NATURAL HISTORY

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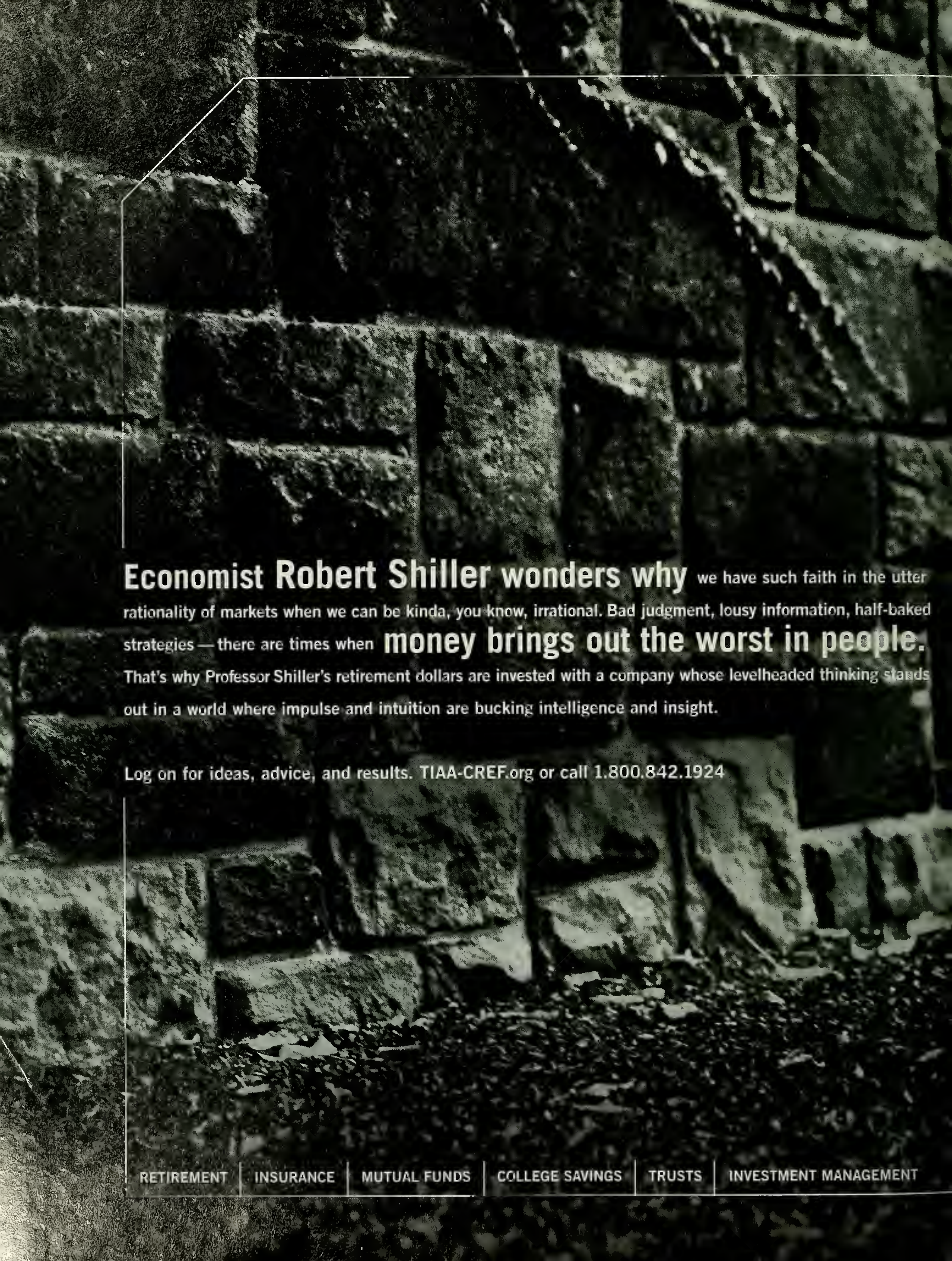
Economist Robert Shiller wonders why we have such faith in the utter rationality of markets when we can be kinda, you know, irrational. Bad judgment, lousy information, half-baked strategies — there are times when money brings out the worst in people.
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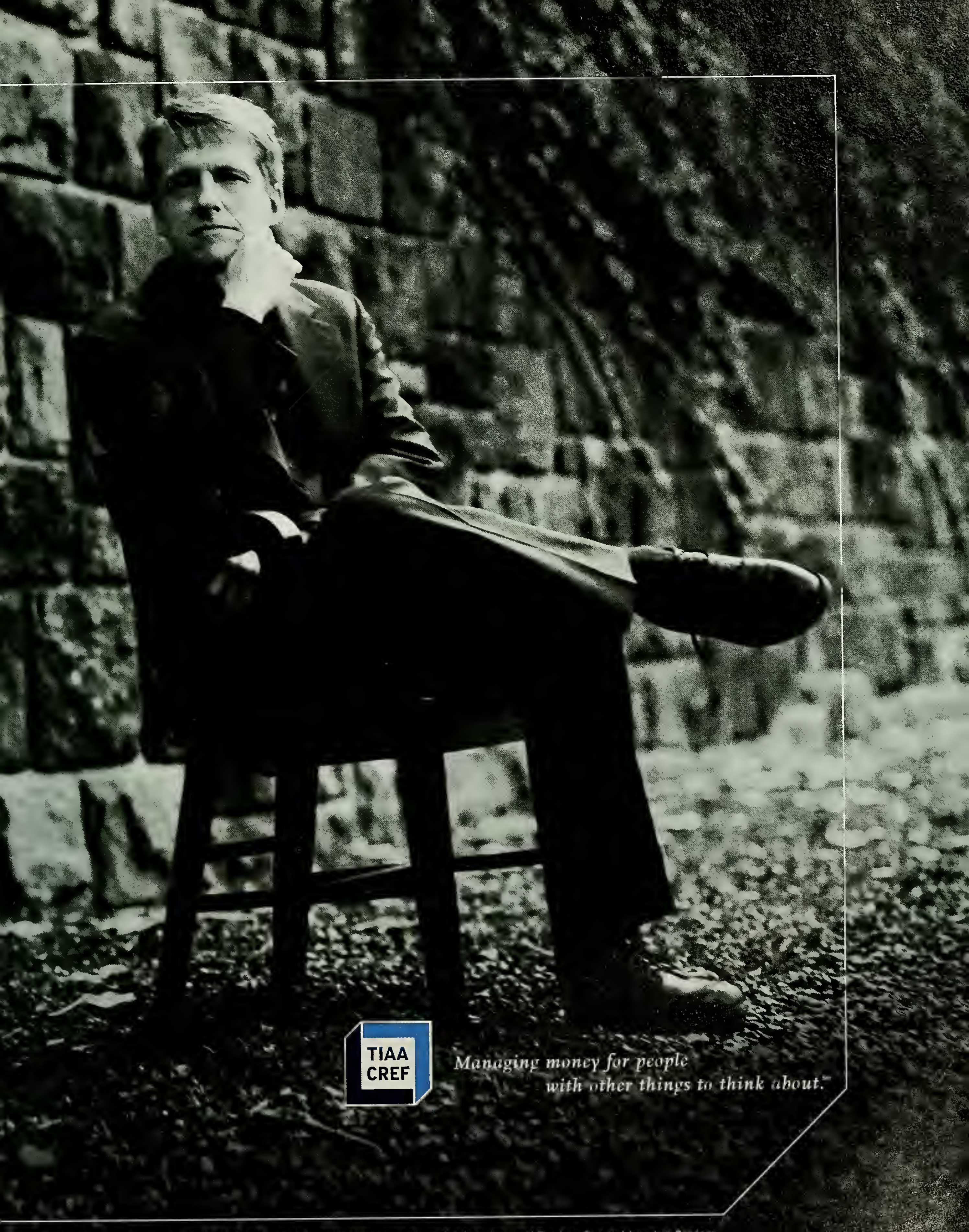
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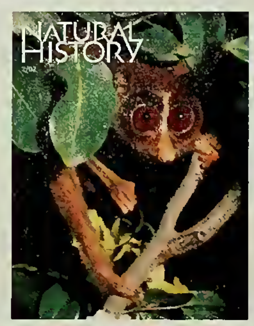
NATURAL HISTORY

FEBRUARY 2002 VOLUME 111 NUMBER 1

FEATURES



COVER The slender loris of Sri Lanka and southern India is a surprisingly social animal.

STORY BEGINS ON PAGE 54

PHOTOGRAPH BY MITSUAKI IWAGO; MINDEN PICTURES

DEPARTMENTS

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GEORGE SCHALLER IS DOING ALL HE CAN TO HELP THE ANIMALS OF THIS PLANET SURVIVE.

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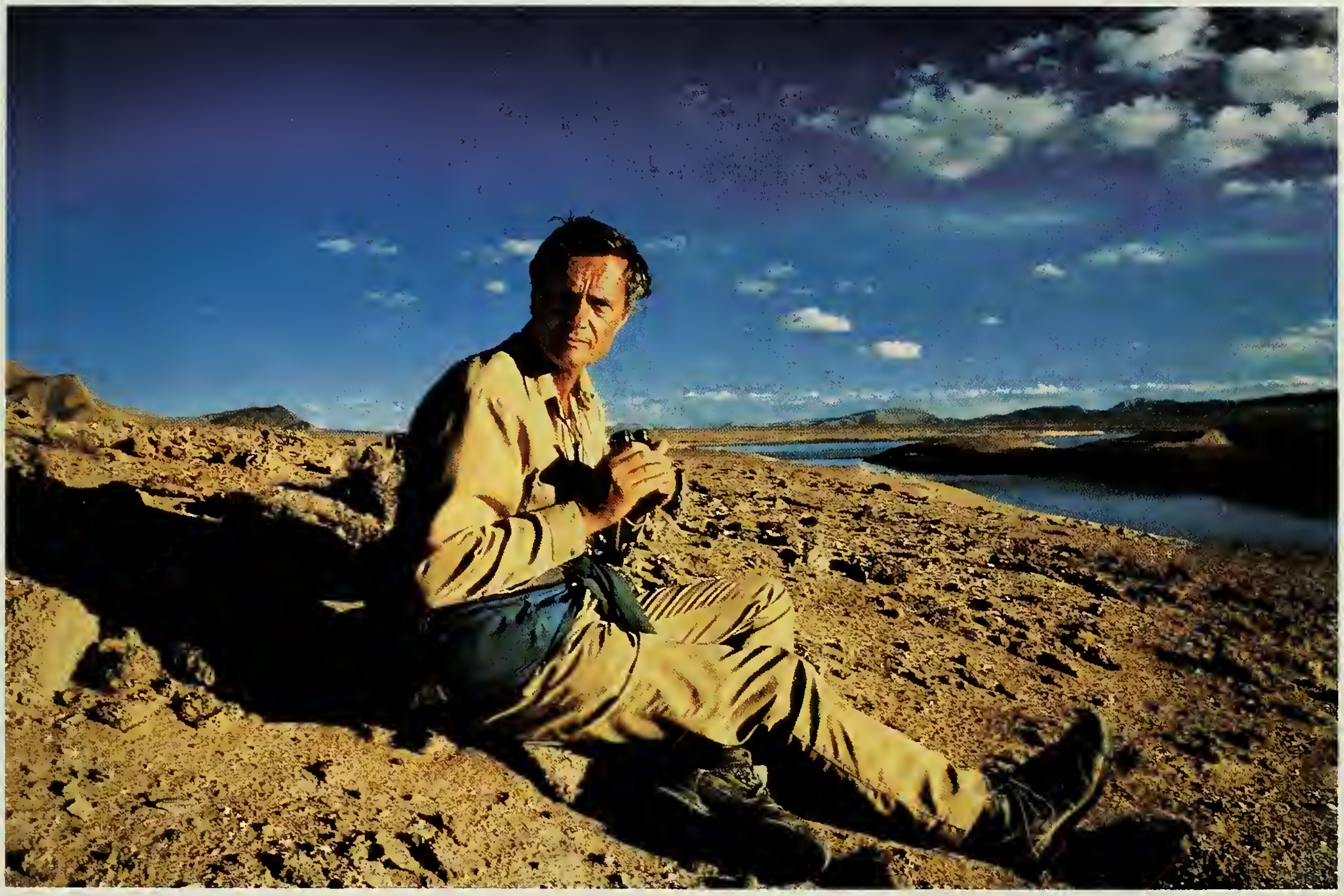

George Schaller, science director of the Wildlife Conservation Society, has spent four decades studying wildlife and fighting for its survival. His Rolex has proven its reliability in some very rugged environments.

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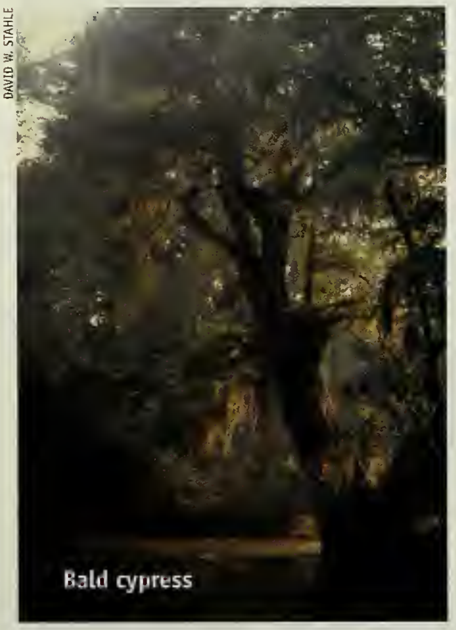
UP FRONT

Survivors

When I was a child, my family lived on the southeastern outskirts of Denver, then a relatively small city just beginning its sprawl onto the Great Plains. The land was flat and treeless except for the occasional streamside cottonwood. We planted an elm in our backyard. Rain was a rarity, so the elm had to be watered regularly. It grew tall and skinny above the sparse grass, and its narrow canopy of leaves provided little shade.

We moved back east to northern New Jersey when I was eleven, and I delighted in the change of vegetative scene. The woods near our home were thick with walnut, white oak, sweet birch, sassafras, hemlock, red maple, juniper, tulip trees, and many more species I couldn't name. In summer their branches were mantled in wild grape and honeysuckle and other, more mysterious vines. To my young eyes, this was a jungle. A forest primeval.



DAVID W. STAHLE

Bald cypress

In college I learned that the woods I loved were not primeval at all but mostly second or third growth—a community of trees that had come up in land once cleared for farming or logging but later abandoned. Really old trees, I was told, were giants, found only in places like California, Washington, and Alaska.

But as David Stahle explains in "The Unsung Ancients" (page 48), stands of truly venerable trees can be seen all around the United States—if you know where to look. Some have been spared simply because their timber is without commercial value; others because they thrive where farmers and loggers, charcoal makers and real estate developers couldn't or wouldn't go. In some places, writes Stahle, these unsung ancients—beeches in the Ozarks, bald cypresses in the Carolinas, hemlocks near the Canadian border—still dominate the local landscape. Many have survived all that has happened to the land since 1492, and as dendrochronologists like Stahle can attest by studying growth rings, a few were witnesses to much that came before.—*Ellen Goldensohn*

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LETTERS

Be Afraid, Be Very Afraid

I'm not afraid of numbers, but I'm afraid Neil deGrasse Tyson got his numbers wrong in the final paragraph of "Fear of Numbers" (12/01–1/02). Unless the recent census undercounted the U.S. population by more than 25 billion (the equivalent of twenty Chinas), Tyson means that $250 million comes to less than one dollar per American, not less than one cent. Sorry, Neil: I can't give this essay a perfect 10. But, unintimidated by decimals, I'll readily give it a 9.9.
Dan Heaton
New Haven, Connecticut

What a boner in an article on numbers!
Theodore Cohn
New York, New York

I find it difficult to believe that there are over 25 billion people in the USA. Perhaps this explains why the A train is so crowded.
Richard Strassberg
New York, New York

My sympathies. Isn't it all too easy to overlook orders of magnitude? Recently in a statistics class I teach, I missed a standard deviation by a factor of ten. I confess, sometimes I do have a fear of numbers.
Victor W. Goodman
via e-mail

I'm still puzzling over the arithmetic in the last paragraph. Let me ask, how many letters have you received on this subject?
James E. Beckman
Leonardo, New Jersey

THE EDITORS REPLY: A zillion.

NEIL DE GRASSE TYSON REPLIES: I had e-mail on this error before I opened my own copy of the magazine. Of all the essays in which to make a mistake of two orders of magnitude, how embarrassing that "Fear of Numbers" was the one. While I regret the error, I remain happily surprised by how many people were paying attention.

Art and History

I read Jay Xu's "The Enigmatic Art of Sanxingdui" (11/01) with pleasure. Having always been interested in early art, and Chinese art in particular, I found this article one of a kind in nature and scope.
Thomas Presbie
Waterbury, Connecticut

Giving Thanks and Credit

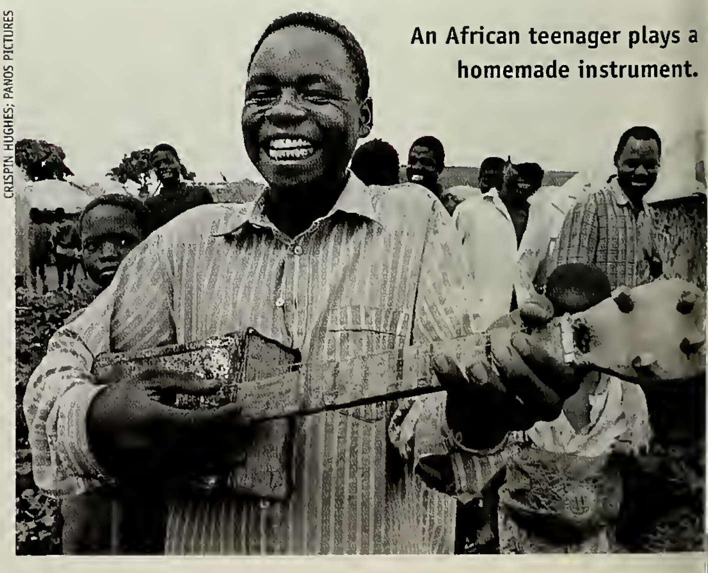
I was delighted to see the photograph of the wild turkey hen sheltering her poults ("The Natural Moment," 11/01), but I was disturbed by the caption below it. The text clearly blamed hunting and loss of habitat for the turkey's decline but did not indicate that it was unregulated, mainly market, or commercial, hunting that was to blame. Yet it was through state game commissions and private organizations like the National Wild Turkey Federation that this bird made its comeback. While you did mention "capture and release" programs, I wish you had given credit where credit is due. Some of the greatest conservation success stories—like the return of the wild turkey—are the direct result of hunters' efforts.
Michael Wujtowicz
Sarasota, Florida

Musical Note

I really enjoyed Susan Milius's article about possible biological bases for music ("Face the Music," 12/01–1/02). But Milius does not mention the great aid that music gives us in memorizing information and stories. We all know how much easier it is to memorize words that are set to music than those that aren't. I wonder if this is a possible explanation of music's benefit to us as a species, since the communication of and passing along of information is so crucial to human society.
Laura Dillaway
via e-mail

ERRATUM: The editors regret that in the feature article "Face the Music," the omission of a word on page 54 inverted the sense of a passage. It should read: "The German pipe . . . dates back to about 36,000 years ago—toward the FARTHER end [that is, the beginning]," of what musicologist Ian Cross called "the sudden efflorescence of visual art and symbolic artifacts that marks the undoubted emergence of modern human capacities."

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



CRISPIN HUGHES; PANOS PICTURES

An African teenager plays a homemade instrument.

CONTRIBUTORS

"To dream of such plants as *Brugmansia* in a foreign land and then to go there and search for them is an adult's version of a treasure hunt," says **Rob Nicholson** ("Naturalist at Large," page 20). Pictured here with his research partner Melvin Shemluck (right) and Colombian herbalist Marcelino Juajibioy (center), Nicholson was one of the many students at Harvard in the 1970s who took courses with botanist Richard Evans Schultes, whose explorations of Amazonia were by then legendary. Nicholson now manages the extensive conservatory collections at the Botanic Garden of Smith College (www.smith.edu/garden/).

During the past decade, **Aparna Sreenivasan** ("Keeping Up With the Cones," page 40) has moved from studying a mutant gene associated with several different cancers to observing the feeding patterns of Asian elephants and working as a journalist in California and, with the National Science Foundation, in Antarctica. She has also studied diphtheria and herpes infections; her Ph.D. was on the mechanics of cell division. Sreenivasan has now returned to the laboratory to study virulence and pathogenesis in *Candida albicans,* a yeast, at the University of California, San Francisco.

David W. Stahle ("The Unsung Ancients," page 48), a professor of geosciences at the University of Arkansas, concentrates on the discovery, tree-ring dating, and conservation of ancient forest remnants, including those that host the oldest known tree in the southeastern United States and Mexico, the *ahuehuete,* or swamp bald cypress. He spent two adventurous years working with Marvin Stokes, longtime professor of dendrochronology at the University of Arizona, on the tree-ring dating of old roof timbers in missionary churches in northern Mexico. Stahle considers the large collection of tree-ring specimens that he culled from ancient forests in North America and Africa—now housed at the University of Arkansas—to be one of his principal achievements.

Primatologist **K. A. I. Nekaris** ("Slender in the Night," page 54) finished her Ph.D. at Washington University in St. Louis in 2000. She is currently a postgraduate research fellow for the Nocturnal Primate Research Group at Oxford Brookes University in Oxford, England. Two apparent subspecies of slender lorises in Sri Lanka are the focus of her next long-term study. Besides working on lorises, she has studied ruffed lemurs, flying squirrels, opossums, civets, and several species of bats. Her research will be featured on the upcoming David Attenborough/BBC production *Lords of the Land.*

Geerat J. Vermeij ("Why Are There No Lobsters on Land or Bats at Sea?" page 60) is a professor of geology at the University of California, Davis. Mollusks, living and extinct, are his first love. Praising their manageable size, varied textures, and great diversity, he says that "shells have just about everything a scientist could want." In 2000, Vermeij received the Daniel Giraud Elliot Medal from the National Academy of Sciences for "extracting major generalizations about biological evolution from the fossil record, by feeling details of shell anatomy that other scientists only see." Blind from age three, he is the author of *A Natural History of Shells* (Princeton University Press) and the autobiographical *Privileged Hands: A Scientific Life* (W. H. Freeman).

Ecologist and photographer **Mark W. Moffett** ("The Natural Moment," page 78) admits to having a soft spot for "the ugly and maligned creatures of the world," among them, ants. Moffett, who studies forest canopies, has climbed trees in forty countries. He was, however, able to shoot this month's featured photograph on terra firma. He used a Canon camera with a 50mm macro lens. Moffett is a research scientist at the University of California, Berkeley, and at the Smithsonian Institution and is the author of *The High Frontier: Exploring the Tropical Rainforest Canopy* (Harvard University Press).

THIS LAND

Going With the Flow

By Robert H. Mohlenbrock

A Texas river winds through town and country.

Texas wild-rice

Texas's San Marcos River has its source in the city of San Marcos, halfway between San Antonio and Austin, where clear water emerges from a series of limestone springs. In the mid-nineteenth century the headwaters of the river were dammed, forming Spring Lake, which remains a popular attraction. From there the river flows sixty-three miles to the Guadalupe River, which feeds into the San Antonio River near its outlet in the Gulf of Mexico. Along the San Marcos's course are numerous pools interspersed with small rapids.

A plant found only in Spring Lake and the uppermost reaches of the San Marcos River is Texas wild-rice, an aquatic grass whose clustered grains and upper leaves ride above the water's surface. This relative of commercially marketed wild rice was first recognized as a separate species in 1932. At that time it was abundant, but in 1967 botanist William Emery reported that only one plant still grew in Spring Lake and the remaining ones were confined to a stretch of river between half a mile and two miles below the dam. Among the causes of the species' decline were pollution and the use of an underwater mowing machine to reduce vegetation in the lake. The debris that floated downstream after each mowing apparently interfered with the plant's pollination. Although conditions have been improved, the grass remains on the U.S. Fish and Wildlife Service's endangered species list.

About ten miles before it enters the Guadalupe River, the San Marcos River passes through Palmetto State Park, an ideal place to observe floodplain and adjacent upland habitats. The most surprising species I

WILLARD CLAY

encountered there was anaqua *(Ehretia anacua)*, a twenty- to forty-foot-tall tree that generally ranges farther south, from along the southern border of Texas into northern Mexico. It is one of about fifteen species in its genus; all the others grow in tropical regions of the Old World. Some of these species are valuable timber trees, while others, such as China's *E. microphylla* (known as Philippine or Fukien tea), are popular with growers of bonsai. The Texas plant, too, is a frequent choice for bonsai, and its white flowers also make it an attractive ornamental in a desertlike landscape. The leaves are among the roughest to the touch of any plant's; to me they feel like Velcro.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of U.S. national forests and other parklands.

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JOE LEMONNIER

HABITATS

Bottomland forest. Hardwood trees common to northern and eastern Texas grow above flood level on a moist river terrace. Cedar elm, sugarberry (a type of hackberry), and red ash predominate in creating a fairly open canopy about sixty feet above the forest floor. Other tall trees are bur oak and Shumard oak. Abundant box elders make up a somewhat shorter layer. Beneath these grows red buckeye, whose clusters of bright red flowers enliven the forest in early spring. This is the habitat for anaqua. Shrubs: chittamwood (a bumelia also called gum-elastic), yaupon, spatulate-leaved hawthorn. Wildflowers: baby blue-eyes, large-flowered buttercup, Missouri violet, white avens, branched foldwing *(Dicliptera brachiata)*.

Palmetto swamp. A lush habitat appears where surface water accumulates in shallow depressions to form seasonal or fairly permanent ponds. These zones harbor dwarf palmetto, with its fan-shaped leaves, and buttonbush, with its spheres of tiny white flowers. Mosquito fern, a diminutive floating fern, grows in some pools. Because the canopy is relatively open here, the vegetation is often overgrown with rattan vine (supplejack), greenbrier, wild grape, pepper vine, trumpet creeper, Virginia creeper, and poison ivy. Wildflowers: wild blue iris, creeping buttercup, brookweed, water pennywort.

Upland forest. Higher and drier terrain supports a scrubby growth of post oak and blackjack oak. Also fairly common are bluejack oak, netleaf hackberry, honey mesquite, and prickly ash. Prickly pear cactus grows here too—evidence of the arid conditions. Shrubs: American beautyberry, wafer ash. Wildflowers: Drummond's phlox, hairy phacelia, Indian paintbrush, smooth spiderwort, Quaker-ladies, wild indigo, yellow wingstem.

IN SUM

GREGORY G. DIMIJIAN; PHOTO RESEARCHERS, INC.

REMEMBERING EWE Sheep have long been regarded as lost without a guide, ready prey for sly foxes and wolves in familiar clothing. But recent research demonstrates that rather than being stupid, they might have elephantine memories.

Keith Kendrick and colleagues at the Babraham Institute near Cambridge, England, worked with a group of twenty sheep and taught them to recognize frontal views of the faces of twenty-five pairs of their fellows by associating one of each pair with a food reward. (The sheep were considered to have learned when they chose the reward face 80 percent of the time.) The perceptive ruminants could still discriminate between the members of the twenty-five pairs up to 800 days after the training period (although in the final 200 days, they made the correct selection less frequently). The test animals were also able to discriminate between profile views of the same faces without being retrained, and they could correctly choose a reward face out of novel pairings of the animals' original mug shots.

The researchers also recorded brain cell activity during these experiments and found that sheep could recall familiar faces after separations of up to twelve months. When presented with pictures of the faces of sheep—and of humans—that either had been or were currently part of the test animals' social groups, the sheep's brains showed increased activity in the same subgroup of cells that encode memories of faces in monkeys and in humans. The sheep vocalized the same way when looking at pictures of former social group members as they did when shown pictures of current ones.

According to the *Oxford English Dictionary*, "sheepish" has meant "silly" since the fourteenth century. Use it if you must, but don't do it around sheep—who knows how long it takes them to forget an insult? ("Sheep Don't Forget a Face," *Nature* 414, 2001)—*T. J.Kelleher*

THE GREAT LEMUR MYSTERY One of the biggest puzzles in primate evolution is how and when lemurs first arrived on the island of Madagascar, the only place they're found today. Though ancient remains of their close relatives, the lorises, have been found throughout Africa and Asia, fossil evidence for lemurs hasn't extended beyond Madagascar—until now.

Digging in Pakistan's Bugti Hills, Laurent Marivaux, of the Université Montpellier II in France, and colleagues discovered the remains of a 30-million-year-old lemur, the oldest such fossil ever unearthed. The researchers believe that the creature, named *Bugtilemur mathesoni*, was most closely related to the modern genus *Cheirogaleus* (dwarf lemurs) and was similar in size to today's hairy-eared dwarf lemur, which weighs in at about three ounces.

Till now, scientists thought the common ancestor of lemurs and lorises was a native of Africa, but the discovery in Pakistan suggests alternative scenarios. According to the team that found the fossil, *Bugtilemur* and *Cheirogaleus* share enough features to preclude their divergence from a common ancestor before Madagascar broke away from India 88 million years ago. Instead, lemurs may have migrated later on a route between the drifting landmasses. But which direction were they headed?

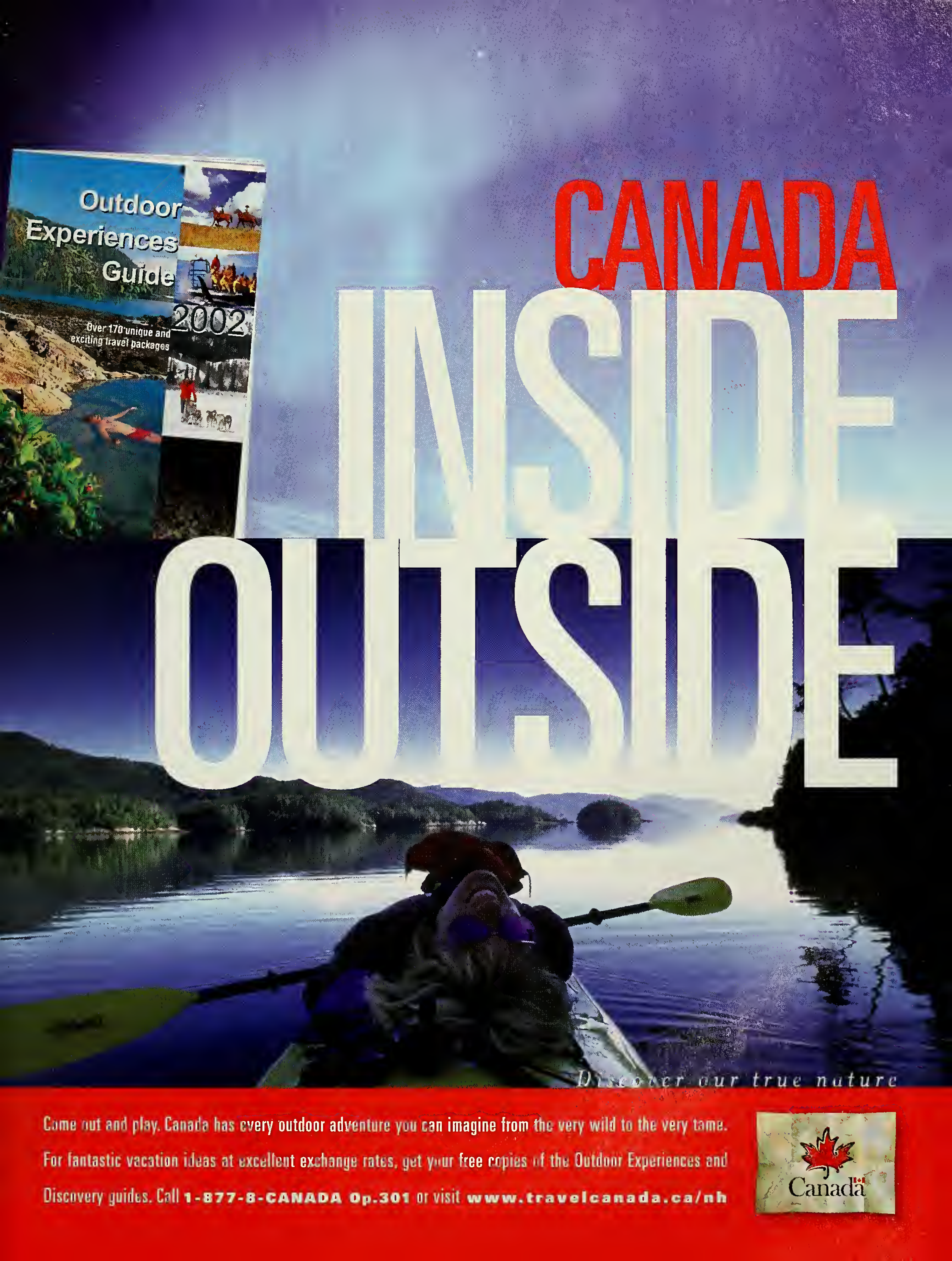
Bugtilemur's ancestor could have migrated from Africa to Madagascar and then toward Pakistan. But it may be just as reasonable to suggest that the group originated in Asia. Whatever the timing and direction of the migrations, the researchers agree that South Asia was "an important theater" of early lemur evolution. ("A Fossil Lemur From the Oligocene of Pakistan," *Science* 294, 2001)— *Kirsten L. Weir*

LITTLE LIZARD A new species of lizard so small it can turn on a dime or stretch on a quarter—that's *Sphaerodactylus ariasae*, discovered on Beata Island (off the southwest coast of the Dominican Republic) by herpetologists S. Blair Hedges, of Pennsylvania State University, and Richard Thomas, of the University of Puerto Rico. Just over half an inch long from the tip of its snout to the base of its tail, the lizard ties its cousin *S. parthenopion* for the title of smallest amniote—a group that includes reptiles, mammals, and birds.

S. BLAIR HEDGES

Island habitats are often home to "extreme" creatures, such as the smallest or largest of a kind. Many groups of organisms that successfully complete the voyage from the mainland to an island outpost evolve to fill niches left empty by taxonomic groups that didn't make the trip. Hedges and Thomas believe that *S. ariasae* may have adapted to occupy an ecological niche that is filled on the mainland by an invertebrate.

On Beata Island, the tiny gecko makes itself at home in moist leaf litter. No word on how many dimes it might come across in a day's slithering. ("At the Lower Size Limit in Amniote Vertebrates: A New Diminutive Lizard From the West Indies," *Caribbean Journal of Science* 37:4, 2001)—*Kirsten L. Weir*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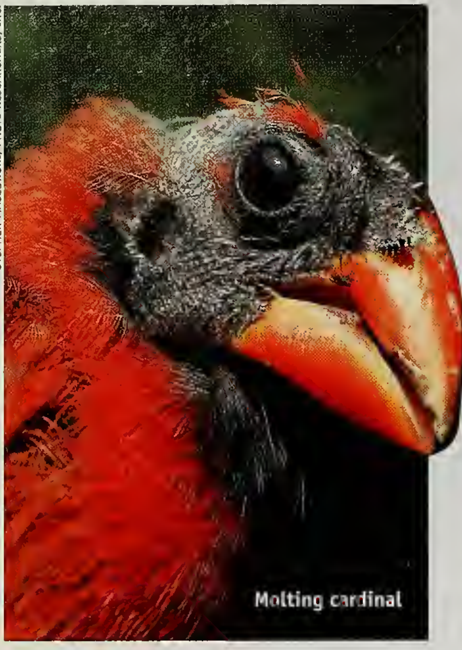

STEPHEN MASLOWSKI; PHOTO RESEARCHERS, INC.

Molting cardinal

MITE LIFE Around the world, birds harbor symbiotic mites of the suborder Astigmata. For the most part, the so-called feather mites live a quiet life, hanging out on the surface of bird feathers, feeding off oil and fungi. Once a year, though, when the birds molt, the tiny arthropods face life-or-death options. A mite that's hitched itself to a falling feather can kiss its home good-bye.

Do mites try to avoid being discarded along with molted feathers? To find out, biologists Roger Jovani and David Serrano, of the Estación Biológica de Doñana in Seville, Spain, studied sixty-three songbirds from thirteen species. Because these songbirds replace wing feathers in the same sequence year after year, the researchers could easily determine which feathers were ready to molt. They discovered that most mites wouldn't be caught dead on the feather that was next in line to fall—or the one after that. This held true especially for the primary, or outermost, feathers.

How do mites sense imminent feather fallout? One possibility is that they perceive changes in air currents flowing through gaps created when nearby feathers drop. Another possibility, favored by Jovani and Serrano, is that the mites are able to detect the vibrations in feathers that are loosening. Apparently for feather mites, choosing a home is all about "location, location, location." ("Feather Mites [Astigmata] Avoid Moulting Wing Feathers of Passerine Birds," *Animal Behaviour* 62:4, 2001)—*Kirsten L. Weir*

PETER PARKS; NHPA

Feather mite

COOL CUSTOMERS Scientists have long believed that the Arctic reaches of Eurasia were uninhabited by humans until the final stages of the Ice Age, 13,000 to 14,000 years ago. Now researchers report signs of human life dating back almost 40,000 years during what was probably an ice-free and relatively dry, mild spell. At Mamontovaya Kurya in the Russian Arctic, Pavel Pavlov, of the Russian Academy of Sciences, and his Norwegian colleagues John Inge Svendsen and Svein Indrelid, of the University of Bergen and the Bergen Museum, respectively, uncovered mammalian bones, stone artifacts, and—most significant of all—a mammoth tusk marked by cuts that are "unequivocally the work of humans." The tusk has been radiocarbon-dated to more than 36,000 years ago.

Incised mammoth tooth

EVA BJØRSETH

The researchers aren't sure if the marks result from the tusk's having been used as an anvil or if they "reflect intentional marks with artistic or symbolic meaning." They're also uncertain about who made the marks: Neanderthals *(Homo sapiens neanderthalensis)* or anatomically modern humans *(H. sapiens sapiens)*. If it was Neanderthals, then members of the group penetrated much farther north than previously thought. If it was modern humans (a possibility the researchers acknowledge), then they reached the Arctic much sooner than might be expected, given that *H. sapiens sapiens* first gained a toehold in southeastern Europe only a few thousand years earlier.

In a companion report on human adaptability to Arctic conditions, University of Liverpool archaeologist John A. J. Gowlett comments that "knowing who made the tools is less important than simply knowing that someone was adapted to the cool conditions." ("Human Presence in the European Arctic Nearly 40,000 Years Ago" and "Out in the Cold," *Nature* 413, 2001)—*Erin M. Espelie*

BEETLE JUICE Scarcely any rain falls in the Namib Desert, on the east coast of southern Africa, but the dense fog that blows across it from the Atlantic Ocean several mornings each month is a source of water that can be harvested—with the right equipment.

Andrew R. Parker, of the University of Oxford, and Chris R. Lawrence, of the British research and development organization known as QinetiQ, recently discovered how beetles of the genus *Stenocara* collect drinking water from Namib Desert fog. The beetles' backs are covered with bumps—under a microscope, they resemble a landscape of peaks and valleys. The peaks attract water, while the valleys, with a complex microscopic structure and a coating of wax, repel it.

Facing into the wind, the beetles tilt their bodies forward as moisture from fog collects on the bumps. Once a collected droplet grows heavy enough, it rolls down to the insect's mouthparts. Water droplets roll off the hydrophobic surface of lotus leaves in the same way, but the raindrops falling on leaves are much larger than fog droplets, which are so light that they travel almost horizontally in a breeze. The beetles' hydrophilic bumps are indispensable equipment for harvesting the tiny beads of fog before they waft away.

ANDREW PARKER; OXFORD UNIVERSITY

Stenocara

Parker and Lawrence believe that *Stenocara*'s structure can have practical applications on a large scale in the manufacture of vapor collectors. A tent that can gather drinking water for its occupants is in the works. ("Water Capture by a Desert Beetle," *Nature* 414, 2001)—*Kirsten L. Weir*

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NATURALIST AT LARGE

Flowers of Evil

By Rob Nicholson

Potent chemicals lurk behind some of South America's most alluring blossoms.

Brugmansia suaveolens, a species of angel's-trumpet, is found in coastal Brazil. The other four or five members of the genus grow in Andean regions.

In 1857 the French poet Charles Baudelaire published a collection of poems entitled *The Flowers of Evil.* Being a botanist, I once searched through the volume, curious as to which flowers he had in mind. I should have realized that poets don't mean things so literally. Had Baudelaire needed to single out a bloom whose beauty was coupled with malevolence, however, I would have offered him a flowering branch of *Brugmansia,* the angel's-trumpet of South America. This tree's flowers are among the largest and most sumptuous in the plant kingdom, while the stems, leaves, and roots contain narcotic and hallucinogenic compounds that alter the behavior of mind and body. Dozens of indigenous peoples in South America have used these plants in ways medicinal, ritualistic, and, in some instances, criminal.

Brugmansia is a genus of small trees and shrubs in the nightshade family, the Solanaceae (which includes potatoes, tomatoes, peppers, and eggplants as well as tobacco and many ornamental genera). The majority of its five or six species are native to the hills and mountains of the Andean countries, but one, *B. suaveolens,* is found in parts of coastal Brazil. I have seen *Brugmansia* resplendent with pendent tubular or trumpet-shaped blossoms, some measuring twenty inches from stem to tip, and can think of no other tree that has such a large proportion of its output diverted to floral flag-waving. The blooms have an almost fleshy texture, and the color may be ocher, ivory, soft pink, yellow, or even, in the species *B. sanguinea,* a combination of blood red and canary yellow. One feels compelled to fondle the flowers and inhale the complex perfume that wafts from the long trumpets. No wonder some native trailblazer was drawn to sample the taste of the plant; what an interesting meal that must have made.

Most potent among *Brugmansia*'s chemicals is the alkaloid scopolamine, formerly used during childbirth for its amnesia-inducing properties. In low doses, it can prevent motion sickness and is one of the ingredients of an antinausea medicine given to astronauts during weightlessness training. Overdosing may lead to delusions, hallucinations, and sometimes death. A modest dose of atropine, another alkaloidal compound found within *Brugmansia,* acts as an antidote to pesticide and nerve-gas poisoning, but an overdose can cause delirium, convulsions, and coma. This is definitely not a plant to be used by the self-medicating.

Although the narcotic and hallucinogenic properties of the angel's-trumpet were well known to various South American peoples at the time of the Spanish conquest, the religious matrix surrounding indigenous consumption of the plants has long since evaporated in most areas. Among the more ghoulish ancient usages were those by the Chibcha Indians of Colombia. According to a sixteenth-century narrative by the soldier and cleric Juan de Castellanos, when a chief died, "his women and slaves" were anesthetized so that they could be buried (quieted, but alive) with the departed. More recent reports from Colombia indicate a burgeoning use of powdered *Brugmansia* or its extracts to dose unsuspecting victims before robbery or rape.

The plant's chemicals include atropine, which can cause delirium and even coma.

The early European explorers who ventured into the South American wilderness included those seeking riches (gold, rubber, and quinine), those seeking souls, and those in pursuit of hidden botanical treasures. They often traveled the same paths and river roads, but of the three types of explorers, botanists may have left the slight-

DAVID L. BRILL

Peruvian shaman Eduardo Calderón Palomino, left, gathers blossoms of *B. sanguinea* for ritual and medicinal uses. Below: *B. suavealens.*

ALDO BRANDO

est footprints and the gentlest wake.

Among the modern-day scientists who explored *Brugmansia* in the field was the late Richard Evans Schultes, of Harvard University, renowned for his research on plants with therapeutic and psychoactive properties. During the winter of 1941–42, Schultes crossed the Colombian Andes before descending into the western Amazon Basin, his Eden. His route took him through the broad bowl of Sibundoy Valley, where the Putumayo, a major Amazonian tributary, begins as a trickle. Living in the verdant valley were Spanish settlers along with Kamsa and Inga Indians. Schultes observed that among the plants they cultivated were potatoes; the tree tomato *(Cyphomandra)*, whose tart fruit makes a lovely juice; and naranjilla, with its large fuzzy purple leaves and delicious fruit.

Schultes also recorded a number of medicinal and hallucinogenic species. The Kamsa had long practiced hallucinogenic healing rituals and had developed a lexicon of angel's-trumpet strains and species, each with its devotees. Hundreds of these plants were propagated throughout Sibundoy Valley, blurring the line between wild and tended plants. Schultes established a rapport with the Kamsa, who shared both their knowledge and their plants with him (some years later, Schultes arranged for one *curandero*, or healer, Pedro Juajibioy, to take a master's degree at Harvard).

Among the species Schultes found was a tree with sixteen- to eighteen-inch-long willowlike leaves. Its white flowers, with five spoon-shaped petals, each ending in a long point, were like no others. He recognized the mystery plant as a member of the nightshade family, but he thought that, while closely related to *Brugmansia,* it warranted designation as a new genus and species, which he named *Methysticodendron amesianum*. Chemical analyses done on the plant during the next five years showed that it possessed the same array of powerful alkaloids as the *Brugmansia* species found in the valley.

My interest in the angel's-trumpet was piqued in 1996 by a letter from a California collector, who alerted me to the fact that Smith College's own con-

FREDERICK D. ATWOOD

Angel's-trumpet trees bloom on a hillside in Ecuador.

servatories, where I work as a botanist, had been a hotbed of genetic research in the 1940s and 1950s. A.F. Blakeslee had used *Brugmansia* and the closely related genus *Datura* as subjects for research into heredity, and this collector wanted to know if we still had some of the rarer species. After fifty years this might have seemed a futile request, but in fact some still thrived in our huge palm house.

I had been exposed to *Brugmansia* while taking courses with Schultes at Harvard and now eagerly delved further into this fascinating group of plants. The genus had been a subject of research by a succession of Harvard botanists and students, whose dissertations, reports, and dried field collections held a wealth of data. The best work was done by Tommie Lockwood, who spent a year researching these plants in the Andes and then doing complex breeding trials to decipher the number of species in the wild and their ability to hybridize. (Tragically, Lockwood died in an automobile accident in Mexico while he was leading students on a field trip.) The more I looked into the genus, the more I became hooked. Next thing I knew, I was planning an expedition.

I contacted my collecting partner, Melvin Shemluck, a botany professor at Quinsigamond Community College in Massachusetts and also a former student of Schultes's. Using samples taken from Sibundoy Valley, he had done his thesis on the chemistry of *Iochroma fuchsioides*—another flowering shrub that is a chemical powerhouse. Mel and I enlisted a third participant, John Bela, who had recently studied botany at the University of Massachusetts Amherst, and together we roughed out an itinerary for collecting new samples from the

The Father of Ethnobotany

By Wade Davis

Richard Evans Schultes, 1915–2001

For more than fifty years, Richard Evans Schultes, a kindly professor of botany, loomed large over the Harvard campus. In South America, mountains bore his name, as did national parks. Students knew him as the world's leading authority on medicinal and hallucinogenic plants—as the plant explorer who sparked the psychedelic era with the scientific discovery of psilocybin mushrooms in Mexico in 1938.

In 1941, searching for wild rubber and the botanical source of curare, Schultes ventured into northwestern Amazonia, where he remained for twelve years, mapping uncharted rivers and living among two dozen indigenous peoples, all the while pursuing the mysteries of the rainforest. He collected more than 27,000 botanical specimens, including 2,000 medicinal plants and more than 300 species previously unknown to science. He was a living link to the great naturalists of the nineteenth century and to a distant era when the tropical rainforests stood inviolate, a mantle of green stretching across entire continents.

Schultes's devotion to students was legendary, his teaching style unique. In all the years I knew him, we never had an intellectual conversation. He was a man of deeds, who would pass along thoughts that were both gifts and challenges. "There is one river that I would very much like you to see," he would say, knowing that the experiences involved in getting there would ensure that, were you able to reach the destination alive, you would emerge from the forest a wiser, more knowledgeable human being.

Wade Davis, explorer-in-residence at the National Geographic Society, has written a biography of Richard Evans Schultes, One River: Explorations and Discoveries in the Amazon Rain Forest *(Simon and Schuster, 1997).*

locations frequented by Schultes and his students. We also wanted to bring back cuttings of *Methysticodendron* and grow a plant so that Schultes, then in his early eighties, could see it flower. (Years earlier, Schultes had distributed cuttings to various institutions, but we could locate no living specimens.)

The prize we had traveled so far to collect was hidden in the farthest corner of the garden.

In the summer of 1997 we traveled to Quito, Ecuador, and set out downslope to the sweltering lowlands around Santo Domingo de los Colorados for our first day of gathering. Here we found both the white- and the pink-flowered forms of *B. versicolor.* (We watched as foraging hummingbirds, finding the huge blossoms too long for their beaks, solved the dilemma by poking holes in the floral tube at the point where the nectary lay.) From there our route took us north into Colombia and on to the town of Sibundoy, in Sibundoy Valley. As we ambled down the main street to get a cup of coffee, trying not to arouse the suspicions of a police garrison on the alert for cocaine smugglers, we quickly found how impossible it is to be anonymous in a small town. Soon everyone knew we were *botánicos.*

After a night's rest, we headed south on a dirt lane toward the Kamsa lands where Schultes had first seen the rare *Methysticodendron.* Our innkeeper had told us we would encounter a small botanic garden. Along our route, the density of angel's-trumpets was astounding. Hundreds of them were planted as ornamentals beside humble cottages; others served as living fence posts or as shade trees for pigs and cattle. But no one we asked gave us clear directions to the botanic garden.

As we continued "botanizing" along the road, however, we encountered a short, rotund, elderly man who introduced himself as Florencio. He had a bowl haircut and wore a tribal tunic and what must have been fifteen pounds of fine white beads. Explaining who we were and what our purpose was, we showed him some fifty-year-old publications about the plants we sought. Florencio immediately recognized a photo of an old Kamsa shaman, Marcelino Chindoy, and announced, *"El finale"* (He's dead now). While the four of us walked back toward Sibundoy together, passing a variety of plants both native and introduced, Florencio expounded on their medicinal uses. We had met one of the valley's elder shamans.

Soon Florencio introduced us to the man in charge of the botanic garden, who turned out to be Marcelino Juajibioy, a son of the *curandero* who had assisted Schultes. We showed him the publications we had brought. In one was Schultes's photo of an eight- or nine-year-old boy, in tribal dress of tunic and beads, holding a blossom of *Methysticodendron.* To our amazement, Marcelino informed us that he was that boy. After gazing at another photo, a mature *Methysticodendron* in a field of corn, he paused and said, "That tree is gone now. It was my aunt's."

The next day Marcelino took us to see his garden. Getting there involved crossing a number of fields, drainage ditches, log bridges, and pastures, with Marcelino pointing out medicinal plants along the way. When we reached his garden, we found its design to be decidedly non-Olmstedian: here, rare native and medicinal plants were pragmatically intercropped with corn. In a drizzling rain, Marcelino showed us the monkey-puzzle tree, a native of Chile; the rare gymnosperms *Decussocarpus* and *Podocarpus;* and the famous vision-inducing *Banisteriopsis* vine. He generously let us take cuttings of whatever we could use.

The prize we had traveled so far to collect was hidden in the farthest corner of the garden. Marcelino brought us to a ten-foot-high, two-year-old tree with narrow, eighteen-inch-long leaves. The plant bore only one flower bud, not yet ready to open. During our days of combing the valley, this was the only *Methysticodendron* specimen we got to see. The plants seem to be jealously guarded by the shamans who own them. I stood atop Mel's shoulders to get cuttings, entertaining Marcelino with our clumsy circus acrobatics.


L.T. BATES

B. sanguinea

On the day of our departure we gave Marcelino copies of Schultes's monograph on *Methysticodendron,* and he handed us a letter to deliver to Schultes. The Harvard botanist's work had been the thread that brought us together. We left feeling certain our paths would cross again.

From Sibundoy we returned to Ecuador and crossed to the western side of the Andes to visit Los Cedros Biological Preserve. Near the town of Pacto, our bus passed an old adobe farmhouse with a thatched roof. I thought I caught a glimpse of a *Brugmansia* with thin leaves and made a mental note to check it out on our return trip. After a five-day stint collecting specimens in the highland rainforests, we passed back through Pacto. While our bus took on more passengers, I hurried up the road to the farmhouse. There they were, a row of what appeared to be mature *Methysticodendron* in full flower.

As I set up a tripod to photograph the blossoms—recorded for the first time outside Sibundoy Valley—a local dog pack descended from the hillside to demonstrate its total disrespect for English commands. They were followed by an old woman carrying an apronful of oranges. We exchanged greetings, and, communicating in pidgin Spanish, I learned that she had been growing the plants for thirty years and knew of both their medicinal use for rheumatism and their hallucinogenic properties. She allowed me to take a few cuttings and offered me some oranges as well, all under the glaring eyes of her dogs. While I would have liked to learn more, the bus rounded the corner and I had to push on.

For Mel, John, and me, this find was the most satisfying aspect of the trip. We now had precious *Methysticodendron* germ plasm to compare with that from Sibundoy. If they proved identical, this might suggest that *curanderos* had transported a cutting or plant from one side of the Andes to the other. On the other hand, *Methysticodendron* might be a mutation that occurs sporadically throughout the natural range of one of the *Brugmansia* species. The plants now growing at Smith College from our two sets of cuttings look sufficiently different that, despite their similar features, we can tell they are not identical clones. DNA testing of this material from well-documented sources should reveal their precise relationship.

Although the slow process of increasing the stock of *M. amesianum* has only begun, we at Smith College should eventually be able to distribute cuttings to other botanic gardens. Given this species' rarity in the wild and given the age of those who tend to it, *Methysticodendron* could conceivably vanish in South America within a generation or two. Eventually, we hope to work with a group of nurseries to market the plant and return a royalty to the botanic garden in Sibundoy.

Following our return home, Mel and I had the pleasure of bringing a rooted cutting to the Botanical Museum at Harvard to show Schultes. At least we *thought* we were just going to show it to him. The little plant went home with him and grew outside that summer on his deck. Two old friends reunited in the sun. □

HANS-GEORG PREISSEL

Methysticodendron amesianum

RICHARD EVANS SCHULTES

Marcelino Juajibioy, the son of a *curandero* who assisted Richard Evans Schultes, was photographed in the 1940s holding a flower and leaves from the enigmatic *Methysticodendron amesianum*.

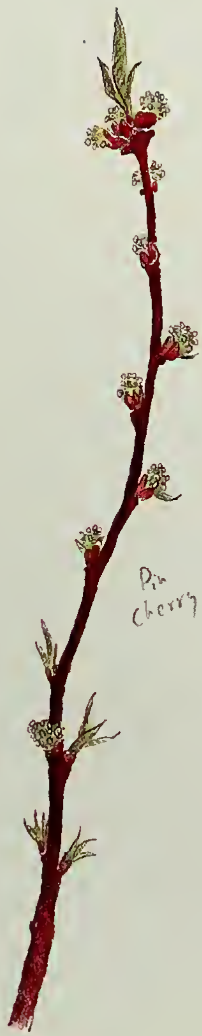
IN THE FIELD

Grand Opening

Coming this spring to a woods near you: breaking buds

Story and illustrations by Bernd Heinrich

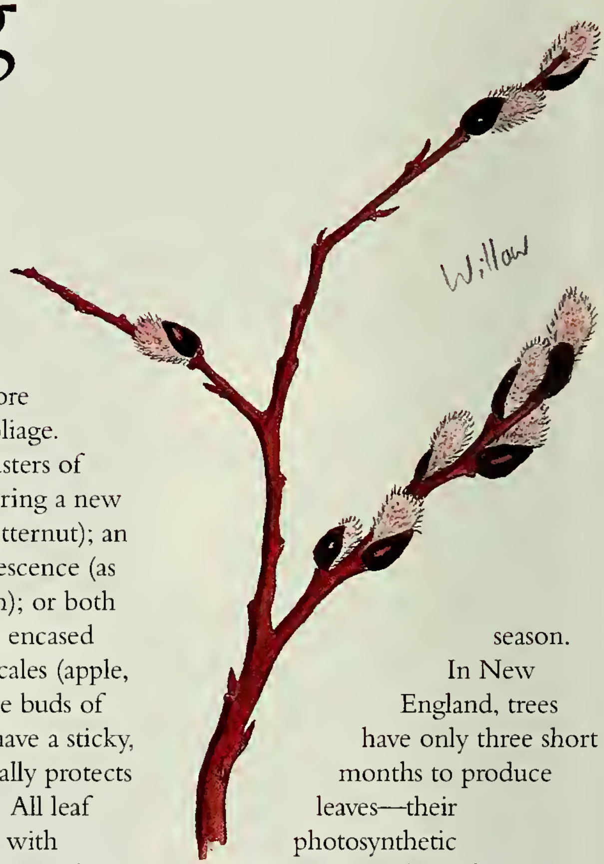
By the end of January, those of us who live in the Northeast have been looking out on starkly bare trees for three months. "Only four more months," we think, before the buds break and trees are again resplendent in green. The wait seems all the harder when you realize that the buds are there all along, biding their time.



Indeed, they were fully formed on the trees the previous summer, long before the shows of brilliant fall foliage.

A bud can consist of clusters of bare miniature leaves harboring a new shoot (as in hickory and butternut); an embryonic flower or inflorescence (as in alder, hazelnut, and birch); or both incipient leaves and flowers encased together under protective scales (apple, cherry, shadbush). The large buds of mountain ash and poplars have a sticky, resinous covering that partially protects them from hungry animals. All leaf and flower buds are packed with nutrition and are a prized winter food for many northern herbivores. Ruffed grouse savor aspen and birch buds, and I've watched purple finches and red squirrels devouring sugar maple flower buds. Moose break off branches of poplar saplings and of red and striped maples to feed on the terminal buds and twigs. In some patches of my woods in Maine, I can hardly find a single sapling that is untouched by moose, deer, or snowshoe hares.

Even for large-budded northern trees, the prepackaging of leaves and flowers into buds must have some advantages that outweigh the considerable cost of maintaining buds for so long before they are activated. I suspect the main benefit is the readiness of buds to break out quickly on cue, thereby allowing the tree to make the most of a short growing season.



In New England, trees have only three short months to produce leaves—their photosynthetic machinery—and use them to make an energy profit. When the long-awaited spring finally arrives in the Northeast, it does so suddenly. Over a week or two, the ice and snow melt, and the bare ground begins to absorb heat. In only three or four days in mid-May, a bare beech forest is crowned with a canopy of pea-green leaves soaking up sunlight.

There, is however, a major constraint in the trees' race to grab light: new leaves are vulnerable to frost damage. As long as they are dormant, buds can survive the lowest subzero temperatures of winter. Once they awaken and begin to draw water into their tissues, they are at risk. They need to open as early as possible, but not too early. Trees, being long-lived, can perhaps afford to lose flowers to frost in any one year, because energy saved one year by not fruiting can instead be invested in growth and can lead to the production of even more fruit the next year. Losing leaves to frost, however, is more serious; if the tree misses out on the sunlight sweepstakes, growth and reproduction will suffer. Re-leafing is sometimes possible but is energetically costly. That said, trees are seldom fooled by a false start, such as a midwinter thaw. How do they know when to start their metabolic engines and break bud?

Buds follow local schedules that are dictated by an interplay of cues involving day length, seasonal duration of cold exposure, and warmth. Warmth alone is not enough. For example, sugar maples from the North, if transplanted to Georgia, won't break bud there because they need a long period of cold beforehand, a kind of reminder that winter has occurred. The strategy is a bit like that of northern cecropia moth pupae, which do not stir unless previously chilled for a sufficiently long time.

Where I spend most of my time, in Maine and in central Vermont, new leaves of all the deciduous tree species usually emerge relatively synchronously in mid-May, over the short span of about two weeks. First to appear are quaking aspen and birch leaves; last are oak and ash. Beech, maples, and the others are in between. Flower buds of the native forest trees, however, open in a progression over a six-month span, starting in April with poplars, willows, alders, and beaked hazel and ending in October with witch hazel. (Significantly, the latest-blooming species do not have visible flower buds in winter.) In trees such as apple, cherry, shadbush, and elderberry, with flowers and leaves packed in the same bud, the flowers generally bloom in one quick burst; the leaves follow almost immediately.

Having separate buds for leaves and flowers allows a tree—a poplar or willow, for example—to open its flower buds a month before the leaf buds or up to five months after them. For example, wind-pollinated trees may produce flowers a month or more before leaves, which tend to block wind flow. In contrast, a bee-pollinated basswood can flower a month or more after the leaf buds have opened, when bee populations peak in late summer. Witch hazel takes advantage of the pollination services of winter moths of the genus *Eupsilia,* which are active in fall.

Bud opening is a wonder but can easily be taken for granted. I like to be reminded of the spring miracle, especially in the depth of winter, when the vibrantly alive trees look so dead. Every year in January, February, and March, I go into the woods, pick some twigs of trees and shrubs, then bring them home and stick them in a jar of water. Indoors, some buds can be "forced" to open at least three months ahead of their normal outdoor schedule. Twigs of trembling aspen, willow, beaked hazel, speckled alder, and red maple, picked as early as January and brought inside, will flower and then shed their pollen. (The flowers of these trees and shrubs are also the first to open in the woods, in early April, when there is still snow on the ground.) In contrast, most leaf buds, as well as the flower buds of late-blooming trees such as basswood, don't respond to the warmth of my office until March.

While snowstorms rage outside and the temperature may dip below 0°F, the jar of twigs gives me hope of balmy days to come. Meanwhile, the buds on the trees outside remind me of runners who have prepared for a big race for more than six months and who now wait for the sign to start. In late April or early May, a warm temperature pulse will be the "go" signal, starting them on their race to the sunlight and summer.

Bernd Heinrich is a professor of biology at the University of Vermont, Burlington. His latest book is Racing the Antelope: What Animals Can Teach Us About Running and Life *(HarperCollins, 2001). This essay is adapted from a chapter of a book-in-progress,* The Winter World, *to be published by HarperCollins this fall.*

FINDINGS


At play in Delhi

SAURABH DAS; AP/WIDE WORLD PHOTOS

Remembrance of Pathogens Past

A physician ponders suggestive evidence that periodic infections are needed to foster a normal immune system.

By T. V. Rajan

I was sitting downstairs having a quiet cup of tea when I heard screaming from one of the bedrooms above. It was my daughter Tara. Between shrieks were occasional bursts of words: "Omigod, omigod! Daddy!" she was yelling in the signature diction of a turn-of-the-twenty-first-century American teenager. "Come here! This is so gross!" Rushing upstairs wondering if a rabid raccoon had somehow made its way into her bedroom, I found my daughter cowering in a corner. She pointed to her bed. There, silently crawling over pristine white bed linens, was a dark spider, no more than a quarter inch long. "Omigod, Daddy, please get rid of it! Eeeewww!" Half relieved, half annoyed, I picked up the errant arachnid with a piece of paper and carried it out.

I couldn't help comparing the circumstances in which my daughter is growing up with those of my own childhood in India. In our house in Madras (now officially known as Chennai), we ended many a searingly hot day by sitting out on an open veranda, trying to cool off in the ocean breeze. After sunset, when the house lights came on, the veranda's whitewashed walls would gradually darken to near black, transformed by the countless insects attracted to the lamps. And with the insects came the geckos that stalked them and swallowed them whole. I don't believe we ever paid particular attention to this nightly panorama; it was just part of our lives. Only now, when I go back to Madras and stay with my parents, do I notice the contrast between my dirt-free, animal-free Connecticut home and my boyhood home, which teemed with untidy, unruly life.

Along with the household cleanliness in Connecticut comes a kind of internal bodily sterility as well. My own childhood in India was characterized by what seems, in retrospect, to have been an interminable series of infections. My cousins and I were always getting diarrhea, colds, and fevers of unknown origin. In a country where potable water and sewage are barely separated at the best of times, a minor inclemency sent by the weather gods can blur the distinction even further, making one family's effluent another's sustenance. Add to that the ubiquitous puddles of water that breed every conceivable species of mosquito, and the result is an environment in which waterborne pathogens compete with those carried by arthropods for a foothold in every available human. Life is so different in suburban America. My own children go through long periods when they are well, truly well. It is difficult to appreciate the wonders of modern sanitation and sewage control if one has never been exposed to the realities experienced by most of the world's population. And of all the accomplishments of modern science, the conquest of childhood illnesses must surely rank among the greatest.

It is in this context that I have become particularly fascinated by two reports about ethnically South Asian children growing up in Canada and the United Kingdom. For many years,

physicians had informally observed that such children are more likely than others in those countries to suffer from ulcerative colitis, an inflammatory bowel disease (IBD) of unknown etiology. IBD patients suffer from attacks of bloody diarrhea and have an increased risk of colon cancer. Following up on physicians' anecdotal reports, Scott M. Montgomery, scientific research fellow at London's Royal Free and University College Medical School, and others recently published a careful analysis of the cumulative incidence of IBD in a group of children born in the United Kingdom during a specific week in 1970. People of Indian, Pakistani, and Bangladeshi backgrounds, Montgomery's team found, were indeed significantly more likely than any others in the group studied to develop IBD (which includes both ulcerative colitis and a similar disorder, Crohn's disease) by the age of twenty-six. The second study, by H. J. Freeman and N. B. Hershfield, of the University of British Columbia, showed that Indo-Canadian children also have a significantly increased risk of developing IBD and that the onset of disease was earlier for Indo-Canadians than for Canadians of other ethnic groups.

Both studies are even more striking because they indicate that the rates of IBD in the United Kingdom and Canada are actually higher than the rate in India. Although the data from India are sparse, they do suggest that, in general, the disease is relatively milder there and has a later onset. Also quite fascinating is the well-documented inverse relationship between infant and early-childhood mortality rates and the incidence of IBD. India, with one of the world's higher rates of infant and child mortality, has one of the lower rates of inflammatory bowel disease.

Why are British-born South Asians much more likely than Britons of other ethnic backgrounds to suffer from ulcerative colitis?

The authors of the Canadian and U.K. studies reasonably conclude that ethnic Indians (and presumably others of South Asian ancestry) have a genetic predisposition for these bowel disorders that expresses itself in combination with an environmental factor. But what might the environmental factor be? To answer that question, an illuminating comparison can be made between the situation of ethnic Indian children in the United Kingdom and Canada and that of a strain of laboratory animal known as the non-obese diabetic (NOD) mouse.

Susumu Makino and colleagues at the Shionogi Research Laboratories in Japan derived the NOD mouse in 1974 from a strain of mouse that was susceptible to cataracts. The investigators hypothesized that because cataracts are a fairly common complication of diabetes, some members of the cataract-prone group might be diabetes-prone as well. Selective breeding resulted in a strain in which females are progressively more likely, as they age, to develop diabetes. By the time they are seven months old, NOD females have a 70–80 percent likelihood of being diabetic, while the figure is only 20 percent for males.

Excellent evidence exists to demonstrate that diabetes in NOD mice is an autoimmune disease caused by malfunctioning T lymphocytes, or T cells, the white blood cells that are a mainstay of the body's immune system. By crossing NOD mice with other inbred mice, researchers have identified a link between many segments of the genome and certain traits that are found in all the diabetic mice. Of these shared areas, among the most important are the genes for the major histocompatibility complex—the molecular flags that tell the T cells what is self and what is nonself. In diabetic mice, the result is that the T cells attack healthy cells rather than going after the pathogens.

In addition, one of the genes associated with the development of diabetes in these mice is located on chromosome 1, near a gene associated with resistance to certain infections, notably the mycobacteria that cause various types of tuberculosis. With this association in mind, A. Bras and Artur Aguas, of Portugal's University of Porto, devised an experiment to find out whether NOD mice were resistant to *Mycobacterium avium*, a pathogen to which other lab mice are highly susceptible. The NOD mice were indeed resistant, but the experiment had another, unexpected outcome: not one of the mice infected with *M. avium* developed diabetes. In other words, exposure to and successful recovery from mycobacterial infection prevented the development of an autoimmune disease in these animals. Two similar studies, conducted by Anne Cooke and colleagues at the University of Cambridge, showed that NOD mice infected with the trematode parasite *Schistosoma mansoni* also had a significantly reduced chance of becoming diabetic.

These intriguing associations are a clue to why an organism would retain a set of genes that seems to favor the development of a lethal disease—whether diabetes in the case of a mouse or colitis in the case of a human. Part of the answer may lie in a paradoxical pattern: ever since scientists have been raising NOD mice, they have noticed that the dirtier the colony, the lower the incidence of diabetes.

Have certain genes persisted in the mouse because they make the animal particularly resistant to infection? While no studies have explored this hypothesis in the wild, a number of laboratory studies done with specific infectious agents suggest it may be correct. Infections result in the development of "memory cells" (T cells that recognize a given infectious agent and will mobilize against it). Rafi Ahmed and coworkers at the Emory University School of Medicine in Atlanta, Georgia, examined the immunological memory of meningitis infection in mice. They found that when an infection was acute, as many as 70 percent of the active T cells in a mouse's spleen (an organ that plays a major role in mammalian immune reactions) "recognized" the meningitis pathogen. After the infection cleared up, the number of meningitis-recognizing T cells dropped to about 1 percent—but they remained at that level throughout the life of the mouse.

Ahmed's findings suggest that for most mammals, infection-specific memory cells accumulate with each subsequent illness, becoming the dominant type of cell in the spleen of aging animals, while the number of "naive" white cells (those that have never encountered a pathogen) come to constitute a lower proportion of the total. If this is so, then animals living in a pathogen-free environment presumably have fewer memory cells and more naive cells than do animals exposed to bacteria, viruses, and parasites throughout their lives. The immune system may in fact be adapted to accumulate more and more of these memory cells, and periodic infections may be necessary to foster normal function. Lack of exposure—the environmental factor that works in tandem with genetic predisposition—may lead to greater vulnerability to autoimmune disorders.

Epidemics of infectious disease have doubtless subjected the human populations of tropical regions to repeated rounds of natural selection.

Over millennia, people living on the Indian subcontinent might well have been strongly selected for genes that confer resistance to a specific set of bacteria, viruses, and parasites. Certainly, most population geneticists and evolutionary biologists believe that infectious agents are major players in the evolution of the human genome. This hypothesis, first stated in 1949 by British geneticist J. B. S. Haldane, is supported primarily by the observation that certain genes—such as those for sickle-cell anemia and Tay-Sachs disease—tend to be found almost exclusively in ethnic groups hailing from regions where a particular infectious disease (malaria in Africa or tuberculosis in northern Europe, for instance) is widespread. But actual data demonstrating that infectious agents have changed a population's genes have always been hard to come by.

However, intriguing research on the role of pathogens in causing shifts in a population's genes was in fact performed in the 1970s by R. R. De Vries et al., of Leiden University Medical Center in the Netherlands. De Vries studied the descendants of a group of Dutch colonists who migrated to Suriname in the nineteenth century. Soon after those settlers arrived, they were hit by major epidemics of typhoid and yellow fever. Most died of one disease or the other. The De Vries team's analyses of the survivors' descendants showed that some of their immune-system genes differed significantly from those of people living in the part of Holland from which the Suriname group's forebears emigrated. The researchers took pains to demonstrate that these changes were not due to genetic drift.

Like the Dutch of Suriname, human populations living in other tropical regions with poor sanitation and high levels of exposure to pathogens have doubtless been subjected to thousands of rounds of natural selection by repeated exposure to epidemics. The survivors probably have immune traits that are well designed to fight off specific infections. If Indian children grow up in India, continually fighting infections, then their immune systems presumably come to some equilibrium with the pathogens in the surrounding environment. On the other hand, children of Indian parentage who are born and raised in more hygienic circumstances in the United Kingdom or Canada may end up with underused and therefore dysfunctional immune systems. In this, they may resemble the NOD mice in the clean environment, spared from exposure to the pathogens found in dirty cages but, as a result, lacking the robust immune systems that would protect them against diabetes.

Other intriguing evidence attests to increases in human immune dysfunction in the developed world: the rate of insulin-dependent diabetes mellitus is on the rise, and asthma is rampant in the inner cities of North America. It is tempting to speculate that various ethnic populations that have proved susceptible to *these* maladies were originally selected for resistance to other constellations of infectious agents—the ones prevalent in the countries of their forebears.

It is also fascinating to think that the human immune system is geared to accommodate a certain number of infectious agents and that, because we have coevolved with these microbial partners, they have come to play the beneficial role of regulating the system. This is not to imply that all infections are salutary phenomena but rather that exposure to infection perhaps confers some significant benefits.

Indeed, I have detected a growing sentiment among biologists that the elimination of exposure to infectious agents may, at least in some genetically susceptible individuals, create a whole different set of health problems. If an oversimplified version of this idea gains currency, I fear that the public may begin to ignore or discount anti-exposure measures, which have had incalculable benefits wherever they have been applied. For every child who now suffers from ulcerative colitis or some other autoimmune disease because he or she was not exposed to childhood illnesses at the appropriate time, our sanitized world is probably saving the lives of tens, if not hundreds, of thousands of children who were at risk of dying from diarrhea, malaria, typhus, cholera, schistosomiasis, and other pathogen-caused illnesses.

Meanwhile, speaking for myself, I am glad that Tara gets to live where she does, rather than where I was raised.

T. V. Rajan, M.D., is chairman of the department of pathology at the University of Connecticut Health Center in Farmington, Connecticut.

THE EVOLUTIONARY FRONT

All for One and One for All

Multicellular organisms have arisen more than once, each time through an intricate dance of cooperation and conflict.

By Carl Zimmer


JAMES MARSH

Viewed under a microscope, a drop of pond water is a liquid game park, squirming with bacteria, amoebas, and other exotic wildlife. One of the prettiest creatures you may catch sight of is a tumbling, crystalline, globe-shaped alga known as volvox. Reaching up to three millimeters in diameter, volvox is essentially a shell formed from cells. Each cell is equipped with a quivering tail, and these appendages spin the globe through water. The alga's gelatinous core holds a few gigantic cells, like jewels encased in a translucent Fabergé egg. For several days of its brief life, volvox basks in the sunlight, using photosynthesis to capture the energy of the sun. Meanwhile, the gigantic cells—the eggs of volvox—start dividing and turning into embryos. When they're ready for life on their own, they digest their way out of their parent's body, which dies after a few more days.

As alien as volvox may seem, we humans actually share a bond with it. Like us, it belongs to that special fraternity of species that are made of many cells living together in a single body. On a planet where life got its start as single-celled microbes, the dawn of multicellular life was a milestone in the history of evolution. And by studying how multicellular creatures such as volvox took that step, scientists can gather clues about how our own bodies evolved.

Multicellularity has emerged dozens of times during the past 2 billion years. Our own multicellular lineage, the animals, probably descends from protozoans that lived in loose colonies, as do some choanoflagellates, the closest living single-celled relatives of animals. The earliest animals (which, according to fossil evidence, emerged at least 600 million years ago) may have consisted of cells glued together with adhesive proteins, as is the case in the most primitive living animals, the sponges. And, like sponges, they may have reproduced by releasing small chunks that developed into full-blown organisms. Eventually animals evolved a system in which only a relatively few specialized germ cells (eggs in females, sperm in males) played a role in reproduction.

Other lineages that became multicellular took on dramatically different forms. Plants, for example, started out as green algae, while mushrooms evolved from several lineages of single-celled fungi. Some single-celled species have evolved the ability to become multicellular in times of crisis. When their food runs out, slime molds (protozoans common in the soil) swarm together, forming a stalk topped by a spore-packed bulb. Wind and water can carry the spores away to a more promising place, where they can revive and go on with their single-celled lives.

Because multicellularity is an experiment that's been run many times in the history of life, scientists may be able to discover some universal rules for how it comes about. Some of the most interesting recent results have come out of the laboratory of Richard Michod at the University of Arizona. Michod and his team have built complex mathematical models of the transition and compared them with processes in the natural world. They conclude that multicellularity arises through an intricate dance of cooperation and conflict.

For microbes, joining together has plenty of potential rewards. First off, multicellular organisms can enjoy the benefits of being big. For example, being big is a good defense, because once you get bigger than the microbes around you, they can't simply swallow you whole. Big organisms can also evolve novel means to swim or crawl faster toward food and away from danger.

On its own, a single cell faces inherent obstacles to becoming larger. In order to keep up its metabolism, it needs to pump molecules in and out through the cell wall. This exchange gets less efficient as a cell expands, because its volume increases far faster than its surface area. Multicellular creatures can skirt this physical constraint by keeping their individual cells small but gluing them together into big bodies. Of course, pathways need to be kept open to ensure that the individual cells are bathed in the necessary fluids.

Size isn't the only advantage of the multicellular lifestyle. A single-celled microbe often has to be a jack-of-all-trades, capable of finding food, defending itself against parasites and predators, withstanding sudden swings in its environment, and creating new copies of itself. By contrast, an organism built out of millions of cells is free to transform them into various types that can carry out such different tasks as detecting light, digesting proteins, or forming a skeleton. Through evolution, each type of cell—whether it is a foot-long neuron in a spinal cord or a keratin-producing cell in a fingernail—can become exquisitely specialized for its job.

So why hasn't all life become multicellular? One important reason may be that whenever a multicellular lifeform emerges, natural selection begins to operate on two distinct levels. One level is that of the individual cell, and the other is that of the whole body. And what is advantageous for one may well turn out to be disastrous for the other.

Life, death, and reproduction differ greatly on these two levels. When we have children, we continue to exist as individuals until our own bodies fail and die. A single-celled microbe, on the other hand, typically reproduces by dividing into two or more "daughter" cells. Once it divides, there is no parent left. While human bodies don't divide this way, each of our individual cells do. As they divide, they give rise to lineages of cells that create and maintain our entire body. But all these lineages are doomed to extinction when we die—except for those that give rise to the few eggs or sperm that create our children.

In multicellular organisms, the cells that can foster a new generation are called germ cells, while all the others are called somatic cells. This division of labor can work only if all the players—the cells—obey the rules. But cheating can be extremely attractive. Imagine a primitive colony of microbes that reproduces by budding off little packages of germ cells (a method used by a number of primitive animals, including corals). Each of these packages of germ cells then grows into a new individual. Suppose a mutant gene arises in one of the microbes in the colony, guaranteeing that the microbe will become a germ cell rather than dying off with the rest of the colony. This "cheater gene" might bring so much reproductive success that more and more cells become germ cells, until ultimately a colony (or body) has too few somatic

Except for the egg and sperm lines that create our children, the lineages of cells in our bodies die with us.

cells to function. This would defeat the whole advantage of multicellular organization and lead to a dead end.

Another way for cells to cheat in such a colony is to replicate madly. Instead of restraining themselves for the good of the colony, these cheaters exploit their fellow cells for their own benefit. Such cheaters are an all-too-common threat to our own well-being. They strike millions of people every year and are best known by their common name: cancer. Cancer cells can mutate at a much higher rate than normal cells, and those that can take advantage of our bodies—by, for example, stimulating the growth of blood vessels that supply them with food—are rewarded by natural selection. Ultimately, of course, their evolution is doomed, because they can never survive outside their host. But natural selection is, by definition, a blind process that cannot recognize a dead end on the road of evolution.

Because our body cells descend from a common ancestor, they gain little by betraying one another.

Michod and his graduate students have suggested that these kinds of conflicts between individual cells and the entire body favor the evolution of what they call conflict mediators—genes that bring the interests of the cells and the body into line. Such conflict mediators, they hypothesize, might ensure that an organism develops from a single cell instead of a package of cells. This would reduce the competition between the organism's cells, because they descend from a single common ancestor. Since the cells share identical genes, the reproductive success of any one of them means success for all. Cheaters would pay a higher evolutionary cost for betraying their fellow cells because they would be harming their cousins rather than strangers.

In other situations, conflict mediators might enforce the bodily peace with a stick instead of a carrot, punishing any cell that mutates into an unruly form. Our own cells are programmed to commit suicide if they start dividing too rapidly; thanks to this mechanism, we suffer far lower rates of cancer than we would otherwise. The genes that trigger this cellular suicide may have arisen as our ancestors adapted to multicellularity.

Every multicellular species confronts this interplay between cooperation and conflict, whether the organism is an animal with trillions of cells and dozens of cell types, or volvox, with a few thousand cells that come in only two types. And because volvox is so simple, scientists such as Michod and his colleagues can study it closely, carrying out genetic experiments to learn how evolution has produced its particular flavor of multicellularity.

A freakish mutant may hold the secret to how volvox made the transition. Every now and then, a volvox is born with a horrible defect. After developing into a normal-looking individual, its somatic cells start dividing into germ cells. The mutant volvox becomes nothing more than a collection of germ cells that, unable to move or feed themselves, inevitably die.

Scientists have discovered that this monster is produced whenever mutations disable a single gene called *Reg*. Normally, *Reg* prevents somatic cells from giving rise to germ cells. It does this by taking advantage of the peculiar way in which cells in some algae, such as volvox, divide—they don't simply divide in two as our cells do; instead, they first grow large and then fragment into thousands of daughter cells. *Reg* can stop this process by curtailing a cell's production of light-catching structures known as chloroplasts. Unable to boost its level of photosynthesis, the cell cannot grow. Unable to grow, it cannot divide. Unable to divide, it cannot give rise to germ cells.

The evolution of *Reg,* which appears to be unique to volvox, may have allowed these algae to become multicellular. When the ancestors of today's volvox acquired *Reg,* they found a powerful way both to segregate germ cells from the rest of their body and to foil cheater cells. But *Reg* is also very crude; it simply stops most of volvox's cells from dividing by starving them. Postdoctoral fellow Aurora Nedelcu and Michod have suggested that *Reg* may have robbed these organisms of the chance to evolve into a more complex form.

Volvox and its relatives went through a burst of evolution 50 million years ago, during a period when many lineages were rapidly changing from single cells to multicellular forms. But after this evolutionary spurt, volvox and its cousins failed to become any more elaborate. By contrast, some of their relatives evolved into land plants some 500 million years ago, going on to become among the biggest, most complex life-forms on the planet.

Multicellularity is a series of developments, not an all-or-nothing affair. At the time our own distant ancestors took the first few steps, there was no guarantee they would go the distance. But not only did they succeed in turning conflict into harmony, they managed to hold on to some evolutionary flexibility. Able to control the differentiation of somatic cells, they produced new organs, such as stomachs and brains. And that's why it is we who look through a microscope at volvox, and not the other way around.

Science writer Carl Zimmer is the author of Evolution: The Triumph of an Idea *(HarperCollins, 2001). His book* Parasite Rex: Inside the Bizarre World of Nature's Most Dangerous Creatures *has recently been published in paperback.*

MUSEUM EVENTS

FEBRUARY 2 AND 3
Demonstration and concert: Following the Beat series, introduced by ethnomusicologist Benjamin Lapidus. "New Fusions": Percussionist Satoshi Takeishi, flutist Steve Gorn, and violinist Jason Kao Hwang demonstrate instruments from AMNH's Hall of Asian Peoples, February 2, 1:00–3:30 P.M., Leonhardt People Center. Concert by series participants, February 3, 3:30 P.M., Linder Theater.

FEBRUARY 4
Lecture: "Journey From the Center of the Sun" (Distinguished Authors in Astronomy series). Astronomer Jack Zirker, of the National Solar Observatory in New Mexico. 7:30 P.M., Kaufmann Theater.

FEBRUARY 8
Lecture: "Flexing the Canon: Divine and Human Muscularity in Late-Twentieth-Century Indian Mass Culture." Changing artistic representations of the Hindu god Rama. Kahri Jain, fellow of the Getty Research Institute. 6:30 P.M., Linder Theater. Presented in conjunction with "Meeting God: Elements of Hindu Devotion" (on view through February 24 in Gallery 77).

FEBRUARY 9 AND 10
Screenings: *Ramayan* (1987): segments from the Indian television series, February 9, 1:30-3:30 P.M. *In the Name of God* (1992): a documentary on the Hindu nationalist campaign in Ayodhya, February 9, 4:00–6:00 P.M. *Hum Saath Saath Hain (We Stand Together)* (1999): a modern epic made in the Bollywood style, February 10, 3:00–6:00 P.M. Kaufmann Theater. Presented in conjunction with "Meeting God: Elements of Hindu Devotion" (on view through February 24 in Gallery 77).

FEBRUARY 9, 16, AND 23
Centennial celebration: "A Tribute to Langston Hughes" (Black History Month 2002 weekend series). Highlights include *Langston Hughes, A Jazz Opera: The Soul of His Words,* with Benny Russell and his Next Jazz Legacy Orchestra. Leonhardt People Center and Kaufmann and Linder Theaters. For details, call (212) 769-5315.

FEBRUARY 13
Members only: "One Thousand Ways To Say 'I Love You': A Valentine's Program." A cross-cultural discussion of love by Museum anthropologists Laila Williamson, Naomi Goodman, and Anne Wright-Parsons. 7:00 P.M., Linder Theater.

FEBRUARY 19 AND 27
Panel discussions and video: Marine Conservation Lecture series. "Coastal Fisheries"(panel), February 19, 7:00 P.M. "Mangroves: The Roots of the Sea" (panel and video), February 27, 7:00 P.M. Kaufmann Theater. Prelude to the March 7–8 symposium "Sustaining Seascapes: The Science and Policy of Marine Resource Management."

FEBRUARY 20
Members only: "Birds of Heaven." Author and naturalist Peter Matthiessen discusses his search for the world's cranes. 7:00 P.M., Kaufmann Theater.

FEBRUARY 21
Members only: "Behind the Scenes in the Department of Mammalogy." AMNH mammalogists Christopher Norris, Darrin Lunde, and Neil Duncan. 6:30, 7:00, and 7:30 P.M.

FEBRUARY 26
Lecture on upcoming sky events: "Celestial Highlights." Amateur astronomer Hank Bartol. 6:30 P.M., Space Theater, Hayden Planetarium.

ROSE CENTER PRODUCTIONS/NASA

"The Search for Life: Are We Alone?"—a new space show—opens at the Hayden Planetarium in mid-February. The show is generously supported by Swiss Re.

FEBRUARY 28
Lecture: "Time Traveler: In Search of Dinosaurs and Ancient Mammals From Montana to Mongolia." AMNH Provost Michael Novacek. 7:00 P.M., Kaufmann Theater.

DURING FEBRUARY
Live jazz, tapas, and beverages: "Starry Nights: Fridays Under the Sphere." Two sets every Friday, 5:45 and 7:15 P.M., Rose Center for Earth and Space. For details, go to www.amnh.org/rose/specials/jazz/.

Registration for March 7–8 symposium: "Sustaining Seascapes: The Science and Policy of Marine Resource Management" (sponsored by AMNH's Center for Biodiversity and Conservation and others). For more information, call (212) 769-5200 or go to research.amnh.org/biodiversity/.

The American Museum of Natural History is located at Central Park West and 79th Street in New York City. For listings of events, exhibitions, and hours, call (212) 769-5100 or visit the Museum's Web site at www.amnh.org. Space Show tickets, retail products, and Museum memberships are also available online.

Keeping Up With the Cones

Chased by evolutionary biologists and pharmacological researchers, a tropical mollusk redefines "a snail's pace."

By Aparna Sreenivasan

In the early 1900s a U.S. marine stationed in the Philippines found a beautiful shell near a coral reef. Thinking it would make a nice gift for his girlfriend back home, he carried it off, placing it on his shoulder to show his friends. As the young man walked toward his buddies, the animal inside the shell extended a needlelike organ and stung him on the neck. Within minutes, the marine was dead.

The unfortunate American died from the sting of a cone snail, a member of the genus *Conus*. Collectors and beachcombers have long admired and coveted the snails' beautiful shells, risking a sometimes fatal sting to get them. The

The barbed, harpoonlike radula of a striated cone snail emerges from its proboscis.

genus includes more than 500 species, whose shells are embellished with a seemingly endless variety of intricate patterns: repeating triangles or tiny cobblestone motifs, stripes, bands, spots. The length of the protoconch (the spiral on the wide posterior end of the shell) and the number of whorls differ by species, and the shells range from the size of a grape to that of a pear. To a collector, the allure of a mature, undamaged specimen—called a gem shell, and nearly impossible to find—cannot be underestimated. Despite the risk, people still pick them up.

Like a chef who compulsively varies a recipe, a cone snail might never shoot out the same toxin combination twice.

"Cone snails don't have big jaws and sharp teeth, and they don't move very fast," says Baldomero Olivera, a University of Utah biology professor who studies these animals. "The only thing they have going for them is their venom." In a comparison among ten groups of carnivorous snails, Suzanne Lawrenz Miller, of the University of Washington, found that *Conus* are among the slowest, moving an average of 0.43 millimeters per second (some other meat-eating gastropods can move twice to ten times as fast). Thus, members of the genus must rapidly overwhelm their prey when they get the chance.

KAREN GOWLETT-HOLMES

To detect prey, a cone snail uses its siphon, an organ that takes up water and directs it over the gills. Once the snail finds a target, it jabs the victim with its radula (a hollow tooth with a harpoonlike barb). Most mollusks use the radula to break up food, but the cone snail uses it to inject venom. A tether attached to the radula allows the predator to retract it quickly; the snail then draws the still-living prey through its proboscis and into its gut. If a fish were still able to twitch after the injection, it could escape before being swallowed, and another creature could swim up and eat it. And a worm-eating snail would be just a hungry snail if its prey could slip back into a burrow to die. The cone snail's venom must be quick-acting and extremely effective or, as with some molluscivorous species, be administered multiple times.

Cone snails have existed for 55 million years, a relatively short time in evolutionary terms. Yet the number of species of *Conus*—the largest genus in the animal world except for insects—has been doubling every 6.1 million years. (Other rapidly evolving snail types have been doubling their numbers every 10.3 million years.) "And these rates are underestimates," cautions biologist Tom Duda, of the Smithsonian Tropical Research Institute in Panama, because the method does not account for *Conus* species that are now extinct. "I call them the fastest

DOUG PERRINE/INNERSPACE VISIONS

An omary cone, above, found under a rock off the coast of Bali, demonstrates what Yale's Jon-Paul Bingham calls the "lay 'em and leave 'em" strategy of rearing young. Right: The waters around the Caroline Islands, a Pacific archipelago east of the Philippines, are home to many cone species.

snails in the West," says Alan Kohn, a biologist at the University of Washington. Possibly driving the rapid expansion of the genus are its venoms, which are mixtures of peptides known as conotoxins.

Like a chef who compulsively varies a recipe each time he prepares it, a cone snail might never shoot out the same toxin combination twice. The genes controlling such variability may be important targets for natural selection, but other pressures might also play a role. "One hypothesis is that conotoxins are evolving in response to changes in diet," says Duda. Conotoxins' effectiveness comes from being adapted to particular prey species. Duda is investigating whether snail species with specialized diets produce highly specialized venoms. Another factor driving the increasing diversity of *Conus* might be their capacity to survive a long-distance drift. Although adults generally do not move far from their coral-reef homes, the minuscule larvae, floating with the oceanic plankton, sometimes end up in unfamiliar territory (some species' ranges extend from Hawaii and Tahiti to Africa's east coast and India; others, however, occupy areas less than one-tenth that size). As the transplanted snails grow up surrounded by prey that their parents never encountered, natural selection may favor those with toxin cocktails and feeding patterns that fit conditions in their new home; hunger would rapidly eliminate those that failed to assimilate. Distance and time could, on their own, account for a far-flung colonist population becoming distinct from its ancestor, but these variables—even accompanied by a change in diet or habitat—do not guarantee that a new species will arise. Kohn reports that *C. miliaris*, for example, feeds on a wide variety of organisms at Easter Island, where it is the only ecologically important *Conus* species, but that in the central Indo-Pacific, where it shares space with many other members of the genus, its diet is very specialized.

CLAY BRYCE; INNERSPACE VISIONS

Cone snail veligers—free-floating planktonic juveniles that are usually less than a millimeter long—will metamorphose into bottom-dwelling adults.

In recent years, medical researchers have been looking for plants and animals whose naturally occurring chemicals—venoms included—might be used to treat disease. Until recently, sea sponges dominated the scene. Two successful drugs—cytarabine, used for non-Hodgkin's lymphoma and for a form of leukemia, and acyclovir, used for herpes infections—were derived from marine sponges. Such discoveries have encouraged researchers to rummage through the rest of the briny deep's offerings. *Conus,* with its hundreds of species and venoms, may be a new pharmaceutical gem. "When people tell me how beautiful the snails' shells are, I tell them that the real beauty lies within the ani-

KERRY MATZ; COURTESY OF OLIVERA LAB, UNIVERSITY OF UTAH

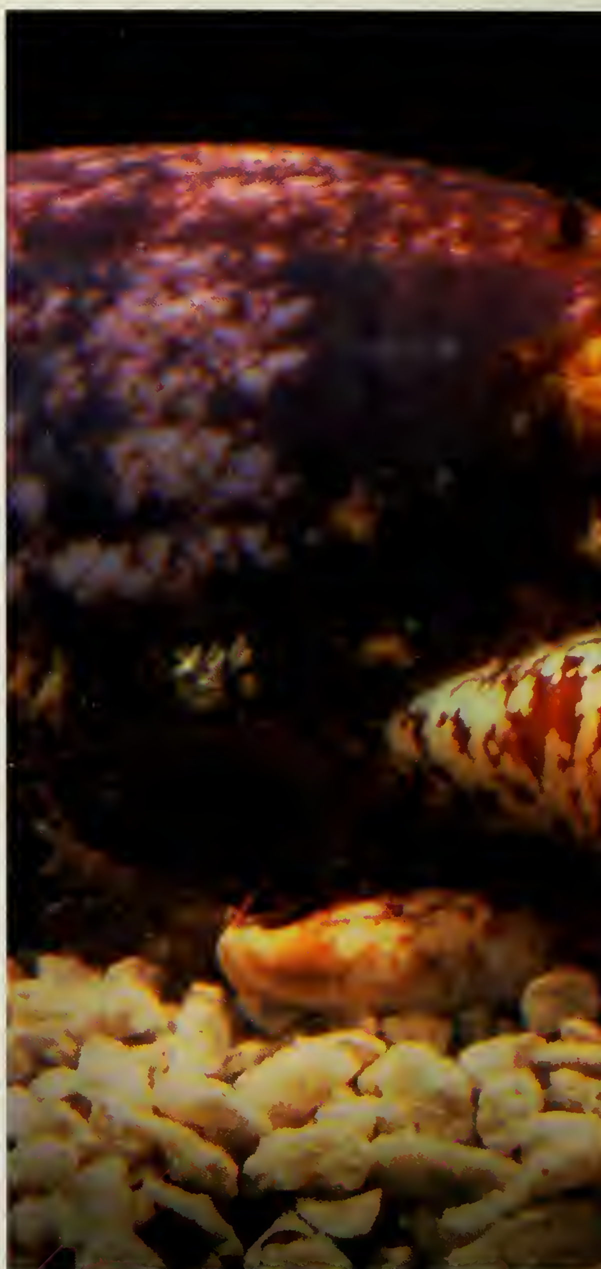
mal," says Joseph Schultz, a postdoctoral researcher at Stanford University's Hopkins Marine Station, who has traveled far and wide to collect *Conus* specimens for study.

The first indications that conotoxins might have therapeutic value came in the early 1970s. In Baldomero Olivera's laboratory, an undergraduate named Craig Clark developed a test that revolutionized the assessment of conotoxin effects. By injecting complex cone snail venoms directly into the brains of live mice, he elicited a variety of symptoms, including sleepiness, intense scratching, and hyperactivity. At about the same time, a high school student named Michael McIntosh established that the venom of *C. magus,* the magician's cone, induced seizurelike tremors in rodents. Thirty years later, McIntosh—now a biologist at the University of Utah—is still studying conotoxins.

Below: The living, organic periosteum, or outer layer of the shell, camouflages and protects a snail. This one is tufted.

JEFF ROTMAN

Investigations of cone snail venoms have revealed that they inhibit motor control and that the paralysis induced by a sting represents the aggregate effect of several varieties of conotoxins. Some, the omegas,



block the release of neurotransmitters; others, the alphas, prevent neurotransmitters from binding with target cells in muscles and nerves. Two other classes, the mu and delta conotoxins, specifically affect muscles, and a unique class known as conantokins targets the brain. The various conotoxins do not compete for binding sites. Each peptide in a snail's venom works by attacking a specific gateway controlling the action of nerves and muscles, either blocking it or forcing it open. There are many classes and subclasses of these gateways in the animal world, and they vary substantially between phyla. Remarkably, *Conus* manages to compensate by generating a plethora of different peptides. Selective

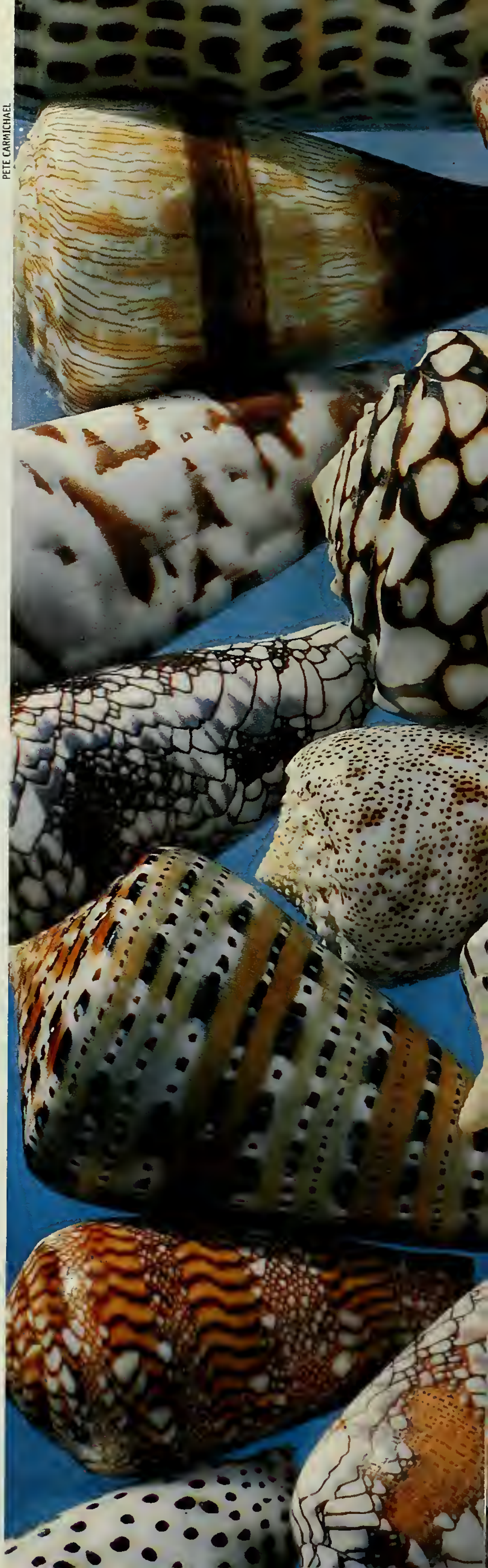
KERRY MATZ; COURTESY OF OLIVERA LAB, UNIVERSITY OF UTAH

pressures, working on the genes regulating conotoxin production, probably act on subtle changes in the structure of peptides. Just as an extra groove on a key allows it to fit one keyhole instead of another, the simple addition of a few amino acids allows a toxin to bind more tightly to its target.

Eventually, working with *C. magus* venom, McIntosh isolated omega-class peptides that cause spasms in mice. He also found that the type of nerve thus affected had been unknown before his discovery. A biotechnology company has now formulated an omega-class peptide into a drug that reduces severe pain in cancer and AIDS patients but does not produce the addictive side effects common to painkillers such as morphine. The drug is in the final stages of clinical trials, and the Food and Drug Administration has deemed it "approvable."

Another promising lead originated with Craig Clark. In the early 1980s, while investigating *C. geographus* venom, he isolated a conantokin that causes drowsiness. This molecule, held together by bonds that differ from the bonds in other conotoxins, is not shaped like most known cone snail peptides and does not bind with commonly targeted receptors in an animal's cells. As a result, venoms containing conantokins attack nervous and muscular systems in a variety of ways. McIntosh later took over the conantokin experiments and uncovered another inter-

A captive *C. geographus* on the hunt with both its siphon (upper appendage) and proboscis extended, above and above left. As always, its prey—fish—goes in headfirst.



PETE CARMICHAEL

Most cone snails, like those at right, have a clockwise twist, while the Rembrandt etching, below, shows the opposite turn. Either the artist didn't reverse the image while engraving the plate or he made a one-in-a-million find.

esting tidbit: the venom contains a component found in human blood-clotting factors but virtually nowhere else. Scientists later established that conantokins turn on a particular nerve "switch" in the brain. A pharmaceutical company in Salt Lake City is now pursuing this lead in hopes of formulating a new treatment for epilepsy.

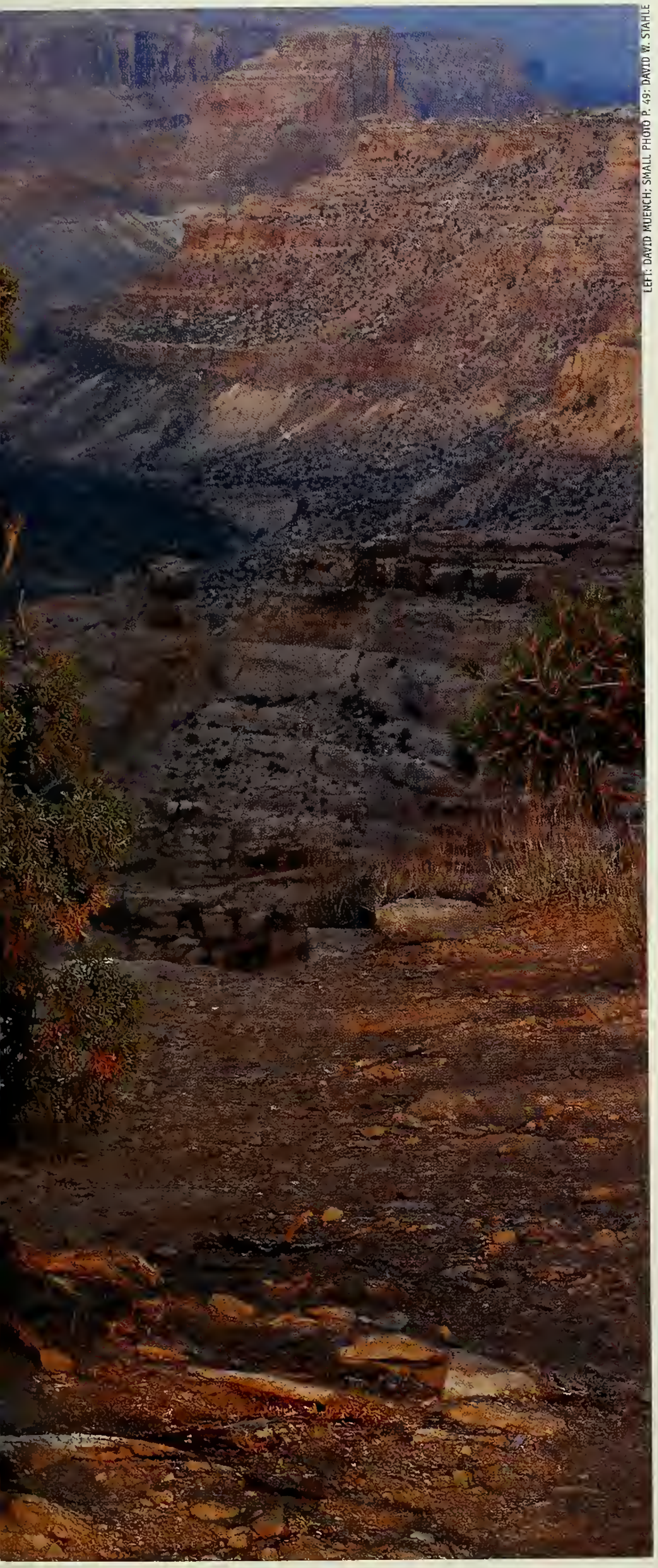
But finding uses for these two peptides is just the beginning, according to Rob Jones, a senior scientist for the pharmaceutical company Cognetix. The possible range of treatments is limited only by the diversity of the peptides in cone snail venoms. Normally when scientists are drug hunting, they test piles of compounds whose functions are unknown, searching for one that proves useful. In this case, with many classes of conotoxins containing hundreds of peptides (the numbers of which, as Duda's work shows, are actually growing as species evolve), the drug hunters already know many of the functions of those peptide classes. Now they must determine which ones—from which species and in which combinations—can best ameliorate specific symptoms. "It is a backward approach to finding drugs," Jones says.

REMBRANDT; MUSEUM HET REMBRANDTHUIS, AMSTERDAM

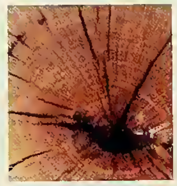
Zoologists and medical researchers have not been studying cone snails for very long. Western

People talk about how beautiful the snails' shells are, but to one scientist the real beauty lies within the animal.

shell collectors have known about these mollusks for more than 200 years—even dueling over them at times, according to Jon-Paul Bingham, a Yale University postdoctoral researcher investigating *Conus*. But the demands of sustenance preceded those of medicine and beauty. Indeed, communities in the Philippines and American Samoa have long considered cone snails a delicacy. No one has been known to die from eating them: digested peptides aren't dangerous. And in any case, *Conus*'s foot, which is not connected to the venom duct, is considered the most flavorful meat on the animal. "When we asked the chief of an island in American Samoa if it would be OK for us to collect snails, he couldn't fathom why we would use them for research," says Joseph Schultz. "He thought we were getting dinner." □



LEFT: DAVID MUENCH; SMALL PHOTO P. 49: DAVID W. STAHLE



The Unsung Ancients

Very old trees aren't necessarily as rare—or as big—as you think.

By David W. Stahle

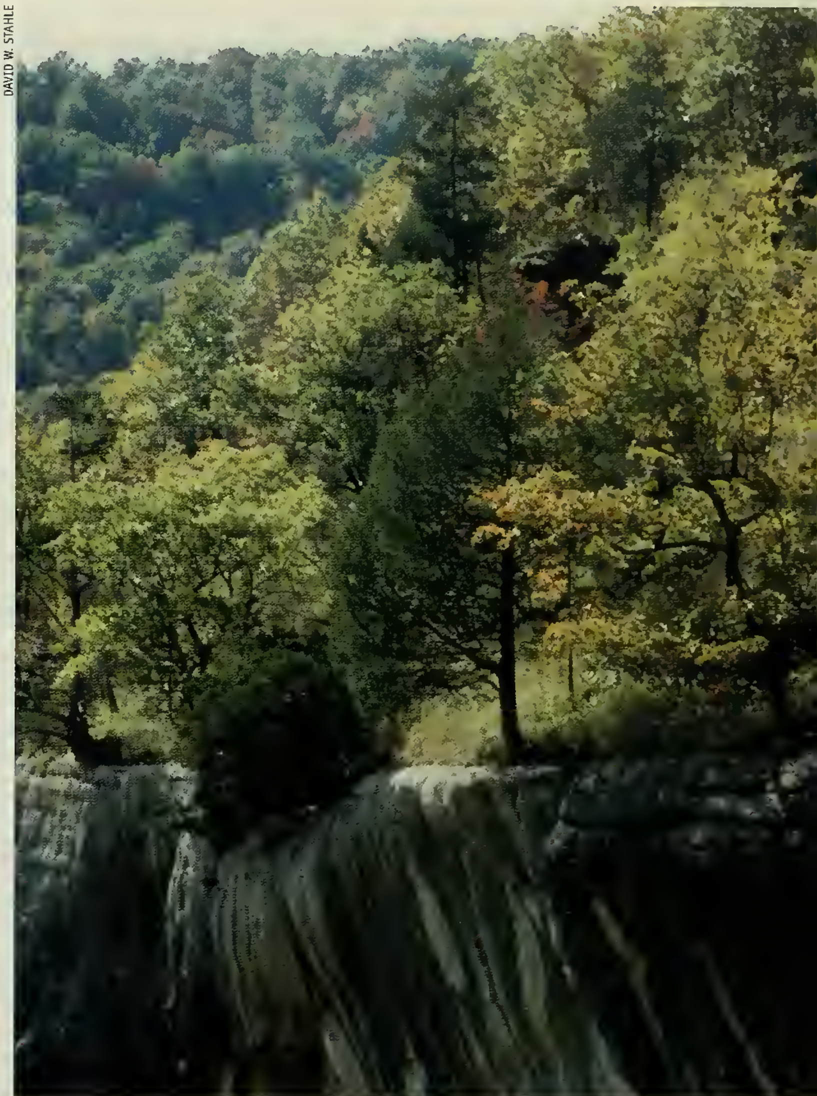
A priceless legacy was lost with the logging and clearing of America's virgin forests: massive, majestic trees growing on productive soil were cut nearly to oblivion. Not all were destroyed—a scattering of big timber survives. Many ancient forests whose trees are of more modest stature also survive, largely because they're at home on rocky, unproductive soil and are considered noncommercial by the lumber industry; some of the oldest trees ever found in North America endure in high, rocky solitude. They may not match our preconceptions of old-growth big timber, but tree-ring dating has proven their antiquity beyond all doubt.

Ancient woodlands are so common that in some areas—such as the Cross Timbers of eastern Oklahoma, the piñon-juniper woodlands of the Southwest, and the blue oak woodlands of central California—they dominate the landscape. Trees in these and other similarly austere woodlands often reach

JUNIPER

An ancient juniper on the San Rafael Swell in central Utah is part of the world's largest drought-adapted coniferous woodland. This ecosystem, which covers terrain from Idaho to Mexico, is home to many stands of antique piñons and junipers, escapees from rapacious bulldozing and timber cutting that sacrificed millions of trees for pastureland and charcoal production.

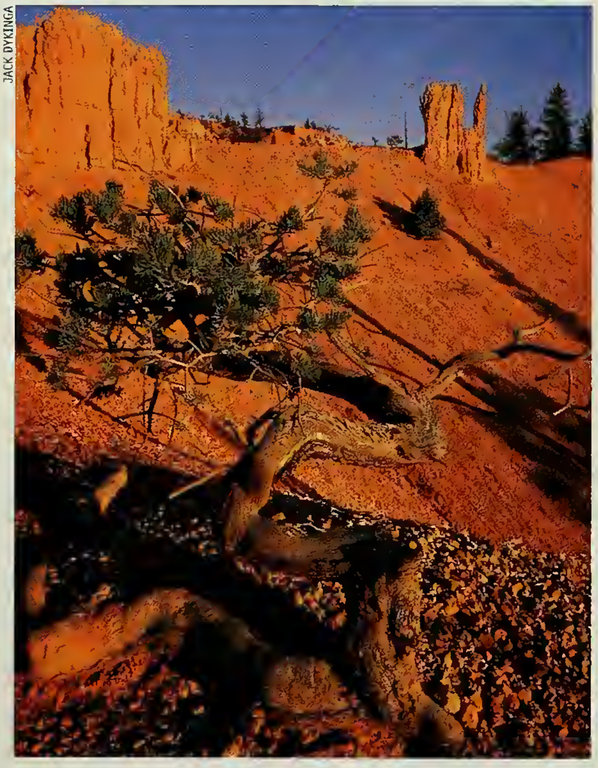
DAVID W. STAHLE



PIÑON PINE

Size can be a poor indicator of tree age, as illustrated by the contorted, centuries-old dwarf Pinus edulis *below (Dixie National Forest, Utah). The oldest piñon yet documented—973 years old—was found in northeastern Utah in 1955.*

JACK DYKINGA

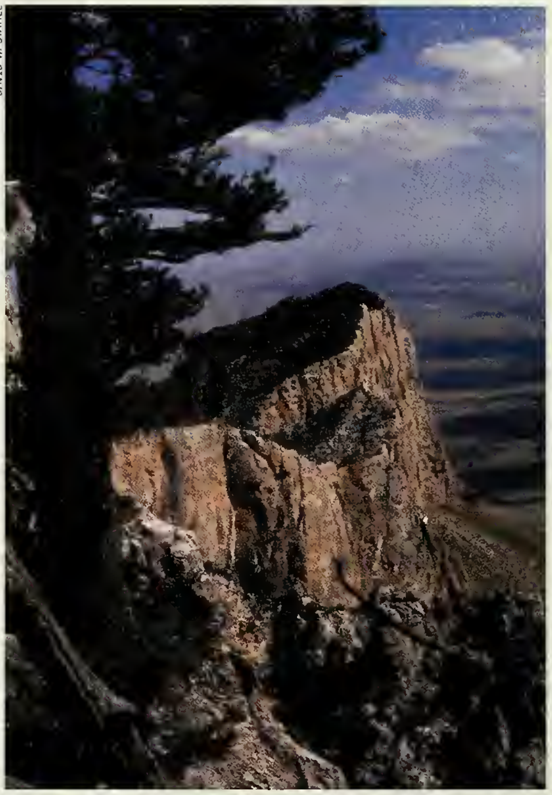


the oldest possible age for their tribe: oaks across the United States routinely live to more than 300 years, bald cypresses in the South to more than 1,000. Bristlecone pine trees more than 4,000 years old have been found in the Great Basin.

Biological superlatives like old giant sequoias are easy to recognize by their size alone. But size gives no hint of the extreme antiquity of the more diminutive survivors of virgin forests. All old trees, no matter their size, share certain unmistakable traits of great age. Heavy limbs, a contorted and leaning trunk or a trunk with a spiral twist, hollow voids, a spiky top, and a craggy silhouette are all giveaways, not unlike the silver hair and wrinkled skin of "overmature" humans. You can often predict where to find ancient woodlands in the modern landscape—usually at steep, rocky, remote sites, where only the thrifty could survive. A careful reading of commercial logging history can also help pinpoint species and woodlands that have been left unmolested. American beeches, for example, were not heavily exploited during twentieth-century hardwood and pine logging on the Ozark plateau; some of the upland Ozark's finest moist forests, containing giant hardwoods, managed to survive because they are dominated by stands of ancient beeches.

For a map of these ancient trees, go to www.naturalhistory.com

The aesthetic appeal of very old woodlands is obvious. Less obvious is the environmental history embedded within them. Among the many fascinating tales told by the growth rings of old trees is one of an epic, thirty-year drought in the sixteenth century that extended from tropical Mexico to the boreal forests of Canada and from the Pacific to the Atlantic. Tree rings from ancient woodlands across North America indicate that this megadrought was even more severe and sustained than the Dust Bowl drought of the 1930s. It affected the British Lost Colony settlement of Roanoke Island and the Span-



ROCKY MOUNTAIN DOUGLAS FIR

Above: A 350-year-old Douglas fir faces El Capitan in Guadalupe Mountains National Park in southwestern Texas. Ancient Rocky Mountain Douglas firs (Pseudotsuga menziesii *var* glauca) *range over the western cordillera from Oaxaca to British Columbia—the oldest found so far was dated at 1,275 years. Their intricate growth rings record the ebb and flow of drought and wetness throughout the West.*

POST OAK AND RED CEDAR

Specimens of post oak (Quercus stellata) *up to 400 years old and red cedar* (Juniperus virginiana) *almost 900 years old survive on bluffs of the Ozark plateau and in the region known as Cross Timbers, which lies along the margins of the southern Great Plains. Above: Survivors on a rock bluff at Hemmed-in Hollow, Buffalo River, Arkansas.*

ish Santa Elena colony of Parris Island, off South Carolina, as well as the Pueblo villages of New Mexico. The drought also aggravated Mexico's gruesome epidemics of hemorrhagic fever (*huey cocoliztli*—"great pestilence"—in Nahuatl) in 1545 and 1576, during which millions died.

Not all the low-value virgin woodlands of America have survived, not by a long shot. Millions of ancient noncommercial trees had enough utilitarian value—or created enough of an obstacle to progress—to be sent to the guillotine. Vast areas of piñon-juniper woodlands were cut or bulldozed to make charcoal for the mining industry or to provide pasture for the cattle empire. Before the Great Depression, level tracts in Oklahoma's Cross Timbers region, dominated by centuries-old post oaks, were cleared for King Cotton—only for the cotton to be blown away in the Dust Bowl drought.

Of the smaller old-growth woodlands that have survived, most have gone unrecognized and unappreciated. Stands of ancient low-grade yellow cypresses—including the magnificent millennium-old bald cypresses at Black River, North Carolina, and along the Cache River and Bayou DeView in Arkansas—grow at incredibly slow rates in a few remnant stands throughout the South. Northern white cedars, some more than a thousand years old, have been found on the Niagara Escarpment.

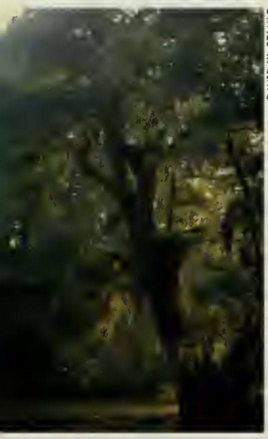
KEN TAYLOR: WILDLIFE IMAGES

BALD CYPRESS

Bald cypresses (Taxodium distichum) *at Black River, North Carolina, above, are among the oldest known trees in eastern North America; some are probably 2,000 years old. The trees, which grow slowly in tannin-stained, nutrient-poor "blackwater," escaped logging because of their low-quality timber. Below left: Ancient bald cypresses along southern bayous such as Devil's Gut, North Carolina, were also unattractive to lumbermen.*

BRISTLECONE PINE

The pioneering dendrochronologist Edmund Schulman, the first scientist to locate the most ancient bristlecone pines (Pinus longaeva), *recognized that the oldest trees are often those growing under the most adverse conditions. Opposite page: Bristlecone pines as old as 4,700 years are found in the rain shadow of the Sierra Nevada range among California's White Mountains (Inyo National Forest, California).*



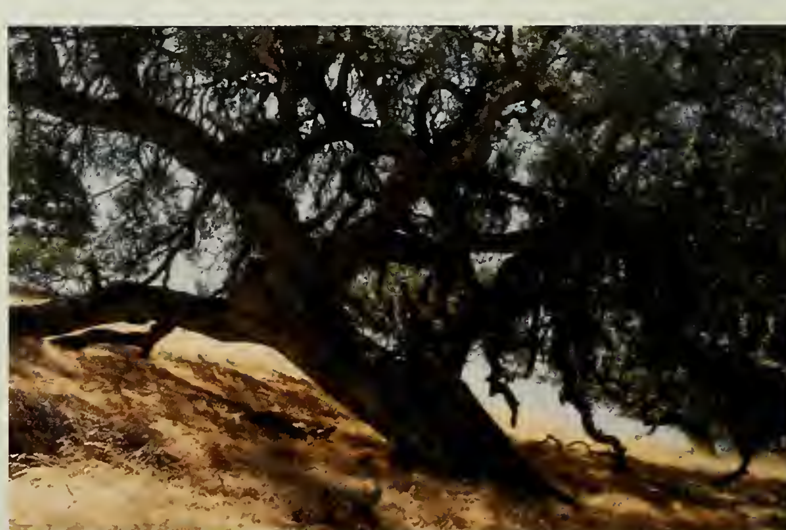
DAVID W. STAHLE

Hemlock trees more than four centuries old still live on steep slopes from Alabama to Maine, although they are now facing destruction by the hemlock woolly adelgid, a pest introduced from Asia forty years ago. Pitch pines pushing five centuries survive on the Shawangunk Mountains, only a short drive from Manhattan; on the ski slopes of Wachusett Mountain (within view of the Boston skyline) stand 400-year-old northern red oaks. Down the famous Blue Ridge Parkway of Virginia and North Carolina, centuries-old weather-beaten chestnut oaks can be seen from the roadway. Bonsai-like Douglas firs and ponderosa pines animate the petrified lava flows of El Malpais National Monument in New Mexico. And so on, across the arid West, culminating with the Great Basin's bristlecone pines, the oldest-known continuously living organisms on earth.

Although we've logged forests and cleared land prodigiously, we still retain a good part of our natural woodland endowment. Yet the significance of many modest-sized but venerable trees is too easily overlooked. Our misperception of their value and our continued disregard for their preservation may one day make them as rare as their big-tree cousins of the forest primeval. □

BLUE OAK

Right: A blue oak (Quercus douglasii) *in Pacheco State Park, central California. Blue oaks are resilient: they live on land that has been heavily grazed and invaded by nonnative grasses, and specimens of 200 to 500 years old are common. Covering almost 3 million acres, blue oak woodlands are one of the most widespread ancient forest types remaining in the Golden State.*



DAVID W. STAHLE


JACK DYKINGA

SLENDER IN THE NIGHT

Long unstudied, the slender loris of South Asia emerges from primatology's shadows.

By K. A. I. Nekaris

What is a slender loris? Given the name, one could hardly be blamed for thinking it's something out of a Dr. Seuss book. And a quick glance at the animal's lithe body and pencil-thin arms might suggest it's a rat or a squirrel (and might immediately indicate why it is sometimes called "a banana on stilts"). Closer examination, however, reveals the loris's close-set eyes and the nails on its feet and hands. A look inside its skull reveals a large brain. Indeed, this animal is neither a mutant plantain nor a rodent. It is a primate, close kin to the bushbabies of sub-Saharan Africa and the lemurs of Madagascar.

These facts about the loris, a native of southern India and Sri Lanka, have been known for some time. But despite being the subject of numerous now-obscure nineteenth-century reports, this small, nocturnal, gremlin-like prosimian long went unexamined by primatologists. Only in recent decades have prosimians—a suborder of primates that includes lemurs, lorises, bushbabies, and tarsiers—begun to be studied systematically. The earliest of these modern investigations emphasized the various species' physical and social similarities and sought, on the basis of these similarities, to reconstruct the behavior of the first primates—also nocturnal, also generally small animals, which evolved about 50 million years ago. More recent studies, however, have uncovered unexpected diversity among extant prosimians, and the group's once-simple portrait is now being redrawn.

Since 1996 I have been traveling to southern India and Sri Lanka in search of the elusive slender loris. Initially I looked for these animals in the forests of India, where I'd hoped to arrive at an estimate of how many remained in the wild, for even such basic information had not yet been recorded. But before I could count lorises I had to find them, and for the first three months I caught fleeting glimpses of retreating lorises on only fourteen occasions. I had little hope of ever seeing them close-up in the wild.

I got my break when an Indian colleague came across an old fortune-teller and his furry "familiar"—a loris whose job it was to pick cards out of a deck with his eerily long arms. When questioned, the old man very hesitantly revealed the name of the forest where he had obtained his companion. Several of my colleagues (associated with the Indo-US Primate Project) set out immediately for the place, a dry, deciduous forest nestled in the foothills of the Eastern Ghats. Once there, they saw more lorises in one night than we had during three months of carefully searching all the major national wildlife refuges in southern India.

I returned to India in the autumn of 1997 to begin a long-term study of the slender loris. Given my experiences the previous year, I would have felt gratified to find one of them within a week. To my delight, I saw more than sixty animals within a few hours during a drive my first night in the area. Lorises were everywhere: crossing the road, walking along thorny fences, climbing banana plants, even sitting on tea shop roofs. It seemed that all the lorises in India had moved to one small corner of the Eastern Ghats.

My first task was to search for a study site where I could work for the next year. I wanted one with short trees, high visibility, and lots of lorises—and I found such a site almost immediately. Houses, cropland, noisy villagers, and even noisier cinema loudspeakers surrounded it. Accustomed to this racket, the animals proved to be intrepid, and I was able to follow them closely, usually from within five feet. From that distance I could identify individuals by the tiniest of features—missing toes, scraggly fur, heart-shaped noses—and see the most minute de-

A slender loris investigates a trumpet creeper, opposite page, but probably not with a mind for eating it: this primate is almost exclusively insectivorous.

VOLKER KESS

Time is running short for a locust. Above: A male slender loris first scrutinizes the insect, then prepares, with ears laid back, to grab it for a snack.

tails of behavior, right down to which little insect they were gobbling up.

This study site became the crucial factor in freeing the loris from being thought of as a "living fossil." Not just a creature that shed light on the earliest primates, it was a real animal roaming the forests of South Asia. Because of the darkness, the dense woods, and the primates' small size and fast moves, studies of nocturnal prosimians often are possible only with the use of radio tracking, night-vision equipment, and elaborate trapping schemes. Making observations as extensive as those recorded for diurnal primates—monkeys, apes, and some lemurs—is often quite difficult, but thanks to the easy visibility at my study site, I could follow the animals for twelve hours at a stretch.

Most nocturnal primates have been reported to lead relatively solitary lives, rarely coming into physical contact with others (except for mating and the nursing of young). Some species use scent markings to communicate; others employ a wide variety of trills, "kriks," and whistles. For the most part, these generally solitary primates are gregarious only at communal sleeping sites, where they huddle, groom, and carry on other activities common throughout the primate order.

No one had expected slender lorises to be different, but I found they clearly were. My first sightings involved multiple animals—up to five in a single bush. Pairs were even more common, and many of their get-togethers, which lasted up to several hours, did not occur at sleeping sites. During these meetings the lorises groomed one another, play-wrestled, and fed. As my study continued, I realized that these activities reflected the species' numerous and complex social connections (a later study I did in Sri Lanka bore out these findings: lorises there moved together in groups of up to nine).

Ultimately, I identified more than twenty individuals in an area about the size of thirty football fields. The boldest and most personable of these animals I named Titania; she was the one that taught me the most about loris behavior. Recognizable even from a distance, she was conspicuous because of her unique habit of treating branches like uneven parallel bars. Her ripe age was evidenced by multiple healed wounds and by very long nipples (an indication that she had given birth several times). Titania was courted by several of the local male lorises, who evidently found her as charming as I did. She commonly fed and played with various males, but none of them could challenge her—two or three swift cuffs were enough to subjugate any of them. Titania always got first access to large, juicy insects, and she always decided whether grooming would be reciprocated. Such primacy, however, was not just a product of Titania's person-

A LORIS LEGEND

Indian and Sri Lankan legends suggest that the slender loris might have a carnivorous streak—specifically, a taste for peafowl. These birds sleep high atop trees, perched rear to rear so that they can look out for predators coming from all directions. Only the loris, legend says, is quiet and careful enough to make it to the top without stirring a leaf; the animal will even carry loosened tree bark in its hand so as not to make a sound. Once a loris reaches the treetop, it pounces on the peafowl, wrings the bird's neck, and then feasts on its brains. I have yet to see this in the wild, but I'm keeping my eyes wide open.—*K.A.I.N.*

VOLKER KESS

ality; I soon learned that all female lorises, both in India and in Sri Lanka, dominate their male counterparts—a rarity in the primate world.

By the third month of the study, male interest in Titania escalated, for she went into heat. Reproduction is one of the few areas of loris behavior that has been well studied, albeit in captivity, but it turns out that behavior in the wild holds few surprises. Female lorises are capable of mating for a couple of days once or twice a year. Pregnancy lasts six months. Studies of captive lorises have shown that after a female has given birth, the demands of lactation and raising an infant may keep her from mating again for ten to fourteen months. Female slender lorises begin reproducing at two and often die in their mid-teens. They may mate as few as seven times in their lives—a limitation that creates severe competition among males, which constantly court females in hopes of mating during the brief time that one of them is in heat. Although in most primate species, fathers and other adult males do not play an important role in infant care, multiple male lorises studied at both the Indian and the Sri Lankan sites lavished attention on the young. Perhaps these males were showing choosy females what good fathers they would be, or even what good fathers they were (or thought they were). But I carried out no genetic studies during my trips to the field, so I don't know which animals were related or which males fathered which young.

In December 1997, during the rainy season, the male lorises of the Eastern Ghats lined up for a chance at Titania. She was typically imperious and cuffed three males before choosing the dominant male of the area: Donald. Quite a Casanova, he had been courting three or four local females, including one who already had a young son (although males hang around multiple females, it is difficult to say whether they mate with more than one). I have observed only four matings in the wild; Titania and Donald's was one of these. Lorises hang upside down from a horizontal branch during copulation. The reason for this is a mystery, but captive animals not provided with the necessary perch will not reproduce. Sex lasts up to fifteen minutes. Donald and Titania copulated several times over three hours, but not without distraction. Despite being chosen. Donald had to fight off three other males to maintain his position. Unwanted but unwilling to accept defeat, and whining loudly from neighboring trees whenever the couple was copulating, the three rivals attacked Donald one at a time. Several rather nasty fights broke out, accompanied by loud chittering and growling. The scene was reminiscent of a barroom brawl. Donald won each time, throwing the other males out of the tree, while Titania played the coquette, daintily stuffing herself with insect truffles.

Titania conceived, as later became obvious, and over the next few months she increased her food intake. Although she did not eat more often, she ate with such fervor that my colleagues and I began calling her "the glutton." Titania simply jammed food into her face: Insect wings would hang from her mouth. Like someone at a movie theater, she would stuff ants in as if they were popcorn. And when she ate slugs, albeit with a disgusted look on her face, she would shake her head

A NOTE ABOUT THE PHOTOS
Because of the difficulty of photographing loris behavior in the wild, all but the last picture in this article are of captive animals.

Two or three swift cuffs from the imperious Titania were enough to subjugate the males.

VOLKER KESS

Tearing into an insect with its cheek teeth, a slender loris answers a question that has bedeviled generations of gingerbread-man munchers: head first or no?

HELGA SCHULZE

With one baby on her back and its twin hanging from her underside, an adult female shares food with her nearly mature daughter and a male.

so much that slime dripped from the branches and landed on my clipboard.

Aside from dining on the occasional slug and maybe some peafowl brains (see "A Loris Legend," page 56), slender lorises consume mostly insects. Only one other primate, the tarsier, is known to include such a high proportion of animal prey in its diet. Relying heavily on insects seems to have played a role in several other attributes of the slender loris. The emergence of primates, with their close-set eyes and stereoscopic vision, coincided with the appearance of flowering plants and the new host of insects that fed on them. This sudden (evolutionarily speaking) explosion of high-energy food resources in the complex terminal branches of trees provided a new niche for animals with good depth perception. Specializing on the insects in these branches, the slender loris has closer-set eyes and an even greater degree of stereoscopy than do other primates, not to mention an unusually thin build, long limbs, and precise movements. These features allow the animal to stretch and twist delicately through the branches, rarely alerting or disturbing its prey (at least not before consuming it).

Lorises hang upside down during copulation; captive animals won't reproduce without the necessary perch.

But feeding on these insects presents the slender loris with some problems. Its prey of choice is the acacia ant, a minuscule beast whose mighty bite is capable of numbing a human arm. Beetles and roaches armed with toxic bites and sprays are also on the menu. When eating such irritating foods, lorises cover their hands, their feet, and sometimes their faces in a coat of urine. And when stung, lorises of all ages and sexes, including very young infants, markedly increase their "urine washing." Since I did not chemically analyze their urine, I couldn't draw firm conclusions about its exact effects; however, reptiles and amphibians with similar diets also use their urine to defend against or soothe such stings.

Six months after Donald won her favor, Titania gave birth to twins. (One of them died soon after.) In the Indian and Sri Lankan slender lorises I have studied, more than 50 percent of births were twins. Mothers carry their infants constantly during the first few weeks but soon begin parking them on branches during the night, when the adults forage. The befuddled little ones resemble hamsters with giant skulls and headlights; they are initially very cautious and may move only a few yards each night until they grow accustomed to maneuvering through the trees. After two months, infant lorises slowly increase their home range, one tree at a time.

Slender lorises are generally most gregarious at their daytime sleeping sites, as are most other nocturnal prosimians. In both my Sri Lankan and Indian study populations, the animals rarely slept alone and often were seen in groups of up to seven individuals, a tangle of dormant arms and legs. Social grooming, playing, and wrestling were common dawn and dusk activities. A male, a female, and her offspring formed the most common grouping, as was the case for Titania (but not for her one-time beau Donald, who disappeared from the site in March 1998). Other sleeping groups consisted of one or two adult males, two juvenile males, and one or two adult females. By the time infants are two months old, more mature lorises that sleep in the same bush or tree may visit them during the night. One adult male often visited Titania's daughter. Juvenile males not thought to be related to parked infants played and ate with them; perhaps these youngsters were practicing the skills needed to become good fathers. Unlike male lorises, females did not spend time with infants unless the little ones were their own.

Where a loris sleeps is crucial. Potential predators abound in India and Sri Lanka. Fish owls, jungle cats, civets (a carnivore related to the mongoose), and even house cats are reported to eat them. Stealthy but not very fast, slender lorises often choose sleeping sites in dense, thorny bushes, trees, and cacti. Other threats besides that of being eaten loom as well. Humans like the old fortuneteller questioned by my Indian colleague kidnap lorises, as do practitioners of Ayurvedic medicine, who think that the animals' eyes are potent love charms, that their legs cure leprosy, and that their bones ward off the evil eye. In some areas of Sri Lanka, humans fear the call of the loris and will stone to death any they encounter. Sri Lankan veterinarians regularly see lorises that have been maimed while crossing live power lines; two animals at our study site in India died this way. In addition, of course, trucks and buses and other vehicles can easily strike a loris as it crosses a road.

The slender loris, long consigned to the category of living fossil, is slowly emerging from the shadows. Studies are now ongoing at several sites, and scientists are asking increasingly complex questions about this primate. We can't say yet if it is threatened or endangered (although it probably is) or even if the different populations of slender lorises should be lumped together into one species or split into many. Now that scientific interest in these nocturnal cousins of ours has finally awakened, we may soon be able to answer such questions. □

Atypically agile mother loris moves through the trees with an infant clinging to her stomach.

DR. MAYILVAHANAN/TROPICAL TRANNIES

Why Are There No Lobsters Bats at Sea?

The answer appears to be a biological version of beginner's luck.

By Geerat J. Vermeij

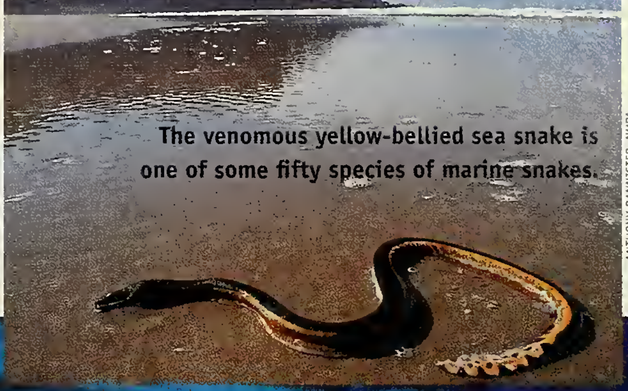
FRANÇOIS GOHIER; PHOTO RESEARCHERS, INC.

FRANS LANTING; MINDEN PICTURES

Wandering albatrosses represent a nearly complete transition from land- to sea-based life: they return to shore only to breed.

Now inseparable from the ocean, whales such as the sperm whale evolved from animals that once walked on land.

I can't help noticing them. With every sweaty step I take along a trail in the magnificent rainforest on Panama's Barro Colorado Island, insects of every description make their presence known. The piercing shrieks of cicadas high overhead drown out the territorial calls of birds. To one side of the trail, a pair of orchid bees, wings vibrating in a low, almost threatening pulsating buzz, engage in an elaborate aerial mating dance. The leaves of the understory shrubs, lianas, and sapling trees bear the unmistakable signs of damage by hungry insects. Some are mere skeletons of veins, all the intervening leaf tissue having been nibbled away by caterpillars. Ants burdened with loads of leaf fragments march toward their underground fungal gardens. And the insects are hardly alone. Lizards scurry in the leaf litter at my feet, monkeys feed noisily in the branches above my head, a vine snake makes its sinuous way toward an unsuspecting small on Land or


The venomous yellow-bellied sea snake is one of some fifty species of marine snakes.
ANTHONY BANNISTER; NHPA

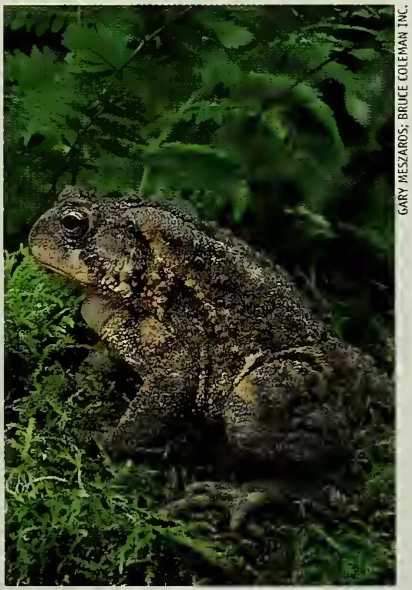
bird. Like the insects and plants, all these creatures are occupied with the business of extracting a living from the land.

Just a few miles away, on the warm rocky shores and mudflats of the Bay of Panama, life-forms are markedly different. There—where the sea has as much influence on living organisms as terra firma does—barnacles and bivalves and bryozoans filter food particles out of the water, snails and sea urchins and octopuses and crabs consume everything from decaying matter to other animals, and tiny corals and seaweeds photosynthesize on tide pool rocks.

Offshore, of course, the contrast with life on land is even greater. All photosynthesis in the sea is carried out by microscopic plants that drift near the surface and find their way up the food chain not only to such typically marine animals as sharks and squid but ultimately also to air-breathing whales and albatrosses.

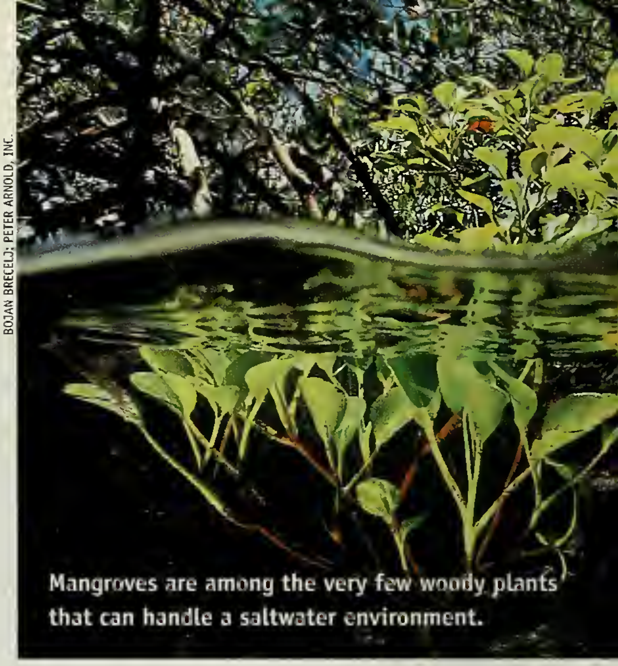
That the cast of characters living on land is so different from the one inhabiting the sea is such a familiar observation that we rarely stop to ask why this is so or how the differences are maintained. Yet such everyday questions provide some of the most interesting puzzles to the naturalist, and the answers can yield deep insight into how nature works.

American toads reveal their freshwater ancestry by returning to ponds to lay their eggs.



GARY MESZAROS; BRUCE COLEMAN INC.

A little history puts the problem in perspective. All the available evidence—derived from studying the evolutionary relationships of all kinds of extinct and living organisms—indicates that plants and animals originated in the sea. Multicellular marine organisms may have existed as early as 1.7 billion years ago, and plants identifiable as red algae were certainly growing 1.2 billion years ago. When marine animals appeared remains a matter of controversy, but an estimate of 700–800 million years ago seems reasonable. By Middle Ordovician times, about 460 million years ago, fungi (the oldest recognized multicellular terrestrial organisms) had colonized the land. During the next 140 million years, other types of organisms invaded terra firma and gave rise to vascular plants, millipedes, mites, insects, spiders, scorpions, land snails, and early amphibians and reptiles.



BOJAN BRECELJ; PETER ARNOLD, INC.

Mangroves are among the very few woody plants that can handle a saltwater environment.

A look at the distribution of the major groups of plants and animals alive today is instructive. (By "group," I mean a clade, an evolutionary branch consisting of an ancestor and all its descendants. A major group is a large and typically old clade, such as insects or vertebrates.) Most of these groups live either in the sea or on dry land, but not in both. A small minority occupy freshwater habitats. Very few groups have made the transition from water to land or from land back to water, and groups that have moved between marine and terrestrial habitats are especially rare. This may seem surprising, since land and sea are both so full of life, but the facts bear out the statement. Mollusks, for example, have occupied the sea for more than 500 million years—seemingly ample time to make the move—but only nine groups of snails, and no clams or cephalopods (the group containing squid and octopuses), have ventured onto dry land. With an equally long history in the sea, arthropods (a huge group of invertebrates including insects, crustaceans, and spiders) have made the transition to land at most nine times. Green plants may have done it only once. Lobsters, sea stars, corals, bryozoans, brown algae, and a host of other marine groups never made it.

After 500 million years, only a few mollusks—nine groups of snails, but no clams or cephalopods—have ventured onto dry land.

Once on shore, of course, some colonizers were spectacularly successful. All the plants in your neighborhood, for example—from the loftiest tree

to little spring pansies—may have evolved from a single ancestor. Groups of animals and plants that made it to land prior to about 300 million years ago were especially prolific in their new surroundings. There are now hundreds of thousands of species of insects and green plants, and tens of thousands of mites, spiders, and pulmonate land snails (those endowed with lungs). Later arrivals, such as sowbugs, crabs, hermit crabs, and some other land snail groups, have remained minor elements of the terrestrial fauna.

Having made the switch to life on land, few groups of organisms returned to the sea. No marine snails or crustaceans can claim terrestrial ancestry. Of the million or so living species of insects, only about 1,400 are marine—the result of an estimated 122 separate invasions from the land, including those involving an intermediate phase in freshwater. Most of these insects colonized the margins of the sea: places such as mangrove forests, salt marshes, tide pools, sandy beaches, clumps of washed-up seaweed, and crevices at the upper reaches of

A.N.T.: NHPA

The saltwater crocodile breeds in freshwater but may swim considerable distances in the open ocean.

J & M BAIN; NHPA

rocky shores. The only insects that make a living in the open ocean are five species of water strider, which skate across the water's surface in warm seas.

Similarly, there are some 300,000 living species of land plants, compared with only sixty truly marine species that have terrestrial ancestors. All these marine plants are sea grasses, representing three separate invasions from the land, all by way of freshwater. Rooted in sand or sandy mud, sea grasses grow offshore—near continents and large islands—in water up to sixty feet deep. Salt-tolerant mangroves and salt-marsh and beach plants evolved into an additional thirty to forty groups of land plants.

Tetrapods (four-limbed vertebrates) are striking exceptions. They have been notably successful at returning from the land to exploit marine habitats. Including extinct groups, marine tetrapods evolved from terrestrial ancestors at least thirty-five times among reptiles (turtles, crocodiles, plesiosaurs, lizards, snakes), seven times among mammals (including whales, seals, and otters, as well as the extinct New England sea mink and a bizarre marine sloth that lived some 4 million years ago in the waters off the coast of modern-day Peru), and ten times among geese and ducks, plus numerous times among other groups of birds. (This adds up to fewer than the 122 insect invasions, but taking the total number of species in both groups into account, tetrapods have made the transition far more frequently.) We humans are the latest and, although atypical, certainly the most successful land animals to exploit the sea. Even with no special physical adaptations, *Homo sapiens* makes use of more marine resources and penetrates the ocean more extensively—from the poles to the equator and from the high-tide line to the deepest trenches—than does any other species.

PETER WEIMANN; ANIMALS ANIMALS

Intertidal periwinkles, top, live halfway between land and sea. The coconut crab, above, may owe its successful invasion of the land to the scarcity of vertebrate predators on the islands it inhabits.

Why has such a small proportion of all living things managed evolutionary leaps between land and sea? The most obvious explanation would seem to be the differing physical demands of air and water. Gravity, for example, is a pervasive force to be reckoned with on land but is greatly reduced in water, because the density of living matter is very close to that of water. Respiration—the uptake and release of gases such as oxygen and carbon dioxide—is much faster in air than in water. These and other physical realities mean that almost every aspect of life, from taking a simple breath or eating to finding a mate, requires different, often incompatible, adaptations in the two media.

But this explanation is not sufficient. If physical differences between air and water accounted for the difficulty, transitions between land and freshwater should be just as rare as those between land and sea. But the evidence suggests otherwise. Land plants have given rise to freshwater species at least 200 times, and the 45,000 or so species of insects in freshwater lakes and streams represent hundreds of separate invasions from the land. Mammals have made the move from land to freshwater at least twenty-four times. Even more telling are the insects that have successfully colonized surf-swept lakeshores but not the shores of wave-swept seacoasts, as well as the insects that live in inland saline

lakes but not in coastal marine habitats. How can some dragonflies and caddis flies live in salt lakes but not in the sea?

Politicians might not readily come to mind as sources of scientific insight, but in this case they understand the basic principle better than almost anyone else. That principle is incumbency. Physical contrasts aren't the only factor that make it difficult to shift from one environment to another; the well-adapted organisms already living there prevent invaders from gaining a foothold.

The only insects that make a living in the open ocean are water striders, which skate across the surface in warm seas.

How does such incumbency work? To succeed in a new environment, an invader must be able to compete effectively with resident species, which will typically, and not surprisingly, have the upper hand because they are already well suited to both their physical and biological surroundings. Before the Middle Ordovician, dryland ecosystems were fairly simple, dominated mainly by mat-forming microbes that would have been unable to compete with larger plant and animal invaders from the sea or from freshwater. But by the later Devonian (about 350 million years ago), terrestrial ecosystems—primarily forests and the many creatures living in them—were much more complex, with established communities of incumbents capable of preventing further invasions by most groups of marine organisms.

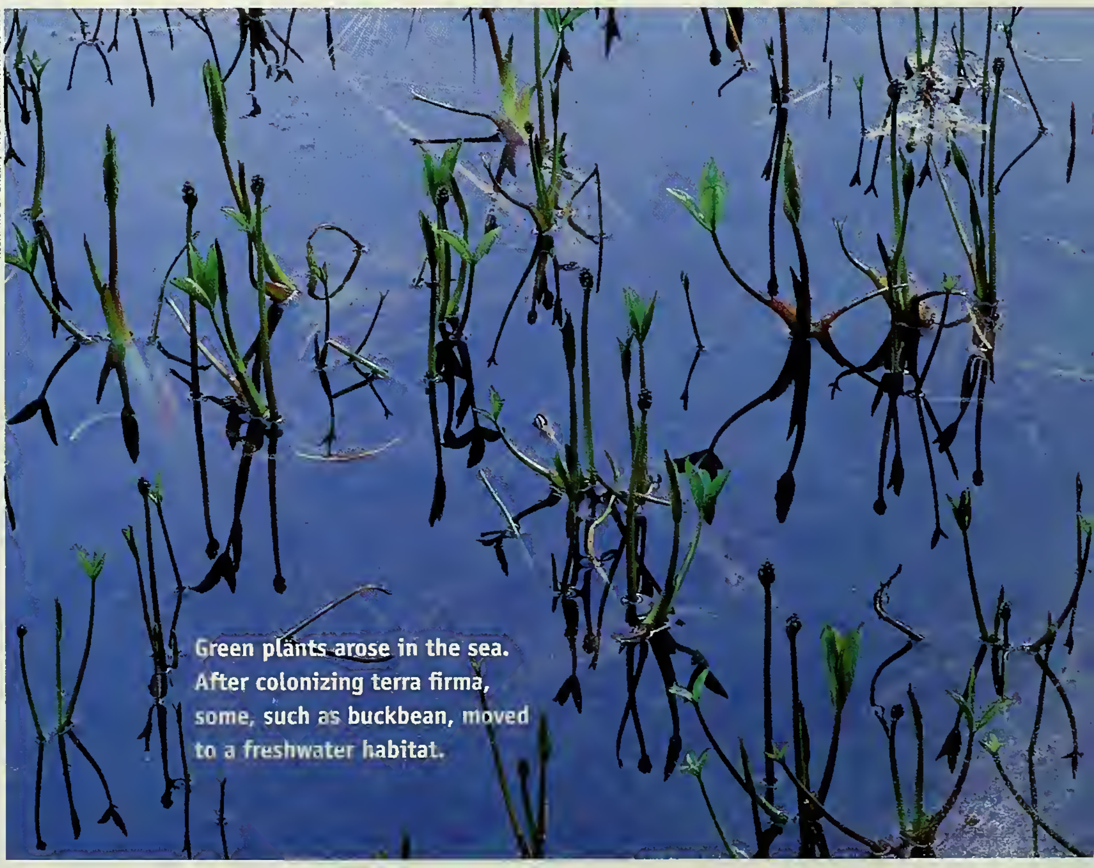
By the Permian Period, about 260 million years ago, the invasion tables had turned. Tetrapods had achieved metabolic levels equal to and often higher than those of marine fish. (Why does this matter? Given enough food, an animal with a high metabolic rate can grow faster, gather and safeguard more resources more quickly, and devote more energy to defense, including the defense of offspring, than can an animal with a low rate. Having a faster metabolism is like having more money: you may not be able to buy happiness, but you can acquire more of the things you need and can carry out more of the essential tasks of life more effectively.) These high-powered terrestrial species still, of course, had numerous obstacles to overcome before carving out a niche for themselves in the sea, but at least by Permian times they stood a fighting chance.

Significantly, incumbents have always been less of a problem in freshwater ecosystems. Part of the reason for this may be that several important groups of marine predators—echinoderms and cephalopods, among others—are, and apparently always have been, absent from freshwater. In addition, many small bodies of freshwater, as well as inland salt lakes, lack fish and other potentially effective predators and competitors. Such safe places may therefore serve as staging areas, places to acquire and hone adaptations necessary for survival in water.

But what is it about tetrapods that has enabled

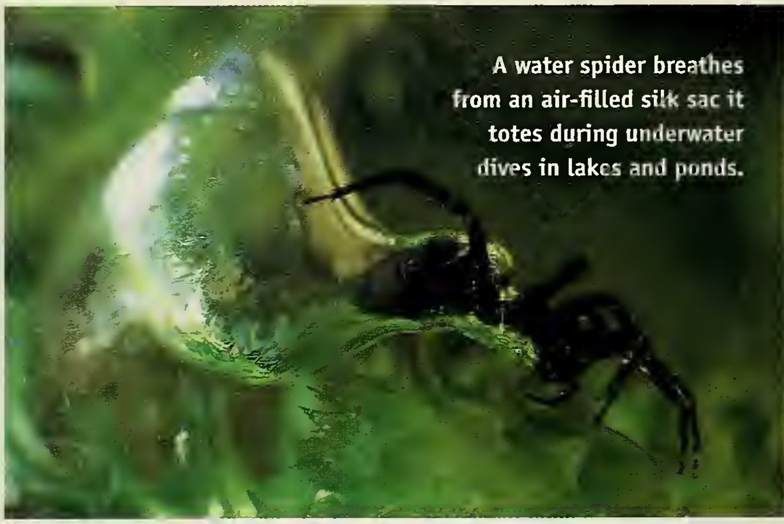
STEPHEN DALTON: NHPA

Above: Although their ancestors evolved in the ocean, some isopods are now at home in Israel's Negev Desert.



RICHARD J. GREEN: PHOTO RESEARCHERS, INC.

Green plants arose in the sea. After colonizing terra firma, some, such as buckbean, moved to a freshwater habitat.



A water spider breathes from an air-filled silk sac it totes during underwater dives in lakes and ponds.

WOLFGANG BAYER; BRUCE COLEMAN INC.

DAVE WATTS; NHPA

With its webbed feet and streamlined body, the platypus is clearly at home in its freshwater habitat.

them to return to a watery way of life—fresh or marine—so frequently and effectively? Unlike marine insects and other arthropods that endure submersion by taking refuge in rock crevices or in self-generated gas bubbles, once tetrapods take the plunge, they remain active. Although they may still need to come to the surface to breathe (or, as in the case of seals and seabirds, return to the land to breed), they are able to feed and carry out many of the other vital functions of life in their adopted medium. Perhaps in the distant past the newcomers, with their revved-up metabolism, thrived because the relatively sluggish incumbents—crustaceans, echinoderms, mollusks, and many fish—offered little resistance. Today the descendants of the invaders often occupy dominant positions in marine ecosystems. Depending on the species, whales are either major consumers of plankton or krill or they are major predators,

Tetrapods may have thrived in the sea because the relatively sluggish creatures already living there offered little resistance.

feeding on seals, fish, and penguins. Seals and marine birds are also carnivores that dine at or near the top of the food chain (as did the extinct marine reptiles). Green sea turtles and sea cows are herbivores with large appetites, as was the Peruvian sloth, presumably. (Even among tetrapods, however, lineages that returned to the sea form a small minority. There are, for example, no marine bats, hoofed mammals, parrots, or songbirds.)

Issues of incumbency may also explain why carrying out a successful invasion of land from the sea is difficult. Most organisms in a position to make the attempt are like periwinkles and other shore snails—creatures that, when exposed to the air at low tide, spend long hours waiting passively behind closed doors until the tide returns. Only then can they begin feeding and moving around again. Such creatures are unlikely to compete successfully for resources with birds that energetically race around on the mudflats in search of nutritious tidbits or with raccoons that come to the water's edge to forage for food. Most of the more recent success stories involve snails, isopods, and other marine animals that have colonized leaf litter or remained in environments close to the sea-

FRANS LANTING; MINDEN PICTURES

shore. One of the more notable recent invaders is the large coconut crab *(Birgus latro),* a hermit crab restricted to islands in the Pacific and Indian Oceans. Large and aggressive, as well as powerful when its shell is hard, this animal is defenseless when molting and would be an easy target for hungry ground-dwelling mammals. It may owe its success to the rarity or absence of major carnivorous vertebrates on islands.

Of course, incumbents and invaders don't live in a vacuum. Both are affected, often dramatically, by external forces, some of which may help topple an incumbent that would otherwise have been able to stand its ground. In nature, there is no such thing as a term limit for incumbents, but they are vulnerable nonetheless. Being well-adjusted to the status quo can be a liability if that adjustment comes at the cost of flexibility. Incumbents often prove to be most at risk during times of major disturbance, such as a sudden change in climate. The disturbance, together with pressure from predators and competitors, may enable upstart, imperfectly adapted invaders to gain a beachhead in a foreign place.

The principle of incumbency is widely applicable in biology and has important implications for our own relationships with the rest of the biosphere. By destroying or modifying most of the world's ecosystems and by exploiting most of the competitively superior animals and plants on land as well as in the sea, we humans are eliminating incumbents. This makes it even easier for the remaining species (many of which are often disparaged, perhaps unfairly, as "weeds" because of their ability to adapt to life in the disturbed environments we have fashioned) to spread to new habitats or regions. Now that humans are the most powerful of all incumbents, let's hope that we can govern wisely and compassionately. □

Otters—amphibious members of the weasel family—inhabit both saltwater and freshwater. Below: A giant otter in Brazil's Pantanal.

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BIOMECHANICS

Hairy Noses

It's a small, sticky world out there.

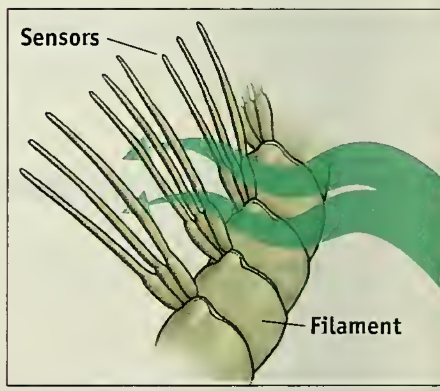
Story by Adam Summers ~ Illustrations by Sally J. Bensusen

Mantis shrimp, or stomatopods, are creatures out of a sci-fi flick. They have a pair of raptorial appendages armed with (depending on the species) either wicked spikes or a crushing mallet. Their elongate, jointed carapace sports stalked eyes, the most complex in the animal kingdom. Each eye is stereoscopic, and in some species the eyes have sixteen visual pigments (humans have three), allowing them to see ultraviolet and polarized light. As good as the eyes of stomatopods are, however, their ability to see clearly is limited by the way light is diffracted, absorbed, and diffused in water. In addition, many stomatopods feed at dawn and dusk, when light levels are low. Therefore, like many other crustaceans, they also rely on an excellent sense of smell to find mates and food and to avoid predators.

Smelling can be tricky. If you think of odor particles as cars passing you on a street corner, then sensing an odor would be like recognizing the make and model of individual cars. Where traffic is light and moving slowly, you can identify the cars easily, but in fast-moving, heavy traffic the task is harder. A stomatopod is faced with a similar problem: it needs to sample a lot of water quickly yet still pick up low concentrations of particular odors. To do this, it samples the environment as frequently as seven times a second with flicks of its "nose"—two whiplike appendages, or antennules, in front of its eyes. Each antennule ends in three filaments, the middle one of which is lined with bundles of tiny, hairlike odor-sensing organs. These organs are only part of the story, though; much also depends on the way water flows past them. For the past several years, Mimi Koehl and Kristina Mead, of the University of California, Berkeley, have been sniffing out the remarkable fluid mechanics behind the stomatopod's olfactory acuity.

The story begins with an 1883 paper by Osborne Reynolds that addresses a common problem in engineering: why the flow of a fluid (out of a pipe, over the wing of an airplane, past the hull of a ship) is sometimes smooth and sometimes turbulent. Through a series of elegant experiments using streams of dye in transparent pipes, Reynolds discovered that smoothness of flow is related to a fluid's viscosity (essentially, its stickiness), whereas turbulence is largely determined by its mass and velocity. By mathematically mashing together such factors as the viscosity, density, and velocity of various fluids and the lengths and widths of various pipes, he came up with what became known as the Reynolds number (Re), which makes it possible to predict whether the flow of a fluid around or along an object will be smooth or turbulent. For example, the seawater surrounding a blue whale swimming at ten knots would have a very high Reynolds number, indicating turbulent flow, while the viscous ejaculate in which a batch of microscopic sperm are swimming would have a low Re, characteristic of smooth flow.

Using high-speed videos and dye streams, Mead and Koehl learned a great deal about how stomatopods sample flowing water for smells, but the researchers wanted to get a close-up look at what was going on. One solution was to build giant (more than 200 times life-size) replicas of the antennules, complete with sensory hairs. What's so useful about the Reynolds number is that engineers and biomechanists don't have to work with life-size models. They can increase or decrease the size of, say, an airplane wing being studied in a wind tunnel or a model of a stomatopod's immersed antennule as long as they change the flow speed and/or viscosity of the fluid so as to produce the same



On the outward stroke, water flows between the bundles of sensors.

Reynolds number that is produced at normal scale.

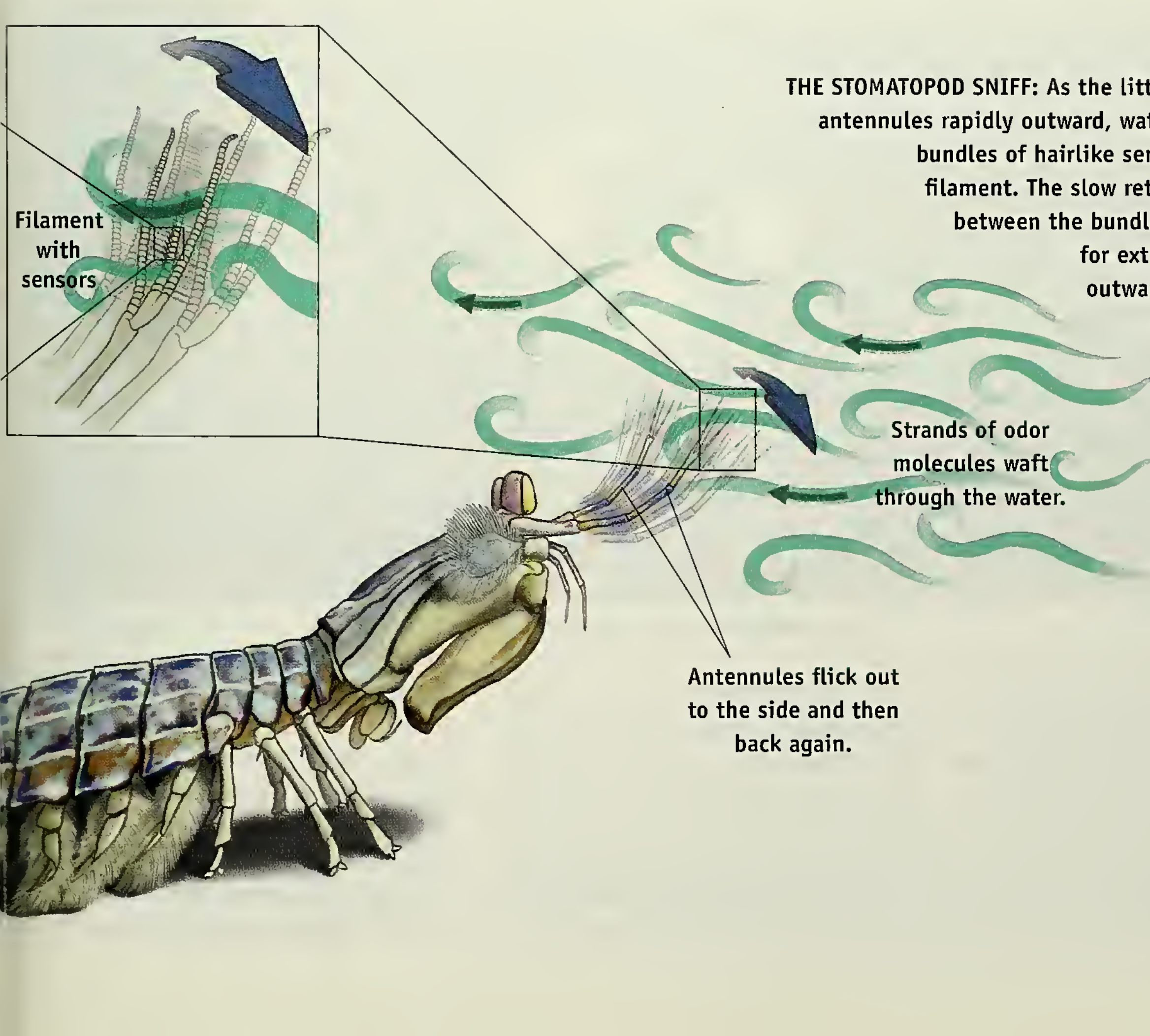
Suppose, for instance, that the screenwriters for the movie *Honey, We Shrunk Ourselves* wanted to know what it would be like for the diminutive parents to sip their morning coffee from a minuscule cup. To see how coffee would behave at that scale, they could experiment with a full-size mug—as long as they replaced the coffee with a sufficiently viscous fluid, such as honey. Doing so would retain the same Reynolds number, so the overall system would behave the same. The experiment would show that, counterintuitive as it may seem, real coffee in a teeny tiny cup would act like honey, and the poor parents in the movie would find that their morning cuppa poured badly, stirred worse, and was hard to drink.

Mead and Koehl immersed their replicas in a large tank of viscous Karo syrup and moved the oversize appendages around at the speed needed to produce the same Reynolds number in the syrup as in the water flowing past the antennules of live stomatopods. Suspended in the syrup were tiny beads, some flowing between the hairs and others bypassing them. Observing the beads enabled the researchers to measure the hairs' "leakiness"—that is, how much fluid passed between the hairs (potentially coming in contact with the odor-sensing organs) rather than flowing uselessly past them. Leakiness is thus a good thing. But what if all that odor information goes by too quickly for organs on the hairs to "read" it?

The speed of the antennules' flick and the distance between the hairs turn out to be the key to keen smelling. During the rapid outward stroke, the array of hairs becomes very leaky, allowing water with lots of interesting smells to contact the sensors. During the much slower return stroke, leakiness drops, not much new water flows through the hairs, and the water from the outward stroke is trapped there until the next flick clears it out and brings in a fresh batch of water and aromas. Each flick is a separate sniff.

Amazingly, as a stomatopod grows, the size of its antennules and the speed with which they flick stay in tune, so that there is always both a leaky and a nonleaky stroke. For these little creatures, a nose has to be more than sensitive; it also has to have all the right moves.

Adam Summers is an assistant professor of ecology and evolutionary biology at the University of California, Irvine (asummers@uci.edu).



THE STOMATOPOD SNIFF: As the little crustacean flicks its antennules rapidly outward, water rushes between the bundles of hairlike sensors lining the middle filament. The slow return stroke holds water between the bundles, allowing more time for extracting odors. The next outward flick—a new sniff—brings in a fresh batch of water.

CELESTIAL EVENTS

What Has Been Will Be Again

Newly forming stars and planets bejewel Orion's sword.

By Richard Panek

It might be true that there's nothing new under the Sun, but what about under the *suns,* the hundred billion other stars throughout the Milky Way? Not only is what's "under" them often new—planets are still accreting out of disks of dust, for instance—but sometimes so are the stars themselves.

Our Sun is a relatively mature star, now midway through its life cycle. It was born some 5 billion years ago, following the gravity-induced collapse of a cloud of gas—a process that is even now repeating itself in other pockets of the galaxy, inside hotbeds of creation that astronomers call stellar nurseries.

To see a particularly vivid example, you need look no further than the Orion Nebula. Only 1,500 light-years from Earth (the visible diameter of our galaxy is about 100,000 light-years; for the invisible part, see "Milky Way Mystery," September 2001), it's practically in our galactic backyard, and probably the stellar nursery closest to Earth. Seen by the naked eye in a location far from city lights, the nebula (from the Latin for "mist" or "cloud") is the faintly fuzzy patch on Orion's sword, which hangs from the constellation's familiar three-stars-in-a-straight-line belt. For observers using binoculars or a telescope, the nebula's greenish white haze provides one of the most attractive targets in the night sky. To professional astronomers, it may reveal insights into our own planet's origins.

The Orion Nebula is an emission nebula, a giant cloud of gas and dust that's lit from within. In this case, atoms of hydrogen, oxygen, and nitrogen are being ionized by ultraviolet radiation from the Trapezium, a quartet of hot young stars at the nebula's heart. These four stars (as well as two fainter companions) are about 100,000 years old—neonates compared with our Sun but the geezers of their neighborhood.

By peering in wavelengths not visible to the naked eye, through the

G. SCHNEIDER, K.L. LUHMAN; NASA

The stars of Orion's Trapezium

nebula's gas and dust, astronomers can identify very young stars and even protostars—those that are about to light up, once the gases reach a critical density. Astronomers estimate that the Orion Nebula may comprise 10,000 stars, many of them similar to our Sun and therefore worthy of intense study. Just this past September, for instance, a team of astronomers using the orbiting Chandra X-Ray Observatory found that these newborns are capable of producing flares hundreds of thousands of times more powerful and hundreds of times more frequent than those generated by our middle-aged Sun. This finding, astrophysicists hope, might help explain the origin of certain mysterious isotopes in our solar system.

But over this past decade, much of the interest in the Orion Nebula has shifted from the stars themselves to what's happening *around* them. In 1992, when astronomers using the Hubble Space Telescope first detected the presence of protoplanetary disks (now called proplyds), they had to wonder if they were seeing early versions of our own planetary system. In 1997 a team of researchers reported that in particularly dense regions of the Orion Nebula, the disk of dust orbiting a star can be scattered as nearby stars bombard it with radiation. This past year, however, another team found that in the less volatile outer reaches of the nebula, the disks might survive long enough to eventually accrete into planets.

And if that turns out to be the case, then we'll finally know where to look—this month, in the southern sky after nightfall—for a reminder of a moment in cosmic history when there was, without a doubt, something new under *our* Sun.

Richard Panek's new book, The Invisible Century: Einstein, Freud, and Our Search for Hidden Universes, *will be published in 2003 by Viking.*

THE SKY IN FEBRUARY

By Joe Rao

Mercury shines low in the east-southeast at mid-dawn for much of February. It is at its highest and easiest to see during the third week of the month, when it rises only a few minutes after the start of morning twilight. On February 21, this zero-magnitude planet will stand at its greatest elongation, 27° west of the Sun.

Venus sets in the west about half an hour after sunset by mid-February. Even skilled observers, however, may be unable to spot the planet until late in the month, when it sets forty-five minutes after sunset.

Mars, in Pisces, moves ever farther from Earth during February, dimming from magnitude +1.0 on February 1 to magnitude +1.3 by the 28th. It sets within a few minutes of 10:00 P.M. local time all month. A four-day-old crescent Moon sits some 6° below and to the left of Mars on the evening of the 16th.

Jupiter shines a brilliant silvery white at magnitude -2.5 amid the stars of Gemini. Lying almost directly overhead during early evening, it doesn't set in the west-northwest until several hours after midnight. Jupiter and a waxing gibbous Moon make for an eye-catching pair on February 22: over most of North America, the Moon appears to pass just above Jupiter, but observers in Arctic Canada, Greenland, Iceland, and western Europe get to witness the Moon's occultation of Jupiter—at about 10:00 P.M. local time that evening.

Saturn glows at magnitude 0.0 close to the Hyades star cluster in Taurus. High up and near the meridian at dusk, the planet is well placed for observation during the first half of the night. Without question, February's highlight comes on the evening of the 20th, when much of North America will be able to watch a spectacular occultation of Saturn by the Moon. Across the central and eastern United States, the event occurs during early evening and should be easily seen by the unaided eye. Farther west, unfortunately, the disappearance and, in some places, reappearance of the planet takes place before local sunset. Saturn becomes obscured by the Moon's dark portion and reappears about an hour later from behind its bright limb. Depending on one's location, the Moon takes between 90 and 120 seconds to completely cover, and then uncover, the ball and rings of the planet. For those with good telescopes, the view of Saturn disappearing behind the Moon's dark edge will be an unforgettable sight. Here are local times for the disappearance and reappearance of Saturn in selected U.S. cities (disappearances before sunset are indicated by dashes): New York: 7:26 P.M./8:45 P.M. Boston: 7:33 P.M./8:47 P.M. Washington, D.C.: 7:18 P.M./8:41 P.M. Atlanta: 6:56 P.M./8:28 P.M. Miami: 7:05 P.M./8:29 P.M. Chicago: 6:05 P.M./7:17 P.M. St. Louis: 5:54 P.M. (right at sunset)/7:14 P.M. Dallas: —/6:58 P.M. Denver: —/5:34 P.M.

The Moon is at last quarter on February 4 at 8:33 A.M. New Moon falls on the 12th at 2:41 A.M., first quarter is on the 20th at 7:02 A.M., and full Moon comes on February 27 at 4:17 A.M.

Unless otherwise noted, all times are given in Eastern Standard Time.

REVIEW

What's It All About, Alfred?

Historians rediscover the quirky genius of evolutionist Alfred Russel Wallace. By Richard Milner

A contentious correspondent once characterized Alfred Russel Wallace (1823–1913) as an enthusiast. By that he meant an obsessive amateur, a field collector full of half-baked theories, from whom no beetle or bird was safe. Far from being insulted, Wallace replied, "It is my pride and glory to be worthy to be so called. Who ever did anything good or great who was not an enthusiast? The majority of mankind are enthusiasts only in one thing—in money-getting. . . . [But the] capability of a man in getting rich is in *inverse* proportion to his reflective powers and in *direct* proportion to his impudence."

Like his hero, Charles Darwin (fourteen years his senior), Wallace had a lifelong enthusiasm for ferreting out the secrets of the natural world, and he gladly risked life and limb in the pursuit of a rare bird or undescribed butterfly. Wallace and Darwin, each acting independently, originated the theory of evolution by natural selection—the concept that came to be known as Darwinism.

Victorianist Peter Raby, lecturer at the University of Cambridge, has written an engaging account of Wallace's long, eventful, and extraordinarily productive life. The discoverer of many tropical species, Wallace lived contentedly among tribal peoples and was the first European to study apes (specifically, orangutans in Borneo) in the wild. By mapping the distribution of living animal populations, he discovered a faunal boundary in Malaysia—known as Wallace's Line—that divides Asian-derived animals from those that evolved in Australia. A century and a half later, geophysicists confirmed that this line corresponds to the edges of ancient tectonic plates that now lie under the sea.

Raised in genteel poverty in rural Wales and then in Hertford, England,


COURTESY OF QUENTIN KEYNES

Alfred Russel Wallace: A Life, *by Peter Raby (Princeton University Press, 2001; $26.95);* **In Darwin's Shadow: The Life and Science of Alfred Russel Wallace,** *by Michael Shermer (Oxford University Press, 2002; $30);* **Infinite Tropics: An Alfred Russel Wallace Anthology,** *edited by Andrew Berry (Verso, 2002; $27);* **The Alfred Russel Wallace Reader: A Selection of Writings From the Field,** *edited by Jane R. Camerini (Johns Hopkins University Press; 2001; $42.50 hardcover; $18.95, paper)*

Wallace was largely self-educated. He became a surveyor and, temporarily, a schoolmaster, all the while developing a passion for natural history. He and his friend Henry Walter Bates became intrigued with the idea of organic evolution, which they first encountered in Robert Chambers's 1844 *Vestiges of the Natural History of Creation*. In 1848, while still in their twenties, Wallace and Bates sailed for the Amazon intending to search for evidence for or against the possibility of evolution. (Young Darwin had no such objective in mind when he joined HMS *Beagle* as ship's naturalist almost twenty years earlier.)

Unlike the well-off Darwin, whose father paid for his voyage, Wallace had to finance his expeditions by selling rare beetles and bird skins to the British Museum. "To generations of field naturalists," Raby writes, "Wallace shines as an inspiration, not just because of his achievements and discoveries, but because of his independence, resilience, courage, and the joy that flashes out again and again in his response to a plant or a butterfly, to any one of the 'perfect little organisms' he encountered in the forest."

On his way back from South America four years later, Wallace's ship caught fire and sank, destroying most of his notes, sketches, and natural history specimens. Yet, on returning to England, he immediately began planning a new collecting expedition, this time to the Malay Archipelago. A colleague warned Wallace, who had been stricken with yellow fever, dysentery, and malaria, that perhaps he should remain in England for a while. Unhesitatingly, Wallace replied, "Being on the eve of a fresh journey . . . I dare say you well know & feel, that to induce a Naturalist to quit his researches at their most interesting point requires some more cogent argument than the prospective loss of health." Now that's an enthusiast.

In 1858, while suffering from a bout of malaria and confined to his forest hut on an island off New Guinea, Wallace wrote a paper proposing evolution by natural selection and posted it to Darwin. It reached him several months later and threw the older man into a panic: had his twenty years of labor been preempted? Without first consulting Wallace, Darwin's friends swiftly arranged for a joint publication. And on July 1, 1858, the Darwin-Wallace theory of evolution by natural selection was read at a meeting of the Linnean Society of London. Although Wallace learned of it by letter almost three months after the event, he was pleased with the outcome. Darwin had been apprehensive about Wallace's reaction, for, as he said later, "I did not then know how generous and noble was his disposition."

Raby's biography is part of a spate of Wallace books that delineate the brilliance, modesty, and charm of this sometimes cantankerous rebel. Michael Shermer's *In Darwin's Shadow,* due out in June, is an intriguing attempt not only to sketch the major features of Wallace's life and thought but also to analyze his quixotic, enigmatic, and "heretical" personality. How could such a brilliant natural scientist seriously claim to have communicated with departed spirits at séances and yet adhere to a naturalism that was "more Darwinian than Darwin"? Shermer, a social scientist and director of the Skeptics Society, concludes that Wallace was so extraordinarily open to experience that his receptiveness to novelty made him a target for spiritualistic con men and impostors.

Among the new Wallace books are two anthologies of the naturalist's writings, some of which have not been available for years. Andrew Berry, of Harvard University's Museum of Comparative Zoology, offers a rich collection of excerpts from Wallace's books and articles arranged by theme, while University of Wisconsin-Madison historian of science Jane Camerini has made a selection of his writings from the field. In both, we are treated to Wallace's direct, unpretentious prose about an array of his favorite topics: butterfly speciation, women's rights, natural selection, utopian socialism, wilderness conservation, social reform, phrenology, spiritualism, and dozens of others. Through their deft biographical essays, Camerini and Berry have both taken a quiet delight in presenting Wallace's long-out-of-print writings as gifts to a generation that has never seen them.

Today biologists tend to be uncomfortable with Wallace's biomysticism and would prefer that his writings on spiritualism and phrenology be relegated to the dustbin of history. Still, Wallace remains a towering figure, a hero of natural history, whose ideas were informed by an uncommon humanity. He hoped that society would evolve more just and equitable systems for distributing wealth and opportunity, and he considered organic evolution to be a noble, progressive process, guided by unseen forces.

Charles Darwin lived to seventy-three, becoming listless and melancholy in his final months, whereas Wallace, who reached his ninetieth year in full possession of his faculties, never lost his youthful enthusiasm for discovery. New explorations and adventures, he believed, were beckoning to him from the spirit world.

Richard Milner, a senior editor of Natural History, *is the author of* The Encyclopedia of Evolution *and the one-man musical* Charles Darwin: Live & in Concert.

nature.net

Now Playing: "Fly Morph-O-Genesis"

By Robert Anderson

Nothing in biology is as amazing as the process by which a single cell becomes a fully formed organism. But the mystery is rapidly fading. A visit to the Web site of the Society for Developmental Biology gave me a glimpse of the remarkable progress being made in deciphering the steps nature takes to fashion a fly or a human being from a simple egg.

Although I am not a biologist, I was drawn by the society's Developmental Biology Cinema (sdb.bio.purdue.edu/dbcinema/index.html). According to the creators of the site, "the stars of this project are the embryos." I have always been a fan of images that impart some new scientific understanding. One of these short clips, "Calcium Tsunami," shows how a wave of chemical reactions sweeps across the membrane of a newly fertilized egg to exclude other sperm. Another, "Dynamics of Thin Filopodia," shows tiny appendages emerging from cells that are feeling their way about as they jostle for proper position within a sea urchin embryo.

The award winner, however, has to be "Fly Morph-O-Genesis." I played some of the clips backward and forward a number of times to watch a variety of developmental steps—such as "gastrulation" (when a multicellular organism's basic body plan is established) and "head involution"—work their magic.

Should these movies spark your curiosity, the society has a great list of links to courses for students at different levels, as well as scientific resources such as the Interactive Fly (sdb.bio.purdue.edu/fly/aimain/1aahome.htm), a cyberspace guide to *Drosophila* genes and their role in development.

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

BOOKSHELF

What Shape Is a Snowflake? Magical Numbers in Nature, *by Ian Stewart (W. H. Freeman, 2001; $29.95)*
A mathematician explores pattern systems and explains the underlying framework of natural phenomena—from rainbows to the shape of liquid splashes and the wind-sculpted patterns of sand dunes.

Wild Health: How Animals Keep Themselves Well and What We Can Learn From Them, *by Cindy Engel (Houghton Mifflin, 2002; $24)*
Zoopharmacognosy—the study of animal self-medication—is enabling biologists to explain such practices as desert tortoises mining calcium to keep their shells strong and monkeys, bears, and coatis rubbing citrus oils and resins into their coats as insecticides.

The Age of Science: What Scientists Learned in the Twentieth Century, *by Gerard Piel (Basic Books, 2001; $40)*
This informed view of the last century's greatest advances in science is conveyed in elegant prose by the founding publisher of *Scientific American.*

Future Evolution, *by Peter Ward; images by Alexis Rockman (Henry Holt, 2002; $35)*
Looking to the past for clues about the future, a geologist predicts that a new age of humanity will radically revise the nature of life on Earth, and an artist envisions startling images of the animals, plants, and other organisms that may evolve thousands, possibly millions, of years from now.

Light at the Edge of the World: A Journey Through the Realm of Vanishing Cultures, *by Wade Davis (National Geographic Books, 2002; $35)*
Through informative personal essays, combined with images taken during twenty-five years of exploration, ethnobotanist Davis celebrates traditional ways of living and thinking.

A History of Great Inventions, *by James Dyson (Carroll & Graf, 2001; $32)*
Inventing Modern America: From the Microwave to the Mouse, *by David E. Brown (MIT Press, 2002; $29.95)*
Patently Female: From AZT to TV Dinners, Stories of Women Inventors and Their Breakthrough Ideas, *by Ethlie Ann Vare and Greg Ptacek (John Wiley & Sons, 2001; $24.95)*
Three new books cover a sweeping array of world-changing devices and those who created them.

The Secret Life of the Brain, *by Richard Restak (Joseph Henry Press/Dana Press, 2001; $35), is the companion volume to a five-part television series of the same name, presented by David Grubin Productions, Inc., and Thirteen/WNET New York. It begins airing on January 22.*
Recent investigations of the human brain at various stages—gestation, childhood, adolescence, adulthood, old age—show that we are only now beginning to recognize its ability to change and grow over the course of a lifetime.

The Future of Life, *by Edward O. Wilson (Knopf, 2002; $22)*
"The totality of life, known as the biosphere to scientists and creation to theologians," writes the eminent entomologist and Pulitzer Prize–winning author, "is a membrane of organisms wrapped around Earth so thin it cannot be seen edgewise from a space shuttle, yet so internally complex that most species composing it remain undiscovered." The book is both an impassioned appeal and a guide to measures that can be taken to save the planet, such as the cessation of logging in old-growth forests and the creation of jobs in conservation and bioprospecting.

These books are usually available in the Museum Shop, (212) 769-5150, or via the Museum's Web site, www.amnh.org.

TELEVISION


MALCOLM HANES; BRUCE COLEMAN INC.

The Blue Planet: Seas of Life, *by Andrew Byatt, Alastair Fothergill, and Martha Holmes (DK Publishing, 2001; $40), is the companion volume to a four-part television series of the same name, a coproduction of Discovery Channel and BBC's Natural History Unit. The first two parts air on January 27 and 28.*
This sweeping investigation, in print and in film, explores the diverse realms within the world's oceans—Earth's largest, and largely unexplored, habitat.

THE NATURAL MOMENT

The Feeding Is Mutual

Photograph by **Mark W. Moffett** Minden Pictures

To a small tropical ant, the spore-containing disks of a *Phymatodes sinuosa* fern are big orange dinner plates. *Philidris* (formerly known as *Iridomyrmex*) ants supplement their carnivorous diet by harvesting the disks, which are packed with oval sacs of oily and nutritious spores (a fern's equivalent of seeds). The fern offers the ants room as well as board. Gaining access through natural cavities in the plant, colonies of the one-eighth-inch-long insects take up residence and rear their brood in the hollow stem. In return, the ants help feed the plant by a system akin to composting.

Ant–plant reciprocity is rather common in tropical regions. In the New World, for example, some acacias play host to stinging ants that guard them by fending off larger plant-eaters. But the rather unaggressive ant above, in Bako National Park in the Malaysian state of Sarawak, on the island of Borneo, feeds

rather than fights. In the park, which is not far from the coast of the South China Sea, vegetation struggles to grow in poor, sandy soil. Biologist and photographer Mark Moffett says the park's many dwarf trees are "covered with bizarre climbing plants." *Philidris* ants have worked out an evolutionary deal with various ant-friendly epiphytes (plants that live on trees), including *Phymatades sinuasa,* which acts like a vine as it reaches up a tree. By stashing the organic remains of their insect prey in the fern's cavities, the ants give the plant needed nutrients. *Philidris* occasionally hunt only to supply their home fern. At Bako National Park in the 1970s, ecologist Daniel Janzen, long a student of ant–plant interactions, took inventories of *Philidris* depots. In one he tallied a fly thorax, a spider thorax, beetle parts, four dead mites, one centipede pincer, and 278 assorted ant, termite, and cricket heads. A feast.
—*Judy Rice*

ENDPAPER

Dinosaur Dreamer

By Michael Novacek

As odd as it may seem, Los Angeles is a particularly good place to become a paleontologist. As a young boy, I didn't always appreciate this. But on rare days when a hair-dryer wind from the desert blew the smog offshore, I would lope up to a hilltop street appropriately named Grandview. The cleansing wind would open the usual view—a bristle of telephone poles and TV antennas rising in the haze—to the whole sweep of the Pacific and the San Gabriel Mountains.

I hardly seemed cut out for bone hunting. I was not much of an athlete and so nearsighted that by third grade I wore gigantic tortoiseshell glasses. But I could run fast and far, climb pretty well, and I was not at all reluctant to be alone over stretches of time. I liked crawling around in the dirt, turning over rocks, and looking at things through binoculars and microscopes. Neighborhood encounters with fossil bones required some imagination. A vacant, weed-choked lot became a fossil-strewn desert with endless prospects. One such area was a spit of eroded sand and gravel that divided a broad street a few blocks from my house. Crossing the gravel one day, I saw a string of fragmented concrete blocks that looked for all the world like the vertebral column of a long-necked sauropod dinosaur. I recruited friends, as well as my rather forcefully conscripted younger brother, to excavate this monster. Our make-believe work on "Dinosaur Island" was my first field expedition.

The author and dreamer in first grade

I read books about real expeditions to canyons and deserts, and I went as often as possible with my parents to Rancho La Brea Park, in the center of Los Angeles. Now the site of the Page Museum, back then the park consisted of poorly manicured tawny grass and dusty oak trees; tar (actually asphalt, a mix of tar and sand) bubbled up in places and formed small pools. I would stare at those pools, hoping to witness history in the making if a hapless squirrel or sparrow got too close and stuck fast. The evidence for occasional deaths was abundant. It was a thrill to see a feather sticking out of the tar like a quill pen in an inkwell. Death did not seem in any way dark or frightening; it was an inevitable conclusion and left fascinating evidence of an earlier life.

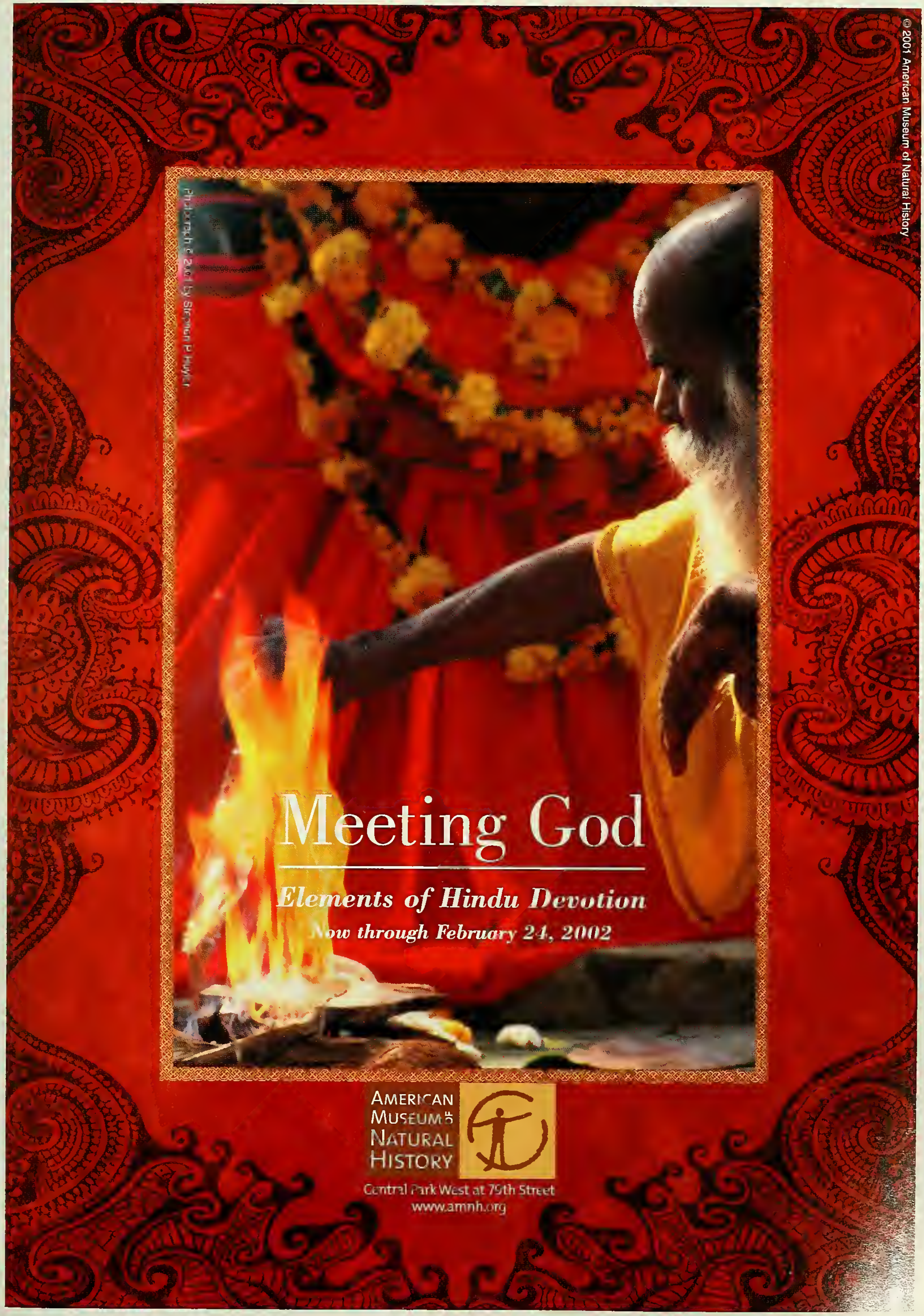
My favorite features at Rancho La Brea were the life-size statues of saber-toothed tigers and imperial mammoths. Some ten miles away, at the Natural History Museum of Los Angeles County, a stupendous array of the tar-stained black bones of such animals filled the halls, and above them was a mural by the great painter of prehistory Charles R. Knight, depicting southern California 12,000 years ago. Against the blue of a mountain range—the same profile of peaks I could see from Grandview—were vultures, mammoths, dire wolves, La Brea camels, saber-toothed cats, and giant ground sloths.

To me, Rancho La Brea and its fossils were a miraculous gift to Los Angeles. In Catholic school, a nun who had visited Lourdes regaled us with tales of the astounding cures of ailing pilgrims who partook of the holy waters there. Lourdes did not seem at all interesting to me, while La Brea was both fantastic and *real*. My predilection for evidence and empiricism, however, was not always rewarded. Our fourth-grade class was divided into three sections according to our perceived intelligence and acceptability: the "Dummies," the "Smarties," and the middle, purgatorial group in which I held a dubious place of honor, the "Spacemen." I tried to transport myself out of my seat as often as possible, usually by concealing my favorite science book behind a catechism. One day as I savored the painting of Ice Age mammals in the large and not easily concealed Time-Life book *The World We Live In*, the nun swooped down on me. "There you are once again reading about monsters!" she shouted.

Later that afternoon I sat on the porch at home reading the book and sipping lemonade. I daydreamed about a Los Angeles lost in time, about Montana badlands and the empty red deserts of Central Asia, of all the continents, canyons, and quarries still waiting to be plundered for fossils. It was good to be a "Spaceman."

Michael Novacek is Senior Vice President and Provost of Science and a curator of paleontology at the American Museum of Natural History in New York.

Adapted from Time Traveler: In Search of Dinosaurs and Ancient Mammals From Montana to Mongolia, *by Michael Novacek. Farrar, Straus and Giroux, LLC.*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