the following situations would be most likely over the next 20 years?
(A) strong economic gains stimulated by population growth
(B) an increased demand for resources based on population growth
(C) a decreased demand for medical services due to the small number of elderly citizens
(D) a decline in housing prices based on lack of demand
Free-Response Question

1. All of the organisms in a community are interrelated by the abiotic and biotic resources they use in the course of their lives.

(a) Describe the relationships that exist among a hawk, a mouse, a plant, and soil in a particular ecosystem.

(b) Discuss two examples of the impact of human population growth on abiotic components of the environment. For each example, explain how a change in the abiotic component will impact the biotic component of the biosphere.