NATURAL HISTORY

10/05

Toxic Treasure

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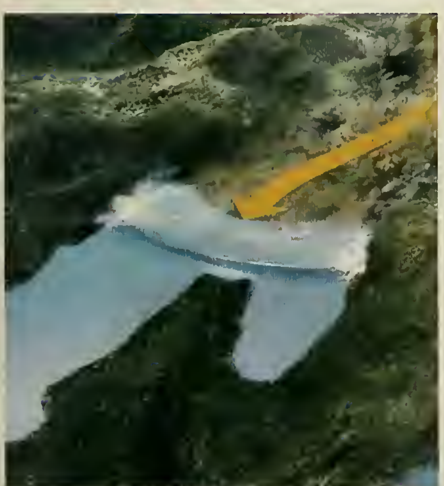
FEATURES



ON THE COVER:
Deadly box jellyfish *(Chironex fleckeri)*, also known as the sea wasp

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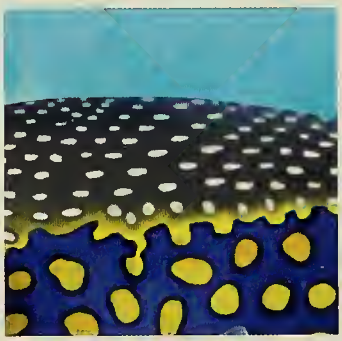
DEPARTMENTS



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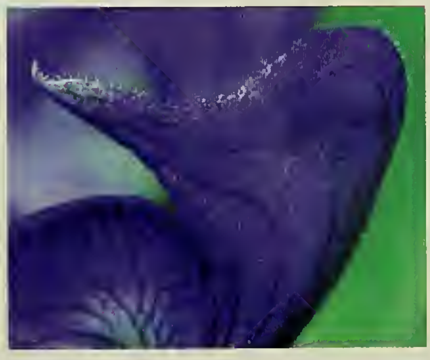

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THE NATURAL MOMENT

Fall Masquerade

Photograph by Art Wolfe

THE NATURAL MOMENT

◄ *See preceding two pages*

If spring in the Minnesota woods sings, autumn exhales softly. Take the inch-long spring peeper, *Pseudacris crucifer,* a chorus frog that lives among leaf litter and logs, near freshwater ponds. Its size and coloring make it easy to miss. The one pictured here didn't make a sound or move a muscle while under the sharp eye of photographer Art Wolfe.

Males start the spring by belting out a chorus of songs. But on finding a mate, they quickly quiet down (why advertise one's presence to predators?). Eggs hatch and tadpoles mature over the summer. When fall comes, the air can feel a bit like spring, and *P. crucifer* occasionally responds with a round peep; the effect is called the fall echo.

Winter is the real silencer. When cold weather sets in, the spring peeper hunkers down under the fallen leaves for a deep, solitary hibernation. Ice crystals start forming on the frog's skin and quickly work their way inside. The frog begins to churn out glucose from its liver, which will protect its cells from the deepening cold; its pulse slows, and its tissues continue to freeze. Finally the peeper's heart stops beating as it, too, solidifies.

Yet after the vernal thaw, the frog emerges no worse for the frigid wear. Its little body can still lighten or darken a few shades to match its surroundings. And it still has the strength for another mating rush—whose object is to be heard, but not seen.

—*Erin Espelie*

UP FRONT

Disciplined Change

What kind of world do we live in? Like everyone else, I learned about the universe from my parents and teachers, and I got used to it. A hundred elements, give or take. Nine planets. Three kinds of elementary particles. Two kingdoms of life. One big bang.

But perspectives change. No one knew about Mendelevium (number 101) when I was born. Kuiper Belt object 2003 UB313 wasn't on anybody's radar screen. Neither were the quarks that make up neutrons and protons, the three "superkingdoms" of life, or cosmic inflation within a multiverse.

Error, obscurity, conceptual fuzziness, and sheer ignorance are part of science, just as they are in any other human activity. The method of science—and science is a method, not a set of conclusions—is to clear away those faults. Geologists once thought that collapsing volcanoes were rare in Earth's history; now they know otherwise (see "Blown Away," by Lee Siebert, page 50). Toxicologists could once do little more than catalogue obscure animal toxins; now molecular and systematic biologists are showing that some toxins can become lifesaving medicines (see "Toxic Treasure," by Robert George Sprackland, page 40). Planetary astronomers long classified Pluto as a major planet; now a raft of newfound Pluto-like objects has forced people to think harder about the very concept of a planet (see "Number Ten?" by Charles Liu, page 64). Scientific ignorance about the number of species on Earth is so deep that the range of informed estimates still spans almost two orders of magnitude (see "Taking Inventory," by Piotr Naskrecki, page 46).

• • •

With all that change and potential for revision, you'd think that diversity of viewpoint would be a core value of science—that "teach the controversy," as proponents of so-called intelligent design put it, would be an unassailable principle of science education. Haven't we learned by now that every opinion counts, that every voice deserves respect?

What a lot of people may not realize, though, is that science doesn't work that way. Not for nothing are the branches of science called disciplines. In science, opinion polls don't matter. Not everyone's voice is equal. Yes, science is, or should be, open to anyone—anyone with the talent and tenacity to pursue it. And if you do earn your scientific "union card," you are still not immune from criticism—far from it. In fact, the criticism you attract from other scientists, grounded in evidence and the canons of valid argument, is a good measure of how seriously your scientific views are taken.

But scientific debate is not for the uninformed. Scientific controversy is for scientists, to be hashed out in conferences and peer-reviewed journals, not in the elementary science classroom or the high school science textbook.

• • •

The human and environmental catastrophe caused by Hurricane Katrina is compounded by the teethgrinding sense that so much of the suffering and devastation was preventable. *Natural History* was only one of many voices calling attention to the precarious plight of prehurricane New Orleans. In his "Taming the River to Let In the Sea" (February 2005), Shea Penland diagnosed the geologic, climatologic, and historical forces that ultimately led to the disaster, and that must still be addressed as the city rebuilds. Penland's article is online at www.naturalhistorymag.com. —PETER BROWN

CONTRIBUTORS

During his thirty-year career, **ART WOLFE** ("Fall Masquerade," page 4) has photographed wildlife on every continent and published more than sixty books. In 2000 he founded Wildlands Press to publish *The Living Wild* and *Africa*, and, in 2003, *Edge of the Earth/Corner of the Sky*. He received the National Audubon Society's first Rachel Carson Award in 1998, and two years later he won an Alfred Eisenstaedt Magazine Photography Award for nature photography.

"I really need to know where to step—and where not to!" says **ROBERT GEORGE SPRACKLAND** ("Toxic Treasure," page 40), a systematist and evolutionary zoologist who studies lizard biology, macroevolution, and the biodiversity of Australia and New Guinea. Although he does not work with venomous animals—his wife Teri insisted on "nothing venomous in the house" as a prenuptial condition—he works where they are common. He has published five books on herpetology and aquatic animals, as well as a CD of the sharks and rays of the world. The second edition of his book *Giant Lizards* (T.F.H. Publications, Inc.) is scheduled for publication in early 2006. So far, both his footing and marriage are doing fine.

PIOTR NASKRECKI ("Taking Inventory," page 46), a research associate with the Museum of Comparative Zoology at Harvard University, is the director of the Invertebrate Diversity Initiative (IDI) for Conservation International, whose headquarters are in Washington, D.C. He earned his Ph.D. in entomology from the University of Connecticut in 2000 with a dissertation on the phylogeny of katydids. At IDI Naskrecki gathers and synthesizes data on the distribution of numerous groups of invertebrates, both by species and by population. The information then becomes the basis for making decisions about how to apply conservation policy, such as when and where to designate hotspots of biodiversity.

A volcanologist with the Smithsonian Institution's Global Volcanism Program, at the National Museum of Natural History in Washington, D.C., **LEE SIEBERT** ("Blown Away," page 50) has spent much of his career compiling data on volcanoes. He is an author of *Volcanoes of the World*, the Smithsonian's comprehensive catalog of the world's Holocene volcanoes and their eruptions, and its updated online version (www.volcano.si.edu/world). The 1980 eruption of Mount St. Helens sparked his research interest in collapsing volcanoes. Field studies of collapse-prone volcanoes have taken him to Alaska, the Cascade Range of the western United States, Guatemala, Indonesia, Japan, and most recently El Salvador and Mexico.

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Going Green

In his excellent article on the future of space travel, ["Heading Out" (7–8/05)], Neil deGrasse Tyson described some, but not all, of the new "green" space-propulsion technologies. One further possibility is the electrodynamic tether (ET), a thin cable that generates a current when it is pulled through a magnetic field. The tether would work best for objects in low orbit around a planet, such as Jupiter.

Another "green" concept in space propulsion is "aerocapture." A probe approaching an atmosphere-bearing planet could slow down by deploying an appropriate shield or inflatable "ballute" (a combination balloon and parachute). The probe would then make a grazing pass through a planet's atmosphere until it was gravitationally captured as an artificial satellite—a maneuver that can be done without using propellant.

Gregory L. Matloff
New York City College of Technology, CUNY
Brooklyn, New York

Leidy's Legacy

In "Jointed Threads" [6/05], Lynn Margulis implies that *Bacillus anthracis*—the bacterium that causes anthrax—violates some law of symbiosis because it is a pathogen. She calls it "a freak of nature"; I disagree.

The ecological role of *B. anthracis* is to prevent overgrazing by animals. Its spores lie dormant in the soil of a field until patches of bare ground appear between the surviving tufts of grasses and forbs. Then, during dry periods, grazers may ingest or inhale the anthrax spores. As the grazers die off, the field can recover. Later, when it is overgrazed again, the anthrax spores will defend it once more.

Donald A. Windsor
Norwich, New York

In Lynn Margulis's article, the caption for Joseph Leidy's teaching chart states that two nematodes are depicted. But the uppermost wormlike organism in the drawing actually appears to be an oligochaete—most likely of the species *Stylaria lacustris*. The specimen in the drawing is segmented, which is a diagnostic characteristic of an oligochaete, and it has a long proboscis, an important feature that occurs in members of the genus *Stylaria*. *S. lacustris* commonly lives in freshwater in North America, but as far as I know, it does not occur as a symbiont.

Michael McMahan
Union University
Jackson, Tennessee

LYNN MARGULIS REPLIES: I implied nothing. I wrote of the need to condemn people who would arm a bacillus to become a human pathogen. I'm grateful to Donald A. Windsor for his elegant ecological explana-

(Continued on page 66)

Steps Back in Time

The announcement that some 160 human footprints have been discovered embedded in an ancient layer of volcanic ash near Puebla, Mexico, has stirred the continuing debate about how, and when, people first arrived in the Americas. In spite of disputed evidence and many challenges to the contrary, the consensus among paleoanthropologists is that the first people to set foot on the continent crossed from Siberia into Alaska by about 11,500 years ago. Clovis points, the spearheads that trace their culture, are scattered across North America.

Human footprints in Mexico, 40,000 years old

But the Mexican footprints have been dated to 40,000 years ago, raising new doubts about the "Clovis-first" theory. Silvia Gonzalez, of Liverpool John Moores University in England, and a team of British, Australian, and Mexican paleontologists are studying the find. Children probably made about a third of the human prints, they report. The investigators also discovered about a hundred animal footprints, mostly from dogs, big cats, and what may have been camels, cows, or deer.

The discovery is also noteworthy because fossilized footprints are so rare. In the present case, they probably formed when people walked along a lakeshore covered with soft ash after the nearby Cerro Toluquilla volcano erupted. When the lake flooded, the imprints were preserved under silt. Where the people came from, and whether they arrived by land or sea, remain open questions. (*Quaternary Science Reviews*, forthcoming)

—*Stéphan Reebs*

Know Thine Anemone

Persistent border separates two clones of sea anemones.

Sea anemones don't come across as particularly complicated social creatures. Who would have guessed they organize themselves into armies, with tentacled soldiers at the front fighting violent underwater battles? Yet that's the conclusion reached by David Ayre, an evolutionary biologist at the University of Wollongong, Australia, and Richard Grosberg, an evolutionary biologist at the University of California, Davis, from their study of the sea anemone *Anthopleura elegantissima*.

The species lives in groups of hundreds to thousands of genetically identical individuals, known collectively as a clone. Within a clone, individual polyps fall into one of several classes, or castes—rather like the castes of social insects such as ants or bees. A polyp's caste may be determined by its location within the clone and by cues it receives from other polyps. Where a clone borders another clone, "warriors"—small, heavily armed polyps, bristling with stinging tentacles—square off against their counterparts in the neighboring clone. Some warriors act as "scouts" that try to infiltrate enemy lines, but often they're forced to retreat to the safety of their own clone. Far from the lines of battle another class of polyp—the large, relatively unarmed, and sexually mature "reproductive"—safely dwells in the center of the clone.

Battlefronts are marked by persistent polyp-free zones, a kind of "no anemone's land." In spite of warriors' struggles to defend and acquire more territory, these borders are stable, and competing clones can remain deadlocked for years. (*Animal Behaviour* 70:97–110, 2005)

—*Nick W. Atkinson*

The Great Neon Sign in the Sky

What do Las Vegas and the Sun have in common? Answer: an apparent abundance of neon. A new study suggests that neon, the fifth-most-common element in the cosmos, is as much as three times more abundant in the Sun than astrophysicists had previously thought.

The astrophysical model of how the Sun works has been at odds with observation for the past couple of years. At issue is the depth of the Sun's convection zone, a 125,000-mile-thick layer of roiling gases that helps transmit energy from the Sun's core to its surface. The model relies on an assumed mix of carbon, neon, nitrogen, and oxygen within the zone to predict one depth, whereas the data suggest another depth. Some investigators have noted that tripling the neon that the model assumes in the mix would resolve the discrepancy.

But measuring the Sun's neon content is tricky. So Jeremy J. Drake of the Harvard-Smithsonian Center for Astrophysics and Paola Testa of the Massachusetts Institute of Technology turned to its neighbors. They analyzed data from NASA's earth-orbiting Chandra X-Ray Observatory for twenty-one sunlike stars within 400 light-years of Earth. On average, they found, the ratio of neon to oxygen in each star is three times what is predicted for the Sun. If the Sun is anything like its neighbors—and astrophysicists think it is—it should have triple the neon previously thought. Astrophysicists can keep their theory about how the Sun works. And the casinos in Las Vegas can rest assured there's enough neon to power the glow of their signs indefinitely. (*Nature* 436: 525–28, 2005) —*Rebecca E. Kessler*

Shades of Green

Coffee is grown in one of two ways: in open fields, an intensive enterprise that relies on fertilizers and pesticides, or in small, shaded plantations, where coffee plants often replace the bushes of a tropical-forest understory. Such shaded coffee plantations are widely regarded as ecologically friendly, because they tend to preserve the diversity and number of bats, birds, and insects that live in tree canopies.

But don't mistake a shaded coffee plantation for an intact forest, warns Roger Guevara of the Institute of Ecology in Xalapa, Mexico. Below the canopy, differences abound. Obviously, the native bushes are gone, and understory-dwellers such as certain ants, birds, and frogs are already known to be adversely affected. Now Guevara's research shows that below-ground organisms may also take a hit. Working in the central part of the Mexican state of Veracruz, Guevara looked at fungi shaped like long, thin cords, which play an important role in decomposing woody debris and in preventing minerals from leaching away. He discovered that the fungi are smaller and about ten times less abundant in the plantations than they are in untouched forests. The cause seems to be the dry soils that result from the relatively open canopy. (*Biological Conservation* 125: 261–68, 2005) —*S.R.*

Beyond shade-grown coffee bushes, which replace a forest understory in Veracruz, Mexico, an open coffee plantation rises on a deforested slope.

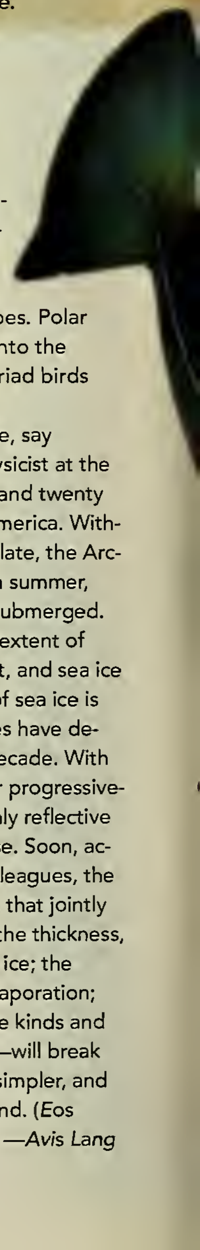
Monarchs overwintering in Michoacan, Mexico, prepare for their springtime migration to the U.S.

Fly Long, Live Longer

In a laboratory in Atlanta, Catherine A. Bradley and Sonia M. Altizer, both ecologists at Emory University, put monarch butterflies through their paces on "flight mills." An insect is glued to the end of a horizontal rod that is free to rotate about a central axle. The monarch flutters round and round, while a computer registers the number and speed of the rod's rotations.

The purpose of the exercise is not to turn the butterflies into paragons of health, but rather to test their long-distance flight performance. Bradley and Altizer found that monarchs heavily infected with the common protozoan parasite *Ophryocystis elektroscirrha* are between 10 and 20 percent less proficient as fliers (measured by a combination of flight speed, endurance, and use of energy reserves) than their parasite-free kin.

The finding can help explain a curious phenomenon. Monarchs from the eastern United States and Canada undertake one of the longest insect migrations known (as far as 3,000 miles) to reach overwintering grounds in Mexico, and less than a tenth of the population carries parasites. In contrast, monarchs from the western U.S. migrate a shorter distance, to coastal California, and many more, about a third, are infected. The most extreme cases are the tropical monarchs, which aren't known to migrate at all; more than three-quarters of them are afflicted with *O. elektroscirrha*. Perhaps, Bradley and Altizer suggest, the rigors of travel cull butterflies infected with parasites. Hence, the longer the migration, the healthier the population. (*Ecology Letters* 8:290–300, 2005) —*S.R.*



Unfrozen North

For at least a million years, summertime north of the Arctic Circle has meant two months of partial melt. Unbroken expanses of sea ice fracture into ice floes. Polar bears dive off the sturdy floes into the temporarily open seawater. Myriad birds nest along exposed shorelines.

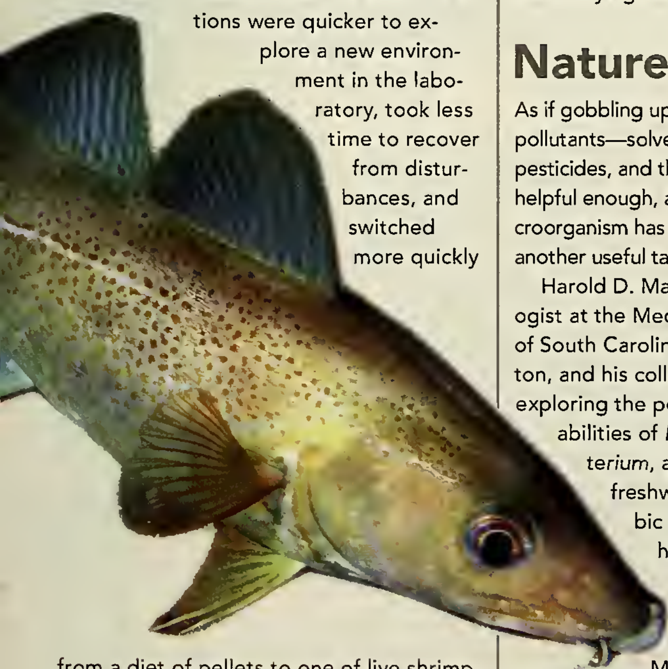
But all that could soon change, say Jonathan T. Overpeck, a geophysicist at the University of Arizona in Tucson, and twenty colleagues from across North America. Within less than a century, they calculate, the Arctic Ocean may well be ice free in summer, and its shorelines permanently submerged.

For the past thirty years, the extent of Arctic snow, glaciers, permafrost, and sea ice has been diminishing. The loss of sea ice is striking: the September averages have declined by about 8 percent per decade. With less and less surface covered for progressively shorter periods by white, highly reflective ice, the melting rate is on the rise. Soon, according to Overpeck and his colleagues, the interrelations among the factors that jointly sustain the Arctic as a system—the thickness, coverage, and reflectivity of the ice; the amounts of precipitation and evaporation; the saltiness of the seawater; the kinds and activities of resident organisms—will break down. The system will become simpler, and the Arctic Ocean liquid year-round. (*Eos* 86:309–16, 2005) —*Avis Lang*

Amuse Me or Lose Me

Fish populations are declining throughout the world. One way to buck the trend is to raise large numbers of fish in hatcheries and release them into the wild. Alas, it's a tough world out there, and artificially raised fish usually grow up lacking the skills and motivation they need to find food and escape predators. But a simple solution to the problem may now be at hand.

According to new research by two behavioral ecologists, Victoria A. Braithwaite of the University of Edinburgh, Scotland, and Anne G. V. Salvanes of the University of Bergen, Norway, the trick is to spruce up the dull environment in which such fish usually grow. Cod, for instance, are reared in featureless tanks, where they get the same food pellets, at the same time, every day. Braithwaite and Salvanes added pebbles, rocks, and plastic kelp to the nursery tanks, and every day they varied the time and location of the meals. Compared with cod artificially raised in the usual manner, the cod raised under the new conditions were quicker to explore a new environment in the laboratory, took less time to recover from disturbances, and switched more quickly from a diet of pellets to one of live shrimp.



Boldness, flexibility, and willingness to try new food may boost the chances of survival in the wild. Restocking programs that combine these rearing methods with careful selection of good local genetic stock could help to mold fully functional citizens of the deep. (*Proceedings of the Royal Society* B, **272**:1107–13, 2005) —*S.R.*

Secret Forays

Many migrating songbirds are on the wing in the middle of the night, a flight risk for birds not accustomed to the dark. So how does a bird develop its "stellar compass"—long suspected as the main navigational tool of long-distance migrators—if it normally sleeps at night? How, for that matter, does it recognize its home turf, its future breeding sight, in the dark (a key question for the return trip)? The answer is surprisingly simple, though it's taken the latest technological gadgetry to tease it out: young songbirds, like teenagers, just stay up late.

A team of Russian ornithologists, led by Andrey Mukhin of the Max Planck Institute for Ornithology in Andechs, Germany, attached miniature radio transmitters to each of several dozen juvenile Eurasian reed warblers, *Acrocephalus scirpaceus*, as the juveniles began to prepare for migration. Young songbirds don't get much time for flight practice; the journey begins, on average, just fifty days after hatching. So the biologists found that the birds cram their "instrument"-flying lessons into twelve days of nocturnal forays around their own patch of Earth. Mukhin and his colleagues conclude that in so doing, the fledglings learn about the subtleties of celestial navigation—not to mention what their home turf looks like from the air—before they depart for good. (*Proceedings of the Royal Society* B, **272**: 1535–39, 2005)

—*N.W.A.*

Eurasian reed warbler

Nature's Little Power Plants

As if gobbling up some of humankind's worst pollutants—solvents, dry-cleaning chemicals, pesticides, and the like—weren't helpful enough, a certain microorganism has revealed yet another useful talent.

Harold D. May, a microbiologist at the Medical University of South Carolina in Charleston, and his colleagues were exploring the pollution-eating abilities of *Desulfitobacterium*, a genus of freshwater anaerobic bacteria, when he discovered that it also makes electricity.

What surprised May was not that bacteria can generate electricity; that has been known since 1912. But *Desulfitobacterium* is quite distinct from other electricity-generating bacteria. Until May's discovery, microbiologists thought only Gram-negative bacteria, with two cell membranes (an inner and an outer), could create a voltage, or electric potential difference, between the two membranes (proteins embedded in the outer membrane then may be able to conduct the electric current generated by the potential difference). *Desulfitobacterium*, however, is Gram-positive, with just one cell membrane that may or may not carry embedded proteins. So the bacterium must make electricity in a distinct way; the mechanism remains a mystery that May is still exploring.

Two wormlike bacteria (genus Desulfitobacterium*), magnified 3,300 diameters, deposit electric charge on an electrode (diagonal substrate).*

Desulfitobacterium is also the only known electricity-producing microorganism that can form spores—inactive life stages that can withstand extreme drying, heat, and radiation. May imagines that a fuel cell powered by *Desulfitobacterium* could remain dormant for long periods before springing to life. Perhaps one could be made suitable for long-distance space travel. (Presented at the 105th General Meeting of the American Society for Microbiology, June 5–9, 2005) —*R.E.K.*

Energy to Burn

Conserved, consumed, or converted, it's the engine that drives every event.

By Neil deGrasse Tyson

The word "energy" pops up everywhere nowadays. Did you have enough energy to get out of bed on time this morning? Does that vitamin-charged, candy-colored sports drink deliver the energy promised in the ads? How much energy do you spend chasing your kids? Are your energy costs going up this winter? Will new sources of renewable energy alleviate the new energy crisis?

Words that get used in many different ways tend to invoke elusive or imprecise concepts. In spite of some abuses within the New Age movement, "energy" is not that kind of word. What it describes is real and measurable. Energy drives everything that has ever happened in the universe. Without it, nothing would move, no tasks would ever be started or finished, and no events would ever take place.

Across the cosmos, energy takes on multiple identities and spans a staggering range of strengths. At the lowest end, though not quite at zero, is the so-called quantum vacuum, also known as the zero-point field. It's the closest possible approximation of total lethargy offered by the universe. (Paradoxically, the zero-point field of the entire cosmic vacuum may account for the mysterious acceleration of the universe.)

Individual electrons are a few steps up the energy scale. They whirl around the protons and neutrons of the atomic nucleus at assorted energy levels that trace concentric clouds. Once every 10 million years or so, the lone electron in any given hydrogen atom in interstellar space does a stately "spin flip," which shifts it to a slightly lower energy and releases a radio wave—a big event in the life of that atom, but nothing you'd write home about.

Take a big leap up the scale, and you get to the destructive potential of the thousand-foot-wide asteroid 99942 Apophis, which has Earth in its path and enough impact energy to wipe a major city clean of all its structures and inhabitants. Unlike friendly asteroids, with friendly names like 445 Edna or 1060 Magnolia or even 13123 Tyson, asteroid Apophis bears the Greek name of the Egyptian god of chaos, darkness, destruction, and evil.

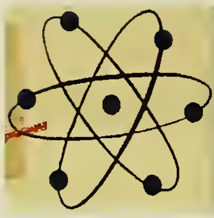
Stronger still is the raging furnace in the Sun's core, which generates enough

nuclear energy in one second to supply the needs of every person on Earth for a trillion years. Up near the high end is the omnipresent cosmic microwave background; although weak and harmless locally, in its entirety it holds some ninety powers of ten more energy than the hydrogen spin flip. Way at the top of the scale is the big bang: the sum total of all the cosmic energy that ever was or will be, and the beginning of everything we know and love.

What we on Earth commonly rank as high-energy events—hurricanes along the Gulf Coast, nor'easters in New England, volcanic explosions in the Cascades, earthquakes in the Indian Ocean—rank rather low on the cosmic energy scale, even though such events take a horrific toll on lives and property. Yet in none of those natural disasters is the energy high enough in any single spot to disturb an atomic nucleus.

What about the energetic domains beyond the natural but limited range available on our own planet? In the 1930s, physicists succeeded in concentrating energy into a very small space for a very short time. They did it by smashing atomic nuclei together in particle accelerators, then watching what took place during the collision. Ever since, with each new generation of technology, increasingly powerful accelerators have slammed subatomic particles together at ever higher speeds, focusing ever more energy into ever smaller volumes. This exercise in energy leapfrogging has pushed physicists to probe regimes of energy that greatly exceed the centers of the hottest stars. The most powerful accelerators probe key episodes in the formation of the universe itself.

Yes, particle physicists do have an occasional twinge of energy envy, the your-smasher-is-bigger-than-my-smasher kind. But building huge accelerators is the only way to cozy up to the building blocks of matter. The latest-generation machine is the Large Hadron Collider at CERN (the European Organization for Nuclear Research), scheduled to be turned on in 2007. Three hundred feet underground at the border between France and Switzerland, inside a tunnel seventeen miles long, two beams of protons will collide with a total energy of fourteen teraelectronvolts. That's the level of collision energy you'd find among particles in a gas heated to a toasty 200 quadrillion (2×10^{17}) degrees. The last time anyplace in the universe reached such soaring temperatures was a trillionth of a second after the big bang.



Never is the energy of a hurricane or an earthquake strong enough to disturb an atomic nucleus.

The quest to explore, control, and ultimately transcend the realm of earthly energy enjoys a history almost as old as civilization. The ancient Greeks, as usual, had something to say about the subject. *Energeia* is their word, usually translated as "activity." To Aristotle the word signified work, movement, or concrete, tangible change. Energeia contrasted with *dynamis*, "potentiality," which signified the ability, capacity, or power to do something. Back then, however, neither energeia nor dynamis was something you measured.

As late as the seventeenth century, energy was an ill-defined concept, even to Isaac Newton, and was all but absent from writings on the physical properties of the cosmos. Only in the nineteenth century did the study of energy come of age, with the invention of the branch of physics known as thermodynamics. When combined with the analysis of stellar spectra, the science of astronomy was reborn near the turn of the twentieth century as the science of astrophysics: the study of the coldest, the hottest, the least energetic, and the most energetic objects and phenomena in the cosmos.

In spite of the near-absence of the concept of energy in seventeenth-century science, the culturally seismic event known as the Industrial Revolution could not have come about without the physics of Newton. The *Principia*, Newton's seminal 1687 treatise on motion and gravity, provided the conceptual machinery to understand and predict the interplay of forces, matter, and motion. That interplay would prove fundamental in the design of any hunk of hardware that expends energy and does work—notably the machines of growing complexity that, during the Industrial Revolution, drastically altered the nature of agriculture, manufacturing, transportation, and daily life. Advances in the design of such machines came in lockstep with advances in the measurement and manipulation of energy—including an understanding of how, when, and where to store it for later use, in everything from batteries to bombs to rocket boosters.

Many kinds of machines, of course, have performed useful work for millennia. The energy of falling water has driven wheels that have turned millstones that have ground grain. In early medieval Europe, waterwheels powered olive presses, crushed mash, drove pumps, and operated the bellows of the blacksmith's furnace and forge. Wind, too, has long driven wheels: windmills were in use by the seventh century A.D. in the Middle East and not long thereafter in Europe and China. By Newton's day, common machines included the foot-operated two-bar loom; the two-wheeled, animal-drawn plow; the spring-driven clock; and the printing press.

Those early machines were useful because they could change one kind of motion into another. But unlike the machines of the Industrial Revolution, they did not meaningfully transform

one kind of energy into another. They did not consume chemical energy in the form of coal or petroleum and turn it into mechanical energy. They were not powered by electrical energy. They did not generate vast amounts of excess thermal energy—otherwise known as heat. In fact, their inventors were not even thinking about energy—which is perfectly understandable, because nobody yet understood the concept.

But in 1769 the technology for energy conversion took its great leap forward. In that year James Watt, a Scottish craftsman who made precision instruments, secured his patent for "A New Invented Method of Lessening the Consumption of Steam and Fuel in Fire Engines." Watt's patent covered an improvement in the design of the steam engine, which at the time was a wildly inefficient (and dangerous) device for transforming heat energy into mechanical energy. The pre-Watt engine converted, at best, only about 1 percent of the steam's heat energy into usable mechanical energy.

As Watt came up with more and more improvements, more and more owners of tin mines, cotton mills, and grain mills turned to steam power, and when his patent lapsed in 1800, other inventors jumped at the chance to make improvements of their own. In 1804 the world's first steam locomotive hauled ten tons of iron and seventy men along a Welsh tramway a few miles north of Cardiff. And in 1807 the world's first commercial steamboat service made its maiden run, plying the Hudson River between New York City and Albany.

A steam engine, like all other machines, runs on fuel—material preloaded with energy that's ready to be tapped. Before the late eighteenth century, machines were powered by the preloaded chemical energy in food: feed a person a bowl of gruel and a beast of burden a pile of hay, attach one to a loom and the other to a plow, and you could get a full day's work out of both. But the steam engine (and other engines) made it possible to extract preloaded chemical energy from wood or coal instead of from food. And the transformation was self-evident: you extracted chemical energy from fuel to heat water so as to make thermal energy (steam) that would produce mechanical energy (the working engine).

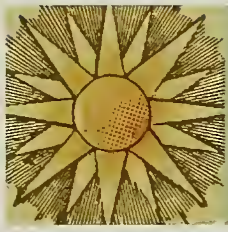
Since the Industrial Revolution, people have depended on machines that convert one form of energy into another.

Since the Industrial Revolution, the natural sources of chemical energy have multiplied: gasoline, kerosene, propane, peanut shells, used cooking oil, sugar beets. Atomic nuclei are just a high-tech variation on the same theme—just another energy source, which happens to be nuclear.

Ways of converting energy have also multiplied. Consider the so-called pyroelectric effect: Take a crystal of lithium tantalate, douse it in deuterium gas, cool it to about −30 degrees Fahrenheit, then apply just enough heat to raise its temperature to about 45 degrees in a few minutes. The crystal will produce an electric field strong enough to accelerate the deuterium nuclei to about 1 percent the speed of light, causing them to fuse together into helium nuclei and release an X ray. Sounds like the pyroelectric effect would make a handy source of free energy, doesn't it?

But somebody had to make the crystal in the first place, somebody else had to isolate the deuterium gas, and a lab technician had to plant the experiment in a freezer plugged into the wall. In this instance, you don't win. You might have, though: the energy of a helium nucleus is less than that of

two separate deuterium nuclei, and the difference gets released as heat and light. Problem is, this emission barely makes up for the investment of energy that got you there. The dream behind nuclear fusion reactors is to fuse hydrogen into helium—as the Sun does every moment of every day—but to do it in a controlled, efficient way that releases significantly more energy than you put in.



A type II civilization could harness, at will, the entire energy production of its host star.

When you pull your fuel supply out of the ground (as with grass or petroleum or coal) or get it from the sky (as with sunlight or wind), it may seem like a free lunch. But preloading a substance with chemical energy, particularly a substance that takes as long to form as petroleum does, requires a lot of work. Earth, rather than a farmer or a coal miner, may have done the physical or chemical labor, and the process may have taken weeks or months or millennia. Nevertheless, converting a forest into petroleum, or grass seed and CO_2 into hay, is not done without the expenditure of at least as much energy as you would recover from the fuel itself. So there's no free lunch.

And no machine is 100 percent efficient: when it converts one form of energy to another, you never get as much usable energy out as the total amount of energy that went in. Because of internal friction, some energy is always "lost" as heat—the lowest, least useful form of energy. That's the main reason no machine, left to its own devices, will run forever. In other words, nature forbids the perpetual motion machine. So, not only is there no free lunch, but the lunch you're served is always smaller than the one you ordered.

But no matter what the attributes of the machine, its behavior follows cosmic rules. Among them are the laws of thermodynamics. Formulated in the nineteenth century, and stated in the form you might recognize from middle-school science class, one key law of thermodynamics is that energy can be transformed from one kind to another but can never be created or destroyed. Modified in the age of Einstein, that law—the first law of thermodynamics—declares that the total of matter *and* energy cannot be created or destroyed. The second law is that the universe is a one-way street, in which systems, left to themselves, will become more and more disordered. Those two laws govern the thermodynamic goings-on within every machine, as well as the sequence of events in every laboratory experiment ever conducted.

In 1964 the Russian astronomer Nikolai Kardashev proposed that access to energy is a meaningful basis for classifying civilizations. On the so-called Kardashev scale, a type I civilization can harness, at will, any or all of the energy on and within its home planet. It controls all the sunlight that falls to its planet's surface, and could, if desired, reach into a volcano or a hurricane and tap its energy the way you tap a faucet. A more advanced, type II civilization can tap the entire energy production of its host star; a type III civilization, all the energy of all the stars in its host galaxy. With access to that much energy, just imagine how much trouble you could get into!

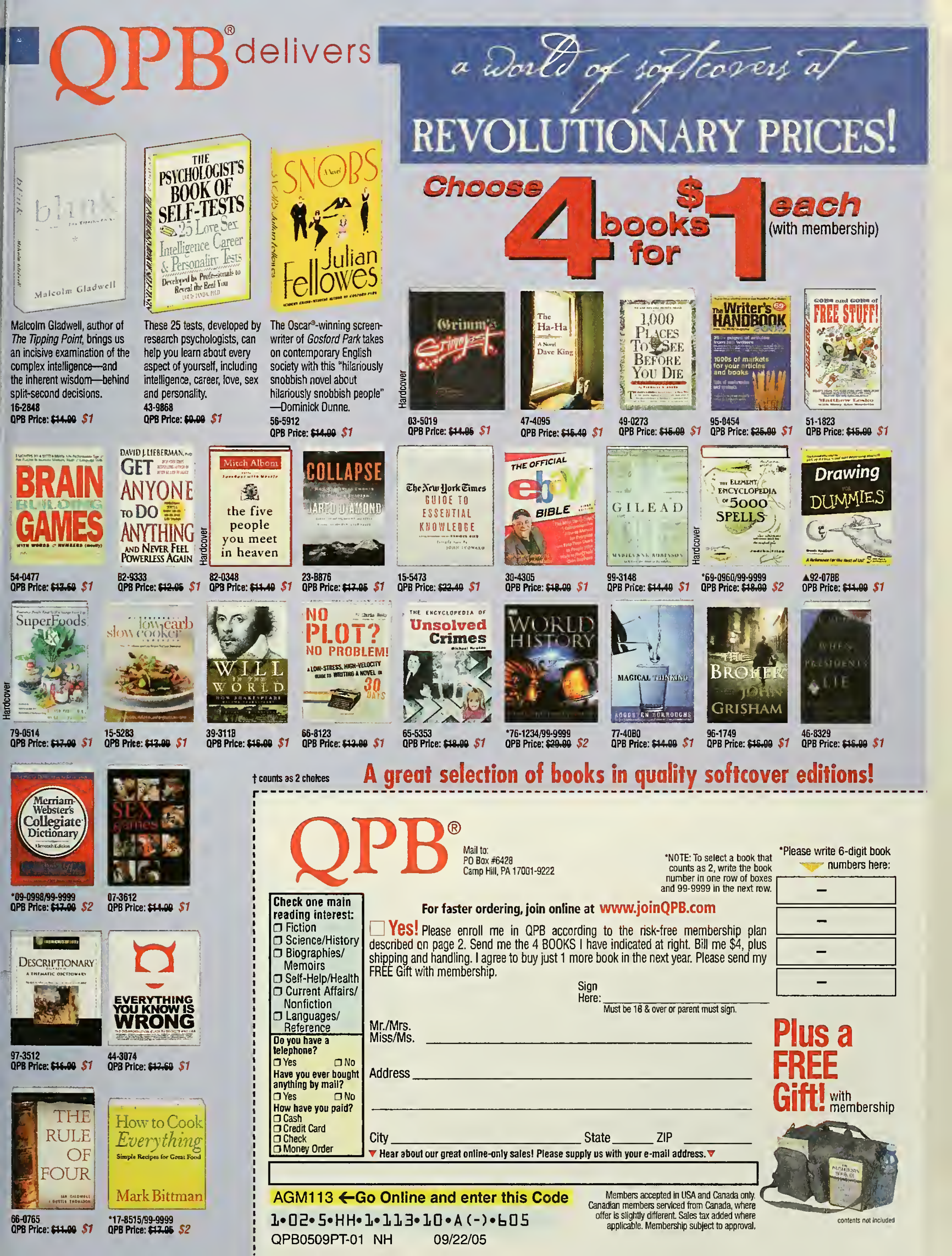
So where do earthlings fit in? Hate to break the news, but any civilization so fragile that its members must stockpile fossil fuels, run away from erupting volcanoes, evacuate cities in advance of hurricanes, and rush to high ground during tsunamis is not in charge of its own planet, and can be none other than type zero.

Access means consumption, of course, and real civilizations here on Earth do plenty of consumption. In the first year of the twenty-first century, fossil fuels—a total of nearly 9 billion tons—provided 80 percent of all the energy our planet's inhabitants consumed. And Americans, who constitute less than 5 percent of the world's population, consume more than one-fifth of the world's energy nowadays. We're not quite in first (or last) place, though. Per capita, Canadians consume more energy than we do. So do Bahraini and Luxembourgers. Icelanders, whose country produces plenty of renewable geothermal energy from its multitudinous hot springs, top the list.

New York City, by the way, is a model of energy efficiency, thanks, in large measure, to mass transit and to the locals' scaled-back use of the automobile. Only one in four residents of the five boroughs owns a car. Nationally, there are three cars for every four people, and the folks who own SUVs might use a gallon of gas for the round trip to the grocery store to buy a gallon of milk.

No discourse on energy should end without noting that Americans are some 6 billion pounds overweight. We carry enough excess preloaded energy—rolls and slabs of fat, layered on our bellies and butts—to sustain the entire population of Afghanistan for a year. Here's another way you could look at it: much of our excess fat comes from the animals we've eaten, which got their energy from the plants they ate, which got their energy from the sunlight they absorbed, which could be traced back to the fusion of hydrogen into helium in the core of the Sun. So, if nothing else, American bodies are formidable repositories of solar energy. Too bad we don't all tap into those "strategic reserves" and walk off our current energy crisis.

Astrophysicist NEIL DEGRASSE TYSON *is the director of the Hayden Planetarium at the American Museum of Natural History. His latest book, co-authored with Donald Goldsmith, is* Origins: Fourteen Billion Years of Cosmic Evolution *(W.W. Norton, 2004).*



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Waimea Valley, occupied in more recent times by plantation workers, cowboys, soldiers, and operators of tourist attractions, conceals most of its indigenous past underground and in hard-to-reach hillside caves.

FIELD NOTES

Kahuna Chronicles

An archaeologist traces a sacred Hawaiian valley from myth to modern times.

By Joseph Kennedy

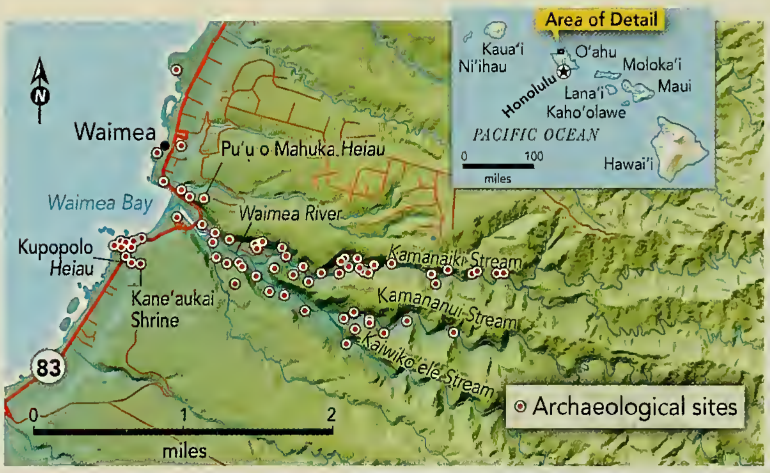
The Waimea River flows westward into the Pacific, on the northwest coast of the island of O'ahu. About 900 years ago, according to Hawaiian lore, a chief named Kaīmapua'a (the breath mark is pronounced as a glottal stop) recognized the rugged valley formed by the river and its tributaries as a special, spiritual place and awarded its oversight to high priests of the Pa'ao lineage. The priests, members of one of the ancient Hawaiian ruling classes, were known as *kahuna*, and the elite members of this group were known as *kahuna nui*, or "big kahunas"—a label that (stripped of its respectful meaning) has found its way into colloquial English. Among the religious structures they erected in and around the valley was Pu'u o Mahuka. Situated on a cliff overlooking the valley, it was O'ahu's largest *heiau*, or temple. The valley was also witness to human sacrifice, the darkest element of the indigenous religion.

For forty generations Waimea Valley and its sacred precincts stood as one of Hawai'i's principal cathedrals. Yet little more than a century after 1778, the year of the first European contact, the native Hawaiians were all but swept from the valley. Much of that pre-contact past now lies buried along with its former residents, whose bones rest in caves on the valley sides. The reconstruction of that past has fallen to historians and archaeologists. As an archaeologist who has reviewed what is already known about the valley, I think its grounds offer tremendous potential for revealing details about past lives.

There are just a few tidbits of ancient lore about the importance of the valley, recorded during the early contact period. One tale about Waimea Valley is set in the bay at the mouth of the river. It seems a man named Kane'aukai transformed himself into a stone the size of a human head and a log the size of a body. Local fishermen pulled his two parts from the sea

Etching based on a sketch by the Protestant missionary Hiram Bingham shows Bingham preaching in Waimea Valley in 1826. Seated near him are the Hawaiian queen, Ka'ahumanu, and, in all likelihood, Hewahewa, the last of the valley's high priests.

and reunited them within a shrine, ensuring ever afterward that fish would be locally plentiful. The stone and the log are long gone, but the shrine, made of rocks and recently reconstructed, still stands on the shoreline.



Author's compilation of known surface sites reflects the archaeological richness of Waimea Valley. Untold additional features lie concealed below ground or in unsurveyed areas upstream and on steep valley sides.

When O'ahu was first visited by Westerners, the *kahuna nui* in charge of Waimea Valley was Ka'opulupulu. According to several later historical accounts, Ka'opulupulu built temples in the valley in the late 1700s and used some of them for psychic communication with people on the island of Kaua'i. He believed that thoughts were like little gods that flew above the earth as freely as soaring birds. Although archaeology certainly cannot verify such psychic events, preliminary radiocarbon dating of the sites attributed to Ka'opulupulu appears to confirm the time frame.

The first Western ships to anchor off O'ahu, in Waimea Bay, were *Discovery* and *Resolution,* commanded by captains Clerke and King, shipmates of the English explorer James Cook. They were on their way to Kaua'i, following Cook's murder on the Big Island of Hawai'i in February 1779. King commented that the setting "was as beautiful as any Island we have seen, and appear'd very well Cultivated and Popular." Clerke wrote in his journal:

> On landing I was reciev'd with every token of respect and friendship by a great number of the Natives who were collected upon the occasion; they every one of them prostrated themselves around me which is the first mark of respect at these Isles.

The Englishmen had Hawaiian women on board, brought from the Big Island. At Waimea the women danced a hula, which the sailors found quite lascivious. From the deck of the *Discovery,* William Ellis, the ship's surgeon's second mate, painted an idyllic watercolor of the valley.

Westerners' next visit to Waimea, thirteen years later, proved to be a far less idyllic encounter. Richard Hergest, a former midshipman on the *Resolution,* was in command of his own vessel, the supply ship *Daedalus.* Recalling the warm reception and sweet water he had earlier received, Hergest anchored in the bay on May 7, 1792. In spite of warnings from two Hawaiians on board that "evil people" resided in Waimea Valley and that there were no chiefs present, Hergest set off with the astronomer William Gooch, a sailor named Franklin, and a Portuguese hand named Manuel.

After reaching shore, Franklin and Manuel busied themselves with the water casks while Gooch and Hergest wandered inland. Suddenly, men armed with spears, daggers, and rocks came running down from the valley's left flank. The men were not ordinary villagers, but the wild and fearsome-looking warriors called *pahupu.* Each man had one side of his body tattooed black from head to toe.

Manuel was killed first, his mangled body left on the beach. Franklin managed to break away and escape in the boat. The last he saw of Hergest and Gooch, they were being mobbed, stoned, and stabbed. Years later a native historian, recounting how the two men met their end, reported that the natives said, "They cry, indeed—they are men perhaps,—we thought them gods, their eyes were so bright."

In 1795 Kamehameha the Great, chief of the Big Island, also brought Maui and O'ahu under his dominion, thereby unifying three of the major Hawaiian islands. As king, with thousands of square miles at his disposal, Kamehameha recognized the importance of Waimea Valley and awarded it to his top spiritual adviser, Hewahewa, the last of the Pa'ao line destined to serve as the *kahuna nui.*

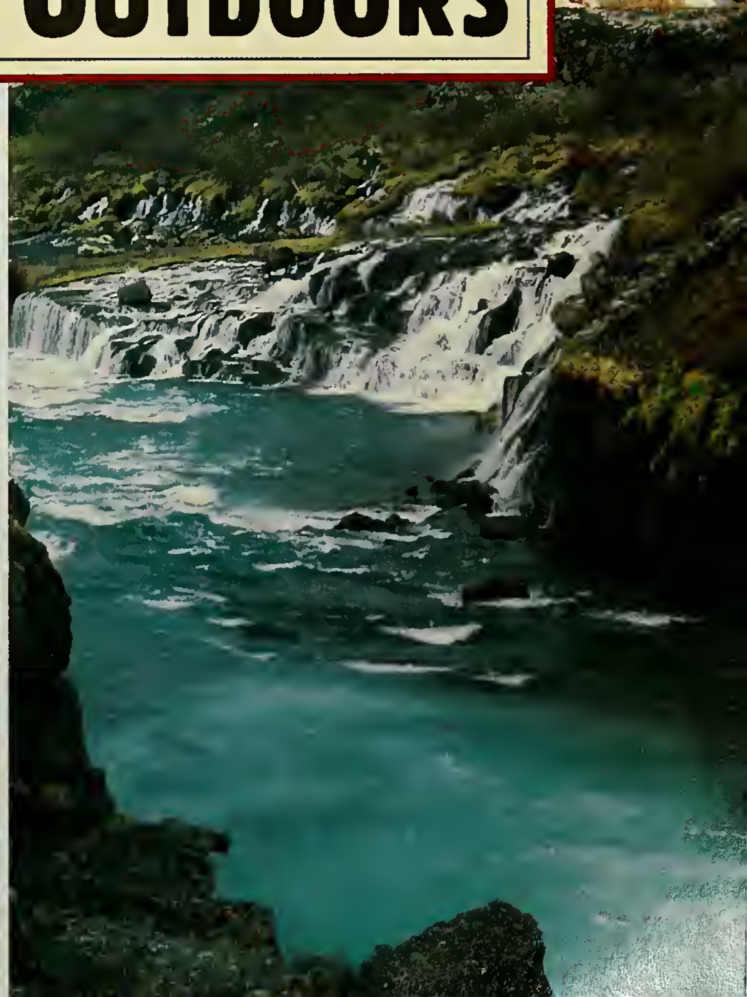
The king died in 1819 on the Big Island, with Hewahewa at his side. The following year the first Christian missionaries reached the archipelago from New England. According to John Swift Emerson, one of the missionaries, their arrival had been prophesied by Hewahewa, who had told Kamehameha, "O King, the god will soon land yonder," and had pointed to the exact spot where the missionaries later made landfall. Hewahewa may well have invented this story as a means of ingratiating himself with the missionaries.

Powerful Western influences were now propelling Hawai'i into an era of rapid change. With Kamehameha's death, the traditional system of laws or rules, called *kapu,* had begun to crumble. In only a few generations, Christianity would supersede Hawai'i's native religion and priesthood. The indigenous population—numbering perhaps a million at the time of first contact—would shrink by three-fourths because of introduced disease. The land itself would fall largely into foreign hands. American business interests would put the final touch on the process in 1898, with the forceful overthrow of the Hawaiian monarchy.

Hewahewa, who saw the beginning of the transition, died in 1837 and was buried in Waimea Valley. Rights to the valley eventually passed to his granddaughter Pa'alua. In 1848 the islands'

(Continued on page 37)

THE GREAT OUTDOORS



India

INDIA—STRETCHING 2,300 MILES FROM north to south—is so vast it has almost every kind of landscape imaginable. It has the stunning Himalayas, the world's highest and youngest mountains. In the far north, you'll find arid mountains, lakes, and forests; moving south, the country flattens out into fertile plains, foothills, and river valley. West India has some of the country's finest beaches and lush rainforests. With such varied terrain, from jungles to deserts, opportunities abound for nature enthusiasts.

Wildlife in India—from elephants to tigers to endangered species such as the leopard, lion, and Siberian crane—is found in more than 70 national parks and about 400 wildlife sanctuaries. Visit the Kaziranga Game Sanctuary to see the one-horned rhino (India has about 80 percent of the world's population) and head to Keoladeo Ghana National Park (popularly known as the Bharatpur Bird Sanctuary) in Rajasthan, near Delhi, to spot indigenous water birds and migratory species. The national animal, the tiger, is protected in two dozen reserves, including Bandhavgarh, where you'll also see leopards, gaurs, and sambhars.

Ecotourism resorts are new to India, but have sprouted everywhere and range from camps inside the jungles of Karnataka to houseboats in Kerala and tree houses in Vythiri. Devotees of the great outdoors can enjoy just about any activity—from whitewater rafting to trekking, cycling, mountain climbing, and rappelling. Wildlife safaris can be relatively tame—perhaps via Jeep or on horseback—or adventuresome: a camel safari in the Rajasthan desert to see the peacock's dance. One ecotourism camp, run by Snow Leopard Adventures (www.snowleopardadventures.com), is situated near Rishikesh, where the Beatles and other followers visited the ashram of the Maharishi Mahesh Yogi in the 1960s. From this camp, nestled in the foothills of the Himalayas, you can embark on several adventures including river rafting, kayaking, trekking, and mountain biking—then relax with some yoga. One expedition takes you to river running on the Ganges, India's holy river, which has rapids ranging from Grade II to IV.

Add magnificent historical sites, bustling cities, a rich heritage and culture, and luxurious accommodations—including forts and palaces that are now heritage hotels—and there is something for everyone in India.

Peru

DOMINATED BY THE ANDES—ONE OF THE world's highest mountain chains—and the legendary Amazon, Peru is a mecca for lovers of nature and the great outdoors.

Peru's astounding variety of climates and ecosystems make it one of the world's top eight nations in terms of biodiversity. It is home to more than 400 species of mammals and more than 50,000 plants, close to 20 percent of the world's birds, and 10 percent of the world's reptiles. About 13 percent of Peru's territory has been converted to Protected Natural Areas, including lakes and lagoons, rivers and canyons, and gorgeous waterfalls.

Swim, raft, or trek along the rivers, which emerge from the glacial highlands of the Andes and vary from black to white, cloudy, ruddy, or salty. The country has thousands of lakes and lagoons, including the tectonic Lake Titicaca and Lake Parinacochas, teeming with pink flamingoes, and the dark jungle lagoons of the Amazon. To see Peru's spectacular waterfalls, head to the area of Huánuco, famed for its beautiful landscapes. Well-known falls are the Velo de Angel (25–28 meters), the Sirena Encantada (70 meters), on top of Pacsapampa, and San Miguel (100 meters), where you can swim in the pools formed nearby.

In addition to its natural attractions, Peru has a rich cultural tradition, with thousands of years of archeological history. It is known as the homeland of the Inca and Machu Picchu, but Peru has been occupied by humans for 20,000 years, and many archeological sites remain from pre-Inca societies such as the Nazca (originators of the famous lines), Chavín, and Moche. Don't miss Peru's colonial cities, especially Lima, the capital, with its distinctive Spanish heritage and incomparable cuisine. Cuzco, the gateway to Manu National Park and to Machu Picchu, is also the capital of the Inca empire and home to many temples and shrines.

All of the attractions are easily reached, thanks to Peru's sophisticated transportation infrastructure. Accommodations range from elegant luxury hotels to affordable hostels and inns.

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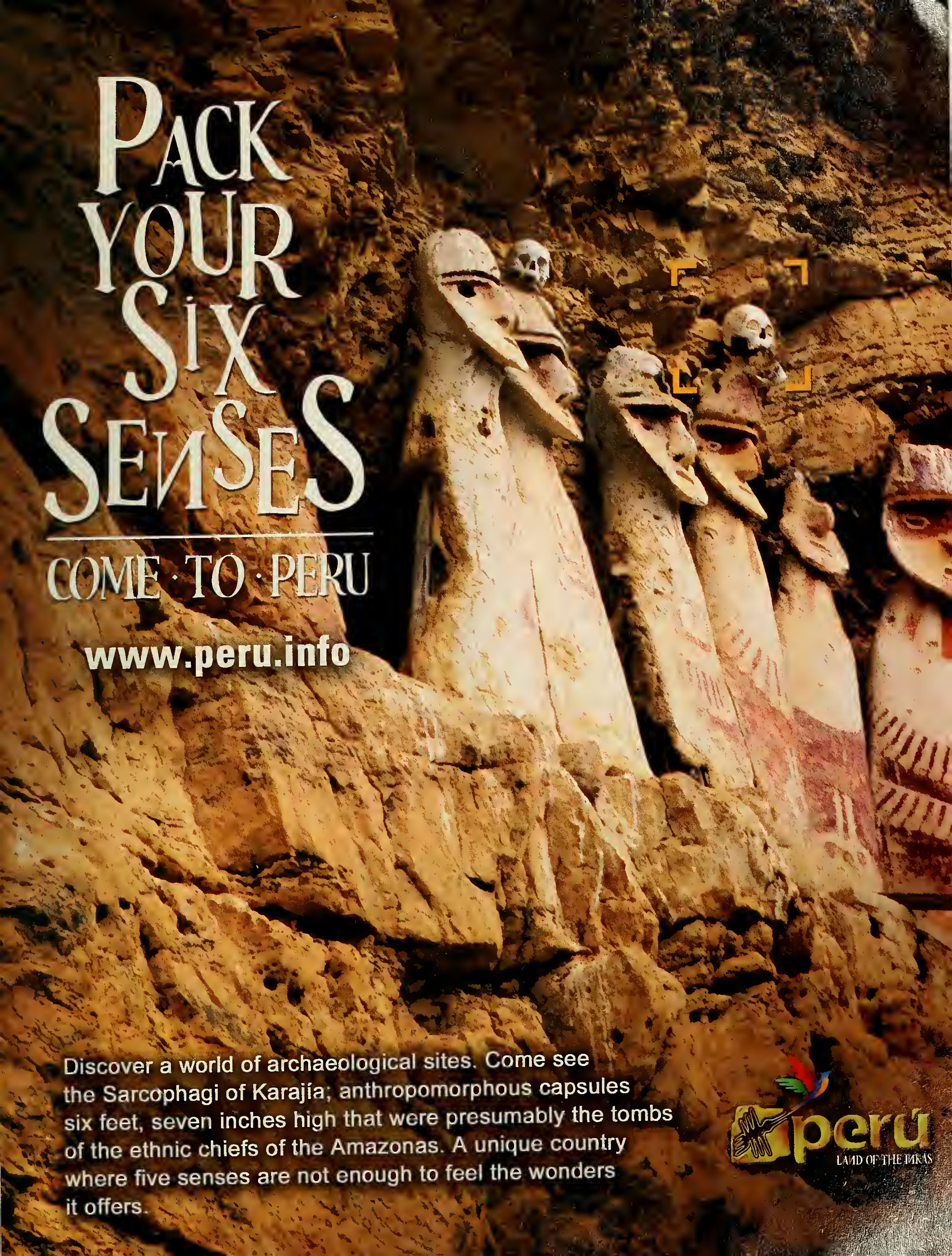
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You can stay in a hotel or inn in Old Québec, enjoy myriad restaurants, bistros, and sidewalk cafés, and yet you are only 40 minutes away from the great outdoors. The best example is Cap Tourmente National Wildlife Area, home to many species of birds and other animals.


Yves Tessier

Nightlife on Grande Allée


Luc-Antoine Couturier

Snow geese at Cap Tourmente

Cap Tourmente National Wildlife Area

Located 30 miles east of Québec City, Cap Tourmente will impress amateurs as well as experts in ornithology, history, and environment while offering a diversified outdoor experience.

Recognized as a wetland of international importance (Ramsar site) in 1981 and renowned for the remarkable spectacle of tens of thousands of greater snow geese in the spring and the fall, the wildlife area is home of more than 305 species of birds, 45 species of mammals, 22 types of forest stands, and 700 species of plants. A total of 150 nesting boxes in summer and 55 feeders in winter attracts a wide variety of nesting and migratory species.

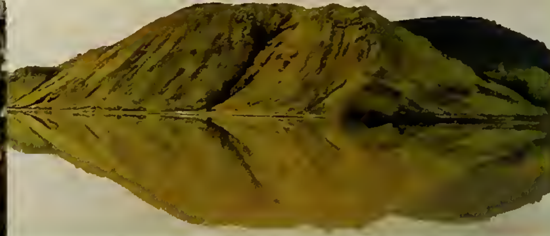
This region also witnessed the beginnings of colonization and French influence in North America. Cap Tourmente National Wildlife Area also offers one of the most beautiful historic sites on the continent, the very place where Samuel de Champlain, founder of Québec City, erected the first farm in the St. Lawrence Valley in 1626.

Nearly 11 miles of hiking trails (6 miles in winter with two heated rest stops) of varying length and difficulty showcase Cap Tourmente's plant and animal life. After a day spent bird-watching, hiking, and walking on the trails, you'll be happy to find the comfort of your hotel and to plan your next day's visit on the town!

For more information, visit www.quebecregion.com, write to Québec City Tourism at Info@quebecregion.com, or call (418) 641-6290.

Icelandic Tourist Board/Frederic Reglain

Icelandic Tourist Board/Ruth Gundahl Madsen



Icelandic Tourist Board/Ruth Gundahl Madsen

Iceland

ICELAND IS A LAND OF FIRE AND ICE: lava fields and black-sand beaches; glaciers and fjords. Located on the Mid-Atlantic Ridge (a rift along the ocean floor caused by shifting tectonic plates), Iceland is bubbling with underground activity and is a living geology textbook. It is full of craters—it has thirty active volcanoes—hot springs, and geysers. This is wild, untamed land, ranging from tundra to grassland, bogs, and desert. And, in spite of its frosty-sounding name, Iceland has relatively mild winters, especially in the south and west, due to the Gulf Stream.

Reykjavik, the capital city, has rows of colorfully painted concrete houses. You can savor some of the country's best attractions by planning day trips from here, from whale watching (http://www.whalewatching.is) to horseback-riding tours (http://www.ishestar.is). Explore the lava fields surrounding Mt. Helgafell volcano, then visit the Geysir hot spring area and the spectacular Gullfoss waterfall. The surrounding area is full of bubbling springs. Or, after a day ice walking on a glacier, take a dip in a geothermal pool, such as the popular Blue Lagoon.

Alex Westner

Pocono Mountains Vacation Bureau, Inc.

Poconos

THE FOUR-COUNTY POCONO Mountains region of northeastern Pennsylvania offers myriad fall and winter activities, from hiking and mountain biking amid spectacular fall foliage to bird watching, scenic road trips, and much more. Seven state parks are located throughout the region, covering a total of 35,537 acres.

The Delaware Water Gap National Recreation Area covers a forty-mile stretch of the Delaware River that passes by the quaint town of Milford and reaches to the town of Delaware Water Gap, Pa. This recreation area offers canoeing, hiking, camping, bicycling, cross-country skiing, gorgeous waterfalls, and much more.

As temperatures drop in winter months, hundreds of bald eagles come from farther north and find sanctuary at the Delaware Water Gap Recreation Area. The Pocono Environmental Education Center (PEEC), located in Dingmans Ferry, lets visitors get a glimpse of this winter phenomenon by offering special Eagle Treks that explore bald eagle hot spots.

Visitors can contact the PMVB, Inc. at 800-POCONOS (800-762-6667) for more information.

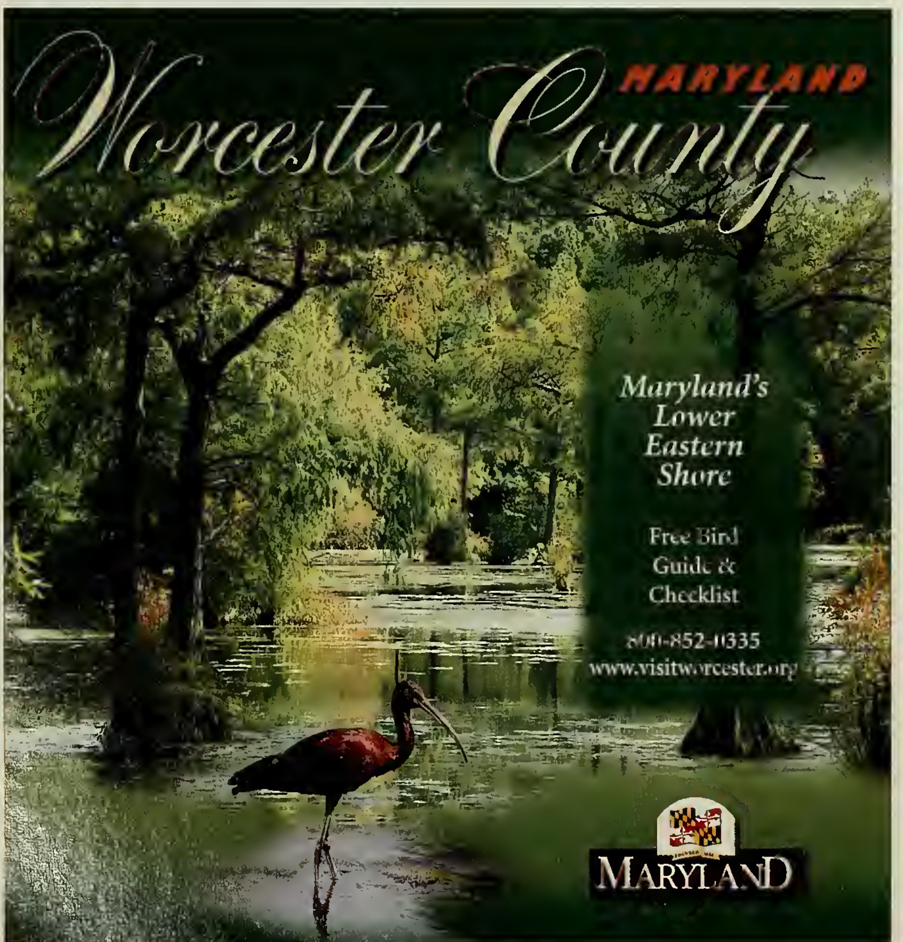
Maryland

Charles County

LESS THAN AN HOUR FROM Washington, DC, Charles County is the gateway to historic southern Maryland. Nature lovers will find first-class fishing, a dense population of nesting bald eagles, acres of forest land, 150 miles of spectacular shoreline, and the wildest wildlife this side of the Potomac. With enough history to fill several books, sumptuous fresh seafood, and top-flight golf, it's no wonder visitors come back to Charles County.

Dorchester County

BOASTING 1,700 MILES OF shoreline, Dorchester County is the heart of Chesapeake Country. Its beautiful unspoiled countryside offers many opportunities to relax and to enjoy the great outdoors.



Enjoy cycling, walking, and driving tours; fishing, boating, kayaking, and canoeing on the Chesapeake Bay and its meandering tributaries; outstanding bird watching, especially waterfowl, raptures, and shorebirds; and excellent golfing and parks.

Much of Dorchester County has been certified as a state heritage area and is rich in many Chesapeake traditions, which you will see in waterfront communities and wealth of museums. Quaint towns dot the northern agricultural areas and to the south, the county has three islands encompassed by the Chesapeake Bay and its tributaries. Don't miss the waterfront villages found on Elliott, Hooper, and Taylors Islands.

Birders should make time to explore Blackwater National Wildlife Refuge, which has one of the largest populations of nesting and resident bald eagles on the east coast. The tidal marshes found on the Refuge are so vast that it has been called the Everglades of Maryland. Along the Cambridge waterfront, you'll see many species of wintering waterfowl, great blue herons, gulls, and swans. Stop by the Dorchester County Visitor Center at Sailwinds Park for your guide, *Birding in the Heart of Chesapeake Country*, for five birding trails to explore.

Frederick County

KNOWN FOR ITS HISTORIC sites—especially those commemorating its Civil War heritage—Frederick County, Maryland, is also a place to enjoy the great outdoors. Framed by the Catoctin Mountains and the Potomac River, Frederick has ninety parks, from federal and state to local, and many recreational facilities. You'll find an activity for every season, including whitewater rafting, swimming, boating, camping, skating, bicycling, horseback riding, and hiking along the Appalachian Trail or the Chesapeake & Ohio Canal National Historical Park.

Montgomery County

A SHORT DRIVE FROM Washington, D.C., Montgomery County is home to the suburbs of Bethesda, Chevy Chase, and Silver Spring. An ideal place to stay while exploring the capital, Montgomery has some worthy attractions of its own. Its hundreds of miles of trails are at their best in the fall. Some are accessible to joggers, cyclists, and wheelchair users as well as hikers, leisurely walkers, and families with strollers. Hikers can learn about the county's environmental, historical, and cultural heritage on the new Rachel Carson Greenway, which includes the Rural Legacy Trail. Beginning in Woodlawn Manor Park and ending at the Sandy Spring, this short trail commemorates the Underground Railroad and Quaker traditions. The ten-mile Black Hills Trail wanders through oak and hickory forests and offers spectacular lake views.

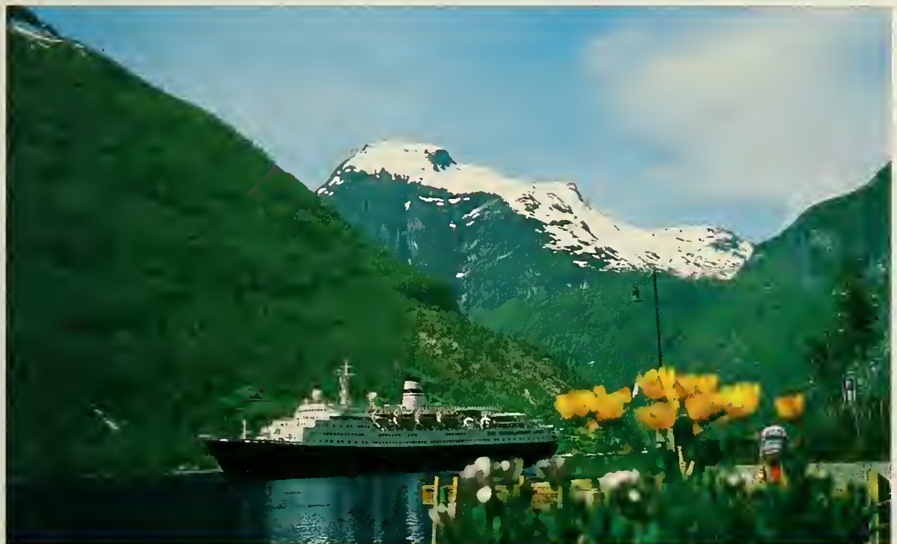
And if you want a break from the great outdoors, this county has plenty of museums, public galleries, theaters, and historic sites. Visit the Clara Barton National Historic Site in Glen Echo, catch a play at the Olney Theatre, or spend a day on the lake at Black Hills Regional Park.

Talbot County

FOR A RICH, RELAXING, AND romantic experience, visit Talbot County, on Maryland's Eastern Shore. On the Chesapeake Bay, Talbot County is a paradise for boaters and fishermen, but it also gives you a glimpse of traditional working life and history on the Bay. Many of its colorful towns are on the waterfront: Tilghman Island, Oxford, St. Michaels, and Easton are especially charming. Ride a historic shipjack or end the day with a sumptuous meal of Maryland crabs.

Worcester County

MARYLAND'S OCEAN SIDE county— home to Ocean City and Assateague National Park—has the best birding in the state. Almost 350 bird species have been sighted in Worcester. From the Atlantic coastline to the Pocomoke River and Forest, Worcester is home to pelicans and peewees, kingbirds and cuckoos, and herons, harriers, and eagles. Habitats range from centuries-old forest to barrier island, cypress swamp, and tidal wetlands. Fall, of course, is the best time to see migrants: peregrine falcons, merlins, and flocks of tree swallows at Assateague; northern gannets just offshore; and plenty of Canadian and snow geese soaring above. The county also has spectacular golf, fishing, kayaking, canoeing, and horseback riding. Fall, when the foliage is ablaze with color, is the perfect time to bike on the "View Trail 100," which takes you on leafy country roads, through farmlands and forests and historic towns, along the swift Pocomoke River, and past



Cruise Adventures

Orient Lines

ORIENT LINES IS A PREMIUM BUT AFFORDABLE LINE OFFERING ten- to twenty-six-day cruises to the Greek Isles, Mediterranean, and Scandinavia during the summer and Antarctica, Australia, New Zealand, Africa, India, Egypt, Asia, and South America during the rest of the year. The 2005–06 program offers sixty separate European Cruise Tours and eleven Exotic Cruise Tours, including the Ancient Civilizations & Empire tour and Ancient Egypt and the Ottoman Empire voyage. Both voyages offer a new port of call—Tripoli, Libya—and mark the return of Orient Lines to Alexandria, Egypt. Orient's intimate, medium-size ships (the 822-passenger flagship *Marco Polo*, celebrating its 10th anniversary, and 1,050-passenger

Crown Odyssey) offer four-star, luxury liner facilities with up-to-date amenities and elegant service. Orient Lines designs complete itineraries, which means all the details are taken care of both on sea and ashore: from deluxe hotels and sightseeing tours to baggage transfers and a staff to help find the best restaurants and sights. New ports on the European cruises this year include Izmir, Turkey; Split, Croatia; Brussels (Zeebrugge), Belgium; Visby, Sweden; Gdansk, Poland; and Riga, Latvia.

Swan Hellenic

WITH FIVE DECADES OF EXPERIENCE, Swan Hellenic is the leader in Discovery Cruises. Voyages on its "floating country house," the *Minerva II*, feature intriguing worldwide destinations and a sophisticated and relaxed style of service and accommodation. High-profile guest speakers are on board each voyage, with tailored talks and programs on everything from the flora and fauna to the history, religion, politics, and culture of the destinations. Destinations include lesser-known and widely varying areas—from the mysterious temples and pyramids of the Maya at Chichen Itza, to the glacial landscape of Arctic Norway and the tropical abundance of the Amazon interior. This year Swan Hellenic has launched The Americas Collection, with longer cruises of up to 34 days combing some of the most exotic places in South and Central America and the west coast of North America.

The Americas Collection visits the off-the-beaten track destinations that Swan Hellenic is famed for, including a full circumnavigation of the east and west coasts of Argentina, Uruguay, and Chile, as well as the chance to experience the remarkable remains of the Maya along the coast of Peru and around Central America.

(Continued from page 22)
newly formed Land Commission offered to give her outright ownership of roughly half of Waimea Valley, on condition that she relinquish any claim to the rest. And to receive even half, she was required to formally present a claim to the Land Commission by a certain time, which she failed to do. She and her husband managed to hold on to a portion of the valley until 1884, but in the process fell heavily into debt. The native Hawaiian descendant of the last *kahuna nui* in Waimea had to mortgage and lease the land. Soon after she died, in 1886, the property was foreclosed.

Over the next twenty years the valley changed hands at public auction several times, and by the turn of the twentieth century it was in the control of a pineapple and sugarcane company. For a brief time cowboys roamed the valley, using it for ranching. After Pearl Harbor soldiers took over, building artillery positions and other installations.

In the 1960s and 1970s commercialism further obscured the valley's sacred past. The Waimea Falls Ranch and Stables offered seventy-five-cent stagecoach rides, complete with actors who rode alongside, playing both cowboys and North American Indians. A restaurant and gift shop appeared, guided tours were offered in open-air trolleys, and visitors could attend a cliff-diving show or see a hula dance. The archaeological richness of Waimea Valley went largely unnoticed.

But neglect has not been the only order of the day. In 1900 the Hawaiian Historical Society conducted the first survey of archaeological sites around O'ahu. At Waimea, though, the survey recorded only the spot where the murder of the *Daedalus* crewmen had taken place. In 1906 Thomas Thrum's *Hawaiian Annual,* an almanac, noted the two largest *heiau* at Waimea, called Kupopolo and Pu'u o Mahuka [*see map on page 22*]. But it was not until 1930 that any more sites were formally recognized. Gilbert McAlister, an archaeologist at the University of Chicago, produced his *Archaeology of O'ahu,* alerting scholars to the existence of thirteen more sites at Waimea. In 1974 archaeologists at the Bishop Museum in Honolulu were able to raise the total to thirty-three.

Kalaipahoa idol was hidden in a cliffside of Waimea Valley, then knocked down by goats and recovered in the mid-1800s. Such idols, used for protection and sorcery, were carved on the island of Moloka'i from trees reputedly rendered poisonous by powerful spirits.

Since that time a botanical garden and an arboretum for native and endangered Hawaiian plants have been established in Waimea Valley. Rudy Mitchell, a native Hawaiian, surveyed the territory and conducted limited archaeological testing. Mitchell even rebuilt a temple site that, through neglect, had become buried under tons of soil and detritus.

Now the City and County of Honolulu has moved to take over the valley, although the financial terms are still in litigation. Meanwhile, the National Audubon Society has managed the property on a month-to-month lease and has shifted the emphasis from commercial entertainment to the valley's natural and cultural attractions. Under the Society's auspices, and with funding from the Office of Hawaiian Affairs, my archaeological consulting firm conducted a preliminary assessment of the valley this past April.

Our reexamination of the literature has already more than doubled the number of sites of interest. Many more undoubtedly await discovery. At least 80 percent of the valley has not even been inspected for archaeological sites, because access to inland areas and up the steepest valley sides is so difficult. Moreover, much of the human history of Waimea is probably hidden well below the surface. In the mid-1980s, for instance, workmen removing soil unexpectedly uncovered a temple buried near the center of modern valley activities. Other surprises should come to light with more deliberate excavations.

How could a valley considered sacred for forty generations be so poorly recorded and understood? The answer is that in the late 1880s the Hawaiian people abandoned it rather suddenly (and not at their own choosing), and they took their stories with them. In the climate of those times, there was little incentive to collect their valuable information or record their sites before they left. Little remains of the oral tradition, often just bits and pieces passed down from grandparents and great-grandparents.

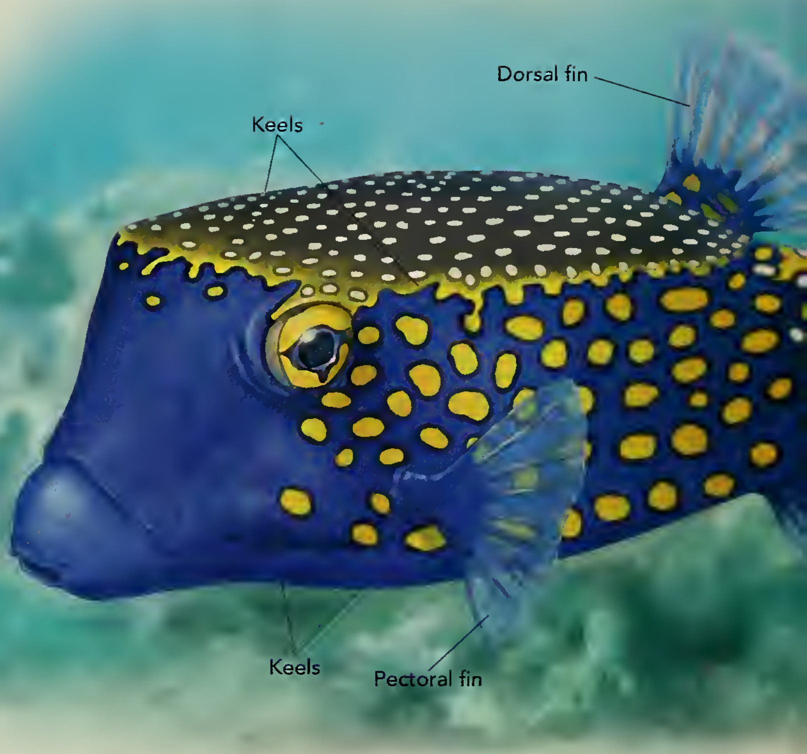
In those circumstances, archaeological investigation is the surest way of recovering the valley's lost story. Once the number of surface sites is determined, such work can establish a reasonably respectable chronology of events and render a better appraisal of what lies underground. With time, that study may even reveal the nature of sacred lands, and tell us what powers were invested in the *kahuna nui.*

JOSEPH KENNEDY is the senior archaeologist with Archaeological Consultants of the Pacific, Inc. His article "The Wild Man of Samoa" appeared in Natural History *in February 2004.*

Boxed Up to Go

The seemingly unwieldy shape of a fish is anything but a drag.

By Adam Summers
Illustrations by Tom Moore

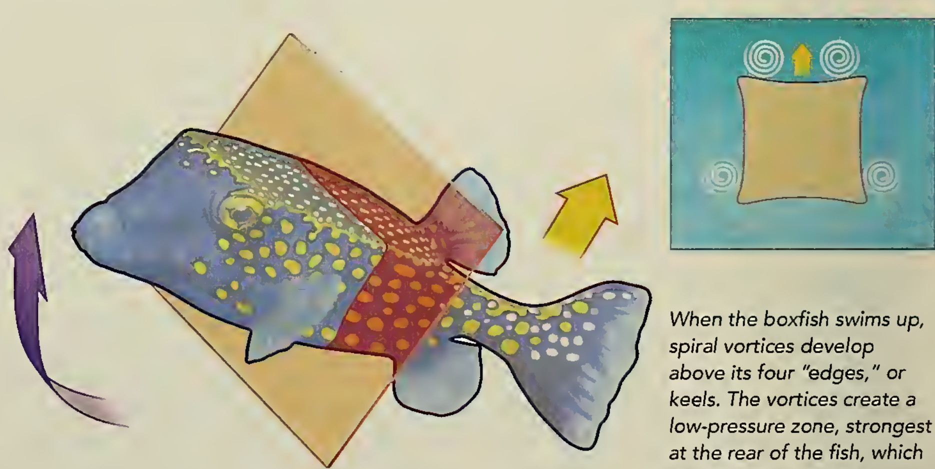


Until recently I would have bet I could tell a fast fish from a slow one by looking at the placement of its fins and the shape of its body. Boxfishes, with their fins at the corners of their "boxy" bodies, would not have made my list of speedsters on either count. But it turns out that boxfishes are fast, stable, and amazingly maneuverable swimmers—so much so as to inspire human designers.

Boxfishes get their name from the rectangular (or sometimes five-sided) shell of bony armor on the front two-thirds of their bodies. The eyes, mouth, and fins poke through holes in the covering, but otherwise the fish's body surface is an uninterrupted mosaic of hexagonal tiles of bone.

The edges of the bony box act as keels, running nearly the entire length of the fish. In some boxfishes, such as the aptly named cowfishes, the keels extend forward, beyond the body, to form sharp horns. Like its relative the puffer fish, the boxfish propels itself by waving its dorsal fin (on top of its body) and its anal fin (on the bottom), and it steers primarily with its pectoral fins and tail fin. Both dorsal and anal fins are situated well to the rear of the fish [*see illustration at top of this page*].

I assumed the hydrodynamic properties of a boxfish were comparable to those of a square compact car or an SUV—a vehicle that's good for carrying loads, with neither speed nor agility. But Ian K. Bartol, a biologist at Old Dominion University in Norfolk, Virginia, and a multidisciplinary team of investigators have proved, once again, the limits of intuition. First, they point out, far from being slowpokes, boxfishes can scoot over a reef at six body lengths per second—an impressive speed by any standard. Moreover, Bartol and company managed to visualize the flow of water around a boxfish by placing neutrally buoyant beads in the water and filming the beads as they swept past plastic models of the fish. They found, with their models, that the drag of the boxfish is surprisingly low, as expressed by a dimensionless quantity known as its drag coefficient. The drag coefficient of the boxfish is just 0.2, which is



When the boxfish swims up, spiral vortices develop above its four "edges," or keels. The vortices create a low-pressure zone, strongest at the rear of the fish, which tends to pull the tail end of the fish up (yellow arrows) and so help keep it level and stable.

comparable to some streamlined airfoils, and falls well below 1.5, the drag coefficient of a flat-faced box.

At first glance, those hydrodynamic properties are puzzling. The dorsal and anal fins, which push the fish along, are way off the central axis of its body, yet the animal swims a straight path without rocking up and down. That would seem to require either perfect coordination of two fins of widely differing shape and size, or a trick that somehow imparts stability to the fish without slowing it down.

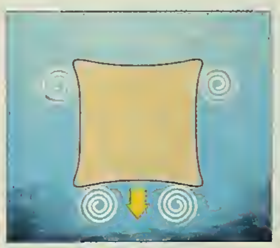
Bartol and his colleagues found that the secret to the dynamic stability of the boxfish lies in the keels that form the edges of the box. The keels set up strong spiral vortices of water that flow along the keels, hugging close to the surface of the fish and intensifying at the rear end. When the fish tilts nose-up, the vortices develop above the keels; when it tilts down, the vortices form below the keels [*see illustrations below*].

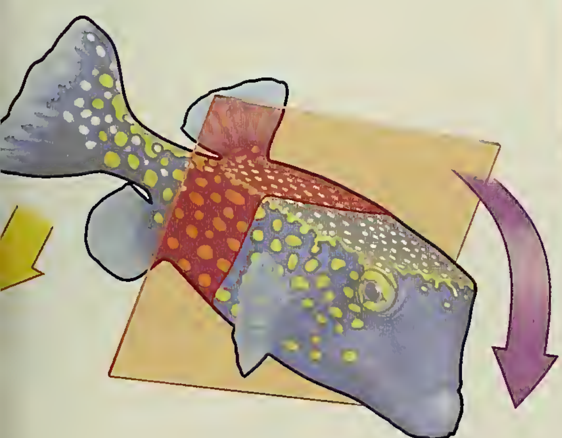
The pressure of the water in these swirling vortices is lower than it is in the undisturbed fluid around the fish. Hence as the nose tilts up, a low-pressure vortex above the keels tends to pull the body upward, leveling it. Similarly, as the nose goes down, the vortices below the keels tend to counteract the upward tilt of the tail end. The pectoral fins, furthermore, are well placed to interrupt or adjust the vortices, and those fins can also act to stabilize the body or propel the fish into a speedy turn.

The beauty of the fish's solution to the problem of propulsion and stabilization is that the functioning of the keels is entirely passive. In other words, it requires no active control from the fish. The vortices automatically stabilize a motion that might otherwise lead to very inefficient head bobbing. Not only is little energy required of the fish, but there are also no complex neural circuits needed for control; a clever set of immovable strakes, shaping the body from stem to stern, lets geometry, and fluid dynamics, do all the work "for free."

Computer-generated model of a car with design elements inspired by the hydrodynamically efficient boxfish

Mercedes-Benz has already taken note of this nice combination of load carrying and low drag. In fact, the boxfish is the basis for the automobile company's latest concept car. The result is a boxfish on wheels, with headlights, windows, and a very slippery drag coefficient of just 0.19—comparable to an airfoil. The vehicle even emulates the hexagonal tiles of the fish's carapace to create strong, lightweight doors. The producers of the next James Bond movie might take a cue from the new design: this car would be an agile underwater performer, with built-in armor and lots of cargo space for spy gear.





In a downward dive, the boxfish generates vortices below its four keels. The low pressures in the vortices help pull the tail end of the fish down (yellow arrows).

ADAM SUMMERS (asummers@uci.edu) *is an assistant professor of ecology and evolutionary biology and bioengineering at the University of California, Irvine.*

NATURAL HISTORY
OCTOBER 2005

Toxic Treasure

Poisons and venoms from deadly animals could become tomorrow's miracle drugs. And few places on Earth harbor so many deadly animals as Australia's Great Barrier Reef.

By Robert George Sprackland

[Australia] has more things that will kill you than anywhere else. . . . This is a country where even the fluffiest of caterpillars can lay you out with a toxic nip, where seashells will not just sting you but actually sometimes go for you. . . . It's a tough place.
—*Bill Bryson,* In a Sunburned Country

Raised, as you probably were, on film or video footage of drowsy koalas hugging eucalyptus trees, or kangaroos bouncing happily around the outback, you might wonder just what country Bryson is talking about. But consider the unassuming cone shell—just the kind of malicious mollusk that will "actually sometimes *go* for you."

The cone shell is a marine snail that lives in tropical regions worldwide, including the waters around northeastern Australia's Great Barrier Reef. The snail aggressively reaches out to sting prey or would-be predators, injecting toxins that are among the most powerful in the animal kingdom. Even a diminutive member of the genus *Conus* can carry enough venom to kill a dozen people; a single careless encounter can bring death in less than thirty minutes. What's more, the radula, a harpoonlike stinger that delivers the venom, can strike with enough speed and force to pierce a diver's wetsuit. There is almost no pain associated with a cone-shell sting, because the venom contains a strong analgesic. That's the good news. The bad news is that the toxin is a nerve agent for which there is no known antidote.

Why would anyone intentionally seek out a creature whose venom packs such a wallop? Answering that question goes a long way toward explaining why Australians, whose continent is well known for its gold and opals, have begun studying their richly varied animal populations with renewed interest. Latter-day prospectors on the continent are searching for biologically active chemicals throughout Australia's biting, stinging, venomous fauna. Those chemicals and their derivatives could turn out to be both a pharmaceutical bonanza and the foundation of a multimillion-dollar industry.

In Brisbane, for instance, laboratory workers at a six-year-old biotechnology company called Xenome

Blue-lined octopus (Hapalochlaena fasciata), photographed at night, shows its displeasure at being disturbed by flashing a vivid array of iridescent indigo rings and lines along its mantle and arms. In spite of its diminutive size (adults typically measure only six inches long), the octopus can be a nasty meal for predators: it defends itself with a potent nerve agent, tetrodotoxin. It deploys a second kind of toxin—much less potent than the first—while hunting the crabs on which it feeds.

Spotted porcupine fish (Diodon hystrix) *is considered poisonous but not venomous: it does not bite or sting, but it is highly toxic if consumed. Like its puffer-fish cousins of the genus* Fugu, *which are prized (and feared) by Japanese gastronomes, the porcupine fish is toxic not by nature but by nourishment. As it feeds, it ingests bacteria that contain tetrodotoxin, which accumulates in the fish's liver and other organs.*

Ltd have the unenviable task of "milking" cone shells. The job is not an easy one. Because the snail can bend its proboscis to sting from virtually any angle, there is no safe way to hold a live cone shell. To get the venom, the technicians dangle a small fish from forceps for the snail to sting. The snail's venom kills the fish, but it can then be safely extracted from the fish's tissue. In spite of that roundabout—and costly—procedure, Xenome's efforts have been worthwhile. The company is developing a drug based on cone-shell toxin for treating severe long-term pain. Its effects are similar to those of morphine, but because of its potency, effective doses are smaller, and so far at least, it seems not to be addictive.

Xenome's work is an outgrowth of a major bioprospecting project in Australia, initiated in 2003 by Peter Beattie, the premier of Queensland, and his government. Known as the Queensland Bioscience Precinct, the project aims to encourage the discovery of new biochemicals that might spawn major pharmaceutical products. What sets apart the Queensland bioexplorers is that they focus on molecules derived from animals, instead of from plants. At least 25 percent of the medicines currently avail-

Geography cone shell, Conus geographus, *is one of some 300 species of cone shells that occur in the waters off Australia—all of them with a ready answer to the biblical query, "O death, where is thy sting?" The probelike structure extending to the right is a siphon, used to detect prey. The cone shell also has a flexible proboscis, inside which is a harpoonlike barb called a radula that can pierce a diver's wet suit. A single untreated jab can kill an adult human in thirty minutes.*

able come from plant products, but relatively few animals so far have been assessed for medically useful chemicals. Thus, animal bioexplorers are entering largely uncharted territory, and the odds are good, they believe, that a mother lode is still out there, waiting to be discovered.

Animals, like plants, have long been known as a source of a vast array of chemicals, many of the with great potential for human use. Many frogs, for instance, secrete compounds through their skin that have powerful antibiotic properties, enabling them to thrive in stagnant water teeming with pathogens. Clown fish—immortalized in the 2003 movie *Finding Nemo*—wear a coat of slime that informs the anemones with which they live that clown fish is *not* on the anemone menu. Corals exude chemicals that protect them from sunburn at low tide; derivatives of those chemicals are already being marketed as sunscreens. Even compounds from sponges have led to valuable drugs: acyclovir, a treatment for herpes, and cytarabine, for a kind of leukemia.

In some cone shells, the venom needed to kill a dozen adult humans would fit on the head of a pin.

The chief attraction of animal biomolecules, particularly the toxins, is their staggering potency: they are often hundreds of times more powerful than plant compounds that deliver a similar medicinal effect. For example, the analgesic alkaloid epibatidine, derived from South American dart-poison frogs, is about 200 times more powerful than an equal amount of morphine, derived from poppy flowers.

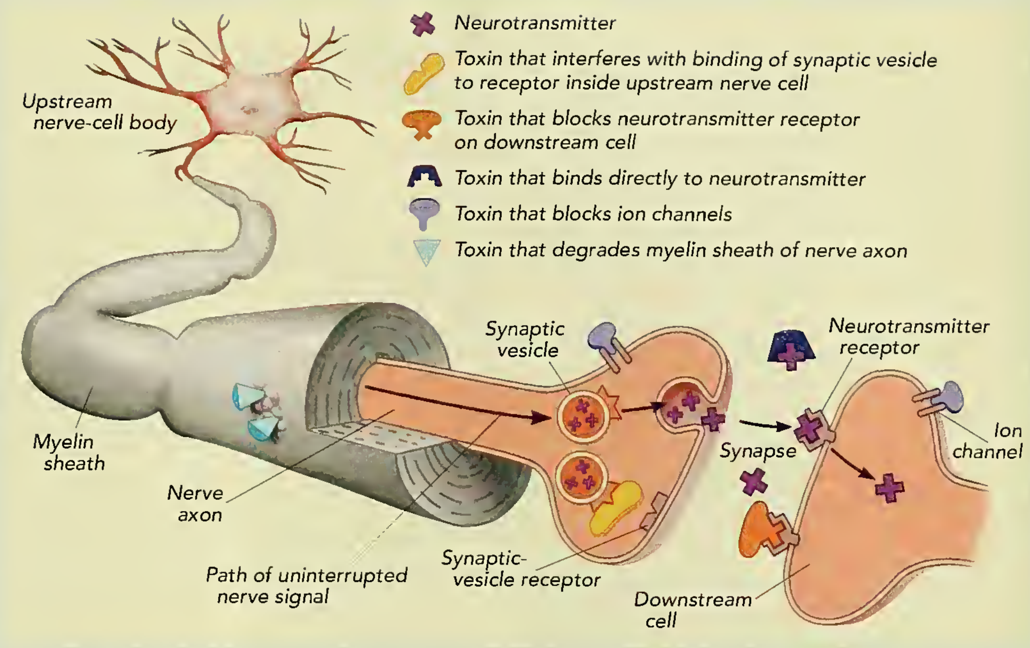
But why seek potency for its own sake? Why not play it safe, and simply use more of some less potent agent? After all, it goes without saying that the more powerful the toxin, the less of it is needed to achieve its effect, and so the greater the risk of an overdose.

The answer lies in the highly specific way that the most potent animal toxins attack certain kinds of cells or cellular processes. That very specificity of chemical action is often a highly prized medicinal property. It enables a drug to attack the site of a disease—a highly localized cancer, for instance—without crippling side effects. A precisely targeted drug can also act as a carrier for some other drug, bringing the second agent to the part of the body where it can do the most good. Hence, investigators reason, pharmaceuticals derived from modified but potent toxins may prove useful in targeting drug treatments.

Many animal toxins, for instance, have evolved that exploit the vulnerability of nerve cells. That makes sense—from the point of view of the attacker—partly because nerve cells, in most cases, cannot be replaced or even repaired. But nerve cells have two other liabilities that make them particularly vulnerable to even small-scale structural problems. First, they can be shut down by minor interference with any one of several critical components [*see illustration on opposite page*]. For example, a toxin could block neurotransmitter sites either upstream or downstream from the synapse between two nerve cells, making it impossible for a nerve impulse to travel across the synaptic gap. A toxin could bind to the neurotransmitter molecules themselves, rendering them useless. Or a toxin could block the channels that enable sodium and potassium to pass through the nerve-cell membrane, and thereby halt a neuroelectrical impulse along the length of each nerve cell. Finally, a toxin could degrade the myelin sheaths that insulate the axons of a nerve cell, causing the nerve impulses to lose strength and dissipate.

The second liability, related to the first, arises simply because part of each nerve pathway is usually made of a single strand of nerve cells in sequence, like the links in a chain. If any single nerve cell is shut down, the entire pathway is neutralized. That's why the system is so readily sabotaged by minute doses of highly target-specific animal neurotoxins. In some cone shells, for instance, the venom needed to kill those dozen adult humans would fit on the head of a pin.

Because a given toxin may target only a specific section of a particular kind of nerve cell—say, the myelin sheath of cardiac nerve cells—bioexplorers have to screen many toxins to identify which ones attack which targets. Suppose, for instance, screening leads to the identification of a toxin that attacks myelin. That toxin then becomes a key factor in a strategy for repairing some of the damage caused by myelin-degenerative disorders, such as multiple sclerosis.



Nerve cells can be attacked by animal toxins in any of several ways, as shown in the schematic diagram. Nerve signals depend on the opening and closing of ion channels along the nerve axon, and on a mechanism that enables neurotransmitter molecules to cross the synapse, or gap between upstream and downstream cells. Interference with any one of the mechanisms can cut off an entire signaling pathway.

One way to use the toxin might be to modify or remove just its toxic part, while leaving the myelin-seeking part intact. Then, in place of the toxic part, the bioexplorer might substitute a therapeutic chemical agent, which could restore or mimic the function of myelin. Because the newly engineered drug would be so target-specific, virtually all of it could act only within the nerve cell's axonal region, making it an efficient fix in small doses. Similarly, other drugs might be designed to retard or alleviate the symptoms of diseases such as Alzheimer's and Parkinson's.

If animal toxins, and their therapeutic potential, are such underexplored pharmaceutical territory, why do so many bioexplorers converge on Australia? Things that sting and bite, after all, occur around the world. The answer is as straightforward as the whereabouts of a gold rush: you go where the yield is most likely to be high. Not only do countless venomous animals live Down Under, but some, such as certain species of cone shells, may also produce toxins with a lengthy list of ingredients. (By contrast, the venom of a typical highly venomous snake may include only a handful of chemical components.) Bill Bryson was exaggerating only slightly when he claimed to have looked up a particular animal in the fictitious "*Things That Will Kill You Horridly in Australia*, volume 19."

Part of the scientific recognition that Australia is such a rich potential source of new animal toxins can be traced to the work, in the 1950s, of Hugo Flecker, a naturalist and physician living in Cairns, Queensland. Ever since records began to be kept, occasional deaths had been reported just off the northern beaches of Queensland. In Flecker's day, the cause of the deaths was still a mystery, but he suspected that they were the work of a jellyfish.

In January 1955, a young boy was fatally stung in the shallow Queensland surf. The local police, acting on Flecker's hunch, set nets to capture the killer. What they caught in the nets were jellyfish, which they turned over to Flecker. Flecker, in turn, sent the specimens to Ronald V. Southcott, another naturalist-physician, who determined that the animal was, indeed, a species of jellyfish previously unknown to science. He named it *Chironex fleckeri*, after Flecker—and so introduced science to the sea wasp.

The sea wasp was dramatic proof that there were still dangerous unknown creatures to be discovered and studied. Since Flecker's time many other toxic marine organisms have been described, and their study has been conducted in a more systematic way. A great many of those animals, as it happens, live in and around Queensland.

Generally speaking, some of the most fertile grounds for bioexploration are tropical reef communities. Such reefs harbor a phyla-spanning host of organisms that produce powerful toxins. So it is no surprise that Queensland, whose coastline includes the entire Great Barrier Reef, is home to the widest array of toxic creatures in Australia. Some 300 species of cone shells live in and around the reef, each with a venom that may

Worker "milks" the venom from an olive sea snake, Aipysurus laevis, *captured along the Great Barrier Reef. Australia is home to all ten of the world's deadliest sea snakes, and the olive sea snake—which can grow to more than six feet long—is among the commonest of them.*

include as many as a hundred distinct chemicals—yielding perhaps several thousand biochemically interesting compounds. Also among the well-armed sea fauna of Queensland are all ten of the most dangerous sea snakes in the world. Many other Queensland creatures—including various species of fishes and mollusks—hold the distinction of being the most venomous of their kind. Among the jellyfish, Flecker's sea wasp, also known as "the stinger," is arguably the most dangerously venomous animal on the planet [*see "One Touch of Venom," by Jamie Seymour, September 2002*].

The diversity of wildlife in Queensland is hardly limited to sea creatures. In the rainforest of the tropical north, more species of flowering plants are thought to occur within a few typical acres than are found in all of North America. Among the land fauna are nine of the ten most venomous land snakes in the world. And new species from northern Queensland are still being discovered and formally described every year; many more are still unknown to science. There is plenty in Queensland to keep bioexplorers busy for a long time.

In those circumstances, bioexplorers are well advised to seek the help of seasoned systematists—taxonomists with a solid grounding in the evolution and natural history of organisms. For one thing, the chemicals that a species produces by itself must be distinguished from the ones it gets from its diet or its environment. And if the target animal isn't ingesting the right bacteria or other toxin producers at the right time, bioexplorers may not be able to extract the chemicals they want.

Some toxin carriers, for instance, including sea slugs and puffer fish, feed on toxic species only seasonally. Bioexplorers once noted, to their dismay, that long-term-captive and captive-bred dart-poison frogs produced less potent poisons than their wild counterparts—or even no poisons at all. Systematists were able to resolve the puzzle. Many precursor chemicals for the poisons come from specific prey insects. Deprived of their natural prey, most of the frog species became harmless.

Systematists can also save both time and money once a particular species has been identified as a source of a particular biomolecule. It is then well worth determining whether a close relative of the species might produce an even more useful version of the molecule. But related species—particularly the ones belonging to the so-called lower taxa—may be hard or impossible to pinpoint without the knowledge of a qualified systematist.

Ranging even more widely through the tree of life, systematists might also help show the way to multiple, alternative sources of a specific biomolecule. Tetrodotoxin, also known as TTX, is a powerful nerve agent, first identified in the tissues of certain puffer fish of the family Tetraodontidae. In Japan the fish is best known for those puffers belonging to the genus *Fugu*, an expensive, high-thrill delicacy, which is served after the poisonous bits have been skillfully carved away—or so the diner hopes—by specially licensed chefs. (Alas, there are some 50 to 150 accidents each year, in which the *Fugu* feast becomes a last meal.)

After tetrodotoxin was identified in

Coastal taipan (Oxyuranus scutellatus) *is reputed to be the third-most-venomous land snake in the world. Yet because of its large fangs, size (some grow longer than nine feet), and nervous disposition, the coastal species is considered more dangerous than its inland relative,* O. microlepidotus, *even though the venom of the inland taipan is the more potent.*

puffers, it started turning up in a variety of places around the globe. In 1982 the ethnobotanist and independent scholar Wade Davis announced that TTX is a major component of the voodoo elixir that turns people into zombies. (A person in a zombie state cannot move, but is fully conscious of everything around him.) TTX was later identified in the skin secretions of the American rough-skinned newt (genus *Taricha*), an amphibian often kept as a pet, and in the venom of Australia's tiny blue-ringed and blue-lined octopuses (genus *Hapalochlaena*). Perhaps most remarkably, it also turned up in the feathers of two genera of birds, *Pitohui* and *Ifrita*, in New Guinea. The source of the toxin turned out to be bacterial. Such microorganisms readily disperse across great distances and throughout a variety of habitats. Thanks to studies by systematists, bioexplorers no longer need to find a particular species of puffer fish in order to obtain TTX.

The question remains, however, whether expertise in taxonomy and biological systematics will be available for the long term. Amid proliferating budget cuts and under increasing pressure to produce "employable" graduates in applied sciences, Australian universities, like many universities elsewhere, have cut back on numerous subjects in the basic sciences. The University of New England in New South Wales is now the only university in eastern Australia to offer courses specifically in biological systematics.

Fortunately, government and commercial interests are stepping into the breach. At the heart of Peter Beattie's Queensland Bioscience Precinct is a partnership between the Institute for Molecular Bioscience, at the University of Queensland, and the Commonwealth Science and Industrial Research Organization. The program has already received $12 million (in U.S. dollars) for the design and construction of a research facility, as well as a ten-year, $60-million commitment for operating funds from the Queensland government. A second project is the Natural Product Discovery Programme, operated in Brisbane by Griffith University, which has received more than $75 million from the London-based pharmaceutical company AstraZeneca.

Such projects have attracted numerous experts in biochemical and pharmaceutical research and development, who are building an industry close to where the raw biomolecules occur in nature. Perhaps some future, revised edition of Bryson's book will mention a very different reference work, something called *Things That Will Save Your Life Derived from Australian Creatures That Can Kill You Horridly.* □

SPECIES	LETHAL DOSE
Anthrax toxin	*0.0002*
Geographic cone shell	*0.004*
Tetrodotoxin in:	
Blue-ringed octopus (venom)	*0.008*
Puffer fish (poison)	*0.008*
Inland taipan snake	*0.025*
Eastern brown snake	*0.036*
Dubois's sea snake	*0.044*
Coastal taipan snake	*0.105*
Beaked sea snake	*0.113*
Western tiger snake	*0.194*
Mainland tiger snake	*0.214*
Common death adder	*0.500*

Various animal toxins are listed by potency (anthrax-toxin potency is shown for comparison). The lethal dose is the so-called LD_{50}, the dose that kills 50 percent of the animals tested with the toxin, in units of milligrams of toxin per kilogram of the victim's body weight.

Taking Inventory

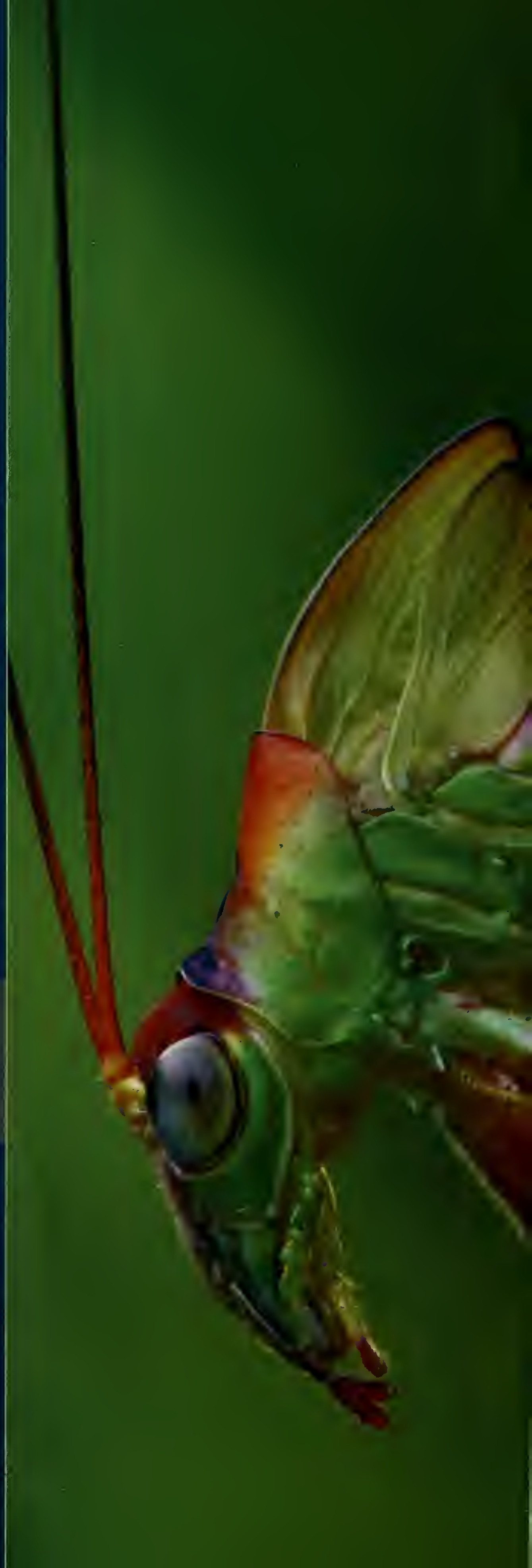
Biologists are still astonished by the diversity of the rainforest.

Text and photographs by Piotr Naskrecki

Some say a biologist in a rainforest is like a kid in a candy store. That's certainly how I feel every time I'm there. Life in the rainforest seems unstoppable; even death loses some of its finality when it happens amidst perpetual rebirth, regrowth, and recycling. The range of species can be staggering, but it is the invertebrate animals living in tropical rainforests that show the true meaning of the word "diversity." A single site can host more species of katydids or beetles than do entire northern continents.

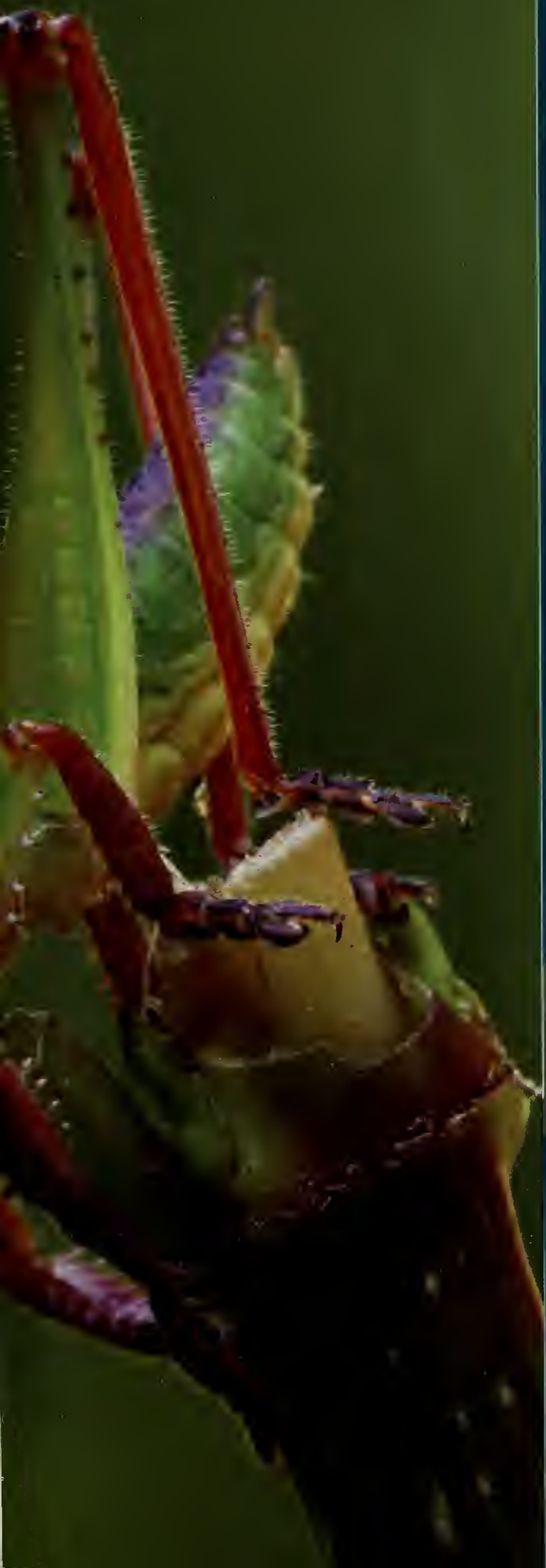
How much life is still left to discover on our unique, green planet—in the rainforests and elsewhere? Nobody knows for sure. In fact, nobody knows exactly how many species have already been described, though the consensus seems to hover around 1.7 million species. Estimates of the total number of species vary from 3 million to more than 100 million; the truth is probably between 6 million and 12 million species. It's likely that most of the yet-unknown organisms are insects and nematodes, but not all new species are small invertebrates. Species of frogs, lizards, and even birds and monkeys previously unknown to science are being discovered in the remote forests of the tropics.

Vividly colored species of katydids, such as the balloon-winged nymph at right (Tympanophora uvarovi), warn predators to stay away or else expect an unappetizing meal. Other species take the quieter route and disguise themselves as leaves or moss. Katydids flourish in humid, tropical regions all over the world.



In my work on insects and arachnids I have discovered about eighty new species so far, some unusual enough to merit placement in a separate, higher taxonomic category: a new genus. But my findings pale in comparison with those of the most prolific taxonomists, some of whom have found thousands of new taxa.

Sometimes one hears the sentiment that descriptive, taxonomic work is not true science. It's an unfortunate attitude, and worse, an expression of ignorance. How can we forget that virtually all great biological principles and discoveries originated from countless individual observations? I hope these photographs will convey some of the thrill of hunting for new forms of life, and of becoming acquainted with some of our more elusive neighbors. □



Smooth skin of a leaf-tailed gecko (*Uroplatus* sp.), pictured above, is velvety to the touch. The gecko, native to Madagascar, is covered with beadlike scales that are readily shed if the animal is caught, making quick escape more likely. Other well-protected creatures include the young Costa Rican treehoppers (*Membracis dorsata*) pictured below. They wield tough armor and sharp, defensive spikes on their backs.

Costa Rican Cholus cinctus, above, is one of roughly 60,000 species of beetles that belong to a single taxonomic family, Curculionidae, or weevils. Weevils are not only the largest family of beetles; they are also the largest family of living organisms on Earth. Their mouthparts, usually affixed to the tip of a long snout, may account for their evolutionary success. They enable weevils to bore deep holes and deposit their eggs even in the hardest seeds or nuts. Many weevils, including this Costa Rican species, are excellent fliers.

Velvet worms (Onychophora), such as the one with giant, drooping antennae at right, run the gamut of mating and breeding strategies. In some species the male deposits sperm on top of the female's head; in others, he puts his head into the female's genital opening at the rear end of her body to deliver sperm. The females of some species lay their eggs outside, others hatch eggs inside their body, and still others form a placenta and give birth to live young, bypassing the egg stage entirely.

Costa Rican dragonfly (Gynacantha tibiata), above, awaits the end of a rain shower to start hunting again. The insect is a true predator, relying on its excellent vision to capture the prey that makes up its diet. Few groups of rainforest organisms have been around as long as the dragonflies: they date back about 320 million years, and their morphology has hardly changed since then.

Spittle bug (Tomaspis sp.), left, undergoes its final molt in the foamy froth where it has spent its entire larval development. Unlike vertebrates, insects protect their internal organs with a hard external armor. Considering the unparalleled evolutionary success of the arthropods, such a skeletal body plan appears to be superior to an internal skeletal structure. But the body plan does have its Achilles' heel: arthropods must periodically shed their exoskeletons in order to grow.

This article, along with the accompanying photographs, is adapted from The Smaller Majority, *by Piotr Naskrecki, which will be published this month by the Belknap Press of Harvard University Press.*

Gaping horseshoe-shaped crater of Mount St. Helens (top), formed in its 1980 collapse, is virtually a carbon copy of the crater at Bezymianny volcano (steaming at right), in Russia's Kamchatka Peninsula; Bezymianny collapsed in 1956. The study of avalanche deposits at Mount St. Helens after 1980 led to the recognition that debris at Bezymianny, and at more than 400 other volcanoes worldwide, was also deposited by volcanic collapse.

Blown Away

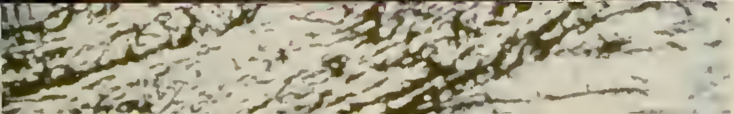
Since the wakeup call at Mount St. Helens, geologists have realized that collapsing volcanoes are far commoner than ever imagined.

By Lee Siebert

A priest by the name of Tsurumaki was relaxing with friends at an enclosed hot spring in central Japan on a clear morning, July 15, 1888. The hot spring was high on the flank of Mount Bandai, a volcano that had undergone a series of earthquakes the preceding week. But it is unlikely that the people on and around Bandai were concerned. The volcano was densely forested and had not erupted for nearly a century. Besides, the mountain had been steaming, nothing more, for as long as anyone could remember.

Then, at about eight o'clock that morning, the earth suddenly shook. Tsurumaki and his fellow bathers rushed outside. While they anxiously tried to find out what had taken place, a powerful explosion rocked Ko-Bandai, the youngest of an overlapping group of small volcanoes that collectively make up Bandai volcano. As the sky turned pitch-black, rocks and stones began raining down around them, and Tsurumaki and his friends fled.

What the priest did not realize was that he had had a front-row seat for one of nature's most dramatic events—the catastrophic collapse of a volcano. Ko-Bandai volcano collapsed in a massive landslide that created a horseshoe-



Composite diagram depicts the initial stage of the supersonic blast at Mount St. Helens, combined with a later stage of the slower-moving avalanche. The avalanche (arrows) swept into Spirit Lake, causing a tsunami 850 feet high; it also overtopped part of Johnston Ridge and ran west down the North Fork Toutle River. The dashed lines show a new lake that formed soon after.

shaped crater, 5,000 feet by 6,500 feet wide, on the northern flank of the mountain. A jagged cliff was left near where the priest had been relaxing. Almost 1.6 billion cubic yards of Ko-Bandai's former summit had collapsed, causing a high-speed avalanche that traveled seven miles, overwhelming several villages and killing 461 people. The avalanche also left massive piles of volcanic debris that covered broad mountain valleys, dammed up drainages, and eventually created five large lakes.

Geologists from the Imperial University of Tokyo immediately studied the eruption in detail. Their thorough report, however, remained relatively unknown to most volcanologists outside Japan for nearly a century. Not until another volcano exploded on the opposite side of the Pacific Rim of Fire, in Washington state, did geologists fully realize the significance of what had happened at Bandai.

The eruption and collapse of Mount St. Helens in 1980 fundamentally changed volcanologists' understanding of how volcanoes work; it led to a reassessment of the role of catastrophic collapse in shaping the Earth's volcanoes. Among Earth's most notable topographic features, volcanoes as prominent as Mount Fuji in Japan, Mount Rainier in the Cascade Range, Popocatépetl in Mexico, Kilimanjaro in Africa, and Mauna Loa in Hawai'i, along with many others, have undergone catastrophic gravitational collapse. Those collapses are manifest in rocky debris that shaped landscapes far beyond the volcanoes. When this debris sweeps into oceans or lakes, it can generate devastating tsunamis. And there is no reason to think that such violent events are confined to the past. The collapse of nearby volcanoes continues to threaten millions of people around the world.

Mount St. Helens stirred to life again this past year, recalling the tragic spring, twenty-five years ago. Volcanologists in Japan had begun putting the pieces of the volcano-collapse story together shortly before 1980. But the Mount St. Helens eruption was the first in which large-scale failure of a volcano was observed and photographically documented at the time of eruption.

The event began with a massive landslide on May 18, 1980, at 8:32 in the morning. Mount St. Helens had been erupting intermittently since March 27. And, in early April, geologists had noted that the northern flank of the mountain was beginning to bulge ominously. In spite of the danger, curious onlookers positioned themselves expectantly around the smoldering volcano, and geologists monitored the mountain at close range.

As they watched, an enormous block of the mountain, including part of the summit and much of the northern flank, broke away [*see illustration above*]. The block had acted as a lid, holding in the magma that was causing the volcano to bulge; removing it suddenly depressurized the magma, which sent a violent blast of rock, gas, and ash sideways, northward out of the flank of the volcano. The laterally moving blast cloud initially expanded at supersonic speeds and ultimately destroyed everything in its path over a 180-degree arc across an area of 230 square miles.

Meanwhile, the landsliding debris rapidly broke apart and formed a high-velocity avalanche that

> *Mount St. Helens was the first large-scale collapse to be extensively photographed at the time of eruption.*

slammed into nearby Spirit Lake. The debris displaced the lake, causing a tsunami whose waves rose 850 feet above the shore and scoured the mountainsides down to bedrock. Today, a quarter of a century later, a massive raft of displaced logs is still floating on the surface of Spirit Lake.

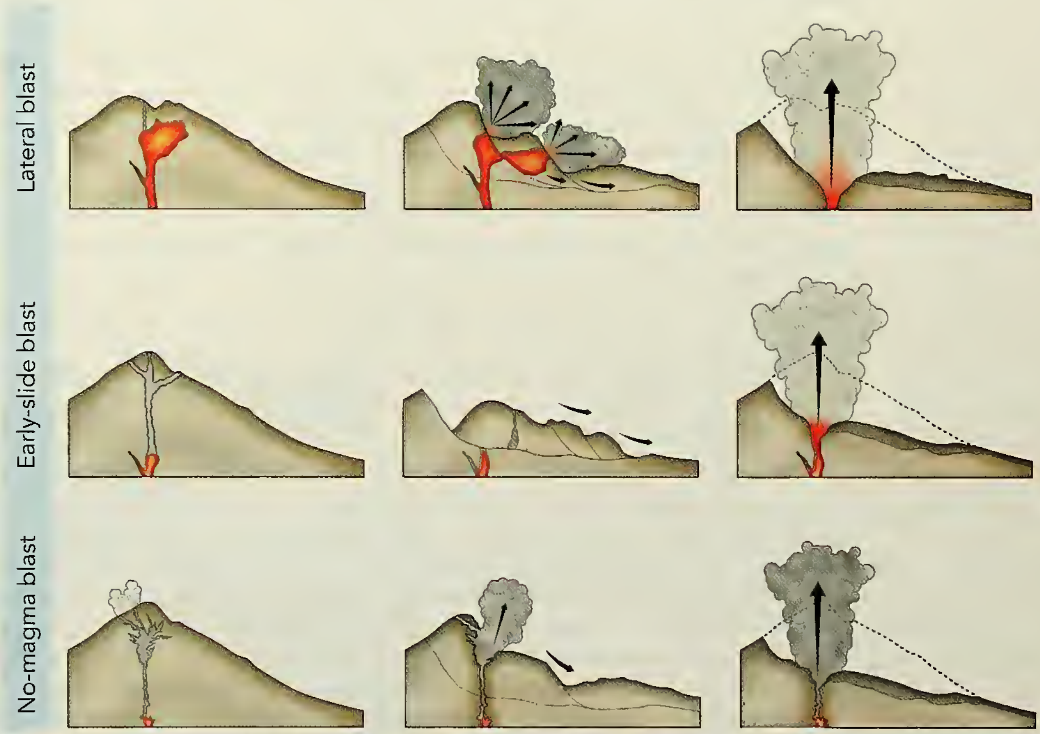
Part of the avalanche had enough momentum to ride up and over a tall mountain ridge—Johnston Ridge—that lay across its path. Most of the debris avalanche was deflected and swept westward another fourteen miles down the North Fork Toutle River, filling the valley with volcanic debris to an average depth of 150 feet.

Detailed studies after the eruption by investigators at the U.S. Geological Survey (USGS) and other institutions showed that the volume of debris from the avalanche closely matched the missing portion of the volcano's summit. Thus, the destruction of the summit and formation of the impressive horseshoe-shaped crater (previously attributed at other volcanoes to explosions) was caused primarily by the avalanche, not the lateral blast. This conclusion has been hard for many people to square with the visual impact of the blast cloud; even today one often hears incorrect assertions that the explosion "blew off the top of the volcano."

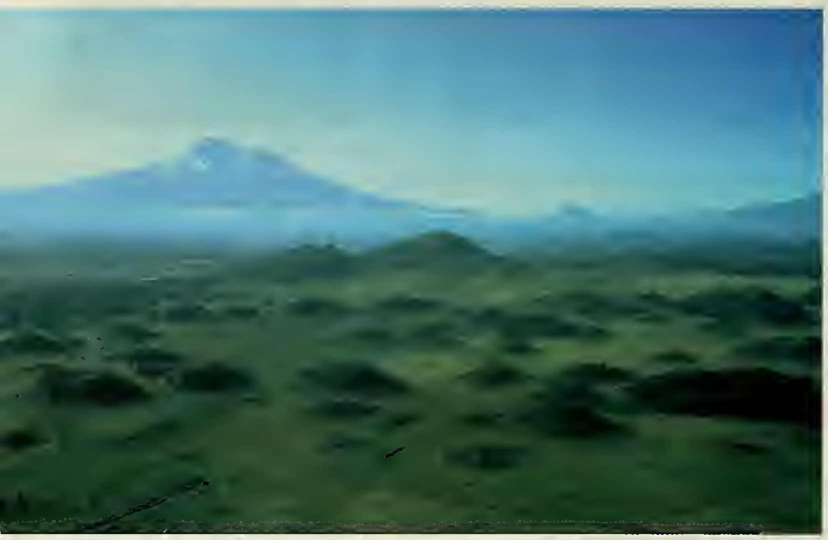
The eruption of Mount St. Helens prompted volcanologists to reexamine puzzling deposits that had been recognized as volcanic, but were far away from any adjacent volcanoes. Geologists had interpreted them, variously, as glacial moraines, individual volcanic vents, or even human structures. One early twentieth-century geologist mistakenly concluded that an area in Java known as the "ten thousand hills of Tasikmalaya" could be explained as the handiwork of farmers, who had supposedly piled up the boulders to clear land for their rice fields.

Since 1980, though, investigators have come to realize that many of the puzzling volcanic deposits are products of what is known as edifice failure. Such failures have been identified so far at more than 400 volcanoes, in a wide variety of geologic settings. The studies of the past twenty-five years make it clear that edifice failure can dramatically reduce the height of a volcano, leaving a large horseshoe-shaped crater or caldera that opens outward in the direction taken by the avalanche. At first, the landslide is relatively coherent. But soon the big blocks break apart, launching a high-speed debris avalanche that comes to rest in the form of hummocky deposits that can cover areas as large as hundreds of square miles.

One distinguishing feature of volcano avalanches is that they preserve the volcanic stratigraphy. Segments of lava flows and delicate features such as layers of ashfall may be transported and come to rest nearly intact tens of miles from the volcano. Sometimes avalanche boulders are also fractured into irregular patterns known as jigsaw cracks: the rocks have been shattered, but the resulting fragments remain in close contact—not unlike a poorly disassembled jigsaw puzzle. The



Three kinds of volcano collapse are shown schematically. When magma is high in the edifice (top left), as it was at Mount St. Helens, a structural failure that leads to rock slippage around a pressurized magma chamber can cause a sudden, lateral blast (top middle and right). A volcano can also collapse with no lateral blast (middle) and still expel magma (middle right), as Shiveluch volcano did in 1964. Finally, even without new magma (bottom), steam and ash alone may be the only visible phenomena associated with a collapse, as they were at Ko-Bandai volcano in 1888. All three kinds of collapse leave U-shaped craters blanketed in debris (dark brown).



Small hills in the foreground are nearly thirty miles from Mount Shasta volcano, in northern California, yet they are now known to be part of the debris from an ancient Shasta collapse. The volcano itself appears hazy in the distance.

contrasting colors of the preserved parts of the original volcanic edifice can provide clues to conditions before the collapse. For instance, the pastel hues of certain rocks may indicate rock that was weakened by extreme heat before the collapse.

In retrospect, it probably should not have been a surprise that volcanoes are prone to collapse. In spite of their topographic prominence, volcanoes are inherently unstable structures. They are made of intermixed layers of solid lava flows and fragmented material, all of which has been weakened by hot gases and fluids and shaken by earthquakes. A host of other factors also contribute to their instability: steep slopes; stress that arises from faulting and from the intrusion of hot magma into vertical fractures, or dikes; and weak, sloping foundations.

Catastrophic collapse was once considered so rare that it was ignored in volcanic hazard assessments. But it is now known that, out of the world's roughly 1,500 volcanoes that have erupted during the Holocene epoch (that is, within the past 10,000 years), at least a sixth of them have undergone major edifice collapse. In fact, some of them have collapsed repeatedly. The Augustine volcano, for instance, which lies about 200 miles southeast of Anchorage, Alaska, has collapsed a dozen times in the past 2,000 years.

"Large-scale" collapses—defined as greater than 100 million cubic meters—have taken place somewhere on Earth at a rate of more than four per century during the past 500 years. Those data suggest that the volcanic landslide may be the most common form of large-scale destruction of volcanic edifices.

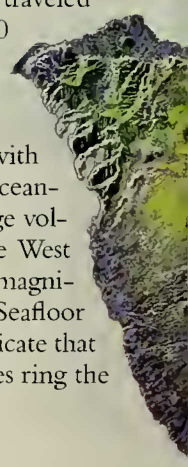
Collapses can take place under a wide range of conditions. Studies of volcano collapse elsewhere have shown that Mount St. Helens was the exception, not the rule. Lateral blasts appear to require unusual circumstances. If a magma body high in a volcano is suddenly unroofed by the breakaway of summit rock, as at Mount St. Helens, the newly accumulated debris from the collapse helps deflect the ensuing explosions. When magma lies deeper beneath the summit, however, the landslide may be over before any explosions begin; in that case, the vent is not obstructed, and normal vertical explosions occur. At some volcanoes, such as Shiveluch volcano, on Russia's Kamchatka Peninsula, collapse has been associated with major eruptions of magma, without lateral blasts [*see diagrams on preceding page*].

Collapse can also ensue without the eruption of any new magma, as it did at Bandai in 1888. Even earthquakes alone can be strong enough to trigger the collapse of a structurally weakened volcano. That fact is particularly disturbing because it means that collapse can take place with little or no warning.

The recent magnitude-9.1 earthquake in Sumatra, and the devastating tsunami that followed, killed some 300,000 people. That extraordinary loss of life has focused attention on earthquakes and their power to move water. But large volumes of volcanic debris falling into the sea can also generate devastating tsunamis, multiplying the effect of a volcanic collapse far beyond the avalanche itself. Out of roughly 25,000 fatalities from large volcanic landslides in historic times, nearly four-fifths of them resulted not from the debris avalanches themselves or the associated volcanic eruptions, but from tsunamis.

The most catastrophic volcano-related tsunami in recorded history took place in 1792. The collapse of Mayu-yama lava dome at Unzen volcano, in southern Japan, caused a debris avalanche that rocked the Ariake Sea. Tsunamis inundated the city of Shimabara as far as the gates of its feudal castle, and swept along a forty-three-mile-long segment of the Shimabara Peninsula. The waves then traveled across the bay, washing away nearly 6,000 houses and 1,600 fishing boats along another seventy-five miles of shoreline. About 14,500 people were killed.

But that event pales in comparison with the size of what the collapse of massive oceanic island volcanoes would cause. The huge volcanoes in Hawai'i, the Canaries, and the West Indies, for instance, are several orders of magnitude larger than Mayu-yama lava dome. Seafloor studies around those island volcanoes indicate that massive deposits of debris from avalanches ring the islands as far out as 150 miles.



Two kinds of island and underwater collapses have been identified: slumps and debris avalanches. Large slumps typically creep slowly, though occasionally they lurch a few feet in response to an earthquake without substantially disrupting the volcano. Debris avalanches, in contrast, move at high speed, and they often transport fragmented debris over long distances, including blocks as large as six miles wide. The surface topography of such a debris field on the seafloor is comparable to that deposited by terrestrial avalanches.

The massive volume of submarine landslides can create very large tsunamis, often called megatsunamis. Rocks with coral deposits 230 feet above sea level on Moloka'i and 1,200 feet on top of Lana'i, in the state of Hawai'i, have been interpreted as tsunami deposits. Some controversy remains, though, in part because the rates of uplift and subsidence of those islands since the time of collapse are not well known. At Kohala volcano on the Big Island of Hawai'i, however, where height changes have been well documented, tsunami deposits were likely carried between 1,100 and 1,600 feet above sea level when neighboring Mauna Loa volcano collapsed.

Avalanches flowing from islands have carried volcanic debris as far as 150 miles along the sea floor.

Models and computer simulations of how tsunamis propagate after large underwater landslides have focused primarily on the Hawaiian Islands and on one volcano in the Canary Islands: Cumbre Vieja on La Palma. The latter volcano collapsed several times during the Pleistocene epoch, and an eruption in 1949 created faulting on the mountain that has caused much concern and controversy about a potential landslide in the future.

One difficulty with modeling is its sensitivity to varying assumptions. Depending on assumptions made, results can differ by a factor of ten or more. For example, models show that a collapse of Cumbre Vieja volcano could cause tsunami inundation on the eastern coast of the United States from as high as eighty feet to less than ten feet above sea level. Obviously, such a difference has widely varying hazard implications.

When volcanoes collapse, no matter what their size, the impact can be substantial. Millions of people now live on top of debris-avalanche deposits or in coastal areas that would be threatened by volcano-driven tsunamis. In the quarter century since the eruption of Mount St. Helens, substantial progress has been made in identifying factors that contribute to volcano instability. Volcanologists have also improved the technology for monitoring eruptions, and they have developed computer models that help anticipate where debris avalanches might travel.

Fortunately, despite the recognition of its increased frequency on geologic time-scales, catastrophic edifice failure remains a rare event—albeit a high-stakes one. The more catastrophic the event, the more attention it garners from media and others, but what is often dismissed is how infrequently the bigger events take place. Ironically, the very rarity of edifice failure makes hazard planning politically difficult. The intervals between collapses may be far longer than most public officials remain in office, and consequently, safety measures are often not even considered. The potential impact zones, moreover, are so large that moving people permanently is not an option. The focus, instead, must be to identify short-term precursors to collapse, as well as to educate public officials and residents about the potential hazards and the appropriate responses to them. Recently, the USGS has greatly improved its educational programs and its methods for predicting collapses for residents near Mount Rainier. Fittingly, Rainier is a close neighbor of Mount St. Helens. □

Volcanoes on Tenerife (satellite image at far left), in the Canary Islands, have collapsed repeatedly. The resulting avalanches have left massive deposits on the seafloor, as shown in the chart at left. Collapses of such island volcanoes can give rise to large tsunamis and reshape the ocean floor.

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THIS LAND

Where Glaciers Did Not Tread

Ice now lodges in crevices, creating miniature ice age habitats in North America's Driftless Area.

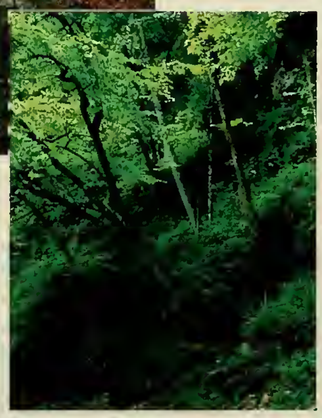
By Robert H. Mohlenbrock

Limestone cliffs loom in the Driftless Area, a region bypassed by the two most recent ice age glaciers.

During the Pleistocene epoch, between about 1.8 million and 10,000 years ago, a series of ice ages swept over the Earth. The glaciers of each ice age covered large regions of the planet, particularly in the Northern Hemisphere. The geological traces of their comings and goings are easy to spot, in scoured bedrock, in large isolated boulders (known as glacial erratics), and in deposits of gravel, sand, silt, and clay (known as glacial drift). The two most recent ice ages, known in North America as the Illinoian (between 170,000 and 120,000 years ago) and the Wisconsinan (between 70,000 and 10,000 years ago), were quite severe at their maximums. Somehow, though, their glaciers bypassed a 15,000-square-mile area of what is now southwestern Wisconsin, southeastern Minnesota, northwestern Illinois, and northeastern Iowa, even though earlier Pleistocene glaciers had covered the region. Because early geologists did not find recent glacial drift in the region, it became known as the Driftless Area.

With precipitous limestone cliffs, deeply shaded ravines, and clear rocky streams, the Driftless Area is a rugged landscape. On steep south- and west-facing slopes of some of the cliffs, exposed to the intense rays of the afternoon sun, are patches of grassland known as hill prairies. The plants that grow there are typical of the tall grass prairies of the plains a few hundred miles to the west. In contrast, the talus, or rock rubble, accumulated beneath cool, north-facing cliffs sometimes provides a very different kind of habitat, one that biologists call algific talus slope, or simply algific slope. "Algific" means cold-producing, and such cool slopes, which may be as small as a few square yards or extend for as much as a half-mile, serve as refuges for plants that usually grow much farther north.

Air circulation is crucial to creating and maintaining the unusual conditions of the habitat. The rocks and boulders that break off the cliffs can be quite large, and as a result many large air spaces pervade the talus. In addition, a cliff top may be pierced by fissures and sinkholes that open the base of the cliff to the flow of air. Where those conditions prevail, cold winter air penetrates the base of the cliffs and freezes water deep within the limestone. During the summer, air draining down through the cliff encounters the ice; the chilled air then flows out through the talus, keeping it cool during the warmer months.



Algific talus slope

On July 30, 1985, for instance, John Schwegman, an Illinois botanist, recorded a surface air temperature on an algific slope of forty-two degrees Fahrenheit; ten inches down between the rocks, the air temperature was only thirty-three degrees.

Biologists think conditions on the algific slopes have remained largely unchanged since ice age times. That would explain why boreal plants and animals persist this far south, in some cases isolated from their next most southerly homes. Botanists are always fascinated by such disjunct, or discontinuous, ranges. One remarkable example—because relatively few species of trees grow in the moss-covered, rocky terrain—is balsam fir. Its major range lies about a hundred miles to the north. As Schwegman noted, another peculiarity of the algific slopes is that plants that normally bloom in the spring in northern Illinois may bloom on the cool slopes throughout the summer and even in late September.

Some quarter-inch-long snails discovered in Iowa in the late 1920s remained in a specimen collection until 1940 before someone recognized them for what they were—*Discus macclintocki*, an organism previously known only from fossils and thought to have become extinct 10,000 years ago. In the early 1970s, Leslie Hubricht, an independent malacologist, or mollusk specialist, discovered new specimens of the snails, living in algific slopes. The Iowa Pleistocene snail, as it is now known, has been included on the federal list of endangered species since 1978. To date, additional searches, by Terrence J. Frest, a malacologist working with Deixis Consultants in Seattle, and others, have found the snail alive in leaf litter on thirty-seven algific slopes in Iowa and Illinois. It lives as long as seven years, hibernating in winter and laying eggs in the spring. Eight other species of ice age snails have also turned up on the algific slopes, including the Minnesota Pleistocene amber snail and the Midwest Pleistocene vertigo.

Many algific slopes are on private property. One accessible to the public is in Iowa's Bixby State Preserve. In addition, the Driftless Area National Wildlife Refuge, which comprises nine scattered tracts of land totaling 781 acres in Iowa, has oversight over perhaps twenty algific slopes. The refuge was established in 1989 to protect both the Iowa Pleistocene snail and the northern monkshood, a relative of the buttercup that the federal government classifies as a threatened species. The U.S. Fish and Wildlife Service is seeking approval to add another 2,275 acres, covering nearly 200 tracts in Iowa, Minnesota, and Wisconsin.

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ROBERT H. MOHLENBROCK is professor emeritus of plant biology at Southern Illinois University in Carbondale.

Habitats

Algific slope In addition to balsam fir, notable for its disjunct range, tree species include mountain maple, paper birch, and yellow birch. Other plants with disjunct ranges include golden saxifrage, hook violet, limestone oak fern, meadow bluegrass, northern currant, northern lungwort, northern monkshood, purple clematis, twinflower, and three species of sedge. Although they are not considered disjunct species, several plants native to the habitat are otherwise rare for this part of the country: bunchberry, Forbes' saxifrage, kidney-leaved violet, marsh bluegrass, one-sided pyrola, pink pyrola, and sullivantia.

More common plants include such shrubs as alder buckthorn, American yew, beaked hazel, beaked willow, dwarf raspberry, highbush cranberry, northern shadbush, prickly rose, and red-berried elder. Among the common wildflowers are alpine enchanter's nightshade, Canada violet, great Indian plantain, green violet, moschatel, rosy twisted stalk, rough bedstraw, single-stemmed groundsel, stiff gentian, woodrush, and yellow trout-lily. Meadow horsetail, mosses, and oak fern also abound.

Moist woods The woods that surround the algific slopes are dominated by American elm, basswood, bitternut hickory, black walnut, box elder, hop hornbeam, sugar maple, and white ash. Among the numerous wildflowers are bellwort, bloodroot, blue cohosh, hairy blue violet, jack-in-the-pulpit, Jacob's ladder, liverleaf, Virginia waterleaf, white avens, and wild bergamot.


Northern monkshood

Complementing the wildflowers are northern lady fern and northern maidenhair fern.

Hill prairie Dominant grasses include big bluestem, little bluestem, prairie dropseed, and side-oats grama. Pasqueflower is the first wildflower to bloom in early spring, followed by thimbleweed, bird's-foot violet, downy painted cup, and two kinds of blazing stars. William C. Watson, an Iowa biologist and independent consultant who has surveyed the hill prairie vegetation, reports that red cedar is displacing the herbaceous cover. The trees have probably benefited from the absence of fires, which in the past kept them in check.

By Laurence A. Marschall

Conflict in the Cosmos: Fred Hoyle's Life in Science
by Simon Mitton
Joseph Henry Press, 2005; $27.95

To those who came of age in the 1950s, the cosmologist Fred Hoyle (1915–2001), like Carl Sagan a generation later, was the popular voice of science. Hoyle's *Frontiers of Astronomy,* published three years before the October 1957 launch of *Sputnik I,* became an instant best seller in both Great Britain and the United States, inspiring legions of overachieving adolescents—including many of today's practicing physicists and astronomers—to choose careers in research. For masses of radio listeners, Hoyle's talks on life, the universe, and everything in between, delivered in his folksy Yorkshire accent, were a delight and a wonderment. "He describes events in interstellar space as if commenting on a cricket match," one BBC blurb proclaimed.

In a 1949 broadcast on the origin of the universe, he coined the term "big bang" to describe theories of a primordial explosion, a term so vivid and descriptive that it soon became standard English. Whether people liked him or not, they followed his talks and his published writings because there was no telling what barroom debate he might stir up next. "It seems to me," he wrote in a typical passage, "that religion is but a blind attempt to find an escape from the truly dreadful state in which we find ourselves."

Professionally, Hoyle was just as creative and controversial. The cosmological theory he favored, against a tide of big-bangers, came to be known as the steady-state universe. Along with the mathematician and cosmologist Hermann Bondi, and the astronomer and geoscientist Thomas Gold, Hoyle argued that there was no big bang, and that time has no beginning and no end. The observed expansion of space, the steady-staters surmised, is accompanied by the continuous creation of matter, which keeps things from thinning out. The universe, on average, has always looked the same.

To those who objected that spontaneous matter creation had never been observed, Hoyle responded that the big bang presupposed it too, but as a single event. Besides, the creation rate that the steady-state theory required to maintain a universal constant density was far too low to detect. As Hoyle put it, for every volume of space the size of a one-pint milk bottle, about one atom is created every thousand million years. For a decade thereafter, the big bang was seldom mentioned without giving equal time to Hoyle's alternate theory.


Fred Hoyle at Caltech, 1967

Beginning in the 1960s, however, a growing mass of evidence, most notably the detection of the background radiation from the big-bang fireball, left the steady-state theory with little to recommend it.

Hoyle's contributions to other areas of astronomy, however, have been lasting and profound. Together with E. Margaret Burbidge, Geoffrey R. Burbidge, and William A. Fowler, Hoyle worked out the details of how the chemical elements were built up from primordial hydrogen in the interiors of stars. He contributed seminal ideas to theories as diverse as the structure of atoms and the formation of planetary systems. His forceful leadership in a variety of administrative roles brought a prominence to British astronomy that it had not enjoyed since the days of Newton.

Simon Mitton, an astronomer, writer, and editor who knew Hoyle in his heyday, has written a sensitive, literate portrait of the man and his science. In spite of Mitton's demurral that he lacks the historian's credentials needed for a definitive biography, he has mined a wealth of personal papers, oral histories, and other primary sources with skill and flair. The result is a balanced and exceptionally readable account of a remarkable man.

Although Mitton only touches on it, it is ironic that today's proponents of so-called intelligent design should claim Hoyle as an ally. They do so mainly by selectively quoting his assertion that life could not have arisen from the random assemblage of molecules on Earth. They ignore (of course) his contention that life arose in clouds of interstellar dust, where, at least in the steady-state universe, there was plenty of time for random processes, and thus no need for a creator. Like so much of what Hoyle wrote, the idea was brilliant, if ultimately more seminal than convincing. Mitton's biography makes one wish Sir Fred (he was made a knight in 1972) were still around to carry on the good fight with his scientific critics, as well as with those pious polemicists who would co-opt him for their own.

Hunger: An Unnatural History
by Sharman Apt Russell
Basic Books, 2005; $23.95

At the risk of oversimplifying, you can think about the body as if it were a car. Ordinarily, about 2,000 calories a day are needed to keep it running, and most of us top the tank off frequently, so that regular meals provide most of those calories. In a pinch, there's a large reserve, about 160,000 calories, stored primarily in fat and muscle tissues: enough to keep a person puttering around, in principle, for about eighty days.

Most everyone has experienced hunger at one time or another. But I would venture that most readers of this magazine know the feeling as little more than a temporary inconvenience. We in the West eat, by and large, whenever we need to, and often when we don't.

Nature writer Sharman Apt Russell explores the subject of hunger far beyond such common experience. What happens, she asks, and what does it feel like, when the body is deprived of food for a day, a week, a month? What happens when food is scarce? It should come as no surprise that there is plenty of historical light to shed on the subject, and even some science: wars and famines, as well as fasting rituals, characterized human experience for far longer than have the relative peace and plenty of the recent past.

Rowan Gillespie, *The Famine Group*, 1997 (permanent installation in Dublin, Ireland)

On the bright side, some people have actually experienced hunger as an "uplifting" experience. In 1877, for instance, a middle-aged physician named Henry Tanner, depressed and ailing, decided to commit suicide by not eating. After ten days, at which time the medical science of his day had predicted inexorable death, Tanner was still feeling fine—so much so that he continued to refuse food for another month. He emerged from his fast a changed man, free of asthma, rheumatism, and self-destructive thoughts, and he embarked on a new career as a lecturer, touting the restorative power of fasting.

Tanner was neither the first nor the last to recommend this extreme form of self-restraint: religious faiths have long promoted regular fasting as a way to purge the soul of worldly distractions, and there seems to be a "health guru" in every generation whose idea of the good life is to restrict meals to merest subsistence. The scientific evidence regarding the benefits of fasting, however, is spotty. Aside from a few well-known studies with mice, whose calorie-restricted diets led to significantly longer lives, persuasive medical evidence that food deprivation promotes health is hard to come by.

But alas, there is no shortage of scientific evidence on the harmful effects of hunger. In one section of her book, Russell recounts the story of the remarkable study of "hunger disease" that Jewish doctors carried on in the besieged Warsaw Ghetto, in 1942. In spite of their own desperate conditions, the physicians meticulously recorded the physiology of starving patients at two hospitals. Their manuscript, at once horrifying and edifying in its systematic detail, is a document that records both unspeakable cruelty and the power of the mind to withstand it. Of course, most of the participants, including the authors, did not survive the war. But as one doctor wrote in the introduction to the manuscript, before he was shipped off to Treblinka, the work of these physicians "could give the henchman the answer. . . . I shall not wholly die."

Not every chapter in Russell's book is that grim, but all of them are thought provoking. She writes of anthropological studies of societies hit by famine; of conscientious objectors during the Second World War who voluntarily starved themselves in order to help nutritionists develop a strategy for reviving the starving masses in postwar Europe; and of anorexic middle-class teenagers in the West who experience a form of psychological gratification by starving themselves to death.

Although Russell flies across this landscape perhaps too quickly to provide more than a glimpse of today's major hunger issues, she writes with immediacy and authority. Readers whose appetites are whetted can find food for further thought in the ample references at the end of the book.

The Great Hurricane: 1938
by Cherie Burns
Atlantic Monthly Press, 2005; $24.00

The devastation wrought by hurricane Katrina still feels like a punch in the belly of the Southeast, but surely, at least, the warning and evacuation saved many lives. Not so with the great storm that hit the Northeast on September 20–21, 1938. Hurricanes hardly happen there anyway, but with no timely warning, the storm caught everyone by surprise.

Spawned in the eastern Atlantic and reported by a few passing vessels as it headed northeast after skirting the Bahamas, the great storm disappeared from weather stations when it missed northern Florida and headed out to sea. There were few ships along its path, and in an age when radar, satellite photos, and oceanographic buoys did not exist, there was no way to know that it was intensifying to what we would now call a category-four hurricane and heading straight for the eastern coast of Long Island with the speed of a bullet train. By the time barometers began to drop precipitously in the Northeast, it was too late. There was no Weather Channel, no Internet, no stand-ups by wind-whipped, rain-soaked TV reporters, and, of course, no evacuation plan.

"Rain, heavy at times" was the official prediction for the Northeast coast when the hurricane slammed into the Hamptons, rolled over Long Island Sound, and pummeled eastern Connecticut and Rhode Island. It was, by then, gargantuan in size and unprecedented in strength: 500 miles across and pushing a storm surge big enough to look like a tsunami. To make matters worse, a high-pressure system moving down from the north collided with the hurricane just as it reached inhabited territory. The storm stalled, dropping between ten and seventeen inches of rain on eastern Long Island, coastal Connecticut, and Rhode Island in a matter of hours, and keeping the floodwaters high for far longer than usual.

Writer Cherie Burns, who has seen her share of wind and weather from her home on Nantucket, has dug up old newspaper accounts and local histories to reconstruct the terror and destruction that accompanied the 1938 hurricane. Those who suffered the most, of course, did not survive to tell their tales. Nearly 700 people died, and about 63,000 were left homeless. Among the coastal enclaves of New York, Connecticut, and Rhode Island, as many as 9,000 homes were totally destroyed. Some communities, such as the cottage colony at Napatree Point, Rhode Island, were so completely obliterated that pictures taken the morning after show nothing but a long stretch of barren sand. At the height of the storm, corpses floated up the city streets of downtown Providence.

Survivor's stories, however, give ample feeling for the power of the rain, tide, and wind. Katharine Hepburn, who wrote about the hurricane in her memoirs, evacuated her home in Fenwick, Connecticut, when the chimneys blew down and a wing of the house collapsed in the wind. The next morning, she found what remained of the blown-off wing, wrapped around a stone bridge a third of a mile away.

With power and telephone lines down, roads washed out, and bridges gone, it was as if the most populous part of the nation had been leveled by an invading army. In fact, had Hitler's armies not overrun Czechoslovakia a few days later, the great storm might still be remembered as a defining moment in history. Burns's narrative makes one appreciate anew the strengths of modern communications and emergency planning, as well as their ultimate powerlessness against the forces of nature.

Hurricane destruction along the coast of Long Island Sound, Niantic, Connecticut, September 1938

Laurence A. Marschall, *author of* The Supernova Story, *is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy. He is the 2005 winner of the Education prize of the American Astronomical Society.*

Maps Take Flight

By Robert Anderson

Recently I read *Fatal Passage*, Ken McGoogan's 2002 biography of a remarkable yet largely forgotten Arctic explorer, John Rae. Traveling by dogsled, in the style of the Inuit, Rae trekked thousands of miles along the northern coast of North America to fill in the blanks on regional maps. On May 6, 1854, from atop a barren ridge, he charted a strait that now bears his name, the final link in the long-sought Northwest Passage.

Like countless explorers before him, Rae always sought the high ground, the better to observe the surrounding terrain. Later cartographers sought the vantage points afforded by balloons, airplanes, and satellites to trace the lines of lands and seas on Earth. Decades have now passed since all the blanks were filled in. Could the glory days of mapmaking have already come to an end?

To judge from some of the tools and information recently available on the Web, the glory days are just beginning. A few months ago Google launched its ambitious new "Google Earth," billed as a "3D interface to the planet" (earth.google.com). You'll need to download Google's free software to use it (it works with computers running Windows 2000 or later, but, at the time of this writing, Macintosh users are out of luck). Enter a street address, at least in the United States, Canada, and the U.K., and you will zoom seamlessly from an *Apollo 8*-like vantage point to right above the rooftops. You can then tilt and rotate the view and soar over the landscape like a bird. You can even exaggerate the vertical relief of the simulated landscape by a factor of three.

If your system won't run Google Earth, the company has another mapping site (maps.google.com) that does much the same thing, but without the ability to "fly" over the landscape or tilt your flight perspective. I entered my street address, but the Web site flagged my next-door neighbor's house by mistake. Nothing's perfect.

The National Atlas of the United States of America (www.nationalatlas.gov) is another remarkable resource for exploring the U.S. through maps and images. Updated quarterly by the U.S. Geological Survey (USGS), it combines data on people, infrastructure, and natural resources culled from twenty government agencies. Visitors can create maps tailored to their needs by clicking on "Map Maker," but I preferred the site's "Dynamic," or interactive, maps. I found the "Tapestry of Time and Terrain" was my favorite, with its overview of our nation's geology.

For much of the twentieth century the best views of the terrain in the U.S. were the USGS's topographic maps. For many purposes, such maps are more practical than satellite images. You can find them for free on the Internet at the National Atlas or at topozone.com.

During an eleven-day mission in February 2000, the Space Shuttle *Endeavour* used radar to generate a new topographic database of our planet. NASA promises to release the finished product to the public by this December. Go to www2.jpl.nasa.gov/srtm/ for more on the "mission to map the world."

For live-feed, up-to-the-minute views from a satellite-borne webcam, see the "Earth and Moon Viewer" (www.fourmilab.ch/earthview/vplanet.html), by software writer John Walker. I particularly like the feature that helps me comprehend global time. Select a location from "various cities" and then hit the "hemisphere" view under the resulting map. From a million kilometers above, you can see the regions of the planet illuminated by the Sun at any given moment. At noon this time of year, I can see Rae's Strait, near the edge of darkness.

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

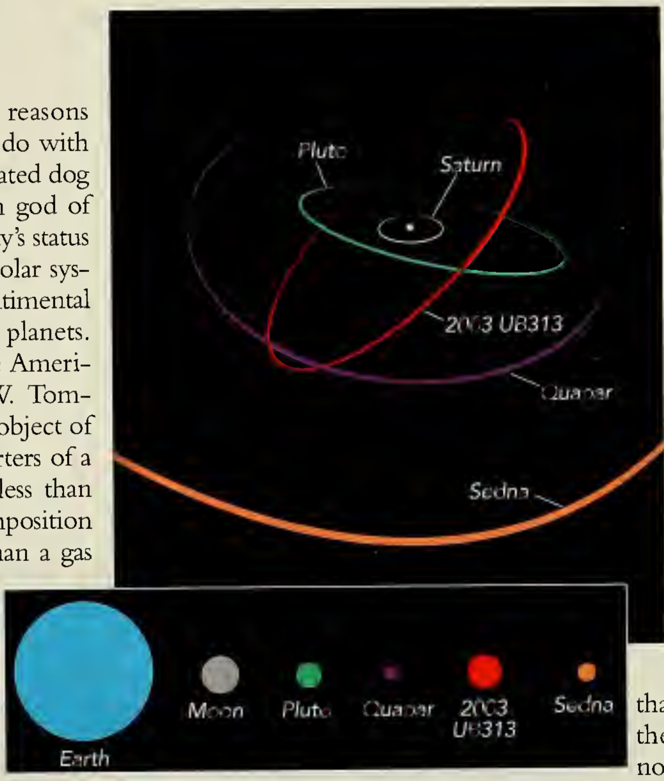
OUT THERE

Number Ten?

A new object, bigger and farther than Pluto, is orbiting the Sun. But is it a planet?

By Charles Liu

Pluto—perhaps for reasons having as much to do with Walt Disney's animated dog as with either the Roman god of the underworld or the body's status as the "little guy" of the solar system—seems to be our sentimental favorite among the nine planets. Discovered in 1930 by the American astronomer Clyde W. Tombaugh, Pluto has been an object of curiosity in the three-quarters of a century since then. It is less than 1,500 miles across; in composition it is more like a comet than a gas giant or a terrestrial planet; it has an eccentric elliptical orbit, whose plane is tilted at seventeen degrees from the orbits of the rest of the planets; and it is just one among the uncounted hordes of similar small, icy and rocky bodies in a bagel-shaped region of the solar system known as the Kuiper Belt.



Schematic three-dimensional view (top) depicts the orbits of Saturn and Pluto, along with the orbits of several recently discovered solar system objects at the same scale (the diameter of Saturn's orbit is nearly 1.8 billion miles). The orbit of 2003 UB313 is a highly eccentric ellipse, and is tilted with respect to the orbital plane of the major planets at an angle of 44 degrees. Above, the relative sizes of the newfound objects are compared with the sizes of the Earth and Moon; the exact size of 2003 UB313 is uncertain, but it is larger than Pluto. For clarity, the objects and their orbits are shown in matching schematic colors.

Faced with overwhelming scientific evidence, many of my colleagues have called for Pluto's reclassification from "major planet" to "minor planet." That action, they argue, would lead to more detailed study of Pluto as a representative of an entire class of objects in the solar system. Many other people, however—including, apparently, much of the American public—passionately oppose reclassification. Why should their beloved ninth planet have to endure the indignity of a "demotion"? Some who defend the status quo have even proposed defining "planet" to exclude every Kuiper Belt object (KBO) *except* Pluto.

Until recently, the commonest way to include Pluto among the planets has been to insist that size matters. The argument goes like this: even though it's smaller than Earth's Moon (or, for that matter, the moons Io, Europa, Ganymede, Callisto, Titan, and Triton), Pluto orbits the Sun. And because it's the largest object to do so—other than Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune—it belongs to the planetary pantheon.

Well, Pluto-bashers can now smugly rejoice. Michael E. Brown, an astronomer at Caltech, together with Chadwick A. Trujillo of the Gemini North Observatory in Hawai'i and David L. Rabinowitz of Yale University, have discovered a new KBO, nine billion miles from the Sun, whose diameter exceeds that of Pluto—possibly by half again as much. At its greatest distance from the Sun, 2003 UB313 (the body's provisional name) is twice as far from the Sun as Pluto ever gets. It takes 557 Earth years for it to make just one solar orbit, compared to "just" 248 years for Pluto.

Most astronomers have figured that one day another KBO would outdo Pluto in size. The basic planet-finding technique hasn't changed much since Tombaugh's time: basically, you look at a series of images of the same area of the sky made at various times, and you scan for objects that have moved between one frame and the next. What has changed is astronomical technology—so dramatically that astronomers such as Brown, Trujillo, and Rabinowitz can readily detect and study solar system objects more than a million times fainter than Pluto.

There's a world of difference, though, between having the ability to detect a KBO and actually discovering one. Discovery is hampered most of all by the simple fact that the sky is really, really big. Planet hunters can search only a small patch of sky at a time, and so they've tended to focus on parts of the sky in roughly the same orbital plane as that occupied by the planets Mercury through Neptune. With literally billions of background stars potentially confusing the field of view, it's hard enough to pick a planet out of a restricted part of the sky—much less the entire celestial sphere.

Nevertheless, undaunted by such an expanded search, planet pioneers have had enough successes in the past half decade to make steady inroads on Pluto's size supremacy among KBOs. Varuna, discovered in November 2000, measures nearly 600 miles across—a little less than half the size of Pluto. Less than two years later, Brown and Trujillo discovered Quaoar (pronounced KWAH-o-wahr), which is about 800 miles wide. In March 2004, Brown, Trujillo, and Rabinowitz announced the discovery of Sedna—probably not a KBO, but rather a member of the even more distant Oort Cloud of cometlike bodies—thereby pushing the maximum size of "nonplanetary" objects in the outer solar system up to about 1,000 miles in diameter.

The new Pluto-plus-size object, announced this past July, came to light the same way Varuna, Quaoar, and Sedna did. Brown, Trujillo, and Rabinowitz actually first recorded it in images made in 2003. Following up with spectroscopic observations, the investigators found that its surface, like Pluto's, is covered mostly with frozen methane. Even at its smallest estimated size, 2003 UB313 has dethroned Pluto, the erstwhile king of KBOs.

With one less argument in their favor, will the Pluto-is-a-(major)-planet crowd abandon Pluto to minor planethood? Nah. Larger bodies notwithstanding, many Pluto lovers still think their favorite should retain its status as a "major." By that logic, though, the new KBO must be hailed as the solar system's tenth major planet. If the pace of KBO discoveries keeps up, there may soon be a dozen or more planets—and with them, new names for schoolchildren to learn, new scripts for planetarium shows, and revisions galore in astronomy textbooks. After seventy-five years of nine planets, is the world ready for such a radical reordering of the cosmos?

By this time, you might be wondering whether all this "planet or not" debate is just an overhyped mental exercise. Well, I wouldn't argue with

THE SKY IN OCTOBER

By Joe Rao

Mercury, shining at magnitude zero, can be seen shortly after sunset all month, albeit with some difficulty. To find the planet, use binoculars to locate Venus in the southwestern sky. Mercury is twenty-nine degrees to the lower far right of Venus on October 12. By month's end the two planets are four degrees closer to each other. The best chance to spot Mercury also comes at month's end, when it lies below and to the right of the star Antares, in the constellation Scorpius, the scorpion.

Venus glitters low in the southwestern sky at dusk, growing brighter throughout the month. On the evening of the 6th Venus sparkles about four degrees above and to the left of a three-and-a-half-day-old crescent Moon. Through a telescope Venus is a remarkable sight, as it changes in phase from gibbous (two-thirds illuminated) at the start of October to half illuminated by the end of the month.

October belongs to Mars, and after Venus sets, Mars is the brightest "star" in the evening sky. In early October it comes up about half an hour after twilight, and by month's end it rises just twenty minutes after sunset. For best viewing, wait about two hours after Mars rises and take a look once it has climbed at least twenty degrees above the horizon (as seen from forty degrees north latitude). Mars comes closest to the Earth—within 43,137,071 miles—on the 29th at about 11:25 P.M. On the evening of the 18th the nearly full Moon rises well above and to the right of the planet.

Jupiter is in conjunction with the Sun on the 22nd; the planet is lost in the solar glare throughout the month.

Saturn rises in the east-northeast about five hours before sunrise on the 1st and about six hours after sunset at the end of the month. By dawn it has shifted to a point high in the south-southeastern sky. The ringed planet is the brightest "star" in the constellation Cancer, the crab. Saturn starts the month very close to the fourth-magnitude star Delta Cancri and slowly moves away to the east as the month progresses.

The Moon is new on the 3rd at 6:28 A.M. It waxes to first quarter on the 10th at 3:01 P.M. and to full on the 17th at 8:14 A.M. Our satellite wanes to last quarter on the 24th at 9:17 P.M.

A partial eclipse of the Moon takes place on the morning of the 17th. At its maximum, at 7:03 A.M. central daylight time, less than 7 percent of the Moon's diameter will be eclipsed. The umbral phase of the eclipse lasts less than an hour. The Moon sets before the eclipse ends in the central and eastern United States and Canada.

The Sun undergoes an annular, or ring-shaped, eclipse on the 3rd. The entire silhouette of the Moon's disk appears against a brilliant "ring of fire" for four minutes and eleven seconds, beginning at 8:56 A.M. Greenwich mean time. The track of the eclipse makes landfall on the Atlantic coast of Europe, near the border shared by Portugal and Spain. The track then crosses the Mediterranean and sweeps south and east across Africa.

Follow safety tips from the local media when viewing eclipses. *Never look at the Sun's disc* unless you are using a proper filtering device, such as #13 welder's glass or aluminized Mylar plastic.

Daylight saving time ends on the 30th; people in Canada and the U.S. should set their clocks back one hour.

Unless otherwise noted, all times are eastern daylight time.

(Continued from preceding page)

that. Most of us astronomers are far more interested in the scientific results coming from studies of KBOs than in the (somewhat arbitrary) argument over nomenclature.

For example, at about the same time that 2003 UB313's discovery was announced, a team led by Michael D. Hicks of NASA's Jet Propulsion Laboratory in Pasadena, California, published observations of Varuna, suggesting the presence of loose rock or dust on the surface. Why would the surface of a frigid, icy body in the outer solar system have surface material typical of the warm, rocky asteroids and planets of the inner solar system? That kind of puzzle, not the hue and cry over classification, is what really drives the quest for celestial answers.

CHARLES LIU *is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.*

(Continued from page 10)

tion of grazer control by anthrax spores. The dead body of a sheep or calf on a drought-ridden, dusty field not only supports generations of bacilli over a long winter, but also releases nitrates, phosphates, sulfur, calcium, sodium, and potassium that plants can use when spring rains arrive.

I looked again today at Leidy's teaching chart on my office wall. Its remarkable fidelity enabled Michael McMahan to recognize that I was wrong: the segmented worm with a proboscis probably is not a nematode, but an annelid. I hope Mr. McMahan finds it, as Leidy did, inside the intestines of *Julus marginatus* or another millipede, so that, if warranted, he can describe a new symbiotic oligochaete. If he uncovers a new species, perhaps he will name it *Stylaria leidyii*, in Leidy's honor. Or maybe he will find that the worm Leidy depicted so accurately in his chart is indeed *Stylaria lacustra* from a nearby lake, taking refuge and food inside the body of an arthropod.

Floridian Melting Pot

Christopher M. Stojanowski's article, "Unhappy Trails" [7–8/05], brings fresh perspective to the riddles of how, why, and when bands of historically and linguistically distinct southeastern Indians came to think of themselves as "Seminole." Mr. Stojanowski's results show that the Creek ancestors of the Seminoles were genetically diverse, but that finding still doesn't fully explain the complexity of the social, political, and economic processes that shaped Seminole cultural identity.

In the nineteenth century, well after the period discussed by Mr. Stojanowski, genetic relationships among the Seminoles became even more complex. For example, Osceola, the icon of the Seminole resistance, is thought to have had a white father, a trader by the name of William Powell. Some scholars also think that Osceola may have married a woman of African descent.

Brent R. Weisman
University of South Florida
Tampa, Florida

CHRISTOPHER M. STOJANOWSKI REPLIES: Brent R. Weisman is absolutely correct: the development of the modern Seminole identity was extremely complex socially, politically, and economically. My research adds a biological component to the existing literature and suggests that early "Seminole" bands may initially have emigrated to Florida, in part because they had biological ties to indigenous Florida groups (the Apalachee in particular) and to the area.

Token of Thanks

The article by Delia and Mark Owens ["Comeback Kids" (7–8/05)] provides a haunting picture of what is happening to the elephant populations of Africa. We should all be grateful to them for their devotion to the preservation of wildlife and for their concern for the people in these regions.

Cherie Prather
San Diego, California

You've Gotta Have Heart

All endothermic vertebrates (mammals and birds) have four-chambered hearts, to satisfy the high oxygen demand imposed by maintaining a high body temperature. After reading the responses by John A. Ruben, Willem J. Hillenius, and Mary Higby Schweitzer to the question, "Were Dinosaurs 'Cold-' or 'Warm-blooded'" [5/05], I wondered, is there any evidence that dinosaurs had four-chambered hearts?

Jordon Hirshon
Long Island University
Brooklyn, New York

JOHN RUBEN REPLIES: No reliable, direct evidence exists for the number of chambers (three or four) in dinosaurs' hearts. Nevertheless, given that living birds and crocodilians both have four-chambered hearts, it is reasonable to infer that dinosaurs did, too.

Natural History *welcomes correspondence from readers* (nhmag@naturalhistorymag.com). *All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

EXPLORER GUIDE

Yunnan Revealed


T. YOSHIKAMI/AMNH

Overlooking the Old Town of Lijiang

In preparation for this month's exciting Global Weekend series of programs, Yunnan Revealed (see p. 70), Teddy Yoshikami, Manager of Public Programs, Department of Education, traveled to China's Yunnan Province.

To reach the village of Yubeng, she traveled by car, by horseback, and on foot. There she met with Tibetan villagers who are documenting the area and their lives as part of the Nature Conservancy's Photovoice project, which puts cameras in the hands of the villagers themselves to empower their participation in regional conservation efforts and cultural preservation. Some of these photographs and their accompanying stories are on view in the Museum in the compelling exhibition *Voices from South of the Clouds* (see p. 70).

The cameras have become a part of the people's lives, capturing their everyday existence against a breathtaking backdrop: steep, rocky, and, at times, muddy terrain against expansive green or glacial-blue mountains; blue skies above with mushrooms, moss, tall pine trees, and mountain flowers blanketing the ground. During the day, the snow-covered tops of Mt. Kawagebo are visible, and at night the stars shine clearly.

Traveling south by van, Teddy and her Nature Conservancy companions were hindered by rockslides but continued on to Deqin, Benzilan, Zhongdian (now marketed as Shangri-la), and Lijiang. They enjoyed delicious meals, mostly spicy, of meats, yogurt, and fresh vegetables and fruits. Teddy claims to have even started liking Tibetan yak tea!

At the end of her trip, Teddy met with the the Yunnan Indigenous Musicians and Dancers in Kunming, where they had gathered to make final preparations for their trip abroad. Anxious and excited about their first trip to the United States, the troupe made last-minute changes to the pieces selected, costumes, and purpose. Teddy worked with the musicians and watched a final preview performance. She observed and learned about the colorful Yi embroidery on their costumes, the Naxi *dongba* ritual, and other elements of the program they will bring to the Museum on October 15.

For details on the Yunnan Revealed programs, visit www.amnh.org.


R. MICKENS/AMNH

The Museum's Halloween celebration offers a safe, warm, and dry evening of ferocious fun! Costumed trick-or-treaters of all ages can wander among the eerie elephants, the unearthly universe, or the dinosaurs of the macabre Mesozoic. Much-loved characters and roving musicians entertain the youngsters (and adults too), and arts-and-crafts tables on each floor, staffed by friendly volunteers, engage kids' creativity. Visit www.amnh.org for details of this year's Halloween party on Monday, October 31.

Discovery Returns Space Station Experiments for AMNH Students

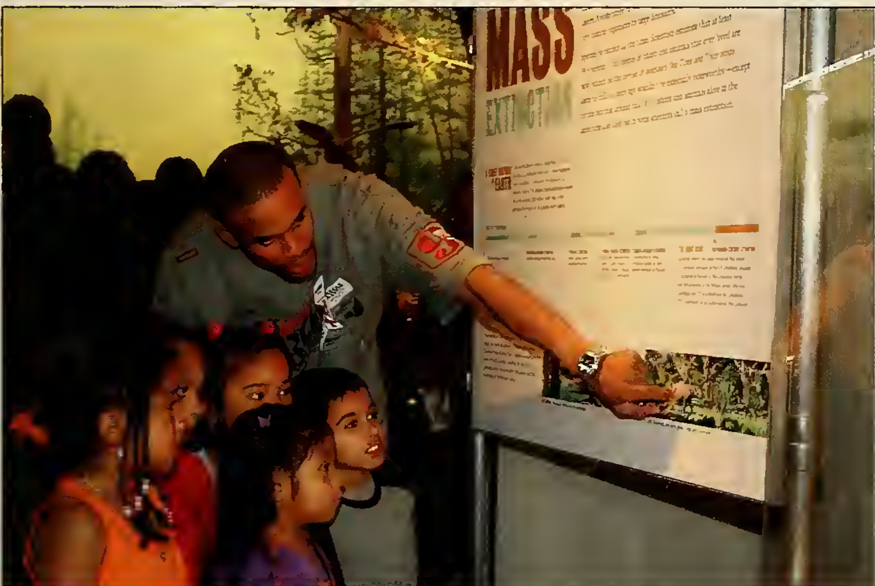
When the crew of the Space Shuttle *Discovery* returned this summer from its historic mission, the astronauts brought back camera film, tadpole shrimp eggs, and a single pea eagerly anticipated by some 20 high-school interns at the American Museum of Natural History.

These seemingly random materials were among tiny experiments delivered to the Space Station on December 25, 2004, on board a Russian Progress supply ship. The experiment samples included those from the Museum and ten additional schools and organizations representing students in elementary through high school.

The Museum experiments contained a variety of materials and seeds—the photographic film and pea, radish and parsley seeds, and dried triops (or tadpole shrimp, crustaceans that resemble miniature horseshoe crabs) eggs—in clear vials with lids. Each vial was wrapped in two vacuum bags and placed in a Student Experiment Module Satchel carrier.

The Museum chose these objects to investigate whether exposure to the zero-gravity environment in space would alter the eggs, seeds, film, and other matter. For instance, they chose the triops eggs to see if they would grow and behave differently in space than on Earth, and the pea and parsley and radish seeds to discover if they would sprout differently on Earth after exposure to space.

The vials will be returned to the Museum and schools this fall when school is in session. After receiving the space-flown samples, the students will be able to compare them to ground samples and take pride in their participation in the nation's illustrious space program.



R. MICKENS/AMNH

Dinosaurs: Ancient Fossils, New Discoveries, which opened this past May, continues to draw crowds, with something for dino-crazy children as well as for their parents. This spectacular exhibition on the latest in paleontology features real fossils, life-size casts, and biomechanical models that bring to life the most up-to-date thinking on these Mesozoic creatures and their modern-day descendants—birds. Visit www.amnh.org for behind-the-scenes views and to purchase tickets.

PEOPLE AT THE AMNH

Hazel Davies
Living Exhibits Coordinator
Department of Exhibition

JOANNE SILVER

Hazel Davies

In 1995, Hazel Davies moved from London to New York armed with degrees in geology and education and a keen interest in natural science. "On my very first day here, I went to check out the Museum, and I never left." Hazel became a volunteer in the Department of Education, and, now, ten years later, works as the Living Exhibits Coordinator in Exhibition.

Hazel primarily works on the perennial *Butterfly Conservatory*, opening this year on October 8, but has also worked on other live-animal exhibitions, including *Frogs* in summer 2004. She oversees the maintenance and care of the butterfly pupae, trains and manages the staff, and coordinates with butterfly farms all over the world, including Kenya, Costa Rica, Malaysia, the Philippines, and other tropical locations.

Her job combines her background in science and her experience as a teacher; she had taught both butterfly life cycles and frog metamorphosis to schoolchildren in London. "My background in education really allows me to reach the public." Still, Hazel admits the best part of her job exists in the day-to-day occurrences. "Watching the butterflies emerge, as their wings dry out...getting to see that on a regular basis—being a part of it—is really amazing."

Visit www.amnh.org/exhibitions/butterflies to learn more about these delicately beautiful insects and to purchase tickets to the vivarium.

Museum Events

AMERICAN MUSEUM of NATURAL HISTORY

www.amnh.org

J. CRACRAFT/AMNH

EXHIBITIONS

The Butterfly Conservatory: Tropical Butterflies Alive in Winter
Opens October 8, 2005
Experience more than 500 live, free-flying tropical butterflies in an enclosed habitat that approximates their natural environment.

Dinosaurs: Ancient Fossils, New Discoveries
Through January 8, 2006
Discover the most current thinking on the mysteries of dinosaurs: what they looked like, how they behaved, and why—or even whether—they became extinct.

Dinosaurs: Ancient Fossils, New Discoveries and its accompanying education and public programs are made possible by Bank of America.
This exhibition is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Houston Museum of Natural Science; California Academy of Sciences, San Francisco; The Field Museum, Chicago; and North Carolina Museum of Natural Sciences, Raleigh. Major funding has also been provided by the Lila Wallace-Reader's Digest Endowment Fund.

Voices from South of the Clouds
Through March 12, 2006
China's Yunnan Province is revealed through the eyes of the indigenous people who use photography to chronicle their culture, environment, and daily life.

Voices from South of the Clouds is sponsored by Eastman Kodak.
This exhibition is made possible by the generosity of the Arthur Ross Foundation.

Beyond
Opens October 1, 2005
A photographic tour of four equally stunning but radically different extraterrestrial landscapes captured by unmanned interplanetary probes.

Vital Variety
Ongoing
Beautiful close-up photographs highlight the importance of the immense diversity of invertebrates.

LECTURES

Tiger Bone and Rhino Horn
Thursday, 10/6, 7:00 p.m.
Richard Ellis discusses traditional Chinese medicine and its effect on species endangerment.

Dinosaur Panel: On Extinction
Tuesday, 10/11, 7:00 p.m.
A panel led by AMNH Curator Mark Norell considers the evidence of a mass extinction 65.5 million years ago.

New Discoveries: Fossil Vertebrates from Liaoning, China
Sunday, 10/16, 2:00 p.m.
(Lecture in Mandarin)
With AMNH Associate Curator Jin Meng and Research Scientist Xing Xu.
Cosponsored with the Museum of Chinese in the Americas (MoCA).

Decade of the Wolf: Returning the Wild to Yellowstone
Tuesday, 10/18, 7:00 p.m.
Doug Smith tells the compelling inside story of a decade-long preservation effort in Yellowstone National Park.

Birds of Central Park: A Guided Tour
Thursday, 10/20, 7:00 p.m.
An armchair stroll with Cal Vornberger and Marie Winn to learn about the more than 200 species of birds found in this urban oasis.

Adventures in the Global Kitchen: Chinese Cuisine
Tuesday, 10/25, 7:00 p.m.
Jacqueline M. Newman will heighten your appreciation for the foods and flavors of China.
Cosponsored with the Museum of Chinese in the Americas (MoCA).

D. FINNIN/AMNH

STARRY NIGHTS
Live Jazz

ROSE CENTER FOR EARTH AND SPACE

Friday, October 7
6:00 and 7:30 p.m.

The 7:30 performance will be broadcast live on WBGO Jazz 88.3 FM.

Visit www.amnh.org or call 212-769-5100 for lineup.

Starry Nights is made possible, in part, by Constellation NewEnergy and Fidelity Investments.

GLOBAL WEEKENDS

Yunnan Revealed
Saturday, 10/15, 11:30 a.m.–4:30 p.m.
Demonstrations, lectures, and performances reveal the indigenous cultures of China's Yunnan Province.

Supported in part by the Whitman College East Asia Initiative Fund. Cosponsored with Connecticut College, The Asia Society, and World Music Institute. The Museum of Chinese in the Americas (MoCA) is a community partner.
Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, and the New York City Council. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

COURSES & WORKSHOPS

Earth and Planetary Sciences: Tsunamis and Earthquakes
Three alternate Thursdays, 10/6–11/3, 7:00–8:30 p.m.
Explore Earth's primeval forces and their consequences.

Culture and Wine
Five Tuesdays, 10/11–11/8

7:00–9:00 p.m.
With Louisa Thomas Hargrave, Stony Brook University Center for Wine, Food, and Culture.

The Method and Madness of Collecting
Three Tuesdays, 10/11–25
7:00–9:00 p.m.
An introduction to the enthusiasts' world of collecting.

Make It, Wear It: Beading
Four Thursdays, 10/20–11/10
7:00–9:00 p.m.
Create beaded jewelry using traditional South African techniques.

FAMILY AND CHILDREN'S PROGRAMS

Space Explorers: The Planets
Tuesday, 10/11, 4:30–5:30 p.m.
(Ages 10 and up)
A hands-on activity and a lecture under the stars of the Hayden Planetarium.

Dinosaurs and Their Living Relatives
Saturday, 10/15
11:00 a.m.–12:00 noon and 1:00–2:00 p.m.
Live animals include a bearded dragon and a red-tailed hawk.

Dr. Nebula's Laboratory: Wind and Water
Saturday, 10/22
2:00–3:00 p.m.
Join Scooter for a "whirlwind" adventure dodging tornadoes and other forces of nature.

Wild, Wild World: Bats
Saturday, 10/29, 12:00 noon–1:00 p.m.
An interactive live-animal program for kids of all ages.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe
Solar System Spectacular
Tuesday, 10/4, 6:30–7:30 p.m.

This Just In...
October's Hot Topics
Tuesday, 10/18, 6:30–7:30 p.m.

Celestial Highlights
Greek Mythology
Tuesday, 10/25, 6:30–7:30 p.m.

LECTURE
The Equation That Couldn't Be Solved
Monday, 10/24, 7:30 p.m.
With Mario Livio, Space Telescope Science Institute

COURSES
Life in the Universe
Saturday, 10/1, 10:00 a.m.–5:00 p.m.

Introduction to Astronomy: The Solar System
Six Mondays, 10/17–11/28
6:30–8:30 p.m.

PLANETARIUM SHOWS

SonicVision
Fridays and Saturdays, 7:30, 8:30, and 9:30 p.m.
Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

SonicVision is made possible by generous sponsorship and technology support from Sun Microsystems, Inc.

The Search for Life: Are We Alone?
Narrated by Harrison Ford

Made possible through the generous support of Swiss Re.

Passport to the Universe
Narrated by Tom Hanks

LARGE-FORMAT FILMS

LeFrak IMAX Theater
For films and showtimes, visit www.amnh.org or call 212-769-5100.

IMAX films at the Museum are made possible by Con Edison.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply. All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

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- Discounts in the Museum Shops and restaurants and on program tickets
- Free subscription to *Natural History* magazine and to *Rotunda*, our newsletter
- Invitations to Members-only special events, parties, and exhibition previews

For further information, call 212-769-5606 or visit www.amnh.org/join.

Wise Guys

By Gary Noel Ross

I garden for butterflies. My Eden in central Louisiana sprawls in wild profusion across my front yard to the sidewalk, giving me and passersby an ever-changing tableau of color and activity.

In the late 1990s the garden became a staging area for observing the zebra longwing *(Heliconius charithonia),* a medium-size butterfly common throughout most of Florida and southern Texas, though only occasionally encountered in Louisiana. The "zebra" gets its name from its dark, elongated wings, accented with vibrant yellowish stripes. But the insect is also known for several specialized traits, including a taste for protein-rich pollen, an exceptionally long life span, and (most intriguing of all) the ability to learn visual cues for navigating in its environment.

Zebra longwing feeds on the pollen of a Mexican flame vine.

After purchasing some zebra eggs and nurturing them to adulthood, I marked each butterfly by writing a number on the underside of its left hind wing with a felt-tipped pen. Then I released the insects into my garden. They circled for a few minutes before settling to feed on the flowers of their choice. After "breakfast," the butterflies flew off in various directions, but a few hours later they returned to the garden to feed once again. The next day I observed two female zebras laying eggs on my native passionflower plant. So it continued; the butterflies laid their eggs or fed, and I watched them with binoculars, taking note of the numbers marked on the butterflies' hind wings. And sure enough, the same butterflies were showing up, day after day.

As the dog days of summer went by, the zebras spent less and less time in my garden, showing up at about midmorning and again at about four o'clock in the afternoon. I was impressed by the fact that they habitually departed toward the southeast, flying about ten to fifteen feet above the street in front of my house, but always returned tailing each other along the side street that formed the northwest border of my corner lot. Even more uncannily, on their return the butterflies would execute a ninety-degree right turn at the stop sign on the corner, before flying the short distance to my front garden.

It happened that at the same time, I had hired a construction crew to remodel a part of my house. One morning, I was talking with them about the advantages of my unconventional, butterfly-oriented landscaping. They were skeptical, to say the least. I hoped to impress them by telling them about the extraordinary behavior of my zebra longwings. So at the telltale hour that afternoon, I mentioned that we would soon be seeing some butterflies approaching the stop sign at the corner, and then turning into my garden.

Within minutes the procession was in sight. "You mean the butterflies can read and are going to stop at the corner?" quipped one of the men. I smiled. Sure enough, as we stood there watching, the butterflies approached and then veered off to the right. The workers' eyes popped, and they began hurling questions at me: How did you train them? What did you put on that sign? Do you have some kind of butterfly whistle? For the rest of the time they worked on my house, each man put down his tools at 3:45 P.M. and positioned himself near the stop sign, in a fruitless quest to figure out what my "trick" was.

There is, of course, a "scientific" explanation. The butterflies had learned a way they could travel, through the streets and probably past some other markers, to find the food and plants they need for their reproductive cycles. Each day the butterflies made their "rounds." Their Methuselah-like lives leave time for such learning, and their high-octane pollen banquets furnish the brain food.

Whatever the explanation, the zebra longwing butterflies entertained me and a lot of other folks that summer and fall. I think I'll get another batch of eggs next spring.

GARY NOEL ROSS is the director of butterfly festivals for the North American Butterfly Association. His most recent Endpaper for Natural History, *"Sultans of Rot," was published in November 2004.*


Now through November 5th!
Spider Pavilion
Face your fears and experience a rare insect exhibit,
The Spider Pavilion at the Natural History Museum of Los Angeles
County. LIVE Orb Weavers create intricate webs as you watch!
See how these fascinating creatures exist in their natural habitat!
Separate admission fees apply:
Adults $3
Students and seniors $2
Children (5-12) $1
Members are FREE
Natural History Museum of Los Angeles County
Support for the Spider Pavilion is provided in part by Richard and Eileen Garson, Miriam and Tom Schulman and the Brotman Foundation of California.
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