

THE LIVING ENVIRONMENT

The field of **environmental studies** uses knowledge from a wide variety of sciences and other disciplines to understand the functioning of the Earth's environment and to understand and address current environmental problems. The **environment** consists of all the living and nonliving components that affect all forms of life on Earth.

ECOLOGY

Ecology is the study of the interactions between and among organisms and their environment. An **organism** is any form of life.

Organisms are broken into two major types:

- **Prokaryotes:** Organisms whose cells lack nuclei
- **Eukaryotes:** Organisms whose cells have nuclei

Traditionally, taxonomists classified organisms in five **kingdoms**. Recent evolutionary research, however, has led to a new classification system that places organisms in three **domains**.

- **Archaea:** Prokaryotic, single-celled organisms that exist in harsh environments, such as oxygenless swamps, very salty bodies of water, and near deep-sea vents and sulfur springs
- **Bacteria:** Includes all other prokaryotes
- **Eukarya:** Encompasses all eukaryotic organisms, including all members of kingdoms Protista, Fungi, Plantae, and Animalia

BIOMES AND ECOSYSTEMS

A **biome** is a large region characterized by certain forms of life. Most biomes are determined by their characteristic weather pattern or **climate**.

- Major **terrestrial biomes** include:
 - **Tropical rain forest:** Infertile soil but heavy rainfall; dense vegetation; greatest biodiversity of any land biome
 - **Savannah:** Open grassland with scattered trees; transitional between rain forest and desert
 - **Desert:** Minimal precipitation; sparse vegetation; extreme daily temperature fluctuation
 - **Chapparral:** Coastal area with short evergreen shrubs; mild, rainy winter; hot, dry summer
 - **Temperate grassland:** Abundant precipitation; rich soils; agriculturally productive
 - **Temperate deciduous forest:** Deciduous trees (have leaves that drop every winter); warm, rainy summer; cool winter
 - **Temperate coniferous forest:** Coniferous trees (have year-round needles); warm, rainy summer; cool winter
 - **Taiga:** Northern coniferous forest; long, cold winter
 - **Tundra:** Cold; little precipitation or vegetation; permafrost exists near the surface
- Major **aquatic biomes** include:
 - **Intertidal (littoral):** Shorelines and coasts; subject to periods of wet and dry
 - **Neritic:** Shallow waters to the continental shelf
 - **Oceanic (pelagic):** Surface layers of the open ocean
 - **Aphotic (abyssal):** Deep-water areas where no sunlight penetrates
 - **Freshwater:** Ponds, lakes, rivers, etc.; tied closely to surrounding terrestrial biomes

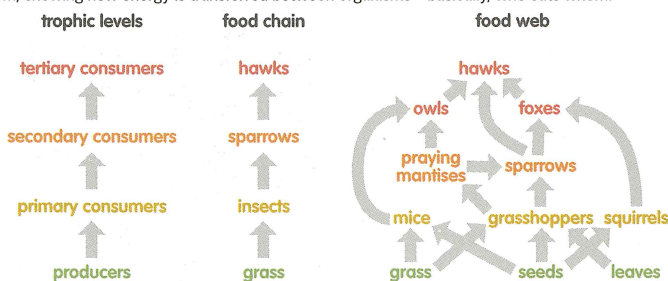
Every biome is home to a number of **ecosystems**. An **ecosystem** is a characteristic community of **abiotic** (nonliving) elements and **biotic** (living) organisms and the interactions between them. The **ecosphere** consists of all the Earth's ecosystems and is defined as all the living organisms and the nonliving elements with which they interact.

Ecosystems may be broken down in a number of ways. A **community** consists of all of the species living in an area; a **population** consists of all the organisms of one species living in an area.

- Communities are not static but change over time through a process of **ecological succession** or **community development**.
 - **Primary succession:** Colonization of an abiotic area by organisms for the first time.
 - **Secondary succession:** Recolonization of an area that has been seriously disturbed (e.g., by a forest fire) by the first organisms.
 - **Pioneer species:** The new organisms to enter (in either primary or secondary succession).
- **Restoration:** The recovery of a site that was disturbed by humans. Restoration may rely on natural succession processes or may utilize more active management.

THE FOOD CHAIN

In any ecosystem, matter and energy are transferred between organisms: some organisms produce energy themselves, while others obtain it by feeding on or decomposing other organisms. Organisms thus are classified according to their **trophic level**—the step that they occupy in their ecosystem's **food chain** or **food web**. A food chain or web details the order of trophic interactions in an ecosystem, showing how energy is transferred between organisms—basically, who eats whom.



Producers (autotrophs): Organisms that can make **organic** (carbon-containing) energy resources (e.g., sugar) from abiotic, **inorganic** (non-carbon-containing) components of the environment. Producers are considered to be in the first trophic level.

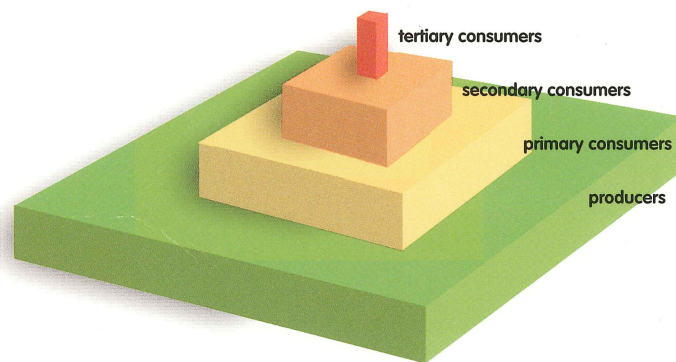
- **Biomass:** The organic material that plants produce
- **Primary productivity:** The rate at which an ecosystem's producers create biomass.
- **Photosynthesis:** The process by which a producer converts energy from the sun, along with carbon dioxide (CO₂) and water (H₂O), to sugar (glucose) and oxygen (O₂). Photosynthesis is the primary means of production in most ecosystems.
- **Chemosynthesis:** Another, less common form of production that relies on energy from chemicals, rather than solar energy, to create organic energy resources.

Consumers (heterotrophs): Organisms that gather energy by consuming organic material from other organisms. Rather than perform photosynthesis or chemosynthesis, consumers perform **aerobic respiration**, which converts sugar (glucose) and oxygen into carbon dioxide and water to give them energy. Consumers are considered to be in the second or higher trophic level.

- **Primary consumers:** Organisms that consume mainly producers. Primary consumers are also known as **herbivores** because they consume mainly plants.
- **Secondary consumers:** Organisms that consume mainly primary consumers. Secondary consumers are also known as **carnivores** because they consume mainly animals.
- **Tertiary consumers:** Organisms that consume secondary consumers. Like secondary consumers, tertiary consumers are carnivores.
- Some organisms cannot be classified in one trophic level because they consume organisms from multiple trophic levels:
 - **Omnivores:** Organisms that consume both producers and other consumers. Omnivores may be in the second and higher trophic levels depending on their level of consumption.
 - **Detritivores:** Organisms that consume **detritus** (the tissues of dead organisms, either producers or consumers) and organic waste.
 - **Decomposers:** Organisms that break down detritus through digestion.

Energy is lost during each energy transfer from one trophic level to the next, so more energy is needed to support higher trophic level feeders.

- As a result of energy loss, there is less biomass at high trophic levels than at low trophic levels.
- **Biomass pyramid:** A graphical representation of biomass in an ecosystem at various trophic levels. The pyramid shows that most of the Earth's biomass exists in producers, less in primary consumers, and increasingly less in higher trophic levels. In some circumstances the pyramid shape can vary.



Carrying capacity: The number of organisms that can be supported by the resources available within a given area. Carrying capacity is determined by the level of primary productivity and other factors.

- **Overshooting:** A situation in which the number of organisms in an area exceeds the area's carrying capacity.
- **Dieback:** The death of many individual organisms in an area, which occurs if carrying capacity is exceeded. Dieback continues until the area is returned to carrying capacity.

Many types of **species interactions** may occur within an ecosystem.

- **Mutualism:** Interaction between two species in which both species benefit.
- **Commensalism:** Interaction between two species in which one species benefits while the other experiences neither harm nor benefit.
- **Predation:** Interaction between two species in which one species preys upon or consumes the other.
- **Parasitism:** Interaction between two species in which one species (the **parasite**) uses or consumes part of another organism (the **host**) over a period of time, harming the host but not necessarily killing it.
- **Interspecific competition:** Competition among organisms of different species for some of the same resources. Both species suffer from this competition.
- **Competitive exclusion:** Principle stating that no two species will use exactly the same resources, as the superior competitor will always outcompete and eventually kill off the inferior competitor.
- **Niche:** A species' specific habitat, lifestyle, and resource usage habits. As a result of competitive exclusion, each species must occupy its own niche.

EVOLUTION AND SPECIATION

Species, interactions, and communities change over time, just as ecosystems do. Species change through the processes of **natural selection** and **evolution**.

Natural selection: First described by **Charles Darwin** in the mid-1800s, the process by which some genes within a population are selected to be replicated more frequently within a population. Those individuals possessing favorable genes—those that allow them to survive the best and reproduce the most—produce more offspring. Therefore, those favorable genes (and the associated traits) are represented in future populations more so than unfavorable genes. Natural selection is often termed the "survival of the fittest" principle.

Evolution: The process by which populations are changed through natural selection.

- **Coevolution:** The evolutionary change of two species together. Because species interact with one another, the evolution of one species may affect the evolution of another.
- **Speciation:** The formation of an entirely new species as a result of evolution. As populations of species evolve, they may become sufficiently different from their ancestors to be considered a new species. Speciation also can occur when geographic boundaries split populations from one another.



ENVIRONMENTAL STUDIES

THE NONLIVING ENVIRONMENT

Environmental studies also takes into account the nonliving components of the Earth's environment, from the geology of the Earth itself to chemical and meteorological cycles taking place on the Earth's surface and in its atmosphere.

THE EARTH AND ITS SURROUNDINGS

The Earth formed 4.5 billion years ago. Since then, it has developed and modified four main physical environments that interact strongly with one another.

Atmosphere: The layer of gases surrounding the Earth. The atmosphere is divided into several levels:

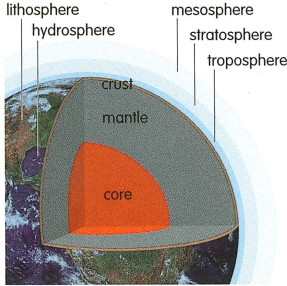
- **Mesosphere:** The outermost layer of the atmosphere, extending from about 50–85km above the Earth's surface.
- **Stratosphere:** The middle level of the atmosphere, extending from about 13–50km above the Earth's surface.
- **Troposphere:** The lowest level of the atmosphere, extending from the Earth's surface to approximately 10–13km above the surface.

Hydrosphere: The cumulative water supply in and on the Earth, including liquid water, frozen water, and water in gaseous form.

Biosphere: The approximately 12-mile-thick area of the Earth in which life exists, on and around its surface. The biosphere includes parts of the atmosphere, hydrosphere, and lithosphere.

Lithosphere (geosphere): The solid portion of the Earth, which contains several layers:

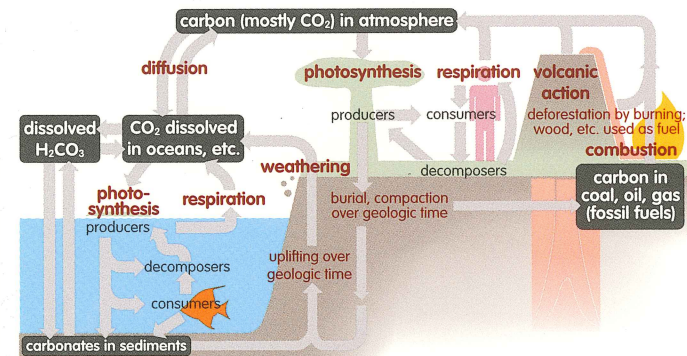
- **Crust:** The outermost layer of the Earth, which makes up only about 2% of the Earth's volume. The crust is composed of eight principal elements: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. It is the only part of the lithosphere that humans have explored.
- **Mantle:** The largest layer of the lithosphere, located beneath the crust. The mantle is composed of a mix of solid and liquid metal and nonmetal elements, such as oxygen, iron, magnesium, and silicon.
- **Core:** The innermost central layer of the Earth. The core is composed of metals—mainly iron and some nickel—at very high temperatures.



IMPORTANT CYCLES IN THE ENVIRONMENT

A number of important **biogeochemical cycles** are at work constantly in the biosphere, recirculating nutrients and other elements through both the biotic and abiotic portions of ecosystems.

Carbon cycle: Carbon is the primary element of life and is found in all living organisms. The carbon cycle describes the movement of carbon through the environment.



- Carbon is found in the atmosphere (primarily as CO_2) and is also found dissolved in water.
- Producers convert carbon dioxide, through **photosynthesis**, to organic (carbon-containing compounds) that store energy.

- Consumers and decomposers use these carbon compounds to produce energy, breaking them down through **respiration**, thereby returning them to the atmosphere or to the water in the form of carbon dioxide.
- Carbon also can be **stored** in organic material, such as trees or fossil fuels.
- The process of taking carbon from the environment and storing it in another form is known as **carbon sequestration**.
- **Fossil fuels**, such as coal, oil, and natural gas, are partially broken-down plant or animal tissues that have been stored and transformed in the Earth's surface for long periods of time under high levels of heat or pressure.
- Carbon can then be released from the above stored forms through **combustion**, or burning.

Nitrogen cycle: Nitrogen is an important nutrient commonly found as a gas in the atmosphere.

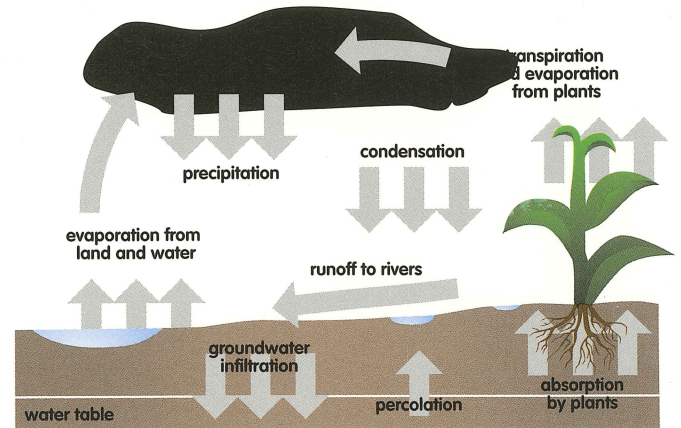
- Because plants and animals cannot use the gaseous form of nitrogen easily, it must first be converted to other usable forms by bacteria through **nitrogen fixation**.
- Some plants, called **legumes**, have nitrogen-fixing bacteria known as **rhizobium** in their roots. These plants take up the converted nitrogen and use it to form organic compounds, and then animals obtain these compounds by consuming the plants.
- After the plant or animal tissue dies or is discarded, the remaining nitrogen, usually in simple forms, is converted back into atmospheric form by specialized bacteria.

Phosphorus cycle: Phosphorus is a crucial element required for energy transfer in organisms, but much of the Earth's phosphorus is contained in rocks.

- When rocks containing phosphorus break down because of erosion or other factors, plants then take up this phosphorus directly, and animals consume the plants.
- Dissolved phosphorus and phosphorus waste eventually settles back to the ocean floor to become rock again.

Sulfur cycle: Another mineral, sulfur, is cycled in a manner similar to phosphorus.

Hydrologic cycle (water cycle): Water, the most vital requirement for most organisms, cycles through liquid, solid, and gaseous states throughout the Earth.



- Water **evaporates** (changes from liquid to gas) from surface water on the Earth and is taken into the atmosphere.
- It then **condenses** (changes from gas to liquid or solid) and falls down as **precipitation** (rain, snow, or ice) on the Earth's surface.
- Some of this precipitated water ends up as **runoff** (moving from the land back into water bodies), while some is taken up by plants.
- Plants may either **transpire** the water (pass it out through their pores back into the atmosphere), or the plants may die or be consumed, passing that water onto higher level organisms, detritovores, or back onto land.
- In addition to being stored in surface water, much of the Earth's water exists as **groundwater**, below the Earth's surface.

NATURAL RESOURCES, CONSERVATION, AND MANAGEMENT

A **natural resource** is any substance created by natural processes that humans obtain from the environment.

- **Nonrenewable resources:** Resources (e.g., oil, metals, or coal) that exist in a fixed quantity and can be renewed only by very long-term natural processes, such as volcanic activity and plate movement.
- **Perpetual resources:** Resources (e.g., solar or wind energy) that are always rapidly replaced through short-term natural processes and can therefore be considered inexhaustible.
- **Potentially renewable resources:** Resources (e.g., fresh water or wildlife) that can renew themselves over the short term and therefore can be used indefinitely. However, unlike perpetual resources, potentially renewable resources can be damaged or overused to the point that they are no longer capable of replenishing themselves, in which case they become depleted.

LAND

Open **land** of all types is under considerable pressure for development and/or resource extraction and must be managed carefully. Two major types of land resources are forests and rangeland.

A **forest** is a biome with enough precipitation to support trees.

- Forests supply many economically useful items—not only **timber** but also numerous **non-timber forest products**.
- Forests also are valuable ecologically: they serve as habitats for wildlife, provide protection for watersheds (see Water, next page), are sites for **carbon sequestration** (the storing of carbon in plant biomass), and contribute to climate stabilization.
- Forests vary widely both by location and by growth stage, and may be categorized in a number of ways.
 - **Closed forest:** A forest in which the **canopy** (the top layer of the forest treetops) is continuous, with few spaces between trees.
 - **Open forest:** A forest in which the crowns of trees do not touch one another.
 - **Old-growth forest:** A very old forest that has not recently been disturbed by either human or natural occurrences.
 - **Secondary forest:** A forest that has regrown after some form of disturbance.
- **Sustainable forestry:** Management of forests in a way such that forest resources are not depleted and instead can be used indefinitely.

- **Even-age management:** A cutting regime in which all the trees in a **stand** (a defined forest area) are harvested or planted at the same time.

- **Clearcutting:** A type of even-age management in which all the trees in a stand are cut at once. Clearcutting tends to favor the establishment of pioneer **shade-intolerant** vegetation species.
- **Shelterwood cutting:** A two-stage process in which some large trees are cut but some are left, creating a semi-shaded, "sheltered" environment for **regeneration** (establishment of new seedlings) while also allowing many large trees to grow without competition. Later, a second cut removes the remaining large trees, allowing the new even-aged stand of young trees to grow into a mature forest.
- **Seed-tree cutting:** The cutting of almost all the trees on a piece of land, leaving only a few to provide a seed source for new regeneration. After the regeneration has been established, the seed trees are cut.

NATURAL RESOURCES, CONSERVATION, AND MANAGEMENT (continued)

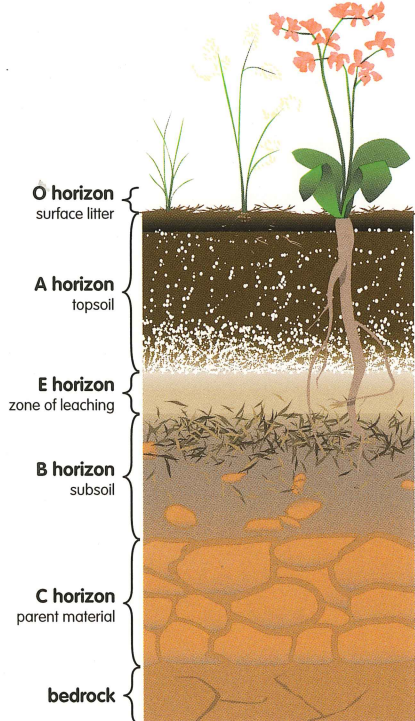
- **Uneven-age management:** Cutting of trees within a stand at different times in order to encourage the growth of a stand with multiple age levels.
- **Selective cutting:** A type of uneven-age management in which single trees or small groups of trees are harvested from within a stand. Selective cutting allows the stand to retain a multiple-age structure more typical of old-growth forests and selects primarily for **shade-tolerant** vegetation species.

Rangeland is land that has the primary purpose of feeding grazing animals. Most rangeland is **grassland**.

- Rangeland **carrying capacity**, the number of herbivores it can handle without becoming degraded, varies depending on the productivity of a specific area of rangeland.
- If too many animals are allowed onto rangeland, it suffers from **overgrazing**, which can lead to **erosion**, species change, and even potentially **desertification**, the transformation of rangeland to desert (see Erosion, below).

SOIL

Soil is the porous substance found in the very top layer of the Earth's crust. **Soil composition** varies widely across regions of the world. Soils are defined and named by a number of different properties, including water-holding capacity, porosity, permeability, and structure of the various **soil horizons**, or layers.



Each soil horizon has specific physical and chemical properties.

- **O horizon (surface litter):** Fresh or decaying organic material (e.g., leaves, twigs, moss) accumulated on the ground.
- **A horizon (topsoil):** Top layer of soil, which holds most of the organic matter and most of the water and nutrients needed for life.
 - **Infiltration:** Seeping of water down through soil.
- **E horizon:** Zone through which leaching occurs.
 - **Leaching:** Process by which infiltrated water picks up nutrients and carries them down to deeper soil.
- **B horizon (subsoil):** Zone that often contains an accumulation of minerals as well as some organic materials.
- **C horizon:** Zone composed of broken-down **parent material**, the basic type of rock from which the rest of the soil is derived.
- **Bedrock:** Parent material below the C horizon.

Erosion occurs when wind, water, or other **erosive agents** dislodge and move soil from one location to another.

- After topsoil is eroded from an area, the area is generally infertile and inhospitable to life, for topsoil contains most of the nutrients and the water-holding capacity of soil.
- If fertile soils are allowed to erode for a long period of time, the land will eventually convert to desert, a process known as **desertification**.
- Although soil can regenerate slowly, the rate of erosion in many places vastly exceeds the rate of potential regeneration.
- **Human behaviors** that increase erosion include forest clearing, agriculture, ranching, and construction. These activities all involve removing vegetative cover or moving soil, thereby increasing the ground's exposure to wind or water.

- **Soil conservation** practices can help stave off erosion and can also temporarily improve the condition of eroded soil.
 - Adding commercial, inorganic fertilizers combined with regular irrigation temporarily restores nutrients and water to eroded soils. However, because of reduced drainage, eroded soils eventually are destroyed due to leaching, water logging, or salt buildup.
 - Land management practices can prevent erosion and soil loss, generally by keeping vegetation on the land.
 - **No-till or low-till farming** methods help conserve soil because they do not expose the soil through tilling.
 - Different types of **agroforestry** practices (planting trees or other perennials in combination with agricultural crops), help reduce erosion by keeping a permanent form of **groundcover**. Agroforestry includes **alley cropping**, in which crops are planted in rows between perennials, and **shelterbelts**, in which trees are planted in such a way as to block wind strength.
 - **Crop rotation:** Practice of alternating between planting nutrient-demanding crops and planting crops or trees that restore nutrients; also helps maintain soils over the long term.
 - **Improved fallows:** Variation of crop rotation in which trees or restorative vegetation are planted over the **fallow period** (when there are no crops).
 - **Contour farming:** Planting of crops across slopes, in order to slow the rate of water erosion. **Terracing**, the creation of a number of small flat areas on a slope, also combats water erosion.

Soil contamination can occur if managed soils are overirrigated.

- Irrigated water contains salts; when the water evaporates, the salts are left behind, causing **salinization**, which reduces fertility.
- Overirrigation can also cause **water contamination** by raising the water table above the roots of plants, essentially drowning the plants.

WATER

The Earth's supply of liquid **water** exists in two main forms.

- **Surface water:** Liquid water that sits on top of the Earth's crust in bodies of water, such as lakes, oceans, and rivers.
- **Groundwater:** Liquid water that penetrates the Earth's surface and seeps into deeper levels of the crust.

Although the Earth's water supply is abundant, water often is not available *where* it is needed. Many areas have insufficient water to meet basic survival needs on a consistent basis and are often afflicted with **droughts**.

- Often, planners attempt to combat water shortages by building **dams** or **reservoirs** in order to capture water for irrigation, to protect against droughts, or to generate hydroelectric power. Such projects frequently are successful at solving the water problem but inadvertently cause many other problems (see Hydropower, *other side*).
- In the United States, it is common practice to move water from one watershed to another. A **watershed** is an area of land from which all precipitation and sediments flow into the same major stream or stream system. **Irrigation** projects can move water successfully between watersheds, reallocating it to those in need; however, these projects also can be exorbitantly expensive and damaging to the environment.
- Another common solution to water shortages is to tap groundwater supplies. However, this approach can deplete **aquifers** (water-saturated areas below ground), which ultimately affects the quantity of water available to aboveground watersheds. Moreover, tapping into groundwater supplies can cause the land above the groundwater to sink and saltwater to intrude into aquifers, destroying existing freshwater supplies.
- **Desalination**, the removal of salts from seawater or other saltwater, is effective but also very energy-expensive and therefore economically unviable in most instances.

Given the lack of affordable and safe water provision technology, **water conservation** is the best available solution to water shortages.

BIODIVERSITY

Biodiversity refers to the variety of life in the world, including species variety and genetic variety.

Biodiversity is important for many reasons:

- Because organisms play particular, specific roles in their ecosystems, the loss of even a single species can cause much larger, often unforeseen changes to the ecosystem.
- Plants and animals can provide medicinal products to humans and are often the source of scientific innovations.
- Moreover, many people believe simply that organisms have intrinsic value and a right to exist beyond human needs or economic returns.

Species extinction and **biodiversity loss** can occur because of a number of causes.

- **Habitat loss:** Any change that renders a habitat unsuitable for an organism; one major cause of biodiversity loss. Organisms that need large habitat ranges, as well as those that are **specialists** and occupy small niches, are more vulnerable to this threat than are **generalists**—organisms that do not have very specific habitat or lifestyle requirements.
- **Overhunting** for food, sport, commercial products (such as fur or ivory), or other purposes (such as exotic pet trade or ornamental plants) can also cause extinction. Species with slow reproductive rates, known as **k-selected species**, are more vulnerable to these types of threats than those with high reproduction rates, known as **r-selected species**.
- Introduction of alien species can also cause destruction of native species.
 - **Native species:** Organisms that are found naturally in a particular ecosystem.
 - **Invasive species:** Species that have been introduced into an ecosystem where they did not originate and that have now **naturalized** or become part of that ecosystem. Invasive species can replace and cause the extinction of native species, as well as disrupt ecosystem functions.

Biodiversity management and protection has been attempted through a variety of ideas and approaches.

- **Fine-filter (species) approach:** Aims to protect individual species that are facing threats. Different types of species may be chosen for protection for different reasons.
- **Keystone species:** Organisms that play particularly vital roles in maintaining an ecosystem's health and survival.
- **Indicator species:** Organisms that provide a good indication of the health of an ecosystem.
- **Flagship species:** Organisms that generate a large amount of public support even if they do not serve a particularly important biological role.
- **Coarse-filter (ecosystem) approach:** Aims to protect habitats or ecosystems rather than individual species. By this reasoning, if areas are protected from major threats, the organisms that live in those habitats will also be protected.
 - One benefit to this approach is its awareness that ecosystems are dynamic and go through successional stages (during which the plant and animal community changes over time) from **early pioneer** species to **mid-successional** species to **late-successional** species.
 - Many current approaches to wildlife management encourage active management of all different types of successional stages of habitat, rather than advocating a hands-off policy to protected areas.

Commercial, recreational, or subsistence uses of wildlife, such as hunting, fishing or gathering, are common. Unmanaged, these pressures can threaten species survival.

- Several tactics have been used successfully to manage commercial, recreational, and subsistence pressures on wildlife:
 - Limits on **time and duration** of the season during which wildlife extraction is permitted.
 - Limits on **number, size, and sex** of wildlife that can be extracted.
 - Requirement of **paid licenses or permits** for those who want to extract wildlife.
 - Restrictions on the **methods and tools** that can be used for wildlife extraction.
- **Revenues** obtained from some of these approaches, such as from permits and licenses, can then be put back into protecting and restoring organisms and their habitats.

FOOD

Responsible **food production** is necessary to support the human population in the long term. Not only must sufficient amounts of food be produced, but the food must get to those who need it and must be produced in a **sustainable** manner.

Much of today's food production is not sustainable, as desertification, erosion, and deforestation take place alongside food production.

Different types of **agriculture**—cultivation of plants and animals for human uses—address these concerns in different ways.

- Early agriculture was mainly **subsistence agriculture**, in which food is produced only for the energy needs of the farmers and their families.
- **Slash-and-burn cultivation:** Traditional form of agriculture in which forests are cleared and burned before being cultivated; replenishes nutrients in the soil.
- **Shifting agriculture:** System in which a plot is cultivated for a period of time and then left to itself while the farmer moves to another plot. Shifting agriculture is beneficial because lands are often productive for only a few years.
- Traditional small-scale agriculture often cultivates multiple species (**polyculture**) and uses few external inputs.
- More common today is large-scale commercial agriculture, generally consisting of a **monoculture** of a single crop and the use of a large amount of external inputs, such as fertilizer.

ENERGY

In the modern world, **energy** resources are just as crucial as food resources. Although much discussion about responsible use of energy focuses on the type of fuel that should be used, energy **efficiency** is also very important in protecting the environment. Some of the largest targets for improvements in energy efficiency are industry (power plants in particular), the transportation sector, and commercial and residential buildings.

Nonrenewable energy sources exist on the Earth only in finite reserves.

- **Oil and natural gas** are the two major liquid fossil fuels. **Crude oil** is composed primarily of hydrocarbon compounds. Oil is often found in combination with **natural gas**, which is composed largely of methane, propane, and butane.
- Oil may be extracted from the Earth via several **recovery methods**. The selection of recovery methods generally depends on costs, oil prices, and the way in which the specific oil deposits are contained in the ground.
 - **Primary recovery:** Simple drilling and pumping.
 - **Secondary recovery:** Water injection.
 - **Tertiary recovery:** More elaborate techniques, such as gas injection.
- As oil supplies are depleted, prices may increase. However, at a certain point, the energetic cost of obtaining the oil is higher than the energetic yield of obtaining the oil. At this point, the oil is considered **nonrecoverable**. Supplies of recoverable oil are expected to be exhausted within 80 years.
- The use of oil and natural gas also has pollution effects.
 - The burning of crude oil produces **carbon dioxide**, a greenhouse gas (see Climate Change, next page), as well as other pollutants. Oil spills from drilling and transport cause water pollution.
 - Natural gas is much cleaner and cheaper per gallon than crude oil, and supplies also are likely to last longer than those of crude oil. However, natural gas is less energetically efficient per unit than crude oil.
- **Coal**, the most prevalent and lowest-cost fossil fuel in the world, is formed primarily from compressed plant remains.
 - Coal is obtained largely from **surface mining**—simply removing the surface of land and extracting the coal.

If restoration is not performed, this practice is very destructive. **Subsurface mining** has less surface impact but is more expensive and more hazardous for miners.

- Coal is one of the most environmentally damaging fuels when burned, producing sulfur dioxide, nitrous oxides, and other chemicals that cause acid deposition or **acid rain**. Acid rain damages wildlife, soils, and crops and causes human respiratory problems (see Air Pollution, below).
- **Nuclear power** is generated by **nuclear fission**, the splitting of the nuclei of radioactive atoms, which releases large amounts of energy.
 - However, the risks associated with **radiation** are high, and public opinion of nuclear power has suffered after several incidents at nuclear plants, such as Three Mile Island, Pennsylvania (1979), and Chernobyl, former Soviet Union (1986).
 - **Nuclear waste**, an unavoidable by-product of nuclear fission, also poses a problem. It is not possible to make these nuclear wastes safe, and there are no generally accepted means of disposing of them.
 - In light of the above challenges, many nuclear power plants have been decommissioned.

Renewable energy sources are inexhaustible.

- **Solar power** utilizes **photovoltaic (solar) cells**, which produce electrical current when struck with sunlight.
 - Sunlight clearly is an abundant, perpetual resource, and photovoltaic cells produce no air pollution. Also, most solar cells are made of **silicon**, which is abundant.
 - However, solar cells are rather large, and water contaminants are often a by-product of their manufacturing process. Moreover, most large-scale applications of solar power are practical only in regions where sunny weather is frequent and sustained.
- **Hydropower** usually is produced by building **dams**, which generate electricity by capturing the energy of water moving downstream in fast-moving rivers.
 - Although use of hydropower does not cause air pollution, dams do cause large-scale, often devastating changes to impacted aquatic areas and surrounding ecosystems.
 - Also, hydropower tends to be very expensive and thus often is not cost-effective.

- **Wind power** is captured by placing large numbers of **wind turbines** in areas with strong, regular winds.
 - Wind power is virtually unlimited and very clean; it can also be very inexpensive in areas with sufficient wind.
 - However, it is difficult to store wind energy once it is generated, so most wind power systems are functional only when the wind is actually blowing. Efforts are being made to couple wind power with **hydrogen fuel cells** (see Hydrogen, below) to remedy this problem.
- **Biomass energy** is obtained from plant or plant-derived **biomass**, such as wood or manure, typically through burning.
 - **Less developed countries (LDCs)** tend to use fuelwood as a major source of energy. Many burn agricultural products and urban waste products in order to provide energy.
 - Burning plant products produces a high amount of pollutants, including particulate matter and carbon monoxide. Burning trash often produces air toxins (see Air Pollution, below). Furthermore, direct burning of plant products is generally inefficient.
- Liquid **biofuels**, such as **methanol** and **ethanol**, can be created by fermenting sugars or grains. These fuels can then be used in much the same way as regular gasoline.
 - Although biofuels produce less carbon monoxide and nitrogen oxide than gasoline, they do produce other chemicals, such as aldehydes, that can cause health risks.
 - Also, a large amount of waste is produced during fermentation of biofuels, production costs are high, and conversion of agricultural products to biofuels often is seen as inefficient use.
- **Hydrogen:** Hydrogen gas offers enormous potential as a fuel because it is very clean-burning and produces no carbon dioxide.
 - **Hydrogen fuel cells** are devices that use hydrogen and oxygen to create electricity through an electrochemical process, with water as the primary waste product.
 - However, hydrogen supplies from which to make the fuel are limited, so hydrogen fuel still is expensive relative to natural gas. Also, there are unsolved problems in storing the electricity generated and delivering that electricity effectively.

POLLUTION

Pollution is any unwanted alteration to the Earth's natural resources, usually with a negative impact on human health or lifestyle.

BACKGROUND

There are many types of pollution, categorized in a variety of ways:

- **Point-source pollutants:** Pollutants emitted from a single, identifiable source.
- **Non-point-source pollutants:** Pollutants emitted from multiple sources, which are often difficult to identify specifically.
- **Degradable pollutants:** Pollutants that can be broken down quickly by natural processes.
 - **Biodegradable pollutants:** Degradable pollutants that can be broken down by organisms.
- **Persistent pollution:** Pollution that can be broken down but only very slowly. Persistent pollutants take many years to disappear from the environment.
- **Nondegradable pollution:** Pollution that cannot be broken down through natural processes over any time period.
- **Toxic pollutants:** Pollutants that are deadly to humans, even at low levels.
- **Hazardous pollutants:** Pollutants that cause harm to humans upon exposure.
- **Carcinogenic pollutants:** Pollutants that increase the incidence of cancer in humans.

When deciding on the best way to manage pollution, researchers perform **risk analysis** in order to identify and quantify the nature and degree of the risk proposed. As there are usually benefits as well as risks to every hazard, the analysis often takes the form of **risk-benefit analysis**.

Epidemiology: The statistical study of disease in human populations and the sources of that disease. Many aspects of epidemiology focus on the health risks associated with chemical pollutants in the environment.

- **Dose response curve:** Shows the relationship between exposure to chemicals and negative human health outcomes.
- **No observed effect threshold:** Derived from the dose response curve; indicates the highest level of chemical exposure at which no negative human health outcome is observed.
- **Median lethal dose:** The point on the dose response curve at which half the study subjects die from a given dose of the chemical.

AIR POLLUTION

There are **three major sources** of air pollution. Much of the pollution from these sources stems from the burning of fossil fuels, including coal and oil.

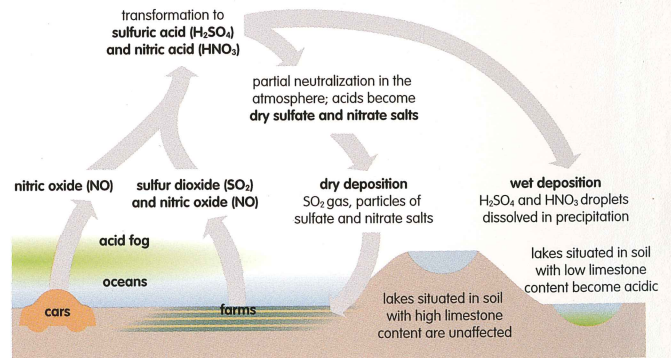
- **Stationary or point sources:** Nonmobile, human-created sources (e.g., factories, power plants)
- **Mobile sources:** Mobile, human-created sources (e.g., cars, trucks)
- **Natural sources:** Stationary or mobile naturally occurring sources (e.g., volcanoes, windstorms)

Air pollutants are categorized in a variety of ways:

- **Primary air pollutants:** Pollutants that are produced directly by the polluter.
- **Secondary air pollutants:** Pollutants that are produced when a primary chemical reacts with other particles in the air.
- **Criteria air pollutants:** The six major outdoor pollutants measured under U.S. clean air law (see Clean Air Act, two pages right). These pollutants constitute the bulk of air pollutants and cause serious degradation of land and water resources, as well as respiratory problems in humans.
 1. **Carbon monoxide (CO)**
 2. **Sulfur dioxide (SO₂)**
 3. **Nitrogen dioxide (NO₂)**
 4. **Suspended particulate matter** (solid material suspended in the air)
 5. **Ozone (O₃)**
 6. **Lead (Pb)**

- **Air toxins (hazardous air pollutants):** Air pollutants that cause serious health damage to humans. Many of these toxins are also considered **volatile organic compounds (VOCs)**.
- **Radioactive pollution:** The emission of radioactive chemicals into the air.
- **Heat pollution:** The release of air of different temperatures into the surrounding environment.

Acid deposition: The process by which acidic air pollutants, generally sulfur dioxide and nitrogen oxides, are deposited on the Earth. Much of this deposition occurs when the pollutants condense in water and fall to the Earth as precipitation, known generally as **acid rain**.



- Acid deposition causes changes in the pH of water and soil, leading to a host of environmental problems:
 - Many aquatic organisms are sensitive to pH levels and may be harmed or killed.
 - Plants, including valuable agricultural and tree crops, may be damaged.
 - Humans may suffer respiratory problems.
 - Visible air pollution may be created.
 - Structures may be damaged.
- Acid deposition may be reduced by switching to **low-sulfur coal** or by removing the sulfur either before or after combustion, often by adding **scrubbers** to smokestacks.

WATER POLLUTION

Water pollutants are categorized in a manner similar to air pollutants.

- **Point-source water pollutants:** Water pollutants that are discharged from specific locations (e.g., factories, mines, or sewage treatment plants).
- **Non-point-source water pollutants:** Water pollutants that are discharged over a larger area (e.g., from agriculture, urban runoff, or eroded areas).

Organic pollution: Pollution that arises from organic materials. It is broken down by **aerobic** (oxygen-consuming) bacteria, which utilize oxygen dissolved in the water. This process lowers the water's **dissolved oxygen content**.

- **Oxygen depletion:** A spiraling cycle that reduces dissolved oxygen content in water bodies. Low dissolved oxygen levels kill many organisms; as these organisms decay, they produce more organic material, causing further oxygen depletion. The mix of species in affected water bodies changes dramatically, and eventually all organisms except for **anaerobic** bacteria (those that do not require oxygen) may die out.

POLLUTION (continued)

- **Eutrophication:** The ecological and chemical changes that occur in a water body after an input of organic matter.
- Bodies of water with rapid flow and low levels of organic pollution are more capable of recovering, whereas lakes and standing water are more vulnerable.
- **Oxygen sag curve:** A curve that shows the amount of time it will take a body of water to recover to normal oxygen levels after an input of organic pollution.
- **Dredging** organic material from the water body may remediate decreased oxygen levels.
- **Major causes of organic pollution** include the dumping of sewage, agricultural inputs (such as fertilizers), soil runoff, and the destruction of natural filters (such as salt marshes).
- Some organic pollution involves the addition of organic chemicals (e.g., pesticides, oil, plastics) that are carcinogenic or otherwise hazardous to humans. Many of these take years to decay.
- **Oil pollution** generally arises from accidental or intentional releases of oil during the recovery, transport, and use of oil. Oil pollution causes immediate death to many organisms and contaminates many others. Cleanup is extraordinarily expensive and often ineffective.

Inorganic pollution: Pollution that is composed of inorganic materials. Inorganic matter high in plant nutrients, such as **phosphate** and **nitrate** compounds, encourages rapid plant growth.

- When these plants eventually die and decay, they are decomposed by aerobic bacteria, and **dissolved oxygen levels** decrease as a result.
- In addition, high levels of some of these chemicals can be directly dangerous to human health. Some, including **heavy metals** and **salts**, can render water highly hazardous to human health and reduce ecosystem functions.

Thermal pollution: Pollution that occurs when water is removed from a water body to be used as a coolant and then returned to the water body at a higher temperature.

- Higher water temperature lowers dissolved oxygen content and raises the risk of disease and death to aquatic organisms.
- Thermal pollution may be lessened by allowing water to cool down again before discharging it back into the water body or by discharging heated water only into deep waters.

Disease-causing pollution: Pollution that causes the transmission of disease-causing organisms (e.g., viruses, worms, bacteria, larvae).

Suspended solid pollution: Particulate matter suspended in water. Suspended solid pollution changes light penetration, photosynthesis rates, and visibility, and generally alters the aquatic ecosystem in harmful ways.

LAND POLLUTION

Solid waste that is not defined as hazardous can be legally disposed of in a number of ways (see Resource Conservation and Recovery Act, *next page*).

- **Sanitary landfills** are essentially holes in the ground lined with materials designed to limit **leaching** of chemicals to the environment. Waste is dumped in layers and covered regularly. Although precautions are taken, groundwater contamination often occurs.
- Another option for getting rid of solid waste is through **burning**. This practice reduces the quantity of waste but can be expensive, often transfers contaminants to the air, and produces a large amount of potentially toxic ash.
- One commonly advocated solution to the waste problem is to move toward **reducing, reusing, and recycling** waste.

Hazardous waste: Defined by law as any item that is flammable, reactive, corrosive, or toxic when in the environment. Specifically exempted from this definition are mining wastes, household and small business waste products, and oil drilling waste, among others.

PESTICIDES

Pesticide, or **biocides**, are chemicals that kill unwanted organisms. **Herbicides** kill unwanted plants, **insecticides** target insects, **fungicides** attack fungi, and **rodenticides** kill rodents.

Pesticides are beneficial in that they kill disease-causing agents, thereby protecting human health. They also increase food production and lower food production costs by reducing **crop damage**.

However, pesticides also have the potential for many **negative impacts**.

- Pesticides may harm or kill **non-target**, or unintended, species. For example, the pesticide **DDT** inadvertently hindered reproduction of many bird species and caused tremendous ecosystem damage before its use was outlawed.
- Pesticides can **build up** in the food chain or water supply and impact human health negatively.
 - **Fat-soluble chemicals:** Chemicals that do not dissolve in water. Fat-soluble chemicals are particularly likely to build up in the water supply.
 - **Bioaccumulation:** The buildup of pesticides through increasing levels of the food chain. Bioaccumulation is a significant problem because it can expose high-end predators, such as humans, to very high levels of pesticides.
- Pesticides may also increase **genetic resistance** in the target species. Because pest species generally reproduce quickly, they also may evolve resistance or immunity to a particular pesticide. As a result, stronger pesticides continually must be developed and larger quantities applied.

GLOBAL ENVIRONMENTAL PROBLEMS

In addition to pollution concerns, a number of other large-scale environmental problems threaten the Earth's natural resources, ecosystems, and human population.

OVERPOPULATION

Overpopulation occurs when the human **carrying capacity** of an area (see The Living Environment, *other side*) is exceeded by the number of people living and using the resources in the area. Overpopulation puts enormous pressures on all types of environmental resources, including food, water, land, energy, and biodiversity.

- The human population's **birth rate** has been surpassing the **death rate** at an alarming rate, causing rapid population growth. The Earth's current population is now more than **6 billion**.
- Higher birth rates tend to be associated with poverty, low levels of education, rural lifestyles, high infant mortality rates, low availability of birth control, and low levels of education and opportunities for women.
- All of these factors tend to be typical of **less developed countries (LDCs)**. Despite the fact that these countries often also have higher death rates, they tend to have rapidly growing populations.
- Many attempts have been made to estimate the Earth's carrying capacity for humans. While the exact carrying capacity has not yet been determined, increasing population growth threatens to push humankind over a realistic capacity.

Urbanization occurs when populations concentrate in small areas, **cities**, usually in search of work. Urbanization poses problems due to unequal **population distribution** rather than overpopulation.

- Urbanization is a large problem in LDCs because governments often are not able to provide basic services, such as sanitation, education, water, or food, to city residents. The resulting **slums** often become environmental hazards, with untreated waste and raw sewage, contaminated surface and groundwater, and higher levels of disease.
- In **more developed countries (MDCs)**, urbanization and population growth is causing **urban sprawl** as cities spread out beyond their boundaries.
 - Sprawl causes an increase in transportation needs and, as a result, an increase in transportation-related pollutants. As more surfaces are paved, wild land and vegetation are lost, and water runoff and flooding increase.
 - In addition, increased concentration of sewage and garbage can be more than the local environment can accommodate.
- Increased use of **mass transit** can alleviate the problems of urbanization, as can improved **land-use planning**—the use of informed decisions about infrastructure planning and city layout to reduce congestion, pollution, and other urban problems.
- **Smart-growth** land-use planning efforts aim to keep cities more integrated, less prone to sprawl, and more capable of providing mass transit and sanitation services to reduce environmental problems.

Overconsumption occurs when humans consume more resources than are needed and more than can be sustained by the Earth's resources. Highly developed countries often are the sites of rampant overconsumption.

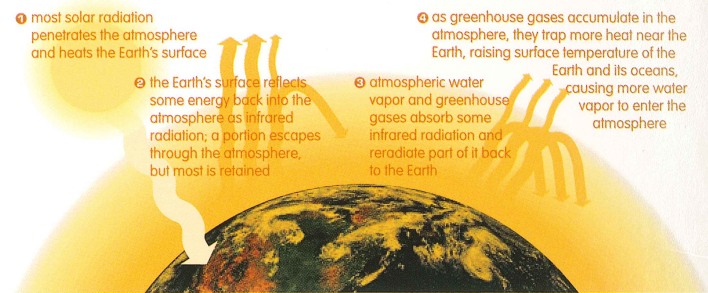
CLIMATE CHANGE

Climate is the average or overall weather pattern of an area over an extended period of time. Climate is impacted by latitude (which determines the amount and directness of solar radiation that hits a particular area), wind currents, ocean currents, and topography.

The **greenhouse effect** is the means by which the Earth retains heat and stays warm.

- The Earth's **troposphere** contains some small amounts of carbon dioxide, water, methane, ozone, **chlorofluorocarbons (CFCs)**, and other **greenhouse gases**. When solar radiation passes through the atmosphere, these gases trap some of this radiation near the Earth, keeping the Earth warm.
- However, as humans produce increasing amounts of greenhouse gases themselves, and simultaneously decrease **forest cover** (which stores carbon dioxide and prevents it from reaching the atmosphere), we increase the amount of heat trapped on the Earth's surface and thus raise the **average temperature**.

- Researchers have predicted that the Earth's average temperature will rise 3–5° C within the next 50 years. By comparison, the last Ice Age was only about 5° C cooler on average than today's climate.



Climate change will have numerous effects and cause **widespread changes** to the Earth.

- **Plant and animal life** will be affected, as the change in the climate will **move ecosystems** toward northern or southern geographical extremes as the Earth's overall climate becomes warmer.
 - Species unable to make this transition will be lost, so **biodiversity loss** will proceed faster.
 - The Earth's food supplies will be diminished due to large-scale **changes in crop production and suitability**.
- **Water and wind cycles** will change, perhaps making some areas of the world significantly colder and leading to unpredictable weather patterns.
 - **Ice caps and glaciers will melt** under the increased heat, **raising sea levels**. This higher water would flood many lowland areas and small islands, moving shorelines and destroying coastal cities and even countries.
 - Increases in temperatures of the world's oceans would also increase the frequency of destructive weather disasters, such as **hurricanes and typhoons**.
 - The spread of tropical climates also has the potential to increase the spread of **insect-borne diseases and crop pests**.

Environmentalists have championed several ways of **reducing or slowing climate change**.

- Reducing the amount of **fossil fuels** being burned. Power plants, industrial facilities, and automobiles are among the largest users of fossil fuels. Shifting to cleaner fuels, reducing energy use, improving energy efficiency, and using cleaner technologies that produce fewer greenhouse gases will also slow climate change.
- Slowing rates of deforestation and increasing **reforestation** will help sequester carbon dioxide from the atmosphere.
- Reducing levels of **methane gas**, a potent greenhouse gas, can be accomplished by burning methane emitted from landfills and by reducing cattle production, as cows are major producers of methane.

OZONE DEPLETION

The **ozone layer** is a layer of ozone (O₃) molecules in the Earth's stratosphere that helps protect life on Earth from **ultraviolet (UV) radiation**.

Ozone molecules react and change form when they encounter certain chemicals containing chlorine or bromine. Many of these ozone-depleting chemicals are manmade.

- **Chlorofluorocarbons (CFCs)** are used in aerosols, coolants, and cleaning solvents
- **Halons** (bromine-containing compounds) are used in fire extinguishers

The production of these ozone-depleting chemicals has caused **holes** to appear in the ozone layer, primarily over Antarctica. This ozone deterioration causes numerous problems:

- Human health problems, such as skin cancer, cataracts, and reduced immune function
- Ecological problems, such as crop damage and global warming.

Because ozone-depleting contaminants spread globally after they are produced, **international agreement** is needed to stop or slow their production and use. The 1987 **Montreal Protocol** was an important step in achieving this needed agreement (see International Agreements, below).

DEFORESTATION AND BIODIVERSITY LOSS

Deforestation has been occurring at a rapid and increasing pace over the last 25 years, particularly in less-developed tropical countries. Deforestation has accelerated for a number of reasons.

- Need for **agricultural land** for subsistence crops to feed a growing population. This is the primary reason for deforestation. It is particularly problematic because tropical soils are generally unsuitable for agriculture, so the farmers must move and deforest new areas after a few years.
- Creation of **roads** to remote regions. This process exacerbates deforestation by allowing access to previously unreachable areas.
- Need for **fuelwood** as electricity and heating are often not available
- High returns from **cattle ranching** for export
- High value of some **timber** species
- Production of **illegal drug crops** in remote areas

Deforestation has a wide range of **negative effects**.

- **Release of carbon dioxide** that was stored in trees, which accelerates global climate change
- **Increased erosion** and soil deterioration
- **Elimination of watershed protection**, and thus reduced regulation of water flow
- **Major losses in biodiversity**, particularly in tropical forests, which contain the highest level of biodiversity in the world

Numerous ideas have been proposed in an effort to protect forests.

- Encouraging **sustainable forestry and land use** so that locals make money off the forest and have an incentive to retain the forests.
- Creating a network of **park systems** to serve as a repository of biodiversity.
- Regulating **timber and beef inputs** to discourage products that come from deforested areas.
- Providing **foreign aid** or other assistance to countries willing to help forest protection.

NUCLEAR CONTAMINATION AND WAR

The first **nuclear testing** in the middle of the 20th century released unexpectedly large amounts of **radioactive compounds** into the environment.

- These compounds traveled through the atmosphere and deposited around the globe, building up in the milk supply and in human and animal bone tissue.
- Radioactive nuclides can cause a number of health problems, even at low doses, and are highly **carcinogenic**.

The U.S. atomic bombings of **Hiroshima** and **Nagasaki**, Japan (1945), killed approximately 110,000 people outright, and tens of thousands more people who had been within several kilometers of the blasts suffered leukemia and other radiation sicknesses in the years afterward.

The **Limited Test Ban Treaty** (1963) banned atmospheric, underwater, and outer-space nuclear testing, and the resulting reduction in testing has been important in limiting radioactive contamination in the environment.

However, **nuclear war** and the resulting **radioactive contamination** remains a threat. The release of nuclear weapons in populous areas would not only cause large-scale death, but clouds of debris that would result from such an explosion would block much of the world's sunlight, killing crops, destroying the ozone layer, and causing massive and sudden climate change. Such an environmental disaster can only be prevented through political action to prevent nuclear war.

HISTORY OF RESOURCE USE AND CONSERVATION

As human societies have become increasingly industrialized and urbanized since the 18th century, resource use has skyrocketed. However, the 19th century also saw the birth of the **conservation movement** and an increased awareness of environmental responsibility.

Agricultural Revolution: When the Agricultural Revolution brought the onset of food production about 10,000 years ago, human populations began to expand rapidly, and urbanization began. Large amounts of land were cleared in order to provide for the needs of the growing, centralized population. Erosion, deforestation, desertification, and overhunting were all early impacts of the change from the previous foraging lifestyle to the more settled agricultural lifestyle.

Industrial Revolution: The late 1700s and early 1800s saw the beginning of the Industrial Revolution, as people switched to large-scale centralized production of goods using machines. The widespread burning of fossil fuel and production of chemicals that accompanied this shift to mechanization began to cause significant air and water pollution. The Industrial Revolution also brought increased urbanization, causing contamination through garbage and sewage.

Early conservationists: In the mid-1800s, a number of American intellectuals, writers, and artists, notably including **Ralph Waldo Emerson** and **Henry David Thoreau**, began to speak out about the importance of wilderness and conservation. In 1872, the first preserve, **Yellowstone National Park**, was created. The early 1900s, under President **Theodore Roosevelt**, saw the creation of the U.S. Forest Service and a large increase in the amount of protected land in the United States (more than 16 million acres).

Government intervention: Prior to 1945, most environmental law was based not on **statutory law** (written state or federal laws) but on **common law**, the body of legal principles based on past judicial decisions. At the time, most environmental problems were dealt with under legal precedents against public nuisance (for example, polluting a public area). Around 1945, the U.S. government started to provide federal money to address environmental issues, such as sewage treatment, and allowed states to set up their own environmental programs.

Modern environmental movement: In the 1960s, people began to rally around environmental protection, starting the modern environmental movement. **Rachel Carson's** book *Silent Spring* (1962) raised awareness of pesticide pollution and helped garner enthusiasm for the movement. In 1970, the first major environmental laws were put in place, and the next 20 years saw the creation of the **Environmental Protection Agency (EPA)** and of virtually all U.S. environmental laws. The **National Wilderness Preservation System** was established, public land was expanded, and a large number of grassroots environmental groups were started.

Regulatory change and backlash: Starting in the early 1990s, a mild backlash began against some of the environmental laws that had been enacted previously. Many were changed or softened in order to alleviate criticisms that they were impractically strict.

ENVIRONMENTAL LAW AND POLICY

As the environmental movement has become more prominent, the United States has passed a number of landmark **environmental laws**. Because pollution, species endangerment, and other environmental problems are a global concern, several major **international agreements** have also been pursued.

MAJOR DOMESTIC LAWS

National Environmental Protection Act (NEPA, 1970): Requires the U.S. government to consider the environmental consequences of any major federal action and to prepare an **environmental impact statement (EIS)** detailing the likely consequences of the action and possible alternatives to the action. This law does not require that the best environmental option be chosen, only that serious consideration be given to environmental consequences before federal resources are committed.

Clean Air Act (CAA, 1970): Established the basic framework for federal regulation of air pollution. First, it requires the EPA to identify air pollutants and set **National Ambient Air Quality Standards (NAAQS)**, and requires states to design implementation plans to meet these standards. The CAA also created a system for **pollution trading** for sulfur dioxide, a chemical known to produce acid rain. Under this program, companies are given allowances for certain amounts of pollution; if a company produces less pollution than allowed, it can sell these allowances on the open market to other companies who have produced too much pollution. The CAA also created a program for the **phaseout of CFCs** to protect against ozone depletion and set a zero-threshold limit for air toxins.

Federal Insecticide, Fungicide, and Rodenticide Control Act (FIFRA, 1972): Requires the EPA to register all pesticides considered safe for public use without unreasonable adverse health effects. It allows the EPA to suspend or cancel registration for pesticides if unreasonable effects are found.

Endangered Species Act (ESA, 1973): Prohibits the **taking** of any plant or animal listed as endangered under this act. Taking includes not only direct harm and killing but also modification of habitat. The ESA describes the process for listing a plant or animal, requires a recovery plan to be developed, and requires critical habitat to be designated. It does not allow financial considerations to be taken into account in protecting endangered species.

Safe Drinking Water Act (SDWA, 1974): Requires the EPA to set **maximum contaminant levels (MCLs)** and **maximum contaminant level goals (MCLGs)** on allowable levels of contaminants in public drinking water. MCLGs are set at a health-protective level at which the EPA considers water to be safe to drink. Only MCLs are legally binding limits of contamination.

Resource Conservation and Recovery Act (RCRA, 1976): Created a two-tier system for waste management by categorizing all as hazardous or nonhazardous and identifying all types of hazardous waste both by name and by nature. The RCRA also details regulations for **transport, storage, and disposal facilities (TSDs)** and requires that all hazardous waste be tracked from cradle to grave. Generally, hazardous waste is disposed of by injecting it into deep wells or burning it at high temperatures. The law also sets guidelines for the disposal of nonhazardous waste, including a ban on open burning, but allows states to determine specific laws.

Clean Water Act (CWA, 1977, 1987): Bans unpermitted discharges of pollutants into surface water and creates a national permit program for monitoring allowable discharges. The CWA also created a grant program that facilitated many towns to build sewage treatment plants and required some technology-based cleanup devices to be applied to discharges.

Comprehensive Environmental Response, Compensation, and Liability Act or Superfund program (CERCLA, 1980): Aimed both at cleaning up hazardous waste sites and discouraging companies from producing new ones. The CERCLA oversees a **National Priority List (NPL)** of sites in need of cleanup and maintains a stringent standard of liability (strict, joint, several, and unlimited) for a number of **potentially responsible parties (PRPs)**, including current owners and operators, owners and operators at the time of dumping, persons who arrange for the disposal of chemicals, and persons who accept such substances. The CERCLA also created the **Superfund** to help fund cleanups unless and until PRPs can be made to pay.

INTERNATIONAL AGREEMENTS

Limited Test Ban Treaty (1963): Bans testing of nuclear weapons in the Earth's atmosphere, underwater, and in space. More than 100 nations have ratified the ban, which has thus far been effective in limiting the amount of test-generated radioactive contamination in the environment.

Convention on the International Trade in Endangered Species (CITES, 1975): Aims to protect wildlife by limiting or prohibiting trade in certain endangered species and their products. All the **parties**, or participating countries, are bound to abide by the trading laws set by CITES.

Montreal Protocol (1987; amended 1990, 1992): Requires that production and consumption of all ozone-depleting compounds, such as CFCs, be phased out by 2005. This agreement has been very effective.

Basel Convention (1989): Aims to limit the dumping of **hazardous wastes** from one country to another, usually less developed country. In addition, the 1995 Basel Ban now prohibits the transfer of hazardous waste from highly developed countries to less-developed countries.

Kyoto Protocol (1997): Aims to phase out the production of greenhouse gases and establish a system for the trading of **carbon credits**. Rejection by the United States and Australia initially threw the agreement's status into doubt, but Russia's approval in November 2004 brings the number of ratifying nations to 127 and puts the protocol into effect as of February 2005.