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Dr. Sylvia Earle's office covers two thirds of the Earth's surface. Her job is a little more difficult to define. Marine biologist. Oceanographer. Botanist. Aquanaut. And explorer. She's spent more than 6,000 hours underwater, discovering things we never knew existed. At 1,250 feet, she set the world record for the deepest untethered, solo ocean dive. To Dr. Earle, it was just one more thing in the endless pursuit of science.
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NATURAL HISTORY

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MAY 2008 VOLUME 117 NUMBER 4

FEATURES

DEPARTMENTS

ON THE COVER: *Wild horses in Brecon Beacons National Park, Wales.* PHOTOGRAPH BY DAVID NORTON

THE NATURAL MOMENT

CELEBRITY WHALE WATCH

Photograph by Brandon Cole

See preceding two pages

THE NATURAL EXPLANATION BY ERIN ESPELIE

Meet Tramtracks (also known as #5727, or "Scar"). He's a nine-year-old sperm whale that still lives with his mother in the calm waters where he was born, in the Caribbean West Indies a few miles off the western coast of Dominica. In cetology circles, he's a famous bloke.

For the past four years, only hurricane season has kept Hal Whitehead's research group (Dalhousie University in Halifax, Canada) from respectfully observing Tramtracks in his natural environment—along with his mother, his half-sister, and four other females. The scientists fondly call the family the "Group of Seven," or GOS. What they have documented about the GOS is unprecedented in its detail.

Unlike most giant land animals, whales cannot be constantly watched. Deep dives, strong currents, and treacherous trade winds have sunk some basic sperm-whale behavior in a pirate's chest of sorts. For example, you might expect that high-seas cetologists know how a calf gets milk from its mother. Not so. Shane Gero, the primary researcher tailing the GOS, set out to map the specifics. But after spending forty-one days with the GOS in 2005, he was forced to reconsider the assumption that a calf puts its mouth to a nipple for milk. Instead, Gero and his colleagues hypothesize that, as unbelievable as it sounds, a mother sperm whale injects milk into the blowhole of a youngster, who then surfaces to swallow and breathe.

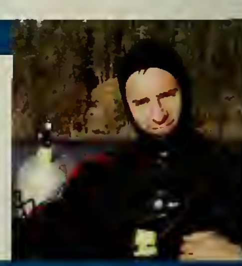
One certainty is that sperm-whale populations differ in their behavior. The approximately 360,000 sperm whales worldwide can be divided up by dialect (different rhythms of clicks) into several "acoustic clans." Each clan has its own distinct ways of traveling, feeding, and even babysitting.

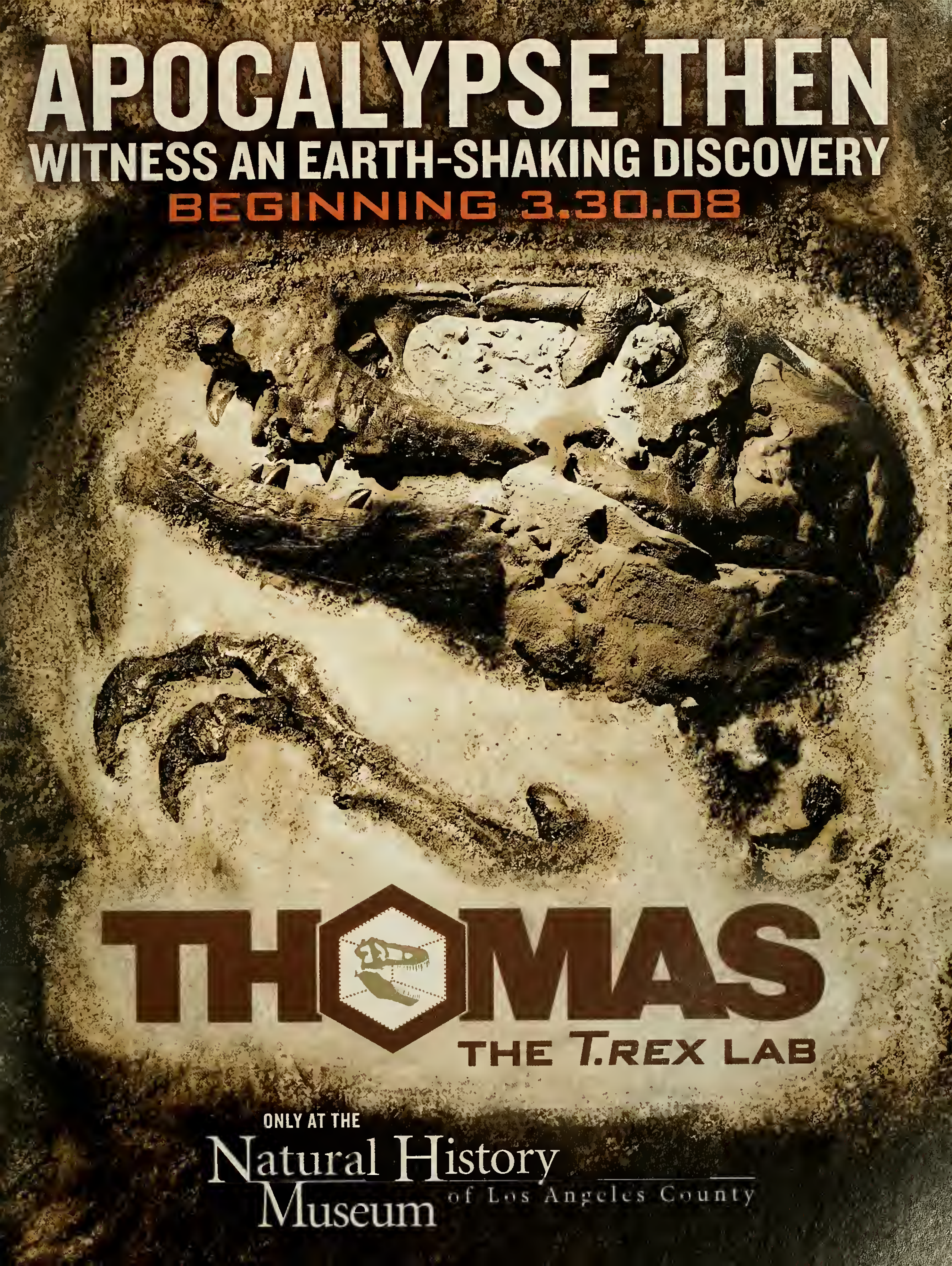
Receiving special permission to snorkel with the GOS, Brandon Cole took this photo of Tramtracks. Almost as soon as Cole slipped into the water, about a hundred feet from his subject, Tramtracks turned and closed the gap between them to ten feet. Initially Cole was thrilled at the proximity, but as the whale became more and more excited, questions of safety bubbled up.

"I felt things were getting out of control: I was worried that it would bump me with its huge head, or strike me with its tail. Not out of malice, of course, but in the spirit of play." So Cole hopped out of the water and marveled at his encounter, which had lasted less than fifteen minutes.

Marvels indeed. The enigmatic sperm whales prompted this question from Herman Melville in *Moby Dick* more than 150 years ago: "Is it not curious, that so vast a being . . . should see the world through so small an eye, and hear the thunder through an ear which is smaller than a hare's?" (See the slit just aft of the eye.) Soon Tramtracks will likely be turning those subtle yet keen eyes and ears to strange new swimming grounds, joining other adult bachelors or going solo, but undoubtedly leaving mom behind.

After getting a bachelor's degree in marine biology from the University of California, Santa Barbara, and conducting underwater research on such topics as kelp forest ecology, **Brandon Cole** now specializes in marine wildlife photography and writing. His file of cetacean imagery is one of the most extensive in the world, covering more than twenty species of whales and dolphins. His Web site, www.brandoncole.com, showcases his portfolio.

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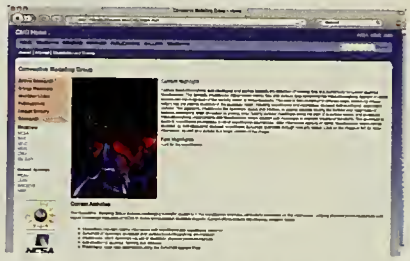
STORMY WEATHER



ONE THING I MISS, living in southern California, is weather. Sure, it rains a little in the winter, but I have yet to see anything like the spectacular lightning shows that would roll across New York City, where I once lived, or my native Virginia. On the Internet, however, there is always a good storm brewing at the site of the Convective Modeling Group (redrock.ncsa.uiuc.edu/CMG/) at the University of Illinois at Urbana-Champaign. A leader in visualizing the complex airflows that create huge thunderheads and tornadoes, this group's supercomputer simulations have been used to illustrate IMAX films. For my guide to this site and others about extreme weather, please visit the magazine online (www.naturalhistorymag.com).

ROBERT ANDERSON is a freelance science writer who lives in Los Angeles.

WORD EXCHANGE

Too Good to Be True?

Convinced that the butterflies in the images were dead specimens, two readers wrote to lament our publication of the photographs by Gary Noel Ross that accompanied his article "Diana's Mountain Retreat" [3/08]. In fact, none of the insects were dead. However, the male Diana and the beetle, in the first two photographs, were chilled in a cooler to inactivate them, then repositioned on their native foliage. Ross's goal was to illustrate his text in a dramatic way with scenes that occur in nature. The insects in the other two photographs were not manipulated at all: the female Diana on a coneflower was photographed at dusk with a flash, illustrating the propensity of females to feed into early evening, and the spicebush swallowtail on the milkweed was feeding naturally. Ross's self-portrait was taken with the camera mounted

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on a tripod and set for delayed shutter release. As a footnote, Ross points out that recreating scenes is a technique long employed by naturalists, painters, and photographers.

Natural History does not have a formal set of guidelines, but we prefer a minimum amount of manipulation. Had we known more about how the first two photographs in question were taken we might have chosen alternate ones or included some clarification in the captions. Or, we might not have: to some degree, all photographs are artistic products, involving at least the original framing and subsequent cropping, selection of a preferred image from a photoshoot, and often the adjustment of color, brightness, and contrast. I would be happy to hear our readers comment on this issue.
Vittorio Maestro
Editor in Chief

If the Glove Fits

In his otherwise delightful article on the history of the use of digitalis derived from foxglove, Druin Burch ["Hearts and Flowers," 2/08] has overlooked what has been demonstrated to be possibly the most beneficial effect of this remarkable agent. The digitalis glycosides are most effective in controlling the very rapid heart rates seen in patients with atrial fibrillation, a common disorder in the elderly. In fact, until about thirty years ago it was the only effective agent for the disorder. Many now believe that, with respect to Withering's study of patients with dropsy, digitalis may have benefited only those who also suffered from atrial fibrillation with a rapid heart rate. Numerous studies in recent years show that advanced systolic heart failure patients without digitalis in their medical regimens have suffered measurable clinical deterioration. More than two centuries later, there is still a place for the drug.
David Shander, M.D.
Denver, Colorado

Druin Burch replies: This is an excellent point, to which I'd add two further thoughts. First, using digitalis to slow the rapid heart rate of atrial fibrillation makes patients feel much better, which is of course a good thing, but does not necessarily have an effect on the patient's lifespan. Historically, that effect on lifespan probably appeared to exist, but many medical theories that seem perfectly reasonable turn out, when tested, to be wrong. In the absence of good trial evidence, doubt is always required! The second issue is that of lingering medical prejudices. We do have other drugs to slow the heart, beta blockers foremost among them. Undoubtedly some people find digitalis suits them better, but I suspect many doctors choose to stick with foxglove simply because it is what they have grown up with. I have been guilty of this myself. Digitalis does remain useful, all these years after Withering popularized it, albeit differently than he imagined. Its exact benefits, and the best way to make the most of them, are things we will continue to find out more about.

Natural History *welcomes correspondence from readers. Letters should be sent via e-mail to* nhmag@naturalhistorymag.com *or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

Surviving

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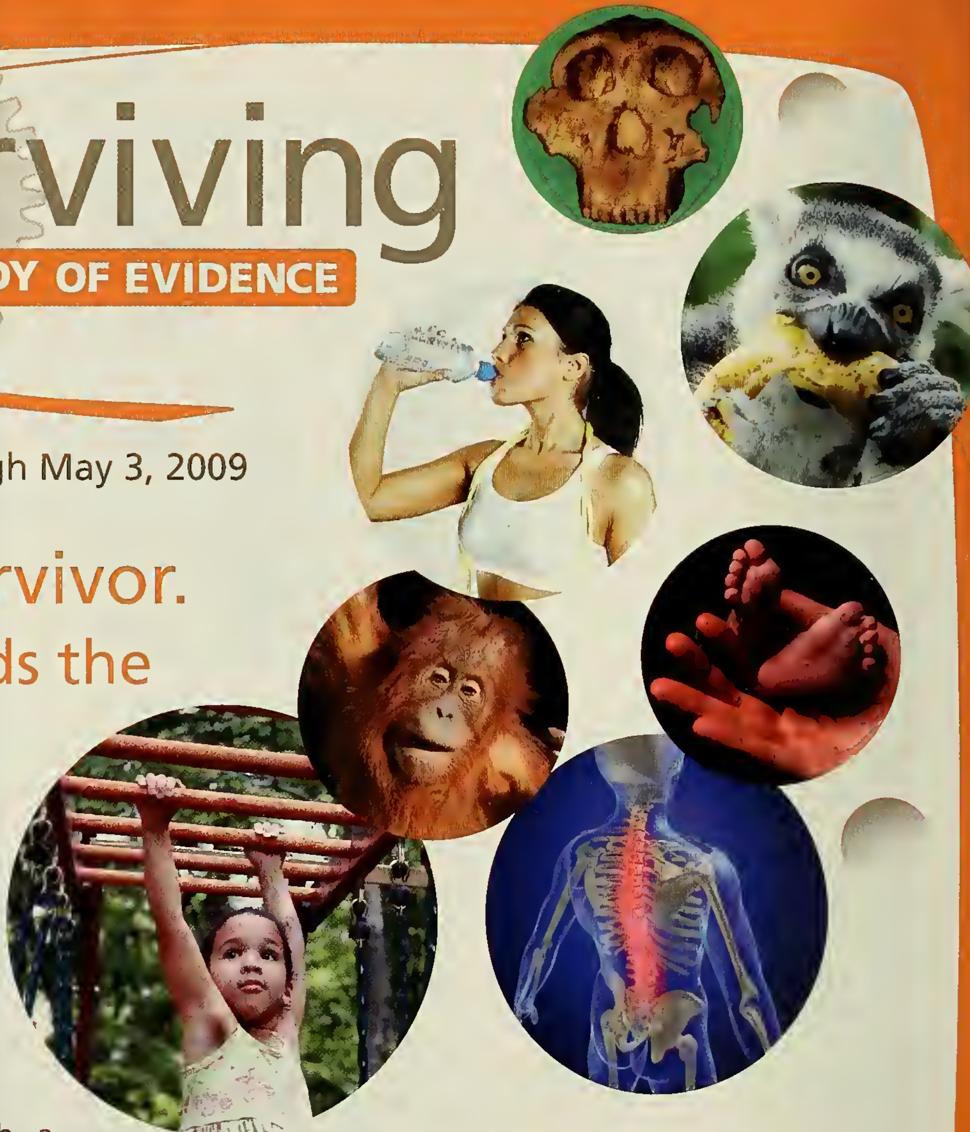

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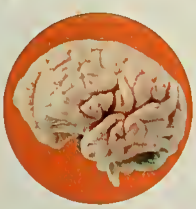

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Eye-Spotting

Illustration of a peacock butterfly, Inachis io

Some moths and butterflies bear circular, high-contrast marks on their wings that have long been thought to scare off predators by mimicking the eyes of the predators' own enemies.

Not so, say Martin Stevens and two colleagues at the University of Cambridge in England, who argue the marks work simply because they are conspicuous. (Predators are wary of prey with striking patterns, as those patterns often warn of toxic substances.)

To test their claim, the team created artificial prey using pieces of gray paper marked with black-on-white spots in various shapes, sizes, and numbers; they attached the paper "wings" to dead mealworms, pinned the worms to trees, and waited. Two days later, they found that the worms affixed to "moths" with eye-mimicking pairs of spots had been devoured by wild birds in numbers equal to those associated with eye-catching shapes: rectangles, single large spots, and trios of small spots. It was conspicuousness that was doing the trick.

Why, then, do wing marks look so much like eyes? The answer may lie in the process of wing formation. During moth development, molecules that cause wing cells to produce pigment can easily radiate from a central point, resulting in circular designs.

Eye-like marks in the animal kingdom are often called "eyespots." Now, Stevens recommends that the words "wing spots," "tail spots," or "fin spots" be used to designate them instead. (*Behavioral Ecology*)

—*Stéphan Reebs*

Shivering Flirts

Show-off males are common among birds, but peacocks stand out for their extravagantly long tail feathers adorned with dramatic spots (let's not call them "eyespots"). There is general agreement that long and elaborate trains have evolved as a result of female preference, but a new study suggests that this selection may not be operating anymore.

Mariko Takahashi of the University of Tokyo and three colleagues studied the sexual behavior of a feral population of the Indian peafowl, *Pavo cristatus*, in Izu Cactus Park, Japan. After seven years, the team concluded that peahens are not sweeter on males with longer trains, more symmetrical arrangements of tail spots, or greater numbers of tail spots. Perhaps, say the ornithologists, the differences between tail features have become too small for females to notice.

Females did, however, spend more time with males that shook their tails at them—a display called shivering. Is a shivering male more attractive to a peahen these days? Takahashi's group warns that high rates of shivering may be a consequence of a female having already chosen a male, not a cause of it. So figuring out what's hot to peahens and what's not may need more study. (*Animal Behaviour*)

—*S.R.*

Masters of Disguise or Display?

In popular culture, chameleons are considered masters of disguise. They can swiftly change their body coloration and thus blend in with their environment. But chameleons can also alter their appearance when expressing aggression and, in the case of males, when courting a female. So, which has driven the evolution of the chameleon's ability to change its livery—camouflage or communication?

If camouflage, one would predict that species living in environments with greater color variation—richer in shades of browns and greens—should have a greater capacity to switch colors. But when measuring color change in twenty-one species of dwarf chameleons, Devi Stuart-Fox at the University of the Witwatersrand and Adnan Moussalli at the University of KwaZulu Natal, in South Africa, found little support for that prediction.

The investigators staged contests between males within each species and, using algorithms that model visual systems, measured how conspicuous a chameleon would appear to other chameleons—and to hungry wild birds. As seen through chameleons' eyes, as well as through the eyes of their avian predators, the greater a chameleon's color spectrum, the more it stood out.

There is little doubt that chameleons in the presence of predators can adopt the hue of their background and thus hide themselves, but this study suggests that, at least in some species, the lizards' striking color changes are first and foremost signals, not cloaks. (*PLoS Biology*)

—*S.R.*

Male dwarf chameleon, Bradypodion transvaalense, *displays for females.*

Preflight Packaging

A two-inch piece of amber discovered among thousands of others at the muddy bottom of a French quarry is helping scientists bridge a gap in their knowledge of the early development of feathers. The fossil dates to the Middle Cretaceous, around 100 million years ago, and encases seven beautifully preserved primitive feathers of a type never before seen, together with various arthropods and several types of microorganisms.

Vincent Perrichot of the Museum of Natural History in Berlin, Germany, and four colleagues carefully cut the piece into twenty-two fragments. From one of the fragments, they isolated the ancient feathers and observed them in three dimensions, using scans, microtomography, and other sophisticated X-ray imaging techniques at the European Synchrotron in Grenoble, France. The feathers' primitive feature—a flattened central shaft composed of not-yet-fused barbs—differs from those of all other feathers, both modern and fossilized, providing evidence for a key step in the evolution of feathers and thus the ability to fly.

So whose feathers were they? Teeth from two species belonging to a group of feathered dinosaurs known as theropods were found in the same quarry as the amber, raising the possibility that the feathers came from a dinosaur. But the researchers would rather not make that call based on isolated feathers alone, since the feathers may well belong to a primitive bird. (*Proceedings of the Royal Society B*) —Harvey Leifert

Three-dimensional reconstruction of a primitive feather

Rainy Workdays

This summer, storm chasers looking for the heaviest average rainstorms in the southeastern United States should venture out midweek in the afternoons.

So suggests a study by NASA meteorologist Thomas L. Bell and five colleagues, who analyzed data gathered between 1998 and 2005 by the Tropical Rainfall Measuring Mission satellite, a NASA spacecraft that uses weather radar and microwave imaging to estimate U.S. rainfall south of latitude 40 degrees north. The team reports that in the southeast—where rainstorms cover more ground and disgorge more water than anywhere else in the satellite's purview—rainfall follows a familiar daily cycle: downpours in the afternoon. Intriguingly, the rain also follows a weekly cycle. Maximum rainfall occurs in the afternoons Tuesday through Thursday—when it's almost double that of Saturday, the day of least rain.

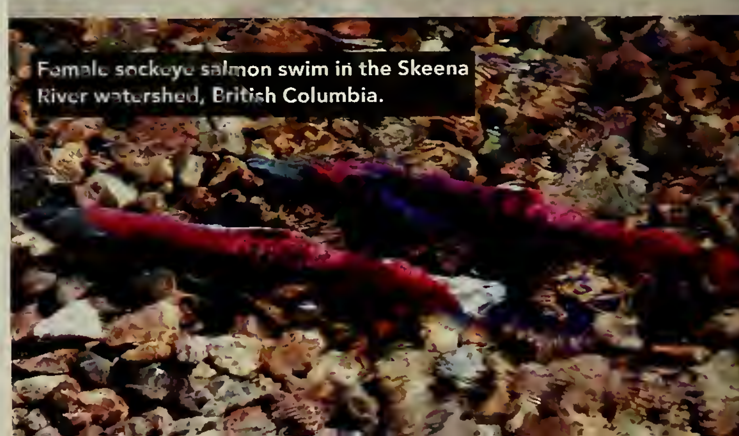
Now, guess what? Air pollution—aerosol particles released by traffic and industrial activities—also peaks midweek, according to monitoring programs by the Environmental Protection Agency. Correlation does not prove causation, Bell duly notes, but he points to the fact that aerosols keep cloud droplets small, allowing updrafts to lift them to greater heights. Higher in the atmosphere they freeze, releasing more heat, and thus intensifying storms. (Indeed, storm clouds grow higher in the middle of the week.) This phenomenon is particularly likely where air is moist and warm—exactly the conditions that prevail on summer afternoons over the southeastern U.S. (*Journal of Geophysical Research*) —*S.R.*

Building Their Own Beds

When a female sockeye salmon is ready to spawn, she finds a spot in stream gravel and sets about digging with her tail. The result is a shallow but large depression, about ten inches deep and three feet in diameter, wherein the female deposits her eggs. A recent study reports that all those excavations add up to rival water erosion as a shaper of streambeds.

A team of biologists and geologists led by Marwan A. Hassan of the University of British Columbia, in Canada, studied the effect of salmon digging in four mountain watersheds of the Fraser River Basin, using sediment traps, magnetized particles as tracers, and detailed channel maps. The researchers found that, on average, salmon activity displaces a third to a half of the total sediments that move within the streams in the course of a year. Water currents, especially during floods, are responsible for the rest. All that hoeing has an indirect, beneficial effect: it loosens up streambeds, letting in oxygen.

Salmon streams are often the targets of restoration projects. Yet such efforts may miss the mark unless landscaping by the streams' inhabitants is taken into account. (*Geophysical Research Letters*) —*S.R.*



Female sockeye salmon swim in the Skeena River watershed, British Columbia.

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SAMPLINGS

ARRRRRRRRRRRRRR!!!!

Pirates may not come across as the most civic-minded folk, but a new study shows that pirate crews operating in the late seventeenth and early eighteenth centuries adopted a democratic constitution and a sophisticated system of checks and balances before France, Spain, and the United States—possibly even before England's Bill of Rights was drawn up in 1689.

Peter T. Leeson, a professor of capitalism at George Mason University in Virginia who is currently studying the economic organization of pirate societies, says that becoming a pirate was a rational choice: merchant marines could make a mere fifteen to thirty pounds per year, whereas an individual pirate could net hundreds and sometimes thousands of pounds in one successful attack. With such high stakes, pirates needed an effective system to keep their captains from becoming tyrants—an all too common phenomenon on the high seas. So crews adopted written constitutions that dictated how laws and leaders were chosen. Those systems typically operated on the basis of "one pirate, one vote." To keep the captain's power in check, crew members elected an independent quartermaster who had much of the authority that captains would hold in times of battle, while simultaneously looking out for the interests of the crew.

Today's pirates, who operate mostly off the coast of Africa and in the South China Sea, are not nearly as civil, because they spend little time together at sea and therefore do not require an elaborate system to govern their offshore criminal behavior. (*Journal of Political Economy*)

—*Brendan Borrell*

Figurine head from Jaina Island, Mexico, A.D. 600-900

Scraping Bottom for Blue

Almost 2,000 years ago the Maya concocted a pigment, since dubbed Maya blue, which has endured the harsh climate of southern Mexico on murals, pottery, and sculptures. Archaeologists, however, never determined how or where the pigment was manufactured, even though they ascertained its chemical composition in the 1960s. Now researchers suggest that residents of Chichen Itzá, an archaeological site on Mexico's Yucatán peninsula, ritually produced the pigment right before offering human and material sacrifices to the rain god Chaak.

While looking through artifacts at the Field Museum of Natural History in Chicago, Dean E. Arnold, an archaeologist at Wheaton College in Illinois, discovered a clay bowl, five inches in diameter, that had been retrieved in 1904 from the Sacred Cenote, a ceremonial well at Chichen Itzá. The bowl was flecked with bits of palygorskite clay and indigo dye—the chemical constituents of Maya blue—and was filled to the brim with hardened copal, an incense made from tree sap.

Arnold and four colleagues realized that burning the copal could have provided the low, steady heat required to form the durable chemical bonds in the pigment—and that priests may have daubed it on sacrificial victims prior to cutting their beating hearts from their bodies. Along with incense and more than a hundred human skeletons, the well contains a fourteen-foot layer of blue sediment. (*Antiquity*)

—B.B.

THE WARMING EARTH

Sulfur Spritzer

In June 1991, Mount Pinatubo in the Philippines erupted and spewed out an estimated 17 million tons of sulfur dioxide into the stratosphere, creating a global layer of sulfuric acid haze that veiled sunlight and temporarily dropped worldwide temperatures by about 1 Fahrenheit degree. That hiccup in the modern trend toward global warming has made some visionaries sit up and take notice. Couldn't mankind, they asked, counteract the warming effect of greenhouse gases by deliberately injecting sulfur-based aerosols into the stratosphere—above and beyond what we already contribute by air pollution?

Curious, Philip J. Rasch, of the National Center for Atmospheric Research in Boulder, Colorado, and two colleagues calculated how much particulate matter would be needed for the job. Running various computer models of climate change, they found that 1.5 million tons of sulfur released every year—15 percent of the annual U.S. production—could keep global temperatures stable in the face of a doubling in carbon dioxide levels. The released particles would have to be small, however. Larger aerosols—of the size produced by volcanoes—do not scatter or trap sunlight energy as well, and would require twice the dosage.

Alas such a geoengineering endeavor would contribute to ozone depletion. Therefore, as Rasch's group recognizes, reducing greenhouse-gas emissions remains society's best strategy to slow down climate change. (*Geophysical Research Letters*)

—*S.R.*

FIELD NOTES

A Desert Galápagos

By William Conrod, with Erica Bree Rosenblum

Some animals inhabiting the white gypsum sand dunes of New Mexico shed their colors in less than 7,000 years.

WILLIAM CONROD

A flash of movement caught my eye. If the lizard had stayed still, I might have stepped on it: its color perfectly matched the dazzling expanse of white sand. Good thing, I thought, that rattlesnakes here in south-central New Mexico aren't white too. Three different species of white lizards can be spotted on the dunes from May through September. That is, if you're looking for them.

I was standing on the world's largest gypsum dune field, at White Sands National Monument, where I have worked as a biologist and land manager for nine years. Looking up from my feet, I gazed out across a sea of snow-white dunes to a rugged skyline of bare limestone mountains. The dune field covers an area of 275 square miles, about half of which is open to the public and managed by the National Park Service. The other half is military land, shared by a missile range and Holloman Air Force Base. Recent findings indicate the dunes formed within the past 7,000 years—a geological blink of the eye. And that gives a useful time frame for the rapid evolution of lizards, like the one I saw skittering across the sand.

Other creatures that, like the lizards, are small and easily preyed upon, have also tended toward lighter colors. With a permanent change of coloration, they can improve concealment on the gypsum dunes and thereby improve their chances of survival, as well as their chances of producing future generations that will inherit the advantage. You can see this on a short stroll from a park road in New Mexico.

Gypsum is the stuff of plaster and drywall: a common mineral also known as hydrated calcium sulfate. But why have some 8 billion tons of it collected in a series of dunes up to forty feet tall? The "white sand" of White Sands had its distant origin when marine deposits were left by an evaporating shallow sea in the Permian period, 250 million years ago. Some of those deposits were uplifted about 10 million years ago into mountain ranges that ring an area known today as the Tularosa Basin. Water leached gypsum out of those mountains and carried the dissolved mineral down into the Basin, where a large saline lake formed during the cooler and wetter times of the Pleistocene, within the past 2 million years.

The environment ultimately changed about 10,000 years ago to arid desert: the lake dried up, and mineral residue was left on the valley floor, forming crystalline gypsum. The same process continues today to a lesser extent, with mineralized groundwater reaching the valley floor, drying, forming gyp-

WILLIAM CONROD

sum, and blowing away to further expand the dune field.

Large deposits of pure crystal gypsum are unusual because the substance is water-soluble, meaning that streams or rivers carry most of it away. But the Tularosa Basin has no surface outlet. Strong spring winds scour out the valley-floor gypsum deposits and move them downwind to where the dunes formed as wind velocity abated. The dunes are still very much on the move: frequent plowing is required every windy spring to keep the national monument's dune road open, just as snow is plowed in colder areas.

In 2004, a geological team from the University of Texas at Austin and the Physical Research Laboratory of Navrangpura, India, determined a precise date for the formation of White Sands. In a core-sampling project, the team drilled down through the gypsum and collected lakebed sediment samples from directly beneath the white sand. Carbon material in the topmost lake sediment was dated to 7,000 years ago. That date marks the drastic environmental change from lake to desiccated dune field.

Knowing when the sand dunes began to accumulate tells us when animals could have begun to adapt to living in a white environment. Between the 1920s and the 1960s, biologists documented seven animal species that had permanently white coloration on the gypsum dunes, with darker forms living nearby in the desert off the dunes: three lizard species, the Apache pocket mouse, the White Sands woodrat (a subspecies of the southern plains woodrat), and two species of camel cricket. With lizards, rodents, and insects making a color change in a few thousand years, something evolutionary was definitely happening.

In the last decade, interest has grown in using White Sands as a natural laboratory. Stephen B. Hager made the first detailed study of the lizard species at White Sands for his Ph.D. at New Mexico State University, investigating color differences and temperature regulation of lizards on and off the dunes. Erica Bree Rosenblum, with the University of California at Berkeley at the time, next set out to understand differences among populations in an evolutionary context. Rosenblum quantified the gradient from light to dark in lizards of three different species. She verified that white lizards have white offspring, indicating that color at White Sands is an inherited trait. Furthermore, Rosenblum and her collaborators identified a single gene that seems to be responsible for light coloration in White Sands lizards. This was an exciting find, given that identifying the genetic basis of an adaptive trait is still rare.

Rosenblum's experiments on mate selection also told an interesting story. In lab tests, white males of the lesser earless lizard (*Holbrookia maculata*) distinctly preferred white females to brown females. Although brown and white forms of the lesser earless lizard are currently considered the same species, they may be in the early stages of speciation.

Natural selection can act as a strong force in such "ecotones," or areas of transition from one habitat to another. Conditions are considerably different on the gypsum dunes than off them. Not only background colors contrast starkly, but also the types of plants found there and how densely they grow. That, in turn, influences the lizards' prey and predators. Such differences can drive rapid speciation, particularly if coupled with a preference for local mates, which

*Below left: Two little striped whiptails (*Aspidoscelis inornata*) on white gypsum sand at White Sands National Monument. Below right: Two lesser earless lizards (*Holbrookia maculata*), both females in "breeding colors," on the white sand. The darker lizards of both species were captured from a different habitat, adjacent to the dunes.*

ERICA BREE ROSENBLUM

can enforce genetic separation even without the geographic separation imposed by islands or mountaintops. White Sands is its own oasis for rapid evolution.

President Herbert Hoover established White Sands National Monument in 1933, proclaiming that his reason for doing so was to preserve "the white sands and additional features of scenic, scientific, and educational interest." There was little scientific understanding of the area at that time. Yet preservation for the sake of science and future discoveries was a noble cause then, and should be considered an equally noble cause now.

The scenic beauty of the expansive white sand dunes will always draw visitors for inspiration and recreation, but strong evolutionary pressure in a changing environment may be the most important scientific attraction at White Sands National Monument. The light-colored species and how they came to be that way could become a textbook example of rapid evolution. Who knows? Maybe the rattlesnakes will be next.

William Conrod recently retired after thirty-two years with the National Park Service, including nine years at White Sands National Monument as the park biologist and natural resource manager. Erica Bree Rosenblum received her Ph.D. from the University of California at Berkeley, and is currently an assistant professor of biology at the University of Idaho. Her research at White Sands continues.


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Scenic Byways

Follow Washington State's Cascade Loop to savor the views and sample fresh local specialties that taste every bit as good as they look. Explore the past and the serene natural settings that have been carefully preserved along Alabama's Coastal Connection and Delaware's Coastal Scenic Byway.

Walla Walla Vineyard, Washington State

Washington State

Lake Chelan, one of Washington's many picturesque bodies of water along the Cascade Loop

Feast your eyes and palate on the scenic and savory delights along the Cascade Loop

WINDING FOR 400 MILES THROUGH the heart of the state, the **Cascade Loop** heads east from the Pacific Coast through the Cascades, along the Columbia River and Methow Valleys, then loops back west through the North Cascades National Park and down to Puget Sound. You can make the loop in a day, but you'll want to stop and linger at the charming villages, vineyards, and beckoning views along the way.

Start your journey with a breakfast of local specialties at Seattle's 100-year-old Pike Place Market, where salmon-tossing fishmongers add entertainment to the market's colorful array of fresh produce, cheeses and local arts. Then hit the road and head for Leavenworth, a timber town that has been transformed into an alpine Bavarian village. Follow a lunch of authentic German food with a wine tasting at one of the local wineries, including Cascadia, Smallwood's Harvest and Icicle Ridge.

Continuing toward Wenatchee, the core of Washington's apple country, you'll want to stop at Ohme Gardens. These gracefully designed gardens, located high on a rock bluff, offer sweeping vistas of the surrounding Wenatchee Valley and the Cascades.

The loop follows the Columbia River, then swings northwestward to ascend the Methow River Valley, reminiscent of the Old West, with its corrals and weathered barns. Continue climbing through the North Cascades, and you'll get still another spectacular view from the Washington Pass Overlook atop Liberty Bell Mountain. You'll be surrounded by glacier-clad towering peaks, with Ross and Diablo Lakes sparkling below.

Head down through the tulip country of Skagit Valley toward the coast and Puget Sound. You'll cross soaring Deception Pass Bridge to reach Whidbey Island and its beautiful Double Bluff Beach. Stroll along the beach to look for seashells, or just watch the whales and ships go by and the eagles soaring above. Wander the wild shoreline around Useless Bay, so-named by early seafarers. Today's travelers will find plenty to do and immense pleasure in completing their journey here.

Originally known as Icicle, the Bavarian-inspired town of Leavenworth is situated against a backdrop of the Cascade Mountains

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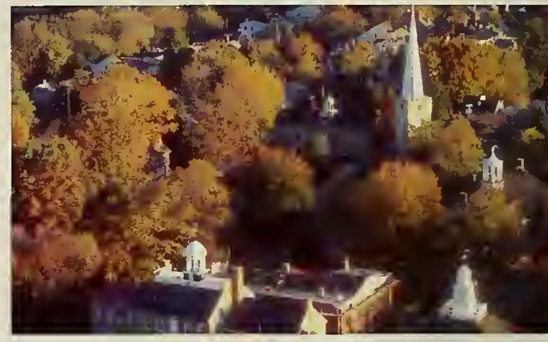
Scenic Byways

Delaware

DELAWARE'S COMMITMENT to historic preservation and to the stewardship of nature is evident in its historic landmarks and its coastline.

Delaware's Coastal Heritage Scenic Byway Route 9 traverses 50 miles of the state's carefully preserved shore, unparalleled on the East Coast. The state's newest scenic byway will take you along Delaware Bay, through historic towns, pastoral farmland, coastal marshland and refuges and unspoiled shoreline.



Right: Historic New Castle, Delaware's restored colonial capital; below: Horseshoe crabs spawn on Delaware Bay beaches once a year

Begin your journey in historic New Castle, Delaware's restored colonial capital on the Delaware River. Walk the cobblestone streets and visit the Dutch House, the Amstel House and the Old Library Museum. Head south for moated Fort Delaware, a Civil War-era fortress and prison, where you can experience living history programs that tell the stories of its Confederate prisoners as well as its mighty Columbiad cannon. For more saturation in the past, visit the historic Houses of Odessa.

Venture along the route's generous stretches of unspoiled marshland, including the Thousand Acre Marsh, the largest freshwater tidal wetland in northern Delaware. Bird watchers will also want to stop at Bombay Hook Wildlife Refuge, recognized as one of America's 100 "Important Bird Areas" by the American Bird Conservancy, and site of an annual Migratory Bird Festival.

Finish your journey near the state capital of Dover with a combination of colonial and recent history, perusing vintage aircraft at the Air Mobility Command Museum and then the relics housed in the John Dickenson Plantation, home of one of the country's founding fathers.

For more information click visitdelaware.com.

Alabama's Gulf Coast

ALABAMA'S SOUTHERN TIP is one of those places where even first-time visitors find a connection and **Alabama's Coastal Connection Scenic Byway** is a treasure to those who discover it. Gulf, bays, lagoons and bayous offer scenic views and recreational opportunities for most every interest. While enjoying a stroll along the shore at sunset or a quiet sail on the back waters suits some, others may opt for more exciting recreational opportunities like the offshore fishing that is a popular pastime here.

History buffs will find plenty to explore, as well. Historic Forts Gaines and Morgan stand united around the mouth of Mobile Bay and tell the stories of battles and soldiers of earlier times. Exceptional museums chronicle the history of heritage of several communities along the coast.

The Dauphin Island Audubon Sanctuary, Bon Secour National Wildlife Refuge and Gulf State Park provide more than 12,000 acres of protected lands along the coast. Weeks Bay National Estuarine Research Reserve is one of only 29 such reserves nationally and is literally where the soil meets the sea. These vast natural assets are complimented by smaller municipal parks and trails and by the sites along the Alabama Coastal Birding Trail.

A variety of accommodations are available, making the shore accessible to those looking for a campsite, a family-friendly beach house, a luxury hotel or anything in between. Special events offer a wide range of experiences including music festivals, historic re-enactments, sporting events and celebrations of seafood, just to name a few.

Whether families on the annual vacation, couples seeking a secluded getaway, birders searching for that rare sighting, or history buffs combing the forts, all can find a connection here. Alabama's Coastal Connection has much to share and it beckons travelers to learn more about *The Waters, Ways and Wildlife of Alabama's Gulf Coast.*


Alabama Gulf Coast Convention & Visitors Bureau

Burrowing owl rests along the Alabama Coastal Birding Trail

For more information visit AlabamasNaturalCoast.org or call 866-324-7776.

Natural History Magazine
May 2008

Hoofprints

Since their domestication, horses have transformed people's lives—leaving a subtle trail of clues along the way.

by Sandra L. Olsen

NAZAR AND I WERE PERCHED ON THE EDGE OF A THIRTY-FOOT RIVER TERRACE, GAZING DOWN AT HIS HERD OF HORSES ON THE OPPOSITE BANK of a shallow river. They were drinking and grazing in total harmony, heads bobbing and tails switching as if to an unheard melody. Beyond stretched the velvety, sage-green steppe, interrupted by the occasional peak or dark patch of pines. Once again that panorama had lured me back to northern Kazakhstan—that, plus the mystery of how, where, and when horses were first domesticated. For Nazar and I were resting on a 5,000-year-old settlement, now known as Botai, that promised to shed light on that critical event. Botai's inhabitants had the same food preference as modern Kazakhs—horsemeat and perhaps mare's milk—and they herded horses to survive. Indeed, unlike the modern herders, they ate little else.

Admittedly, Nazar's people have lived in this region for only about 1,100 years: the Kazakh language and culture likely originated farther east, in Siberia. However, they are part of the larger tradition of horse pastoralism, which extends across most of the Eurasian steppes, from Ukraine to Mongolia. During my years of archaeological excavation here, from 1994 to 2002, it therefore made sense for me to watch and learn from the local practices. Along with Bruce A. Bradley of the University of Exeter, in England, I led teams principally from Kokshetau University and North Kazakhstan University. Many members of our crews were ethnic Kazakhs.

I could see that Nazar and the one other herder from his village led a quiet life, with little human interaction. They were shy and hesitant in the company of the archaeological field crews. But the two men would emerge confident and powerful when mounted on the tall gray Russian stallions they rode to oversee their herd of 250 smaller, bay-colored Kazakh horses. The herders' life may seem tranquil compared with the stresses of urban dwellers, but it is quite arduous. The herd must be taken out to graze on natural vegetation, and tended through the night, even in the dead of winter, here where temperatures often plummet to a bracing −50 degrees Fahrenheit. (That does not include the wind chill factor, which takes on new meaning when one rides a horse at full gallop!)

It might seem unduly cruel for the horses themselves, having to scratch through the winter ice and snow to find enough of the sparsely spaced, shriveled *Artemisia* and feathergrass to survive, until you realize that wild horses thrived near the Arctic Circle during the last glacial maximum of the Pleistocene epoch, the Ice Age that ended about 11,500 years ago. Horses, it seems, are quite well adapted to a cold, dry environment.

YEARS OF EXCAVATING THE BOTAI CULTURE, AT THE SETTLEMENT OF BOTAI ITSELF and at two smaller village sites of the same antiquity, have taught me a great deal about how horses and humans forged their enduring bond. The sites' configurations and artifacts speak volumes if you can figure out how to interpret them. To do that, I had to fall back on the experience of my Kazakh friends and crew. I watched the herders and their dogs rounding up the horses, the local women milking the mares to make *koumiss,* a mildly fermented beverage that is a community favorite, and villagers preparing horsemeat in various dishes. Gradually I came to understand that those traditions illuminated the lives of their predecessors in the Copper Age, when people made tools of stone, bone, and more rarely, copper, but not yet of bronze or iron.


ROBERT HARDING

Paleolithic cave painting from Lascaux, in southwestern France, dates from about 17,000 years ago, when wild horses were human prey. Opposite page: A horse herd grazes on the steppes of northern Kazakhstan, a region that may have been among the first where the animals were domesticated.

I saw Botai for the first time in 1993. Discovered only a decade earlier, it had been partly excavated under the direction of Kazakh archaeologist Victor Zaibert, then of the Petropavlovsk Pedagogical Institute (which later became North Kazakhstan University), who claimed to have found the first domesticated horses. The odds that Botai was the very first or the only place where horses were domesticated were incredibly small. But Botai was clearly an ideal place to begin to unravel that mystery. We archaeologists must

Horses in northeastern Kazakhstan, not far from the so-called Semipalitinsk Polygon, where nuclear weapons were tested by the Soviet Union

resign ourselves to never finding the first stone tool ever knapped by humans or the first instance of making fire. Such ephemeral incidents leave few, if any, traces in the archaeological record, and even if they do, the chances are small that we will stumble upon them. We have to settle for pushing back the dates of important episodes to as close to the origin as possible and focusing in on the regions where they might have happened.

Botai and its smaller sister village sites, Krasnyi Yar and Vasilkovka, were inhabited about 5,300 years ago, not long after horse domestication is thought to have occurred. They are located in the heart of the natural range of the tarpan (*Equus ferus*), the wild horse that was the likely ancestor of the domestic horse. No other prehistoric culture we know of focused so utterly on a diet and economy based on the horse. More than 90 percent of the animal bones from Botai sites are derived from horse, with only a scattering of domestic dog and such wild game as aurochs (wild cattle), moose, red deer, and saiga antelope.

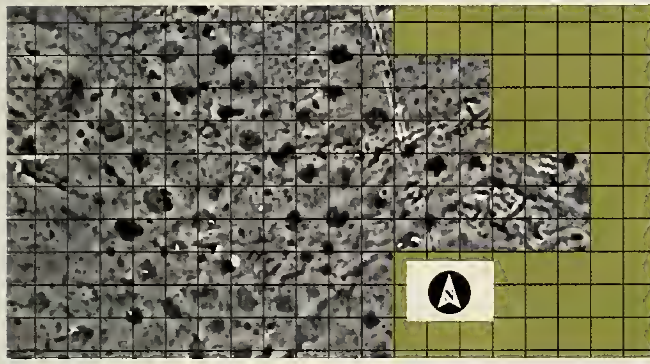
MANY ANIMALS—DOGS, CATTLE, GOATS, PIGS, AND SHEEP—WERE DOMESTICATED before the horse, but breeding that one species of livestock was a seminal event. Horses stand apart because of their versatile roles in human society, which came to include dairy production, transportation, haulage, plowing, sports, warfare, religion, and status. It is difficult to place those functions in order of importance, but the horse's part in warfare does rise above the rest in its effects on geopolitics and human history.

Horse-drawn chariots were not used in battle on a large scale until 1500 B.C., in the Near East, and cavalries only supplanted chariots by around 900 B.C. But you need only recite a short list of ancient empire builders—Alexander the Great, Attila the Hun, Genghis Khan, Charlemagne, and Napoleon Bonaparte—to realize they all relied mightily on their cavalries. Indeed, more than two millennia later, we even know details about Alexander's trusted mount Bucephalus. Legend tells us that, as a youth, Alexander tamed this wary animal when no one else could, and that Bucephalus was a dark stallion with a large white star on his forehead and one blue eye. Bucephalus died of injuries received in the Battle of the Hydaspes, in June of 326 B.C.

Before humans forged such partnerships with horses, the interactions were those of predator versus prey. Ice Age hunters in Europe, Asia, and North America tracked and even drove horses, dispatched them with spears, and butchered them for food. In France and Spain, lively images of the forebears of our domesticated horse adorn the cave sanctuaries of early hunters, dating from late Ice Age times, some 12,000 to 30,000 years ago. The European depictions, which reveal that horses were greatly sought-after prey, also show that the ancient wild horse had a dun coat, erect mane, and stripes on the withers and legs. In those features, as well as in its stocky conformation and broad, massive head, it closely resembled the Przewalski's horse (*Equus przewalskii*), a relative that nearly became extinct but which has been restored in limited numbers to Asiatic preserves. But based on evidence from chromosomes and mitochondrial DNA, the Przewalski has been ruled out as the ancestor of the domestic horse, so by a process of elimination, the most likely candidate was the tarpan.

The tarpan, unfortunately, *is* extinct. As the Ice Age drew to a close and global warming shifted ecological zones all over the world, the animal's natural habitats—the

SANDRA OLSEN



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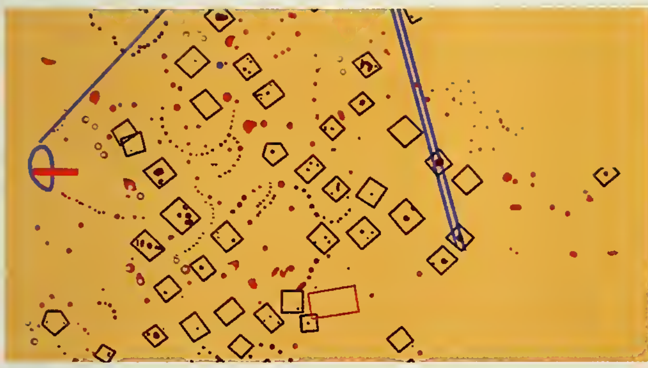


SANDRA OLSEN

ASHLEY BRICKMAN

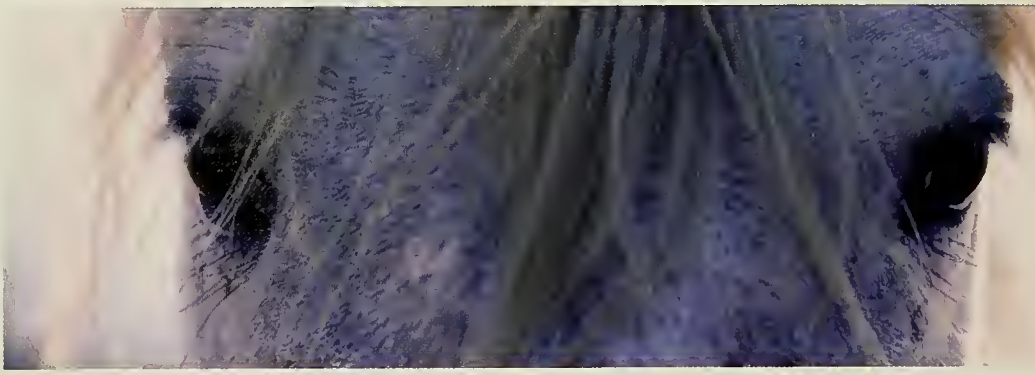
Circular depressions at the 5,000-year-old settlement of Krasnyi Yar hint at the presence of house pits (top). Magnetic gradient imaging, a remote-sensing technique employed by David Maki, of Archaeo-Physics in Minneapolis, Minnesota, revealed anomalies below the ground surface (second from top). These enabled archaeologists to map house foundations, corral postholes, and other settlement features (third from top), and to create a rendering of how Krasnyi Yar once looked (bottom).

large expanses of cold, dry steppe—began to contract and be replaced, often by deciduous forests. As the vegetation changed, so did the species of large herbivores living in a region. Cold-adapted animals shifted northward as far as possible, but eventually the largest of them all, the mammoth, went extinct. Reindeer persisted in the higher latitudes, but horse populations dwindled significantly, reduced to small enclaves sprinkled across the continent. Only on the Eurasian steppe from the Carpathian Mountains of Hungary across to Kazakhstan, and in a small part of northern Europe, did the tarpan survive. By about 9,000 years ago, it seems to have vanished from France, England, Spain, Italy, and the Near East; when the horse begins to be reintroduced into those regions 4,000 years later, it is most likely as domesticated livestock. The last tarpan finally died in Ukraine in the winter of 1918-1919.

Archaeologists have heated debates about where and when horses were domesticated for the first time. For many years, textbooks cited Dereivka, a 6,000-year-old site in Ukraine excavated in the 1980s, as having the strongest early evidence. The "smoking gun" was a horse skull, found in a sacrificial pit, that had wear on the lower premolars likely caused by champing at the bit. But many archaeologists, including me, puzzled over how bit wear could have formed when the earliest metal bits found in that region did not appear for another 3,000 years. David Anthony, an anthropologist at Hartwick College's Yager Museum of Art and Culture in Oneonta, New York, had the skull itself radiocarbon dated, and demonstrated that it was in fact an intrusive Iron Age offering—dating from sometime between 700 and 200 B.C. Dereivka should not be taken off the short list of possible early domestication sites, but it has been stripped of the most concrete evidence for its claim to fame, opening the field to competing sites across the Eurasian steppe.

Apart from, possibly, the dog and the pig, no other animal has provoked such contention over the "where" and "when" of its domestication. That is because the wild progenitors of many other domesticated animals had more restricted ranges, which meant that the potential places for domestication were much more restricted. The Eurasian steppe is probably the largest terrestrial ecological zone in the world, stretching across thousands of miles. With few geographic barriers, it has long served as an open freeway for travel by animals and humans.

The ability of archaeologists to identify the timing of domestication often depends on detecting skeletal changes that appeared not long after the process began. One example is the shortened muzzle of the dog, compared with that of the wolf. Others are smaller tusks on the domestic pig and smaller horns on domestic cattle, goats, and sheep than on their wild relatives. The overall body size often changes, too, as people selectively breed to make the animal more tractable, and less dangerous to handle. The aurochs, the ancestor of our domestic cattle, was a formidable beast: bulls could be seventeen hands, or 5.75 feet high, at the withers, with a horn span some



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Ecce Equus

By Jay F. Kirkpatrick and Patricia M. Fazio

Modern horses, zebras, and asses belong to the genus *Equus*, the only surviving genus in a once diverse family, the Equidae. Based on fossil records, the genus appears to have originated in North America about 4 million years ago and spread to Eurasia (presumably by crossing the Bering land bridge) 2 to 3 million years ago. Following that original emigration, there were additional westward migrations to Asia and return migrations back to North America, as well as several extinctions of *Equus* species in North America. The last prehistoric North American horses died out between 13,000 and 11,000 years ago, at the end of the Pleistocene, but by then *Equus* had spread to Asia, Europe, and Africa.

Animals that on paleontological grounds could be recognized as subspecies of the modern horse originated in North America between 1 million and 2 million years ago. When Linnaeus coined the species name, *E. caballus,* however, he only had the domesticated animal in mind. Its closest wild ancestor may have been the tarpan, often classified as *E. ferus;* there is no evidence, though, that the tarpan was a different species. In any case the domesticated horse probably did not arise at a single place and time, but was bred from several wild varieties by Eurasian herders.

In recent years, molecular biology has provided new tools for working out the relationships among species and subspecies of equids. For example, based on mutation rates for mitochondrial DNA (mtDNA) Ann Forstén, of the Zoological Institute at the University of Helsinki, has estimated that *E. caballus* originated approximately 1.7 million years ago in North America. More to the point is her analysis of *E. lambei*, the Yukon horse, which was the most recent *Equus* species in North America prior to the horse's disappearance from the continent. Her examination of *E. lambei* mtDNA (preserved in the Alaskan permafrost) has revealed that the species is genetically equivalent to *E. caballus.* That conclusion has been further supported by Michael Hofreiter, of the Department of Evolutionary Genetics at the Max Planck Institute in Leipzig, Germany, who has found that the variation fell within that of modern horses.

These recent findings have an unexpected implication. It is well known that domesticated horses were introduced into North America beginning with the Spanish conquest, and that escaped horses subsequently spread throughout the American Great Plains. Customarily, such wild horses that survive today are designated "feral" and regarded as intrusive, exotic animals, unlike the native horses that died out at the end of the Pleistocene. But as *E. caballus,* they are not so alien after all. The fact that horses were domesticated before they were reintroduced matters little from a biological viewpoint. Indeed, domestication altered them little, as we can see by how quickly horses revert to ancient behavioral patterns in the wild.

Consider this parallel. To all intents and purposes, the Mongolian wild horse (*E. przewalskii,* or *E. caballus przewalskii*) disappeared from its habitat in Mongolia and northern China a hundred years ago. It survived only in zoos and reserves. That is not domestication in the classic sense, but it is captivity, with keepers providing food and veterinarians providing health care. Then surplus animals were released during the 1990s and now repopulate a portion of their native range in Mongolia and China. Are they a reintroduced native species or not? And how does their claim to endemism differ from that of *E. caballus* in North America, except for the length and degree of captivity?

The wild horse in the United States is generally labeled non-native by most federal and state agencies dealing with wildlife management, whose legal mandate is usually to protect native wildlife and prevent non-native species from having ecologically harmful effects. But the two key elements for defining an animal as a native species are where it originated and whether or not it coevolved with its habitat. *E. caballus* can lay claim to doing both in North America. So a good argument can be made that it, too, should enjoy protection as a form of native wildlife.

Jay F. Kirkpatrick, who earned a Ph.D. in reproductive physiology from the College of Veterinary Medicine at Cornell University, has studied fertility control for wild horses. He is the director of the Science and Conservation Center at ZooMontana, in Billings. Patricia M. Fazio, a research fellow at the Science and Conservation Center, earned her Ph.D. in environmental history from Texas A&M University. Her interests include reproductive physiology, the monitoring of wild horse ranges, and the evolution of equids.

eight feet across! But early horses' skeletons provide no such obvious transition in morphology or size. Ancestral male horses had no horns or tusks, and even their canine teeth were relatively small in the wild state. It is only by about 1200 B.C. that some change is noticeable in the domestic horse's skull and stature.

Another tool archaeologists use to identify livestock is the relative frequencies of different age and sex groups in a collection of animal remains—the so-called mortality pattern. For example, did many of the animals die as juveniles, or did they live to a ripe old age? (Ages are largely determined from the teeth.) Livestock herds are generally managed by culling most of the males before they reach reproductive maturity. By then, as meat animals, they have reached most of their full adult body weight. In addition, the herds are easier to control with fewer adult males competing for the females; the pastoralists can save the males with the most desirable qualities for breeding.

Unfortunately, with horses, particularly once they began to be ridden, such clues to domestication break down. Stallions were preferred over females for riding by nearly every culture through time, except by people in Arabia. The stallions are slightly bigger and more aggressive, which is advantageous in hunting and battle. Further, females distract the males when they enter estrus, and they have to care for their foals for a period of months after birth, so they complicate missions in which groups must ride over long distances. As a result, the mortality pattern of ancient domestic horses often fails to show significant culling of young males.

To further compound the situation, recent mitochondrial DNA studies suggest horse domestication may have occurred many times; or at the very least, many female lineages (which are the source of mitochondrial DNA) were drawn upon from the wild populations across the steppes to supplement small domestic herds.

GIVEN ALL THOSE LIMITATIONS OF THE ARCHAEOLOGICAL RECORD, HOW CAN ARCHAEOLOGISTS make progress in identifying where and when domestication began? Our team's approach has been holistic—piecing together as much evidence as possible, whether direct or more circumstantial. We also take an upside-down approach. If the prehistoric horse bones are difficult to decipher, then why not look at the settlement and traces of the human lifestyle for evidence that they were influenced by horse domestication?

As already mentioned, the Botai primarily used horses for food. The high frequencies of butchering marks made by stone knives on the bones tell us that. Compared with the Neolithic hunters who preceded them, the Botai people left behind fewer bones from other game animals. And they also differed by living in large, permanent settlements. The earlier hunters had small transient camps or home bases of one to a few houses. Botai has more than 160 houses, Krasnyi Yar 54, and Vasilkovka 44. The houses, made of adobe and roofed over with saplings and clay, were semi-subterranean. They were arranged in rows along streets and around small plazas. Most of the houses had their corners oriented toward the cardinal directions [*see illustrations on page 29*].

But to play devil's advocate, couldn't these have been communities of horse hunters? Imagine that for decades, if not hundreds of years, a large concentration of people fixed in one place focused on hunting just one type of game in the surrounding region. Eventually, they would exhaust local wild horse herds, making it necessary to go farther and farther afield to find prey. Even if small bands of hunters left the village periodically on long-distance missions on foot, they would not be able to return home with enough meat on their backs to feed the whole community. Surely they would broaden their dietary scope and take more deer or wild cattle; but we don't see that happening at Botai. In addition, wouldn't they be selective in what parts of a horse carcass they carried back over long distances? But we find bones from the whole horse, even the heavy pelvis and skull, indicating that the animals were probably killed nearby or in the village.

Moreover, circular arrangements of possible postholes suggested a number of enclosures at the Krasnyi Yar settlement. By taking twenty-five soil samples within one such enclosure and comparing them with soil sampled from outside it and from far away from the site, geologists Michael Rosenmeier and Rosemary Capo, of the University

"THE HORSE," *a special exhibition at The American Museum of Natural History, premieres May 17 and remains on view until January 4, 2009. It covers 50 million years of the animal's evolution and shows how the horse transformed human art, culture, and civilization.*

JOE LEMONNIER

CHRISTOPHER HERWIG

A young girl rides home on the steppe in northeast Kazakhstan.

of Pittsburgh, discovered obvious differences. When the soil chemistry was analyzed, the area inside the enclosure proved much higher in phosphates, indicating a dense concentration of manure. Because the Botai had no cattle or sheep, it was clear that this was a horse corral.

Our colleagues Charles French and Maria Kousoulakou, of the University of Cambridge, also identified horse manure in the collapsed remains of houses from Botai and Krasnyi Yar. This probably reflects a practice found even today among Kazakhs, Mongols, and others on the Eurasian steppe: they layer their roofs with livestock manure as a means of insulation.

The Botai lacked bronze or iron technology, as mentioned earlier. Even so, it is reasonable to conclude that they used simple bridles, hobbles, lassoes, whips, and other tack made from rawhide thongs, as North American Plains Indians often did. Prehistoric rawhide does not survive 5,000 years in a site like Botai, which is shallow and lies out in the open, but tools used to manufacture thongs do. Abundant in all of the Botai settlements is a type of notched tool made from the lower jawbone of a horse; high polish and fine striations along the notch suggest the tool was used to work over strips of rawhide to prevent stretching during use. Horse herders require more thongs than nearly any other society, with the exception of polar peoples, who use them for sleds, snowshoes, and fishing equipment.

THE HORSE HISTORICALLY HAS HAD A CLOSE ASSOCIATION WITH THE SUN GOD ALL ACROSS the Eurasian steppes and in Indo-European cultures. There are enormous religious sites in Mongolia, called *khirigsuurs*, dating from Bronze Age times, from about 1500 to 500 B.C., where hundreds or even thousands of horse heads and necks are buried beneath mounds of stones. In most cases the heads were carefully arranged to face southeast, where the rising sun emerges over the horizon in late autumn. Presumably that is the season when they were slaughtered. Mongols and Kazakhs usually do most of their horse slaughtering in the late autumn. At that time of year, horsemeat is most fatty and nutritious and can be frozen in boxes outside the home for several months.

Although they lived at an earlier time, the Botai villagers also used horses for religious purposes: fourteen horses were sacrificed and placed in a grave that contained two men, a woman, and a child—perhaps to provide them with food for the afterlife. But the most telling discovery for us was at Krasnyi Yar: a house encircled by ceremonial pits containing horse heads and necks. We believe the house belonged to a shaman. Most of the skulls pointed to the southeast, but one clearly pointed to the northeast, indicating a spring sacrifice. To learn that the horse was linked with the Sun God, the most powerful god in the Eurasian pantheon, as much as 5,000 years ago, was strong proof that the animals had begun to shape human society.

SANDRA L. OLSEN is co-curator of "The Horse," a special exhibition that will open at the American Museum of Natural History on May 17, 2008. A zooarchaeologist, Olsen is a curator of anthropology at the Carnegie Museum of Natural History, in Pittsburgh, and an adjunct associate professor at the University of Pittsburgh. She has examined the roles that wild and domesticated animals have played in the lives of various prehistoric peoples, from the American Southwest to much of Western Europe, Russia, and Central Asia.

Web links related to this article can be found at ***www.naturalhistorymag.com***

Natural History Museum of Los Angeles County

naturalist

THE CALENDAR OF EVENTS FOR THE NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

May 2008

© Ryan Miller/Capture Imaging

Enter the Insect World

With your donation of $100 or more you will receive a beautiful ***certificate of adoption***, personalized with your name and your chosen species of butterfly, plus a butterfly fact sheet describing your butterfly.

As your contribution grows, so do the possibilities! With a gift of $300 or more you will see ***your name*** in flight, colorfully featured on the ***2008 Wall of Wings***.

Spread Your Philanthropic Wings!

Every contribution is a generous one, and with your help this spring we will greet over 9,000 young visitors for free school field trips to the **Pavilion of Wings**.

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ADOPT A Butterfly

Natural History Museum of Los Angeles County

A LETTER FROM THE PRESIDENT

A Commitment to Science and Education

Dear Friend,

From often humble and homegrown roots, science and education departments at the Natural History Museum of Los Angeles County have evolved greatly over time.

Entomology was one of the original disciplines of the Museum when it opened its doors in 1913. Though it started with a small assortment of beetles, the department has grown into a renowned resource, with holdings of, and research on, specimens from around the world. Its collection of 5.7 million insects is one of the largest on the West Coast.

Objects and specimens are the Museum's cornerstone, but it is not enough that they exist under our auspices. We must also make them accessible. To that end, the Education Department was formed in 1940. Today, with a busy slate of activities, day camps and outreach, Education reaches hundreds of thousands of children and young adults each year.

As our science and education departments grew, they did not grow apart. The month of May illustrates how they collaborate to support programming and exhibits. On the South Lawn, our Education Department manages the Pavilion of Wings where our visitors interact with free-flying butterflies. Inside the Museum, the Discovery Center's Insect Zoo allows close observation of local and exotic insects. In both exhibits, our Entomology Department and Curator Brian Brown ensure the science is sound. Then Brent "the Bug Guy" Karner and a team of gallery interpreters can do what they do best — put a fun and relatable spin on science, and effectively relay the wonders of the insect world.

From May 17-18, we welcome the 22nd annual Bug Fair, the weekend event that combines Museum science with visiting vendors, artisans, and bug world aficionados. Here too, the Entomology Department's staff provides specimens and knowledge, manning booths that display their research and answering our visitors' questions. Karner provides a network of bug enthusiasts and his trademark knack for de-mystifying insects, both of which make the event come alive.

When scientists and educators work together, our visitors are getting the best of both worlds — foundational scholarship and interpreters who can inspire anyone, no matter their age or experience. We hope you will join us.

Sincerely,

Jane G. Pisano
President and Director

"Our mission is to inspire wonder, discovery and responsibility for our natural and cultural worlds."

515 GOLDEN FRUIT — WINTER IN CALIFORNIA

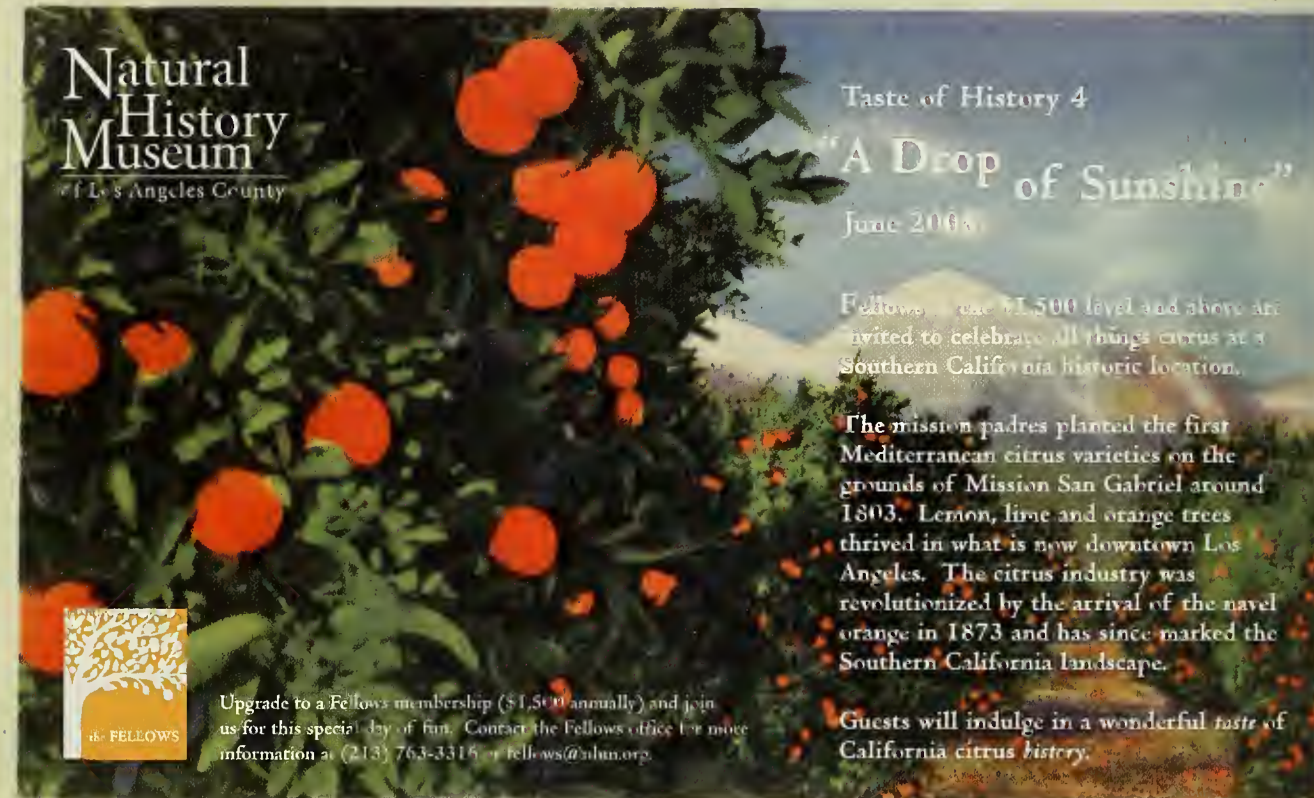

Image courtesy of the Seaver Center for Western History Research, Natural History Museum of Los Angeles County

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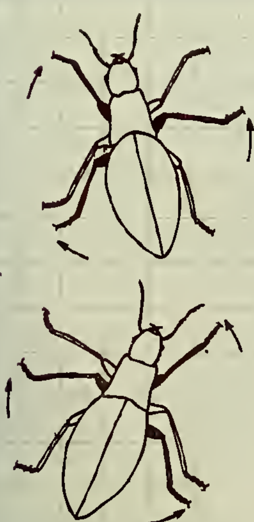

beetle walking

Junior Scientist: Insect Investigation

Saturday, May 24, 2008
10:15-11:30 am

There are more insects than any other kind of animal on Earth, so being an insect investigator means that there is always something new to discover! Help us examine the amazing world of insects as you become a Junior Entomologist, observing our six-legged neighbors and exploring the Natural History Museum through new (compound) eyes.

bee wing

New format! Junior Scientist is for 6-10 year-olds and their families. All programs are FREE with paid Museum admission. No reservations are required, but start times may be delayed for some attendees based upon the popularity of the program. Please check in at the Museum's south doors. For more information about Junior Scientist, please contact the Discovery Center at (213) 763-3230.

Weekends at NHM is made possible by a grant from the Ralph M. Parsons Foundation.

Natural History Museum of Los Angeles County

FEATURE

Bugs in May

It's a buggy month, May. The Pavilion of Wings is open on the Natural History Museum's South Lawn and the wildly popular Bug Fair unfolds May 17-18. But there are also entomological activities behind the scenes — from a backyard biodiversity experiment to the rescue of 1,000 imperiled millipedes. As has become a bit of a *Naturalist* custom, we devote this month's issue to a few of the Museum's entomological endeavors.

One of these transpired in a Brentwood backyard. Though many assume the discovery of new species is only possible in faraway, exotic locales, Museum Entomology Curator Brian Brown is known to brag that he can find undescribed fly species in even the most local of environs. Eventually Museum Trustee and entomology enthusiast Miriam Schulman challenged him to do just that — and better yet, invited him to go to work in her backyard. Brown set up a tent-like Malaise trap outside the Schulmans' home, and on the night of a Fellows event they hosted, he sorted through the accumulated sample under a video-microscope.

Even smack in the middle of suburban Los Angeles, there were surprises. The first was an interesting looking phorid fly that turned out to be an undescribed species of the genus *Megaselia*, new to science. A second belonged to the species *Megaselia scutellaris*, previously known only from Europe, and therefore a new continental record for the species. A third phorid that Brown found came from the genus *Chonocephalus*, which he had never seen on the west coast of North America before. Brown sent it to an English colleague, an expert on the genus, who revealed that this fly, *Chonocephalus bentacaisei*, was a species previously chronicled only in Madagascar, the Canary Islands and the Comoros

After setting up this Malaise trap in a Brentwood backyard, Entomology Curator Brian Brown found one fly species new to science and two species never before seen on the west coast of North America. *Photo by Miriam Schulman*

Islands. A tiny fly that normally makes its home in the islands off Africa, in other words, had made its way to Southern California.

"One of the Museum's primary missions is exploration to find new things, and when we are talking about insects, this discovery can take place nearly anywhere," Brown says. "We already know most of the world's birds and mammals, but for six-legged creatures it is still a largely unexplored planet."

Brown's third fly wasn't the only newcomer from Africa. In early February, Associate Manager of Entomological Exhibits, Brent "the Bug Guy" Karner, got a call from the United States Department of Agriculture. That's not particularly unusual — USDA officers frequently contact him when they have questions about confiscated animals, and the agency is also in charge of issuing permits for the Museum's Insectary, Insect Zoo and Pavilion of Wings. But this time they had a problem — three crates containing over 1,000 giant African millipedes, seized at LAX. Ranging in size from six inches to nearly a foot, these wild-caught creatures were as hungry as they were shy, and now in need of a foster home.

Though the Museum occasionally takes a box or two of confiscated insects, a cache this large is unusual. But because we boast an impressive containment site, there was room, and permits, for all the animals. With his Living Collections staff and a couple of volunteers, Karner moved the millipedes into spacious new homes and supplied them with mushrooms, apples, oranges, lettuce and even chalk (for calcium carbonate) to eat. Had the Museum not accepted them, their futures were bleak — the USDA would have disposed of them, as is required by law.

In the space of a couple of weeks, by enlisting a huge network of insect world contacts, Karner found homes for all of them. They'll be picked up by, or shipped to, zoos, insectaries, museums and nature centers all over the country. "I certainly can't stop the millipede trade, but I can try to let people know what it's really like," Karner says. "The millipedes reminded me of the importance of what we do here and what we stand for, even if it means some extra effort."

—*Kristin Friedrich*

THOMAS THE T.REX LAB

N NATURAL HISTORY MUSEUM

Ongoing

Visit the *Thomas the T. rex Lab*, the NHM's own working paleontological laboratory devoted to the preparation of our most famous *Tyrannosaurus rex*. With a skeleton that is nearly 70% complete, this fossil was a rare discovery and now an integral part of our remarkable *T. rex* growth series. As the Lab's work continues, it will surely unlock mysteries about this fascinating species — how and where it lived, grew and died *Director's Gallery, Second Floor.*

© Ryan Miller/ Capture Imaging

Pavilion of Wings

N NATURAL HISTORY MUSEUM

Through Sept. 1, 2008

Enter a world of free-flying butterflies in this enclosed, lush habitat. More than 30 species — including giant swallowtails, monarchs and the American Painted Lady — flutter throughout the grounds. *Separate admission ticketing applies. Members receive FREE tickets.*

© Ryan Miller/ Capture Imaging

FIRST | FRIDAYS

N NATURAL HISTORY MUSEUM

Friday, May 2, 2008; 5:30 pm – 10 pm

Once a month, the Museum stays open late for dinner, discussion, live music and more. Join Dr. Leah Krubitzer, from UC Davis' Department of Psychology and the Center for Neuroscience, for a discussion about what accounts for the differences in behavior among mammals. The Dodos and other special guests play live, and DJs Carlos Nino and Morpho of dublab.com spin. *More information at www.nhm.org/firstfridays.*

Ladybugs and Butterflies!

Hey 3-5 year olds, this club's for you!

N NATURAL HISTORY MUSEUM

Sunday, May 11, 2008

10:15 am – 11:15 am

Sprout the seeds of knowledge and fun. Let's visit our gardens where we will meet and release some helpful bug friends. You will hear buggy stories and even take home your very own seedling! *For 3-5 year olds and a participating adult. All programs free with paid Museum admission. Events available on a first come, first served basis. No reservations required; check in at Museum's south doors. For more information, call (213) 763-ED4U.*

Junior Scientist

Insect Investigation

N NATURAL HISTORY MUSEUM

Saturday, May 24, 2008

10:15 am – 11:30 am

There are more insects than any other kind of animal on Earth, so being an insect investigator means that there is always something new to discover! Help us examine the amazing world of insects as you become a Junior Entomologist, observing our six-legged neighbors and exploring the Natural History Museum through new (compound) eyes. *The Junior Scientist program is for 6-10 year olds with a participating adult. Free with paid Museum admission. Check in at the South Doors. For more information, call the Discovery Center at (213) 763-3230.*

Fossil Hunting in Silverado Canyon

OFFSITE

Saturday, May 10 & 31, 2008

9:30 am –

SOLD OUT

Sea... fos... ...roves, Collections Ma...ger of Malacology, and LouElla Saul, former Collections Manager of Invertebrate Paleontology and current Museum Research Associate. This rich fossil site is a great place to learn the basics of fossil excavation along side Museum scientists. Bring a bag for your best finds! Participants provide their own transportation. *Grades 2 and up, accompanied by an adult. Members $29; General Admission $39.*

©Ryan Miller/Capture Imaging

Mary Ellen's Tea Party

WILLIAM S. HART MUSEUM

Saturday, May 17, 2008; 12:30 pm

The Friends of Hart Park and Museum present the second annual Mary Ellen's Tea Party, where guests indulge in a variety of refreshments including specialty teas, scones with cream, assorted finger sandwiches and delicious desserts. It makes a great Mother's Day gift, so order soon! Tickets are $40 per person. *For more information and ticket reservations, please call the William S. Hart Museum at (661) 254-4584.*

22ND ANNUAL bugfair

NATURAL HISTORY MUSEUM

Saturday – Sunday, May 17 – 18, 2008

10 am – 5 pm

The Museum's hugely popular Bug Fair is North America's largest celebration of our multi-legged friends. In addition to many live specimens, many of which visitors can touch and hold, the Fair features animals for purchase and an endless array of bug-related toys, gift items and art. Staff from our Research and Collections department will be at interactive tables where visitors can ask questions and discuss science. *FREE with Museum admission.*

SCAVENGER'S SAFARI

MEMBER

FOR PATRON FAMILY MEMBERS!

©Ryan Miller/Capture Imaging

He Knows Sea Shells

NATURAL HISTORY MUSEUM

Saturday, May 24, 2008
11 am: Family Tour
Noon: Adults Tour

Mollusks are one of the most diverse groups of invertebrates on Earth (second only to insects). Join Malacology Collection Manager Lindsey Groves for a behind-the-scenes tour of one of the largest collections of mollusks in the nation. This tour will feature representatives of most of the major classes of mollusks including rare and common species, large and small varieties, and weird and bizarre forms. *This monthly program is free with Patron Family Membership ($185 annually). RSVP today at (213) 763-3426.*

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Weekend programs at the Natural History Museum are supported by a major grant from Farmers Insurance Group.

Additional support for Family and Children's Programs is provided by the Ralph M. Parsons Foundation, Avery Dennison Foundation and The Gary Saltz Foundation.

the FELLOWS

Birding Safari: A Fellows Family Adventure

OFFSITE

Saturday, May 31, 2008: 9:30 am – 2 pm

Join Ornithology Collections Manager Kimball Garrett and explore the Bolsa Chica Ecological Reserve wetlands, which contain 300 acres of one of the nation's best birding sites. You might see endangered birds such as Belding's Savannah Sparrow and the California Least Tern. After a picnic style lunch, you'll embark on a behind-the-scenes tour of the Wetlands and Wildlife Care Center of Orange County and learn about bird rehabilitation. *For more information, contact (213) 763-3316 or fellows@nhm.org.*

BioBlitz

OFFSITE

Friday – Saturday, May 30 – 31, 2008

noon to noon

Chart the species that live in the Santa Monica Mountains during BioBlitz, a 24-hour inventory event. Sponsored by National Geographic and the National Park Service, teams of scientists, naturalists and volunteers will comb the mountains' more than 150,000 acres, observing and recording as many species as possible. There will be junior ranger activities, a "scientist tent," booths and demonstrations. The BioBlitz itself is noon to noon; it's followed by the Celebrate Biodiversity Festival, which runs on Saturday until 6 p.m. *Free for Museum members or visitors with paid Museum admission, though registration is required. Free transportation to and from the site will be provided by the National Geographic Society in partnership with the Museum on Saturday. Call (213) 763-ED4U to register.*

	SUN	MON	TUES	WED	THURS	FRI	SAT
MAY					1	2 N First Fridays	5
	4	5	6 Free Tuesday	7	8	9	10 Fossil Hunting (sold out)
	11 N Critter Club					16	17 H Mary Ellen's Tea Party N Bug Fair
	18 N Bug Fair					23	24 N Scavenger's Safari N Junior Scientist
	25					30 BioBlitz	31 BioBlitz Birding Safari Fossil Hunting (sold out)
JUN	1	2	3 Free Tuesday	4	5	6	7


photo by Arnold Small

activities at NHM

time	activity	location
11:00 am*	Live Animal Presentations/Family Programs	Discovery Center
1:00 pm	Story Time	Discovery Center
2:00 pm	Museum Hall Tour	Dueling Dinosaurs
3:00 pm	Live Animal Presentations/Family Programs	Discovery Center

Page Museum

time	activity	location
1:00 pm	Hancock Park and Pit 91 Tour	Page Museum
2:15 pm	Gallery Adventure Tour	Page Museum

*These activities take place on Saturdays and Sundays only

Natural History Museum of Los Angeles County
900 Exposition Blvd.
Los Angeles, CA 90007
www.nhm.org
213-763-DINO
213-763-3569 (TTY hearing impaired)

Page Museum La Brea Tar Pits
5801 Wilshire Blvd.
Los Angeles, CA 90036
www.tarpits.org
323-934-PAGE

William S. Hart Museum
24151 San Fernando Rd.
Newhall, CA 91321
www.hartmuseum.org
661-254-4584

MENTAL mirrors

SPECIAL CELLS IN THE BRAIN MIMIC THE ACTIONS AND INTENTIONS OF OTHERS, FORMING THE BASIS OF EMPATHY AND SOCIAL CONNECTIONS.

BY **MARCO IACOBONI**

What do people really do all day, every day? We "read" the world. And much of the world consists of other people. When a tennis player raises his racquet, for example, you know instantly whether he's going to take a practice swing or throw his racket across the court in anger. We all make dozens—hundreds—of such distinctions every day. It is, quite literally, what we do, usually without a second thought. It all seems so ordinary.

In fact, it's extraordinary—and even more extraordinary that it feels ordinary! We achieve our very subtle understanding of other people thanks to certain collections of special cells in the brain called mirror neurons. They are at the core of how we navigate through our lives. They bind us with each other, mentally and emotionally.

Mirror neurons are incredibly powerful; "vicarious" would not be a strong enough word to describe their effects. When we watch movie stars kiss onscreen, some of the cells firing in our brains are the same ones that fire when we kiss our lovers. And when we see someone else suffering or experiencing pain, mirror neurons help us to read her or his facial expression and make us viscerally feel the suffering or the pain of the other person. Those moments, I will argue, are the foundation of empathy (and possibly of morality). Research on mirror neurons gives anyone interested in how we understand one another some remarkable food for thought.

Consider the teacup experiment I published an account of in 2005 [*see illustration on following page*]. Test subjects are shown three video clips involving the same simple action: a hand grasping a teacup. In one clip, there is no context for the action, just the hand and the cup. In another, the subjects see a messy table, complete with cookie crumbs and dirty napkins—the aftermath of a tea party, clearly. The third video shows a neatly set table, in apparent readiness for the tea party. In all three video clips, a hand reaches in to pick up the cup. Nothing else happens, and the grasping action observed by the subjects in all three versions of the experiment never changes. Besides the difference in context, there is only one other variation: in the "neat" scenario the cup is full, whereas in the messy one the viewer cannot tell if the cup contains liquid.

Do mirror neurons in the brains of the subjects notice the differences in context and in the contents of the cup? Most definitely. When a subject observes the grasping scene with no context at all, mirror neurons are the least active. The neurons are more active when the subject watches the after-tea-party scene, but they are *most* active during the neat, full-cup scene. Why? Because drinking is a much more fundamental intention for us than cleaning up. The teacup experiment—now well known in the field of neuroscience—belongs to a wealth of recent empirical evidence suggesting that our brains are capable of mirroring the deepest aspects of the minds of others at the fine-grained level of a single brain cell. Reading the intention of others is only one example of the kinds of distinctions that can be made with a remarkable lack of effort. We do not have to draw complex inferences or run complicated algorithms. Instead, we use mirror neurons.

Mirror neurons were first discovered in the brains of monkeys, where they are concentrated in two linked areas, called the ventral premotor cortex and the inferior parietal lobule, that are important for selecting appropriate motor behavior. Mirror neurons make up approximately 20 percent of the neurons in those regions, which lie close to the primary motor cortex, the area of the brain that sends electric signals to the muscles. In humans, however, mirror neurons may be located in many more regions of the brain, in varying amounts. (I hope to publish new findings about their location soon.)

Mirror neurons seem to have nothing in common with deliberate, effortful, and cognitive attempts to imagine

When an observer watches an athlete swing to hit a forehand, so-called mirror neurons that fire for a swinging motion discharge in the observer's brain. The same mirror neurons would fire if the observer were performing the swinging action himself, but in that case, pure motor neurons controlling his arm muscles would also fire. The observer thus experiences something similar to what the tennis player does when he hits the ball, regardless of whether the observer has ever played tennis.

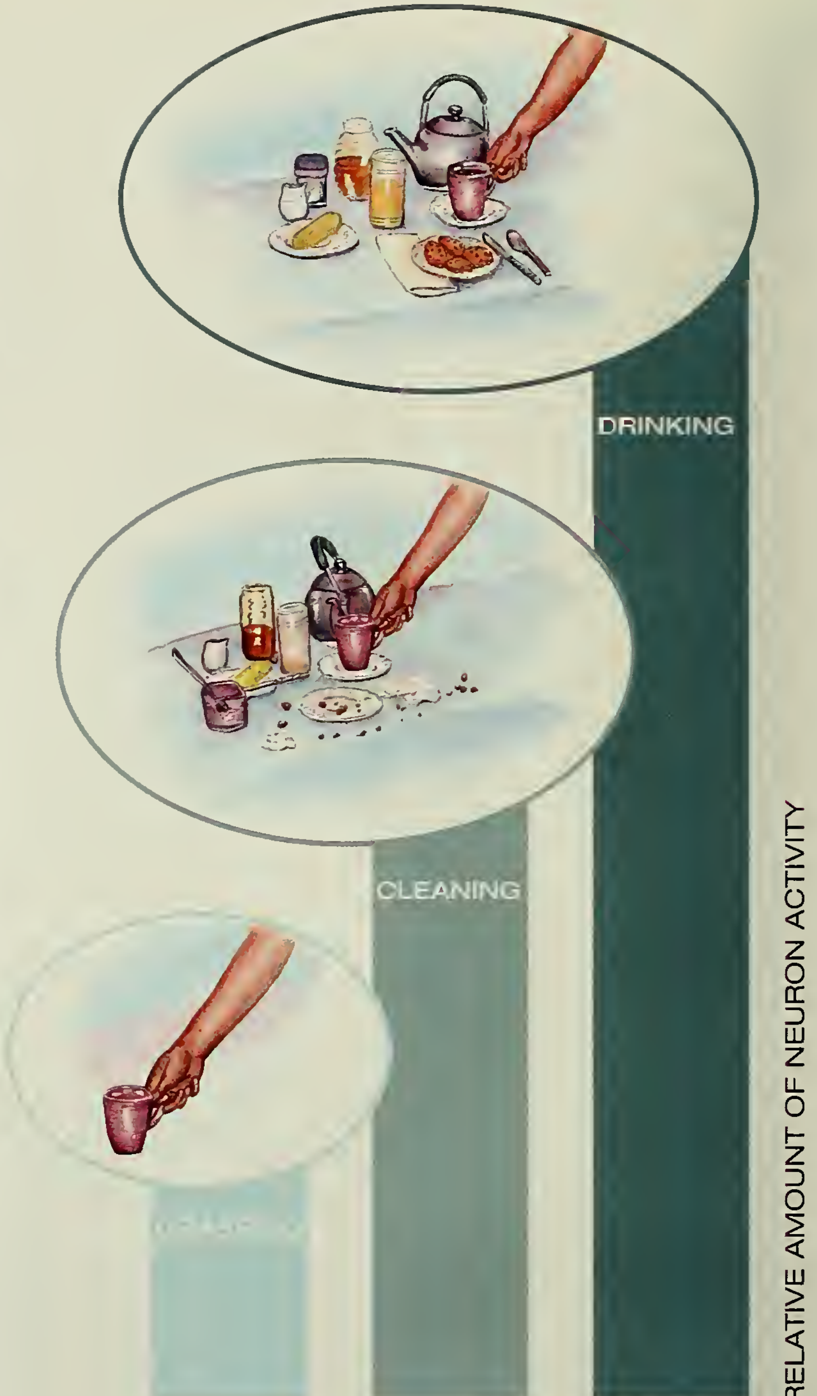
being in somebody else's shoes. So how do they actually predict the action that will follow an observed scene? How do they let us understand the intention associated with such an action? My hypothesis is this: we activate a chain of mirror neurons when we watch an action. This chain of neurons can anticipate a whole sequence—say, reaching for the cup, grasping it, bringing it to the mouth—and so can simulate the intention of the human we are watching.

Mirror neurons in such a chain may be of different types. One kind—so-called *strictly congruent* mirror neurons—respond to identical actions, either performed or observed. For instance, a strictly congruent mirror neuron fires both when a monkey grasps an object with two fingers, in a "precision" grip, and when that same monkey sees another primate grasping with a precision grip. A different mirror neuron, also strictly congruent, fires when the monkey grasps with its whole hand as well as when the monkey sees somebody else grasping in the same fashion.

Other mirror neurons, however, show a less strict correspondence between performed and observed actions. Those are known as *broadly congruent* mirror neurons. They fire at the sight of actions that may not be identical, but that achieve similar goals. For instance, a broadly congruent mirror neuron may fire when the monkey is grasping food with its hand, and also when the monkey sees somebody else bringing food to the mouth.

An important subset of the broadly congruent type of mirror neurons fire in anticipation of logically related actions. These *logically related* mirror neurons, as they are logically called, are probably the neuronal elements needed to understand intentions associated with observed actions. I see you grasping a cup with a certain kind of grip, and my grip mirror neurons fire, the strictly congruent ones. So far I am only simulating a grasping action. However, given that the context suggests drinking, my logically related mirror neurons, the ones that code for the action of bringing the cup to the mouth, fire even before the cup is brought to the mouth. By activating this chain of mirror neurons, my brain is able to simulate the intentions of others.

Why do some cells fire for actions that are logically related? No one knows for sure, but it's likely that mirror neurons "learn" from experience—such as when babies watch or interact with their caregiver. Suppose a baby



Three video clips involving the same simple action of grasping a cup were shown to test subjects: in the first, the action occurs against no background (left); in the second, the background is a messy table complete with cookie crumbs and dirty napkins, implying the aftermath of a tea party (middle); in the third, the context is a neat tabletop, in apparent preparation for a party (right). The neat scenario suggests that the intent behind grasping the full cup is to drink, whereas the messy scenario suggests an intent to clean up. The blue bars under the images represent the relative amount of activity of the observer's mirror neurons. Based on context, mirror neurons can distinguish intention. The activity of the observer's mirror neurons is greatest for the neat scenario—almost double the amount in the messy one—because drinking is a more fundamental intention than cleaning up.

sees a caregiver's hand put food on the table, and then the baby grasps the food to eat. Grasping food and seeing food placed become associated in the baby's brain. It's not that the mirror neurons know there is a logical connection between the two actions; rather, the baby-caregiver interaction links the two as part of a sequence.

Mirror neurons help explain an essential characteristic of humans: we have an instinct to imitate one another—to synchronize our bodies, our actions, even the way we speak to each other. This synchrony we enjoy with others often has an emotional component. For example, a study of how an interviewer's warmth impacts an interviewee's reaction showed that warm interviewers—those that leaned forward, smiled, and nodded—elicited similar movements, smiles, and nods from interviewees.

Such motor mimicry seems to play not only a communicative role, but also a perceptual one. Psychologist Ulf Dimberg of Uppsala University in Sweden demonstrated exactly that by studying the activity of facial muscles of subjects looking at pictures of happy or angry faces. When subjects were observing happy faces, activity increased in the cheek muscles that contract to smile; when they were observing angry faces, activity spiked in brow muscles that contract in anger.

Why all the mimicry? The answer comes from a study led by Paula M. Niedenthal, an American social psychologist who is director of research at Université Blaise Pascal in France. In her experiment, two groups of participants were asked to detect changes in the facial expressions of other people. The key was that one group was prevented from freely moving their own faces by holding a pencil between their teeth. The pencil severely restricts the ability to smile, frown, and make most other facial expressions—just try it. Therefore, the pencil hinders mimicry. Surprisingly, the participants holding the pencils between their teeth were much less successful in detecting changes in others' emotional facial expressions than were participants who were free to mimic the expressions they observed. Mimicking others is not just a way of communicating nonverbally; it helps us to perceive others' expressions (and therefore their emotions) in the first place.

I believe that mirror neurons provide an automatic simulation (or "inner imitation") of the facial expressions of other people, and that the process of simulation does not require explicit, deliberate recognition of the expression mimicked. Mirror neurons send signals to the emotional centers located in the limbic system of the brain, and thus trigger emotions appropriate to the observed facial expressions—the happiness associated with a smile, the sadness associated with a frown. Only after we feel the emotions internally are we able to explicitly recognize them. When a participant is asked to hold a pencil between his teeth, the motor activity required by that action interferes with the motor activity triggered by mirror neurons to mimic the observed facial expressions. The subsequent cascade of neural activations that would lead to explicit recognition of emotions is also disrupted.

If mimicry indeed supports recognition of emotions, then it follows that good imitators should also be good at recognizing emotions, and so endowed with a greater empathy for others. The tendency to imitate others and the ability to empathize with them ought to be correlated. That is exactly the hypothesis tested by the social psychologists Tanya L. Chartrand and John A. Bargh, then of New York University. In one experiment of theirs, the subjects were asked to choose the most stimulating pictures from a set of photographs. They were videotaped, and their motor behavior was measured. An experimenter pretending to be another subject sat in the same room with every real subject. (In experimental jargon, the posing subject was the "confederate.") While the real subject was choosing a picture, the confederate was engaged in a very deliberate action, either rubbing his face or shaking his foot. Analyzing the videotapes, Chartrand and Bargh discovered that subjects unconsciously mimicked the action of the confederate. Subjects sharing the room with the face-rubbing confederate rubbed their own faces more than subjects who shared the room with shaking confederates, and vice versa.

In a second experiment, Chartrand and Bargh tested

Red area shows location of mirror neurons in the ventral premotor cortex, the part of the brain responsible for coding object-oriented movements such as grasping, holding, and manipulating. This region lies adjacent to the primary motor cortex, which sends electric signals to the muscles.

the hypothesis that one of the functions of the "chameleon effect," or mimicry, is to increase the likelihood that two individuals will readily get along. Again, participants were asked to choose pictures in the company of a confederate pretending to be another participant. This time the participant and confederate took turns describing what they saw in various photos. All the while, the confederate either imitated the spontaneous postures, movements, and mannerisms of the subject or kept a neutral posture. At the end of the interactions, participants were asked to complete a questionnaire to report how much they liked the other participant (that is, the confederate) and how smoothly they thought the interaction had gone. You can predict the results by now: the participants who were mimicked by the confederates liked those confederates much more than the participants who were not imitated. Furthermore, the mimicked subjects rated the smoothness of the interaction higher than the participants who were not imitated. Clearly, imitation and "liking" tend to go together.

In their final, most critical experiment, Chartrand and Bargh tested the hypothesis that the more you mimic others, the more you are concerned about other people's feelings—that is, the more empathy you have. The setting was the same as in the first experiment, with the confederates either rubbing their faces or shaking their feet. The novel aspect, though, was that the participants also responded to a questionnaire that measured their empathic tendencies. Chartrand and Bargh found a strong correlation between the degree of imitative behavior displayed by a participant and his or her tendency to empathize. The more the subject imitated the face rubbing or the foot shaking, the more empathic an individual that subject was. These results suggest that it is in large part through mimicry that we are able to feel what other people feel, and so to respond compassionately to their emotional states.

The well-designed studies of Chartrand and Bargh are compelling, and join a host of others. For example, couples tend to have a "higher facial similarity" (they look more alike) after a quarter century of married life than at the time of their marriage. Moreover, the happier the marriage, the higher the couple's facial similarity. That's no surprise, really. Loving, sharing, and living together makes a spouse somewhat like a second self. Such examples point to the vital role of mirror neurons in our interactions with others.

Because "mirroring" is essential for empathy and social connection, impairment of the capacity to mirror can have profoundly negative consequences. In the late 1980s, psychiatrist and developmental psychologist R. Peter Hobson at University College, London, made a series of observations about children with autism that are very suggestive in the light of the later discovery of mirror neurons. Hobson was convinced that the main deficit in autism was emotional, not cognitive, and that it lay in the children's inability to "identify" with the emotions of others. To explore this hunch, Hobson devised a series of experiments that tested the ability of children with and without autism to notice facial expressions and to imitate behaviors associated with emotions—two skills vital to social communication and bonding that we now think may depend on normally functioning mirror neurons.

With his colleague S. Jane Weeks, a psychologist then at the Institute of Psychiatry in London, Hobson showed children with and without autism pictures of women or men, wearing either woolen caps or floppy hats, and making either happy or gloomy faces. The children were asked to sort the pictures based on how they differed. Obviously, the children could have chosen to sort by gender, hat, or facial expression. The first time, both the non-autistic children and those with autism used gender to sort the pictures. Weeks and Hobson then asked them to sort the pictures again, this time without regard to gender. Here came the difference: non-autistic children picked facial emotion as the sorting factor, whereas children with au-

An individual with autism would have a hard time perceiving the happy demeanor of another person. That's because a deficit in the mirror neuron areas of his brain makes it hard to notice and identify with emotions in others, and thus impedes the formation of social connections.

tism picked the hat. Such results encouraged Hobson in his conviction that the problem for children with autism is the missing emotional connection.

To test whether imitation deficits in children with autism are linked to their inability to resonate emotionally with other people, Hobson and his colleague Anthony Lee of the Tavistock Clinic, London, came up with an experiment in which children could imitate both what people did to accomplish a goal and the "style" with which they conducted themselves. Initially the children—divided into one group with autism and another without—were not even told to imitate Lee, who simply said, "Watch this." Then he performed simple actions with a number of objects. For example, he strummed a stick along a pipe rack, making a graceful and gentle strumming action for half of each group, and a harsh strumming for the other half of each group. After a break, the children were allowed to use the stick and pipe. What did they do? All the children strummed the stick along the pipe rack, but only the non-autistic children imitated the harsh or gentle style that Lee had adopted in front of them.

It should come as no great surprise, then, but serves as important proof, that at least six different laboratories using a variety of techniques for studying the human brain have recently confirmed deficits in mirror neuron areas and their interactions with the limbic system in individuals with autism.

Our growing knowledge of the powerful neurobiological mechanisms underlying human sociality provides an invaluable resource not only for understanding and helping children with social deficits, but also for helping all of us learn how to increase empathy in our lives and in the world. My hope is that a more explicit understanding of our empathic nature will become a factor in the deliberate, reflective discourse that shapes society. For instance, our knowledge of the basis of human sociality can help us open ourselves to other cultures without losing touch with our own.

People often say that they are moved to sadness when they watch a tearjerker film; they are moved to joy when their child hits a home run or performs in a recital. In a literal sense, they are indeed "moved." Their mirror neurons are subtly activating the matching muscles in their faces and bodies. There is something like physical contact, like a beautifully synchronized partner dance, when we orchestrate motions and emotions in our minds while watching someone else.

People seem to have the intuition that "being moved" is the basis of empathy, and thus of morality. We have evolved to connect deeply with other human beings. Our new awareness of how literally this is true can and should bring us even closer to one another.

Marco Iacoboni is a neurologist and neuroscientist originally from Italy. Today he is at the David Geffen School of Medicine at University of California, Los Angeles, where he is Director of the Transcranial Magnetic Stimulation laboratory at the Ahmanson-Lovelace Brain Mapping Center. His brain-imaging studies have pioneered the investigation of the mirror neuron system in humans. He lives in Los Angeles, California.

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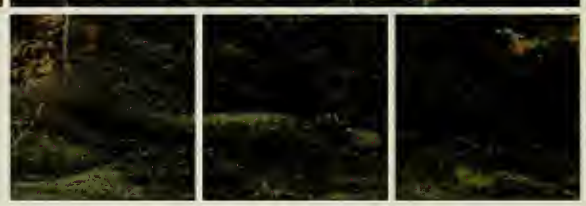
POOR NUTRIENTS, THIN SOILS, AND A HELPING OF HEAVY METALS MAKE FOR RICH, YET VULNERABLE PLANT COMMUNITIES.

GARDEN ON THE ROCKS



By SUSAN P. HARRISON and ARTHUR R. KRUCKEBERG

In 1872 a journalist from the *Napa Reporter* ventured to a remote mine at the northern tip of Napa County, California, far from the area's fertile wine-growing valley. At the time, the so-called Knoxville Mine was a major producer of mercury that was used to extract gold from the California Mother Lode, a 120-mile-long bonanza of ore to the east. After a steamy and sulfurous descent to a depth of 220 feet, the journalist emerged to describe the surrounding landscape as "a terrible waste of God's country, for as far as the eye could reach it presented a terribly broken aspect being nothing in fact but a jumble of hills and canyons covered with sage brush."

If the journalist had been a naturalist, he might have recognized that the "waste" was an expanse of shattered serpentine, an unusual, mostly greenish rock, and that the "sage brush" harbored neither sage (plants in the genus *Salvia*) nor sagebrush (*Artemisia*). Instead, an unusual mix of stunted shrubs and rare herbs was growing on the soils worn from those particular rocks. Unwittingly, in fact, the journalist surveyed a prime example of one of the harshest natural substrates on Earth.

Today, the jumble of hills and canyons is alive with activity. Researchers at the McLaughlin Reserve, a field station administered by the nearby University of California, Davis, are learning how plants cope with the inhospitable serpentine soils. The researchers transplant species from one soil to another to check whether they've adapted to local conditions; they measure how much water the plants can extract from the rocky ground; and they build rainproof shelters to test how climate change might affect the soil-restricted plant species. As they work, gunshots and the roar of four-wheelers and dirt bikes pierce the air from nearby public lands, as the wasteland also attracts a hard-playing weekend crowd. The conjunction of severe landscapes, rare plants, unsolved evolutionary puzzles, and less-than-gentle land use is emblematic of the ways that serpentine alters the web of terrestrial life, wherever it appears.

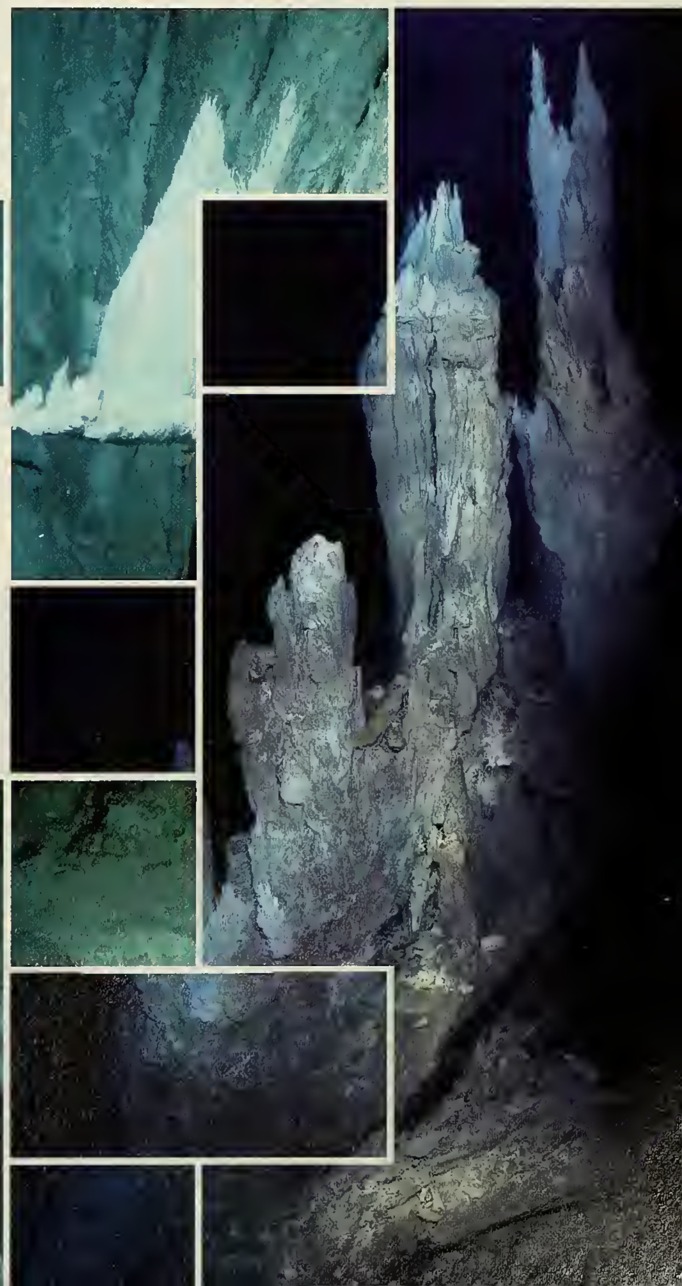
Snakes are at the root of the word "serpentine," from the Latin *serpens*. The association is most obvious in the resemblance between serpentine's mottled surface and the skin of snakes, which may be what led the Greek physician Dioscorides to recommend pulverized serpentine rock as an antidote for snakebite—not a prescription you'd want to rely on in an emergency. The rock can be beautiful, and the typical green forms in particular are often fashioned into jewelry and sculpture or used as an architectural embellishment.

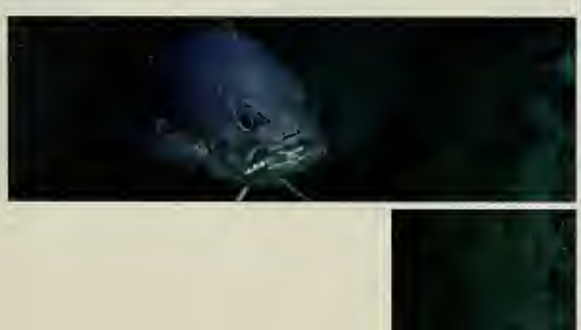
Serpentine rock (serpentinite to the geologist) belongs to a family of rocks known as the ultramafics, which are largely composed of iron magnesium silicate. Ultramafics from the Earth's upper mantle emerge at mid-ocean spreading centers, where new oceanic crust is forming and tectonic plates are moving apart. In the presence of water, such ultramafics as dunite and harzburgite may be transformed into serpentine.

In 2000, scientists discovered the so-called Lost City, a cluster of towering, bizarrely shaped carbonate formations in the Atlantic abyss [*see photographs on this page*]. The formations arise from mineral-rich hydrothermal vents produced where extensive faulting has stripped away the upper layers of the crust, thus exposing ultramafics to seawater. The Lost City vents are powered not by volcanism (as are sulfurous "black smoker" vents), but by heat and gases from the chemical reactions that form serpentine. The waters around them are relatively cool, alkaline, and abundant in hydrocarbons, such as hydrogen and methane. Indeed, the wealth of hydrocarbons—molecules essential to life—have led scientists to speculate that serpentine vents played a role in how life on Earth arose.

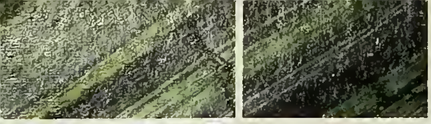
Serpentine and its ultramafic relatives are slow to join the terrestrial world. As part of the mantle underpinnings of new ocean crust, they move outward from spreading centers in the ocean floor until they reach the edge of a continent. There they may be forced down, or "subducted," beneath the lighter continental plate. But some of the rocks escape subduction and get scraped onto the edge of the continental plate, like a berm scraped up by a bulldozer. That helps to explain why serpentine outcroppings are generally small areas within large expanses of other rock types. Yet naturalists have encountered them on every continent, in every major biome, and at every altitude from sea level to alpine [*see map on following page*].

Where serpentine turns up on land surface, chemical and physical weathering transform it into soil. Serpentine soils have a nearly universal set of attributes—what the late Swiss soil scientist Hans Jenny called the "serpentine syn-



Opposite page: Fragments of serpentine rock and photos of the McLaughlin Reserve in northern California. Right: Towers of carbonate formations found in the Atlantic abyss, dubbed "The Lost City," arise from hydrothermal vents powered by chemical reactions that form serpentine.



drome"—that profoundly affects the plants that grow on them. They're deficient in calcium and other essential nutrients, such as nitrogen and phosphorous. They contain large amounts of magnesium, which interferes with the uptake of what little calcium there is. They usually have high levels of the heavy metals nickel, chromium, and cobalt. And they're often rocky and shallow and thus very dry.

Plants have evolved a variety of ways to cope with serpentine soils' atypical and stressful chemistry. In the 1940s and 1950s, Richard B. Walker, who is now a professor emeritus of botany at the University of Washington in Seattle, conducted a series of experiments in which he altered the amount of calcium in test plantings. Plants endemic to serpentine soils thrived on the low calcium levels, while non-serpentine species grew poorly. The serpentine plants evidently have adapted to make efficient use of what little is available. In addition they may have developed ways to cope with the excess magnesium that inhibits the uptake of calcium: they either exclude it when they take up water and minerals from the soil or sequester it in their tissues.

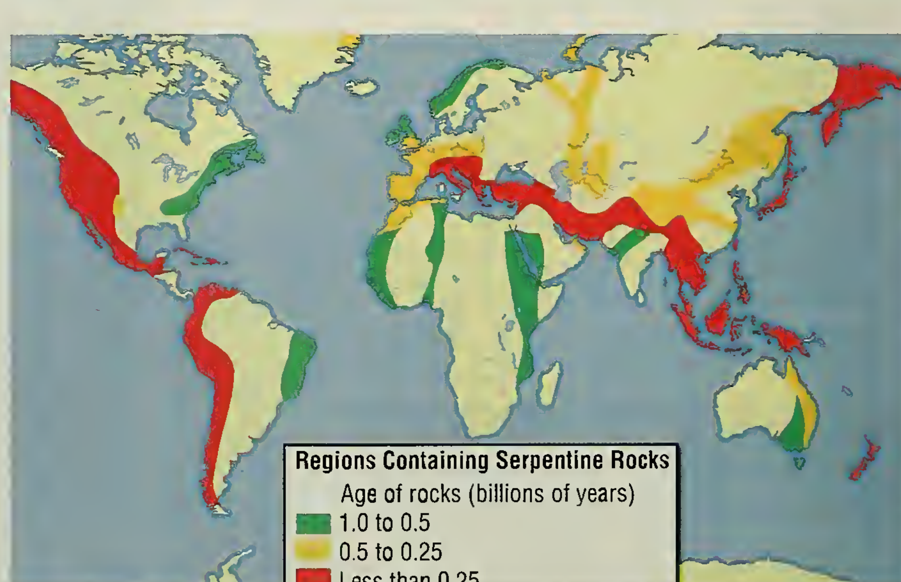
Nickel is also abundant in some serpentine soils, and certain species can take it up and store very high levels of it in their tissues—sometimes more than 1 percent of their dry weight. Such plants, mostly serpentine endemics, are known as hyperaccumulators, and they occur most often in the tropics, where nickel levels are particularly high. Some—such as *Berkheya coddii* (a South African member of the aster family)—are deliberately grown on nickel-rich soils, then harvested and burned to collect the mineral for industrial use or to remove it from contaminated sites. Not much is known, however, about how cobalt and chromium affect plants.

Another adaptation is evident in the leaves of many serpentine plants, which are small, thick, grayish, hairy, wax-coated, or spiny—or a combination thereof. Those features generally help minimize water loss and conserve nutrients. It's hard to say whether the plants are responding to an actual water shortage or compensating for a scarcity of nutrients, or both. Attila Borhidi, a botanist at the University of Pécs in Hungary, calculated that the leaves of plants growing on serpentine are similar in their size, thickness, and spininess to the leaves of plants growing on normal soils that receive twenty inches less rain every year.

With such physiological challenges, it's no surprise that the hallmark of serpentine vegetation worldwide is its slow growth. Serpentine vegetation thus takes longer to recover after a fire, and planned burnings must be used cautiously, if at all. In addition to slow growth, the plants tend to be stunted and sparse compared with vegetation on surrounding soils—a distinction that often makes for a patchwork landscape. If a region's dominant vegetation is closed-canopy conifer forest, for example, nearby serpentine might support open pine savannahs; if the dominant vegetation is oak woodland, intrusions of serpentine might host shrublands (also called chaparral); if grassland dominates, then serpentine might consist of open, rocky barrens; and so on.

Paradoxically, serpentine that supports spare woody vegetation often has an abundance of species, which thrive in the open, sunny understories. Indeed, in spite of the stresses, some plants have adapted to serpentine so successfully that they grow nowhere else. In California alone, about 12.5 percent of the state's 2,000 endemic species are restricted to serpentine, and many are quite showy. In the tropics, New Caledonia (in the Pacific) and Cuba vie for world championship; each island has more than 900 known serpentine endemics [*see photographs on page 44*].

Serpentine is soft and weak, and has usually been shattered by tremendous tectonic forces during its journey to Earth's surface, so it readily forms vast masses of sharp-edged scree that drift down hillsides. That is the most barren of serpentine habitats, where only the hardiest plants can survive. The same rock characteristics, however, allow underground water to move through cracks in the masses of shattered rock instead of through pores in rock, as it does elsewhere. When such water encounters an impermeable layer, it may emerge at a slow but steady rate, often enabling small wetlands to flourish within otherwise desolate serpentine areas. These contrasting habitats support some of the rarest serpentine endemics,



JOE LEMONNIER

such as the Snow Mountain buckwheat (*Eriogonum nervulosum*) and the swamp larkspur (*Delphinium uliginosum*).

Besides the wealth of endemics, serpentines support numerous species that range widely elsewhere. Within some of those species, though, there are marked differences in populations growing on and off serpentine. The common yarrow, *Achillea millefolium*, for instance, has genetic races that grow well or poorly on serpentine soils.

Jewelflowers of the genus *Streptanthus* neatly illustrate the evolutionary path from mere tolerance to obligate growth on serpentine soils. At one end of the spectrum is *S. glandulosus*, which is widespread both on and off serpentine soils; one race of that species is tolerant of serpentine soil and one is intolerant. Other species have taken a further evolutionary step: after living on serpentine for many generations, their "tolerant" races became genetically isolated from their parent populations. A striking example is the delicate, maroon-petaled Tiburon jewelflower, *S. niger*, found only on a sliver of serpentine on the Tiburon Peninsula, just across the bay from San Francisco.

An alternative pathway to serpentine endemism is the stranding of a species on serpentine outcrops following climate changes. In Norway, for instance, the sandwort *Arenaria norvegica* was widespread during the ice ages, when forests were temporarily absent. When forests later recolonized southern Scandinavia, the sandwort was confined to serpentine, the only place it could remain free from competition with trees. In treeless northern Scandinavia, however, the sandwort still occurs on other soils.

In addition to plant life, serpentine habitats support characteristic microorganisms, plant-dependent insects, and even some birds and mammals. The role of the microbial biota, including bacteria and fungi, in serpentine habitats is becoming an active field of study. Researchers would like to know if microorganisms have evolved tolerance to the demanding properties of serpentine, and if they in turn partly account for serpentine tolerance in plants. That certainly seems to be the case with the longspur lupine, *Lupinus arbustus*, a legume from the western United States that bears nitrogen-fixing *Rhizobium* bacteria in its root nodules. The strain of *Rhizobium* particular to the longspur lupine has evolved its own tolerance to the deviant chemistry of serpentine soil. Researchers are also examining whether ubiquitous fungi that are symbiotically linked to the roots of their host plants, mycorrhizae, have any role in serpentine tolerance.

Herbivorous insects on serpentine must cope with the unusual chemistry of their food—and high nickel levels are particularly demanding. At first, scientists thought hyperaccumulation in plants simply reflected the plants' own way of coping with nickel-rich soil. But Robert S. Boyd, a plant ecologist at Auburn University in Alabama, and his colleagues had another idea. Through a series of tests they established that hyperaccumulator plants have the extra advantage of deterring most herbivores. Only insects that spend their lives on serpentine vegetation can tolerate grazing on the hyperaccumulators. Insects that tolerate such a high-nickel diet have now been documented in California and New Caledonia. Those herbivores, it seems, have won the coevolutionary race—for now, at least!

ROBERT S. BOYD

Jewel flower, Streptanthus polygaloides, *is a hyperaccumulator of heavy metals, which keeps most pests away. Yet a few creatures, such as the jewel bug* (Melanotrichus boydi) *seen above, can tolerate the high levels of nickel and spend their lives feasting only on serpentine vegetation.*

Human activities have taken their toll on serpentine landscapes worldwide. Miners scoop up large swaths of serpentine soil to remove nickel in New Caledonia and Cuba. They have also extracted chromium in Oregon, gold and mercury in California, and asbestos in Vermont, from within or near serpentine formations. In recent years, off-road vehicles have damaged serpentine areas in California and elsewhere, while urbanization threatens the endemic-rich serpentine of the San Francisco Bay Area. Geochemists have proposed strip-mining vast quantities of serpentine in an effort to sequester carbon dioxide emitted by power plants. The serpentine would be ground up, dissolved in sulfuric acid, and mixed with lye to produce a cocktail that readily reacts with carbon dioxide; the byproducts are magnesite (a useful building material) and sulphur dioxide, which could be recycled. This daring idea has yet to be implemented on a large scale.

Fully half of California's 200 or so serpentine endemics are considered rare or endangered; their natural rarity is often compounded by human disturbance. The harshness of serpentine soils has the fortunate effect of keeping many invasive introduced species at bay. But in California, at least two widespread exotic grasses—wild oat (*Avena fatua*) and soft chess (*Bromus hordeaceus*)—have evolved serpentine-tolerant races in the two centuries since their arrival from the Mediterranean region. More ominously, a newer invader from southern Europe, barbed goatgrass (*Aegilops triuncialis*), appears capable of moving into some of the state's most pristine serpentine habitats, where it excludes nearly all natives.

Historically, the United States has reserved its highest levels of land protection for scenic wonders such as the Grand Canyon or Mt. Rainier. The U.S. Forest Service and the U.S. Bureau of Land Management oversee the majority of serpentine lands in the West, and those agencies have only slowly come to appreciate them enough to extend a degree of protection. In eastern North America, the only major preserve with serpentine is Gaspé Provincial Park in Quebec. Elsewhere, serpentine preserves are limited to a handful spread about in Great Britain, Switzerland, Italy, and Cuba, with not even one preserve for the rich serpentine flora of New Caledonia. Serpentine habitats provide one of the most compelling environments for the study of natural selection and the origin of new species—but they are fragile and often neglected. We who study them can only hope that the botanical richness of these "wastelands" will become more widely known and cared for.

Susan P. Harrison is a professor of conservation biology at the University of California, Davis. She has studied how the distribution of serpentine outcrops affects plant diversity and the persistence of rare plants. She is coauthor of *Serpentine Geoecology of Western North America: Geology, Soils, and Vegetation* (Oxford University Press, 2007). **Arthur R. Kruckeberg** is emeritus professor of botany at the University of Washington in Seattle. His studies, particularly of flora in the western U.S., are cornerstones in understanding serpentine ecology. The books he has written include *Introduction to California Soils and Plants: Serpentine, Vernal Pools, and Other Geobotanical Wonders* (University of Californial Press, 2006).

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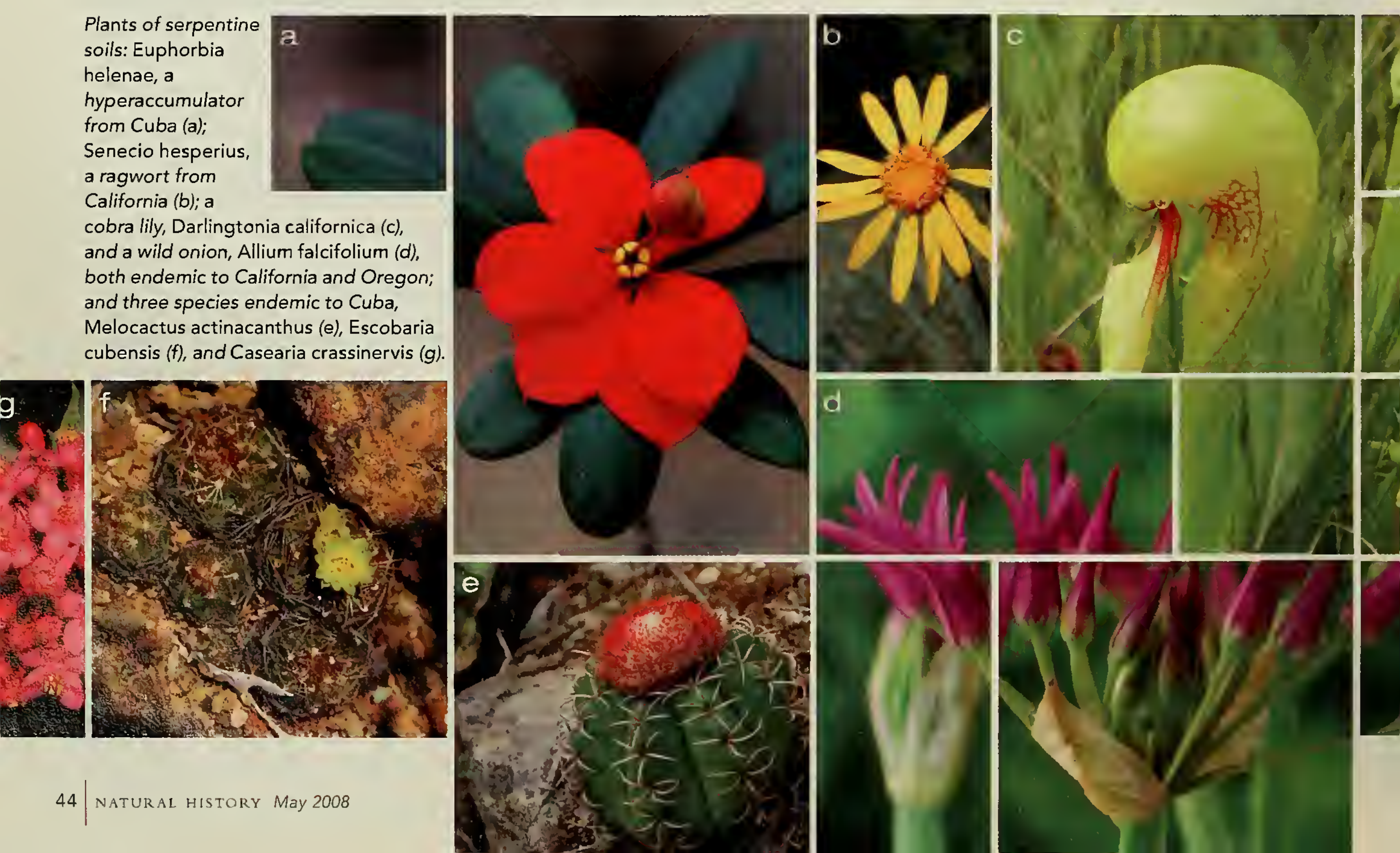


Plants of serpentine soils: Euphorbia helenae, *a hyperaccumulator from Cuba (a);* Senecio hesperius, *a ragwort from California (b); a cobra lily,* Darlingtonia californica *(c), and a wild onion,* Allium falcifolium *(d), both endemic to California and Oregon; and three species endemic to Cuba,* Melocactus actinacanthus *(e),* Escobaria cubensis *(f), and* Casearia crassinervis *(g).*

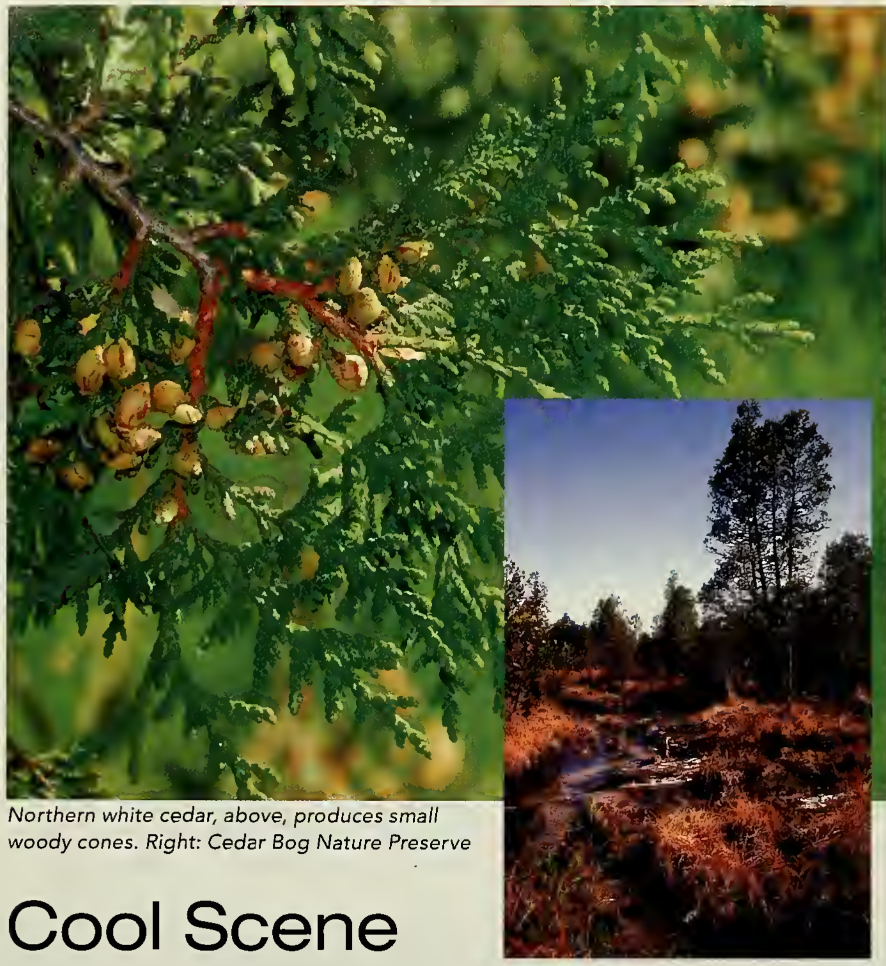


PHOTO BY ANDRE KARWATH, CC-BY-SA; INSET: COURTESY OHIO HISTORICAL SOCIETY

Northern white cedar, above, produces small woody cones. Right: Cedar Bog Nature Preserve

Cool Scene

A bog in Ohio is a reminder of the last ice age.

Northern white cedar bogs are common in Canada and in the northern parts of some adjacent states, notably Michigan, Wisconsin, and Minnesota, but they rarely turn up farther south. One outlier of this boreal ecosystem, however, is the centerpiece of the Cedar Bog Nature Preserve in western Ohio, operated by the Ohio Historical Society. It is a relict habitat, a leftover from the environmental changes that came after the last ice age. Between about 30,000 and 12,000 years ago, ice covered most of modern-day Ohio. When the glaciers retreated northward, such evergreen trees as northern white cedar—tolerant of the cold, boggy conditions—colonized the area. Then deciduous forests, along with tongues of grassland that extended from the west, took over the region. But in depressions where temperatures are relatively cool and cold-water springs maintain a stable water table, plant species such as white cedar have retained a roothold.

Although the white cedar bog occupies only about a tenth of the 428-acre preserve, the habitat was once much larger. It was reduced in 1912, 1915, and 1929 by nearby ditch digging and dredging of the Mad River, to drain land for farming and deepen the river. A small spring-fed stream known as Cedar Run flows north to south in the eastern side of the preserve, and most of the white cedars grow there. The water level in the bog varies only a few inches during the year, assuring a stable water supply, and the soil is consistently cooler than in the surrounding habitats. A study conducted in the winter of 1966–1967 recorded soil temperatures in the white cedar bog that regularly fell below freezing during a seventeen-week period, while surrounding soils never dropped below 32 degrees Fahrenheit. And as far as surface temperatures go, on average there are only 84 frost-free days annually in the bog, while the surrounding areas average 153 frost-free days.

The northern white cedar species in the bog—also called arbor vitae—is not a true cedar. Native to the Old World, true cedars, such as the cedar of Lebanon, belong to the genus *Cedrus*. They fall within the pine family, because their needles grow in clusters, like those of pines and larches. The white cedars found in North America have tiny, scale-like

HABITATS

White cedar bog Plants commonly found growing beneath the northern white cedar trees include bishop's-cap, Canada mayflower, jack-in-the-pulpit, partridgeberry, rue anemone, sharp-lobed hepatica, starflower, and swamp thistle. The habitat is also home to such orchids as lesser purple-fringed orchid, oval ladies'-tresses, small green wood orchid, and small yellow lady's slipper.

Marl meadow Sedges include needle beakrush and two spikerushes (none of which are rushes) and seaside arrowgrass (which has grasslike leaves but is not a grass). Two other species in the habitat are fringed gentian and white camas.

Bog meadow Scattered among the hummocks of grasses and sedges are small shrubs of shrubby cinquefoil and swamp birch. The many wildflowers include bog goldenrod, Canada burnet, fringed gentian, grass-of-Parnassus, grass-pink orchid, Ohio goldenrod, queen-of-the-prairie, showy lady's slipper, sticky tofieldia, white turtlehead, wingstem, and round-leaved sundew, a carnivorous plant.

Michigan lily

leaves that are not borne in clusters. These trees actually belong to the cypress family.

Northern white cedar (*Thuja occidentalis*), which grows in the northeastern U.S. and Canada, has flattened branchlets, produces small woody cones, and has light-colored to white wood. In many of those respects it resembles both the Atlantic white cedar (*Chamaecyparis thyoides*—*thyoides* means "like *Thuja*"), found in the eastern U.S. from Florida to Maine, and a member of its own genus, *T. plicata*, found in western states and Alaska. The latter species has pale-reddish heartwood, and its common name—understandably but unhelpfully—is western red cedar. I say unhelpfully, because the eastern red cedar, a member of the genus *Juniperus* (also in the cypress family), differs dramatically: it does not have flattened twigs, and it produces berrylike fruits instead of cones.

Many of the white cedars in the preserve are quite old—perhaps 200 years or more. The soil beneath them is moist, pooling occasional surface water during rainy spells in spring and fall. Most of that soil and any exposed white cedar roots are covered by mosses and liverworts. Among other plants that thrive on the forest floor are various orchids.

Near the stands of white cedar trees are three habitats with shallow standing water. Where there's a three- to four-foot-thick underlying layer of marl—a lime-rich soil—a mucky habitat known as a marl meadow develops. Meadow zones without marl are called bog meadows. Dominated by sedges and cold, alkaline ground water that rises to the surface, both habitats are more accurately termed alkaline fens. Collectively they contain the vast majority of the forty-two Cedar Bog species that are listed by the state as threatened, potentially threatened, and endangered. In transitional areas between the white cedar bog and the two kinds of meadows are zones dominated by shrubs.

Immediately west of the white cedar bog is a swamp forest, and west of that forest, at slightly higher elevations, is a deciduous hardwood forest. The latter falls within the preserve boundaries but is not a wetland habitat, as are the others.

Robert H. Mohlenbrock is a distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.

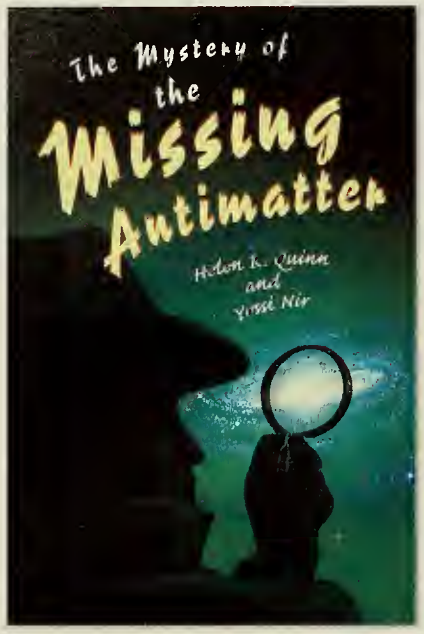
VISITOR INFORMATION
Cedar Bog Nature Preserve
980 Woodburn Road
Urbana, OH 43078
800-860-0147
ohsweb.ohiohistory.org/places/nw02
and www.cedarbog.org

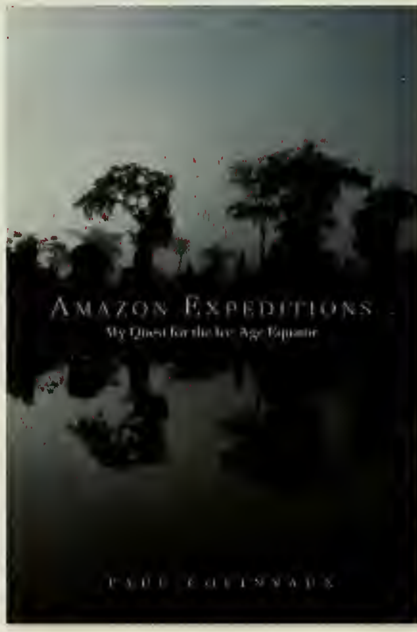
Sharp-lobed hepatica

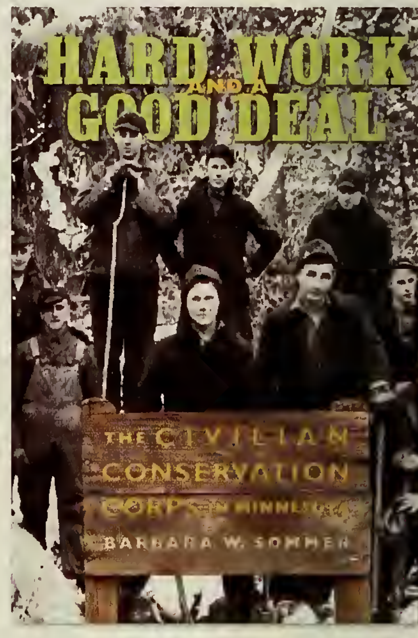
Shrub community Among the shrubs are alder-leaved buckthorn, blue-leaf willow, gray alder, gray dogwood, ninebark, poison sumac, pussy willow, red elderberry, and swamp birch.

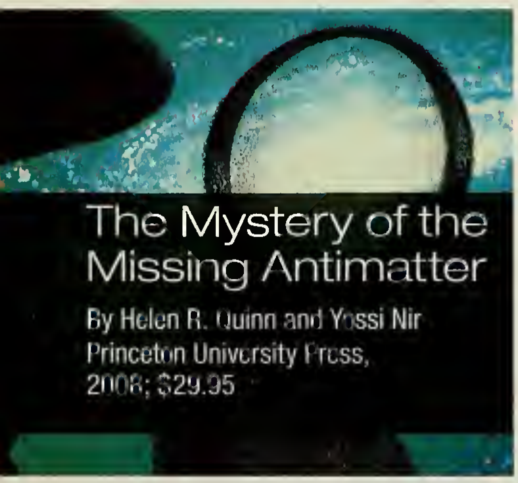
Swamp forest The higher terrain contains American basswood, American hornbeam, black ash, red maple, tulip poplar, and wild black cherry. Beneath those trees are a mix of upland and wetland species, including goldenglow, Michigan lily, purple meadow rue, and white snakeroot. In lower elevations the forest is made up of black ash and red maple above a ground layer dominated by two ferns—cinnamon fern and silvery spleenwort.

Hardwood forest Large American beech and sugar maple trees are joined by chinquapin oak, Ohio buckeye, pignut hickory, red maple, shagbark hickory, and slippery elm. Wildflowers include American germander, bluestem goldenrod, hairy pagoda plant, putty-root, Solomon's-seal, spring beauty, star sedge, white avens, wild blue phlox, wild geranium, wild ginger, woolly blue violet, and zigzag goldenrod.









The Mystery of the Missing Antimatter

By Helen R. Quinn and Yossi Nir
Princeton University Press, 2008; $29.95

There was a time, around the 1960s and 1970s, when it was easy to tell a particle physicist from a cosmologist: the former studied the smallest things in nature, the latter the largest. But more recently, particle physicists have come to view the Big Bang as a particle experiment of cosmic proportions, an accelerator far more powerful than any they could ever create on Earth, and cosmologists have realized that they must study the small bits of the cosmos to understand its large-scale formation.

That is why Helen R. Quinn and Yossi Nir, both eminent particle physicists, have written a book about one of the most mysterious properties of the cosmos at large: the virtual absence of antimatter. The laws of microphysics tell us that, just after the Big Bang, every particle had a mirror twin, opposite in charge but equal in mass. For each electron there was an antielectron, for each quark an antiquark, and for every neutrino an antineutrino.

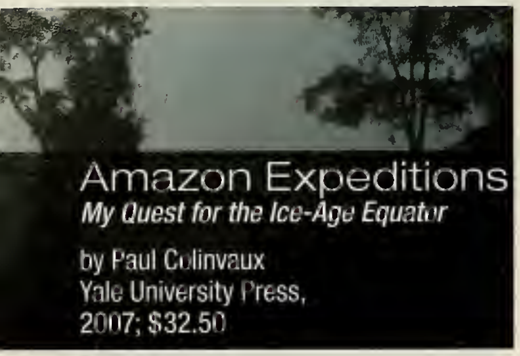
And presumably it should have stayed that way. Particles and antiparticles are created in pairs and destroyed in pairs; when an electron and an antielectron collide, for example, both vanish in a flash of light. Such fundamental symmetry means that, as the universe expands, the balance sheet for matter and antimatter shouldn't change. Yet the balance today is skewed toward matter—in fact, there is almost no antimatter in our known universe —so it must have shifted sometime, probably after the first few instants of ultrahot homogeneity, leaving behind a universe of matter particles with no anti-"twins" to annihilate them. How that happened is not yet clearly understood.

The most likely explanation lies somewhere deep in the physics of fundamental particles, a theory that cannot yet adequately describe the earliest moments of creation. We know that the answer must involve some tiny asymmetry in the way the laws of physics operate under extreme conditions, which would produce more particles of regular matter than antimatter. Although a consistent mathematical theory of such conditions has not yet been developed, it's one of the most active areas of theoretical physics today.

Quinn and Nir have a daunting task explaining the ongoing work in nonmathematical terms, which may make their book hard going for those whose last exposure to physics was in high school. Still, if you liked reading cosmologist Steven Hawking's *A Brief History of Time*, or particle physicist Brian Greene's *The Elegant Universe*, you will find *The Mystery of the Missing Antimatter* an absorbing scientific whodunit.

Continued on page 52

Continued from page 50

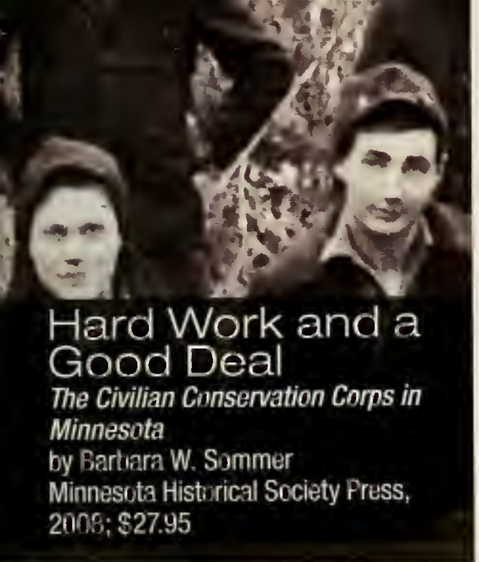


Paul Colinvaux may be in his seventies, but he still has the spirit of a young Turk. Throughout this feisty and often inspiring memoir of his life as a plant ecologist runs a constant stream of argumentation. As he states repeatedly, Colinvaux is convinced that during the last ice age, which ended about 10,000 years ago, the climate of the Amazon forest was not too different from what it is today. That, Colinvaux hastens to state, runs contrary to the orthodox view that during ice ages the Amazon became a much drier place, with only a few "refuges" of rainforest surrounded by semiarid grassland.

Colinvaux begs to differ with conventional wisdom, largely on the basis of evidence he and his colleagues have gathered from lake bottoms and swamps along the equator. The method he employs sounds fairly straightforward, but in practice it's extremely difficult: First you find a remote lake whose bottom has been collecting sediment for tens of thousands of years. Then you paddle a rubber dinghy out into the lake, hoping for no sudden storms, and sink a coring tube as deep into the lake bottom as you can to extract an undisturbed sedimentary sequence. Safely back in the lab, you examine each layer in the core for evidence of the age and type of vegetation that lived in the vicinity when the layer was laid down. A wide variety of chemical and physical techniques help at this stage, chief among them radiocarbon dating of organic material and a close analysis of the types of pollen found in the layer.

The difficulty of surveying ice-age sediments along the equator is so great that the project took Colinvaux nearly forty years, first to find the proper lakes, then to reach them, and finally to learn to recognize and analyze the pollen they contained. Colinvaux has rappelled into the craters of extinct volcanoes, feasted on roast caiman a hundred kilometers from the nearest human habitation, and battled mites, mosquitoes, and (worst of all) customs agents. He's backpacked and helicoptered into virtually inaccessible spots encumbered by a full complement of rubber rafts, sounding gear, and drilling pipe.

You don't need to share his obsession to understand both the difficulty of this enterprise and the care and passion with which he carried it out. And best of all, thanks to this welcome book, you don't need to break a sweat to accompany him on his journeys.



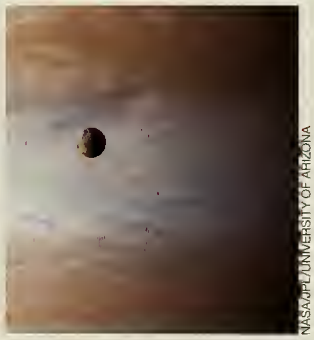
The Emergency Conservation Work Program, popularly known as the Civilian Conservation Corps (CCC), was one of the first established and most fondly remembered programs of the New Deal. Proposed to Congress on March 21, 1933, its aim was to put jobless young men to work on the land. By the summer of that year there were already over a thousand CCC camps scattered around the nation, and over a quarter million recruits had moved into barracks where they lived frugally and labored hard.

Doubtless there were those who regarded the CCC as a form of welfare in disguise. But its environmental impact was far more important and lasting than its economic effects. In Minnesota, the focus of oral historian Barbara W. Sommer's study, the CCC came at a time when the conservation ideals of Teddy Roosevelt's era were only beginning to take root. Logging of the 1800s had turned vast northern forests into rocky wastelands. In the southern part of the state, intensive farming had stripped the land of grass and woodland. State forests had been established, and soil conservation agencies existed, but they were still small and poorly funded.

The CCC brought discipline, direction, and most important, manpower, to the conservation tasks at hand. The "boys," as they called themselves, set up nurseries to grow seedlings and went out in platoons to plant and prune. The combined camps eventually planted over 120 million trees statewide. Brigades of CCC work-

Continued on page 56

SKYLOG BY JOE RAO



Io, one of Jupiter's moons, cruises the planet's surface.

It's not very often that Mercury is easier to see than dazzling Venus. But Mercury begins May in the midst of its best evening apparition of the year for northern observers. It's an easy to see naked-eye object, while Venus is hopelessly hidden deep in the glow of sunrise all month. Mercury sets an hour and a half after sunset on the 1st; by the 14th it is setting nearly two hours after the Sun.

As it happens, one of Jupiter's four largest moons is as big as Mercury, and another one is even bigger, though they are too far from us to be seen without binoculars or a small telescope. The Giant Planet's main moons are, in descending order of size, Ganymede, Callisto, Io, and Europa. They are commonly known as the Galilean satellites, because they were first described by Galileo in 1610. (Nearly sixty smaller moons also orbit the planet, two-thirds of them discovered only in the past decade, thanks to advances in digital imaging and computer analysis.)

Sky watchers in the eastern United States and Canada who look at Jupiter on the night of May 21-22 are in for a surprise: all the Galilean satellites will be briefly hidden. From 11:51 P.M. until 12:10 A.M. eastern daylight time (EDT), Io and Callisto will be eclipsed by Jupiter's shadow, while Europa is passing in front of the planet and Ganymede is behind it. Such a coincidence happens only about twenty-five times per century.

JOE RAO (hometown.aol.com/skywayinc) *is a broadcast meteorologist and an associate and lecturer at the Hayden Planetarium in New York City.*

May Nights Out

1 and 2 Look for Mercury low above the west-northwest horizon about an hour after sunset; nearby are the Pleiades (discernable through binoculars), the V-shaped Hyades star cluster, and, seemingly part of the Hyades, the orange star Aldebaran.

3 High in the south-southwest as evening twilight ends, Saturn is set to resume its direct (eastward) motion against the background stars. The ring system is at its maximum tilt toward us for the year.

4 Mars, well up in the western sky as darkness falls, moves into a straight line with Pollux and Castor, the "twin stars" of Gemini.

5 The Moon is new at 8:18 A.M. EDT.

6 A thin crescent Moon sits a couple of degrees above and slightly to Mercury's right, low in the west-northwest before they both set at evening twilight's end.

11 The Moon waxes to first quarter at 11:47 P.M. EDT.

14 Mercury reaches its greatest eastern elongation, or apparent distance, from the Sun, 22 degrees. After sunset it remains in sight for nearly two hours, setting three minutes after full darkness descends.

19 The Moon becomes full at 10:11 P.M. EDT.

21 For viewers in the eastern U.S, and Canada, Jupiter briefly appears without moons, low in the southeast (see story above). The phenomenon ends at 12:10 A.M. EDT (May 22), when Ganymede pops out from behind Jupiter. Farther west, Jupiter will not rise until after Ganymede has emerged.

27 The Moon reaches last quarter at 10:57 P.M. EDT.

BOOKSHELF

Continued from page 53

ers also labored at soil conservation, building stone dams to trap topsoil in outwash gullies, planting windbreaks to prevent wind erosion, and more.

There's nothing like the CCC nowadays. The last camp in the U.S. closed in 1942 as prosperity reduced the number of recruits and the national priorities of wartime came to the fore. But the marks of the CCC remain in park buildings and wilderness roads, windbreaks and trailside shelters, revitalized forests and reclaimed farmland. And, thanks to Sommer, the words and photographs of a generation of CCC workers bring this history of the land of ten thousand lakes to life.

Laurence A. Marschall is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.

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Located in historic St. Michaels, the Museum boasts ten waterfront exhibits, working boat yard, and the largest collection of Bay boats.

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Home to Blackwater National Wildlife Refuge; explore the heart of Chesapeake Country.

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Maryland's Crossroads of History. Antiques, battlefields, covered bridges, parks, wineries and more close to Gettysburg and DC.

27. KENT COUNTY
A scenic peninsula on the Chesapeake Bay, offering fishing, boating, kayaking, small beaches, great shopping, and museums.

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Beaches, mountains, big cities, small towns. Maryland has so many things to do, so close together.

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30. ST. MARY'S COUNTY
Potomac River lighthouses, Chesapeake Bay seafood, and maritime history. Cozy inns, waterside dining and fantastic festivals.

31. WORCESTER COUNTY
Maryland's only seaside county. Visit Assateague Island National Seashore. Kayak, canoe, bird watch, golf, bed and breakfast inns.

MISCELLANEOUS

32. ATHENA REVIEW
Athena Review, journal of archeology, history and exploration, invites you to send for more information on a free issue.

33. ENDLESS POOLS
Swim or exercise in place against a smooth current adjustable to any speed or ability. Installed indoors or outdoors. Request a free DVD.

34. MASHANTUCKET PEQUOT MUSEUM AND RESEARCH CENTER
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EXPLORER GUIDE

Around the Country

ARIZONA

Mesa

ARIZONA MUSEUM OF NATURAL HISTORY
Through September 28: **"Feathered Dinosaurs and the Origins of Flight."** Fossils of feathered dinosaurs from Liaoning, China, are displayed, along with life-size reconstructions and new findings about the evolutionary relationships between birds and dinosaurs.
53 North Macdonald
480-644-2230
www.azmnh.org

Phoenix

ARIZONA SCIENCE CENTER
Ongoing: **"Wired for Thought: The Developing Brain."** What does current research tell us about how the brain grows and changes over time? This exhibition explains what science has discovered about the brain in early childhood, teen years, and adulthood. Visitors can perform activities based on scientific experiments that study how the brain changes and adapts in response to biological and environmental conditions, including substance use and abuse.
600 East Washington Street
602-716-2000
www.azscience.org

CALIFORNIA

Los Angeles

NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY
Ongoing: **"Hall of Gems and Minerals."** Dig into this expansive suite of galleries and discover the science behind the beauty of Earth's treasures. Presenting mineralogy basics and mining practices, as well as specimens you can touch, the exhibition is a dazzling delight. Don't miss the Hixon Gem Vault and its stunning collection of diamonds, emeralds, rubies, sapphires, and other rare gemstones.
Exposition Park
900 Exposition Boulevard
213-763-DINO
www.nhm.org

San Diego

SAN DIEGO NATURAL HISTORY MUSEUM *Ongoing:* "Fossil Mysteries." Dioramas, fossils, models, murals, and plenty of hands-on activities tell the changing story of the bioregion encompassing southern California and Baja California in this exhibition spanning 75 million years of history. Examine fossil clues—just as scientists do—to answer questions about plants and animals (including dinosaurs), changing environments, evolution, extinction, and more.
Balboa Park
1788 El Prado
619-232-3821
www.sdnhm.org

COLORADO

Denver

DENVER MUSEUM OF NATURE AND SCIENCE
Through June 8: "Gold." Some of the world's largest and most spectacular gold nuggets are on display in this exhibition, along with cultural artifacts such as gold records, Oscar and Emmy statuettes, and a Kentucky Derby trophy. The show also illustrates historical and current processes of prospecting, mining, and refining. Brilliant gold objects document the various ways people have valued and used gold—in art, culture, fashion, and religion—across continents and through time.
2001 Colorado Boulevard
800-925-2250
www.dmns.org

CONNECTICUT

New Haven

PEABODY MUSEUM OF NATURAL HISTORY
Through July 19:

Coastal dinosaurs gather at the beach in one of the 12 major new murals by artist William Stout in the "Fossil Mysteries" exhibition at the San Diego Natural History Museum.

"Las Artes de México." Spanning more than 3,500 years of art and culture across a broad spectrum of Mexican life, this exhibition features pre-Columbian artifacts from the celebrations and rituals of Mayan, Aztec, and other civilizations; folk art from the time of the Spanish conquest and colonization, including Catholic iconography; and modern works from artists such as Miguel Covarrubias and Diego Rivera.
Yale University
170 Whitney Avenue
203-432-5050
www.peabody.yale.edu

FLORIDA

Gainesville

FLORIDA MUSEUM OF NATURAL HISTORY

Through September 7: "Inside Africa." Discover the many facets of Africa's people, animals, lands, and rich cultural history. Interactive displays, multimedia presentations, and a collection of artifacts help illuminate the biological, cultural, and human diversity of the world's second largest continent. See a goatskin tent used by the semi-nomadic Tuareg people of the Saharan region; discover what scientists are learning about gorilla families, and peer through binoculars to see videos of them playing in the wild; walk through a re-created slave ship and hear the stories of enslaved people; and much more.
University of Florida
Cultural Plaza
SW 34th Street and Hull Road
352-846-2000
www.flmnh.ufl.edu

Tampa

MUSEUM OF SCIENCE AND INDUSTRY (MOSI)

Ongoing: "Disasterville." Hold on tight in this new permanent installation that vividly simulates floods, hurricanes, tornadoes, wildfires, and other natural disasters in the unfortunate town of Disasterville. The interactive exhibition explains the science behind each threat, as well as constructive steps you can take to prepare your own home for nature's fury. The WeatherQuest area provides an innovative role-playing experience, in which teams form TV news crews that investigate and report on the crises as they unfold.
4801 East Fowler Avenue
813-987-6100
www.mosi.org

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See www.astc.org/passport for more information.

Visitors discover facets of desert living—including the stamina and strength needed to lift a heavy water bucket from a 98-foot well—in the "Inside Africa" exhibition, now at the Florida Museum of Natural History.

HAWAII

Honolulu

BISHOP MUSEUM

Opening May 17: "Whales: Wonders of the Ocean." Spanning more than 50 million years, this exhibition explores the mammals' ancient history as land animals, subsequent adaptations, and modern behaviors including swimming, feeding, reproduction, respiration, and vocalization. See lifelike, full-size robotic models move the way that real whales do; hear a whale's heartbeat; discover how to identify the animals by their markings, fins, and tails; and much more.
1525 Bernice Street
808-847-3511
www.bishopmuseum.org

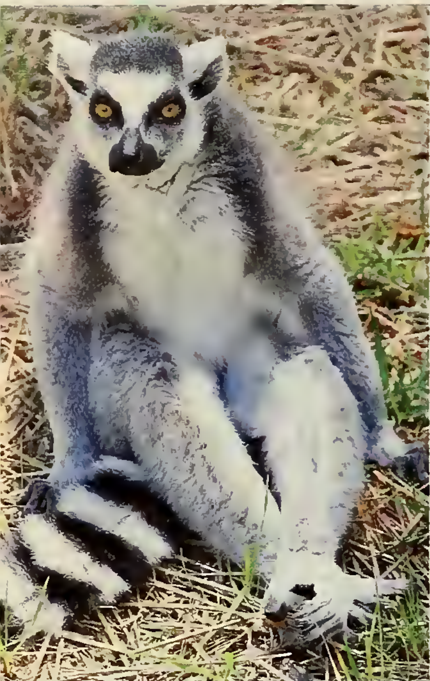
ILLINOIS

Chicago

THE FIELD MUSEUM

Through July 6: "George Washington Carver." Artifacts, videos, and hands-on activities help tell the story of the scientist, educator, and humanitarian in this new exhibition. See actual equipment he used in his lab, and discover how his work contributed to today's organic farming methods and current research on plant-based fuels, medicines, and everyday products. The show also includes oral histories told by people whose lives were changed by Carver's revolutionary ideas and agricultural techniques.
1400 South Lake Shore Drive
312-922-9410
www.fieldmuseum.org

FROM LEFT: SAN DIEGO NATURAL HISTORY MUSEUM/WILLIAM STOUT; EVERGREEN EXHIBITIONS



Ring-tailed lemur is one of the many live animals visitors can see in the naturalistic environment of the "Explore the Wild" outdoor exhibition at the Museum of Life and Science in Durham, N.C.

MASSACHUSETTS
Cambridge
HARVARD MUSEUM OF NATURAL HISTORY *Through June 30:* "Looking at Animals: Photographs by Henry Horenstein." A selection of sepia images of terrestrial and aquatic animals make the strange intimate and the familiar strange with unusual views of favorite and exotic creatures. The exhibition invites visitors to look closely and examine details they might never have noticed before, from the stippled pattern of a lizard's scales to the wild striping on a turtle's leg to the folds of skin encircling a Komodo dragon's eye, and much more.
26 Oxford Street
617-495-3045
www.hmnh.harvard.edu

MISSOURI
Saint Louis
SAINT LOUIS SCIENCE CENTER *Ongoing:* "DNA Zone." Dedicated to exploring biotechnology and genetics, this exhibition enables visitors to learn how genetic traits are passed from generation to generation. They can also explore the science behind some of the biggest news of the day—from discoveries about the human genome to the uses of DNA testing in criminal investigations.
5050 Oakland Avenue
800-456-SLSC
www.slsc.org

NEW MEXICO
Albuquerque
NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE *Ongoing:* "STARTUP: Albuquerque and the Personal Computer Revolution." Historical artifacts, interactive exhibits, and videos in this new permanent exhibition explain how microcomputers developed—and how they transformed society. From early electronic computer toys such as Hasbro's Think-A-Tron, through an early personal computer (the Altair 8800), to today's advanced hardware and software, the show traces the PC industry's Albuquerque roots and subsequent growth.
1801 Mountain Road NW
505-841-2800
www.nmnaturalhistory.org

NEW YORK
New York
AMERICAN MUSEUM OF NATURAL HISTORY *Ongoing:* "Discovery Room." Designed for families with children ages 5 to 12, this unique gallery covers every major field of the museum's scientific research activities, from anthropology to zoology, and can serve as a springboard for exploring the exhibitions in the rest of the building. Try to find all the birds, insects, reptiles, and mammals that live in an African baobab tree; make your own collection of arthropods, minerals, or skulls from a specimen cabinet; put together a life-size cast model of the 14-foot-long, Triassic reptile *Prestosuchus*; and much more.
Central Park West at 79th Street
212-769-5100
www.amnh.org

Tupper Lake
THE WILD CENTER, NATURAL HISTORY MUSEUM OF THE ADIRONDACKS *Ongoing:* "Living River Trail." Follow a river's course from the mountains down to the marshlands, and along the way discover bog, forest, and stream ecosystems. You'll also find the plants and animals that live in these environments, including live river otters and rare brook trout species.
45 Museum Drive
518-359-7800
www.wildcenter.org

NORTH CAROLINA
Durham
MUSEUM OF LIFE AND SCIENCE *Ongoing:* "Explore the Wild." This new, six-acre woodland and wetland habitat is also a big outdoor science exhibition, where you can put yourself in the shoes of a wildlife biologist. Use zoomable and infrared cameras, microscopes, and computer kiosks to investigate the animals, plants, and tiny life-forms teeming in water; take a stroll down the boardwalk and look for animal tracks and wild birds; or visit the habitats of the exhibition's black bears, endangered red wolves, and three lemur species.
433 West Murray Avenue
919-220-5429
www.ncmls.org

Raleigh
NORTH CAROLINA MUSEUM OF NATURAL SCIENCES *Through December 28:* "Dead Sea Scrolls." Telling the story of one of the 20th century's greatest archaeological finds, this exhibition explores the history of the oldest known biblical manuscripts and related artifacts. On display are 12 original scrolls from the settlement of Qumran near the Dead Sea, representing portions of the books of Genesis, Isaiah, Deuteronomy, Exodus, and others, and graphic panels that explain these ancient texts. The show also presents coins, pottery, and other artifacts from Qumran and a variety of exhibits that explain the science and technology behind the excavation, conservation, and interpretation of the scrolls.
11 West Jones Street
877-4NATSCI
www.naturalsciences.org

OHIO
Cincinnati
CINCINNATI MUSEUM CENTER *Through September 1:* "Bodies." Authentic, preserved human specimens provide a rare window to the inner workings of our bodies in this new exhibition that features more than 250 organ, partial-body, and full-body specimens. Visitors gain an understanding

of the body's muscular, respiratory, skeletal, and other systems, and can also learn about common medical conditions—such as arthritis, colon cancer, lung cancer, and obesity—by examining their effects on the human body.
Union Terminal
1301 Western Avenue
800-733-2077
www.cincymuseum.org

PENNSYLVANIA
Philadelphia
THE ACADEMY OF NATURAL SCIENCES
Opening May 24: **"Gregor Mendel: Planting the Seeds of Genetics."** Featuring most of the surviving artifacts from Mendel's life, this exhibition tells the story of his investigation into the way pea plants inherit physical traits, and how his theories influenced the modern field of genetics. In addition, interactive exhibits let visitors recreate some of his experiments, use DNA to determine where flamingos belong on a "family tree" of birds, and more.
1900 Benjamin Franklin Parkway
215-299-1000
www.ansp.org

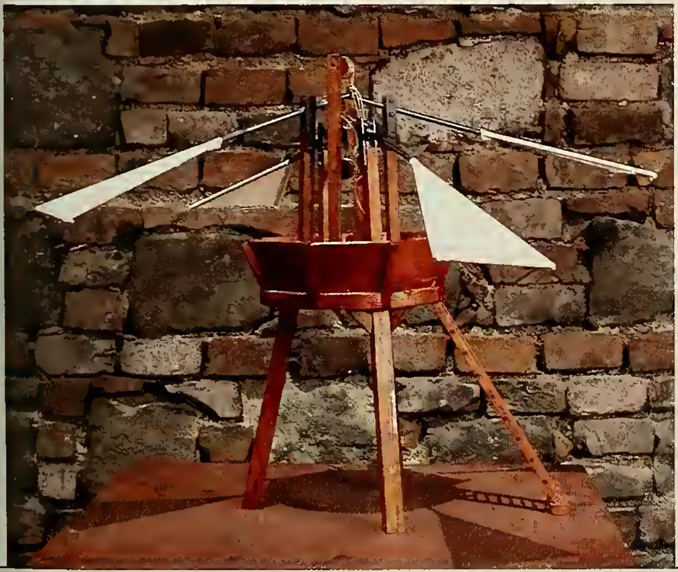
TEXAS
Fort Worth
FORT WORTH MUSEUM OF SCIENCE AND HISTORY
Ongoing: "Seeing." Take a close look at this exhibition, and discover how our eyes and brains work together—and what a subjective and interpretive process seeing really is. Find out if your friends and family see a particular color differently than you do, try shooting baskets while wearing glasses that shift your field of vision, watch as spinning objects seem to disappear before your eyes, and more.
1501 Montgomery Street
817-255-9300
www.fwmuseum.org

Houston
HOUSTON MUSEUM OF NATURAL SCIENCE
Through September 1: **"Leonardo da Vinci: Man, Inventor, Genius."** Dozens of custom-built wooden models—handcrafted in Italy from da Vinci's drawings—help illuminate the life and work of the man who has come to epitomize the inquisitive spirit of the Renaissance era. Models, which visitors can touch, include a predecessor of today's helicopter, a precursor to modern scuba-diving gear, an early design for a military tank, a gearshift similar to those now used in automobiles, and many other inventions in the fields of flight, hydraulics, military machinery, and mechanics.
One Hermann Circle Drive
713-639-4629
www.hmns.org

VIRGINIA
Martinsville
VIRGINIA MUSEUM OF NATURAL HISTORY
Ongoing: **"Uncovering Virginia."** This new, permanent gallery tells the story of Virginia's natural history over the course of the past 300 million years. Six exhibits focus on different geologic epochs being studied by scientists in various locations around the commonwealth. Each exhibit describes the animals and plants that lived there in the past and features a laboratory-like environment where visitors can use the same tools scientists do to interpret fossils and archaeological items. See a tropical swamp from a time when Virginia was south of the equator, visit a site occupied by Native Americans both before and after Europeans arrived, and much more.
21 Starling Avenue
276-634-4141
www.vmnh.net

WASHINGTON
Seattle
PACIFIC SCIENCE CENTER
Through May 4: **"Strange Matter."** Bend a metal with a "memory" and watch it return to its original shape when it gets hot, make magnetic liquids "dance," try smashing heat-tempered glass with a bowling ball, or discover how sand gets turned into computer microchips in this fascinating materials-science exhibition that explores the science behind both everyday and exotic materials.
200 Second Avenue North
206-443-2001
www.pacsci.org

WISCONSIN
Milwaukee
MILWAUKEE PUBLIC MUSEUM
Ongoing: **"Body Worlds: The Original Exhibition of Real Human Bodies."** Visitors can learn about anatomy, physiology, and health by seeing real human bodies that have been preserved through a process called *plastination.* The exhibition includes more than 200 human specimens—entire bodies illustrating neurological, circulatory, and other systems, as well as individual organs and transparent body slices.
800 West Wells Street
414-278-2702
www.mpm.edu



Model of Leonardo da Vinci's *ornitottero verticale* (vertical ornithopter), a flying-machine design that would allow the pilot to control the machine using hands, feet, and head, now on display in the "Leonardo da Vinci" exhibition at the Houston Museum of Natural Science.

FROM LEFT: MUSEUM OF LIFE AND SCIENCE; HOUSTON MUSEUM OF NATURAL SCIENCE/EMS EXHIBITS-VIENNA

ENDPAPER

Aqua-Rock Climbers

By Jeremy B. Monroe and Julian D. Olden

A fear of falling limits most people to Earth's gentler slopes. Yet there are those among us who venture onto cliff faces and stone spires, armed with ropes, harnesses, and anchoring devices, to challenge the unforgiving force of gravity. As soggy-shoed graduate students studying insect behavior in the streams that drain Colorado's Rocky Mountains, we occasionally looked up to marvel at the rock climbers ascending the crags and cliffs of this rugged area. Curiously, the insects we study brave an equally unforgiving force—flowing water—and have found a similar solution to their own "falling" problem.

Nearly 12,000 caddisfly species (order Trichoptera) pass their early life stages in freshwater lakes, streams, and wetlands around the world. The insects typically spend one or two years in these environments, completing their larval and pupal stages. Then they emerge from the water to briefly live and mate as winged adults [*see photograph above*].

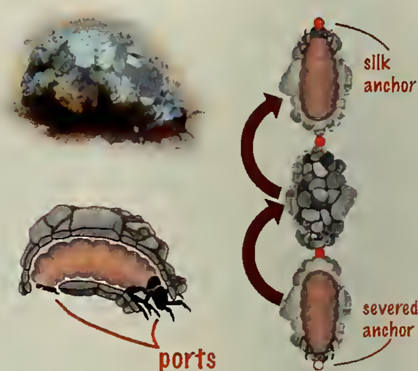
Before growing wings that offer total freedom from falling, caddisflies rely on glands near their mouths to produce an ultra-useful silk—nature's duct tape. Silk is best known as an adaptive tool in silkworms and spiders, but caddisflies use it in ways that are crucial to life underwater. They create all sorts of aquatic gear with silk, from nets that filter food particles, to wearable protective shelters, to pupal cases in which they metamorphose.

Larvae of one family of caddisflies, the Glossosomatidae, use silk to bind together tiny rock fragments into a mobile home of sorts. The portable case resembles a tortoise shell and features two small openings on the underside through which a larva can stick its front legs and its rear claws.

The case protects the soft-bodied larva, just as a suit of armor might protect a rock climber from giant predators, but consider the energetic cost of lugging it around! The drag exerted by the current and the friction between the case and the rocks, appears to slow larvae down substantially. The glossosomatids' movement is clunky, with top speeds of only a few inches per hour, but they can crawl freely in slow currents without threat of being washed away. Remarkably, though, the larvae are also found in swift, turbulent currents. How is that possible?

To find out, we recently observed a particular glossosomatid, *Agapetus boulderensis*, in the swift-flowing headwaters of the Colorado River. The species appears to have combined its gymnastic flexibility with a clever way of belaying using silken anchors. Facing upstream, an *A. boulderensis* larva will affix a small silk "line" to a rock. Once anchored, the larva turns completely around inside its case. It then sticks its front legs out the back opening and crawls around, pivoting its case 90 to 180 degrees on the silk anchor until it is facing upstream again. Then the larva places another anchor, turns around inside its case, and severs the old anchor [*see illustrations on this page*]. With a succession of pivots, *A. boulderensis* thus moves slowly but safely against hazardous currents—as a mountaineer would maneuver up a rock face. Interestingly, much as mountaineers are wary of downclimbing, we have yet to see a larva make pivoting movements in the downstream direction.

Spinning silk anchors takes energy, though, and pivoting is even slower than the usual forward scrabble in calm currents. So why risk the swift ones? For food, most likely. Faster-flowing environments often host algal mats that are nutritious and rapidly replenished. And indeed, pivoting movements are



Caddisfly larva encased in armor (exterior and cutaway views, above left) uses silk anchors to pivot upstream (above right).

often punctuated by bouts of eating, in which larvae graze in arcs around anchor points.

The motives of pivoting caddisflies may differ from those of mountaineers, yet we wonder whether to chalk their convergent strategies up to simple coincidence. Perhaps some early climbers were closet entomologists? Either way, we have learned this: gravity's a downer, current's a drag, and wise climbers anchor their rope to the crag!

Jeremy B. Monroe, a biologist-photographer, currently directs a non-profit foundation, Freshwaters Illustrated. *Julian D. Olden is an aquatic ecologist and assistant professor in the School of Aquatic and Fishery Sciences at the University of Washington. They were graduate students together at Colorado State University in Fort Collins.*

PHOTOS AND ILLUSTRATIONS: J.B. MONROE


Dive into Belize.
"Hannah and Suzy's excellent adventure"
"A few years ago I convinced my mother to get scuba certified so we could do one mother-daughter bonding trip a year. For our last trip we decided on Caye Caulker in Belize. I knew it long ago as a place of perfect peace and tranquility, but didn't realize then it was such a phenomenal dive spot. The island is just one mile off the Belize Barrier Reef, so we found it to be a great jumping off point for our dives.
Our divemaster, Pattie Holden, worked with a local dive company and was wonderfully friendly and experienced. She made our time together so special, taking us on a variety of dives from wrecks, to swim throughs to wall dives. All the dives were in water that was 80+ degrees with visibility out to at least 100 feet. Incredible! We were thrilled diving a wreck at Hol Chan canyons. Even more thrilling was spotting a huge, beautiful spotted eagle ray and giant sea turtle on our next dive through the canyons.
"Fresh Cay Caulker lobster hot off the grill-- Yummy!"
Our time at Turneffe islands atoll was also spectacular. You're doing a wall dive with tons of sea life on one side, and a dropoff of 3,000 feet on the other. With the great visibility below you, you feel like you're flying through the water—not swimming—with thousands of grouper, permit, eagle rays and jacks flying alongside you.
My mom and I both said that after this experience, it kind of makes you feel like you can handle anything."
— Hannah Wolken —
Make time for the adventure of your life.
You can tell us about your Belize adventure at www.travelbelize.org/mystory
Call 1-800-624-0686 or visit our website: www.travelbelize.org
BELIZE
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