FIGURE 5.18 *Coral reefs harbor some of the most diverse biological communities on earth, rivaling tropical rainforests in species diversity and surpassing any biome in the number of phylla (broad taxonomic groups) represented. Surprisingly, almost all the organisms you see here are animals.*

Coral reefs are among the world's most productive ecosystems (see fig. 3.21). Reefs accumulate from the skeletons of innumerable tiny, colonial coral animals, which derive energy from photosynthetic algae that live in the reef. Reefs develop in warm, shallow environments, and they support a fabulous diversity of organisms (fig. 5.18). They also serve as nurseries for many fisheries on which humans depend for food.

Reefs are vulnerable to human activities onshore, especially farming and land-clearing that causes erosion or pollution. Silt and mud clouds the water, reducing photosynthetic activity. Destructive fishing practices, aimed at capturing exotic fish for American and European aquarium markets, have also destroyed reefs in many parts of Southeast Asia.

Deep ocean communities are also threatened by fishing. Almost completely unknown before the development of fishing boats with modern sonar devices, these cold, dark environments can contain myriad unfamiliar organisms and marvelously abundant fish. When orange roughy were discovered in the deep ocean canyons near New Zealand and Australia, they were so numerous that 60 tons of the fish could be caught in a 20-minute trawl. But the inhabitants of such cold, dark waters grow slowly. Orange roughy take 20 years to reach reproductive age and 80 to 100 years to reach market size. Further, nets scraping the ocean bottom destroy the complex communities in which the fish live and breed. The fishery collapsed in just a few years. Marine biologists are now proposing international no-fishing zones to protect these delicate, largely unknown, ecosystems.

BIODIVERSITY

The biomes described earlier shelter an astounding variety of living organisms. From the driest desert to the dripping rainforests, from the highest mountain peaks to the deepest ocean trenches, life occurs in a marvelous spectrum of sizes, colors, shapes, life cycles, and interrelationships. The varieties of organisms and complex ecological relationships give the biosphere its unique, productive characteristics. **Biodiversity,** the variety of living things, also makes the world a more beautiful and exciting place to live. Three kinds of biodiversity are essential to preserve ecological systems and functions: (1) *genetic diversity* is a measure of the variety of different versions of the same genes within individual species; (2) *species diversity* describes the number of different kinds of organisms within individual communities or ecosystems; and (3) *ecological diversity* means the richness and complexity of a biological community, including the number of niches, trophic levels, and ecological processes that capture energy, sustain food webs, and recycle materials within this system.

How Many Species Are There?

The 1.4 million species presently known probably represent only a small fraction of the total number that exist (table 5.1). Based on

TABLE 5.1 Approximate Numbers of Known Living Species by Taxonomic Group

Bacteria and cyanobacteria	5,000
Protozoans (single-celled animals)	31,000
Algae (single-celled plants)	27,000
Fungi (molds, mushrooms)	45,000
Multicellular plants	250,000
Sponges	5,000
Jellyfish, corals, and anemones	10,000
Flatworms (tapeworms, flukes)	12,000
Roundworms (nematodes, hookworms)	12,000
Earthworms and leeches	12,000
Clams, snails, slugs, squids, and octopuses	70,000
Insects	750,000
Mites, ticks, spiders, crabs, shrimp, centipedes, and other non-insect arthropods	120,000
Starfish and sea urchins	6,000
Fish and sharks	22,000
Amphibians	4,000
Reptiles	6,000
Birds	9,000
Mammals	4,000
TOTAL	1,400,000

Source: World Resources Institute, 1999.

APPLICATION: Comparing Endangered Species

The majority of identified endangered species are birds, mammals, and amphibians (table 5.1). (a) What proportion of all known species do these three groups represent? (b) How might you explain this disproportionate listing?

Answers: (a) 1.2 percent. (b) Humans frequently hunt these animals or displace them from their habitat; they also are more visible and of greater interest to us.

the rate of new discoveries by research expeditions—especially in the tropics—taxonomists estimate that somewhere between 3 million and 50 million different species may be alive today. In fact, there may be 30 million species of tropical insects alone (fig. 5.19). About 70 percent of all known species are invertebrates (animals without backbones such as insects, sponges, clams, worms, etc.). This group probably makes up the vast majority of organisms yet to be discovered and may constitute 90 percent of all species.

Biodiversity Hot Spots

Most of the world's biodiversity concentrations are near the equator, especially tropical rainforests and coral reefs (fig. 5.20). Of all the world's species, only 10 to 15 percent live in North America and Europe. Many of the organisms in megadiversity countries have never been studied by scientists. The Malaysian Peninsula, for instance, has at least 8,000 species of flowering plants, while Britain, with an area twice as large, has only 1,400 species. There may be more botanists in Britain than there are species of higher plants. South America, on the other hand, has fewer than 100 botanists to study perhaps 200,000 species of plants.

Areas isolated by water, deserts, or mountains can also have high concentrations of unique species and biodiversity. Madagascar, New Zealand, South Africa, and California are all midlatitude areas isolated by barriers that prevent mixing with biological communities from other regions and produce rich, unusual collections of species.

HOW DO WE BENEFIT FROM BIODIVERSITY?

We benefit from other organisms in many ways, some of which we don't appreciate until a particular species or community disappears. Even seemingly obscure and insignificant organisms can play irreplaceable roles in ecological systems or be the source of genes or drugs that someday may be indispensable.

Food

All of our food comes from other organisms. Many wild plant species could make important contributions to human food supplies either as they are or as a source of genetic material to

FIGURE 5.19 *Insects make up more than half of all known species and may comprise more than 90 percent of all species on earth. There may be more than a million species of beetles alone.*

improve domestic crops. Noted tropical ecologist Norman Myers estimates that as many as 80,000 edible wild plant species could be utilized by humans. Villagers in Indonesia, for instance, are thought to use some 4,000 native plant and animal species for food, medicine, and other valuable products. Few of these species have been explored for possible domestication or more widespread cultivation. A 1975 study by the U.S. National Academy of Science found that Indonesia has 250 edible fruits, only 43 of which have been cultivated widely (fig. 5.21).

Drugs and Medicines

Living organisms provide us with many useful drugs and medicines (table 5.2). More than half of all prescriptions contain some natural products. The United Nations Development Programme estimates the value of pharmaceutical products derived from developing world plants, animals, and microbes to be more than $30 billion per year.

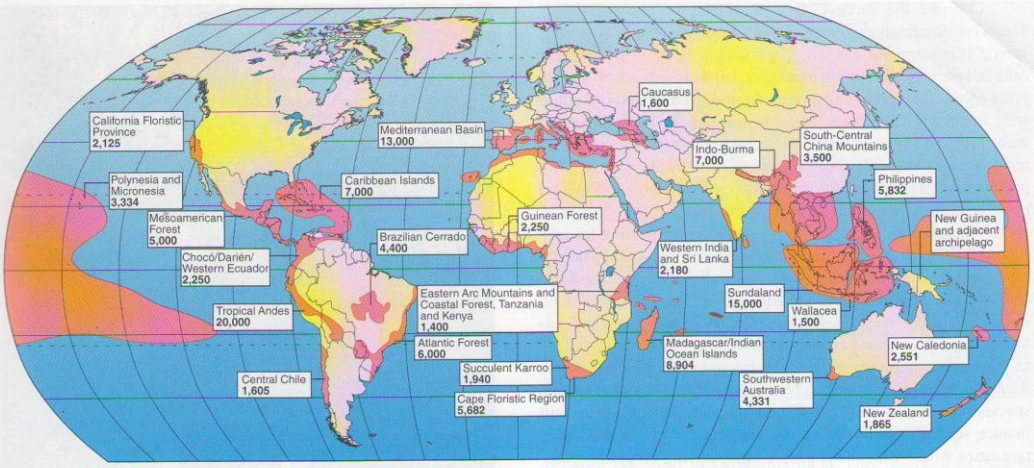

FIGURE 5.20 *Biodiversity "hot spots" identified by Conservation International tend to be in tropical or Mediterranean climates and on islands, coastlines, or mountains where many habitats exist and physical barriers encourage speciation. Numbers represent estimated endemic (locally unique) species in each area.*
Source: Data from Conservation International.

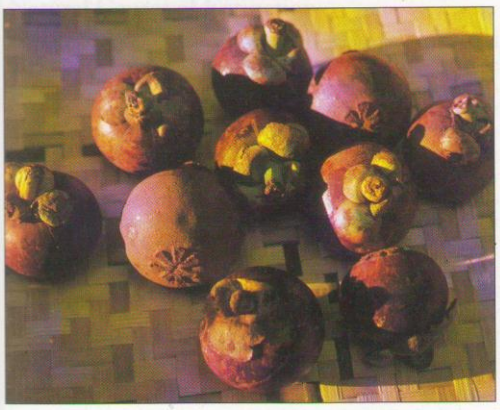

FIGURE 5.21 *Mangosteens from Indonesia have been called the world's best-tasting fruit, but they are practically unknown beyond the tropical countries where they grow naturally. There may be thousands of other traditional crops and world food resources that could be equally valuable but are threatened by extinction.*

TABLE 5.2 Some Natural Medicinal Products

PRODUCT	SOURCE	USE
Penicillin	Fungus	Antibiotic
Bacitracin	Bacterium	Antibiotic
Tetracycline	Bacterium	Antibiotic
Erythromycin	Bacterium	Antibiotic
Digitalis	Foxglove	Heart stimulant
Quinine	Chincona bark	Malaria treatment
Diosgenin	Mexican yam	Birth-control drug
Cortisone	Mexican yam	Anti-inflammation treatment
Cytarabine	Sponge	Leukemia cure
Vinblastine, vincristine	Periwinkle plant	Anticancer drugs
Reserpine	Rauwolfia	Hypertension drug
Bee venom	Bee	Arthritis relief
Allantoin	Blowfly larva	Wound healer
Morphine	Poppy	Analgesic

Consider the success story of vinblastine and vincristine. These anticancer alkaloids are derived from the Madagascar periwinkle (*Catharanthus roseus*). They inhibit the growth of cancer cells and are very effective in treating certain kinds of cancer. Twenty years ago, before these drugs were introduced, childhood leukemias were invariably fatal. Now the remission rate for some childhood leukemias is 99 percent. Hodgkin's disease was 98 percent fatal a few years ago, but is now only 40 percent fatal, thanks to these compounds. The total value of the periwinkle crop is roughly $15 million per year, although Madagascar gets little of those profits.

Pharmaceutical companies are actively prospecting for useful products in many tropical countries. Merck, the world's largest biomedical company, is paying $1 million to the Instituto Nacional de Biodiversidad (INBIO) of Costa Rica for plant, insect, and microbe samples to be screened for medicinal applications. INBIO, a public/private collaboration, trains native people as practical "parataxonimists" to locate and catalog all the native flora and fauna—estimated to be between 500,000 and 1 million species—in Costa Rica (fig. 5.22). Selling data and specimens will finance scientific work and nature protection. This is one of the rare cases where indigenous people are receiving economic benefits from the ecological knowledge they possess and the biodiversity they struggle to protect. Pharmaceutical companies often have been accused of "biopiracy," using traditional knowledge and resources without paying royalties to native peoples.

Ecological Benefits

Human life is inextricably linked to ecological services provided by other organisms. Soil formation, waste disposal, air and water purification, nutrient cycling, solar energy absorption, and food production all depend on biodiversity (see chapters 2 and 7). Total value of these ecological services is at least $33 trillion per year, or more than double total world GNP. In many environments, high diversity may help

FIGURE 5.22 *Costa Rican taxonomists study insect collections as part of an ambitious project to identify and catalog all the species in this small, but highly diverse, tropical country. The knowledge gained may contribute toward valuable commercial products that will provide funds to help preserve biodiversity.*

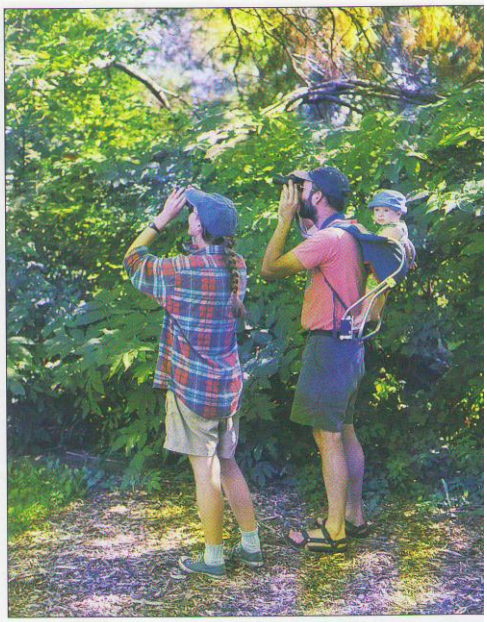

FIGURE 5.23 *Birdwatching and other wildlife observation contribute more than $29 million each year to the U.S. economy.*

biological communities withstand environmental stress better a recover more quickly than those with fewer species.

Because we don't fully understand the complex interrel tionships between organisms, we often are surprised and dismay at the effects of removing seemingly insignificant members of bi logical communities. For instance, it is estimated that 95 perce of the potential pests and disease-carrying organisms in the wo are controlled by natural predators and competitors. Maintaini biodiversity is essential to preserving these ecological services.

Aesthetic and Cultural Benefits

Millions of people enjoy hunting, fishing, camping, hiking, wildl watching, and other nature-based activities. These activities p vide invigorating physical exercise, and contact with nature can psychologically and emotionally restorative. In many cultur nature carries spiritual connotations, and a particular species landscape may be inextricably linked to a sense of identity a meaning. Observing and protecting nature has religious or mo significance for many people. Some religious organizations call the protection of nature simply because it is God's creation.

Nature appreciation is economically important. The U Fish and Wildlife Service estimates that Americans spend $1 billion every year on wildlife-related recreation (fig. 5.23). T