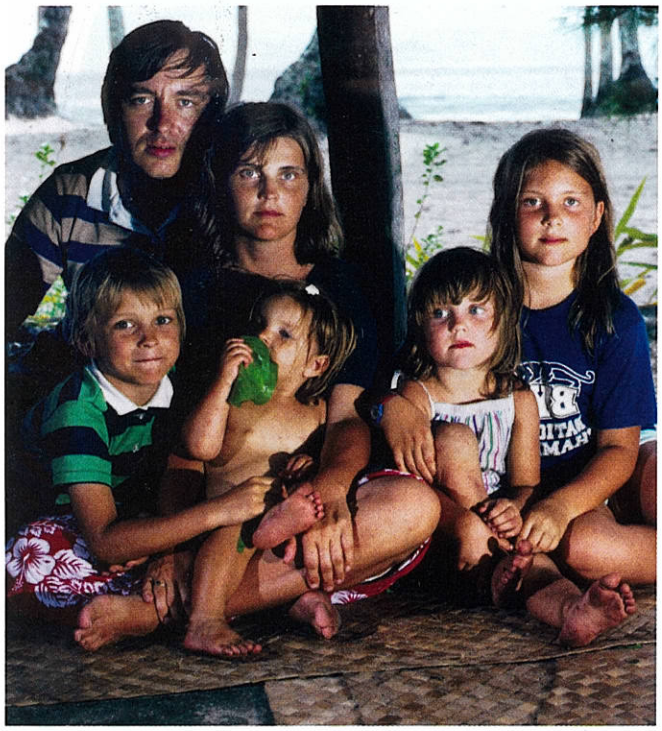
Benefits of Biodiversity

It was his mother's death in the fall of 1984, from a particularly aggressive form of breast cancer, that drove Paul Cox back to the Samoan rainforest. Cox had first visited the South Pacific island in 1973, through an undergraduate research program with Brigham Young University, where he was majoring in botany. Since then, the Utah native had earned a Ph.D. from Harvard and made a career studying plant physiology in the United States.



↑ Paul Cox and family in Samoa, 1986.

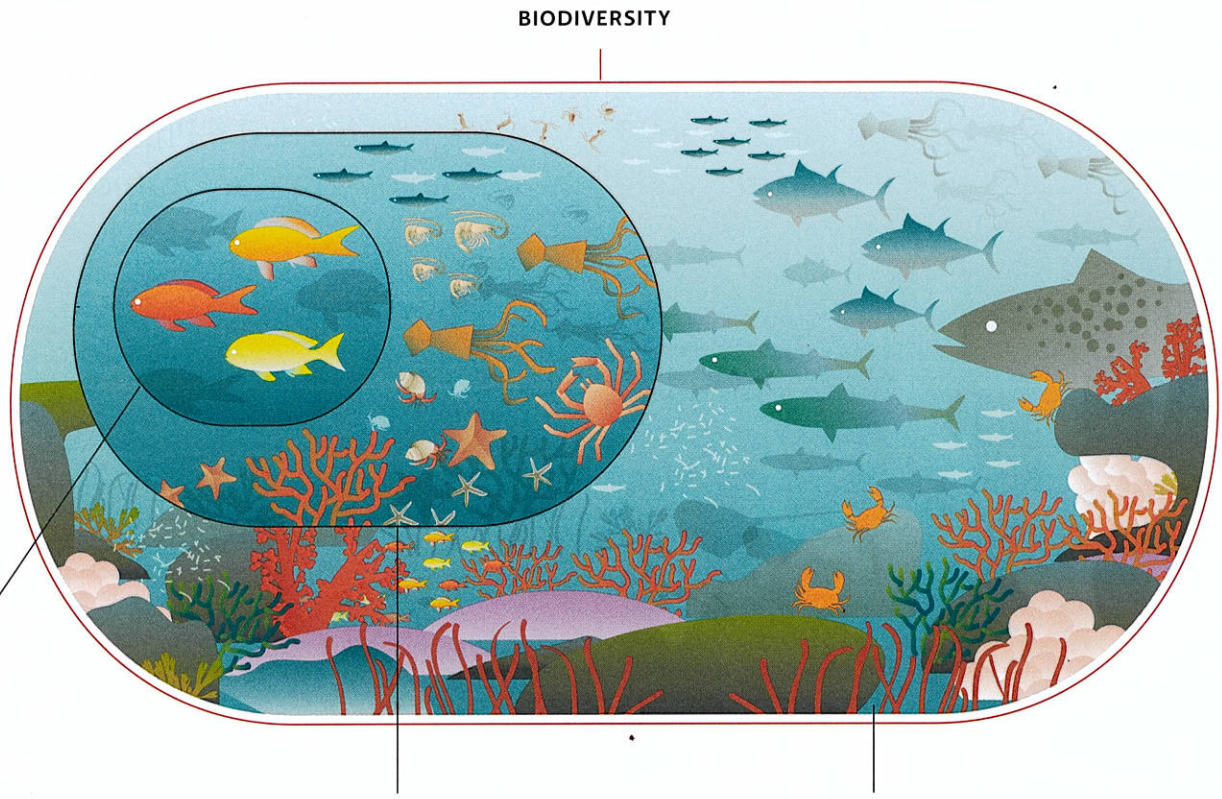
But when the best of Western medicine failed to cure his mother, Cox remembered the Samoans—their rich folk healing traditions, and the profound influence that jungle plants had on their health and well-being. Surely, he thought, somewhere in the lush abundance that had long sustained this impoverished island nation must be a compound powerful enough to obliterate the most insidious of tumors. "I told my friends at the National Cancer Institute, 'If there is even a 1% chance of finding something, it's worth taking a look,'" he recalls. "They said 'We think there is like a 3% chance.' So I went." Six months after his mother's funeral, with his wife and four young children in tow, Cox returned to Samoa.

Biodiversity benefits humans and other species.

Why did Cox suspect that Samoa might hold the key to a cancer cure? Tropical regions like Samoa—warm, lush, close to the equator—contain the greatest concentration and variety of plant and animal life forms on Earth. This variety is called **biodiversity**. Countries of this region have both high **species diversity** and high **genetic diversity**. They also usually have high **ecological diversity**, a wide variety of communities and ecosystems with

biodiversity The variety of life on Earth; it includes species, genetic, and ecological diversity.
species diversity The variety of species, including how many are present (richness) and their abundance relative to each other (evenness).
genetic diversity The heritable variation among individuals of a single population or within the species as a whole.
ecological diversity The variety within an ecosystem's structure, including many communities, habitats, niches, and trophic levels.

Infographic **9.1** | **BIODIVERSITY INCLUDES GENETIC, SPECIES, AND ECOSYSTEM DIVERSITY**



GENETIC DIVERSITY
Variations in the genes among individuals of the same species

↑ Though these squarespot anthias fish are members of the same species, *Pseudanthias pleurotaenia*, they show tremendous genetic diversity.

SPECIES DIVERSITY
The variety of species present in an area; includes the number of different species that are present as well as their relative abundance

↑ The area of Polynesia where Samoa is found has some of the highest coral reef species diversity in the world.

ECOLOGICAL DIVERSITY
The variety of habitats, niches, trophic levels, and community interactions

↑ Samoa's rainforest and coral reef ecosystems contain complex, three-dimensional structures with varied habitats and multiple niches that support high species diversity and a complex community.

different habitats, many trophic levels, and lots of niches. [INFOGRAPHIC 9.1]

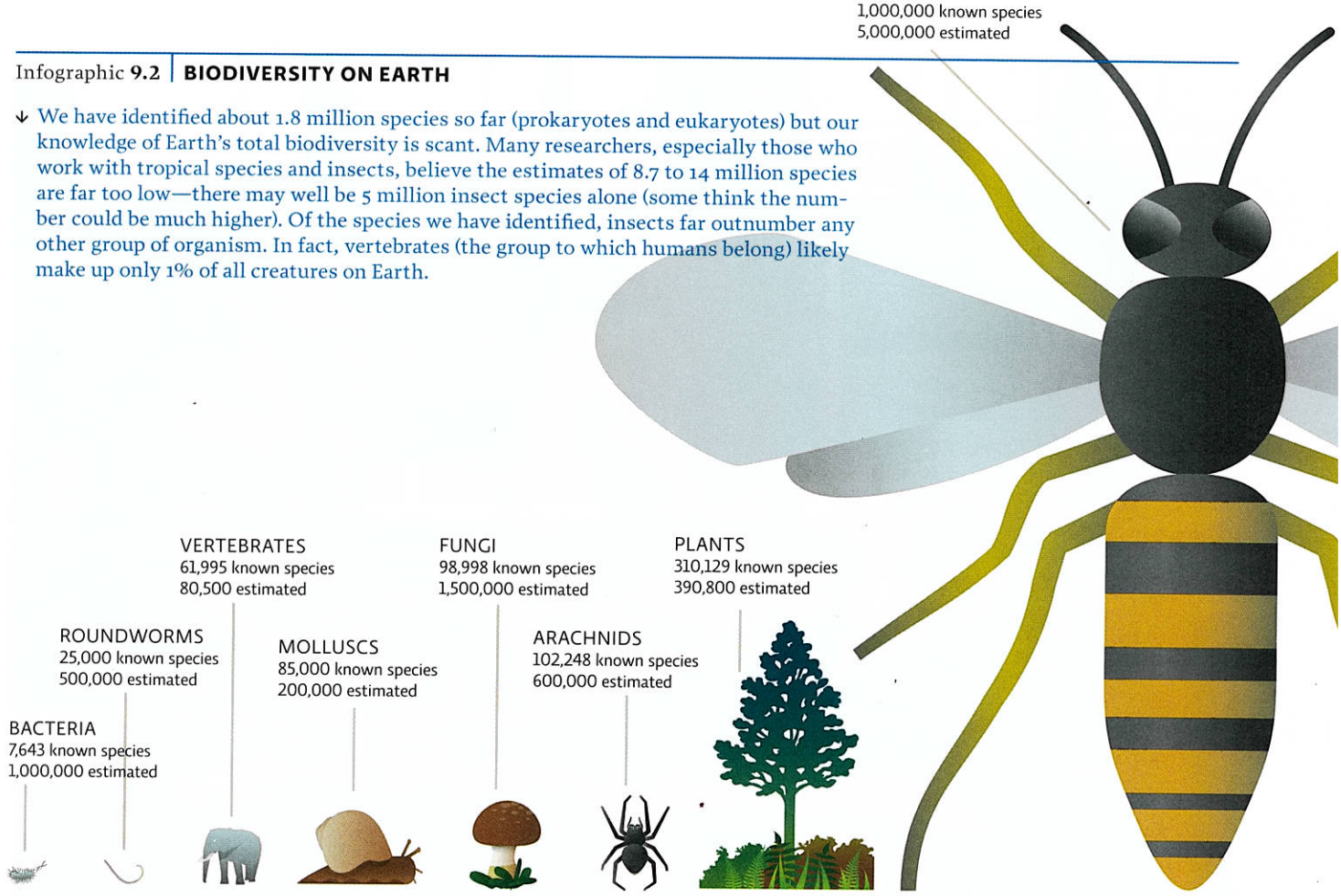
It is virtually impossible to know just how many species exist on Earth. This uncertainty has given rise to a wide range of estimates—anywhere from 3 to 100 million. Further, in a 2011 paper, researchers estimated that of all the species now living on Earth, we humans have yet to discover or identify about 86% of them. [INFOGRAPHIC 9.2]

Such nearly unfathomable biodiversity brings with it many benefits. Samoa, like most other places around the world, depends on biodiversity to provide a vast array of **ecosystem services**: Photosynthetic organisms (plants on land; algae and phytoplankton in the sea) bring in energy, produce oxygen, and sequester carbon. Other organisms capture and pass along important nutrients like nitrogen and phosphorus. Others still help purify the air and water and eventually become food for other creatures. And populations are kept in check by predators and competitors so that no single species grows too populous or gobbles up too many needed resources. For example, in the forests of Samoa, the tooth-billed pigeon is important for the propagation of mahogany, a species of tree found throughout Polynesia. The pigeon may be the only native

ecosystem services Benefits that are important to all life, including humans, provided by functional ecosystems; includes such things as nutrient cycles, air and water purification, and ecosystem goods, such as food and fuel.

Infographic **9.2** | **BIODIVERSITY ON EARTH**

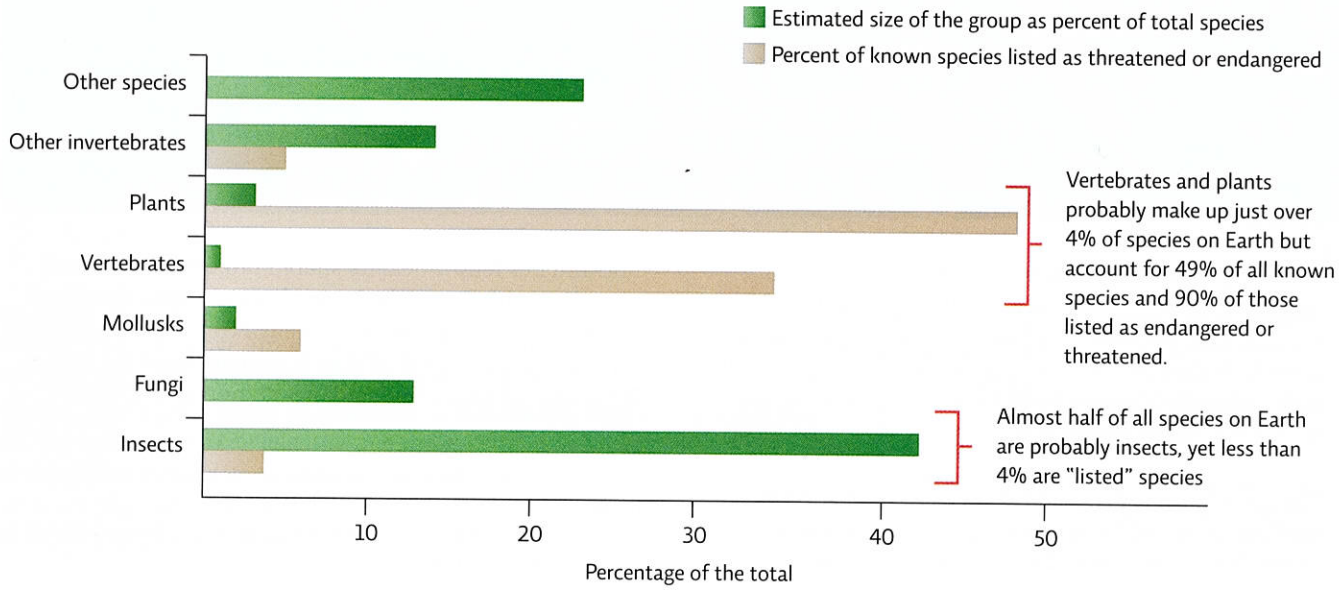
We have identified about 1.8 million species so far (prokaryotes and eukaryotes) but our knowledge of Earth's total biodiversity is scant. Many researchers, especially those who work with tropical species and insects, believe the estimates of 8.7 to 14 million species are far too low—there may well be 5 million insect species alone (some think the number could be much higher). Of the species we have identified, insects far outnumber any other group of organism. In fact, vertebrates (the group to which humans belong) likely make up only 1% of all creatures on Earth.



Size roughly equals the proportion of all known species

When we compare the estimated size of different groups of species to the number within each group listed as endangered or threatened, there is a clear bias toward species of interest to us (large animals and plants). However, we are discovering that the lesser-known or -appreciated groups, such as worms and insects, perform vital ecosystem services and also warrant our attention.

PERCENT OF SPECIES LISTED AS ENDANGERED COMPARED TO THE ESTIMATED SIZE OF THE GROUP



↑ Samoan healer, Pela Lilo, with her daughter-in-law, Fa'asaina Lamositele, treating a patient with traditional medicine.

animal that can open the tree's seeds so new seedlings can take root. Meanwhile, adult mahogany trees provide habitat and food to a variety of insect, bird, mammal, and reptile species. They are also key players in carbon cycling and soil stabilization, and serve as a windbreak in coastal areas. (See Chapter 5 for more on ecosystem services.)

Biodiversity supplies cultural benefits as well—whether it is the enjoyment of a natural area for recreation or aesthetic appreciation, or a societal tradition rooted in nature. In Samoa, native foods are an important part of traditional feasts; the Sunday meal typically features tropical foods like fresh fruit, root vegetables including taro, and lots of seafood. Kava, a traditional drink prepared from the roots of a native pepper plant, is often drunk before ceremonial events and has a mild tranquilizing effect. It is also purported to have analgesic effects.

Biodiverse ecosystems have economic value, too. In Samoa, the forests provide not only food, fuel, and building material, but also pharmaceuticals. People use the chemicals they extract from plants not only to attend to their individual human health issues, but also as a source of income. [INFOGRAPHIC 9.3]

The growing appreciation for the value of ecosystem services provided by species highlights the importance of species as members of an ecological community. But many people feel that the value of any given species goes beyond its **instrumental value** (i.e., the ecological, medicinal, or monetary benefits it can provide for humans) and contend that all species have **intrinsic value** and are therefore worth preserving.

Once they arrived in Samoa, Cox and his family settled in a thatched hut on the far western edge of the island in the village of Falealupo—just a few steps from the sea and as far as they could get from the comparatively modern neighboring island of American Samoa. There, amid a tropical swirl of insects, humidity, and white sand, with no electricity or running water, Cox apprenticed himself to a mostly female cadre of healers. His primary teacher was Pela Lilo, an 82-year-old woman whose particular collection of plant-based remedies had been passed down to her through generations.

Lilo and her fellow healers shared hundreds of natural remedies with Cox—the bark of vavae (*Ceiba pentandra*) to treat asthma, leaves of the kuava tree (*Psidium guajaba*) for diarrhea, and root of 'Ago (*Curcuma longa*) for rashes. It turned out that the Samoans did not have a word

instrumental value An object's or species' worth, based on its usefulness to humans.

intrinsic value An object's or species' worth, based on its mere existence; it has an inherent right to exist.

Infographic 9.3 | **ECOSYSTEM SERVICES**

↓ We depend on genetically diverse, species-rich communities to provide the goods and services we use every day. Impoverished ecosystems that have lost genetic, species, or ecological diversity cannot perform these tasks as well as highly diverse ecosystems can.

1. CULTURAL BENEFITS
- Aesthetic
- Spiritual
- Educational
- Recreational

2. HUMAN PROVISIONS
- Food
- Fiber products such as cotton and wool
- Fuel
- Pharmaceuticals

3. ECOSYSTEM REGULATION AND SUPPORT
- Nutrient cycling
- Pollination and seed dispersal
- Air and water purification
- Flood control
- Soil formation and erosion control
- Climate regulation
- Population control

for breast cancer (one purported treatment for "lumpy breasts" did not prove effective against breast tumors). But they did have a treatment for "yellowing fever," a disease Westerners know as Hepatitis C; boiling the bark of the mamala tree (*Homalanthus nutans*) and drinking the extract twice a day was known to relieve symptoms. After seeing a demonstration of the potion's power, Cox gathered samples of mamala bark and sent them off (along with dozens of other promising roots, stems, and leaves) to colleagues at the National Cancer Institute (NCI), in Bethesda, Maryland, for testing.

But what he saw as a garden of medical promise, others saw as timber. And just as the mamala bark was yielding up its secrets to scientists at the NCI, loggers were negotiating with Falealupo's villagers to *clear-cut*, or remove, all

of the trees from the forests where this tree grew most abundantly. In Samoa, habitat destruction such as this had already gobbled up nearly 80% of the island's lowland forests. Cox despaired at the thought of how many undiscovered medicines would be annihilated if the loggers had their way.

Plants gain medicinal qualities as they adapt to other species.

The tropics are home to roughly 5.3 billion people, or 80% of the world's population. Because many of the countries in this region are poor, medicinal plants provide both a primary form of health care and a major source of income to local communities. Medicinal plants are one of the most prominent facets of *ethnobotany*—the study of how different cultures make use of the plants that surround them.

According to the World Bank, the international trade in medicinal plants was worth nearly $100 billion in 2011. Roughly half of all prescription drugs—including some medicine cabinet staples like aspirin, codeine, and most hypertension drugs—were originally derived from plants. And by most accounts, there are many more medical treasures just waiting to be discovered: Less than 1% of the world's 265,000 known flowering species have been tested for their effectiveness against human diseases. "We are barely scratching the surface now," says Jim Miller, a scientist at the New York Botanical Garden in New York City. [INFOGRAPHIC 9.4]

Despite that untapped potential, the role of plants in Western medicine has waxed and waned throughout history. For one thing, the odds are daunting. On average, only 1 in 15,000 compounds will demonstrate the potential to treat a human condition. For most of the modern medical era, finding that 1 compound took an average of 12 years and $300 million—enough to dissuade the most tenacious of scientists.

Roughly half of all prescription drugs—including some medicine cabinet staples like aspirin, codeine, and most hypertension drugs—were originally derived from plants.

Plants were once the biggest source of new medications in Western society. But advances in pharmacology quickly turned scientists' attention away from the forest and toward the test tube, where they could design molecules from scratch, rather than search for them like needles in a haystack. A few decades ago, scientists predicted that advances in biochemistry would eliminate the need to exploit fragile ecosystems for our own medical needs; they believed any molecule we discovered could easily be replicated in a test tube or Petri dish.

But with the exception of a few remarkable successes, like the cancer drug paclitaxel that is now synthesized in the lab rather than being extracted from the bark of Pacific yew trees where it was first found, that prediction didn't quite pan out. "An overwhelming number of plant-derived compounds have eluded all attempts to copy," says Sarah Oldfield, director of the nonprofit Botanic Garden Conservation Initiative. Because copying plant-derived molecules has proven so intractable, modern medicine continues to depend on their availability in nature. And by many accounts, evolution has bested the most apt chemists, resulting in molecules too complex to fathom, let alone replicate. "Mother Nature is the ultimate chemist," says Oldfield. "Modern chemistry has barely enabled us to copy her creations, so you can imagine the near impossibility of designing them from scratch."

It's little wonder. Plant chemicals evolve over eons, as individual plant species strive to fight off predators. Because they can't run or physically fight, the way animals can, plants employ two main anti-predator strategies: physical defense structures like thorns, thick seed coats, or bark, and chemical weapons, like the ones that ultimately find their way into our medicine cabinets. In short, it's the diversity of life itself, challenging the plant kingdom in a mind-boggling variety of ways, that spurs such a broad range of protective chemicals, and in so doing, provides us with some precious life-saving medicines. (See Chapter 10 for more on natural selection of adaptive traits.)

In 1988, the villagers of Falealupo were being pressured by the government to build a school. Knowing this, a logging company offered to pay the villagers nearly $2 per acre for the nearby 30,000-acre forest, where the mamala tree grew most abundantly—just enough to cover school construction costs. Scientists were only beginning to study the mamala bark and Cox knew that any health or financial benefits from the tree would be decades off.

But he also knew that if the loggers had their way, hundreds of other plants with potential medicinal properties might never be found. So he negotiated with the villagers, promising them he would raise the school money himself if they agreed to protect the forest from logging. Then Cox went knocking on the doors of nonprofits and

Infographic 9.4 | NATURALLY DERIVED MEDICINES

Opium (flower)
Medicine: Morphine
Use: Pain

Foxglove (flower)
Medicine: Digoxin
Use: Heart disease

Madagascar periwinkle (flower)
Medicine: Choroquine
Use: Malaria

Ephedra (shrub)
Medicine: Salbutamol
Use: Asthma

Curarea (woody vine)
Medicine: Tubocurarine
Use: Muscle relaxant

Cobra (snake)
Medicine: Corboxine
Use: Pain

Pacific yew tree
Medicine: Paclitaxel, Taxol
Use: Cancer (lung, breast, ovarian)

Penicillium (fungus)
Medicine: Penicillin, Metavastin
Use: Antibacterial, Cholesterol lowering

Streptomyces (bacteria)
Medicine: Ivermectin
Use: Parasites

↑ Top: Leaves from the Samoan mamala tree *Homalanthus nutans* from which the anti-HIV drug candidate prostratin was derived. Middle: Samoan healer Ake Lilo preparing a branch from the mamala tree. Bottom: The bark of the mamala tree is boiled down into an extract the Samoans use to treat Hepatitis C.

↑ More than 90% of the native species on the Hawaiian islands are found nowhere else, making these populations more vulnerable to extinction; if they are lost there, they are lost forever. The smaller the island, the smaller the population of a given species, another vunerablility for extinction. Here, botanists work through the night setting up a protective fence around the last specimen of *Delissea undulata* found in the wild. This endangered plant was growing on the side of a collapsed lava tube, but had been knocked over by wind or animals and was dangling from its roots.

conservation groups back in the United States. Before too many trees were felled, he had scrounged up $85,000—enough money to build the school and spare the forest. It was a rare victory. "It's common for indigenous people to have to choose between saving a forest or coral reef and building a school or medical clinic," says Cox. "Because they don't typically have the resources to do both, they must sacrifice one to pay for the other. And the loss when that happens is often incalculable."

Especially in the Pacific Islands like Samoa and Hawaii. The region has the highest percentage of threatened and endangered species (those at risk for extinction) of any region on Earth; these species are often specialists that occupy narrow niches. It also contains a high proportion of **endemic** plants and animals—those that exist nowhere else on Earth. Areas like this that contain a large number of endemic but threatened species are known as **biodiversity hotspots**. Many hotspots are in tropical regions, where biodiversity abounds. [INFOGRAPHIC 9.5]

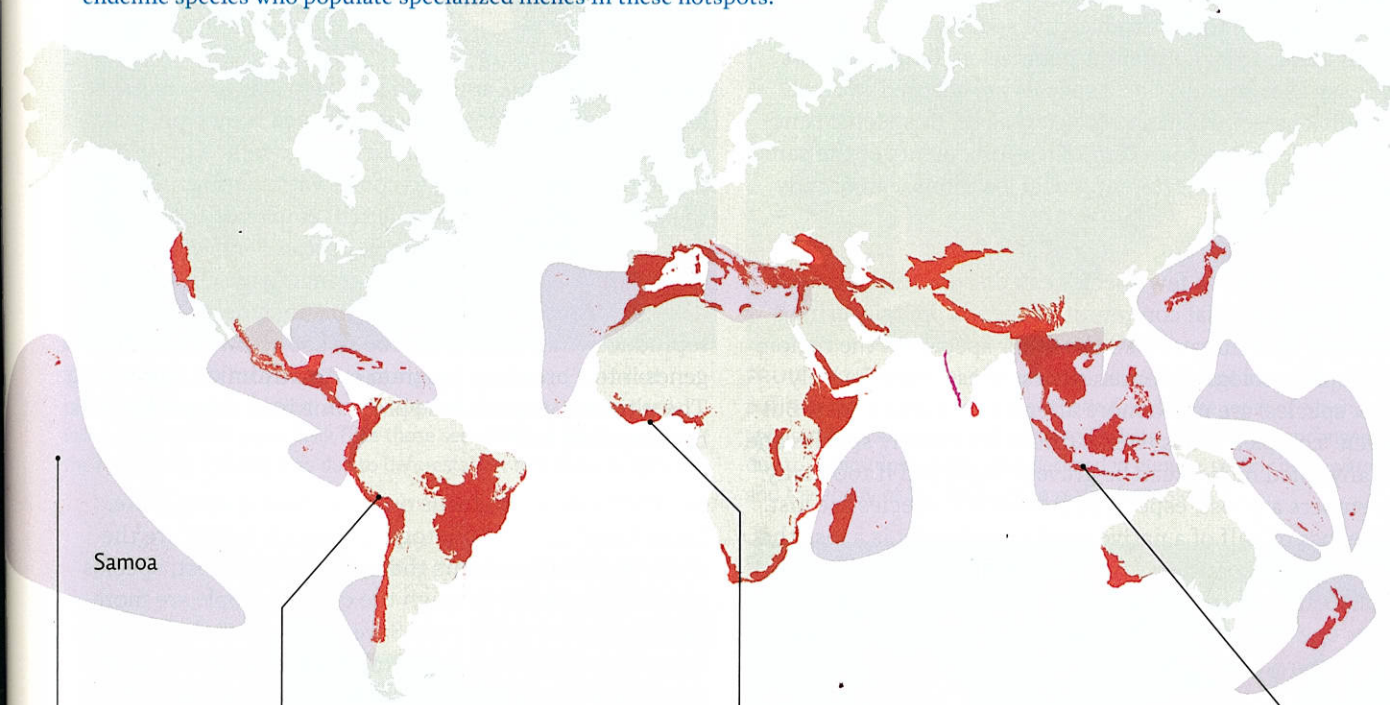
Islands are particularly vulnerable to species loss since they are isolated from other islands or from the mainland; new individuals who might bring genetic diversity rarely arrive. In Hawaii alone, fully one-half of the indigenous flora faces immediate extinction. Such a high extinction rate threatens the fragile tapestry of life on these islands,

endemic Describes a species that is native to a particular area and is not naturally found elsewhere.

biodiversity hotspot An area that contains a large number of endemic but threatened species.

Infographic **9.5** | **BIODIVERSITY HOTSPOTS**

↑ Biodiversity hotspots, areas with a high number of endemic but threatened or endangered species, cover a small percentage of land and water areas but hold more than 40–50% of all plant and vertebrate endemic animal species. Most hotspots are located in tropical biomes or in isolated terrestrial ecosystems such as mountains or islands. Even small disturbances can threaten endemic species who populate specialized niches in these hotspots.



TROPICAL ANDES 15,000 endemic plants, 487 threatened species, 2 extinct

GUINEAN FORESTS 1,800 endemic plants, 115 threatened species, 0 extinct

POLYNESIA–MICRONESIA 3,074 endemic plants, 99 threatened species, 43 extinct

INDO–MALAYAN ARCHIPELAGO 15,000 endemic plants, 162 threatened species, 4 extinct

from their soil and freshwater supplies to the health and economic future of their residents.

If a species is **extirpated**—that is, if it goes extinct in one ecosystem but still exists elsewhere—it is sometimes possible to reintroduce the species by bringing in individuals from a different population. But this is not as easy as it sounds. Local species are adapted to local conditions—they fill an *ecological niche*, or specific functional role in an ecosystem. Therefore, plants of the same species, but from different global locations, can occupy different niches.

The loss of even a few species can disrupt the connections that the ecological community depends on, triggering a cascade that threatens all the other species in the region. "Simple" ecological communities (ones with relatively few species) are much more affected by a single loss. But even "complex" ecosystems (those with many species and many filled niches) can be gravely imperiled if too many members are lost, especially if keystone species are lost. The loss of half of a native plant community is a loss that few, if any, ecosystems can endure without completely collapsing. Of course, once one ecosystem collapses, a new one may emerge. But such recovery takes a very long time. [INFOGRAPHIC 9.6]

There are many different ways to protect and enhance biodiversity.

Cox has deployed a small team of ethnobotanists throughout the Pacific to take a census of island plants and to collect seeds from those species with fewer than 100 remaining specimens. This careful accounting—which often requires scaling down cliffs and dangling from helicopters—will provide the basis of a large-scale conservation effort that scientists hope to replicate in other regions of the world. "If we know what we are losing and where we're losing it, we can plan a counter-offensive," says David Burney, from the National Tropical Botanical Garden on the Hawaiian island of Kaua'i. "The census helps us to figure out what's due to habitat loss, and so on."

This type of basic field research—evaluating an area to see what species are present, how healthy and genetically diverse that species' population is, and what threats the species face—is essential to protecting and maintaining biodiversity. After all, we can't save or protect what we don't even know exists or don't realize is in danger of extinction. But it is only the first step.

Early programs that addressed species endangerment often took the *single species approach*: They singled out well-known animals, like pandas and condors, and focused on the specific threats those individual species faced, often using captive breeding programs to increase population sizes.

In some ways, this approach has been a huge success: It has saved gray wolves, eagles, and even brown pelicans from complete decimation. And it's brought a great deal of attention and funding to conservation efforts. Indeed, the single species approach is still employed today. Zoos around the world participate in *Species Survival Plans* which use careful breeding programs to maximize genetic diversity. Among other things, this includes moving reproductive animals from zoo to zoo to introduce new genes into a breeding program or to minimize inbreeding. The ultimate goal of these programs is to release animals back into the wild.

But the tendency to focus on only those species (cute, furry, large) that are photogenic enough to capture the public's attention means that many, if not most, species in need of help fall through the cracks (people are more likely to donate money to "Save the panda!" than to "Save the white warty-back pearly mussel!"). For that reason, many experts now support an *ecosystem approach*. This means identifying entire ecosystems—often biodiversity hotspots—that are at risk, and taking steps to restore or rehabilitate damaged habitat and then to protect it from further damage or exploitation. It may involve reforestation projects, removal of non-native species, restoration of a natural river's flow patterns, or the clean-up of pollution (remediation)—the restoration goal depends on the ecosystem in question. Proponents of the ecosystem approach point out that by focusing on the ecosystem as a whole, the entire community benefits—not only the species we knew were endangered, but also those that we didn't even know were there.

In order to shift to an ecosystem focus we must know how to identify when an ecosystem is in danger. Ecologists are developing metrics (factors that are measured) to assess ecosystem quality, such as species richness and evenness, soil health, water quality, plant community composition, and the abundance of non-native species.

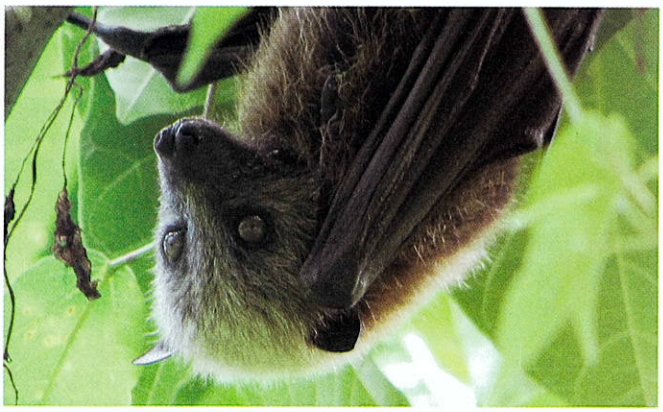
The protection of habitat often includes establishing preserves—which can include national parks, forests, grasslands, and in the ocean, marine protected areas—where

extirpated Describes a species that is locally extinct in one or more areas but still has some individual members in other areas.

Infographic **9.6** | **BIODIVERSITY OF SAMOA**

↓ Samoa has high biodiversity and is part of the diverse but threatened Polynesia/Micronesia hotspot. Some of the species that live in Samoan ecosystems are shown here.

TOOTH-BILLED PIGEON The endangered endemic tooth-billed pigeon (*Didunculus strigirostris*) specializes in eating mahogany seeds, using its sawtooth lower beak (like those seen in fossil birds) to open the hard seeds. Habitat loss due to deforestation threatens its survival.



FRUIT BAT Flying foxes (*Pteropus samoensis*) are fruit bats that pollinate large, tree climbing Freycinetia flowers, the roots of which are used by Samoans to make fishing baskets. The bats are endangered due to habitat loss; as the bats declined in number so did the flowers and the ability of the Samoans to make the baskets.

SAMOAN MOORHEN The endemic Samoan moorhen (*Gallinula pacifica*) may be extinct (last sighted in 1984) due to habitat loss from deforestation.

RED GINGER (*Alpinia purpurata*) is the national flower of Samoa (known as *teuila*) and a popular garden plant with its own national festival.

SAMOAN SWALLOWTAIL BUTTERFLY This endemic butterfly (*Papilio godeffroyi*) is critically endangered due to forest clearing for farming.

RACCOON BUTTERFLYFISH Samoan seas have at least 250 species of coral and almost 1,000 species of fish. These raccoon butterflyfish (*Chaetodon lunula*) are one of 30 or so species of butterflyfish found there.

Infographic 9.7 | **CONSERVATION PRACTICES TO PROTECT AND ENHANCE BIODIVERSITY**

Biodiversity monitoring	Monitoring that allows us to see which species are present and how robust their populations are; also helps identify specific threats to populations' well-being.
Species Survival Plan (SSP)	A program developed by the Association of Zoos and Aquariums (AZA) that includes captive breeding plans to selectively breed individuals and maximize genetic diversity. The ultimate goal is to release individuals back into the wild to build up wild populations.
Ecosystem restoration	The repair of natural habitats back to (or close to) their original state. This may include the reintroduction of native species in an attempt to reestablish community connections. The restoration not only improves ecological diversity, it also increases or helps maintain species diversity.
Ecosystem remediation	The clean-up of pollution that is often a part of ecosystem restoration. Physical, chemical, or biological methods might be employed to remove or decontaminate an area and make it suitable for wildlife.
Preserves/parks	Protected areas that have been set aside and that limit human impact and provide sanctuaries for wildlife. These may be public areas (such as national parks, forests, or marine protected areas) and may be funded by ecotourism or debt-for-nature swaps.
Laws and treaties	Many nations have laws that protect endangered species, such as the U.S. Endangered Species Act or Canada's Species at Risk Act. International treaties include the Convention on International Trade in Endangered Species, which forbids trade of any endangered species or any product made from one, and the Convention on Biological Diversity, which promotes sustainable use of ecosystems and biodiversity.

human access is deliberately restricted. In Samoa, 5% of the land is legally protected to one degree or another; the goal of Cox and his colleagues is to increase that to 15%. In other parts of the world, the preservation of natural areas can be funded by **debt-for-nature swaps** in which a wealthy nation forgives part of the debt of a developing nation in return for the developing nation's pledge to protect certain ecosystems. So far, almost $1 billion in debt has been forgiven in these programs.

Laws and international treaties also offer species more formal protection, often by mandating the steps outlined above (namely monitoring, restoration, and protection). The **U.S. Endangered Species Act** (passed in 1973) provides provisions for officially identifying a species as endangered (a *listed species*) and mandates that listed species and their habitats be protected in the United States. In many cases, this law has been very successful, but its effectiveness is perpetually hampered by inadequate funding and by conflicts with landowners who oppose restrictions on how they can use their land. International treaties such as the Convention on International Trade of Endangered Species and the Convention on Biological Diversity offer protection of endangered and threatened species beyond the borders of an individual country. [INFOGRAPHIC 9.7]

debt-for-nature swap A wealthy nation forgives the debt of a developing nation in return for a pledge to protect natural areas in that developing nation.
Endangered Species Act The primary law under which biodiversity is protected in the United States.

Biodiversity is proving invaluable in the search for cures.

For its part, the mamala tree turned out to be a good save. NCI researchers boiled down the bark and purified the remaining substance, which they named prostratin. Although prostratin had no effect against cancer, as Cox had hoped, it did prove to be a valuable weapon against HIV, the virus that causes AIDS. The first human trials of prostratin began in 2008. Researchers expect the drug to be commercially available in a few years.

So far, mamala bark provides the only known source of prostratin. While small amounts of the compound have

been enough to conduct preclinical animal studies, much larger quantities will be needed for large-scale drug manufacturing. Stripping the Samoan rainforest of its mamala trees would be environmentally destructive, not to mention inefficient. So synthetic biologists are looking for better options. By locating the genes responsible for prostratin synthesis and cloning them into a simple organism, like bacteria, they hope to spare the mamala tree from overexploitation. The genetically altered bacteria would then serve as mini prostratin factories—quickly and efficiently producing mass quantities of the molecule which could then be used to make medication. This approach has already been successfully used to scale up production of the plant-derived antimalaria drug, artemisinin.

Cox is quick to point out that without the Samoans' help, he would never have found prostratin. The forest he scoured housed two varieties of the tree; only one contained prostratin and within that variety, only trees of a certain size seemed to work (thus emphasizing the value of genetic diversity). The Samoans freely shared this knowledge with Cox. In exchange, he negotiated a profit-sharing agreement with the people of Falealupo. The U.S. government has promised that half of all royalty income from prostratin will go back to them. This represents one of the first formal legal recognitions of indigenous intellectual property rights. In addition to the profit sharing, any commercialized drug developed from prostratin will be supplied to developing countries for free.

While Cox and his colleagues believe ardently in each species' intrinsic value, they also agree that ethnobotany offers one of the best chances to preserve as many plant species as possible. "There is a strong link between the health of forests and the health of humans," he says. "If people understand that a rainforest might contain the best cures for diseases that plague us, they will care a whole lot more about saving it."◉

Research articles referenced in this chapter:
Mora, C. *et al.* (2011) *PLoS Biology* 9(8): e1001127.doi:10.1371/journal.pbio.1001127
Cox, P. A. (1993) *Journal of Ethnopharmacology*, 38: 181-188

BRING IT HOME

➲ PERSONAL CHOICES THAT HELP

Species and habitats provide numerous benefits to people, including water and air purification, food sources, recreation, and medicine. Unfortunately, many species are facing threats at ever-increasing levels. The good news is that we as a society have a direct impact on these threats and can make changes to ensure the survival of many of our at-risk species.

Individual Steps

→ Don't buy products made from wild animal parts such as horns, fur, shells, or bones. Only buy captive-bred tropical aquarium fish, not wild-caught fish.

→ Research the policies of a not-for-profit organization that protects biodiversity, such as World Wildlife Fund (WWF), Ocean Conservancy, Defenders of Wildlife, or the African Wildlife Foundation. Is it worth donating money to their cause?

→ Make your backyard friendly to wildlife, using suggestions from www.nwf.org.

→ Install an Audubon Guide app on your smartphone, or buy a field guide to learn the plant and animal species in your area.

Group Action

→ Work with faculty and other students to organize a bioblitz for a protected area in your region. A bioblitz, which is an intensive survey of all the biodiversity in the area, can generate a large amount of data to be used for habitat management and species protection.

→ Join a citizen science program monitoring wildlife. Many regional conservation groups have monitoring opportunities and provide training. For national programs, see the Cornell Lab of Ornithology website at www.birds.cornell.edu and the Izaak Walton League website at www.iwla.org.

Policy Change

→ The Endangered Species Act was the first U.S. legislation established to protect species diversity. To learn more about current challenges and updates to the program, visit epa.gov/espp.

UNDERSTANDING THE ISSUE

CHECK YOUR UNDERSTANDING

1. **Which of the following explains why there are more endangered tropical species than temperate species?**
   a. More people live in the tropics.
   b. Tropical species are more likely to be generalists with broad niches.
   c. Global climate change is warming the tropics more rapidly.
   d. Both a. and c. are correct.

2. **Why are many of the biodiversity hotspots around the world on islands?**
   a. Islands accumulate species from many different areas.
   b. Populations of island species are isolated.
   c. Islands have more diverse habitats.
   d. There are more niches on islands.

3. **The 'single species' conservation approach _____ the whole ecosystem conservation approach.**
   a. has never been as successful as
   b. focuses more on less conspicuous species than
   c. has the same ultimate goals as
   d. None of the above.

4. **If you live in a suburb or housing development and put out bird feeders, what kind of species are you likely to attract?**
   a. Core species
   b. Edge species
   c. Extirpated species
   d. Both b. and c. are correct.

5. **Whereas an individual with an anthropocentric worldview would stress the _____ value of species as a reason to conserve biodiversity, most environmental scientists would stress their _____ value.**
   a. intrinsic; medicinal
   b. instrumental; ecological
   c. ecological; instrumental
   d. intrinsic; cultural

6. **Which of the following does NOT directly contribute to biodiversity loss?**
   a. Habitat loss in tropical hotspots
   b. Invasive species in areas with high endemism
   c. Synthetic drugs derived from plants
   d. Fragmentation of habitat

WORK WITH IDEAS

1. Which is the most convincing reason for protecting endangered species: the intrinsic value of biodiversity, the possibility of finding medicines, or preserving ecosystem function? Why?

2. What are the ethical issues involved in preserving biodiversity in tropical areas?

3. Some agricultural researchers are interested in finding the wild ancestors of our domesticated animals and plants. They are concerned that modern food production uses only a few varieties of a given species, although there are many varieties that could be used. How is the protection of genetic diversity within a species both similar and dissimilar to the conservation of threatened species?

4. Of the different organizations, laws, and treaties that protect biodiversity (the Endangered Species Act, the Convention on International Trade of Endangered Species, etc.), which one do you think is the most powerful and effective globally? Why?

5. Describe how biodiversity and national security may be connected. Why do some people make the argument that maintaining biodiversity is critical to national and international security?

6. How can you, as an individual, help maintain biodiversity worldwide? Choose at least two actions that you can take; justify your choices as they relate to biodiversity.

ANALYZING THE SCIENCE

Biodiversity hotspots are regions of the world that are of particular importance to global biodiversity both because of the total number of species they contain and because of the number of *endemic species* they have.

The map on the following page shows the location of biodiversity hotspots around the world as well as the human population density.

INTERPRETATION

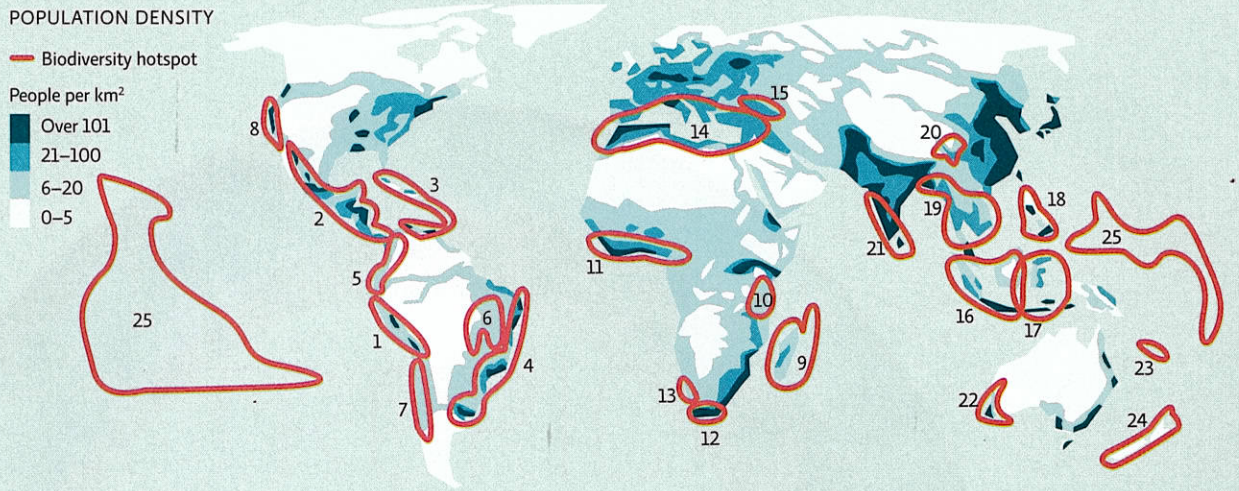
1. How many of the 25 hotspots include islands?

2. Describe the relationship between population density and biodiversity in one or two sentences.

3. Can you assume that biodiversity hotspots in highly populated areas are the most at risk? What other factors would you look for?

ADVANCE YOUR THINKING

4. Based on what you've already learned about human population growth, do you think that any hotspots that are not being threatened by development will become threatened in the next 50 years?



EVALUATING NEW INFORMATION

Visit the World Wildlife Fund website (www.worldwildlife.org). Start your exploration of the site by selecting the "What We Do" menu and reading the overview under the "Protect Wildlife" menu; note the conservation approach that WWF takes using flagship species as representatives of ecosystems.

Evaluate the website and work with the information to answer the following questions:

1. From the Protect Wildlife page, click on the "Flagship Species" link.
   a. What is the difference between a flagship species, a priority species, an indicator species, and a keystone species?

2. Does WWF provide evidence that its flagship species approach works?
   a. What scientific evidence does the organization provide?
   b. Does it mention any alternative conservation approaches?

3. Do you agree with WWF's approach to species conservation?
   a. How would you approach conservation?
   b. Do you think the WWF could get as many donations if it did not use charismatic species?

4. Select the "Conserve Places" menu and choose a conservation region to read about.
   a. What species are used to represent this region?
   b. What are the main threats to diversity in this region?
   c. What strategy is the WWF using to conserve the region?
   d. Would you do anything differently? Why or why not?

MAKING CONNECTIONS

PUBLIC WELFARE VERSUS PROTECTING A SPECIES

Background: The U.S. Endangered Species Act (ESA) has been controversial since its beginning around 40 years ago. One of the first major challenges to the ESA was the controversy surrounding the Tennessee snail darter. This small fish was endemic to a stretch of the Little Tennessee River that would be flooded due to the completion of the Tellico Dam by the Tennessee Valley Authority, a federal agency created to provide flood protection and electricity to the residents of the Tennessee River Valley.

Scientists, especially Dr. David Etnier, believed that the dam would eliminate the snail darter's habitat, since it needs shallow streams to live in, and therefore lead to its extinction. They argued that the snail darter added to the ecosystem diversity of the region, which is one of the most diverse in the United States.

U.S. congress members, especially Representative John S. Duncan Sr. and Senator Howard Baker (both of Tennessee), believed that construction should continue. Halting construction on the dam would cost millions of dollars and keep thousands of citizens without reliable electricity. Members of Congress eventually brought to the Supreme Court the case that, since construction of the dam began well before the enactment of the ESA, the project should be exempt. The Supreme Court decided that the Endangered Species Act did not make provisions for the construction of the dam and that the project must cease. Unhappy with the decision, Duncan and Baker led an anti–snail darter movement that was aimed at amending the Endangered Species Act.

Case: You are a stakeholder in the controversy (a scientist, dam builder, politician, etc.). Write a letter to your representative or senator to make your case on the issue of amending the ESA to allow the dam building to continue. Research the following opinions in your argument:

1. How much would the local citizens benefit from the dam?

2. What are the implications of exempting the protection of a species on the grounds of public welfare?

In your letter, be sure to include the following:

   a. Specific facts to support your argument
   b. Facts in support of the alternate argument that you can counter
   c. A discussion of the ethical implications of your position

As a follow-up to your letter, research and write a short discussion of your opinion of the actual outcome of the controversy (don't let this influence your position). Make sure to explain whether or not you think this was the best decision.