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Psychedelic Treasure

- Scientists have named and described 1.8 million species
- Biologists estimate 10–100 million species exist on Earth
- Tropical forests contain some of the greatest concentrations of species and are being destroyed at an alarming rate
- Humans are rapidly pushing many species toward extinction

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Figure 56.1

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Figure 56.1a

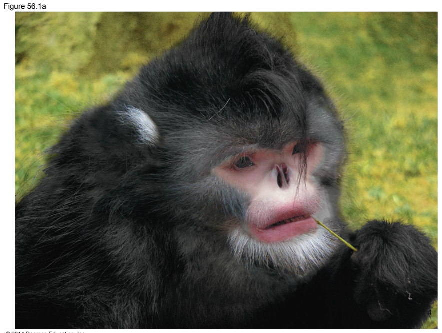

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Figure 56.2

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- **Conservation biology**, which seeks to preserve life, integrates several fields
  - Ecology
  - Physiology
  - Molecular biology
  - Genetics
  - Evolutionary biology

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Concept 56.1: Human activities threaten Earth's biodiversity

- Rates of species extinction are difficult to determine under natural conditions
- Humans are threatening Earth's biodiversity

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Three Levels of Biodiversity

- Biodiversity has three main components
  - Genetic diversity
  - Species diversity
  - Ecosystem diversity

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Figure 56.3-1

Genetic diversity in a vole population

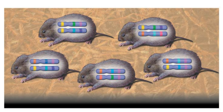

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Figure 56.3-2

Genetic diversity in a vole population

Species diversity in a coastal redwood ecosystem

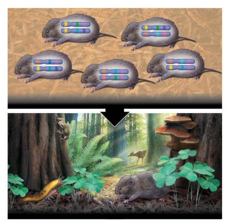

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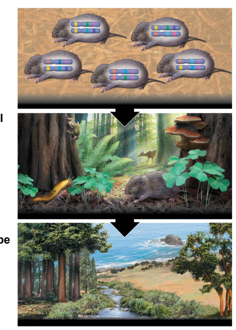
Figure 56.3-3

Genetic diversity in a vole population

Species diversity in a coastal redwood ecosystem

Community and ecosystem diversity across the landscape of an entire region



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Genetic Diversity

- Genetic diversity comprises genetic variation within a population and between populations

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Species Diversity

- Species diversity is the variety of species in an ecosystem or throughout the biosphere
- According to the U.S. Endangered Species Act
  - An **endangered species** is "in danger of becoming extinct throughout all or a significant portion of its range"
  - A **threatened species** is likely to become endangered in the foreseeable future

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- Conservation biologists are concerned about species loss because of alarming statistics regarding extinction and biodiversity
- Globally, 12% of birds, 21% of mammals are threatened with extinction
- Extinction may be local or global

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Figure 56.4

Philippine eagle

Yangtze River dolphin

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Figure 56.4a

Philippine eagle

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Figure 56.4b

Yangtze River dolphin

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Ecosystem Diversity

- Human activity is reducing ecosystem diversity, the variety of ecosystems in the biosphere
- More than 50% of wetlands in the contiguous United States have been drained and converted to other ecosystems

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- The local extinction of one species can have a negative impact on other species in an ecosystem
  - For example, flying foxes (bats) are important pollinators and seed dispersers in the Pacific Islands

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Figure 56.5

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Biodiversity and Human Welfare

- Human biophilia allows us to recognize the value of biodiversity for its own sake
- Species diversity brings humans practical benefits

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Benefits of Species and Genetic Diversity

- Species related to agricultural crops can have important genetic qualities
  - For example, plant breeders bred virus-resistant commercial rice by crossing it with a wild population
- In the United States, 25% of prescriptions contain substances originally derived from plants
  - For example, the rosy periwinkle contains alkaloids that inhibit cancer growth

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Figure 56.6

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- The loss of species also means loss of unique genes and genetic diversity
- The enormous genetic diversity of organisms has potential for great human benefit

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Ecosystem Services

- **Ecosystem services** encompass all the processes through which natural ecosystems and their species help sustain human life
- Some examples of ecosystem services
  - Purification of air and water
  - Detoxification and decomposition of wastes
  - Cycling of nutrients
  - Moderation of weather extremes

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Threats to Biodiversity

- Most species loss can be traced to four major threats
  - Habitat loss
  - Introduced species
  - Overharvesting
  - Global change

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Habitat Loss

- Human alteration of habitat is the greatest threat to biodiversity throughout the biosphere
- In almost all cases, habitat fragmentation and destruction lead to loss of biodiversity
- For example
  - In Wisconsin, prairie occupies <0.1% of its original area
  - About 70% of coral reefs have been damaged by human activities

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Figure 56.7

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Introduced Species

- **Introduced species** are those that humans move from native locations to new geographic regions
- Without their native predators, parasites, and pathogens, introduced species may spread rapidly
- Introduced species that gain a foothold in a new habitat usually disrupt their adopted community

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- Sometimes humans introduce species by accident
  - For example, the brown tree snake arrived in Guam as a cargo ship "stowaway" and led to extinction of some local species

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- Humans have deliberately introduced some species with good intentions but disastrous effects
  - For example, kudzu was intentionally introduced to the southern United States

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Figure 56.8

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Overharvesting

- Overharvesting is human harvesting of wild plants or animals at rates exceeding the ability of populations of those species to rebound
- Large organisms with low reproductive rates are especially vulnerable to overharvesting
  - For example, elephant populations declined because of harvesting for ivory

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- DNA analysis can help conservation biologists identify the source of illegally obtained animal products
  - For example, DNA from illegally harvested ivory can be used to trace the original population of elephants to within a few hundred kilometers

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Figure 56.9

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- Overfishing has decimated wild fish populations
  - For example, the North Atlantic bluefin tuna population decreased by 80% in ten years

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Global Change

- Global change includes alterations in climate, atmospheric chemistry, and broad ecological systems
- Acid precipitation contains sulfuric acid and nitric acid from the burning of wood and fossil fuels

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- Air pollution from one region can result in acid precipitation downwind
  - For example, industrial pollution in the midwestern United States caused acid rain in eastern Canada in the 1960s
- Acid precipitation kills fish and other lake-dwelling organisms
- Environmental regulations have helped to decrease acid precipitation
  - For example, sulfur dioxide emissions in the United States decreased 40% between 1993 and 2008

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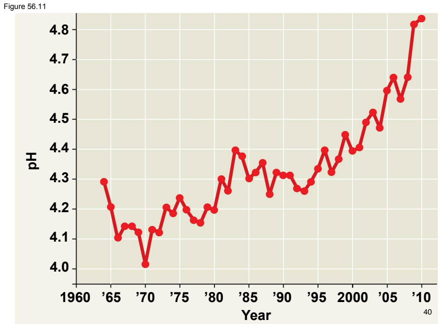
Figure 56.11



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Can Extinct Species Be Resurrected?

- Species recovery may be possible through cloning technology if frozen tissue is available
- Current research is underway to determine if ancient extinct species frozen in Arctic ice can be successfully cloned
- Resurrection of extinct species raises ethical questions

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Figure 56.12

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

- Biologists focusing on conservation at the population and species levels follow two main approaches
  - The small-population approach
  - The declining-population approach

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Small-Population Approach

- The small-population approach studies processes that can make small populations become extinct

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The Extinction Vortex: Evolutionary Implications of Small Population Size

- A small population is prone to inbreeding and genetic drift, which draw it down an **extinction vortex**
- The key factor driving the extinction vortex is loss of the genetic variation necessary to enable evolutionary responses to environmental change
- Small populations and low genetic diversity do not always lead to extinction

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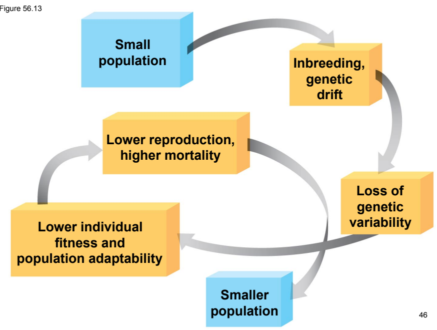
Figure 56.13



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Case Study: *The Greater Prairie Chicken and the Extinction Vortex*

- Populations of the greater prairie chicken were fragmented by agriculture and later found to exhibit decreased fertility
- To test the extinction vortex hypothesis, scientists imported genetic variation by transplanting birds from larger populations
- The declining population rebounded, confirming that low genetic variation had been causing an extinction vortex

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Figure 56.14

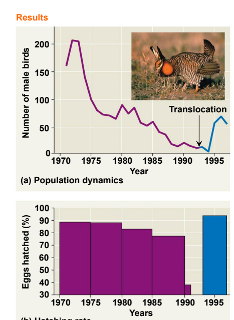

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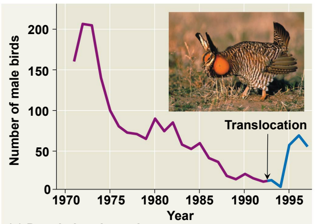
Figure 56.14a

Results



(a) Population dynamics

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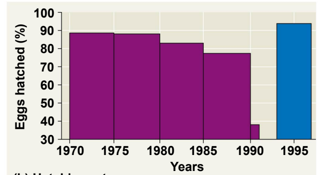
Figure 56.14b

Results



(b) Hatching rate

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Minimum Viable Population Size

- **Minimum viable population (MVP)** is the minimum population size at which a species can survive
- The MVP depends on factors that affect a population's chances for survival over a particular time

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Effective Population Size

- A meaningful estimate of MVP requires determining the **effective population size**, which is based on the population's breeding potential

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- Effective population size (N_e) is estimated by

$$N_e = \frac{4N_f N_m}{N_f + N_m}$$

where N_f and N_m are the number of females and the number of males, respectively, that breed successfully

- Viability analysis is used to predict a population's chances for survival over a particular time interval

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Case Study: *Analysis of Grizzly Bear Populations*

- One of the first population viability analyses was conducted as part of a long-term study of grizzly bears in Yellowstone National Park
- It is estimated that a population of 100 bears would have a 95% chance of surviving about 200 years
- This grizzly population is about 500, but N_e is about 125

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- The Yellowstone grizzly population has low genetic variability compared with other grizzly populations
- Introducing individuals from other populations would increase the numbers and genetic variation

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Declining-Population Approach

- The declining-population approach
  - Focuses on threatened and endangered populations that show a downward trend, regardless of population size
  - Emphasizes the environmental factors that caused a population to decline

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Steps for Analysis and Intervention

- The declining-population approach involves several steps
  1. Confirm that the population is in decline
  2. Study the species' natural history
  3. Develop hypotheses for all possible causes of decline
  4. Test the hypotheses in order of likeliness
  5. Apply the results of the diagnosis to manage for recovery

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Case Study: *Decline of the Red-cockaded Woodpecker*

- Red-cockaded woodpeckers require living trees in mature pine forests
- These woodpeckers require forests with little undergrowth
- Logging, agriculture, and fire suppression have reduced suitable habitat

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Figure 56.16

(a) Forests with low undergrowth (b) Forests with high, dense undergrowth

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Figure 56.16a

(a) Forests with low undergrowth

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Figure 56.16b

(b) Forests with high, dense undergrowth

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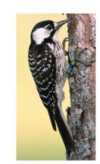
Figure 56.16c



Red-cockaded woodpecker

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- Red-cockaded woodpeckers take months to excavate new nesting cavities
- In a study where breeding cavities were constructed, new breeding groups formed only in these sites
- Based on this experiment, a combination of habitat maintenance and excavation of breeding cavities enabled this endangered species to rebound

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Weighing Conflicting Demands

- Conserving species often requires resolving conflicts between habitat needs of endangered species and human demands
- For example, in the U.S. Pacific Northwest, habitat preservation for many species is at odds with timber and mining industries
- Managing habitat for one species might have positive or negative effects on other species

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Concept 56.3: Landscape and regional conservation help sustain biodiversity

- Conservation biology has attempted to sustain the biodiversity of entire communities, ecosystems, and landscapes
- Ecosystem management is part of landscape ecology, which seeks to make biodiversity conservation part of land-use planning

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Landscape Structure and Biodiversity

- The structure of a landscape can strongly influence biodiversity

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Fragmentation and Edges

- The boundaries, or edges, between ecosystems are defining features of landscapes
- An edge has its own set of physical conditions, which differ from those on either side of it
- Some species take advantage of edge communities to access resources from both adjacent areas

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- The Biological Dynamics of Forest Fragments Project in the Amazon examines the effects of fragmentation on biodiversity
- Landscapes dominated by fragmented habitats support fewer species due to a loss of species adapted to habitat interiors

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Corridors That Connect Habitat Fragments

- A **movement corridor** is a narrow strip of habitat connecting otherwise isolated patches
- Movement corridors promote dispersal and help sustain populations
- In areas of heavy human use, artificial corridors are sometimes constructed

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- Corridors can also be harmful by facilitating the spread of disease between populations

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Establishing Protected Areas

- Conservation biologists apply understanding of ecological dynamics in establishing protected areas to slow the loss of biodiversity

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Preserving Biodiversity Hot Spots

- A **biodiversity hot spot** is a relatively small area with a great concentration of endemic species and many endangered and threatened species
- Biodiversity hot spots are good choices for nature reserves, but identifying them is not always easy

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- Designation of hot spots is often biased toward saving vertebrates and plants
- Hot spots can change with climate change

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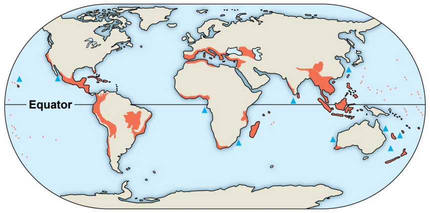
Figure 56.20



Earth's terrestrial (■) and marine (▲) biodiversity hot spots

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Philosophy of Nature Reserves

- Nature reserves are biodiversity islands in a sea of habitat degraded by human activity
- Nature reserves must consider disturbances as a functional component of all ecosystems

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- An important question is whether to create fewer large reserves or more numerous small reserves
- One argument for large reserves is that large, far-ranging animals with low-density populations require extensive habitats
- Smaller reserves may be more realistic and may slow the spread of disease throughout a population

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Zoned Reserves

- The **zoned reserve** model recognizes that conservation often involves working in landscapes that are largely human dominated
- A zoned reserve includes relatively undisturbed areas and the modified areas that surround them and that serve as buffer zones
- Costa Rica has become a world leader in establishing zoned reserves

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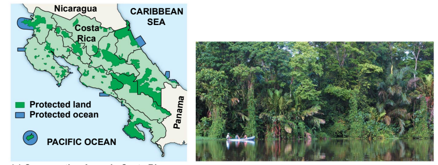
Figure 56.21



(a) Conservation Areas in Costa Rica (b) Tourists in one of Costa Rica's protected areas

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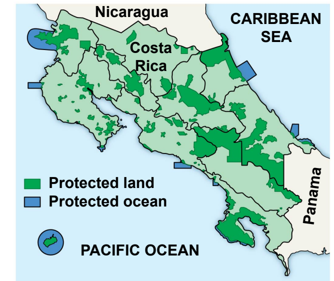
Figure 56.21a



(a) Conservation Areas in Costa Rica

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Figure 56.21b

(b) Tourists in one of Costa Rica's protected areas

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- Some zoned reserves in the Fiji islands are closed to fishing, which actually improves fishing success in nearby areas
- The United States has adopted a similar zoned reserve system with the Florida Keys National Marine Sanctuary

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Figure 56.22

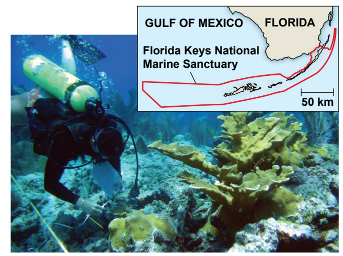

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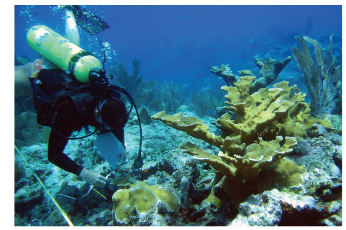
Figure 56.22a



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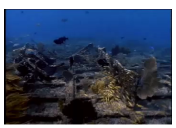
Video: Coral Reef



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Urban Ecology

- The field of **urban ecology** examines organisms and their environment in urban settings
- A critical area of research centers on urban streams, which experience rapid water fluctuations after rainfall
- Restoration of Guichon Creek, near Vancouver, British Columbia, has allowed for the successful reestablishment of cutthroat trout

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

- The locations of preserves today may be unsuitable for their species in the future
- Human-caused changes in the environment include
  - Nutrient enrichment
  - Accumulation of toxins
  - Climate change
  - Ozone depletion

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Nutrient Enrichment

- Human activity often removes nutrients from one part of the biosphere and adds them to another
- Harvest of agricultural crops exports nutrients from the agricultural ecosystem
- Agriculture leads to the depletion of nutrients in the soil
- Fertilizers add nitrogen and other nutrients to the agricultural ecosystem

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Figure 56.23

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- **Critical load** is the amount of added nutrient that can be absorbed by plants without damaging ecosystem integrity
- Nutrients that exceed the critical load leach into groundwater or run off into aquatic ecosystems
- Agricultural runoff and sewage lead to phytoplankton blooms in the Atlantic Ocean
- Decomposition of phytoplankton blooms causes "dead zones" due to low oxygen levels

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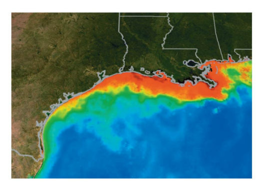
Figure 56.24



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Toxins in the Environment

- Humans release many toxic chemicals, including synthetics previously unknown to nature
- In some cases, harmful substances persist for long periods in an ecosystem
- One reason toxins are harmful is that they become more concentrated in successive trophic levels
- **Biological magnification** concentrates toxins at higher trophic levels, where biomass is lower

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- PCBs and many pesticides such as DDT are subject to biological magnification in ecosystems
- Herring gulls of the Great Lakes lay eggs with PCB levels 5,000 times greater than in phytoplankton

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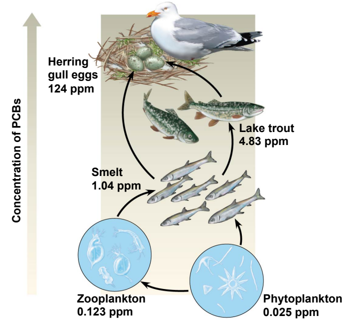
Figure 56.25



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- In the 1960s Rachel Carson brought attention to the biomagnification of DDT in birds in her book *Silent Spring*
- DDT was banned in the United States in 1971
- Countries with malaria face a trade-off between using DDT to kill mosquitoes (malarial vectors) and protecting other species

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- Pharmaceutical drugs enter freshwater ecosystems through human sewage and agricultural runoff
- Estrogen used in birth control pills can cause feminization of males in some species of fish

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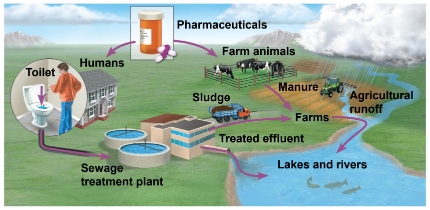

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Greenhouse Gases and Climate Change

- One pressing problem caused by human activities is the rising level of CO_2 and other greenhouse gases in the atmosphere

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Rising Atmospheric CO_2 Levels

- Due to burning of fossil fuels and other human activities, the concentration of atmospheric CO_2 has been steadily increasing

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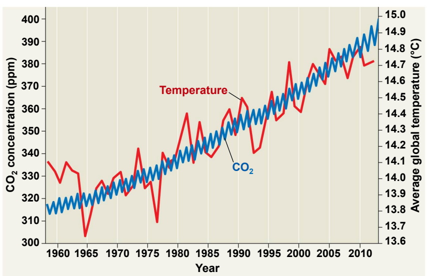
Figure 56.28



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- CO_2, water vapor, and other greenhouse gases reflect infrared radiation back toward Earth; this is the **greenhouse effect**
- This effect is important for keeping Earth's surface at a habitable temperature
- Increasing concentration of atmospheric CO_2 is linked to increasing global temperature

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- Climatologists can make inferences about past environments and their climates
  - Pollen and fossil plant records reveal past vegetation
  - CO_2 levels are inferred from bubbles trapped in glacial ice
  - Chemical isotope analysis is used to infer past temperature

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- Northern coniferous forests and tundra show the strongest effects of global warming
  - For example, in 2012 the extent of Arctic sea ice was the smallest on record
- A warming trend would also affect the geographic distribution of precipitation

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- Many organisms may not be able to survive rapid climate change
- Some ecologists support **assisted migration**, the translocation of a species to a favorable habitat beyond its native range

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Climate Change Solutions

- Global warming can be slowed by reducing energy needs and converting to renewable sources of energy
- Stabilizing CO_2 emissions will require an international effort
- International negotiations have yet to reach a consensus on a global strategy to reduce greenhouse gas emissions
- Reduced deforestation would also decrease greenhouse gas emissions

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Depletion of Atmospheric Ozone

- Life on Earth is protected from damaging effects of UV radiation by a protective layer of ozone molecules in the atmosphere
- Satellite studies suggest that the ozone layer has been gradually thinning since the mid-1970s

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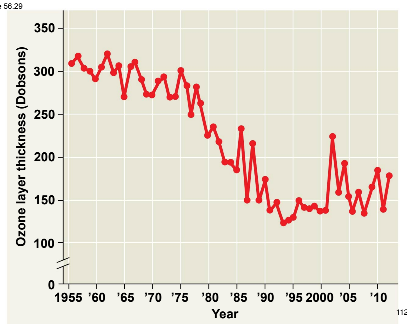
Figure 56.29



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- Destruction of atmospheric ozone results mainly from chlorofluorocarbons (CFCs) produced by human activity
- CFCs contain chlorine, which reacts with ozone to make O_2
- This decreases the amount of ozone in the atmosphere

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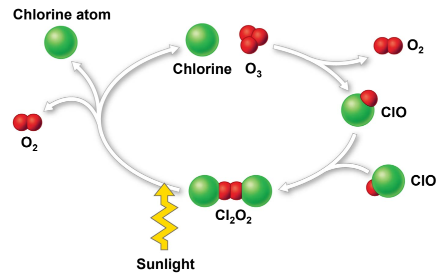
Figure 56.30



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- The ozone layer is thinnest over Antarctica and southern Australia, New Zealand, and South America
- Ozone levels have decreased 2–10% at mid-latitudes during the past 20 years

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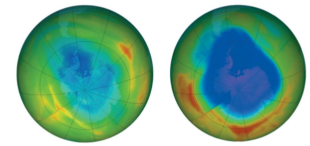
Figure 56.31



September 1979 September 2012

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Figure 56.31a

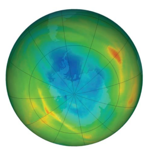

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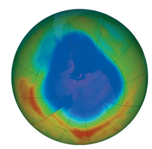
Figure 56.31b



September 2012

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- Ozone depletion causes DNA damage in plants and poorer phytoplankton growth
- An international agreement signed in 1987 has resulted in a decrease in ozone depletion
- Chlorine molecules already in the atmosphere will continue to influence ozone levels for at least 50 years

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Concept 56.5: Sustainable development can improve human lives while conserving biodiversity

- The concept of sustainability helps ecologists establish long-term conservation priorities

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Sustainable Development

- **Sustainable development** is development that meets the needs of people today without limiting the ability of future generations to meet their needs
- The goal of the Sustainable Biosphere Initiative is to define and acquire basic ecological information for responsible development, management, and conservation of Earth's resources

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- Sustainable development requires connections between life sciences, social sciences, economics, and humanities

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Case Study: *Sustainable Development in Costa Rica*

- Costa Rica's conservation of tropical biodiversity involves partnerships between the government, nongovernmental organizations (NGOs), and private citizens
- Human living conditions (infant mortality, life expectancy, literacy rate) in Costa Rica have improved along with ecological conservation

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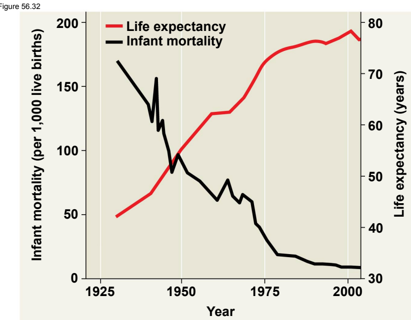
Figure 56.32



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The Future of the Biosphere

- Our lives differ greatly from those of early humans, who hunted and gathered and painted on cave walls

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Figure 56.33

(a) Detail of animals in a 17,000-year-old cave painting, Lascaux, France

(b) A 30,000-year-old ivory carving of a water bird, found in Germany

(c) Nature lovers on a wildlife-watching expedition

(d) A young biologist holding a songbird

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Figure 56.33a

(a) Detail of animals in a 17,000-year-old cave painting, Lascaux, France

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Figure 56.33b

(b) A 30,000-year-old ivory carving of a water bird, found in Germany

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Figure 56.33c

(c) Nature lovers on a wildlife-watching expedition

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Figure 56.33d

(d) A young biologist holding a songbird

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- Our behavior reflects remnants of our ancestral attachment to nature and the diversity of life—the concept of biophilia
- Our sense of connection to nature may motivate realignment of our environmental priorities

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Figure 56.UN01a

Month	1990	2000	2010
January	353.79	369.25	388.45
February	354.88	369.50	389.82
March	355.65	370.56	391.08
April	356.27	371.82	392.46
May	359.29	371.51	392.95
June	356.32	371.71	392.06
July	354.88	369.85	390.13
August	352.89	368.20	388.15
September	351.28	366.91	386.80
October	351.59	366.91	387.18
November	353.05	366.99	388.59
December	354.27	369.67	389.68

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Figure 56.UN01b

A researcher sampling the air at the Mauna Loa monitoring station, Hawaii.

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Figure 56.UN02

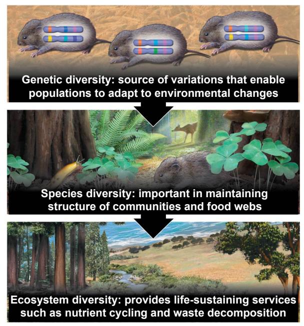

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Figure 56.UN03

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