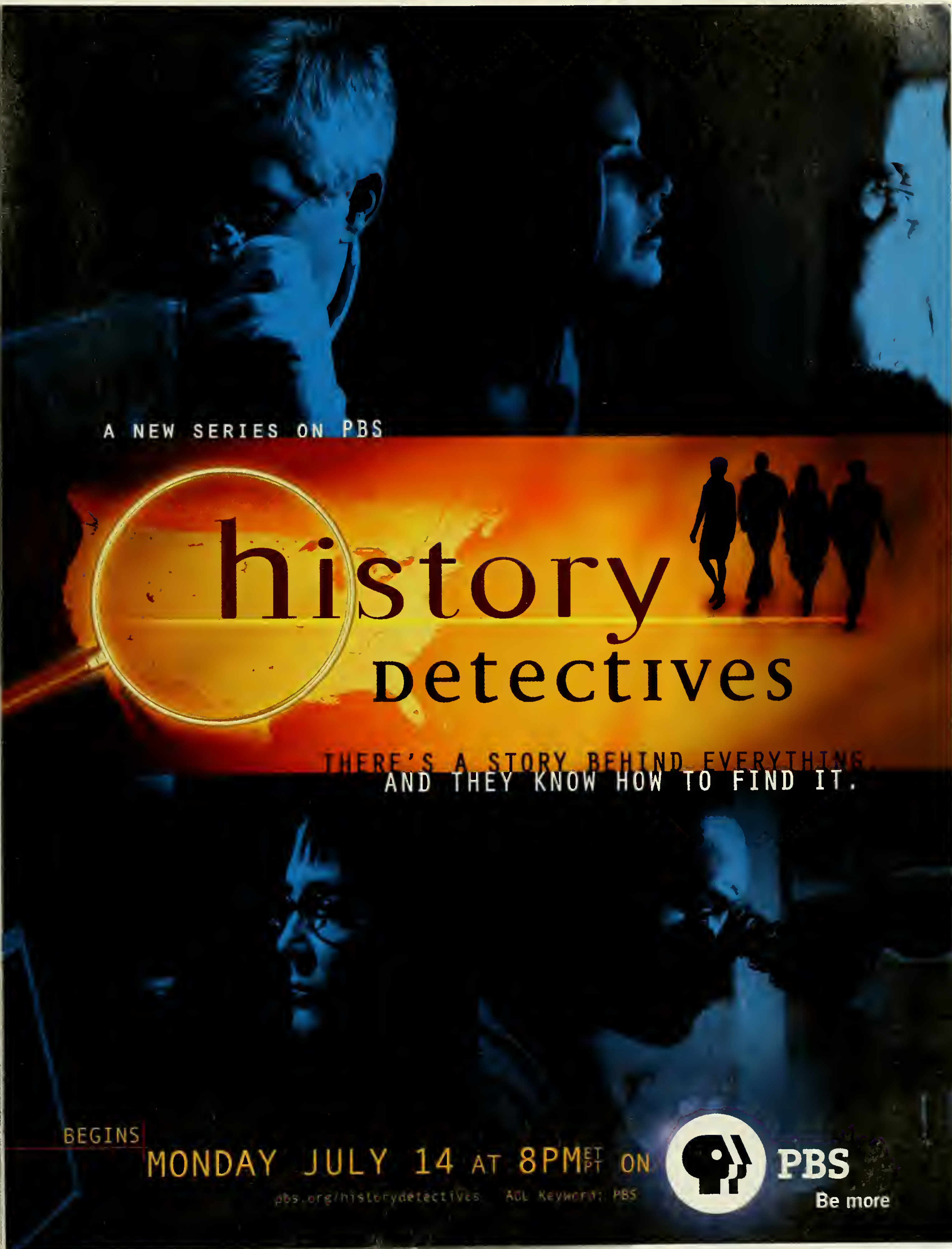
NATURAL HISTORY

7/03–8/03

THE BIRTH OF WAR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NATURAL HISTORY

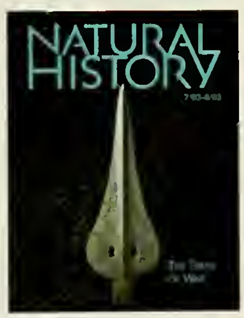
JULY/AUGUST 2003 VOLUME 112 NUMBER 6

FEATURES

COVER

Spearhead from the Aegean island of Amorgos, Early Cycladic II, 2700–2300 B.C.

STORY BEGINS ON PAGE 28



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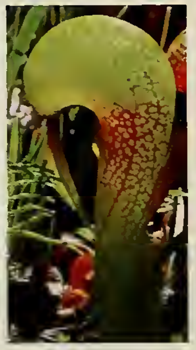

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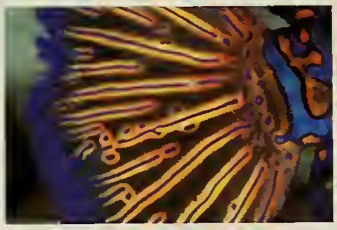

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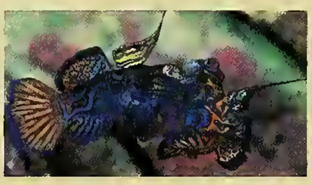
Turf War

Photograph by Constantinos Petrinos

THE NATURAL MONMENT

◄ *See preceding pages*



Staking out the boundaries of your spread can be a heedless act: In a Gary Larson cartoon a man points out a chirping sparrow to his son—emphasizing that territorial behavior occurs only among "lower" animals—while he stands amid a maze of picket fences in suburbia. But the male mandarin fish *(Synchiropus splendidus)* is anything but heedless about asserting its property rights. Every evening for about fifteen minutes the largest males—a whopping two inches long—among them the two fish pictured, fight their ongoing turf wars.

Alone by day, the psychedelically patterned mandarins graze on minute crustaceans—copepods—in the Indo-Pacific Ocean, hardly bothering to notice one another. But when the Sun begins to set, the focus turns to sex, and the large alpha males conspicuously secure a two- or three-square-foot plot of coral rubble for courting. Some nights, a harem of females joins a successful male that leads them one by one to the surface to spawn.

Photographer Constantinos Petrinos found a meeting site for mandarins in the Lembeh Strait, off the northern tip of the island of Sulawesi, Indonesia. He watched the alpha males seen here erect their spiky dorsal fins—a characteristic display of dominance—and was astonished when the mandarin on the left sank its teeth into its rival's neck. "They swirled for a few seconds," Petrinos reported, "until the loser fled to seek new territory."

—*Erin Espelie*

EDITOR'S NOTEBOOK

Tracks of War

After the disastrous looting of archaeological artifacts in Iraq, reported by our correspondent David Keys in our June issue, any positive news sounds virtually miraculous. So it was a relief to learn that many of the antiquities that had been on public display in Baghdad's National Museum had been hidden away by museum staff members before the war, sometimes in their own homes. Yet though some of the signature artifacts are safe, Keys still puts the number of stolen items in the thousands. Outside the Iraqi capital, where there are literally thousands of ancient sites, security remains patchy, and widespread looting, driven by the black market in antiquities, is continuing as we go to press.

For a broad perspective on warfare in this time of war, *Natural History* asked the anthropologist R. Brian Ferguson to describe his ongoing survey of the evidence for conflict at prehistoric archaeological sites around the world (see "The Birth of War," page 28). In a sense, his findings so far are encouraging: no unequivocal evidence of warfare appears at any site before sometime between 12,000 and 10,000 years ago—suggesting that war is by no means an inevitable feature of the human condition. Yet if warfare is a "recent" invention, its present near-universal reach makes it one of the most "successful" inventions ever made.

Seldom has scientific nomenclature been so aptly applied as in the botanical name for the genus of the cacao tree: *Theobroma,* "food of the gods" (see "The Chocolate Tree," by Robert A. Rice and Russell Greenberg, page 36). As an unrepentant chocoholic, I've accumulated enough T-shirts on chocolate themes to have a decent collection of the genre. My favorite is the "Will Rogers" version: on the front it says, "I never met a piece of chocolate I didn't like," and on the back it has a large hole made by the bite of what must have been a partly literate (but very confused) dog.

You won't find that shirt in the gift shop for the "Chocolate" exhibition, which just opened in New York City at the American Museum of Natural History. But you will see plenty of other offerings—and a lot of botanical and cultural artifacts on display as well.

• • •

Readers who don't want to miss a single one of Neil deGrasse Tyson's columns should not panic over this month's table of contents. Neil is taking a much-deserved vacation this month; his column "Universe" will return in the next (September) issue of *Natural History*.

—PETER BROWN

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CONTRIBUTORS

Soon after graduating from Dartmouth College with an MBA, **CONSTANTINOS PETRINOS** ("The Natural Moment," page 6) decided to trade in his business suits for diving gear. Based in Athens, Greece, Petrinos produced both text and photographs for the book *Realm of the Pygmy Seahorse: An Underwater Photography Adventure* (see www.petrinos.gr). His photograph of mandarin fish was particularly hard won, he says, because the fish were small, fast, and swimming among sharp coral.

Whether surveying the archaeological evidence of humanity's first armed conflicts, or evaluating biological theories about aggression in chimpanzees and in humans, **R. BRIAN FERGUSON** ("The Birth of War," page 28) keeps one goal in mind: to help address current crises by expanding anthropological theory and linking it with other disciplines. A professor of anthropology at Rutgers University in Newark, New Jersey, Ferguson directs the Working Group on Political Violence, War and Peace at the university's Center for Global Change and Governance. He recently edited a collection of case studies of modern violence, *The State, Identity and Violence: Political Disintegration in the Post-Cold War World* (Routledge, 2002).

ROBERT A. RICE ("The Chocolate Tree," page 36) (far left) works predominantly on issues of tropical agriculture and land management. A geographer and policy researcher at the Smithsonian Migratory Bird Center in Washington, D.C., Rice helped organize the Smithsonian's first workshop on sustainable cacao production. His coauthor, the ornithologist **RUSSELL GREENBERG**, investigates the ecology of the migrant birds that winter in Latin America's human-dominated landscapes, such as coffee farms, cacao farms, and cattle pastures. Associated with the Smithsonian Institution for nearly thirty years, and director of the Smithsonian Migratory Bird Center since 1992, Greenberg helped launch conservation initiatives such as the Smithsonian's bird-friendly coffee program.

Since her early years as a graduate student at Duke University in Durham, North Carolina, evolutionary ecologist **SARA LEWIS** ("Summer Flings" page 44) (near right) has been fascinated by fireflies. She is now an associate professor of biology at Tufts University in Medford, Massachusetts. In addition to inhaling countless mosquitoes while investigating firefly nuptial gifts, she and her colleagues study sexual selection in flour beetles and seahorses. Coauthor **JAMES E. LLOYD**, perhaps the foremost expert on firefly taxonomy in the world, is a professor of entomology and nematology at the University of Florida in Gainesville. Lloyd, who has been investigating firefly ecology and behavior since 1962, is at work on a taxonomic monograph about *Photuris* fireflies, a genus whose deceptive signaling—the females rely on tricking other fireflies into becoming dinner—has provided much of the material for his work. In the guise of the "Firefly Doc," Lloyd is also the editor of *The Fireflyer Companion & Letter*, available at http://firefly.ifas.ufl.edu

NATURAL HISTORY

Water for All

In her review of two books about Earth's supply of freshwater, Sandra Postel ["Hydro Dynamics," 5/03] writes of the need for a program that "fairly allocates the available water among all the parties." She speaks of a lasting Mideast peace depending on a "more equitable apportionment" of water between Israel and its neighbors; cites a UN convention calling for "equitable and reasonable use"; and warns that for most of the world's 261 rivers shared by two or more countries, "there is no treaty that divides the water equitably among all the parties."

But what is fair and equitable in the distribution of water? The same amount per capita, regardless of a country's total population? The same amount per country, regardless of the number of users? Should distribution be proportional to surface area, or should the country where the headwaters lie receive a greater share? Once set, should allocations stand for all time, or should they be renegotiated as population and other factors change?

John Tanton
Petoskey, Michigan

SANDRA POSTEL REPLIES: There is no magic formula for achieving an equitable apportionment of water among users of a shared river or aquifer. Many conditions must be factored into the calculations, such as climate, hydrology, population, existing and potential uses of the water, and the availability of alternative sources. It's up to all the parties involved (perhaps with help from an outside mediator) to hammer out a treaty that all will sign. Sometimes that may entail sharing the benefits of the river (irrigated crops, hydroelectric power) rather than fairly allocating the water per se.

Ideally, water treaties will be resilient. A good example is the treaty signed by India and Pakistan in 1960 to share the Indus River. The treaty took twelve years to negotiate (facilitated in the final nine years by Eugene R. Black, then president of the World Bank). But despite two subsequent wars and ongoing tensions between the signatories, the treaty has survived.

Too Close?

Although outstanding, Duncan Murrell's photograph of a feeding humpback whale in Alaskan waters ["The Natural Moment: Bubble Feast," 5/03] troubled me. The image and its accompanying text suggest it is acceptable to closely approach whales and other marine mammals. That is not the case.

The Marine Mammal Protection Act of 1972 requires those who "take" or "harass" marine mammals in U.S. waters to have a permit for doing so. The act treats commercial and educational photography as "level B harassment," and regulates it the same way it regulates research. Because humpback whales are an endangered species, additional regulations established in 2001 make it unlawful for anyone to come within less than 100 yards of these animals unless authorized to do so.

Jennifer Burns
University of Alaska
Anchorage, Alaska

DUNCAN MURRELL REPLIES: It is unfortunate that the law does not distinguish between low-impact kayaks and massive cruise ships, and that the whales are not conversant with the regulations and persist in approaching me closer than 100 yards. The encounter described was a freak incident, the result of the animal's approach without warning.

In my twenty years of kayaking in the presence of humpback whales in Alaska, I have never witnessed any perceivable change in their behavior patterns. That is in sharp contrast to the way I've seen them respond to motorized vessels—even if those boats remain outside the regulation distance and even if the people on board have research permits.

I stopped using boats with engines many years ago because I wanted to observe and photograph the whales for my educational work without disrupting their normal activities. (I do presentations for the Whale and Dolphin Conservation Society.) I think the sea would be a far better place for all creatures if more people followed this approach.

> *"In my twenty years of kayaking [with] humpback whales, . . . I have never [seen it lead to] any perceivable change in their behavior."* —DUNCAN MURRELL

Wondrous Strange

Adam Summers has cleared the air about a memorable encounter I've wondered about for decades ["Biomechanics: Serpents in the Air," 5/03]. Walking alone along a jungle path on the Philippine island of Bongao, I spotted, coming from the high green canopy, a snake gliding toward me. I felt more awe than fear, and quickly eluded the snake, which, upon landing, darted rapidly up a tree nearby, tongue flicking, seemingly ready to try again. Knowing I would not be believed, I told no one. Mr. Summers has at last assured me that the experience had a mechanical explanation.

Richard Sutherland
Metchosin, British Columbia

Magnificent Monitors

Adam Summers's essay on how monitor lizards can effectively breathe while running ("Biomechanics: Monitor Marathons," 6/03) could have discussed other unusual, but related, biological features of these most advanced of all lizards. Many monitor lizards are top predators in their communities. They are more active and much more intelligent than other lizards, and their greater stamina enables them to search widely for food. Savannah monitors, living in Africa, range several miles a day in search of prey.

The exceedingly successful body plan of varanid lizards and their close relatives has been around at least since the days of a creature that lived in what is now Mongolia, 80 million years ago. Most monitors are larger than most other lizards. Indonesian Komodo dragons *(Varanus komodoensis)* attain lengths of ten feet or more and can weigh as much as 350 pounds. Komodo monitors, however, are themselves dwarfed by the closely related—though, unfortunately, now extinct—Australian monitor *Varanus priscus.* The latter species (formerly known as *Megalania prisca*) reached more than twenty feet long and weighed more than half a ton. Fossils of this giant are estimated at between 19,000 and 26,000 years old.

Varanid teeth are serrated along the rear edge, which helps the animals cut and tear the skin and flesh of their prey as they pull back on their bite. That is how *V. komodoensis* routinely kill deer and pigs; one Komodo monitor even eviscerated a water buffalo! With its slashing bite that could disembowel large mammals, *V. priscus* was the Australian ecological equivalent of the large saber-toothed cats that lived on other continents. People were probably among these monitors' victims; curiously, though, fierce, giant man-eating lizards don't appear in the Dreamtime stories of Australian Aborigines.

Eric R. Pianka
University of Texas
Austin, Texas

Small Farmers

Jessie Gunnard, Andrew Wier, and Lynn Margulis ["Mycological Maestros," 5/03], having discovered that some populations of the termite *Heterotermes tenuis* consume spores of the fungus *Delortia palmicola,* suggest the termite might be a "missing link" to the higher termites that farm *Termitomyces* as their sole food source.

But the behavior of *H. tenuis* is not unique: many nonfarming termite species feed on fungus-infested wood. Because *H. tenuis* (of the family Rhinotermitidae) is not a direct ancestor of the Macrotermitinae, the "incipient farming" in *H. tenuis* is analogous, rather than homologous, to the elaborate fungus farming in the Macrotermitinae (a possibility the authors themselves raise).

Moreover, a "missing link" position for the South American *H. tenuis* is at odds with the supposedly African origin of fungus farming in termites. Likewise, for the fungi a true "missing link" would have to be a fungus that is sometimes farmed by termites and is also closely related to *Termitomyces.* This is not the case: *D. palmicola* (of the phylum Ascomycota) is as distantly related to *Termitomyces* (of the phylum Basidiomycota) as human beings are to protozoa.

Duur K. Aanen
University of Copenhagen
Copenhagen, Denmark

By colonizing wood, fungi "precondition" it, making it palatable to lower termites. No surprise, then, if fungal parts can be found in the guts of those termites. But the Macrotermitinae—the Old World subfamily of higher termites that engage in rather advanced fungus growing—feed predominantly on dry or freshly dead organic materials. which contain few fungi. The *Termitomyces* fungus farmed and ingested by those termites is therefore the first microorganism to attack the forage. Many species of Macrotermitinae degrade cellulose internally. with assistance from the fungus: in other species the fungus breaks down the plants' xylan and lignin.

The overall picture is one of an evolving diversity of mutualisms. Fungal nodules pass rapidly through the gut and germinate. Not enough are consumed to fully support the colony nutritionally; most termites feed on the fungus's more general fungal threads. which are richer in nitrogen than primary forage is. Thus the fungus is a composter. making energetically expensive nitrogen fixation unnecessary.

In spite of the complexity of the Macrotermitinae's mound constructions. the latest phylogenetic evidence places that subfamily in a basal position within higher termites. where the broadly dominant habit is the use of soil as a building material and/or as a food. We think the fungus found the termite and not vice versa.

David Bignell
University of London
London, England

Paul Eggleton
The Natural History Museum
London, England

After reading "Mycological Maestros." I finally know why the huge mushrooms I once (and only once) collected from a big termite mound in Zimbabwe are so rare: mushrooms appear only after the termite colony has abandoned the mound and stopped farming the fungus's mycelium. Those mushrooms. avidly sought by local residents. have a delicious. meatlike taste and texture strongly resembling that of the best commercial portobello mushrooms.

My own Zimbabwe research focused on the foraging habits of African elephants. I found strong ecological linkages between elephants and termites in woodland and savanna habitats in Africa: termites are the principal recyclers of elephant dung during the dry season.

Because both elephants and termites rely on microbial gut symbionts for digestion and nutrition. and because termites in Africa and Asia are intimately associated with elephant dung. it would be exceedingly interesting to determine whether any species of cellulose-digesting protists live not only in termites but also in the guts of elephants.

Joseph P. Dudley
The Pentagon
Washington, D.C.

Lynn Margulis replies: Duur Aanen is correct. The behavior of the South American *H. tenuis* stimulates us to imagine the lives of the 200-million-year-old African ancestors of today's fungal gardeners.

David Bignell and Paul Eggleton assert that "the fungus found the termite and not vice versa." But whether the fungus found the termite or the termite discovered the fungus is scientifically indistinguishable. Wind-blown spores became delicious, fattening pinheads because of hungry insects. That's coevolution.

Could cellulose-digesting protists live in the guts of elephants as well as termites?

Joseph Dudley astutely suggests that elephants be examined for cellulose-digesting protists living in their guts. In fact. the search for cellulose-degrading microorganisms in elephants, as well as in beavers, pandas, and other mammals that feed on woody materials, promises rich rewards, particularly when the studies incorporate observations of the fossil record. With the electron microscope, my colleagues and I have observed. in 20-million-year-old Miocene amber. fragments of clearly identifiable plant xylem harboring protists and their adhering bacteria. We find termite muscle tissue. the cell nuclei and cell walls of wood. and even molecules of intestinal gas. such as methane and carbon dioxide. Similar success can be predicted with African elephant material.

Amendments: The letter by Maxwell Manes ["Letters," 5/03] concerning phi, the golden ratio, included a slip of the pen. The square of phi (not. as stated, phi) plus the reciprocal of phi is equal to two times phi.

Because of editing errors. two captions in last month's issue (6/03) made mistaken identifications. In "This Land: Ages of Aquarius." the plant shown in bloom in the bottom photograph on page 59 is mock orange *(Philadelphus lewisii)*. In "Peering at the Edge of Time," by Fulvio Melia, the caption on page 53 switched the identifications of the two constellations Scorpius and Sagittarius.

Natural History's e-mail address is nhmag@amnh.org

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By Stéphan Reebs

Little Engines That Could

It's hardly news that for many species, raising offspring takes a lot of energy. Add to that the wide variations among individuals, and you might well ask, What accounts for differences in energy, and do they affect reproductive success?

Consider an extreme case: the European beewolf, a species of wasp. To provision her young, the female stings and paralyzes honeybees that each weigh more than she does. Then she lofts the bees one at a time back to her nest-in-progress. During her lifetime a laid-back mama beewolf might hunt down five bees and lay five eggs, giving each of her offspring just one bee to see it through the larval stage. But a supermom might hunt four fat bees for each of as many as thirty-four eggs, more than twenty times the workload of her laid-back counterpart.

The biologists Erhard Strohm of the University of Würzburg and Wiltrud Daniels of the University of Bayreuth, both in Germany, decided that the beewolf was just the critter they needed to prove a direct connection between reproductive success and the ultimate source of animal energy: the mitochondria within every working cell. Specifically, they looked at the folded membranes on the insides of the mitochondria in the beewolves' flight muscles. Why? The denser the mitochondria's inner membranes, the faster the production of energy.

Beewolf hauling dinner to her nest

Strohm and Daniels orchestrated mating, breeding, and honeybee-hunting opportunities for a group of female beewolves. Each wasp was then killed, its weight and fat reserves (good determinants of reproductive success in other species) were measured, its age recorded, and the mitochondrial density and mitochondrial-membrane density of its flight muscles examined at high magnification.

The only factor that correlated with the beewolves' rate of bee killing was the membrane density. And the more bees a developing larva had to munch on, the more likely it was to survive. In beewolves, at least, being a supermom pays off. ("Ultrastructure meets reproductive success: Performance of a sphecid wasp is correlated with the fine structure of the flight-muscle mitochondria," *Proceedings of the Royal Society of London* B 270:749–54, April 7, 2003)

Ocean Dwellers of Avalon

Paleontologists once thought the shells and bones left by the organisms that emerged from the Cambrian explosion, some 545 million years ago, were remnants of Earth's earliest complex life-forms. But then fossils of earlier, soft-bodied creatures, now called Ediacarans, began to come to light. Recently the oldest such fossils in the world were discovered, on the Avalon peninsula at the southeastern tip of Newfoundland. Among them was a new species, *Charnia wardi.*

Twelve-inch segment of a fossilized Charnia wardi, *part of a six-foot-long specimen*

C. wardi grew to as much as six feet long but less than three inches wide, with slender, plantlike fronds branching off a midline. The organism was discovered, along with a less slender, equally ancient, and better-known cousin, *C. masoni,* in a rock formation 575 million years old. Guy M. Narbonne and James G. Gehling, both geologists at Queen's University in Kingston, Ontario, note that the creatures' fossil fronds lie parallel to one another, suggesting the *Charnia* were attached to the seafloor, and were reclining in a strong current before being covered by volcanic ash.

The fossils' age places them right on the heels—geologically speaking—of the last planetwide glaciation, 580 or so million years ago. Perhaps the aftermath of the freeze created the conditions for the rapid evolution of multicellular life [see *"The Longest Winter," by Gabrielle Walker, April 2003*]. Another possibility is that the Ediacarans evolved just before the glaciation and managed to live through it. ("Life after snowball: The oldest complex Ediacaran fossils," *Geology* 31:27–30, January 2003)

Experiment of the Month

Chances are that the birds breeding in your backyard this summer are the same individuals that did so last year. Some might have traveled thousands of miles to return to the red maple next to your rosebushes. But how could you prove your suspicion that the long-term memory of migrants is any better than that of nonmigrants?

Claudia Mettke-Hofmann and Eberhard Gwinner of the Max Planck Research Center for Ornithology in Andechs, Germany, had an idea. They hand-raised seventy-six garden warblers—a species that breeds in Europe and overwinters south of the Sahara—and fifty-five Sardinian warblers, a close relative that stays put around the Mediterranean. The investigators then gave all 131 birds two adjacent, identical-size rooms to explore for a few hours, one decorated with fake ivy, the other with fake geraniums. Only one room (sometimes the ivy room, sometimes the geranium room) contained food. On several subsequent occasions, the ornithologists offered groups of migrants and of nonmigrants the same choice of rooms—minus the food. Each bird was tested just once.

One month later the homebody Sardinian warblers showed no preference in rooms, presumably having forgotten where the benefits lay. But even a year after the initial exposure, the migratory garden warblers spent significantly more time in whichever room—ivy- or geranium-laden—had initially provided lunch. A migratory lifestyle thus seems to go hand in hand with a good memory. And that kind of memory might not be innate: the part of the brain that's crucial for processing environmental information is relatively larger in adult migrants than it is in untraveled juveniles. ("Long-term memory for a life on the move," *Proceedings of the National Academy of Sciences* 100:5863–66, May 13, 2003)

Computer simulation of a Neanderthal's thumb and index finger

Bones of Contention

In 1856 two quarrymen found an ancient cranium in the limestone-rich Neander Valley near Düsseldorf, Germany. Anthropologists have been arguing about Neanderthals ever since.

One controversy centers on the utility of the Neanderthal thumb. Well-preserved, 60,000- to 70,000-year-old remains from the La Ferrassie rock-shelter in south-central France show that Neanderthal thumb bones weren't proportioned like their modern counterparts. Hence some physical anthropologists have argued that Neanderthals couldn't grip tools securely—perhaps contributing to the species' extinction. But Wesley A. Niewoehner of California State University in San Bernardino disagrees.

Niewoehner and a team of colleagues made a computerized model of a crucial part of the hand by doing laser scans of epoxy casts of the thumb and index-finger bones of the adult male found at La Ferrassie. Then they conservatively estimated the bending and straightening capabilities of each joint. The digital data, along with the estimates, were then fed into the same animation program that created special effects for *The Lord of the Rings* and *Spider-Man*. The crucial test of manual dexterity was, Could the tip of the index finger be made to touch the tip of the thumb? Pressing "enter," the modelers watched the two Neanderthal digits on their computer screen slowly but surely form a fine A-OK sign.

Conclusion? The Neanderthals' demise couldn't have been caused by a physical inability to make and handle the tools of the time. Their hands worked much the same way as those of modern humans. ("Manual dexterity in Neanderthals," *Nature* 422:395, March 27, 2003)

Up in Smoke

Burning grassland, Royal Natal National Park, South Africa

Grassland fires are often deliberately set by ranchers to remove dead, unwanted vegetation. Richard W.S. Fynn, a soil scientist at the University of Natal, and his colleagues can now reassure ranchers that for the most valued native grasses, regular annual burning doesn't have much of a downside.

A fifty-two-year study at a research farm in South Africa shows that burning leads to denser roots and more microbial activity, and springtime fires don't reduce the soil's organic carbon content. Burning does indeed deplete the topsoil of nitrogen, converting it to a gas, but native grasses don't need much soil nitrogen. And other studies at the same farm show no long-term reduction in the amount of grass produced. ("Burning causes long-term changes in soil organic matter content of a South African grassland," *Soil Biology and Biochemistry* 35:677–87, May 2003)

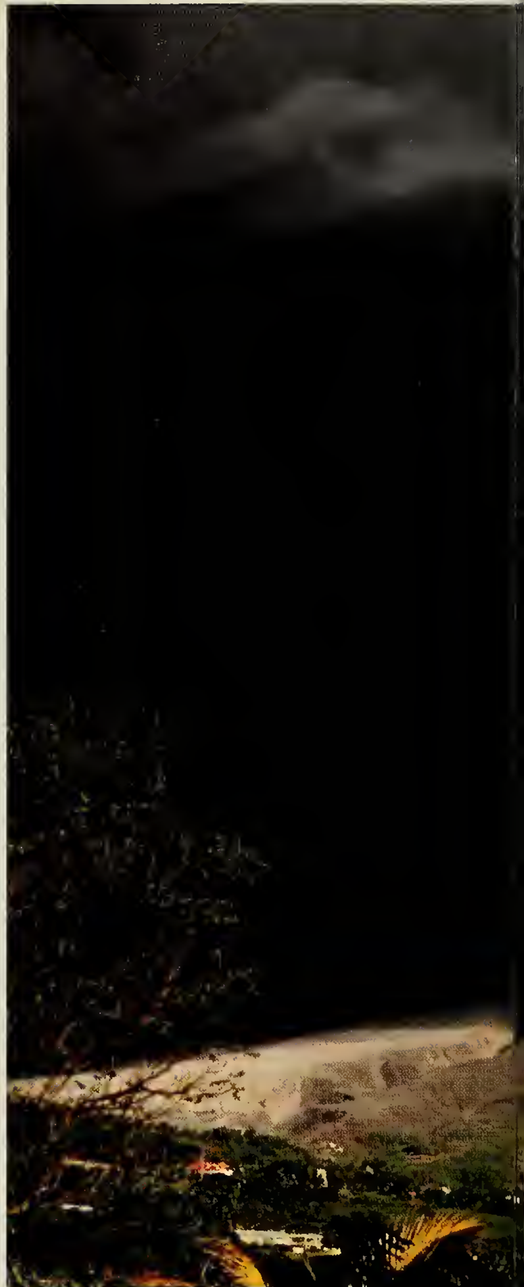
Stéphan Reebs is a professor of biology at the University of Moncton in New Brunswick, Canada, and the author of Fish Behavior in the Aquarium and in the Wild *(Cornell University Press).*

NATURALIST AT LARGE

Earth, Wind, and Fire

The fruit bats of Montserrat have had to contend with most of nature's torments.

By Scott C. Pedersen



It was July 1997, and a long night, which had followed a long day, was finally nearing its end. A volcano was grumbling, and rain had just begun . . . again. My right boot was quickly filling with water and sinking deeper into cold mud, and a large, muscular pig-nosed fruit bat *(Brachyphylla cavernarum)* had latched its mouth firmly onto the flesh of my thumb. I had been careless taking the bat out of one of my mist-nets—a finely spun net—and the bat was impressing this fact on me.

For once, though, the truth didn't hurt. Typically a bite from this species would have left me trying to stifle a string of colorful expletives, but this animal didn't have a tooth left in its head. The rather soggy-looking, unfortunate animal was also just about entirely bald. Things were getting a bit surreal: a hairless, toothless bat was gumming my thumb as I stood on the flanks of an active volcano; large, glowing rocks were rolling down the slope in my general direction; and now the mud was beginning to swallow my other boot. I suddenly felt the need for a very cold beer.

The pig-nosed fruit bat, *Brachyphylla cavernarum*

The pathetic bat and I were in the British crown colony of Montserrat, a rugged, forty-square-mile tropical island in the northern Lesser Antilles, some 250 miles southeast of Puerto Rico. Although Columbus never bothered to land on the island, he named it, in 1493, after a Spanish monastery near Barcelona, famous for its wooden statue of the Virgin and child. The British colonized the island in 1632, and a succession of sugar cane, cotton, and lime plantations dominated the local economy.

Montserrat lies in the middle of the Atlantic Ocean's "hurricane belt," a highway of sorts for the storms heading north from the Tropics. At least thirty hurricanes have battered Montserrat in the past 360 years; twelve have been severe, and Hurricane Hugo, in 1989, was the most destructive in recent history. Montserrat also lies near the convergence of the North American and Caribbean tectonic plates, so if the hurricanes don't get you, the earthquakes and volcanic eruptions might. Major temblors hit the island in three periods: 1898–1900, 1933–36, and 1966–67. Seismic activity in the Soufriere Hills volcano, beginning in 1992, resulted in an explosive eruption in July 1995, followed by a series of pyroclastic mudflows that destroyed and buried most of Plymouth, the island's capital, by 1998. Subsequent eruptions have reduced much of the southern half of the island to a wasteland. (Although the volcano's activity has decreased for

The Soufriere Hills volcano on Montserrat simmers with clouds of ash and steam. The volcano erupted explosively in July 1995, and subsequent eruptions have covered a large part of the island with hot ash and rock.

the moment, it is too soon to tell whether the current cycle of eruptions is at an end.)

It is hard to convey the scope of the human tragedy the recent eruptions have visited on this small island community. Casualty reports vary widely, but officially, at least twenty-one Montserratians were killed. Between 1997 and 1998, thousands were forced to emigrate, to neighboring islands, Canada, England, or the United States. Many families were separated, and a vibrant and unique culture was temporarily put on hold until the volcano settled down and the islanders could begin to rebuild the island's infrastructure.

In the midst of all this suffering, it might seem crass to worry about wildlife. But even before the eruption, Montserrat—a small but lush island—had been getting a great deal of attention from biologists interested in island biogeography. Bat biologists had been at work there since 1978; I arrived in 1993. Since our studies began, my coworkers and I have compiled a reasonably complete natural history of ten bat species (six fruit bats, three insectivores, and one carnivore that specializes in capturing small fish with its hind feet), covering the good times as well as the periods marred by the overlapping effects of devastating natural disasters.

Hurricane Hugo was the first such disaster under our watch; it smashed directly into Montserrat, careened into Puerto Rico, and eventually hit the eastern seaboard of the U.S. For the fruit bats on the two islands, survival in the aftermath of the storm was a matter of size—the islands' size. On Puerto Rico, fruit bat

The fishing bat, Noctilio leporinus, *swoops low over water, hunting with its feet. Volcanic eruptions destroyed the bat's only known habitat on Montserrat.*

populations could abandon hurricane-damaged forests and disperse across a larger landmass into unscathed areas. On Montserrat, Hugo was a crushing blow for tree-roosting and other highly specialized bat species; their numbers fell twentyfold. Many fruit bat populations suffered primarily because there was nowhere for them to go. Their roosts and food sources—much of the island's forests, really—had simply been blown out into the Caribbean.

Not all the island's bat populations crashed in Hugo's wake. A large colony of pig-nosed fruit bats roosts in a series of relatively hurricane-proof caves at the northern end of the island. The animal also enjoys a catholic menu of flowers, fruits, insects, leaves, nectar, and even immature legumes. Such omnivory proves to be a powerful survival strategy when disasters limit the availability of particular foods.

I fully expected to spend many years monitoring the post-Hugo recovery of Montserrat's bat populations, with a special focus on the cave-dwelling colony of pig-nosed fruit bats. The 1995 eruption of the Soufriere Hills volcano, however, dramatically redirected my research program.

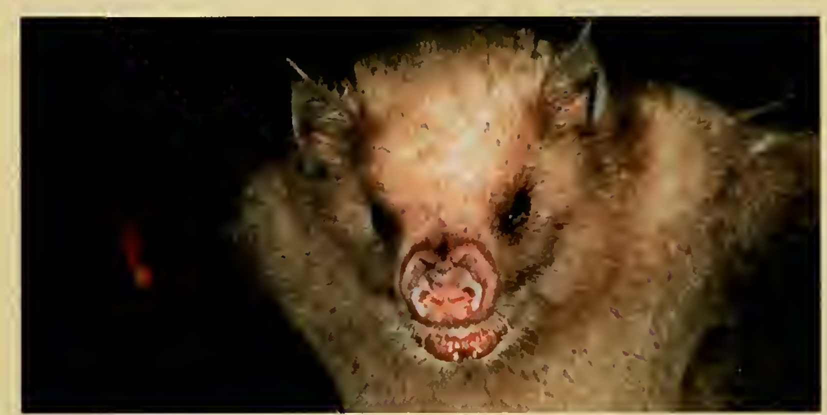
Ash mixed with water became massive mudflows, which buried entire towns in Montserrat.

Hurricanes and volcanic activity differ fundamentally in both their immediate and long-term effects on ecosystems. The tremendous wind speeds of hurricanes typically strip foliage and most of the trees' fruit crop. Large hurricanes such as Hugo also strip bark from large trees and knock smaller trees over, destroying roost sites for tree-roosting species of bats.

Volcanoes are another matter. Explosive eruptions result in pyroclastic flows—landslides of superheated gas, rock, and clouds of volcanic ash that typically move faster than fifty miles an hour and reach temperatures of between 200 and 700 degrees Celsius. They incinerate, suffocate, or bury everything in their paths. Unconsolidated deposits of ash may eventually mix with water to become massive, quick-moving mudflows, called lahars, that can fill in small valleys. Lahars have buried entire towns and villages on Montserrat. Together, the pyroclastic flows and the lahars have devastated the southern half of the island, burying many river drainages under tens of feet of sterile volcanic ash. On many parts of the island, ash smothered all vegetation; the weight of the ashfall stripped limbs from trees and toppled smaller plants, such as banana and heliconia. The destruction turned several of my old sample sites—once deep, lush valleys, replete with streams, pools, luxuriant vegetation, and huge trees—into nightmarish visions of the surface of the moon.

For example, large mudflows and a number of small pyroclastic flows from the Soufriere Hills volcano partially destroyed the Belham River and obliterated a quirky thirteen-hole golf course that had meandered across the river's bottomlands. Although the episode was clearly a setback for the Montserratian golfing community, the flows were catastrophic to a unique ecosystem that was also the island's only known habitat for the fishing bat *(Noctilio leporinus)*.

Fishing bats are large, yellow-orange, and rather pungent creatures that can hawk large flying insects or snag small ocean fish from the surf. But they much prefer to take minnows from the surface of freshwater streams and ponds—exactly what the course of the Belham River afforded. The fishing bats had survived Hugo as well as two years of volcanic eruptions. But with the loss of the river, they have not been seen on Montserrat since mid-1997.



Palates of two female pig-nosed fruit bats on Montserrat demonstrate the effect of volcanic ash on their teeth. The 1994 individual (far left) is healthy, but ash has worn away the enamel of the 1998 individual (near left). The wear exposes the underlying pulp cavity, which then becomes impacted with fruit. The acids in the fruit etch the rest of the tooth, causing abscess and, eventually, loss.

The pervasive destruction of foraging and roosting habitat across the southern portion of Montserrat forced the fruit bats (as well as the people) remaining on the island to relocate to its northern half. Predictably, the initial competition within the bat colony for limited food and shelter there was intense.

The survival struggles of Montserrat's large population of pig-nosed fruit bats became a lesson in the effects of overcrowding. Before 1995 the colony would alternate between a roost on the flanks of the Soufriere Hills volcano and another in one of the caves at the northern end of the island. For several weeks at a time, each location served as the regional shelter; from there the entire colony would fan out to mob the fruiting trees in the vicinity. (Archaeological evidence suggests that Amerindian populations as long ago as A.D. 200 took culinary advantage of this predictable clustering of large fruit bats.) But by 1996 the eruption had destroyed the southern roost, leaving only the northern cave as a home for the colony.

Since that time the fruit-bat population has rebounded and stabilized, but not without complications. External parasites on the bats are significantly more numerous than anyone had ever previously recorded, either on Montserrat or on any of the nearby islands. I had interpreted the bats' alternation of roost sites as a means to better exploit regional food resources. In fact, though, it may have had more to do with escaping roosts that had become heavily contaminated by blood-sucking ectoparasites. Ever since the fruit bats have been forced to take permanent residence in one location, the walls of that northern cave have been literally crawling with parasitic insects and their larvae.

So what explains the bald, toothless bat that was clamped onto my thumb in 1997? Before the onset of volcanic activity two years earlier, less than 1 percent of the fruit bats examined by biologists on Montserrat showed any sign of tooth wear or hair loss. The bats that did were elderly animals with other obvious signs of age: scarring, broken bones that had healed, arthritic joints. Yet between 1995 and 1999 the teeth of nearly half of the fruit bats we captured were worn at least half way to the gum line, and a quarter of all the bats had lost 50 percent of their hair.

Excessive dental wear is caused by

the fine, abrasive ash that blankets everything after a pyroclastic eruption. It is next to impossible for a fruit bat to avoid the grit, which adheres to the sticky fruit it eats as well as to the animal itself: even as a bat grooms itself, it gets a mouthful of the ash. For now, since the volcanic activity has at least temporarily decreased, we are finding progressively fewer bats with tooth wear. The ones that do have worn-out teeth are older animals, veterans of earlier exposures to ash. For our 2002 census it was easy to tell old bats from younger ones simply by offering them an exposed thumb.

What about the loss of fur? One might expect to find some kind of skin inflammation or skin infection associated with the loss, but not one of the hundreds of bald fruit bats we have examined has shown either. There are several other possibilities under active study: Perhaps in response to external parasites such as streblid batflies, the bats simply groom themselves until their hair falls out. Perhaps the hair loss is caused by mineral imbalances associated with the ingestion of ash. Or perhaps the bats, deprived of their preferred fruits by the pyroclastic flows, are reduced to eating foods they normally shun. The false tamarind *(Leucaena leucocephala)*, for instance, contains noxious chemical compounds such as mimosine, which induces hair loss.

As forested land on Montserrat has been lost to the volcano, both the number of species and the number of animals on the island have declined. Ten bat species lived on Montserrat before Hurricane Hugo struck in 1989. By 2002 three species that either had persisted as marginal populations or were habitat specialists—the fishing bats, yellow-shouldered bats *(Sturnira thomasi)*, and white-lined bats *(Chiroderma improvisum)*—had been locally extirpated.

That is not to say they might not return. Tropical storms and hurricanes regularly transport insects, birds, and bats from one island to another throughout the Caribbean. Once a storm drops flying animals such as bats on an island, they tend to stay put. They have no way of knowing what is out there, and a fruit bat that ventures out over the empty sea runs a big risk, given what seem to be the species' limited navigational abilities over long distances.

Two bat species that lived briefly on Montserrat in small transient populations—the yellow-shouldered bat and the white-lined bat—had previously been known only from Guadeloupe. It is likely that large storms will eventually return those and other species to Montserrat. Fishing bats are strong fliers, and could return to Montserrat on their own, probably from the neighboring islands of Antigua or Barbuda. Similar extirpations and reintroductions occur throughout the "hurricane belt" with some regularity, changes that are of great interest to those of us who study the biogeography of bats in the West Indies. We now have genetic data that also support this rare but consistent storm-blown reintroduction of new animals. The cycle suggests that the biogeography of the West Indies is far more dynamic and changeable than ecologists had previously suspected.

Tropical storms and hurricanes regularly transport insects, birds, and bats from one island to another throughout the Caribbean.

Fruit bats are critical to the rejuvenation of the forests destroyed by Montserrat's volcano, primarily because they play such a crucial role in dispersing seeds and nutrients. Hence the dramatic loss of biodiversity within the bat population jeopardizes the forests' recovery. Our plan is to document the excursions of fruit bats into marginal areas, tracking the dispersal of seeds into heavily damaged regions and the beginnings of a recovery that will take many human lifetimes.

In spite of the "inconveniences" of being blown out to sea by hurricanes or endangered by pyroclastic flows, the fruit bats of Montserrat have soldiered on. Their tenacity has given me a unique opportunity to study how animal populations respond to a variety of natural disasters. And the news is finally taking a turn for the better. My 2002 census of Montserrat's fruit bats followed the wettest spring since 1995. Several varieties of fig trees were heavy with fruit for the first time since 1995. And we were able to capture nearly three and a half times more fruit bats last summer than we had during the peak of volcanic activity in 1997. The rain, the dramatic rejuvenation of Montserrat's remaining forested areas, and a great increase in fruit bat populations are all most welcome.

In fact the entire island—its resilient people, forests, and wildlife—seems well on its way to recovery from a very long volcanic nightmare. Who knows what the future will bring to the people and bats of Montserrat? Before I returned to the vast wind-blown expanses of South Dakota (where my alter ego is that of university professor), I treated myself to one last night in the small village of Cudjoehead. There I was immediately struck by a strong sense of déjà vu: the beer was cold, the town throbbed with reggae music that pushed its way along the narrow streets, the warm tropical breeze that blew overhead was once again full of large fruit bats—the way Montserrat used to be.

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Extreme Forestry

What does bungee jumping say about parasitic vines?

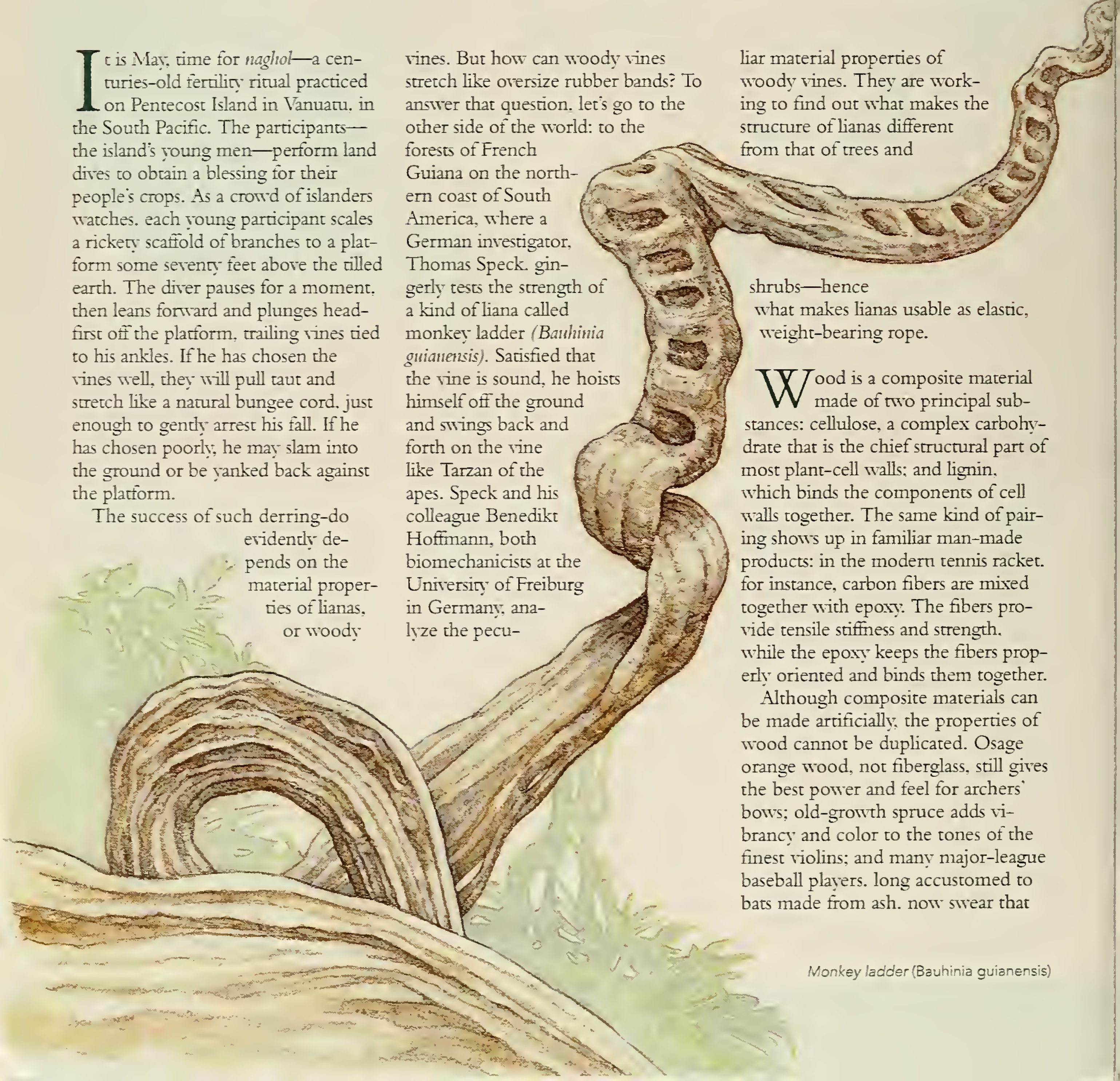
Story by Adam Summers ~ Illustration by Mick Ellison

It is May, time for *naghol*—a centuries-old fertility ritual practiced on Pentecost Island in Vanuatu, in the South Pacific. The participants—the island's young men—perform land dives to obtain a blessing for their people's crops. As a crowd of islanders watches, each young participant scales a rickety scaffold of branches to a platform some seventy feet above the tilled earth. The diver pauses for a moment, then leans forward and plunges headfirst off the platform, trailing vines tied to his ankles. If he has chosen the vines well, they will pull taut and stretch like a natural bungee cord, just enough to gently arrest his fall. If he has chosen poorly, he may slam into the ground or be yanked back against the platform.

The success of such derring-do evidently depends on the material properties of lianas, or woody vines. But how can woody vines stretch like oversize rubber bands? To answer that question, let's go to the other side of the world: to the forests of French Guiana on the northern coast of South America, where a German investigator, Thomas Speck, gingerly tests the strength of a kind of liana called monkey ladder *(Bauhinia guianensis)*. Satisfied that the vine is sound, he hoists himself off the ground and swings back and forth on the vine like Tarzan of the apes. Speck and his colleague Benedikt Hoffmann, both biomechanicists at the University of Freiburg in Germany, analyze the peculiar material properties of woody vines. They are working to find out what makes the structure of lianas different from that of trees and shrubs—hence what makes lianas usable as elastic, weight-bearing rope.

Wood is a composite material made of two principal substances: cellulose, a complex carbohydrate that is the chief structural part of most plant-cell walls; and lignin, which binds the components of cell walls together. The same kind of pairing shows up in familiar man-made products: in the modern tennis racket, for instance, carbon fibers are mixed together with epoxy. The fibers provide tensile stiffness and strength, while the epoxy keeps the fibers properly oriented and binds them together.

Although composite materials can be made artificially, the properties of wood cannot be duplicated. Osage orange wood, not fiberglass, still gives the best power and feel for archers' bows; old-growth spruce adds vibrancy and color to the tones of the finest violins; and many major-league baseball players, long accustomed to bats made from ash, now swear that



Monkey ladder (Bauhinia guianensis)

sugar maple is the finest for swatting one out to the center-field bleachers.

Lianas are woody vines that parasitize trees for structural support. A liana climbs its host tree, called a trellis, by laying down a network of tendrils, spikes, and hooks. Thus, it reaches the light of the upper canopy without having to invest in building up enough wood in its stem to support its weight. In American tropical forests, lianas may account for nearly half the leaf productivity, yet they amount to less than 5 percent of the biomass.

But a liana does not begin life as a parasite. It grows on its own until it finds a tree to cling to. Monkey ladder can reach a height of nearly six feet as a freestanding shrub. But when it finally finds a trellis, the vine begins to grow rapidly, the stem cross section becomes thicker and rectangular, and the material properties of the stem change radically.

The wood of a self-supporting monkey ladder shrub can be as stiff and dense as the hard, heavy wood of black locust trees that commonly occur in North American deciduous forests. The wood developed by the vine during the climbing, parasitic phase is less dense—the vessels in the wood that conduct water up the stem become much larger, and the wood itself absorbs more water. The increased water content makes the mature monkey ladder vine as much as three times more elastic than the shrub. So it's not surprising that the land-diving ceremony on Pentecost Island is held just after the wet season, when the vines are presumably filled with water and become most springy.

According to Speck's work on South American lianas, if a land diver were attached to a fifty-foot-long vine of shrub wood, it would stretch only five more feet. That would leave the diver far short of the ground (recall that the towers in the *naghol* ceremony are seventy feet high). But perhaps more important to the diver, the vine's arrest of his fall would be so abrupt that he would risk injury to both ankles (assuming the sudden loading didn't simply break the vine).

How do lianas make the transition from shrub to creeper? Speck and Hoffmann have shown that both monkey ladder and an unrelated South American liana, *Condylocarpon guianense,* undergo a marked drop in the cellulose, or fiber, content of the wood. (The amount of lignin—the epoxy analogue—remains the same in both kinds of liana.) But in all its stages of life *Condylocarpon* contains between 10 and 20 percent less cellulose than does the monkey ladder, and is about a third as stiff. Those data suggest that cellulose content is critical to stiffness.

A second change that occurs in the parasitic phase is the arrangement of the fibers, at least in *Condylocarpon.* In its self-supporting, shrub phase, the wood fibers of *Condylocarpon* are oriented longitudinally, nearly parallel to the stem's long axis. In contrast, when the plant becomes a creeper, the fibers run more at a slant [*see illustration below*]. In the slanted orientation the fibers can rearrange themselves as the wood stretches; the energy absorbed as the fibers shift is either dissipated as frictional heat or stored as potential energy in the wood's elastic tissue. Either way, the vine does not break.

Now that Speck and his colleagues are getting to the root, so to speak, of the changes in vines as they shift from shrub to creeper, the next step is to understand the genes that drive the changes. That understanding might one day make it possible to fine-tune the properties of wood to our liking. And what's next? High-tech tennis rackets and affordable Stradivarius-like violins that, quite literally, grow on trees?

An artist's conception of the parasitic liana Condylocarpon guianense shows the wood both unloaded (left) and under load. The cellulose fibers in the wood, shown in white, shift their orientation toward the vertical as the monkey pulls on the vine. As it stretches, the vine becomes thinner and as much as 30 percent longer.

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NATURAL HISTORY
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THE BIRTH OF WAR

Thirty years ago all the anthropologists studying war would have fit into one small room. Granted—and guaranteed—that room would frequently erupt in heated debate, but few outside would notice or care. Tribal warfare? Exotic, maybe, but so what? Anthropologists see war as potentially lethal violence between two groups, no matter how small the groups or how few the casualties. But how much light could such a broad definition of conflict, or cases of precivilized human strife, shed on modern warfare, the struggles that have flared in Iraq, Kosovo, Rwanda, Vietnam, Korea—and on and on?

How times have changed! The anthropological study of war has expanded and matured. Ideas from academic debates are finding their way into foreign policy journals and, yes, the mass media. The questions raised by anthropologists and the once-academic disputes within the discipline have become important public issues, to be debated by pundits and politicians.

To appreciate how much things have changed, consider how the understanding of one famous ethnographic case has been transformed: that of the Yanomami of Venezuela and Brazil. Following the publication of Napoleon A. Chagnon's study *Yanomamö: The Fierce People,* in 1968, the book began to appear frequently and prominently on lists of readings for college students in introductory anthropology—often the only anthropology they would ever learn. And what an object lesson! Engaged in endless wars over women, status, and revenge, the Yanomami were supposed to exemplify the natural human condition of eons past. Some people took Chagnon's work to imply that aggression is in our genes—disturbing news if true.

In 1974 the anthropologist Marvin Harris offered a different view. Yanomami warfare, Harris argued, was an adaptive response from a population

A rock painting in Tassili n'Ajjer, a Saharan plateau in southeastern Algeria, illustrates a battle between two prehistoric groups. Armed mostly with bows and arrows, the group at right braces in firing position for an assault by the group at the left. The scene was created sometime between 6,000 and 4,500 years ago, perhaps by nomadic cattle herders.

An archaeological survey concludes that warfare, despite its malignant hold on modern life, has not always been part of the human condition.

By R. Brian Ferguson

stressed by limited food resources, specifically game animals. But detailed examination of Yanomami ecology failed to support Harris's hypothesis.

In 1995, in *Yanomami Warfare: A Political History,* I described how the Yanomami have been coping with European intrusions since the 1700s. As I read the evidence, Yanomami wars were tightly linked to changes in the European presence. Recent wars, including the ones described by Chagnon, seemed to have been fought over access to steel tools and other goods distributed by Westerners. Yet despite such basic disagreements within anthropology, the discussion of the Yanomami remained confined to academic circles.

Then came a media frenzy. In the fall of 2000, Patrick Tierney, a journalist, published *Darkness in El Dorado: How Scientists and Journalists Devastated the Amazon.* The book essentially blamed Chagnon himself for instigating war. Now it was the anthropologists' turn to be fierce. Opponents and defenders of Chagnon exchanged bitter broadsides. Not a few anthropologists felt that the resident missionaries, for all their good intentions, were more at fault than any anthropologists. One outcome of the episode, though, is that no one paying attention to this controversy still claims that Yanomami wars can be understood without taking into account the tribe's highly disrupted historical circumstances.

What is more, studies that go far beyond the Yanomami are questioning the idea that war has always been part of the human condition. It looks as if, all around the world, what has been called primitive or indigenous warfare was generally transformed, frequently intensified, and sometimes precipitated by Western contact. A collection of historical studies that I edited in 1992 with Neil L. Whitehead, an anthropologist at the University of Wisconsin–Madison, concludes that such changes often took place in far-flung "tribal zones," even before literate observers arrived on the scene. Indigenous warfare recorded in recent centuries cannot be taken as typical of prehistoric tribal peoples (see *War in the Tribal Zone: Expanding States and Indigenous Warfare*). We need archaeology to tell us about ancient war.

In 1996 the issue took a new turn with Lawrence H. Keeley's book *War before Civilization*. Keeley, an archaeologist at the University of Illinois at Chicago, compiled archaeological cases of some of the worst violence known, thereby creating the impression that these examples were typical, that humans have always made war. As he told the journal *Science*, "War is something like trade or exchange. It is something that all humans do." Here I must unequivocally disagree: in my view the global archaeological record contradicts the idea that war was always a feature of human existence; instead, the record shows that warfare is largely a development of the past 10,000 years.

Five layers of human skeletons, some decapitated and some showing signs of struggle that suggest the victims were thrown in alive, fill the bottom of a water well excavated at the site of Chien-kou, near Handan, about 250 miles southwest of Beijing. The site, belonging to China's Longshan culture and dating from about 4,400 years ago, provides strong evidence of warfare between communities.

In the new book *Constant Battles: The Myth of the Peaceful, Noble Savage* (written with the writer Katherine E. Register), Steven A. LeBlanc, an archaeologist at Harvard University, confidently asserts that wherever good archaeological evidence exists, there is "almost always" evidence of warfare, that "*everyone* had warfare in *all* time periods." LeBlanc has a theory for his sweeping conclusion. Contrary to a commonly held view, he argues, pre-state peoples were never "true conservationists." They degraded their resources, and as their numbers grew, they suffered food scarcity and were drawn into war. Basically, it's Malthus with ethnographic detail.

An execution appears to be the subject of this painting in Remigia cave, in the eastern Spanish province of Castellón. Such depictions caution archaeologists that when they find a single skeleton with an embedded arrow point, it may not be a sign of warfare. The original painted image, from which this reproduction was made, may be 7,000 years old.

But what kind of archaeological evidence could show that war was waged? Lots. The best evidence comes from collections of skeletons, which can still bear witness to the violence of war: the embedded points of spears, arrows, or other weapons [*see photograph on opposite page*], depression fractures or scalp marks on skulls, "parry fractures" of forearms, and solitary skulls or bodies missing skulls (strongly suggesting that war trophies were taken). Mass burials or the absence of burial, as well as disproportionately few battle-age men in cemeteries, are also signs of war. Of course, such finds, particularly if the evidence is a single skeleton, could represent a murder, an execution, or an accident—hence a "false positive" as a piece of evidence about early tribal warfare. But nothing like tribal warfare could be going on without leaving some signs in a good collection of skeletons. If the collection comprises multiple examples of such evidence, it pretty conclusively demonstrates war.

Settlement patterns—such things as defensive walls and defendable locations or nucleated populations with empty buffer zones—also provide significant evidence of warfare. Violent destruction of a settlement is a telling clue. Specialized war weapons may be lacking—after all, war can be fought with such ordinary tools as adzes or hunting spears. But implements such as maces and daggers are usually for killing people, and when found, they are fairly definitive. Paintings or carvings on walls can provide graphic evidence of combat. Many peoples did not leave recoverable representations of human beings, but if such depictions are preserved, they can make a persuasive case. In short, when and where the archaeological recovery is good, with many settlements and many skeletons, war can usually be detected—not in every single case, certainly, but in a good number of them. That is the basis for supposing that archaeology can contribute to some of our most basic questions about war.

I am midway through a global survey of such early evidence. What does the record show? Many hominid remains once thought to establish the most ancient evidence of homicide or cannibalism were actually gnawed by predators or just suffered postmortem breakage [*see "The Scavenging of 'Peking Man,'" by Noel T. Boaz and Russell L. Ciochon, March 2001*]. Some cases of ancient cannibalism have been confirmed, but there is nothing to tell us that the remains in question were casualties of war.

The earliest persuasive evidence of warfare uncovered so far comes from a graveyard along the Nile River in Sudan. Brought to light during an expedition in the mid-1960s led by Fred Wendorf, an archaeologist at Southern Methodist University in Dallas, Texas, this graveyard, known as Site 117, has been roughly estimated at between 12,000 and 14,000 years old. It contained fifty-nine well-preserved skeletons, twenty-four of which were found in close association with pieces of stone that were interpreted as parts of projectiles. Notably, the people of Site 117 were living in a time of ecological crisis. Increased rainfall had made the Nile waters run wild, and the river dug its way deeply into a gorge. The adjacent flood plain was left high and dry, depriving the inhabitants of the catfish and other marshland staples of their diet. Apart from Site 117, only about a dozen *Homo sapiens* skeletons 10,000 years old or older, out of hundreds of similar antiquity examined to date, show clear indications of interpersonal violence.

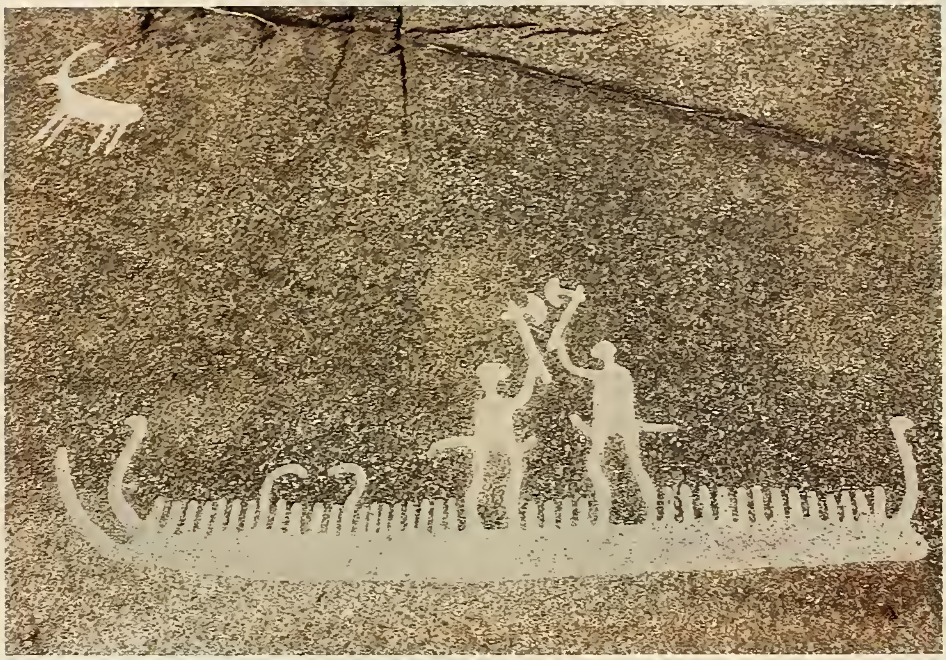
In northern Australia, rock art depicts what appear to be duels between two or a few individuals as early as 10,000 years ago. Large group confrontations—war—appear by 6,000 years ago. Climate change was a factor here too, as rising sea levels gradually submerged a vast plain that once connected Australia and New Guinea.

The ancient Middle East provides some of the best evidence for the emergence of war from a warless background. Extensive remains have been found of the Natufian hunter-gatherers, who lived between about 12,800 and 10,500 years ago in what are now Israel, the West Bank, Jordan, Lebanon, and Syria. Careful analysis of 370 skeletons has turned up only two that show any signs of trauma, and nothing to suggest military action. The first walls of Jericho (dating from between 10,500 and 9,300 years ago) were once taken as conclusive evidence of war, but they are now understood to have been built for flood control, not defense.

Pierced by a bone arrowhead, the skull of a thirty-five-year-old man was discovered in eastern Denmark. Another arrowhead pierced the man's breastbone. Was this death, 5,000 years ago, that of a warrior, a criminal, or perhaps a sacrificial victim? Although the violent death is apparent, its interpretation is uncertain.

There is a certain ironic logic, given recent events, that the regular practice of warfare that has continued without interruption down to the present began about 10,000 years ago in what is now northern Iraq. Evidence from three early farming sites, the earliest from Qermez Dere, includes maces, arrowheads found associated with skeletons, defendable locations, and village defensive walls. That's war—the true "mother of all battles."

Signs of war appear beginning 8,000 years ago along mountain routes through southern Turkey. Along the southern Anatolian coast, a specialized fort—not just a walled village—has been unearthed at İçel; the fort was built around 6,300 years ago, then destroyed and later resettled by a different culture. The early record along the Nile in what is now Egypt was wiped out by the river's erosion, but when the record picks up again, about 6,300 years ago, maces similar to those found in Mesopotamia are present. Far upriver, near Khartoum, what may have been maces show up 2,000 years earlier, even before agriculture began in that area.



Two Bronze Age figures raise their axes on a rock outcropping in Sweden known as the Fossum panel. Whether the scene, carved about 900 B.C., represents a battle, a ritual, or a dance, by this time war had become a cultural preoccupation all across Europe. The paint that highlights the carving is a recent addition.

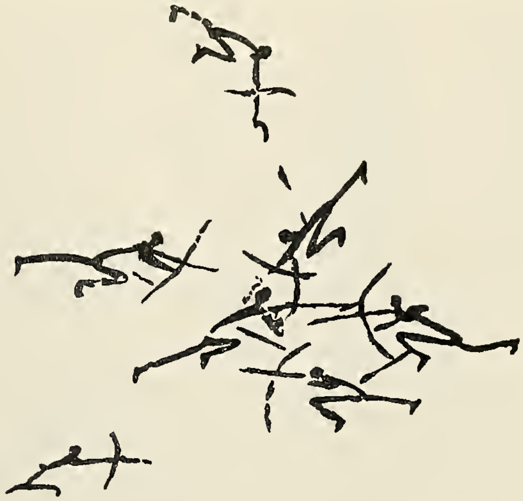
In Central Asia, east of the Caspian Sea, the remains of settled hunter-gatherers and early farmers show no signs of war, but war was clearly going strong by 5,000 years ago. In the high country of what is now Pakistan, farmers began to put up walls at least 6,000 years ago.

The archaeological record in China shows that though millet was under cultivation at least 8,000 years ago, no signs of war appeared for more than a thousand years after that. Starting 7,000 years ago, in one Neolithic cultural tradition, deep ditches were dug around villages, some accompanied by palisades. Elsewhere in China, except for a single skeleton with a point embedded in its thigh, there are no hints of war until at least 4,600 years ago. Then, rammed earthen walls and other signs of war occur throughout the core areas of historical China. One village well contained layers of scalped and decapitated skeletons.

In Japan, intensive agriculture came in with migrants from the mainland about 2,300 years ago. Archaeologists have excavated some 5,000 skeletons that predate the intrusion, and of those only ten show signs of violent death. In contrast, out of about 1,000 postmigration excavated skeletons, more than a hundred show such signs.

Evidence from Europe offers a clear window into preagricultural practices. There is no firm evidence of war for thousands of years during Paleolithic times—though some scholars see suggestive indications in a few places. After 10,500 years ago, however, as the population of foragers became larger and more settled, several sites show individual violence, and others show the more collective casualties that signal war. Still, the evidence of violence is present at only a small minority of all excavated sites. Beginning around 6,500 years ago, however, fortifications, embedded points, and even clear signs of village slaughters become common. By the Bronze Age, 2,000 years later, war and weaponry had become a veritable cult.

North America presents a highly complex and regionally divergent picture. Kennewick Man, a skeleton unearthed in Washington state and considered between 7,500 and 9,200 years old, contains an embedded stone point. But because the skeleton is an isolated find, the injury is difficult to interpret. On the coast of the Pacific Northwest, skeletal trauma and other signs of conflict begin to appear about 4,200 years ago in the northern regions, but show up farther south only many centuries later. Many of the excavated skeletons from the ancient eastern woodlands show signs of violence. In a few cases multiple individuals were involved, including one site in Florida dating from more than 7,000 years ago. Still, such cases remained extremely unusual until 5,000 years ago. In the southern Great Plains, out of 173 skeletons reported from before A.D. 500, only one indicates homicide, a woman killed by two blows to the head. The first clear evidence of warfare in the Southwest dates from less than 2,000 years ago, and it is quite dramatic. At least two-thirds and perhaps all of the ninety-odd individuals interred in a cave in southern Utah were killed.



Archers clash in a cave painting from Morella la Vella in eastern Spain. The composition, perhaps 7,000 years old, seems to depict a flanking maneuver by the figure on top. This image is a tracing of a photograph.

Roughly speaking, that is where my survey leaves off. But my preliminary work leads me to expect no major surprises from Africa, Mesoamerica, Oceania, or South America. In sum, if warfare were prevalent in early prehistoric times, the abundant materials in the archaeological record would be rich with the evidence of warfare. But the signs are not there; here it is not the case that "the absence of evidence is not evidence of absence."

So how did peaceful tribal peoples of the distant past turn into the war-prone societies observed in recent centuries? Specific causes are elusive, but I see five preconditions that, in varying combinations, contributed to the onset of warfare in prehistoric times. One was a shift from a nomadic existence to a sedentary one, commonly though not necessarily tied to agriculture. With a vested interest in their lands, food stores, or especially rich fishing sites, people no longer could walk away from trouble.

Another precondition was a growing regional population and probably, in consequence, more competition for resources. Third was the development of social hierarchy, an elite, perhaps with its own interests and rivalries. Fourth was an increasing long-distance trade, particularly in prestige goods: something else worth fighting over. Finally, the first appearance or later intensification of war was often associated with a severe climatic change that broke down the subsistence base.

Raymond C. Kelly, an anthropolgist at the University of Michigan in Ann Arbor, in his book *Warless Societies and the Origin of War*, has detected what may be another important pattern in the origins of war. In examining the ethnographic literature to compare hunter-gatherers who make war with those who do not, he finds a pattern: Among the few known cases of warless societies of hunter-gatherers, social organizations do not extend beyond family and a loose, flexible network of kin. In contrast, hunter-gatherer societies that make war have larger and more defined groupings such as clans. The existence of bounded groups makes for a sense of collective injury and desire for collective retaliation.

Over the millennia, tribal warfare became more the rule than the exception. As the preconditions for warfare (permanent settlements, population growth, greater social hierarchy, increased trade, and climatic crises) became more common, more tribal peoples in more areas adopted the practice. That development in itself spread warmaking to other groups. Once ancient states arose, they employed "barbarians" on their peripheries to expand their empires and secure their extensive trade networks. Finally, the European expansion after 1492 set native against native to capture territory and slaves and to fight imperial rivalries. Refugee groups were forced into others' lands, manufactured goods were introduced and fought over (as with the Yanomami), and the spread of European weapons made fighting ever more lethal.

Maces, skeletons with arrowheads, and village defensive walls have been discovered in Iraq, all signs of the true "mother of all battles," 10,000 years ago.

When I began studying war in the mid-1970s, I was trained in an approach called cultural ecology, which argued along the lines that Steven LeBlanc does today. Population pressure on food resources—land, game, herd animals—was seen as the usual cause of indigenous warfare. In some cases the theory did work. Among the peoples of the Pacific Northwest Coast prior to the depopulation of the nineteenth century, groups fought to gain access to prime resource locations, such as estuaries with good salmon streams. But in far more cases around the world, such as that of the Yanomami, warfare could not be linked to food competition.

Today, under the rubric "environmental security," many nonanthropologists who work on issues of international security embrace that ecological view. Recent outbreaks of violence, they argue, may be rooted in scarcities of subsistence goods, fueled by growing populations and degraded resources (such as too little and eroded cropland). But when you examine the cases for which that interpretation seems superficially plausible—the conflicts of the past several years in Chiapas, Mexico, for instance, or in Rwanda—they fail to confirm the "ecological" theory.

A chariot with warriors is among the trappings of warfare included on the so-called Standard of Ur, a Sumerian object dating from about 2500 B.C. By that time, war was a normal practice between rival city-states.

We anthropologists are just beginning to bring our experience to bear in the environmental security debate. What we find is that if a peasant population is suffering for lack of basic resources, the main cause of that scarcity is an unequal distribution of resources within the society, a matter of politics and economics, rather than the twin bugbears of too many people and not enough to go around.

Anthropology can offer an alternative view on such terrible disasters as the Rwandan genocide or the civil wars in the Balkans. Case studies of modern-day conflicts show that a broad range of factors may be interacting, including subsistence needs and local ecological relations, but also political struggles over the government, trends in globalization, and culturally specific beliefs and symbols. Moreover, when hard times come, they are experienced differently by different kinds of people. Who you are usually determines how you're doing and where your interests lie: identity and interest are fused. Once a conflict gets boiling and the killing starts, all middle grounds get swept away, and a person's fate can depend on such simple labels as ethnic, religious, or tribal identity. The slaughter of Tutsis in the Rwandan genocide of 1994 is only one of the latest examples of that horrific effect. But such differences are not the cause of the conflict.

My view is that in most cases—not every single one—the decision to wage war involves the pursuit of practical self-interest by those who actually make the decision. The struggle can be joined over basic subsistence resources, but it can just as easily erupt over goods available only to elites. The decision involves weighing the costs of war against other potential hazards to life and well-being. And most definitely, it depends on one's position in the internal political hierarchy: from New Guinean "big men" to kings and presidents, leaders often favor war because war favors leaders.

Of course, those who push toward war do not make their case in terms of their own selfish interests. Around Amazonian campfires and within modern councils of state, their arguments invoke collective dangers and benefits. But even more, those advocating war always define it in terms of the highest applicable values, whether that involves the need to retaliate against witchcraft, defend the one true religion, or promote democracy. That is the way to sway the undecided and build emotional commitment. And always, it is the other side that somehow brought war on.

Such drumbeating is not only, or even primarily, cynical manipulation. Perhaps owing to a basic human need for self-justification, those who start wars usually seem to believe in the righteousness of their chosen course. It is that capability that makes human beings such a dangerous species. □

The White House ruins in Canyon de Chelly National Monument, Arizona: Archaeological investigation shows that this particular cliff dwelling—although seemingly designed for defensive purposes—was a ceremonially significant complex built between A.D. 1050 and 1150, a century before deteriorating climatic conditions in the Southwest led to intense warfare.

Charles Plumier, *Cacao, from a manuscript on plants and civilization in the Antilles,* c. 1686

The Chocolate Tree

Growing cacao in the forest can provide a living to small farmers and a habitat to diverse creatures.

By Robert A. Rice and Russell Greenberg

To most North Americans the word "chocolate" probably conjures visions of a fragrant, nut-studded brown slab, or a box full of small but elaborate variations on gooeyness, or one of those outrageous dark desserts with names such as "mud pie" or "death by chocolate." Few of us who savor and consume such delights think about moist, lush foliage, the shrieks of toucans and parrots, or a Maya ruler from the seventh century A.D. sipping chili-spiked cocoa froth.

Cacao beans in a pod, Grenada

But perhaps we should. *Theobroma cacao*—the tree whose giant pods contain the seeds that, when roasted and then ground, become the powder that is the basis of chocolate—is an evolutionary product of the vast tropical rainforests of the New World. Indigenous peoples domesticated the tree in the northern Amazon basin and seemingly independently somewhere in what is now southern Mexico, Guatemala, or Belize (recent genetic work, however, suggests that the Mesoamerican domesticated stock originated in South America). To those fortunate people, the cocoa drink made from cacao was, as reflected in the genus name, indeed the "food of the gods."

Today, however, this forest tree is cultivated far from its birthplace. In 2002 more than 40 percent of the world's cacao came from Côte d'Ivoire. Ghana, Indonesia, and Nigeria together produce about 33 percent, Brazil less than 5 percent. But though well-heeled *norteamericanos* may be laying down a ten-dollar bill to pay for half a dozen hand-crafted chocolate delights, the world's average rate for cacao beans in 2002 was not much more than eighty cents a pound, and many farmers who grew the beans were paid far less.

Yet a look at the biology, history, ecology, and economics of the cacao tree—and the industry that has sprung up around it—shows that unlike many products of the developing world that the developed world enjoys, cacao can be a relatively benign crop. It can be grown economically on small farms, bringing individual farmers into the world's cash economy without destroying their independence and self-determination. As a shade-tolerant tree, it can also be cultivated under a canopy of larger trees already living in the tropical forest; clear-cutting is actually detrimental to a sustained crop yield. That means that cacao growing, albeit not entirely without harm to the forest ecosystem, is far less destructive than most other forms of cultivation. Preserving the canopy, in turn, helps in maintaining populations of indigenous birds and other forest animals, and in pulling carbon dioxide out of the air. Inside the wrapper of this food we have come to take for granted is a complex web of interrelating factors that ecologists are only beginning to understand.

The cacao tree grows naturally in the shaded, humid understory of lowland tropical forest, reaching heights of some twenty feet. Twenty or thirty large, gently fluted pods grow directly from the tree's trunk and branches, dangling like holiday ornaments. Each pod is between six and twelve inches long, its hue orange or reddish orange by the time it matures. Inside the pod are two or three dozen seeds—the cacao beans—surrounded by a sweet, milky-white gelatinous pulp that is the main ingredient for a South American drink.

The cacao beans themselves, which are dull brown on the outside and a striking purple within, are an unlikely resource for the dessert-hungry people of the world. A mere brush against the tongue imparts a strong and bitter flavor. The pods and their beans probably evolved as they did by taking advantage of the cravings of nonhuman primates. The sweet pulp is an attractive food, encouraging the animals to remove the pods. The beans, or seeds, however, are enriched with distasteful alkaloids, and thus are discarded wherever the pulp is consumed. The combination virtually guarantees seed dispersal.

The native cacao tree also depends on minuscule flies, attracted by the overripe pods that fall to the ground and rot around its base. The flies require large pieces of moist tropical detritus (such as rotting cacao pods) to carry on their own life cycle; while thus occupied, they pollinate the tree's small flowers, which develop into the next generation of pods. Because of that natural history, cacao is much more likely to be pollinated in a forest with a moist, messy understory than in a commercial plot cleared or raked by human tools.

Cacao has been cultivated for hundreds if not thousands of years, and so has been subjected to plenty of ad hoc horticultural experimentation. Even before European contact, cacao trees had been planted far from their natural origins, and their beans were a treasured Mesoamerican resource. By the time of contact, according to the early sixteenth-century Spanish chronicler Gonzalo Fernández Oviedo y Valdés, the beans had become so widely cultivated that they were used as money: to acquire "gold, slaves, clothing, things to eat and everything else," Valdés wrote. Between the late seventeenth and the late nineteenth centuries, the heyday of Europe's colonial empires in the tropics, cacao joined coffee and rubber as crops transplanted to distant shores.

All three of those transplants proved highly successful. They benefited, at least initially, from the enforced separation between the plant and its coevolved insect pests and diseases. Coffee, native to tropical Africa, is now grown for export in Brazil, Colombia, and Vietnam; rubber, native to South America, is cultivated in Malaysia. For cacao, the heavy-hitting region for production quickly became West Africa.

Cross section of forest in a small West African cacao farm includes trees at three distinct levels. Among the tallest are such plants as (left to right) oil palm, Terminalia *(a source of timber), and rubber. At the second level are trees that offer the cacao farmer a further hedge against fluctuations in the price of cacao: depicted here (left to right) are guava, avocado, mango, orange, and coconut. At the lowest level are the cacao trees (the three trees in the foreground with reddish pods), which thrive in the shade. The planted, mixed forest, known as polycultural farming, maintains a level of biodiversity much greater than does plantation cultivation of cacao as a single crop.*

Like its sister crop coffee, cacao is still commonly grown in a forest or forestlike setting called an agroforest, where shade trees tower over cacao plants that have been pruned to harvestable height. Botanists classify such agroforests (at least for cacao or coffee) according to the stature and diversity of the shade-tree canopy. In "rustic" cacao farms, large canopy trees in the original tropical forest are thinned out, to enable more light to penetrate to lower heights. Cacao trees are simply cultivated beneath the remaining shade trees. This is in considerable contrast to the large, technologized "zero-shade" cacao plantations, which apply generous amounts of highly toxic herbicides, such as paraquat, and potent insecticides such as endosulfan.

The shade-tolerant cacao tree can be cultivated beneath a canopy of taller trees, sparing existing tropical forest from clear-cutting.

But most cacao today is grown on so-called polycultural farms, under planted shade—a somewhat more managed environment than the rustic farms, but still far more biodiversity-friendly than the zero-shade plantations. In a polycultural system the farmer selects and manages much of the canopy, or even all of it. A single species, usually a fast-growing legume, supplies most of the shade. Trees that yield fruit for human consumption often form a second, intermediate canopy. Beneath it all are the low-growing cacao trees [*see illustration on opposite page*].

To be fruitful, a cacao tree must get individual attention—something the family farm and the small farmer are best suited to provide. Less than a third of the cacao flowers become fruit—in other words, pods—and the careful cultivator will remove defective pods throughout the growing season. Not surprisingly, hired hands on huge plantations are sparing with such tender loving care. Furthermore, large areas planted with a single crop give rise to serious agronomic problems of their own. The typical smallholder's practice of growing cacao along with an array of shade trees reduces such difficulties.

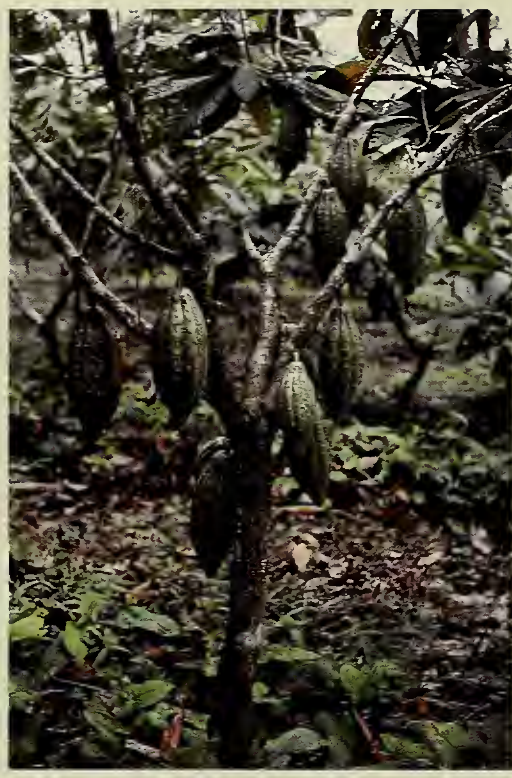
Small and medium farms of all kinds are often more productive—in terms of total useful product per unit area of land—and cacao farms are no exception. There is no big secret about what makes that so. Small peasant producers simply must work harder and smarter if they are to survive. Tied to the land, with only the occasional chance to supplement their agricultural earnings with gainful off-farm labor, small farmers are highly motivated to anticipate (and, as much as possible, to mitigate) the risks of farming: natural forces such as weather, insect infestations, and disease, and human (but still uncontrollable) factors such as export-price fluctuations and societal upheavals.

Traditional rustic and polycultural cacao systems seem well suited to cope with such risks. Part of their success comes from diversification: the multilayered forest yields not only cacao beans but also a cornucopia of other products. Farmers can harvest avocados, bananas, breadfruits, mangoes, and oranges, as well as medicinal plants, rubber, and timber. Harvesting wood from a traditional cacao farm has the added benefit of protecting other extant forests from the ax. And when cacao bean prices are low, a farm's noncacao products can still supplement the household diet and generate cash at nearby markets. Finally, polycultural cacao farms that are abandoned when world cacao prices fall or disease attacks the trees may devolve into patches of secondary forest, a habitat that remains conducive to preserving biodiversity.

Today some 17 million acres worldwide are planted in cacao, an increase of 60 percent since the early 1960s—when the North American dessert

The pink-legged graveteiro, first recorded scientifically in 1996, forages in canopy trees that shade cocoa plantations on Brazil's Atlantic coast. A juvenile is at left, an adult at right.

choice was far more likely to be cherry pie à la mode than chocolate mousse. Production of cacao beans approached three million metric tons in 2002. On a global scale, about 90 percent of all cacao farmers are "small"—defined as holding less than twenty-five acres. In some nations, such as Ghana and Cameroon, "small" almost certainly refers to a farm of less than half that area. Plantation farming was particularly popular in Malaysia, where in the early 1990s total cacao acreage soared to 750,000. But large-scale farming proved unsuccessful, and so most of the country's 125,000 acres of cacao today are small-scale farms.



A fruiting cacao tree, Belize: Cultivated trees are pruned so that the pods are at a convenient height for harvesting.

In 1996 ornithologists announced the discovery of a new species of Neotropical ovenbird, the pink-legged graveteiro *(Acrobatornis fonsecai)*, within the rustic cacao farms of the state of Bahia, Brazil. An endangered monkey, the golden-headed lion tamarin, had already been spotted in the same habitat. Those sightings were turning points for conservation biologists. After decades of focusing on pristine habitats, the biologists began to pay increasing attention to agricultural settings. Part of the shift came from their realization that, in many areas, agroforests and forest fragments are all that remain of the original, vast forestlands. Cacao farms quickly came to be regarded as preservers of biodiversity.

Surveys of the flora and fauna of rustic cacao farms in West Africa have been conducted since the 1950s, but the recent sightings of rare birds have brought new energy to the fieldwork. We and our colleagues at the Smithsonian Migratory Bird Center, as well as other groups working in Brazil, Central America, the Dominican Republic, Mexico, and West Africa, have consistently found greater diversity of species in the agroforests than we can document on other kinds of agricultural lands. Agroforests still harbor such forest species as bats, canopy birds, and migratory birds.

Compared with natural forest, of course, even agroforest lands are generally depauperate. The main casualties are tree species characteristic of old-growth forests. Such trees appear doomed to vanish because regeneration is unlikely wherever the understory has been highly altered. With their disappearance comes the disappearance of the coevolved fauna: large mammals and understory birds native to pristine forests are absent in the agroforest. For that reason, the rustic cacao farm is probably not an ecologically stable system. But the findings of the biodiversity surveys suggest that even some of the small-scale polycultural cacao farms offer shelter to many otherwise doomed forest organisms. Perhaps the best hope for the future is a polycultural system developed out of a combination of traditional practices and modern research, planted with shade trees that are valuable to wildlife as well as people.

After decades of looking to pristine habitats to preserve biodiversity, biologists are noticing the potential value of agricultural settings.

For the past decade, those of us at the Smithsonian Migratory Bird Center have been surveying the composition and diversity of birds in southeastern Mexico, both in natural and human-created systems. Two quite different kinds of cacao farms are included in the survey. The first are small, rustic farms in a "buffer zone"—a belt of well-forested but still partly cultivated land—surrounding the completely uncultivated 1,300-square-mile Montes Azules Biosphere Reserve in the Selva Lacandona, a huge lowland tropical forest in the Mexican state of Chiapas. The second are small, polycultural, planted-shade farms in the lowlands of the state of Tabasco, on the coast of the Gulf of Mexico. The diversity of bird species we measured on the Selva Lacandona farms is more similar to what it is in pristine forests, or at least in forests that have been only slightly altered from their pristine state. Moreover, that diversity is between one and a half and seven times as great as it is in pastoral, open, or other more traditional agricultural habitats. A quarter of the most common species—mostly forest-breeding birds, both resident and migratory—occur both in the Lacandona agroforest and in undisturbed tropical forest.

In contrast, unfortunately, Tabasco's polycultural farms support substantially fewer bird species than do the rustic farms—eighty-four compared with 142. We found virtually no forest-breeding species on the polycultural farms.

We and our colleagues have also conducted extensive surveys on the cacao farms in the Apurímac valley of south-central Peru, an area known for its production of alkaloidal crops: coffee, cacao, and coca (the last grown for both legal and illicit markets). Several decades ago, much of the low-elevation, shade-grown coffee land was converted to cacao production and then, in an attempt to control a fungal disease known as monilia pod rot, the shade canopy was removed. Years of civil war involving the Shining Path guerrilla movement left much of the zero-shade cacao abandoned. Today the area is dominated by tall scrub, particularly cacao, much of which is being brought back into production.

A harvester empties cacao pods of their seeds and pulp.

Cacao seeds and pulp are collected for carrying and weighing.

The Apurímac valley had been notable for both the diversity and uniqueness of its bird populations. We were disheartened, therefore, to sight only ninety-three species of birds (a low figure by Peruvian standards), all of which are commonplace even in disturbed habitats. Presumably even though our study area encompassed small fragments of forest and was only a few miles from more continuous stretches of woods, the many years of zero-shade cultivation had rendered the habitat inhospitable to the endemic birds. They may never return.

If cacao—appropriately grown—can do good things for biodiversity, what can biodiversity do for cacao? Both planned and unplanned diversity—what farmers put in place, as well as what just shows up—contribute to the crop's successful cultivation, often in ways biologists don't yet understand. Recent experiments with shade-grown coffee have shown that birds remove more than 70 percent of the arthropod population both from the canopy and from the understory crop plants. That number includes at least half the herbivorous insects. Ants play a complex and less well understood role: they are major predators on other arthropods, including many herbivores, but they also protect scale insects, which harm plants by living off plant juices.

Biodiversity on a cacao farm also includes towering shade trees, whose leaf litter slowly releases nutrients back into the soil, and offers an attractive habitat to a host of organisms that may be critical in the breakdown and recycling of the nutrients. If the shade trees include legumes, as is the case in many polycultural cacao farms, bacteria that live symbiotically in their roots supply the soil with usable nitrogen. The shade canopy also shields understory plants from the relentless tropical sun, as well as from the physical impact of driving tropical rains, thus reducing soil erosion. The diversity of species that follows from the presence of shade trees undoubtedly helps control certain pests and pathogens as well; taken together, the elements of the system embody the ecological mantra that diversity enhances stability. It is also worth noting that crops grown under a range of shade-tree species support substantially greater local diversity than do those grown under a single such species.

There is an even broader benefit from the massive shade trees that are an integral part of a rustic or polycultural cacao farm. They effectively sequester, or capture, carbon—acting as carbon "sinks" that shunt atmospheric carbon dioxide into fixed sites. That helps alleviate the buildup of the greenhouse gases in the atmosphere that are causing global climate change.

The "cocoa cycle" begins when growers clear forest vegetation to plant cacao seedlings. Later, when yields decline, they move on to new lands.

Historically, cacao itself has been a vagabond crop. Production levels have always been maintained largely by exploiting new forest frontiers worldwide. According to the botanist François Ruf of CIRAD, a French organization devoted to agricultural research for developing countries, the cycle begins as new forest is cleared. Seedlings are then planted that can take advantage of the cost-free nutrients in the soil of the newly cleared plot of land. With time, though, the cacao yields decline, until eventually the plot is abandoned. Then the "cocoa cycle" begins once again, on another patch of untouched forest.

In that way, as the worldwide craving for chocolate has grown, the unfettered forces of production have continued taking huge bites out of tropical forests around the globe. With no national guidelines—much less a global, or at least industrywide, policy—to address the hungry advance of cacao into natural forests, some of the very forests that have served as raw material for cacao production in the past 200 years will soon disappear.

It is true that, in global terms, cacao accounts for a small fraction of forest degradation and clearing at any given moment. Yet the impact of such production methods in particular areas, such as West Africa and the Indonesian island of Sulawesi, can be substantial, and where clearing targets forest that harbors endemic species, the threat to biodiversity can be great. Furthermore, if production continues to be concentrated in particular frontier regions, the crop becomes increasingly vulnerable to new fungal diseases. Geographical diversification can help maintain the supply, but eventually a long-term vision is needed.

Some large companies have accepted responsibility for taking that long view, and have begun to fund research on natural agents that could control some of the diseases that plague cacao trees. There is a growing realization that maintaining cacao as an environmentally and economically sustainable crop is inextricably linked with the well-being of the hundreds of thousands of small farmers who tend the crop—and hold the key to future supply. And for small growers, biological methods of controlling disease are far more affordable—and far safer—than the expensive, environmentally detrimental chemicals so often applied by the owners of monocultural plantations.

Along with the recognition of the importance of the small farmer, a consensus is emerging among ecologists, economists, experts in economic development, and industry-based investigators that agroforestry, employing a diverse shade canopy, is the cornerstone of sustainable cacao farming. In Brazil's cacao zones, recent planting schemes have been incorporating multiple species of shade trees, native forest species, and hardwoods or other economically valuable crops such as palms or bananas, all of which can increase the cacao farmer's income and diversify the farmer's product.

Certain enduring problems have relatively simple solutions. In Indonesia, for instance, the early harvest of the pods has reduced losses from a moth pest. Other initiatives are more complex. In Peru, treating the trees with certain plant-dwelling microorganisms, as well as with ecologically benign fungi that parasitize other fungi, has cut infestations of the witches'-broom fungus by 50 percent, and yields have increased by 20 percent (those programs, funded by Mars, Inc., of Hackettstown, New Jersey, draw on the resources and expertise of the U.S. Department of Agriculture). Scientists at the Smithsonian Tropical Research Institute have begun to identify some fungal endophytes—species that grow within plant tissues—that when present in cacao leaves and fruits may serve as natural biological controls against other fungi, such as those that cause the devastating disease known as black pod. Private chocolate interests have sponsored projects that link grower groups with disease experts and are funding research whose findings will be published in scientific journals.

But the economic factors that affect cacao farmers are less easily controlled. Cacao is a poor farmer's crop, and the pluck and perseverance of the growers who migrate to remote areas to carve out a livelihood are rarely rewarded with fair prices. No matter how well they anticipate adversity, they are constantly buffeted by market fluctuations in the price of cacao beans, driven by forces far away from the farm. A good example is last fall's surge in world cacao prices to eighteen-year highs, about $2,500 per metric ton, caused in part by civil turmoil in Côte d'Ivoire. Yet at the same time in neighboring Ghana, where the government sets the price growers receive, farmers had to settle for just $763 a metric ton—70 percent less than the market rate.

Thus the fundamental issue of what the grower gets paid remains unsolved. Activists in the "fair trade" movement have convinced some of the major players in the chocolate industry that price has to cover the true costs of production by the small farmer and provide a living wage to the farm family. Several industry giants are now buying cacao at a higher-than-market price from associations of small growers; part of the money then goes toward community development and the implementation of sustainable production techniques. And several smaller but quite upscale companies are working directly with producers to showcase their cacao beans in certified organic chocolate products.

So the next time you order chocolate mousse, topped by a few shavings of bitter chocolate and a dab of whipped cream, think of it the way you might think of homemade strawberry jam, or hand-rolled sushi, or a top-flight French wine—something that's worth paying extra for. Chocolate, too, at least at the grower's end of the production chain, remains a cottage industry: the work of many hands, by people who have to pay their own bills. And then, because you truly enjoy it, savor their work. □

Mexican Indian woman is pictured as she prepares a chocolate-flavored drink, in this facsimile of a page from the Codex Tudela (1553).

Summer Flings

Firefly courtship, sex, and death

By Sara Lewis and James E. Lloyd

The fireflies, twinkling among leaves, / make the stars wonder.
—Rabindranath Tagore (1861–1941)

As light slips from the summer sky, an army of male fireflies awakens from its daytime slumber. One by one, the insects march up blades of grass, waiting until dusk to lift off like miniature helicopters into the night. Yet these fliers aren't bent on military conquest; their goal is simple evolutionary survival. The fireflies we study—bioluminescent members of the genus *Photinus*—devote every night of their short adult lives to courtship, first broadcasting their amorous intentions with flashing light signals, then seeking to mate with responding females.

Few insects are considered charismatic, but fireflies are a clear exception. All over the world their spectacular courtship displays have long delighted children and inspired poets. On long summer evenings throughout the United States countless children chase fireflies through fields and backyards. In Japan, where a broad respect for nature is both traditional and deeply felt, fireflies—*hotaru*—are particularly revered. School graduation ceremonies feature the song "Hotaru no Hikari," which means "fireflies' light," and many cities celebrate communal firefly watching with annual festivals known as *hotaru matsuri* ("fireflies' festival"). In the popular Japanese cartoon *Sailor Moon,* the heroine is Tomoe Hotaru, a name that means "firefly of earth." And in Japanese poetry the firefly serves as a metaphor for silent yet passionate love.

As biologists, the two of us still fall under the spell of fireflies. In particular, it is their single-minded focus on procreation that has inspired us, as students of the evolutionary process of sexual selection, to spend countless nights for the past several decades observing their drama of love and death. We, along with our colleagues, have been keen to learn what makes certain individual fireflies more likely than others to find mates and insure that their genes are passed on to future generations. And our observations, both in the wild and in the laboratory, have led to new insights into how fireflies (and other

Bo Bartlett, *Firefly,* 1994

species as well) play the game of evolutionary survival—how they live, love, and die.

Fireflies are not flies at all, but beetles, belonging to the family Lampyridae. To date, entomologists have formally described some 2,000 firefly species worldwide. The family includes some nonluminescent (and often diurnal) species that rely on pheromones to locate mates, as well as some species that merely glow rather than flash. In North America the flashing fireflies fall into three main genera: *Photinus, Photuris,* and *Pyractomena*.

To the uninitiated, the adults of the three genera look almost identical. Like all beetles, they have elytra, the hardened front wings that form a protective sheath above the hind wings; it is the latter that are used for flight. Most of the fireflies in the three genera have black elytra edged with yellow, and a shieldlike head covering, typically with red markings. Subtle morphological differences separate the genera; within each genus, entomologists distinguish species by differences in coloration, in the shape of male genitalia, and in flash behavior.

Fireflies themselves generally have no trouble determining whether another firefly belongs to their own species, or to their own sex for that matter. To do so, they rely solely on species-specific flash patterns—one or more short pulses of light. To iden-

tify males of their own species *Photinus* females key in on several flash characteristics, including pulse rate, duration, and the number of pulses in the overall flash pattern. *Photinus* males, in turn, usually focus on the length of the time delay before a female responds with a flash of her own.

By mimicking the signals of each sex with a penlight, you, too, can attract males and get responses from females. With one in hand, you can distinguish males from females by the size of the light-producing lantern on the underside of the abdomen. In the *Photinus* male, the lantern takes up the entire last two abdominal segments. In the female, the lantern is much smaller, restricted to the middle of the penultimate segment.

Fatal attraction: after luring a small Photinus *male firefly with false signals, the large* Photuris *female firefly devours him.*

However conspicuous it is, the adult stage of the firefly makes up only a small fraction of the life cycle. In North American fireflies the adult stage lasts at most a few weeks. The life cycle begins when the female lays her eggs in moist soil or moss. After about two weeks the eggs hatch, and minute, carnivorous larvae emerge. Firefly larvae live underground or beneath leaf litter, feeding on earthworms, snails, slugs, and soft-bodied insect larvae. In the northern United States fireflies probably spend between one and three years as larvae; farther south they can complete their development within a few months of hatching. Firefly larvae pupate in late spring within an igloo-shaped underground chamber. They emerge a few weeks later, having assumed their familiar adult form.

Once fireflies reach adulthood, the race for reproduction is on. *Photinus* fireflies devote their entire adult lives to reproduction; most of them do not eat after they become adults. Triggered by dusk's fading daylight, male fireflies lift off into the air and begin their courtship. The roving males fly slowly, between three and six feet above the grass, advertising their availability with a flash pattern of one, two, or several short light pulses, repeated at regular intervals [*see diagram at bottom of opposite page*].

Females, meanwhile, remain perched low in the vegetation; in *Photinus* species the females rarely fly. Females respond to male advertisements with a single pulse (or in a few species, multiple pulses). After a male sees a female response, he drops out of the air to continue his search "on foot." The flash dialogues continue, often lasting more than an hour, and the ongoing conversation acts as a magnet for other males. By the time courtship flight ends, several males can often be found scrambling up and down blades of grass, searching for the stationary female.

Biologists have long pondered how fireflies generate their precisely timed flashes. Work done recently by an interdisciplinary team of cell biologists, physiologists, and ecologists from Tufts University and Harvard Medical School has provided a key piece to the puzzle.

In fireflies light is produced in a chemical reaction, which can occur only in the presence of oxygen, between the compound luciferin and the enzyme luciferase. In the firefly lantern, thousands of specialized cells called photocytes sequester luciferin and luciferase deep within their interiors. Densely packed around the photocyte margins are mitochondria, the oxygen-consuming power plants that occur in nearly all eukaryotic cells. The team found that the firefly nervous system does not control the photocytes directly; instead, the flash-triggering nerve impulse arrives in the lantern at nonluminescent cells adjacent to the photocytes.

The nerve signals trigger the production of nitric oxide (NO). That discovery offered significant insight into firefly flash control. The NO molecule is a ubiquitous intercellular messenger that has an astonishing array of biological functions. In people, it controls blood pressure, regulates penile erection, and mediates learning and memory. In the firefly lantern, NO switches the flash on by temporarily shutting down the oxygen consumption of the photocyte's mitochondria. Oxygen can then diffuse farther into the interior of the photocyte, where it triggers the light-producing reaction between luciferin and luciferase. The flash turns off as NO quickly degrades and mitochondrial oxygen consumption is restored.

The highly visible courtship signals among fireflies, and their short adult lifespans, make fireflies particularly amenable to studies of sexual selection. Darwin coined the term "sexual selection" to refer to differences among a species' males and how successful they are at gaining access to females. According to Darwin, the reproductive advantage goes to males that can prevail over rivals or that can more effectively attract females. Later biologists have realized that mere copulation is not sufficient to ensure a male's reproductive success; in many animals females mate with multiple males, and both male sperm competition and female sperm choice can create differences among mating males in the number of offspring they sire. In fireflies, a male's reproductive success depends not only on his courtship ability, but also on his postcopulatory ability to fertilize his mate's eggs.

A maturing firefly larva attacks a hapless slug.

Sexual selection in fireflies begins during courtship. Recent studies show that female *Photinus* fireflies discriminate between potential mates by evaluating their flash patterns. The flash pattern of *Photinus consimilis* males is made up of four to twelve rapid pulses. Marc A. Branham, now of Ohio State University in Columbus, and Michael D. Greenfield of the University of Kansas in Lawrence found that among *P. consimilis* fireflies, the faster the male's pulse rate, the more frequently the female responds. Yet males of many other *Photinus* species emit singly pulsed courtship flash patterns. For example, Christopher K. Cratsley, now at Fitchburg State College in Massachusetts, found that in *P. ignitus,* the longer the male's courtship flashes, the more likely the female is to respond. As one might expect, getting a female to respond is crucial to a male's mating success. Field studies show that firefly males that elicit more female responses during courtship are most likely to succeed in mating.

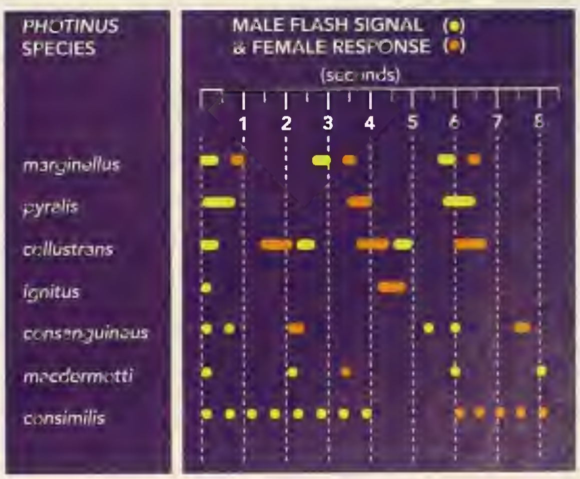
The light show is over when copulation begins. In *Photinus* fireflies, copulations generally last several hours, a practice that limits both males and females to a single mating each night. One reason for such prolonged mating is that the males are busy transferring a "nuptial gift" to their mates. The nuptial gift of the firefly is an elegant, spirally coiled sperm-containing package called a spermatophore [*see photomicrograph on next page*].

Because *Photinus* fireflies do not feed as adults, male nuptial gifts may be particularly important as supplementary nourishment for the female's eggs. Radiotracer studies found proteins derived from the spermatophore in the developing eggs. Females, too, may benefit from male nuptial gifts: *Photinus* females that have mated with three different males can produce nearly twice as many offspring in their lifetimes as can females with only one mate. Cratsley's studies also show that the longer the duration of the courtship flash of *P. ignitus* males, the bigger the male's spermatophore. Hence male courtship flashes might signal to females the size of the male's intended nuptial gift. If so, the female preference for longer male flashes in this species should allow her to produce more offspring.

But even after his gift is accepted, the male's quest to propagate his genes has not necessarily succeeded. In most *Photinus* species each female typically mates with many different males, yet the mating males are not all equally likely to fertilize her eggs. Only the females of the species *Photinus collustrans,* studied by Steven R. Wing at the University of Florida in Gainesville, are known to mate just once before death. In most *Photinus* species the sperm of several males compete.

A glimpse into the male firefly's struggle for paternity comes from doctoral work done by Jennifer Rooney at Tufts. She discovered that males providing larger spermatophores also sired a greater fraction of a female's offspring. But such success is not without cost; a male's spermatophore size declines steadily with each additional mating.

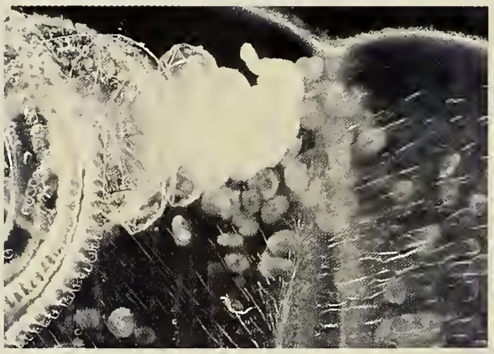
The traditional theory of sexual selection holds that males, whose gametes are relatively small and



energetically inexpensive to produce, will mate as often as opportunity allows. Females, in contrast, whose gametes are large and costly, will be much more selective than the males about their mates. For at least some of the *Photinus* firefly mating season, that pattern seems to hold. Early on, males compete for access to females, whereas females respond to flashes only if they're impressed.

But because *Photinus* fireflies don't eat once they become adults, the males can produce only a limited number of spermatophores in their lifetimes. As the availability of spermatophores dwindles, the males become increasingly selective about which female they mate.

Firefly flashes may be a natural form of poetry, but they are also highly visible signals that make courtship a risky business. Flashes are readily intercepted by predators. As protection, *Photinus* species and some other fireflies contain noxious, extremely bitter compounds known as lucibufagins, which deter many potential predators such as spiders, primarily, as well as birds, lizards, and ants.



Firefly spermatophore delivers both the sperm of the male (here still bundled into rings) and sustenance for the eggs of the female. The image shown is magnified approximately 100 diameters.

But not even noxious chemicals can protect *Photinus* fireflies from their archenemies, the larger, quicker *Photuris* fireflies. Female *Photuris* fireflies are leading ladies among the insect world's infamous troupe of femmes fatales. *Photuris* females are highly specialized predators that spy on *Photinus* courtships, then imitate the flash responses normally given by *Photinus* females. Those false signals lure unsuspecting *Photinus* males into the clutches (and guts) of their predators. The *Photuris* female is a voracious predator that can devour several *Photinus* fireflies each night. And, in the process, she gets much more than just a nutritious meal. The ecologist Thomas Eisner and the chemist Jerrold Meinwald, both of Cornell University, discovered that *Photuris* females can co-opt the bitter chemical deterrents produced by their *Photinus* prey to deter their own predators.

In addition to such natural hazards, human activities pose problems for fireflies. Pesticide use takes a toll, and urban sprawl increasingly threatens the open fields and woodlands inhabited by various firefly species. Fireflies tend to be highly site-specific, gathering and mating year after year in the same spot. If a population's breeding site is disturbed, migration to nearby areas is unlikely, and local extinction is almost certain.

Bounty hunters, too, may have been contributing to declining firefly populations. For about forty years the Sigma-Aldrich Corporation in St. Louis, seeking luciferin and luciferase, sponsored a firefly-collecting club. The company paid a network of collectors nationwide a penny a firefly (with quantity bonuses that total $600 for 200,000 fireflies). Millions were collected. Although a few firefly species might be abundant enough to support such harvesting, many less-abundant species (and species are collected indiscriminately) could readily be snuffed out. Fortunately, there is no longer any reason to collect fireflies from the wild. Synthetic luciferin has long been available, and the firefly luciferase gene has been cloned. Sigma-Aldrich ended the collecting club a few years ago.

Fireflies have been at risk even in Japan, where they are so revered. Japanese firefly larvae live in water, and by the 1960s industrial pollution and residential development had so damaged the rivers that larval survival rates had dropped precipitously. Many communities responded by setting up river restoration projects aimed at reviving local firefly populations. The projects were largely successful and, combined with citizen efforts to rear firefly eggs into healthy larvae that could be released into the rivers, they have transformed fireflies into a national symbol for environmental conservation in Japan.

"Photopollution" too endangers fireflies. The insects depend on low-light backgrounds for their courtship signals to be seen. But bright streetlights and floodlights may overwhelm firefly courtship flashes, and so reduce breeding populations. Yet simple remedies, such as shades and timers, can minimize such disruptions.

As biologists continue to learn about firefly behavior, this knowledge—how courtship signals are generated, how nuptial gifts affect mating behavior, how a male's success at mating is related to his success at fertilizing eggs—may help biologists clarify and strengthen the understanding of life in general. And we hope that the enhanced understanding of firefly ecology will help ensure that fireflies continue to thrive on Earth, to inspire wonder in our children—and in the stars. □

During mating a Photinus *male firefly (lower beetle) donates a nuptial gift to a female.*

Valley High

A California forest harbors cobra plants and other treats for plant lovers willing to get their feet wet.

By Robert H. Mohlenbrock

Oxeye daisies, originally introduced from Europe, bloom on private land along Butterfly Creek.

When I first read about Butterfly Valley in an issue of *Fremontia,* the journal of the California Native Plant Society, I knew I had to see it. The valley's boggy areas, seeps, and ponderosa-pine forests are home to more than 500 kinds of plants. Among them are large concentrations of the insect-eating cobra plant (whose hoodlike leaf bears what looks like a forked tongue); four other species of insectivorous plants (two sundews and two bladderworts): and twelve kinds of wild orchids. Butterfly Valley, through which runs Butterfly Creek, lies in the northern Sierra Nevada mountains and is named for its overall shape, discernible when viewed from mountain heights. A 500-acre portion of the valley, part of California's Plumas National Forest, is designated a Botanical Area, which protects it from wildflower picking and commercial logging.

Green-leaf manzanita

On a pleasant morning in August my wife Beverly and I set out on California Highway 70, which crosses east-west through the national forest. Roughly midway, near the community of Keddie, we found the unposted turnoff onto County Road 417, a narrow asphalt road that turns to gravel after about a mile and a half. Continuing another mile on the gravel we took a left turn onto a Forest Service road that led southward through the botanical area. At first all we saw were woods dominated by ponderosa and sugar pines. Then we sighted our first cobra plants, growing in standing water along with sedges, rushes, and other wetland plants. This boggy habitat, best termed a fen because it is fed by water seepage from the bottom of the adjacent hillside, parallels the road for a hundred feet or so.

Less than a quarter-mile farther down the road, we came to Sweetwater Marsh, ten acres of open land surrounded by a narrow border of alders. The continuous cover of vegetation obscures a very wet terrain, which I deemed it best not to enter.

A short distance past Sweetwater Marsh we came to Pond Reservoir, the deepest body of water in the botanical area, thanks to a dam constructed there around the turn of the twentieth century. This pond and its muddy borders support additional communities of plants. I noticed that most of the aquatic species I could identify are also familiar in the Midwest and eastern United States. As a matter of fact, aquatic plants generally do have broad geographical ranges, which botanists attribute to the relative uniformity of their watery environment, compared with the variability of soil and other conditions on dry land.

Proceeding along the road to the south end of the botanical area, we came upon a moist, heavily shaded area known as Fern Glen. True to its name, it was home to an assortment of gorgeous ferns, which grew amidst numerous wildflowers. Exploring on foot, we also found a small zone dominated by bear grass, a huge plant with long, narrow, grasslike leaves that is actually a member of the lily

White-flowered bog orchid

family. It produces a large spike of white flowers in August.

From there we continued south and east, and the road eventually turned into the paved Blackhawk Creek Road and connected directly with California Highway 70 (the Forest Service prefers visitors to enter as well as leave the botanical area using this route). On the way the road crosses Big Blackhawk Creek and parallels Little Blackhawk Creek, which like Butterfly Creek are lined with dense thickets of willows, alders, and red osier dogwoods. The waters of all three eventually travel southward down the Feather River, all the way to San Francisco.

The cobra plant, or California pitcher plant, traps and digests insects.

HABITATS

Mixed conifer forest Ponderosa pine, locally often called yellow pine, grows with other tall conifers—sugar pine, white fir, Douglas fir, and incense cedar. Deciduous trees, such as California black oak, Pacific dogwood, and big-leaf maple, are much less common. The most plentiful shrubs are green-leaf manzanita (with thick, leathery leaves and a red trunk) and white-leaf manzanita (with its pale leaves). Two wildflowers that are striking because of their white-striped leaves are giant rattlesnake plantain and white-veined wintergreen. Other species include purple fritillary, Sierra iris, crimson columbine, slim larkspur, two kinds of lupines, mosquito-bills, and woolly mule ears.

Cobra plant fen The cobra plant *(Darlingtonia californica,* also known as California pitcher plant) lives mostly among sedges and rushes. There are also round-leaved sundews, some shrubs of Labrador tea and bog bilberry, and various colorful wildflowers, including four members of the lily family—bog asphodel, western tofieldia, beavertail grass, and *Hastingsia alba.* Some other wildflowers are white-flowered bog orchid, California grass-of-Parnassus, Sierra gentian, Plumas alpine aster, western sneezeweed, and the highly toxic western water hemlock.

Marsh The vegetation in Sweetwater Marsh is made up mainly of grasses, sedges, and rushes, but here also grow cobra plants, two sundews, including the round-leaved one common in the fen, and various wildflowers—among them wild hyacinth, bog saxifrage, yellow monkey flower, Parish's yampah, sheep parsnip, and a species of Saint-John's-wort.

Pond Standing water in Pond Reservoir harbors two bladderworts (which trap small aquatic insects), as well as arrowhead, water plantain, water smartweed, blister sedge, marsh cinquefoil, two buttercups, water-shield, a pondweed, watercress, and the tiny water starwort. Common in the surrounding mudflats are a variety of sedges and rushes, northern bog violet, water purslane, and primrose monkey flower.

Glen Sierra water fern, lady fern, and California grape fern grow in Fern Glen beneath a canopy mostly of ponderosa pine. One attractive shrub is the Sierra currant. Wildflowers include wild ginger, two species of woodland-stars, Mt. Lassen fleabane, broad-leaved aster, red larkspur, false Solomon's-seal, fawn lily, twisted-stalk, and Kelley's lily.

Glade Growing with the bear grass in Beargrass Glade are Washington lily, Oregon white-topped aster, pearly everlasting (whose white, paperlike flower heads persist for weeks), and a shrub known as Sierra laurel.

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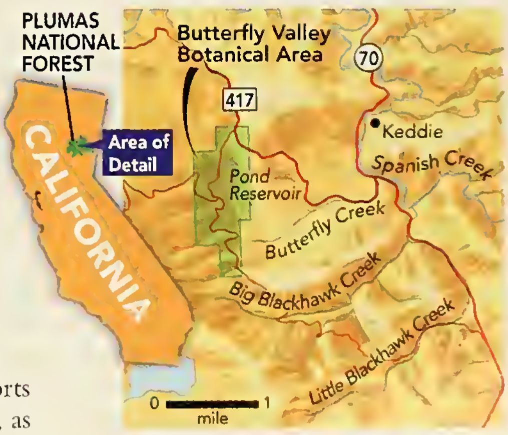

The Mismeasure of Science

In his last book Stephen Jay Gould argues it is a mistake to judge the "magisterium" of science for its failure to engage ethical questions.

By Michael Ruse

My most vivid memories of Stephen Jay Gould date back to December 1981. The place was Little Rock, Arkansas, and the scene was a courtroom where evolution was under attack by so-called scientific creationists. The two-year interregnum in Bill Clinton's five-term gubernatorial leadership was at its midpoint, and had left the state with a governor whose surprise at gaining office was matched only by his inadequacy for the post. The creationists had managed to get the Arkansas house and senate to pass a bill mandating the teaching of both evolution and Genesis in publicly funded school biology classes, and the governor had signed it into law. The American Civil Liberties Union (ACLU) immediately sprang into action to have the law declared unconstitutional, arguing an unwarranted breach of the separation of church and state. Steve and I served as expert witnesses, testifying that evolution is genuine science and that creationism is old-time religion.

In the end the ACLU won the case handily, but at first things were tense. The state's attorney-general hammered away at the pro-evolution witnesses and, as happens in these cases, a certain amount of mud was thrown, and some of it stuck. But by the end of the third day it was clear that we were starting to come out on top. The Arkansas schoolteachers proved to be the most impressive witnesses of all, simply by demonstrating why they could never teach Genesis as biology, no matter what their religious beliefs. (As I remember the episode, all of them were Christians.)

That evening all the ACLU supporters—lawyers, expert witnesses, hangers-on—were relaxing in one of the superb restaurants of Little Rock. A lot of wine was drunk. Then the singing began—instigated by some rather angelic-looking law clerk. The only songs most of us knew in common were the Christian hymns of our childhood, so that was the way we went. And I'll never forget Steve Gould—Harvard professor, secular Jew, eminent evolutionist—belting out "Amazing Grace," especially those lines about being in heaven and praising God's grace for the first ten thousand years, at which point: "We've no less days to sing God's praise/Than when we'd first begun."

> ***The Hedgehog, the Fox, and the Magister's Pox: Mending the Gap between Science and the Humanities***
> *by Stephen Jay Gould*
> *Harmony Books, 2003; $25.95*

For me those recollections epitomize what Stephen Jay Gould was all about: First, that he was there at all—many other prominent figures, beginning with Carl Sagan, had been too busy to take time out to go to the South and fight the creationists. But Steve felt it was his public duty, and he never gave it another thought. Second, that he could fight a good fight. Guess who had just roughed up the lawyers for the state? Guess who had just given them a science lesson that they must remember to this day? Third, that he acted as part of a community, willing to share in the group's tensions as well as its triumphs. And fourth, that he could, and would, sing. Steve was well-known for his love of oratorio, and appreciated its power to move people's hearts.

Personally, Steve had no time for creationism, or for evangelical religion generally, but he understood why others were attracted to it. He was a genius, tremendously creative, and, to the regret of those of us who knew him, terribly arrogant at times. Yet ironically, one of his strengths lay in his capacity to empathize with regular folk, because he was regular folk—he was a born and bred New Yorker whose daddy had been a court reporter, who loved baseball, whose aged relatives could never understand why he hadn't become a "real" doctor. Those things stayed with him.

Stephen Jay Gould is gone now. Those of us who knew him, and many who didn't, are pained by the thought that he died too young, and yet inspired by the example of his personal courage: twenty years ago (shortly after the Arkansas trial), he fought back a particularly vile form of cancer and then continued writing, teaching, and lecturing for another two decades.

Now we have Gould's final book on science, published posthumously. The title—*The Hedgehog, The Fox, and the Magister's Pox: Mending the Gap between Science and the Humanities*—is a bit misleading. Frankly, I am still unsure how "the magister's pox" fits in. But "the hedgehog" and "the fox," Gould tells us, refer to some lines attributed to the seventh-century B.C. Greek poet Archilochus: "The fox devises many strategies; the hedgehog knows one great and effective strategy." The sentiment might lead you to think Gould chose his title to differentiate between science on the one hand (perhaps foxlike in its many ways of going at things) and the humanities on the other (hedgehoglike in sticking to one theme or topic). But that reading doesn't hold up for long: foxlike behavior and hedgehoglike behavior, Gould says later on, characterize both fields, and neither approach can be considered entirely right or entirely wrong.

Not that the distinction matters terribly much. In several passages throughout the book Gould seems to remember the hedgehog-fox theme he started with, but only somewhat guiltily, at the ends of chapters. No doubt much of this textual confusion would have been addressed in a final rewriting, but Gould died before there was time for that. Because the publisher has seen fit to issue the book anyway, the text as it now stands demands a more interpretative reading than one would ordinarily expect to accord it.

Recognizing this practicality and its pitfalls, I see Gould posing and tackling three interrelated questions: First, is there a divide between science and the humanities? If there is, what is its nature and how did it come about? Finally, what, if anything, should people do about it?

The Natural Sciences in the Presence of Philosophy, engraving attributed to Hans Holbein the Younger, 1497–1543

On the first question Gould is surprisingly ambivalent. He properly focuses on the essay "The Two Cultures," written in the late 1950s by the English novelist and physicist C.P. Snow. The scientists and the humanists, Snow argued, are practitioners of the two distinct cultures, and they don't talk to each other—to the particular detriment of the humanities. The average scholar of a subject such as English literature knows nothing of quantum mechanics, and the world and its governance are the poorer for it.

Snow was attacked—brutally—by British humanists when his essay was published. But Gould, though uncomfortable with some of Snow's more venomous critics, is by no means content to toe the "scientist" party line in defending Snow. Snow's complaint that humanists are ignorant of basic science, Gould charges, was grossly exaggerated, overgeneralized to the entire Western world on the basis of the highly limited form of education Snow was familiar with in mid-twentieth-century England. (I can personally attest, though, that Snow was right about England: one began specializing at the age of fifteen, effectively ignoring everything that was not related to one's chosen field.)

More important, Gould seems reluctant to embrace Snow's contention that such a divide exists in England, or that it goes very deep. And even if it does, Gould acknowledges, the English cannot be held responsible for single-handedly keeping science separate from the humanities. The so-called science wars between scientists and humanists in the past decade demonstrate that the divide exists in North America as well.

On one side of those wars are scientists who remain convinced that they are objectively mapping reality—in the immortal words of Howard Cosell, they "tell it like it is." Their patron saint is Sir Karl Popper, the Austrian-born English philosopher who spoke of science as "knowledge without a knower," meaning that it rises above the individual and his or her culture. On the other side of the science wars are historians and sociologists of science and various others, particularly in departments of English and cultural studies, who think that science is as subjective as religion or philosophy. Their patron saint is the French critic and philosopher Michel Foucault, who believed that true objectivity is as untenable in science as it is anywhere else.

In that rancorous debate Gould the scientist seems to be at war with Gould the historian. On the one hand, he clearly thought that science makes it possible for people to discover truths about reality. He would have claimed that punctuated equilibrium—a theory he developed in 1972 with the evolutionary biologist Niles Eldredge of the American Museum of Natural History, to explain the jerky nature of the fossil record—genuinely says something about the real world. On the other hand, Gould the historian—for instance, in his account of the sorry history of I.Q. testing, in his book *The Mismeasure of Man*—was at the forefront of those showing that people can be as creative about finding "objective" support for their positions as their pernicious ideology demands.

James Barsness, *The World All Around*, 1998

Gould's second question in *The Hedgehog, the Fox, and the Magister's Pox* is, What is the divide between science and the humanities all about, and how did it come to be? Given his insightful earlier work, I do not find him as helpful on that topic in this book as one might have hoped. As I understand it from my reading of his 1999 book *Rocks of Ages,* his position is that, because science and the humanities deal with different kinds of issues and topics, neither their methodologies nor their conclusions can be the same.

Take the paired concepts of science and morality, or science and religion. Morality and religion—two concepts Gould often runs together—seem to belong to one domain and science to another (Gould calls these domains *Magisteria*). They are two world systems that cannot intercept each other, both because they ask different questions of different things and because the answers appropriate to one system are not the ones appropriate to the other. Although they can exist together (and, one hopes, in harmony) they cannot, by their nature, conflict.

Several times in *The Hedgehog, the Fox, and the Magister's Pox* Gould makes approving reference to the philosopher David Hume's division of things into matters of fact and matters of obligation: "I have this," as opposed to, "It is right and proper that I have this." Gould also agrees with Hume's assertion that, logically, there is no way to get from one to the other. He goes on to argue (though with less force than he does in *Rocks of Ages*) that science answers factual questions, whereas religion deals with matters of feeling, sentiment, and obligation. Again, the two cannot conflict. I think this is Gould's position, but I'm not sure it's as conciliatory toward religious points of view as Gould, with his avowed ecumenical spirit, might have hoped.

Certainly history suggests that conflict between science and religion in particular, and science and the humanities in general, is nothing new. The breakdown began during and immediately after the scientific revolution, in the sixteenth and early seventeenth centuries. I suspect, however, that much of the present divide can be traced to the epochal nineteenth-century battles between scientists and humanists, the latter often associated with powerful religious groups. A good example is the debate that erupted soon after the publication of *Origin of Species* between Thomas Henry Huxley, Darwin's bulldog, and Samuel Wilberforce, Bishop of Oxford. Such conflicts generated great tension on both sides of the science-humanities divide: to a large extent, we are still living with the legacy of the Huxley-Wilberforce debate, and of similar hostile encounters. Would that I could sit down for an evening with Gould and argue the issue.

If Gould is less than forthcoming on the first two questions, he is eloquent and articulate about how people ought to respond to the divide. Science and the humanities will always remain separate, he says, because they belong to separate *Magisteria,* and any attempt to combine them is doomed to fail. His motto is: Separate but Equal, with Respect. But what about those who don't agree with this opinion? Gould concludes his book with an extensive, two-chapter critique of the position taken by his colleague at Harvard, the entomologist and sociobiologist Edward O. Wilson.

Wilson wants to combine everything—science, politics, religion, ethics, you name it—within one massive framework. To capture his vision, Wilson borrows a word from the nineteenth-century English historian and philosopher of science, William Whewell (pronounced "Hule"). In speaking of Newtonian mechanics, Whewell praised it for bringing so much under so few hypotheses, and spoke of it as a "consilience of inductions." Wilson, too, wants a consilience, not just of all knowledge but especially of all knowledge about humans. He wants it all brought under, and explained by, evolution, particularly the part of evolution that pertains to brain science. For him, Hume's distinction between *is* and *ought* is something to be brushed away as irrelevant. What people ought to do is no more and no less than what our brains tell us, and what our brains tell us is what our genes, as naturally selected, dictate.

To Gould, that conclusion is anathema. It is false as science, fallacious as philosophy, and foolish as religion. Life is more than biology. Right and wrong, love and hate, beauty and ugliness, happiness and misery, and so much more may owe their existence to genes, but they also transcend them. To adopt Gould's most famous metaphor (referring in its literal sense to the triangular, often ornamented space on the exterior curve of an arch, sometimes seen atop columns in medieval churches), such emotions and concepts are, biologically speaking, "spandrels," things that seem to have a purpose but do not. As Gould argued at length in his 2002 book *The Structure of Evolutionary Theory,* culture in some sense takes off on its own, and to pretend otherwise is to commit the sin (just about the greatest sin, in Gould's book) of reductionism.

As Gould acknowledges in a lengthy footnote, he and Wilson were at odds for many years. So in a way, it is a little unfortunate, and somewhat petty, that Gould should have gone out with yet one more diatribe against Wilson. But in another way, that's not such a bad thing. As Gould stresses, the differences are intellectual, not personal. At stake is the choice—an important choice—between two quite different visions of the way people think and, in consequence, of the direction research should take. Gould airs the two visions and once again defends his own stance—on balance, an excellent way to finish off a glorious career.

I confess that my own inclinations are with Wilson. Science really does matter; and it matters to everything, not excepting emotions and concepts, the most significant of human aspects and activities. Without going to the extreme of embracing the position of a philosopher such as Daniel C. Dennett—who thinks that once you know all about the brain, you know all about the mind—I just do not see how one can think seriously about the mind without paying at least some attention to the brain, to the physical. And that includes asking biological questions about how and why natural selection gave rise to the human brain.

The paradox is that, in major respects, Gould seems to agree with this position. He writes movingly of his older son, who is autistic, and about what a relief it is for parents to find that the cause of their child's affliction is biological, not bad parenting. At some level, Gould allows that biology does something important with the mind, and that if biology is not working properly, the mind does not work properly. The question is: How much further would Gould have been prepared to go?

Even though, as I mentioned, my inclinations are with Wilson, I think Gould is right in staying onside with

Gould the scientist would argue that science says something about reality; but Gould the historian would say that people can find "objective" support for whatever their ideologies demand.

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(Continued from page 55)
Hume—I think one is always right in staying onside with Hume!—and arguing that Wilson is mistaken in claiming that ethics is simply a consequence of biology. At least Gould is right in maintaining that biology does not justify ethics—or, more pointedly, ethical lapses. What has evolved is not necessarily what is right and good. As Katharine Hepburn says to Humphrey Bogart in the movie *The African Queen:* "Nature, Mr. Allnut, is what we were put in this world to rise above."

So I find myself attracted to a position somewhere between Gould's and Wilson's: Wilson is right in thinking that biology can explain the origin and continued existence of ethics. Gould is right in thinking that biology does not justify ethics. And both are wrong in thinking that there is nothing more to be said on the matter. My philosophical instinct accords with Hume's: there can be no ultimate justification, whether it is provided (Wilson-style) by evolution or (Gould-style) by something other than evolution. Ethics just is.

By this point both Gould and Wilson would be after my hide, so this is a good point to draw to a close. *The Hedgehog, the Fox, and the Magister's Pox* is not one of Gould's greatest books. In science, that honor belongs to *Ontogeny and Phylogeny.* Among essay collections, I would still opt for one of Gould's first books, *Ever Since Darwin.* Of his monographs, *Wonderful Life* is way ahead of the others, and for me wins the prize as the best book overall. But in everything Stephen Jay Gould wrote there was always an abundance—to read, to reflect on, to learn from. I mourn his passing. I give thanks for his life. And I rejoice in how he enriched all of our lives.

Michael Ruse is a professor of philosophy at Florida State University. His most recent book is Darwin and Design: Does Evolution Have a Purpose?

BOOKSHELF

By Laurence A. Marschall

How the Cows Turned Mad
by Maxime Schwartz
University of California Press, 2003; $24.95

English farmers first sounded the alarm in April 1985, when otherwise healthy cattle started acting edgy, showing random fear and aggression, and kicking their handlers. The afflicted animals also wavered as they walked, then lost their ability to stand, to lift their heads, and, eventually, to breathe. Postmortem inspection of their brains exposed a tangle of lesions that had turned once-solid gray matter into a spongelike mass. Bovine spongiform encephalopathy, or BSE, was its official name, but to a frightened, beef-loving public it became "mad cow disease."

A caricature of cowpox doing battle with the medical profession, glazed ceramic, c. 1800

The threat of mad cow disease, however, goes deeper than its monstrous effects on livestock or its economic impact on farmers. About a decade after the first cows went mad, ten cases of a new form of the degenerative brain disorder known as Creutzfeldt-Jakob disease (CJD) turned up in the U.K. CJD had been an extremely rare disease among people aged forty to sixty, but the average age of these newest victims was twenty-nine, and autopsies of their brains revealed lesions similar to the ones in diseased cattle. Just over a hundred deaths were reported from the new variant of CJD by 2001, and the evidence clearly suggests that the most likely cause is the consumption of beef.

Maxime Schwartz, a molecular biologist and now a professor at the Pasteur Institute in Paris (which he headed for a decade, from 1988 until 1999), has written a lucid and gripping account of these events in the context of the latest scientific research. "The Disease," as he prefers to call it, is actually one of several maladies similar in both cause and effect. In the mid-1700s, when it was first recognized in sheep, The Disease was called scrapie, because suffering animals tended to rub their skins raw. By the 1900s scrapie was recognized as infectious, but unlike viral or bacterial diseases, it seemed to produce neither a fever nor an immune-system response. Moreover, healthy sheep inoculated with tissue from animals with scrapie took years to develop symptoms, far longer than for any other known infection.

In the 1950s a similar disease was recognized in people: kuru, a wasting of the brain found among the Fore people of New Guinea, appeared to be transmitted by their traditional habit of eating deceased (and diseased) family members. Like scrapie, it was slow to manifest itself, and also like scrapie, it led to no immune response. Its symptoms resembled those of Creutzfeldt-Jakob disease, but since no CJD sufferers were ritual cannibals, the connection between kuru and CJD was unclear.

Around the time the mad cows first staggered onto the scene, Stanley

Prusiner, a microbiologist at the University of California, San Francisco, suggested that both diseases were caused by a new kind of infectious agent that was neither a virus nor a bacterium. He named it a "prion," and identified it with a nondescript protein that normally occurs in many mammals, including people. Although prion molecules do not incorporate DNA, and thus cannot reproduce by conventional means, mutant forms do have a primitive ability to induce identical imperfections in healthy prions. Schwartz calls it the molecular "kiss of death." The process leads to a growing accumulation of bad prions that eventually destroy nerve cells in the brain. At first Prusiner's idea was controversial, but biologists have gradually come to accept it, and in 1997 Prusiner won a Nobel Prize for his work.

Thanks to vigorous public-health measures, including a ban on feeding animal tissue to livestock, mad cow disease seems to be on the wane. But prion disease remains frightening. Because it takes years for its symptons to develop, Schwartz cautions, the extent of cow-induced infection in people may not be known for another generation. Nor can we assume that BSE is the ultimate prion infection. Suppose "The Disease" morphs into a form that causes few symptoms in animals but moves much more readily than BSE from livestock to people? Then even Ronald McDonald might decide to become a vegetarian.

An Obsession with Butterflies: Our Long Love Affair with a Singular Insect
by Sharman Apt Russell
Perseus Publishing, 2003; $24.00

Butterflies, as nature writer Sharman Russell aptly observes, can be practically invisible at times, as though they inhabited a separate dimension; they flutter among us in full view and yet we scarcely notice them. She's right. I can distinguish a robin from a blue jay, a crow from a sparrow (and even, like Hamlet, "a hawk from a handsaw"), but I couldn't identify a single one of the ninety-three common species of butterflies Russell lists in the preface to this slender collection of essays. If my experience is any measure, many people probably regard butterflies as elements of the landscape, flashes of color no more distinctive than a dropping leaf or a flower petal floating on the wind.

From a butterfly's point of view, that is all to the good; a typical member of the order Lepidoptera devotes its brief life to being neither noticed nor eaten before it mates and produces its young. To Russell, however, that is a pity. An acute awareness of butterflies, which she developed after a brief encounter with a swallowtail in New Mexico, has convinced her that butterflies add a luminous dimension to one's life.

Obsessive butterfly collectors, the subject of her title essay, can take this pleasure to extremes. Take Lord Walter Rothschild, a quintessential Victorian eccentric: Over a lifetime of collecting, with the help of professional collectors, he amassed 2.25 million specimens. Rothschild's collection resides in the Natural History Museum in London, along with six million other butterflies and moths collectors have added over the years. Or take Vladimir Nabokov, the most famous of the bunch: not only did he insert allusions to butterflies throughout his fiction, he also wrote twenty-two scientific papers on members of the order, and discovered several new species.


Gregory Halili, *Butterfly Collection (Fabrics) #2*, 2002

Russell's obsession is more benign: she collects facts and stories about butterflies and then writes about them with grace and good humor. Did you know that most butterflies have taste buds on their feet, and "eyes"—light-sensitive cells—on their genitalia? That the caterpillars of the Panamanian metalmark butterfly secrete an intoxicating fluid they exchange with ants in return for protection from wasps? Can you appreciate the endurance of the male and female queen butterflies, which are locked in coitus for as long as eight hours at a time (a sizable fraction of their active lifespan)? Does it seem amazing that, during a migration of snout butterflies in September 1921, many millions crossed a 250-mile-long corridor between San Marcos, Texas, and the Rio Grande River each minute, for eighteen solid days—tens of billions of insects in all?

There are lessons to be learned from this assortment of lepidopteran lore. Many of the oddities of butterfly life are Darwinian adaptations to a harsh world in which birds and insects are looking for a handy afternoon snack. Colorful bands on a butterfly's wing provide camouflage among leaves and flowers, of course, but they can also divert a predator's eye toward the butterfly's tail, where a little bite won't matter as much as a chomp on the head. Some markings mimic the eyes of creatures frightening to predators; other markings, common among "sweet-tasting" species, mimic the patterns of unrelated butterflies that birds know to be "bitter."

Overall, however, Russell's lyrical stories appeal to our aesthetic, rather than to our moral, sensibilities. We don't ask what lessons we learn from a Mozart concerto; nor should we ask more of butterflies. Better to enjoy them, not for their utility, but for their quirkiness and their beauty. She quotes Miriam Rothschild, niece of the great Victorian collector, who viewed them, not with the eyes of a professional entomologist (which she was) but as "dream flowers—childhood dreams—which have broken loose from their stalks and escaped into the sunshine."

Oxygen: The Molecule that Made the World
by Nick Lane
Oxford University Press, 2003; $35.00

Our Earth is an odd place. No other planet in the solar system has so much oxygen in its atmosphere. Although oxygen is a relatively common element in the universe, its atoms are so reactive that they never float around by themselves. Pump an atmosphere full of monatomic oxygen, chemists will tell you, and every unattached oxygen atom will immediately rush off to find a mate, combining with iron to form rust, with carbon to form carbon dioxide, with hydrogen to form water. Even the diatomic molecule (O_2) that occurs in the air we breathe is reactive enough to form ferric and carbonate compounds. Those compounds should be abundant on a planet, but pure oxygen, whether monatomic or molecular, should be vanishingly scarce—as it is, in fact, on Mars and Venus.

When Earth's atmosphere formed 4 billion years ago, pure oxygen was probably rare here, too. Hyperactive volcanoes, more common during Earth's early years than they are now, cloaked the primordial planet with nitrogen, sulfur dioxide, carbon dioxide, and water vapor. But sometime around 2 billion years ago the oxygen presence began to increase, soon reaching levels of between 5 and 18 percent of what we have today. The evolution of life, of course, was what made that possible. Photosynthetic organisms, using chlorophyll and other pigments to capture sunlight, were turning carbon dioxide and water into molecular oxygen. As those new forms of life flourished, oxygen began to be pumped ever faster into the atmosphere. Earth blossomed with life, the composition of its atmosphere closely coupled to the evolutionary process that was taking place in its seas and on its continents. With every breath we take, we benefit from that momentous chain of events.

Nick Lane, an English biochemist, has written a meticulously detailed history of oxygen on our planet, organized around two major themes. The first is the tricky problem of how the presence of atmospheric oxygen has risen to its present level over time. Alternating layers of red- and black-banded ironstone, as well as coal beds, provide some benchmarks, because the rusting of iron and the fossilization of coal depend on how much oxygen is present in the air. Pockets of "ancient atmosphere," trapped in 100-million-year-old amber, may add direct evidence: in the mid-1980s geochemists using a quadrupole mass spectrometer measured the oxygen in amber samples from various geologic periods and reported that atmospheric O_2 levels had been higher than 30 percent during the Cretaceous Period, nearly twice what they are today. (According to Lane, however, the controversy is still raging within the scientific community about whether the air inside amber has been hermetically sealed since the time it solidified from drops of tree sap.) And the size of fossilized insects provides tantalizing, albeit indirect, clues that the atmospheric oxygen level may have been much higher during the age of the dinosaurs.

Only with such high levels of oxygen, Lane argues, could a Carboniferous dragonfly called *Meganeura*, which had a wingspan of almost a yard, have been able to fly. (The largest modern dragonflies, by comparison, are no more than four inches across.) In the end, such high oxygen levels may have been lowered by a worldwide firestorm that ended the age of the dinosaurs 65 million years ago. According to this scenario, the highly oxygenated atmosphere was sparked by an incoming asteroid, and the forests lit up as if they were tissue paper.

Lane then jumps to a second major theme: the role of oxygen in health and longevity. Fragments of molecules containing oxygen, called free radicals, form during the natural process of respiration. Free radicals can chemically alter the normal functioning of cells. According to a growing body of evidence, the accumulated damage plays an important role in aging. Oxygen, in effect, is a highly reactive fuel; the cell, in relying on oxygen to promote life, courts death and, sooner or later, succumbs. Lane's book ranges widely over a host of topics, from the usefulness of antioxidants such as vitamin C in curing colds, to the potential for prolonging human life with enzymes that repair damaged DNA. And it turns out that the jump from the geologic theme in the first part of the book to the medical theme in the second is not as great as it seems. A unifying thread of Lane's narrative, fascinating in its irony, binds it all together: oxygen, essential element of life, is also an agent of death.

Laurence A. Marschall, author of The Supernova Story, *is the 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.*

nature.net

Big-Fish Drought

By Robert Anderson

On a recent deep-sea fishing trip—my first—off the coast of southern California, the yellowfin tuna were nowhere in sight. We were surrounded instead by scores of other boats, all equally idle, and the only fish I saw all day were the silvery small fry used for bait, swimming in tight circles in their holding tank.

That same week, as it happened, the journal *Nature* published a startling report on the rapid decline of large ocean species all over the globe: populations of fishes such as cod, halibut, marlin, shark, swordfish, and tuna have sunk to about 10 percent of their pre-industrial levels. Not only are big fish disappearing at an alarming rate, but the top predators are also only about a fifth to a half the size they once were. You can access recent news stories about these and other, related findings at www.seaweb.org. To view graphs and charts that summarize the depletions, go to ram.biology.dal.ca/depletion and scroll down the page.

The importance of large marine fishes, of course, goes far beyond sport; they are vital to the health of marine ecosystems. At "Oceana" (www.oceana.org) click on "Empty Oceans—Where Are the Fish?" to learn how large-fish species and other marine animals become casualties, or "bycatch," of such industrial fishing gear as pelagic (oceanic) longlines, gill nets, and shrimp trawls.

Rational management of large-fish populations, moreover, would have enormous economic benefits worldwide. To bone up on current policies and proposals for restoring and safeguarding fish populations, go to "Environmental Defense" (www.edf.org) and click on "Oceans." You can also select "Marine Protected Areas" and "Sustainable Fishing" from the drop-down menu at the right. Or consult "American Oceans Campaign" for a long list of multiuse fish links (americanoceans.org/fish/link.htm). Finally, to view the results of an unusual effort by private citizens to protect the Gulf of California (also known as the Sea of Cortez), take a look at www.seawatch.org. Be sure to scroll to the bottom of the page to read the bad news firsthand from a series of interviews with Mexican fishermen.

The rapid decline of "big game" fish in the last few decades has not gone unnoticed among sport fishers. To get some idea of how it used to be, go to www.antiquefishingreels.com and click on "Classic Fishing" in the tool bar at the left: you'll find vintage photos of Ernest Hemingway and Zane Grey, among others, with their prize trophies. Then go to a site maintained by consultants for private-sector clients trying to protect marine fisheries and habitats (Chambers-Associates.org/Big-Marine-Fish/home.html). Click on "Daily 'Kill-o-Meter'" to learn how the ongoing decimation of big fish is tied to the phases of the moon. (Commercial longliners fish hardest on bright nights when swordfish—their primary targets—feed most actively and closest to the surface; many other large species are killed incidentally.)

As consumers, we are all affecting the ocean's ecosystem every time we choose a fish to buy. At the Monterey Bay Aquarium's Seafood Watch Web page (mbayaq.org/cr/seafoodwatch.asp), type in your favorite fish to find out if its catch is putting additional pressure on one of the world's critically low fisheries.

Robert Anderson is a freelance science writer living in Los Angeles.

Hazy, Hot, and Hidden

Dust-laden clouds at the centers of some galaxies may enshroud titanic starbursts or baby quasars.

By Charles Liu

Russell Mills, *Between Two Lights*, 1994–95

Galaxies illuminate the universe, and not just with visible light. Think, for a moment, about an incandescent light bulb—it's not only bright, it's hot, too; and the heat we feel comes mostly from infrared radiation emitted by the bulb's filament. Similarly, stars in galaxies pour out visible light, as well as plenty of radiation at wavelengths beyond the visible, such as infrared and ultraviolet. A typical galaxy (or more precisely, its constituent stars) emits that invisible radiation much the way the light bulb does: roughly proportional to the amount of visible light it emits. Our Milky Way, with its several hundred billion stars, is a fine example of a galaxy that emits light broadly over the range of the electromagnetic spectrum.

There are, of course, some spectacular exceptions. In the 1980s surveys by NASA's Infrared Astronomical Satellite revealed an entire class of galaxies shining far more intensely in infrared light than they did in visible light. We astronomers, straightforward as always, named the group "luminous infrared galaxies"—LIRGs for short—and the brightest among them, "ultra-luminous infrared galaxies" (ULIRGs). Some of the LIRGs emit more than 90 percent of their energy as infrared radiation; the brightest ULIRGs generate a hundred times more infrared energy than the total energy output of the Milky Way—at all wavelengths combined.

Those findings were more than puzzling. No normal population of stars can produce so much infrared energy without generating a corresponding amount of visible light. Something else in those galaxies must be converting most of the visible light into infrared light. For that matter, the total energy output, whatever the wavelength, was (and remains) a mystery. Whatever generates the observed energies streaming out of a LIRG must be far more powerful than any collection of stars known.

In the past twenty years astronomers have learned that the "infrared converter" is a cloud of intervening dust. Now, in a recently published study, Aaron S. Evans, an astronomer at Stony Brook University in New York State, and his collaborators have focused on the riddle of the total output energy. They haven't identified the energy source churning inside LIRGs—mainly because of an obscuring cloud of dusty gas—but they have offered new insight on how LIRGs might be put together.

According to recent measurements, about half of the background light generated in the universe today (not including the cosmic background radiation left over from the big bang) originates from LIRGs. LIRGs typically radiate more energy in just a few seconds than our Sun does in millennia. It is also known that the energy from LIRGs originates from compact regions near their galactic centers.

So what is the likely source of such energy? Think about how stars arise [*see "Universe: Dust to Dust," by Neil deGrasse Tyson, May 2003*]. Deep within interstellar clouds of gas and dust, dense clumps form and collapse under their own weight. Eventually the collapsed matter becomes so dense and hot that nuclear fusion begins, and the clumps become fledgling stars. Millions of years later, the stars' radiation ionizes the clouds still surrounding them and pushes the clouds away, unveiling the bright new stars to the rest of the universe. But while the stars are being formed, all that's visible from the outside is the dust and gas surrounding them.

The clouds that enshroud the center of a LIRG are thousands of times more massive than typical star-bearing clouds, but they may be analogous. Current models suggest that the object they hide—the energy source for the LIRG's radiation—could take one of two forms. It might be an aggregate of billions of stars formed in a massive burst in the recent past. Or it might be a single supermassive black hole—a newborn quasar, still swaddled in a cocoon of dusty gas—much larger than the black hole now thought to lie at the center of the Milky Way [*see "Peering at the Edge of Time," by Fulvio Melia, June 2003*]. In that case, the energy output would come from huge amounts of potential energy released by matter falling into the black hole.

In either case, the dust surrounding the energy source would absorb visible and ultraviolet light and re-emit it later as infrared light. That's why almost all the radiation coming from LIRGs is infrared. All that remains, then, is to confirm either one of the two scenarios; if one is confirmed, astronomers will know which objects, stars or black holes, emit half of the background light in the universe.

But as much as we would like to glimpse the center of a LIRG, the dusty, surrounding clouds present a daunting observational obstacle. Dust not only quenches visible light, but it also degrades our view. Imagine watching from a distance as a powerful searchlight shines into a pea-soup fog. From a distance you can see a bright glow coming from a spot in the fog, but you can't make out its source. That's exactly what we have to deal with when we look at a LIRG. Dust in the universe, like earthly fog, scatters light; it turns straight beams of light into a crisscrossing mishmash of unfocused glare. And because the cloud itself is aglow in infrared light—also an effect of dust—seeing inside it is all the harder.

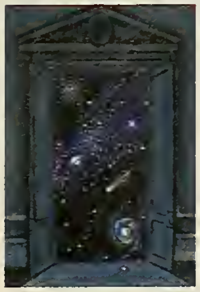
Ironically, it turns out that to peer through the haze, we need to look for emissions from the interior energy source at infrared wavelengths. Radiation at the relatively long wavelengths of infrared light slips past the dust more readily than visible light does. A bright spot against the overall infrared glow would mark the position of the galaxy's power source. Then, to distinguish between a single supermassive black hole and a clutch of hot, young stars, astronomers need high-resolution images of that hot spot.

Evans and his collaborators studied NGC 4418, a relatively "nearby" LIRG about 90 million light-years from Earth. They aimed two infrared camera systems—NICMOS on the Hubble Space Telescope and MIRLIN on the Keck Telescope in Hawaii—in an effort to pierce the haze surrounding the galaxy's central engine. Their observations confirmed that the galaxy's vast infrared luminosity originates from a high-powered, compact energy source. But even with these powerful infrared instruments, they couldn't see all the way to the center of the LIRG. An inner dust cloud, several hundred light-years across, obstructed their attempts to identify the source—star cluster or black hole—of the galaxy's prodigious radiation.

To put things into perspective, the density of all that obscuring dust is, on average, a few grains per cubic centimeter—far, far cleaner than the air we breathe. Yet it's still enough to confound our best astronomical technology, and to keep us wondering about the mysterious source of power that lurks in LIRGs.

Charles Liu is an astrophysicist at the Hayden Planetarium and a research scientist at Barnard College in New York City.

By Joe Rao



Mercury makes an evening appearance, albeit a poor one, during late July and early August. The little planet shines above the west-northwestern horizon about forty-five minutes after sunset, then follows the Sun behind the horizon fifteen minutes later. Otherwise it's not visible. Two conjunctions are of note: On the evening of July 25 Jupiter slips less than one-half a degree to the south of Mercury, but the king of the gods is four times brighter than the gods' messenger. On the evening of the 30th Mercury passes a fraction of a degree north of the blue star Regulus; in this instance, the gods' messenger is four times brighter than the little king (which is what "regulus" means). Binoculars, a "severe-clear" sky, and an open view to the horizon are practically musts to catch these events. Mercury vanishes into the blaze of sunset around the middle of August.

Venus lingers in the dawn sky and is still detectable in early July roughly thirty minutes before sunrise; look for it just two degrees above the east-northeastern horizon. The planet's proximity to dawn's rosy fingers makes it hard to see. Binoculars certainly help: with such aid Venus may actually appear quite brilliant despite the bright morning twilight. Venus passes behind the Sun on August 18, leaving the night sky until late September.

Mars gets top billing throughout July and August. Rising in the east-southeastern sky, the yellowish-orange "star" looms ever brighter as it approaches its rendezvous with Earth in late August. It rises about three hours after sunset on July 1, but less than two hours after sunset by the 31st. As its distance from the Earth closes from 52 million to within 39 million miles, the planet brightens from magnitude −1.4 to −2.3. The waning gibbous Moon passes exceedingly close and to the south of Mars during the predawn hours of July 17—in fact, Floridians living south of a line running roughly from Fort Myers to Vero Beach will see the Moon occult, or hide, the planet at around 4:14 A.M. Mars's disk, readily visible through a telescope, expands throughout July, making surface features easier to see.

During August Mars rises about four minutes earlier each night and becomes simply dazzling, shining at magnitude −2.9 from August 22 until September 3. During this apparition Mars is the closest it has been to Earth in nearly 60,000 years.

In late August Mars will be closer to Earth than it has been in nearly 60,000 years.

Anyone who has a telescope will want to find out what it can do when it's trained on Mars this August. What's to be seen there? By now (it's mid-spring on southern Mars) the south polar cap should have shrunk to a small white speck. White clouds may highlight the disk elsewhere. The largest dark markings should be fairly easy to see with almost any telescope at 100-power and greater, but the finer details are always hard to resolve. Mars comes closest to the Earth on the morning of August 27 at 5:51 A.M. The distance between the two planets, measured from center to center, will be just 34,646,418 miles. The next day Mars reaches opposition to the Sun.

Jupiter begins July as the brightest "star" in the evening sky, but by midmonth you may need binoculars to spot it as it sinks deep into the glow of sunset. On the evening of July 2 a three-day-old crescent Moon passes four degrees north of Jupiter. Later in July Jupiter pairs off with Mercury, as I noted earlier. In August Jupiter is unobservable; it reaches conjunction with the Sun on the 22nd.

Saturn, too, is lost in the solar glare as July begins. It emerges into view by the 15th; look above the east-northeastern horizon about an hour before sunrise. By month's end it's coming up about two-and-a-half hours before the Sun. By August Saturn has moved into the constellation Gemini, and its visibility in the morning sky improves; the planet is well above the eastern horizon as dawn breaks. On the morning of the 23rd Saturn can be found near the crescent Moon, shining at magnitude 0.2.

The Moon in July reaches first quarter on the 6th at 10:32 P.M. It waxes full on the 13th at 3:21 P.M., and wanes to last quarter on the 21st at 3:01 A.M. The Moon is new on the 29th at 2:53 A.M. In August the Moon reaches first quarter on the 5th at 3:28 A.M. and becomes full on the 12th at 12:48 A.M. It wanes to last quarter on the 19th at 8:48 P.M. and returns to new on the 27th at 1:26 P.M.

The Perseid meteor shower, on the night of August 12–13, is spoiled this year by the light of a full Moon. Perseids are typically fast and bright, and they frequently leave long-enduring trails; the best hope for seeing them is to look in a direction of the sky away from the Moon.

Earth reaches aphelion—its farthest point from the Sun—on July 4 at 2:00 A.M. Our star is 94,510,793 miles away.

Unless otherwise noted all times are given in Eastern Daylight Time.

EXPLORER GUIDE

AMERICAN MUSEUM OF NATURAL HISTORY

YOUNG NATURALIST AWARDS 2003

Scientific discovery begins with expeditions.

Over the past 134 years, American Museum of Natural History scientists have mounted thousands of expeditions to observe, gather, and analyze data to further our understanding of the natural world and human culture. Now in its sixth year, the Museum's National Center for Science Literacy, Education and Technology's Young Naturalist Awards program challenges students in grades 7 through 12 to embark on their own scientific expeditions, exploring and reporting on a question in biology, Earth science, or astronomy.

These expeditions need not involve specialized equipment or travel to distant lands. Science can begin with a keen eye and a backyard. From a park in Brooklyn to the rain forest of Hawaii, from a home aquarium to the coastal waters of Nova Scotia, this year's Young Naturalists met their challenge with a passion for inquiry, a recognition of the interdependence of life, and a concern for the human impact on the environment.

The winning entries (chosen from nearly 800) are summarized here. To read the complete essays on the Museum's Web site, which also features a brief profile of and interview with each winner, visit www.amnh.org/youngnaturalistawards.

Entries are already being accepted for the 2004 Young Naturalist Awards and will continue to be accepted until January 9, 2004.

The Young Naturalist Awards are made possible by a generous grant from The J.P. Morgan Chase Foundation.

Oscawana: A Dying Lake?, by Sarah Beganskas (Woodland Middle School, East Meadow, New York; Grade 7)

While on vacation in upstate New York, Sarah decided to find out why the once crystal clear waters of Lake Oscawana were turning a murky green. Not only did she discover the causes of the lake's problems, she also discovered what local residents are doing to save the lake.

"I hope that the lake will improve so that my children and grandchildren can enjoy its beauty and recreational uses, as my great-grandfather envisioned. By doing this project, I have discovered more about the lake I have known and enjoyed my entire life."

Bobwhite Quail Decline in Texas, by Donald Capra (Branch and Leaf Academy Home School, Abilene, Texas; Grade 11)

Concerned that bobwhite quail might be on their way toward extinction, Donald volunteered for the Texas Quail Index. As a member of the TQI, Donald examined the factors that affect quail populations on his family's ranch. He conducted surveys which he hopes to use to develop a management plan that will help to reverse the trend in quail decline.

DONALD CAPRA

Bobwhites roost in a circle for protection.

"Now that I have completed my first year of observations...I feel that I know our land better and the animals that live there, too....I am glad I can enjoy the early-morning call counts."

Aspen Island, by Elspeth Iralu (Home School, Gallup, New Mexico; Grade 10)

While hiking with her family, Elspeth came upon an aspen grove in a valley where aspens are scarce. Her investigation centered on the environmental

ELSPETH IRALU

Aspen grove near Lost Lake, New Mexico

characteristics that favored aspen growth in this location. She compared the aspen grove with a control area, examining factors such as elevation, humidity, and temperature.

"From where I stand, I can't see the emerging patterns in my life. I only remember moments and short seasons. But aspens look back 10,000 years and see what has changed. I am dwarfed by tall trees with long memories."

Exploring the Mystique of the Mushroom, by Yushan Kim (Athens High School, Troy, Michigan; Grade 12)

Yushan ventured into her backyard—rich in biological activity due to a large amount of decaying wood. Having never seen a mushroom there before, she was surprised when she found one cluster and then another. In her investigation, Yushan examined the connection between these organisms and their environment, generating informative illustrated charts, field sketches, and photographs.

"Natural wonders awaiting our discovery teem all around us, even in the tiniest of environments. Discovering them for myself has been a wonderfully fulfilling experience."

Worms in Prospect Park, Brooklyn, by Linda Lam (Gladstone H. Atwall Middle School 61, Brooklyn, New York; Grade 8)

While looking for worms for a fishing trip, Linda became intrigued: why were worms found in some locations and not in others? She investigated three locations in her local park to determine what environmental factors contribute

LINDA LAM

Spiders prey on earthworms, contributing to low population densities.

to varying worm populations.

"Completing these field expeditions has given me greater insight into how scientists observe and study the world around them. During my expeditions, I got a glimpse of an underground world located just across the street from where I live."

Survival in the Northeast Wilderness, by Seth Levin (Moses Brown School, Providence, Rhode Island; Grade 9)

After watching some news stories of hikers being lost in the woods, Seth theorized that a lost individual could survive on what he or she found in the forest. After several expeditions to a local nature reserve, Seth compiled a long list of edibles and concluded that

SETH LEVIN

The parasol mushroom *(Leucocoprinus procera)*

the forest was a virtual smorgasbord of nutritious and tasty berries, nuts, leaves, and fungi.

"Until now, I hadn't realized the importance of these local plants, trees, and mushrooms, many of which I had seen while walking in the woods around my home."

Comparing Streams in Southwest Washington to Determine the Needs of Salmon, by Kristen Marini (Maple Grove Middle School, Battle Ground, Washington; Grade 8)

Kristen focused on a question: why hasn't there been a large salmon run in Salmon Creek since the early 1990s? She compared local streams in southwest Washington, some of which have healthy salmon runs, to determine what environmental factors are beneficial to salmon. She discovered that some parts of Salmon Creek are polluted and the probable cause for the lack of salmon runs.

"I would like to travel to other creeks...and examine them to see if they are providing the basic requirements for salmon, and to ensure that my findings are not coincidental."

KRISTEN MARINI

A butterfly seen along the stream in Pumice Plains, Washington

Arsenic and Zinc Distributions in Streams near Park City, Utah, by Doug Naftz (Park City High School, Park City, Utah; Grade 10)

After learning that his city's drinking water supply contained elevated levels of zinc and arsenic—both toxic to humans—Doug built a miniature permeable reactive barrier chamber to see if he could remove arsenic from water he collected. His experiment was a success. He concluded that if PRBs are installed in the main tunnel that supplies water, then enough arsenic could be removed to lower the concentration to acceptable levels.

"After identifying that there was a serious problem concerning arsenic in the streams and possibly in the drinking water of Park City, I decided to see if there was a natural and cost-effective way to remove it."

Surviving against All Odds: Investigating the Adaptability of the Common Periwinkle, by Natalie Parks (Halifax West High School, Halifax, Nova Scotia; Grade 12)

Natalie decided to investigate the biological implications of a polluted environment using periwinkles. She collected periwinkles from the North West Arm area of Halifax and also from a pristine environment and compared them. She concluded that chemical changes alone in its environment will not eradicate the periwinkle as it will always find ways to adapt.

"Examining this species has given me insight into the ability of creatures to adapt to even the most hostile of environments...I have a greater appreciation for the survival abilities of all creatures."

KYLE SHEETS

This 25-foot-tall saguaro is estimated to be 100 years old.

Aquarium: An Ecosystem in Miniature, by Charlotte Seid (Thomas Jefferson High School for Science and Technology, Alexandria, Virginia; Grade 9)

A tropical fish enthusiast, Charlotte decided to examine the aquatic community she had created in an aquarium in her home. During her expedition she examined how each fish species adapted to the aquarium environment, and observed how fish that never meet in nature interacted.

"Through observing, sketching, and ultimately becoming more familiar with my aquarium and its piscean inhabitants, I realized how natural forces and behaviors are prevalent even in an artificial setting."

Saguaro Cactus: From Life to Death, by Kyle Sheets (Doolen Middle School, Tucson, Arizona; Grade 7)

Kyle wanted to see if he could find examples of each stage of a saguaro's life. He made several trips to the Sonoran desert where he documented, in words and images, the life cycle of this monumental plant.

"After spending all this time with the saguaro cactus, I felt as if I had gained another friend....I learned that being a scientist is a lot of work, but also a lot of fun."

A Comparison of Native Tree Seedling Growth on Fallen Hapu'u Ferns and the Adjacent Forest Floor in Volcano, Hawaii, by Kolea Zimmerman (Waiakea High School, Hilo, Hawaii; Grade 11)

Venturing into the rain forest just behind his house, Kolea noticed an abundance of tree seedlings growing on the fallen logs of the hapu'u tree fern. He hypothesized that the fallen hapu'u logs served as "nursery logs" for the development and growth of certain species. To test his hypothesis, he compared the number of seedlings and saplings on hapu'u logs to the number of seedlings and saplings on an equal area next to the logs.

KOLEA ZIMMERMAN

The endangered oha' grows in the Hawaiian rain forest.

"Fond childhood memories always included being respectful of all the native plants. We were taught from a very young age to respect the hapu'u and other native plants of our forest."

MUSEUM EVENTS

EXHIBITIONS

Chocolate

June 14–September 7
Gallery 3, third floor

The delicious story of chocolate spans more than two thousand years. This fascinating exhibition will explore the legends, history, ecology, economics, and enduring allure of this delectable phenomenon.

Chocolate *and its national tour were developed by The Field Museum, Chicago. This project was supported, in part, by the National Science Foundation.*

Chocolate Tastings and More

Weekends during the run of *Chocolate*, you can sample fine chocolate in the retail shop outside the exhibition or in the Food Court and purchase luxurious treats. Visit www.amnh.org for a schedule of events.

Vietnam: Journeys of Body, Mind & Spirit

Through January 4, 2004
Gallery 77, first floor

This comprehensive exhibition presents Vietnamese culture in the early 21st century. The visitor is invited to "walk in Vietnamese shoes" and explore daily life among Vietnam's more than 50 ethnic groups.

Organized by the American Museum of Natural History, New York, and the Vietnam Museum of Ethnology, Hanoi. This exhibition and related programs are made possible by the philanthropic leadership of the Freeman Foundation. Additional generous funding provided by the Ford Foundation for the collaboration between the American Museum of Natural History and the Vietnam Museum of Ethnology. Also supported by the Asian Cultural Council. Planning grant provided by the National Endowment for the Humanities.

Discovering Vietnam's Biodiversity
Through January 4, 2004
Akeley Gallery, second floor
This exhibition of photographs highlights Vietnam's remarkable diversity of plants and animals.

This exhibition is made possible by the Arthur Ross Foundation and by the National Science Foundation.

DEMONSTRATION

Traditional Mexican Chocolate Preparation
Saturday, 7/26, 3:30–4:30 p.m.
With Zarela Martínez, restaurateur and cookbook author.

©2002 THE FIELD MUSEUM, TERESA MURRAY

Molinillos are used to blend and froth chocolate.

LECTURES

Art(ifacts) and Science of Chocolate
Thursday, 7/17, 7:00–9:00 p.m.
Museum-inspired chocolate sculptures will be showcased and discussed.

Pre-Columbian History of Chocolate
Saturday, 7/26, 2:15–3:15 p.m.
With Michael D. Coe, author of *The True History of Chocolate*.

Experience the sights and sounds of a bustling

Vietnamese Marketplace

and sample traditional foods at Café Pho.
Through January 4, 2004
77TH STREET LOBBY, FIRST FLOOR

The Indigenous Peoples of Guyana
Saturday, 8/9, 1:00–2:00 p.m.
Lal Balkaran discusses indigenous Guyanese cultures.

Africa: Facing the Challenges of Globalization
Sunday, 8/10, 2:30–4:00 p.m.
This panel examines how multinational partnerships affect the local economies and peoples of Africa.

PERFORMANCES

Passing on Traditions: Aztec Music and Dance
Saturday, 8/9, 2:15–3:15 p.m.
The ancient music and dance of Mexico.

Kotchegna Dance Company
Sunday, 8/10, 1:15–2:15 or 4:15–5:15 p.m.
Stories from the Ivory Coast.

COURTESY CTMD

Kotchegna Dance Company

HAYDEN PLANETARIUM PROGRAMS

Virtual Universe
The Structure of Our Galaxy
Tuesday, 7/1, 6:30–7:30 p.m.
Our Place in the Universe
Tuesday, 8/5, 6:30–7:30 p.m.

Celestial Highlights
Stars of Summer
Tuesday, 7/29, 6:30–7:30 p.m.
Here's Mars!
Tuesday, 8/26, 6:30–7:30 p.m.

INFORMATION

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

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 8:00 a.m.–5:00 p.m., and Saturday, 10:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply.

All programs are subject to change.

Starry Nights: Live Jazz

Friday, 7/4, 5:30 and 7:00 p.m.
Norman Hedman's Tropique

Friday, 8/1, 5:30 and 7:00 p.m.
Visit www.amnh.org for lineup.

The 5:30 performance on 8/1 will be broadcast live on WBGO Jazz 88.

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

ENDPAPER

On Hostile Ground

By Oliver L. Gilbert

Only once have I been seriously embarrassed while searching for lichens. The incident took place in 1999, a more innocent time, before it became pretty much unthinkable to "wander onto" a military installation. I was poking around the perimeter of a military airfield in Cornwall, England, the inside of which, even then, was strictly "off limits." But there was no one around, and the control tower was just a smudge on the horizon. I crawled through a hole in the fence and started my survey.

Why would I take such a risk? Lichens have been intensively studied in Great Britain by an army of amateur naturalists since about 1750. In the beginning they came from the leisured class of doctors, clergymen, and the landed gentry. But soon they were joined by members of all classes: schoolteachers, gardeners, coal miners, peddlers, even a Scottish umbrella maker. In short, thousands of lichenophiles have been crisscrossing the countryside for more than 250 years.

Lichen community (mixed species), Golspie, Sutherland, Scotland

That long history of study has created a dilemma for modern British lichenologists: how can one make one's mark in such a well-tilled field? An ability to think laterally helps. But true devotees recognize that the key to discovery lies in new habitats that are emerging all the time in unlikely places, many virtually unexplored.

The first neglected habitat I discovered was associated with the pylon towers that support high-voltage lines. The pylons are coated with zinc, and so the ground underneath them gets a highly toxic drip during rain. That keeps out most of the higher-order plants, but it opens up a niche to swards of tiny lichens belonging to little known species.

Not only are such "pylon lichens" rare, but their biology is unusual in other respects as well. Instead of being slow growing, like most lichens, they can complete their life cycle in less than a year. Their natural habitat is the spoil heaps of heavy-metal mines. I spent one holiday following pylon lines across the countryside before turning to a similar niche—the ground under the galvanized crash barriers beside the British motorways. Word soon spread, and it wasn't long before my North American colleagues were recording similar species along the interstates and around other American analogues to the British sites.

Lichens can grow in such stressed places because they are made up of fungi and algae living together symbiotically: the algae supply the fungi with carbohydrates, and the fungi supply the algae with minerals and much-needed shade. When they team up that way, they can live closer to the poles, higher up in the mountains, and farther out in the deserts than other organisms can.

What is more, they can live in places that didn't even exist in the earliest days of lichen-hunting—industrial wasteland, concrete structures, tarmacs, railway lines, abandoned cars. All have proved fruitful.

The day I crawled through the fence around the airfield, it was high summer, and the air was still enough for me to hear the sound of bees droning. I was also aware of—though, as usual, indifferent to—the human activity around me, the occasional helicopter flying overhead. But a pilot must have spotted a furtive figure walking, stooping, sometimes lying prone. Before long a Land Rover full of armed guards in riot gear pulled up beside me, no doubt wary of the hammer and chisel I was clutching. I pleaded that I was just a harmless "nature watcher," pursuing my hobby. But the station commander was not amused. He gave me a dressing down, and sent me packing.

Oliver L. Gilbert is a retired lecturer from Sheffield University, England. He has been interested in botany since an early age.

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It's 3 a.m. You have exactly two hours until you have to get up for work, and you still can't seem to fall asleep. At this point, the phrase "tossing and turning" begins to take on a whole new meaning for people whose mattresses simply aren't giving proper support anymore. Your mattress may dictate your quality of sleep. Even if you merely suspect that your mattress may be outdated, that's when you need to take action. Some mattresses fail to support your spine properly, which can result in increased pressure on certain parts of your body. Other mattresses, sporting certain degrees of visco-elastic foam, can sometimes cost you well over $1000. Now, one of the world's leading manufacturers of foam products has developed an incredibly affordable mattress topper that can actually change the way you sleep. Introducing the future of a better night's sleep: The Memory Foam Ultra Mattress Topper.

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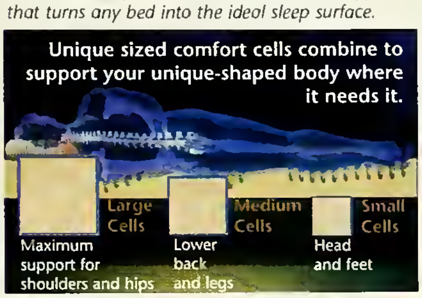

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