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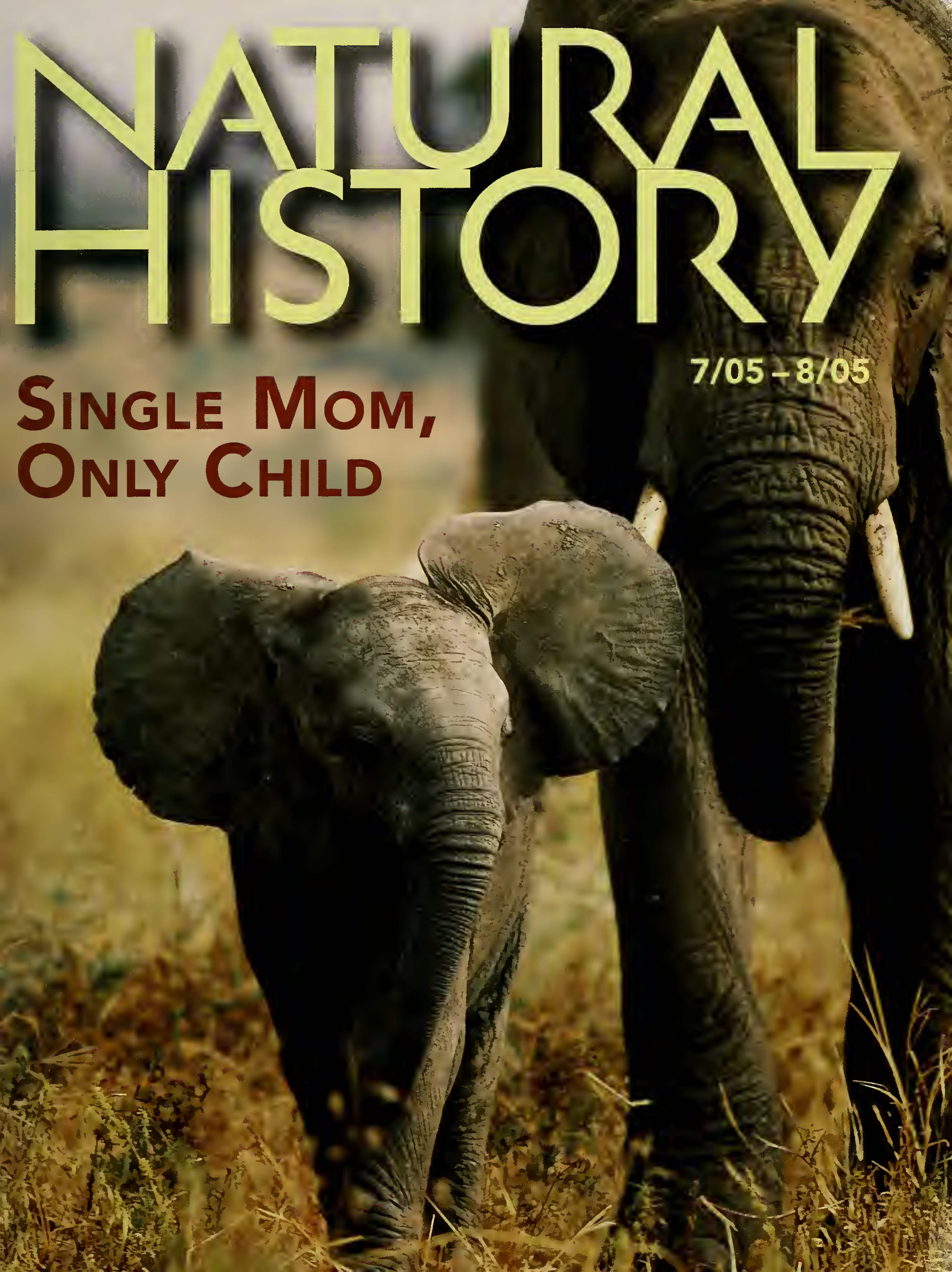
7/05 – 8/05

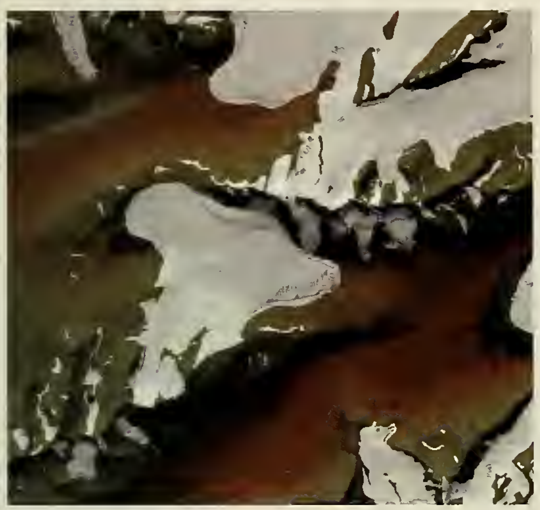
Single Mom, Only Child



NATURAL HISTORY

JULY/AUGUST 2005 VOLUME 114 NUMBER 6

FEATURES



ON THE COVER:
Mother African elephant and her calf

NATURAL HISTORY

DEPARTMENTS

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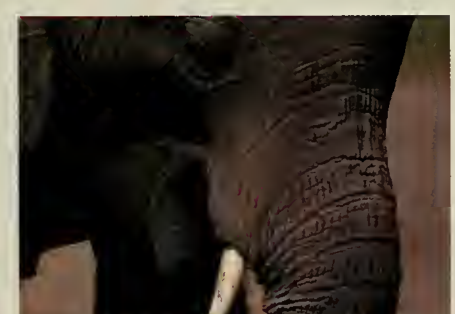

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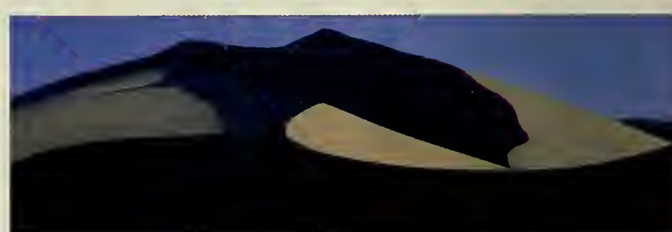

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THE NATURAL MOMENT

Down the Hatch

Photograph by Solvin Zankl

THE NATURAL MOMENT

◄ *See preceding two pages*

Great Inagua, the southernmost island in the Bahamas, hosts a massive colony of wild West Indian flamingos *(Phoenicopterus ruber ruber)*. The resident birds—about 50,000 of them—nest around the salty flats of Lake Rosa, a reservoir ringed by mangrove trees. Photographer Solvin Zankl chose one of the mangroves as a "hide." To minimize the disruption, he installed himself and his camera at the end of the breeding season, when only ten pairs of nesting flamingos were still mouth-feeding their newborn chicks.

Parent flamingos usually have one offspring each year, which they nurture jointly. Rather than regurgitating food for it, both mom and dad secrete a bright red, nutritious liquid in their crop called "flamingo milk." The color of the milk—and the rose hue of the adults' feathers—comes from high levels of hydrocarbon pigments (alpha- and beta-carotenes) in their diet. Fly larvae and other microgoodies are the birds' main fare, filtered out from lake water through the flamingo's pumplike beak.

Unlike the baby pictured here—a two-day-old hatchling—most of the chicks Zankl observed were born a month earlier. Zankl fondly recalls the day several thousand chicks waddled past his hide, creating an incredible splashing sound. "One chick could not keep up with the group and decided to stay behind, between my tripod and my feet." After two hours, the straggler finally rejoined the raucous group. —*Erin Espelie*

UP FRONT

Epilogue

Smart. Gregarious. Long-lived. Gentle when treated well. Dangerous when angered. No, not people; I'm talking about elephants. Our cover story by Delia and Mark Owens, about the aftermath of many years of elephant poaching in Zambia's North Luangwa National Park ("Comeback Kids," page 22), tells of another striking likeness between our species and elephants, revealed only in times of desperation. Elephants from ravaged families act just like kids from broken homes. Young males form gangs and raise hell. Adolescent females get pregnant. The focus of social life shrinks from the extended family to the single mom and her only calf. The lore of elephant society, vested in elders, dies with them. The good news is that, thanks to the efforts of the authors and others, poaching has been all but eliminated in the park. The bad news is that the consequences of poaching live on.

Graciela Flores has a different perspective on consequences: after years of careful scientific work, she doesn't see many. Flores studied heat-sensing in the blood-sucking "assassin bug" of Latin America, the insect vector of Chagas' disease ("In the Heat of the Night," page 32). The ultimate goal of her research was to control a protozoan infection that afflicts some 20 million people in the region. But the substantial scientific knowledge of the assassin bug's behavior rarely seems to translate into actions that could sharply reduce its impact. Money for fighting Chagas' disease is tight: although it may count Charles Darwin among its illustrious victims, the disease, Flores notes, has been mostly an affliction of the poor. Research remains the province of a few dedicated scientists. The thatch-roofed houses where the insects thrive remain home to 120 million people—all at risk of a malady that can kill or debilitate, virtually without warning. Flores has now traded the lab bench for a career in science journalism (she is an editor-at-large for this magazine).

• • •

Edmond A. Mathez presents another kind of epilogue, in his story of geological discovery in a remote corner of Antarctica ("Cold Fire," page 26). Long before it was covered with ice, Antarctica was part of a supercontinent geologists call Gondwana. One hundred eighty million years ago, parts of what was to become the frozen continent were wracked with violent volcanism, the surface repeatedly covered with hot lava, the underlying rock layers repeatedly pried apart by intruding magma. Fast-forward in time, and a series of uplifts and deep cuts by ancient rivers exposed the underground "plumbing" of the molten rock. Miraculously, some of that plumbing occurs in valleys so dry they harbor bare rock for all to see.

Mathez and his colleagues reached this obscure Antarctic landscape as travelers from an unimaginably distant time (our present), to try to make sense of the aftermath. Mathez's story encompasses hundreds of millions of years and a continent-size portion of the Earth's surface. But it begins in camp, where he and his twenty-four companions toast their collective good fortune with Scotch whiskey splashed over 18,000-year-old glacial ice. Who says natural science is dry?

—PETER BROWN

You Have an Important Engagement with Honduras

The Honduras Institute of Tourism, through its innovative—SAVE strategy, seeks to engage Scientific, Academic, Volunteer and Educational travelers in conserving and enhancing the country's diverse natural and cultural attractions. Scientists and academics can orient their research toward conservation goals, and help us build our knowledge base, the better to interpret our unique resources to our visitors. Active engagement of SAVE travelers with our communities will provide invaluable opportunities to develop our human resources.

Honduras has much to offer SAVE travelers. Our system of parks is extensive and diverse, including world-class coral reefs, old-growth mangrove wetlands, vast tropical rain forests and cloud forests. Nine cultural groups speak nearly as many languages. Copan is the artistic capital of the Maya world, and an important collection of non-Maya sites awaits discovery. Friendly and gracious, the Honduran people are eager to share perspectives on the myriad ways we humans adapt and thrive in this diverse world.

If you are interested in this unique Honduran initiative, contact the Honduras SAVE Program:
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CONTRIBUTORS

Before embarking on a career as a freelance photographer, **SOLVIN ZANKL** ("The Natural Moment," page 4) studied marine biology at the University of Kiel in Germany. His scientific interests are evident in his focus on photographic essays featuring wildlife behavior. Zankl's work has been widely published, both in books and in such nature magazines as *GEO* and *BBC Wildlife*. More of his award-winning wildlife images can be seen at his Web site (www.solvinzankl.com).

A geologist and curator in the department of earth and planetary sciences at the American Museum of Natural History in New York City, **EDMOND A. MATHEZ** ("Cold Fire," page 26) studies the geochemistry of the volatile elements. His research interests include the solidification of large magma bodies, the origins of platinum deposits, the electrical properties of rocks, and the early Earth. He has done fieldwork in many parts of the world, from the platinum mines of South Africa to the ancient rock-strewn mountains of Greenland. This past January he joined a group of geologists on an expedition to the McMurdo Dry Valleys of Antarctica, to study the ancient basalt deposits known as the Ferrar dolerites. His most recent article for *Natural History*, "A Birthstone for Earth," on zircon crystals, was published in May 2004.

GRACIELA FLORES ("In the Heat of the Night," page 32) earned her Ph.D. in biology at the University of Buenos Aires in Argentina. There she met the entomologist Josué Núñez and was drawn by Núñez's contagious enthusiasm to the laboratory of insect physiology, run by Núñez and Claudio Lazzari, to study the behavior of *vinchucas*, or "assassin bugs." Flores subsequently left research to pursue a career in science writing and editing. She has designed biology courses for high school teachers and co-authored two college-level biology textbooks, and has also completed a degree in science and environmental reporting at New York University. Flores is now an editor-at-large at *Natural History* magazine, and freelances for publications such as *The Scientist*.

Browsing the cultural anthropological literature on ethnogenesis, the process by which new ethnic groups form, **CHRISTOPHER M. STOJANOWSKI** ("Unhappy Trails," page 38) realized that his dissertation research in physical anthropology might offer clues to the rise of the Seminole, the Indian nation that figures so prominently in the history of Florida. His work, based on human remains excavated from archaeological cemeteries in Florida and Georgia, documents genetic changes among Native American groups during the sixteenth and seventeenth centuries. Stojanowski is an assistant professor of anthropology at the Center for Bioarchaeological Research at Arizona State University in Tempe.

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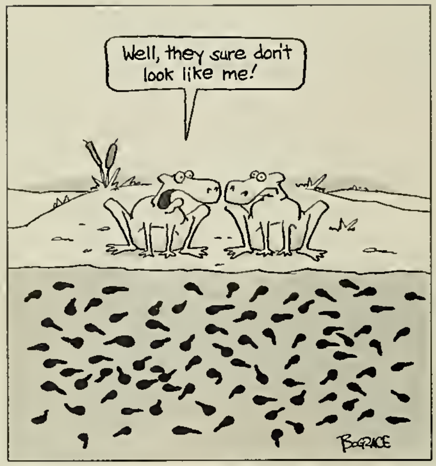
Dinosaur Geography

Mark A. Norell and Xu Xing's tyrannosaur history ["The Varieties of Tyrannosaurs," 5/05] was lucid and informative, but I would amend their assumption that all North American tyrannosaurs are of Asian ancestry. During the Late Cretaceous the vast Western Interior Seaway split North America into East and West. If the eastern genera *Appalachiosaurus* and *Dryptosaurus* are derived from Asia, their ancestors must have crossed the continent before the sea was present, at least 100 million years ago.

Although that is plausible, a recent cladistic analysis that Thomas D. Carr, Thomas E. Williamson, and I published shows that both *Appalachiosaurus* and *Dryptosaurus* were more primitive than their contemporaries in the North American West. Ironically, *Dryptosaurus*, the most primitive tyrannosauroid, only appears in the fossil record nearly as late as the least primitive, *Tyrannosaurus*. *Dryptosaurus* may have been a "living fossil" in its own time. It might be useful to look east, to Europe, for its nearest ancestry.



Messrs. Norell and Xu also maintain that tyrannosaurs "lived at the top of the food chain." That is evident in Asia and the western United States. But in the lowlands of the southern U.S. the gigantic crocodilian, *Deinosuchus*, grew to more than thirty-three feet long and was very abundant. The animal not only topped the food chain, but also ate juvenile tyrannosaurs.

David R. Schwimmer
Columbus State University
Columbus, Georgia

MARK A. NORELL AND XU XING REPLY: Our article was in press before the paper by David R. Schwimmer and his colleagues was published, so the interesting results they found were not included. With the sample they used in their study, they cannot empirically reject an Asian origin for tyrannosaurs. Furthermore, several primitive key Asian taxa, such as *Dilong*, *Alectrosaurus*, and *Alioramus*, were not included in their analysis. We

(Continued on page 54)

Chain Letters

There's a game known as "word chains" in which you go from one word to another by changing one letter at a time (*hat, hot, dot, doe*). Geneticists sometimes see the same thing happening with DNA.

Marc Monot and Nadine Honoré of the Pasteur Institute in Paris and a host of collaborators analyzed the otherwise extremely stable genome of *Mycobacterium leprae*, the microorganism responsible for leprosy, and discovered variations in the DNA sequence at three widely separated places in the genome. The DNA "alphabet" has just four "letters"—A, C, G, and T—and so the total number of possible combinations at those three places is sixty-four. But the geneticists found only four: C,G,A; C,T,A; C,T,C; and T,T,C. Mapping out where and in what proportion each combination occurs today, the investigators realized, could track the spread of the disease through time and space.

Previously it was thought that leprosy originated in India (which still has the most cases) and was introduced into Europe when the armies of Alexander the Great returned from their Indian campaign. But Monot, Honoré, and their colleagues now say East Africa or the Near East is probably the birthplace of the disease. From there, leprosy spread around the globe via human migration, trade, and colonialism.

M. leprae was likely brought to West Africa, for instance, by infected explorers or traders from North Africa or Europe, then followed the slave trade to the Americas. And emigration from Europe in the eighteenth and nineteenth centuries may have brought *M. leprae* to northern North America: while a leprosy epidemic was taking place in Norway, Scandinavian immigrants were settling the Midwest and manifesting the disease. (*Science* 308:1040–42, 2005)

—*Stéphan Reebs*

Keeping an Eye Out

Like most animals, adult giraffes are a watchful crew. But even when they're alone, even when hungry lions and opportunistic hyenas may lurk nearby, and even when their own youngsters could be in danger, giraffes seem more concerned about watching one another than watching out for predators.

A recent field study in South Africa's Kruger National Park by two biologists, Elissa Z. Cameron of the University of Nevada–Reno and Johan T. du Toit of the University of Pretoria in South Africa, suggests that when giraffes periodically interrupt their lunch to scan their surroundings, they're mostly monitoring the whereabouts of the local male giraffes. Small bulls and females are both more vigilant when large bulls are nearby.

Animals generally face a trade-off between checking for possible predators and spending their time eating. Giraffes face an additional problem. Individual females are sexually receptive at varying times of year, and so lusty males are continually on the lookout for a willing partner. But the males' attentions can interrupt the all-important business of eating enough greenery to get through the day. Receptive females, say the biologists, are probably on the lookout for approaching males so that they can move away before being pestered. And the younger, smaller males need to watch out for superior competitors: giraffe fights can be brutal indeed.

It also turns out that the giraffe's long neck can be more hindrance than help. A giraffe holding its neck vertically to reach the uppermost branches of a tree ends up looking at the sky, and can't see what its neighbors are up to. So it, too, frequently interrupts its feeding and spends more time scanning its surroundings than do neighboring giraffes that are feeding on the middle branches. (*Animal Behaviour* doi:10.1016/j.anbehav.2004.08.015, 2005) —*Nick W. Atkinson*

Growing Strains

One must suffer to become beautiful, say the French. So it is with the rose. Making all those gorgeous colors and alluring scents does take its toll. According to Alexander Vainstein and Mery Dafny-Yellin, molecular biologists at the Hebrew University of Jerusalem, and their collaborators, each rose petal produces almost a thousand different proteins, a fair share of which are devoted to fighting stress.

As the petals emerge from their protective covering, the sepals, and turn into a full-fledged but still-closed flower, they

acquire their familiar color, and treble or quadruple their weight. Subsequent growth, and the opening of the flower, comes from the very rapid expansion of already existing cells in the petals, rather than from the addition of new cells. To study the process in detail, the investigators divided flower development into three stages—tightly closed bud, fully colored but loosely closed flower, fully open flower—and analyzed how much of each kind of protein was present at each stage. They expected essentially the same proteins to persist throughout the flowering process, though perhaps in varying quantities.

Instead, they found that only about 40 percent of the proteins were present at every stage. Almost 30 percent made just a single-stage appearance, and then were gone. What a lot of change for a romantic emblem to endure! No wonder nearly 20 percent of the rose's proteins were involved in fighting stress, and that most of them were not only present at every stage but also increased in quantity as the flower matured. (*Planta* doi:10.1007/s00425-005-1512-x, 2005) —*S.R.*

Shakers and Movers

Eggs, whether from amphibians, birds, insects, or reptiles, cannot move on their own, and few carry noxious chemicals. So when a predator chances on a clutch of eggs with no parent in sight, it's breakfast time! Case in point: a mass of red-eyed treefrog eggs glued to a leaf above a tropical pond. But as soon as a snake chomps down on that clutch, breakfast is likely to change from lavish Sunday brunch to basic continental.

Karen M. Warkentin, a biologist at Boston University, has discovered that if the frog embryos are in the final third of their development, a predator attack on their egg clutch leads to quick group action. The embryos wriggle frantically, break out of the capsule that detains them, and drop into the water below. Because the escapees are not yet fully developed, they may soon fall prey to other predators—but any chance of survival is better than certain demise in the gut of the snake.

What triggers the embryos' response? It's the precise pattern of vibrations caused by the snake's first few bites. The soon-to-be frogs react by hatching a day or even two days earlier than their usual six- to seven-day stint on the leaf. By recording and then mimicking the shaking of an egg clutch under attack by a snake, Warkentin has shown how well the embryos can distinguish the telltale signs of an important predator from the tremors caused by innocuous disturbances such as rain—and how well-developed an embryo's decision making can be. (*Animal Behaviour* doi:10.1016/j.anbehav.2004.09.019, 2005) —*S.R.*

As a snake shakes a mass of frog eggs, an embryo escapes and hatches (center right).

Red Power

For millennia, the vivid orange-red pigment called vermillion has decorated pottery and preserved royal bones. Recently a team of geologists and archaeologists, led by Takeshi Minami, an environmental chemist at Kinki University in Osaka, Japan, traced large quantities of the prized pigment found in some central Japanese burial mounds to their source: local mines in the ancient Yamato kingdom, which flourished early in the first millennium A.D. in central Japan. Controlling access to those mines may have been an important element of Yamato realpolitik.

Funerary uses of vermillion, a form of mercuric sulfide, were common in China before they spread to western Japan. To find the source of the central Japanese vermillion, and thus help trace the region's political history, the investigators measured the relative abundances, or ratios, of two sulfur isotopes in the vermillion from twelve ancient mounds, because the ratios serve as indelible "birthmarks." Then they compared those isotope ratios with the ratios in vermillion from three central Japanese mines, as well as from an important ancient mine in Guizhou province, China.

Vermillion from the Chinese mine, they found, is high in sulfur-34; vermillion from the central Japanese mines, in and around the Yamato kingdom, is far richer in sulfur-32. Correlating the ratios showed that the vermillion in the western Japanese burial mounds originated in China, whereas the vermillion in the central Japanese mounds—datable to the time of the Yamato kingdom—was local.

One way the Yamato clan built alliances with neighbors was to distribute their stash of Chinese bronze mirrors. Handing out locally mined vermillion, say the investigators, may have been another. (*Geoarchaeology* 20:79–84, 2005) —*Caitlin E. Cox*

Play Ball!

All summer long, kids will be waiting eagerly to catch balls tossed by Dad or Grandma. And more than likely, they're going to wait too long: the grown-up, intending an easy catch, will make a slow toss that turns out to be just the reverse of easy. A group of Canadian investigators has now shown that kindergarteners—and their parents—can much more readily assess the speed of faster-moving objects than that of slower ones.

Terri L. Lewis, a neuroscientist at McMaster University in Hamilton, Ontario; Iram J. Ahmed, now a medical student at Queen's University in Kingston, Ontario; and their colleagues tested five-year-olds and adults (average age twenty) on speed assessment. Each subject was asked to watch two grids of identical stripes, both shown moving across a computer monitor, and to say which was moving faster. When the "reference grid" moved slowly, at 1.5 degrees a second (equivalent to a ball approaching at six feet a second), the kids could not see a difference until the second grid moved more than twice that fast; the adults required a speed-up of only one-third.

But when the first grid sped along at six degrees a second (equivalent to a ball approaching at twenty-four feet a second), both groups saw the difference much more readily. The kids became accurate when the second grid moved just 44 percent faster than the first grid; the adults were accurate with a speed-up of just 13 percent.

According to the investigators, it's all about the neurons in the middle temporal area of the brain. Few of them specialize in responding to dawdlers, and those few take many years to mature. In any event, being better at noticing speed than noticing slowness was a useful bit of evolution for the human race, making it easier for our ancestors to close in on a four-legged dinner sprinting across the savannah. So go ahead, put some heat on that ball! (*Vision Research* 45:2129–35, 20 —*Elizabeth M. Donohue*

Yoju, *Heart Mountain*, 1997

Air Hockey for Giants

The Heart Mountain rockslide in northwestern Wyoming is the world's largest rockslide and one of geology's biggest puzzles. What could cause a mass of rock nearly 450 square miles in area, and weighing trillions of tons, to slide along a stretch of nearly flat ground and end up, in a matter of minutes, as a sheet of rubble covering about 1,300 square miles? Two geologists, Edward C. Beutner of Franklin and Marshall College in Lancaster, Pennsylvania, and Gregory P. Gerbi of the Massachusetts Institute of Technology, have a theory: the slide was a gas.

Beutner and Gerbi examined an unusual layer of rock known as a microbreccia, lying along the fault on which the Heart Mountain rocks broke free and slid. That layer holds minute grains of carbonate rock and volcanic glass. The grains, the investigators point out, are much like the ones that often form in gas clouds released by volcanic eruptions. Beutner and Gerbi say the microbreccia layer is made of fragments carried in a gaseous cushion that "greased" the surface along which the rocks slid 48 million years ago.

The slide was probably triggered by a nearby volcanic eruption. Then the heat and pressure generated by the friction of the moving mass caused the limestone below it to break down, releasing a cloud of carbon dioxide gas that floated the rubble. Relieved of the ordinary friction of rock on rock, the slide could have traveled extraordinary distances at a hundred miles an hour. (*GSA Bulletin* 117:724–35, 2005)

—*Dave Forest*

By Any Means Available

Sex in the microbial realm is, as you might expect, not quite the same thing as what people like to do in their spare time. But it does take place.

The fungus *Cryptococcus neoformans*, for instance, has two "sexes" (more technically, mating types): *alpha* and a. According to new research by Xiaorong Lin, a microbiologist at Duke University in Durham, and her colleagues, the *alpha* type swings both ways: it can exchange genetic material not only with a individuals but also with other *alphas*. The two processes are different—the same-sex one requires the formation of a fruiting body, which is inefficient—but both require pheromones, the fusion of haploid cells (cells with just one copy of each chromosome), and meiosis, all of which are hallmarks of sexual reproduction. Furthermore, both produce spores.

When you add *C. neoformans*'s newly examined sexual flexibility to its known capacity for cloning itself (asexual reproduction), you're looking at populations of organisms with a lot of potential to adapt to new conditions as well as to multiply rapidly. And that's bad news, because this fungus (most likely, its spores) causes meningoencephalitis in people whose immune systems can't put up a fight. (*Nature* 434:1017–21, 2005)

—*S.R.*

Heading Out

To explore deep space—and make stops along the way—spacecraft will need new forms of propulsion.

By Neil deGrasse Tyson

Launching a spacecraft is now a routine feat of engineering. Attach the fuel tanks and rocket boosters, ignite the chemical fuels, and away it goes.

But today's spacecraft quickly run out of fuel. In fact, by the time a craft exits Earth orbit, there's no fuel left in its main tanks—which, no longer needed, have dropped back to Earth. Only tiny tanks remain, permitting only mild midcourse corrections. All the spacecraft can do is coast to its destination.

And what happens when it arrives?

Without the benefit of filling stations or sizable tanks of spare fuel, the craft cannot be made to slow down, stop, speed up, or make serious changes in direction. With its trajectory choreographed entirely by the gravity fields of the Sun, the planets, and their moons, the craft can only fly by its destination, like a fast-moving tour bus with no stops on its itinerary—and the riders can only glance at the passing scenery. That's what happened with the *Pioneer* and *Voyager* spacecraft in the 1970s and 1980s: they simply careened from one planet to the next on their way out of the solar system.

Poster for Deep Space 1, *a NASA spacecraft launched in 1998*

If a spacecraft can't slow down, it can't land anywhere without crashing, which is not a common objective of aerospace engineers. Lately, however, engineers have been getting clever about fuel-deprived craft. In the case of the Mars Rovers, their breakneck speed toward the Red Planet was slowed by aerobraking through the Martian atmosphere. That meant they could land with the help of nothing more than parachutes and airbags.

Today, the biggest challenge in aeronautics is to find a lightweight and efficient means of propulsion, whose punch per pound greatly exceeds that of conventional chemical fuels. With that challenge met, a spacecraft could leave the launchpad with fuel reserves onboard, and use them much later. Scientists could think more about celestial objects as places to visit than as planetary peep shows.

Fortunately, human ingenuity doesn't often take no for an answer. Legions of engineers are ready to propel us and our robotic surrogates into deep space with ion thrusters, solar sails, and nuclear reactors. The most efficient engines would tap energy from a nuclear reactor by bringing matter and antimatter into contact with each other, thereby converting all their mass into propulsion energy, just as *Star Trek*'s antimatter engines did. Some physicists even dream of traveling faster than the speed of light, by somehow tunneling

through warps in the fabric of space and time. *Star Trek* didn't miss that one either: the warp drives on the starship USS *Enterprise* were what enabled Captain Kirk and his crew to cross the galaxy during the TV commercials.

In October 1998, an eight-foot-tall, half-ton spacecraft called *Deep Space 1* launched from Cape Canaveral, Florida. During its three-year mission, *Deep Space 1* tested a dozen innovative technologies, including a propulsion system equipped with ion thrusters.

Acceleration can be gradual and prolonged, or it can come from a brief, spectacular blast. Only a major blast can propel a spacecraft off the ground. You've got to have at least as many pounds of thrust as the weight of the craft itself. Otherwise, the thing will just sit there on the pad. After that, if you're not in a big rush—and if you're sending cargo rather than crew to the distant reaches of the solar system—there's no need for spectacular acceleration. And that's when ion thrusters work best.

Ion-thruster engines do what conventional spacecraft engines do: they accelerate propellant (in this case, a gas) to very high speeds and channel it out a nozzle. In response, the engine, and thus the rest of the spacecraft, recoils in the opposite direction. You can do this science experiment yourself: While you're standing on a skateboard, let loose a CO_2 fire extinguisher (purchased, of course, for this purpose). The gas will go one way; you and the skateboard will go the other way. This equivalence of action and reaction is a law of the universe, first described by Isaac Newton in the late seventeenth century.

But ion thrusters and ordinary rocket engines part ways in their choice of propellant and their source of the energy that accelerates it. *Deep Space 1* used electrically charged (ionized) xenon gas as its propellant, rather than the liquid hydrogen-oxygen combo burned in the space shuttle's main engines. Ionized gas is easier to manage than explosively flammable chemicals. Plus, xenon happens to be a noble gas, which means it won't corrode or otherwise interact chemically with anything. For 16,000 hours, using less than four ounces of propellant a day, *Deep Space 1*'s foot-wide, drum-shaped engine accelerated xenon ions across an electric field to speeds of twenty-five miles per second and spewed them from its nozzle. As anticipated, the recoil per pound of fuel was ten times greater than that of conventional rocket engines.

Cosmos 1, shown here in an artist's conception, is intended to be the first solar sail placed in orbit around Earth. Its launch is scheduled for this summer. When all its sails are fully unfurled, the craft will be propelled solely by the pressure of the Sun's rays.

In space, as on Earth, there is no such thing as a free lunch—not to mention a free launch. Something had to power those ion thrusters on *Deep Space 1*. Some investment of energy had to first ionize the xenon atoms and then accelerate them. That energy came from electricity, courtesy of the Sun.

For touring the inner solar system, where light from the Sun is strong, the spacecraft of tomorrow can use solar arrays—not for propulsion itself, but for the electric power needed to drive the equipment that manages the propulsion. *Deep Space 1* has folding solar "wings." Fully extended, they span almost forty feet—about five times the height of the spacecraft itself. The arrays on them are a combination of 3,600 solar cells and more than 700 cylindrical lenses that focus sunlight on the cells. At peak power, their collective output was more than 2,000 watts, enough to operate only a hair dryer or two on Earth but plenty for powering the spacecraft's ion thrusters. And last I heard, the radio was still on.

Other, more familiar spacecraft—such as the now-disintegrated Soviet space station *Mir* and the nearly seven-year-old International Space Station (ISS)—have also depended on the Sun for the power to operate their electronics. A work-in-progress orbiting about 250 miles above Earth, the ISS will eventually carry more than an acre's worth of solar panels. For about a third of every ninety-minute orbit, as Earth eclipses the Sun, the station orbits in darkness. So by day, some of the collected solar energy gets channeled into storage batteries for later use during dark hours.

Although neither *Deep Space 1* nor the ISS uses the Sun's rays to propel itself, direct solar propulsion is far from impossible. Consider *Cosmos 1*, an engineless, 220-pound spacecraft that will be propelled (once it achieves Earth orbit) solely by the pressure of sunlight. In fact, *Cosmos 1* is a solar sail. By the time you read these words, it may have entered its initial intended orbit, 500 miles above Earth. The project is a privately funded collaboration between U.S. and Russian space scientists, led by The Planetary Society. This summer's launch will culminate nearly five years of work by rocket scientists who would rather collaborate than contribute to mutual assured destruction (aptly known as MAD).

Shaped like a supersize daisy, this celestial sailboat folds inside an unarmed intercontinental ballistic missile left over from the Soviet Union's cold war arsenal, and then launches from a Russian submarine. *Cosmos 1* has a computer at its center and eight reflective, triangular sail blades made of Mylar reinforced with aluminum. When unfurled in space, each blade extends fifty feet yet is only 0.0002 inch thick—much thinner than a cheap trash bag—and can be individually angled to steer and sail the craft.

Once aloft, the solar sail will accelerate because of the continual, collective thrust of the Sun's gazillion photons, or particles of light, hitting its blades and bouncing off the reflective surfaces. As they bounce, the photons will give rise to a gazillion little recoils in the opposite direction. No fuel. No fuel tanks. No exhaust. No mess. You can't get greener than that.

Having entered space, a lightweight solar sail could, after a couple of years, accelerate to 100,000 miles an hour. Such a craft escapes from Earth orbit (where it was deposited by conventional rockets) not by aiming for a destination but by cleverly angling its blades, as does a sailor on a ship, so that it ascends to ever-larger orbits around Earth. Eventually its orbit could become the same as that of the Moon, or Mars, or something beyond.

Obviously a solar sail would not be the transportation of choice if you're in a hurry to receive supplies, but it would certainly be fuel efficient. If you wanted to use it as, say, a low-cost food-delivery van, you could load it up with freeze-dried veggies, ready-to-eat breakfast cereals, Cool Whip, and other edible items of extremely high shelf life. And as the craft sailed into sectors where the Sun's light is feeble, you could help it along with a laser, beamed from Earth, or with a network of lasers stationed across the solar system.

Speaking of regions where the Sun is dim, suppose you wanted to park a space station in the outer solar system—at Jupiter, for instance, where sunlight is only 1/27 as intense as it is here on Earth. If your Jovian space station required the same amount of solar power as the completed International Space Station will, your panels would have to cover twenty-seven acres. So you would now be laying solar arrays over an area bigger than twenty football fields. Fuggedaboutit.

To do complex science in deep space, to enable explorers (or settlers) to spend time there, to operate equipment on the surfaces of distant planets, you must draw energy from sources other than the Sun.

Since the early 1960s, space vehicles have commonly relied on the heat from radioactive plutonium as a power supply. Several of the Apollo missions to the Moon, *Pioneer 10* and *11* (now more than 8 billion miles from Earth, and headed for interstellar space), *Viking 1* and *2* (to Mars), *Voyager 1* and *2* (also destined for interstellar space and, in the case of *Voyager 1,* farther along than the *Pioneer*s), and *Cassini* (now orbiting Saturn), among others, have all used plutonium for their radioisotope thermoelectric generators, or RTGs. An RTG is an inefficient but long-lasting source of nuclear power. Much more efficient, and much more energetic, would be a nuclear reactor that could supply both power and propulsion.

Nuclear power in any form, of course, is anathema to some people. Good reasons for this view are not hard to find. Inadequately shielded plutonium and other radioactive elements pose great danger; uncontrolled nuclear chain reactions pose an even greater danger. And it's easy to draw up a list of proven and potential disasters: the radioactive debris spread across northern Canada in 1978 by the crash of the nuclear-powered Soviet satellite *Cosmos 954;* the partial meltdown in 1979 at the Three Mile Island nuclear power plant on the Susquehanna River near Harrisburg, Pennsylvania; the explosion at the Chernobyl nuclear power plant in 1986 in what is now Ukraine; the plutonium in old RTGs currently lying in (and occasionally stolen from) remote, decrepit lighthouses in northwestern Russia. The list is long. Citizens' organizations such as the Global Network Against Weapons and Nuclear Power in Space remember these and other similar events.

But so do the scientists and engineers who work on NASA's Project Prometheus.

My favorite science-fiction engine is the antimatter drive. Put antimatter and matter together, and they turn into a puff of pure energy.

Rather than deny the risks of nuclear devices, NASA has turned its attention to maximizing safeguards. In 2003 the agency charged Project Prometheus with developing a small nuclear reactor that could be safely launched and could power long and ambitious missions to the outer solar system. Such a reactor would provide onboard power and could drive an electric engine with ion thrusters—the same kind of propulsion tested in *Deep Space 1.*

To appreciate the advance of technology, consider the power output of the RTGs that drove the experiments on the *Vikings* and *Voyagers*. They supplied no more than a hundred watts, about what your desk lamp uses. The RTGs on *Cassini* do a bit better: they could power your thousand-watt microwave oven. The nuclear reactor that will emerge from Prometheus should yield as much as 200,000 watts of power, equivalent to the energy needs of a small school—or a single SUV. To exploit the Promethean advance, an ambitious scientific mission has been proposed: the Jupiter Icy Moons Orbiter, or JIMO. Its destinations would be Callisto, Ganymede, and Europa—three of the four moons of Jupiter discovered by Galileo in 1610. (The fourth, Io, is studded with volcanoes and is flaming hot.) The lure of the three frigid Galilean moons is that beneath their thick crust of ice may lie vast reservoirs of liquid water that harbor, or once harbored, life.

Endowed with ample onboard propulsion, JIMO would do a "flyto," rather than a flyby, of Jupiter. It would pull into orbit and systematically visit one moon at a time, perhaps even deploying landers. Powered by ample onboard electricity, suites of scientific instruments would study the moons and send data back to Earth via high-speed, broadband channels. Besides efficiency, a big attraction would be safety, both structural and operational. The spacecraft would be launched with ordinary rockets, and its nuclear reactor would be launched "cold"—not until JIMO had reached escape velocity and was well out of Earth orbit would the reactor be turned on. As of this writing, however, plans for JIMO are on hold: a series of simpler missions will more expeditiously test the new Promethean propulsion systems.

Someday there might be wackier ways to explore within and beyond our solar system. The folks at NASA's now-defunct Breakthrough Propulsion Physics Project, for instance, were dreaming of how to couple gravity and electromagnetism, or tap the zero-point energy states of the quantum vacuum, or harness superluminal quantum phenomena. Their inspiration came from such tales as *From the Earth to the Moon,* by Jules Verne, and the adventures of Buck Rogers, Flash Gordon, and *Star Trek.* It's okay to think about this sort of thing from time to time. But, in my opinion, though it's possible not to have read enough science fiction in one's lifetime, it's also possible to have read too much of it.

My favorite science-fiction engine is the antimatter drive. It's 100 percent efficient: put a pound of antimatter together with a pound of matter, and they turn into a puff of pure energy, with no by-products. Antimatter is real. Credit the twentieth-century British physicist Paul A.M. Dirac for conceiving of it in 1928, and the American physicist Carl D. Anderson for discovering it five years later.

The science part of antimatter is fine. It's the science-fiction part that presents a small problem. How do you store the stuff? Behind whose spaceship cabin or under whose bunk bed would the canister of antimatter be kept? And what substance would the canister be made of? Antimatter and matter annihilate each other on contact, so keeping antimatter around requires portable matterless containers, such as magnetic fields shaped into magnetic bottles. Unlike the fringe propulsion ideas, where engineering chases the bleeding edge of physics, the antimatter problem is ordinary physics chasing the bleeding edge of engineering.

So the quest continues. Meanwhile, next time you're watching a movie in which a captured spy is being questioned, think about this: The questioners hardly ever ask about agricultural secrets or troop movements. With an eye to the future, they ask about the secret rocket formula, the transportation ticket to the final frontier.

[*This is part two of a two-part article.*]

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

Max Stührling's big mistake

When quality isn't enough to take on the big guys.

The fine horologists (watchmakers) at Stührling just built a super luxury watch for this Christmas. Using one of the most complex regulator movements ever designed, they engineered the Regulator Series 3. With it's large separate minute dial and small hour dial, this watch was built to take on the likes of Rolex™ and Patek Phillipe™ and was to retail for $5,750. Well, Max made a mistake. The other luxury watch manufacturers had locked up the shelf space at the high end jewelers by offering large advertising contracts, so Max is left with 3,435 of these magnificent "Regulator Series 3" watches.

Max needs to liquidate these luxury watches so he came to us at NextTen. You see, NextTen has become synonymous with high quality watches at extraordinary values. We are offering the Regulator for a miraculous price—$349.75. Max is in tears, but he needs the cash. When the 3,435 watches are sold, that will be the end of them. I am keeping three for myself since I'm convinced that the rare design will make this watch sought after by collectors in years to come.

A back as beautiful as the front

The unique bronze-finished movement is absolutely stunning. You can watch the smooth movement of the rotor and the 22 jewels work in precise harmony.

What makes it special?

The Regulator will make you want to learn how to tell time all over again. The Regulator movement is utilized in the master clocks at observatories, but Stührling has miniaturized this complex movement for the Regulator Series 3. Separate hour and minute dials will make you stare at this unique watch. The dial is machined in a silver-white star burst and the escapement is visible through the dial so you can watch the balance wheel in action. The movement oscillates at 21,600 vibrations per hour for accuracy to within seconds per day. The tonneau styled case is fused in 23k gold and the alligator-embossed band is fitted with the finest butterfly clasp that we have seen in our travels. If you desire the best, the unique and the rare, the Stührling Regulator is built for you. We do expect to be out of this watch in just a few weeks, so please act quickly.

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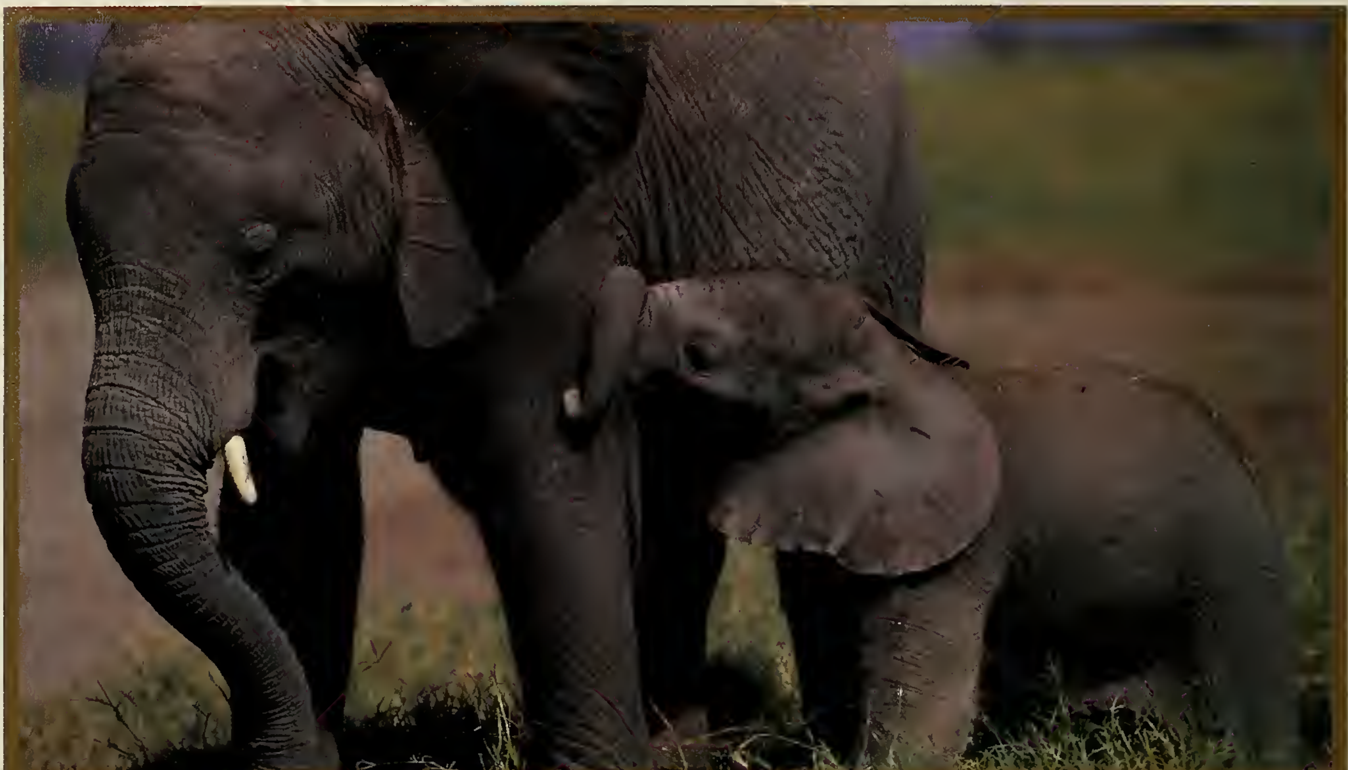


Young female African elephant nurses her calf. Before the years of heavy poaching, elephants in the Luangwa Valley of northeastern Zambia were usually sixteen years old before they became mothers. Poaching has led to a sharp rise in the incidence of single adolescent mothers as young as eight years old.

Comeback Kids

Elephant "single moms" are struggling to recreate family life after the traumatic years of poaching.

By Delia and Mark Owens

"There—a baby! She is coming to us by the river," Patrick Mwamba, a Bemba tribesman, whispered. Across the river from our camp a small female elephant trotted along the shore, her trunk flopping loosely like a garden hose. Abruptly, she stopped and looked into the tall grass, then turned and walked slowly south. Holding her little trunk in the air like a periscope, she twisted the end around in all directions.

As we watched her, Patrick whispered what each of us was thinking: "She is very much alone in this place."

Another orphan. They had become commonplace here, in North Luangwa National Park (NLNP), Zambia. From the late 1970s through the 1980s, commercial poachers had shot 93 percent of the elephants in the population for their ivory, skin, or meat. The population had declined from 17,000 in the mid-1970s to approximately 1,500 by the mid-1990s. When we arrived in the park, in the middle of this devastating period, the Zambian government simply did not have the resources to stem the onslaught.

Part of the problem was the park's remote wilderness. It is nestled under the shoulder of the Muchinga Escarpment, where waterfalls tumble a thousand feet over forested mountains [*see map on opposite page*]. To the east of the mountains, the wide Luangwa River snakes its way through a valley, creating enormous floodplains and habitat for Cape buffalo, Cookson's wildebeest, puku antelope, and zebras. In 1986, gliding over the plains for the first time and peering down from our small airplane, we saw a landscape that looked wild and free. In fact, though, poachers had taken it over. Bands of as many as a hundred men had set up makeshift encampments, from which they would sally forth to shoot elephants and lions. Then, like scurrying ants, they would carry the illegal ivory and meat over the escarpment, where it was sold to smugglers.

For more than 200 years, the high value of ivory and other elephant products have made hunting and poaching ongoing facts of life for elephants, both in Africa and in Asia. The easiest way to get the ivory has always been to kill the giant creatures, and as firearms have become more common, more accurate, and more deadly in the past two centuries, more elephants have been killed. The elephants of Luangwa were, to some extent, protected by their remote location and by the ruggedness of the terrain. In the early years of the ivory trade they had fewer losses than did elephants in other, more densely human-inhabited areas, such as South Africa. But by the late 1970s, intense poaching finally reached NLNP. There were still 5,000 elephants in the park when we arrived in 1986, but the poachers were shooting about a thousand every year.

Working with the Zambian National Parks and Wildlife Services and the Anticorruption Commission, we assisted government game scouts by providing housing, trucks, uniforms, and food for their patrols. With new training and incentives, the scouts began capturing poachers.

But even more important, in fourteen outlying villages we set up the North Luangwa Conservation Project (NLCP), which offered alternative jobs, rural health care, and conservation education. Poaching is not only illegal, it is dangerous and not very profitable for the villagers. Ivory smugglers paid villagers only ten dollars for shooting an elephant. With the village jobs program in place, many of the former poachers and other villagers became beekeepers, fish farmers, millers, or sunflower-press operators. Men and women had safe, profitable jobs that fed and supported their families.

Another tool that proved essential in the struggle against poaching was the international ivory ban, adopted in 1989. Smugglers could no longer make large sums of money from ivory, so they could no longer afford to hire villagers to be shooters or porters.

Finally the poaching declined to fewer than ten elephants killed in 1991, and even fewer per year in the next decade. Still, a few elephants were being shot. The entire family of the orphan that Patrick spotted had been mowed down with machine guns, before she made her way to our camp.

Patrick and the two of us watched as she slowly dropped her trunk,

North Luangwa National Park, where the authors have studied the effects of poaching on elephant populations, lies in northeastern Zambia. The park is approximately the size of the state of Delaware.

walked into the tall grass, and disappeared. We crossed the shallow river, keeping an eye out for Ripples, a crocodile that frequented the pools and eddies near camp. We studied the footprints the little elephant had left in the white-hot sand. African elephants grow throughout their lives, so one can estimate their ages by measuring the length of their hind footprints. The method is particularly accurate up to fifteen years of age, and so we were fairly certain from our measurements that the orphan was about five years old. We named her Gift; we didn't expect to see her again.

African elephants usually live in tight social groups—in fact, family units—whose gene lines persist for generations. Females remain within the group throughout their lives, and each family unit is led by a matriarch that, in the days before widespread poaching, could live to be sixty years old. Grandmothers, mothers, aunts, sisters, and female cousins feed together, romp in the rivers, and play on the plains. There is a lot of touching and bumping of body parts, and the animals, like affectionate tanks, show very little aggression toward each other.

Young males stay in the group into which they were born until they reach puberty (nine to fourteen years of age). Since they are related to every female in their natal family unit, when testosterone kicks in, they leave the security of the unit in search of a suitable mate. Adult males spend much of their time alone, or with several other males that stay together while feeding. When a receptive female comes along, however, it's every bull for himself.

Young females learn a great deal about maternal behavior from their elders. Long before they are old enough to reproduce or lactate, female adolescents "practice" the art of nursing infants by putting one forefoot forward; for a mother and her calf, that movement gives the calf easier access to its mother's teats. If any infant in the family squeals, all the females run to its aid—pulling it out of the mud, pushing it up an embankment.

The old matriarchs are the group's storehouses of knowledge. They know the water sources in times of drought, the ancient routes across the mountains for the best dry-season forage. They lead the other elephants across the Luangwa River in darkness to avoid the poachers. The matriarch's guidance is the glue that holds the elephant family together, making it among the most social and cooperative groups of animals on Earth.

But little Gift was alone. She was obviously weaned or she would not have survived, but she had no family members to touch her, to lead her, or teach her the ways of the elephant world.

The next day Camp Group—a loose alliance of males that often visited our camp to eat the crab-apple-like marula fruit—wandered across the river and fed on the tall grass by our cottage. Forty yards behind them was the diminutive Gift. Abandoning all normal elephant behavior in the absence of a female family, Gift had taken up residency with the Camp Group males. Almost every day we could see her feeding near them.

Now and then Gift would walk up to Survivor, the first male to accept our presence after poaching was reduced, or to Long Tail, another male in Camp Group, whose tail was so long it almost touched the ground. She would hold up her toy-size trunk to theirs in greeting. But the males ignored her; after all, she was much too young for breeding. In our experience, females did not ovulate before the age of eleven, and usually not until age fourteen. They never gave birth before age sixteen. Gift was only five. So instead of reaching out a trunk or bumping foreheads, as her mother or aunts would have done to Gift, the males turned their backs to her.

Gift's first calf, Georgia, shares a drink at a river with her mother, in North Luangwa National Park. Gift, an orphan elephant, became a "single mom" at the age of eight. Because of poaching, a quarter of the family units in the park include just a mother and a single calf. Before poaching became common, Gift and Georgia would have had calf-rearing help from a group of female relatives; now, they are on their own.

For ten years we studied the effects of the severe poaching on the NLNP elephant population. We fitted radio collars on one female in each of sixteen family units, and measured the footprints of most of the remaining elephants, thereby determining the ages of the population.

One of the most striking effects of poaching we documented was that by the 1990s, 38 percent of the NLNP elephants were tuskless. In elephant populations where poaching had not been a problem, approximately 2 percent of elephants had no tusks. Because poachers had obviously selected individuals for their tusks, the percentage of the elephants remaining without tusks had greatly increased.

But it was not just the number of elephants or the presence of tusks that had changed with poaching. Their very social structure was being transformed. The average size of the family unit had been cut almost in half: from eight individuals to only five. The age structure had also been heavily skewed: only 6 percent of the population was older than twenty. Before the most recent fifteen-year stretch of severe poaching, more than half the elephants in a neighboring population had been older than twenty. In fact, females between twenty and forty-five years old had been the most reproductively active members of populations in which poaching was not severe. Now very few females in that age group in the NLNP remained alive.

No longer were massive and wise old matriarchs leading the family units. A third of the units included no adult female older than fifteen years. Eight percent of the groups were made up entirely of orphans. Young males, which, in an undisturbed elephant society, would still be living in their mothers' groups, formed groups of their own. They reminded us of inner-city gangs, chasing nonreceptive females and fighting among themselves. The NLNP elephant population had essentially been reduced to groups of teenagers.

But the makeup of the groups also posed a mystery. Many of the family units had more infants than adult females. Elephants do not normally adopt orphans, so how was such a shift possible? It would take us years to unravel that question.

Almost three years after we first saw Gift, Patrick Mwamba walked softly to our cottage and knocked on the door. "Come see," he said. "The baby elephant, the one you call 'Giftee,' has got a baby."

"What! That's impossible." Gift could not be more than eight and a half years old. She was only half the age at which females usually gave birth.

But sure enough, we found Gift with a small, dark-gray infant at her side. At first we thought it might be another orphan, clearly too small to survive on its own, but looking to Gift for security. But we soon saw the little female nursing and knew for sure that it was Gift's daughter. We named her Georgia.

At eight and a half, Gift had become a single mom. Single moms are almost unheard of in normal elephant populations. Before the severe poaching in Luangwa, family units of two elephants made up only 3 percent of the total. But our data told us that now one-quarter of the elephant families in North Luangwa were made up of just a single mother and her first calf.

Of course, the infants born to single moms were not surrounded by grandmothers, aunts, female cousins, and sisters. Investigators in East Africa have determined that in normal unstressed, unpoached populations of elephants, allomothering—care given by female relatives other than the mother—greatly enhances the survival of a calf. Other females of the family group even help remove the birth sac from newborns. But Georgia had no one but Gift.

What was most amazing to us, however, was that Gift had given birth at such a young age. We thought that perhaps she was a fluke. Because she was an orphan, and because she hung out with males all the time, never with adult females, she had become pregnant against all odds. But at least it gave us a good opportunity to observe the maternal behavior of an orphan.

By that time, Gift had accepted us completely, and so Georgia did, too.

Her newborn wobbling at her heels, Gift walked down the paths in our camp; they looked more like two small sisters than mother and offspring.

Gift was not a good mother. For one thing, of course, she was very young. But since she had not been raised in a family unit, she also had no experience with the frequent touching and gentle care that are part of normal elephant social life. Gift rarely reached her trunk to her calf, and sometimes hardly seemed to notice her. In the first weeks of life, a calf stays close to its mother, sometimes leaning against her large leg as if it were a tree trunk. When it is a few months old, it begins to explore farther away, but if it strays too far, the mother or another female will follow it. Not so with Gift and Georgia.

One morning when Gift was feeding on marula fruits in camp, Georgia, now about three months old, wandered away from her mother. Gift walked quickly and silently in the opposite direction, toward some large marula trees about forty yards away. Moving her trunk along the ground like a vacuum cleaner, she searched for fruits until she was out of sight of her calf.

Suddenly Georgia looked up and could not see her mother. Squealing loudly she dashed around camp, her little legs pumping and her trunk wriggling. She trotted up to us, stared at us for a few seconds, and then ran toward the office cottage in the opposite direction from her mother. We backed up so that we could see Gift. The young mother continued to feed on marula fruits, completely ignoring the shrill cries of her calf. We fought the urge to chase Georgia toward her mother, for fear of making matters worse.

Finally, Gift walked into view and Georgia saw her. The calf trotted to her mother's side, and stayed very near her until they both ambled out of camp several minutes later.

Meanwhile NLCP, our project to assist villagers, had grown. We were now offering aid and education to approximately 20,000 Zambians in remote villages near the park. And to our great relief, in 1996, we recorded no elephants shot in NLNP.

But because the North Luangwa elephants had been harassed and killed for so long, many of them were still wary of people. The best way to observe them was from the helicopter purchased by the NLCP. Two or three times a week we took off in the chopper and soared over the radio-collared elephants as they moved over the lush plains or riverine forests. We stayed high enough to keep from disturbing them, and monitored the new infants born into each family. We also continued to determine the age of the population by measuring footprints. But we had still not solved the mystery of why each family unit always included more infants than adult females.

One morning we watched a young female, about the same age as Gift, suckling a newborn. Mark said into the radio intercom, "That's it. Gift giving birth so young is not a fluke. The adults are dead, so the adolescents are giving birth!"

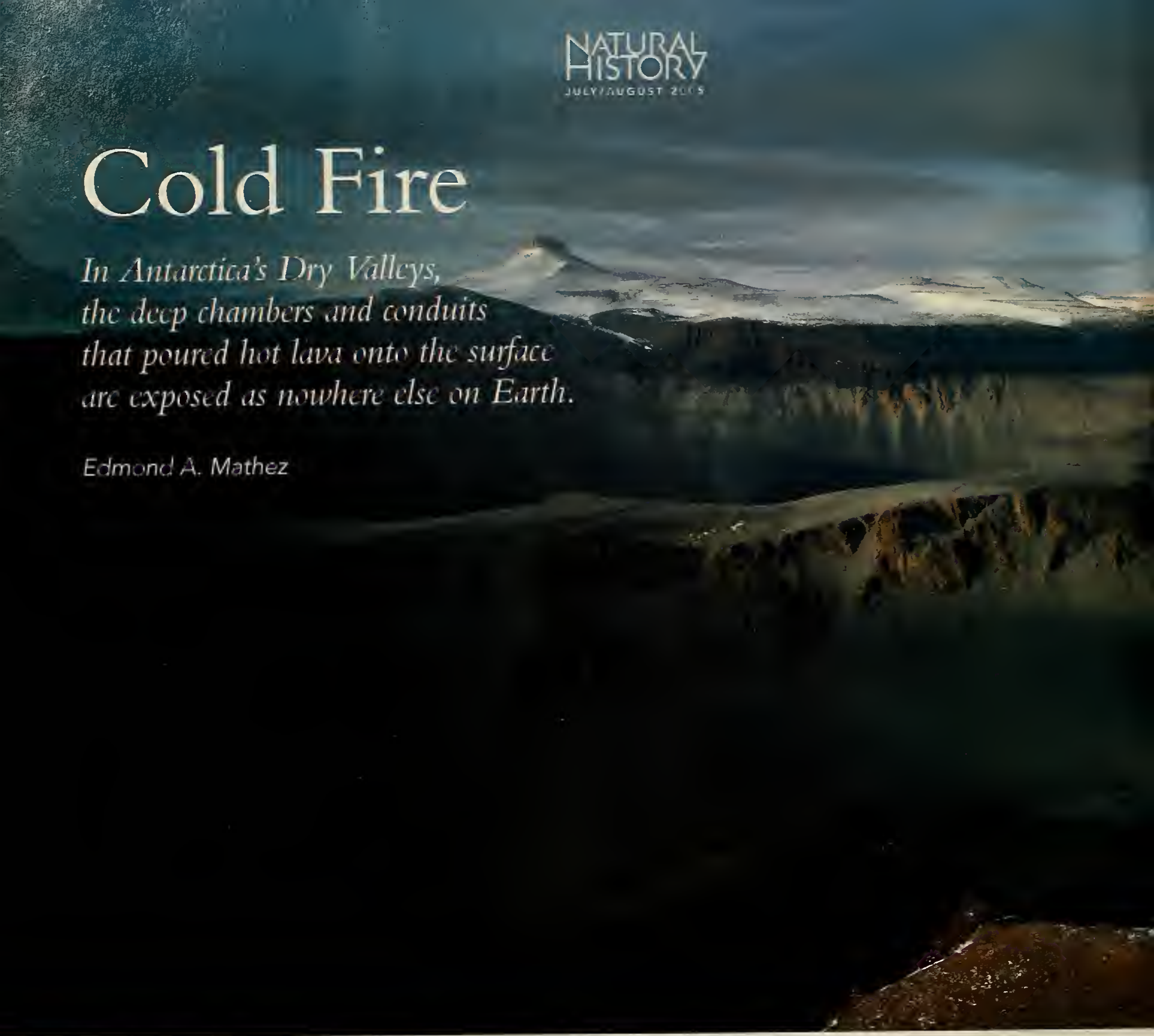
We flew a beeline back to camp, and revisited our data. In 70 percent of the family units there were not enough adult females to account for the number of infants. But there were plenty of adolescent females that could have been the mothers. We started making detailed observations of these family units. And, sure enough, in the absence of adults, females in North Luangwa between eight and a half and fourteen years old were accounting for 48 percent of all births. On their own or in small family units of only two or three elephants, these "teenage" mothers were slowly, haltingly fostering the next generation. They had no old matriarchs to lead them, almost no aunts or female cousins to assist with the squealing infants, no sisters to help protect their offspring. Our aerial counts showed that even though the poaching had stopped, the elephant density was not increasing, possibly on account of high calf mortality and the protracted reproductive cycle. It will probably take many years for the numbers to recover.

By the time Gift was sixteen years old—an age when, under normal circumstances, she would have been giving birth to her first calf—she had three calves of her own and one grandcalf. The grandcalf (Georgia's calf) eventually died, but this small family unit, founded by an "ivory orphan," was making a comeback. Like a single mother in a disrupted human family, she was making the best of a bad situation without relatives, without culture, without much social support. But she was still making a go of it.

Poaching has cut the average size of the elephant family unit in half.

The disruption we have seen in elephant social behavior in North Luangwa is mirrored in other populations of African elephants on the continent. They too are facing decreased numbers of matriarchs, the breakdown of family units, and a shift in sex ratio favoring females. But Gift's abilities as a family leader, which have improved as her family has grown, is her little herd's foothold on the future, and perhaps the best hope for the return of the great herds of yesterday.

DELIA and MARK OWENS have conducted research and established conservation projects on endangered species in Africa for twenty-three years. From 1986 until 1997 the Owenses developed the North Luangwa Conservation Project in Zambia, which was financed by the Owens Foundation for Wildlife Conservation and the Frankfurt Zoological Society. The project's village programs continue today under the direction of Zambians. The Owenses are the authors of numerous articles and the best-selling books Cry of the Kalahari *and* The Eye of the Elephant.



Cold Fire

In Antarctica's Dry Valleys, the deep chambers and conduits that poured hot lava onto the surface are exposed as nowhere else on Earth.

Edmond A. Mathez

Normally one would think nothing of pouring Scotch whiskey over a few chunks of ice. But this ice was more than 18,000 years old! It came from the Taylor Glacier, an enormous river of ice flowing off the polar ice cap into Antarctica's Taylor Valley. The wall of the glacier is marked by a pair of thin, brownish layers of volcanic ash, each containing mineral grains that have been dated by radioisotope decay. The lower layer is 18,000 years old, and since our ice came from below it, we knew the ice must be older than that.

The "we" in this band of Scotch drinkers included me and twenty-four other geologists. At the behest of Bruce Marsh, a geologist at Johns Hopkins University, and with the support of the U.S. National Science Foundation, we had assembled in Wright Valley, one of the McMurdo Dry Valleys of Antarctica—or simply, the Dry Valleys. The region is surely among the most remote, exotic, and starkly beautiful corners of the planet. In spite of the ice and snow that blanket the rest of Antarctica, Wright, Taylor, and other parts of the Dry Valleys are deserts, among the most waterless places on Earth.

For the past decade, Marsh has been studying a labyrinth of basaltic rock spectacularly exposed in the walls of the Dry Valleys. The labyrinth is made up of dikes (sheetlike bodies of rock that cross the surrounding strata) and sills (bodies parallel to the strata). Basalt, a fine-grained black rock, is the most common igneous rock on Earth. It forms when the Earth's upper mantle partially melts, and the resulting magma rises to places where it can solidify rapidly, either within the crust, as dikes and sills, or at the surface, as erupting lava.

The dikes and sills of the Dry Valleys are the remnants of a kind of plumbing system through which magma

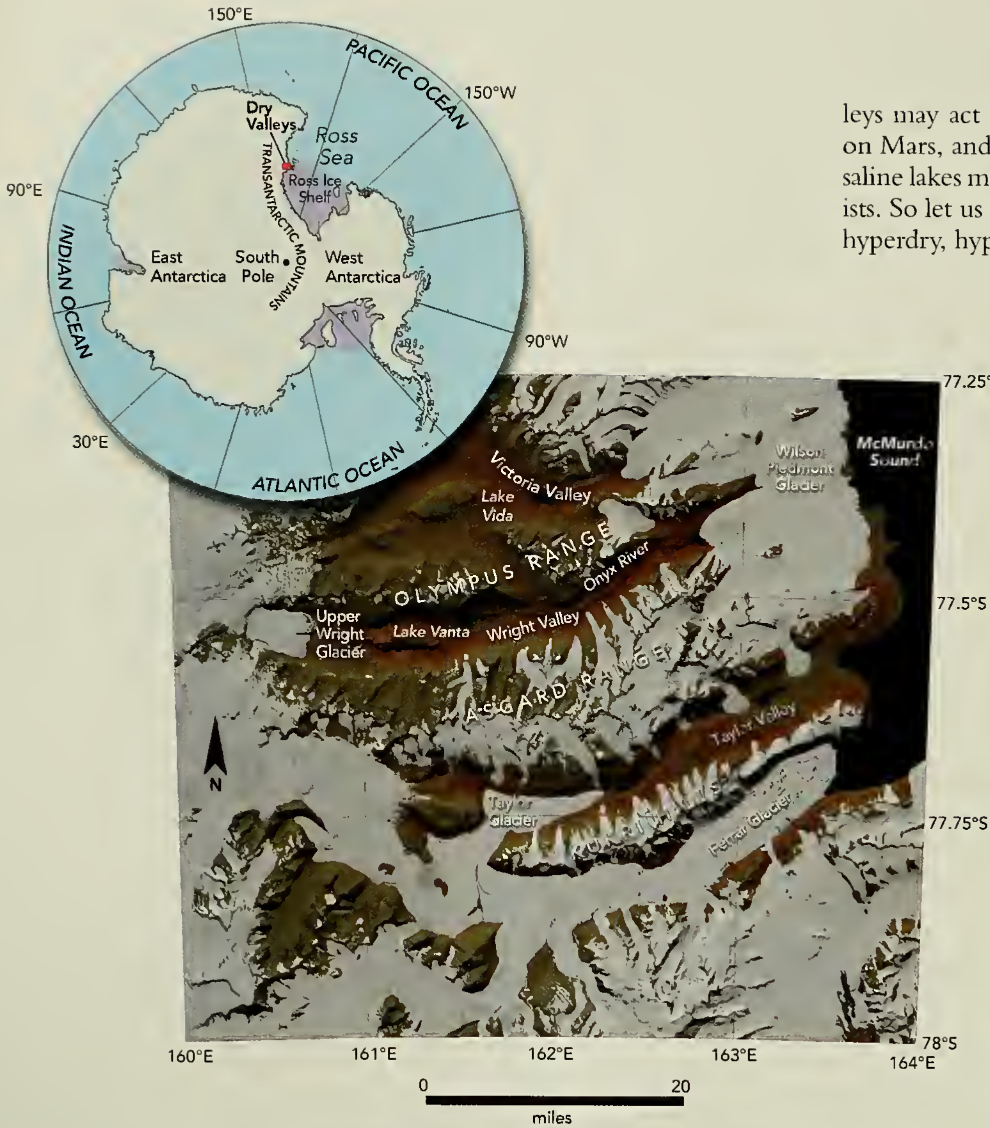
McMurdo Dry Valleys of Antarctica are remarkable not only as a hypercold desert, but also geologically: the bare landscape, free of ice and snow cover, offers earth scientists unparalleled opportunities to study the geologic record of phenomena as diverse as plate tectonics, past climate, and old volcanic systems. Here the view is seaward down Wright Valley, with Lake Vanda in the distance.

worked its way to the surface in a series of eruptions about 180 million years ago. Volcanic plumbing systems are rarely exposed at the surface. The reason is simply that around active volcanoes, lava covers everything. Even at old, inactive volcanoes that have been deeply dissected by erosion, geologists commonly see only the interior of the volcanic edifice, not the structure of the rocks below.

Exposed to view in various parts of the Dry Valleys, however, is a vertical slice of the dikes and sills immediately beneath the lavas, which cuts across layers of rock two and a half miles thick. Hence along the valley walls, geologists can see much deeper into the volcanic plumbing than they can almost anywhere else. Taken together, the dikes and sills of the Dry Valleys are known as the Ferrar dolerites, after Hartley Ferrar, the geologist who, as a member of Robert F. Scott's 1901–1904 Discovery Expedition, first recognized the valleys' dolerites as such. Dolerite is basaltic magma that solidifies rapidly in sills and dikes near the surface.

The dikes and sills bear on several questions geologists ask. One of them is why volcanoes commonly erupt lavas that vary so widely in composition—a major factor in creating the planet's surface. Marsh had chosen to study the Ferrar dolerites because they are quite variable in composition and also extremely well exposed in the valley walls. Now he had assembled a group of geologists, all experts in the physics and chemistry of magmatic systems, to share insights, help discover the reasons for the compositional diversity, and use the lessons learned in Antarctica to understand complex bodies of rock elsewhere in the world.

Sipping Scotch in our isolated camp, though, we were fascinated not only by the rocks, but also by the enormous scale and alien nature of our surroundings. The Dry Valleys



Shaped like a set of fingers, the Dry Valleys extend toward the open sea. Only Taylor Valley reaches the sea, however. The valleys' extreme aridity is a consequence of their position flanking the Transantarctic Mountains and the polar plateau. Cold, dense, dry air masses form on the plateau and tumble down the valleys with the prevailing wind. As the air descends, it warms and thereby expands its ability to hold moisture, carrying off virtually every bit of water in its path. The Transantarctic Mountains also hold back the seaward movement of the East Antarctic Ice Sheet, keeping the valleys largely free of ice.

feature rivers that stay bone-dry except for summer trickles that flow inland to frozen lakes many times saltier than seawater; glaciers whose surfaces sublime (turn from solid ice directly into water vapor) but do not melt; microbial communities that live in bubbles of liquid water locked within subliming lake ice for hundreds to thousands of years. The region opens a window into igneous geology, as well as into how the Antarctic ice sheet responded to climate fluctuations in the past, and how it may respond in the future. Finally, the glaciers impinging on the Dry Valleys may act somewhat like icy features discovered on Mars, and the bacteria that occur in the ice and saline lakes may resemble extraterrestrial life, if it exists. So let us take a moment to wander through the hyperdry, hypercold landscape.

Antarctica is a gigantic continent, with an area far larger than that of the United States (5.25 million versus 3.5 million square miles). Obscured by the continent's ice cover, the Transantarctic Mountains divide Antarctica into two parts [*see map at left*]. The major part of the continent lies in the Eastern Hemisphere, on one side of the mountains, where it is apparently made up of ancient, crystalline bedrock. Most of that rock lies above sea level and is covered by the East Antarctic Ice Sheet, a body of some 6 million cubic miles of ice. On the other side of the mountains is the much smaller (0.8-million-cubic-mile) West Antarctic Ice Sheet, which rests on an ancient bedrock that would be submerged, were it not topped by ice.

Immediately to the east of the Transantarctic Mountains, the Dry Valleys extend from the polar plateau seaward toward McMurdo Sound, an arm of the Ross Sea, roughly sixty miles away. The reason the valleys exist at all is that the Transantarctic Mountains dam the East Antarctic Ice Sheet, largely preventing it from flowing toward the sea.

At the floor of the valleys the average annual temperature is minus four degrees Fahrenheit (minus twenty degrees Celsius), and the annual snowfall amounts to less than half an inch of equivalent liquid water. The valleys are kept both cold and dry by cold, dense air masses that form on the polar plateau and then tumble down the valleys in what are called katabatic winds, displacing warmer air over McMurdo Sound. As the air descends from the plateau, it warms, amplifying its ability to evaporate moisture. Summer, naturally, is the "warm" season, with temperatures near freezing. In Wright Valley, the summer meltwater collects in the Onyx River, the largest "river" in Antarctica—a rather highflown description for what is hardly more than a trickle in the Antarctic summer and nonexistent the rest of the year.

The lakes scattered throughout the valleys are perennially covered by ice, which is typically ten feet or more thick. They would probably freeze completely were it not for the summer sun that warms them and the ice cover that insulates them during the winter. In fact, the bottom of Lake Vanda, in the heart of Wright Valley, is 226 feet deep; there, the water temperature is a comfortable seventy-nine degrees F (twenty-six degrees C).

Despite being fed by meltwater, most of the lakes are extremely salty. For example, the salinity of Lake Vida, in Victoria Valley, is seven times that of seawater. The basic reason for the high salinity is that the lakes are extremely old—old enough for salt to have built up, even though the waters that enter the lakes bring only minuscule amounts. Fundamentally, the lakes lose water as the top of each lake's ice cover sublimes and is lost to the dry atmosphere. The lost ice is replaced by new ice forming at the bottom of the ice cover. In the process, salt gets left behind in the liquid water.

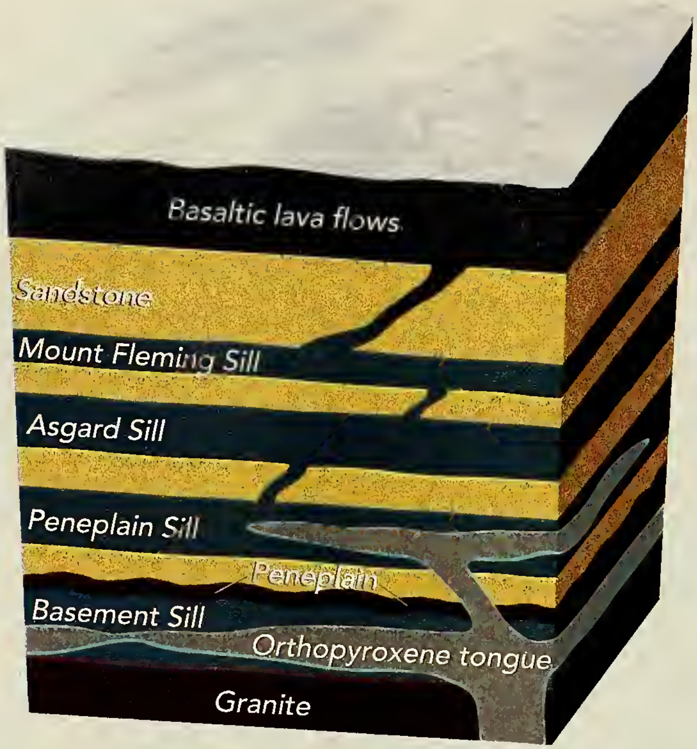
The glaciers of the Dry Valleys are as exotic as the lakes. The glaciers are said to be "cold-based," which means that, unlike nearly all glaciers outside Antarctica, their bottoms are frozen. That property makes them act idiosyncratically. In places such as Greenland or the high peaks of the Alps, "wet-based" glaciers scrape the bedrock over which they flow, picking up substantial quantities of rocky debris. Where the ice melts, the debris accumulates in ridgelike piles known as moraines. Cold-based glaciers, by contrast, flow mainly by deformation: the ice itself flows like putty, pushed by its own inexorable weight. These glaciers pick up very little debris, cause little erosion, and leave only small moraines. Cold-based glaciers even look different. Instead of being thick rivers of ice full of crevasses, the glaciers within the Dry Valleys are flat and rather smooth; some are even shaped like pancakes. They, too, lose their ice mostly by sublimation, so little or no meltwater issues from them.

The enormous riverlike glaciers, such as the Taylor Glacier, that enter the heads of the major valleys do provide some liquid water. In summer they absorb solar heat, which melts the subsurface ice, leaving, within the glaciers, bowl-like pools called cryoconite holes. Because the summer air temperature is commonly still below freezing, the "holes" remain sealed by ice. Nevertheless, the water collects in small, coalescing passageways and eventually trickles out of each glacier.

Where liquid water does occur, life finds a toehold. The cryoconite holes, encased in ice, host communities of bacteria. The same organisms also occur in the lakes of the Dry Valleys, where they form algal mats. Sometimes pieces of the mats become encased in ice that migrates upward as the top of the ice sublimes. The process takes a long time, and microbial mats as old as 2,800 years have been identified. Besides bacteria, life is limited to a few lonesome lichens, which grow on protected rock surfaces, and to several species of microscopic worms known as nematodes, which live in the soil in the few places that become damp in summer.

Since nearly all of Antarctica is covered by ice,

Wall in a side canyon of upper Wright Valley exposes two dark bands of rock; at the base is a talus slope made of those rocks. Each band is a basaltic sill, formed when magma intruded into and then solidified between the layers of the surrounding rock—in this instance, light-colored Beacon sandstone. The topmost dark body capping the cliff face is the Mount Fleming Sill; below that is the Asgard Sill, here about 800 feet thick. To the right is Wright Upper Glacier.



Geologic strata exposed at one or another part of the Dry Valley walls and floors include four basaltic sills (dark blue), as shown in the schematic diagram, based on a model by Bruce Marsh of Johns Hopkins University. Tongue-shaped regions of basalt (gray) rich in crystals of the mineral orthopyroxene protrude into the sills from basaltic dikes, or vertical intrusions of once-liquid rock, that cross the intervening rock layers. The topmost stratum is made up of basaltic lava that erupted, still molten, after ascending through the labyrinth beneath.

one might reasonably suppose that the Dry Valleys were simply carved by glaciers that overtopped the Transantarctic Mountains. Unlike rivers, which tend to cut valleys that are V-shaped in cross-section, glaciers characteristically carve a U (think of California's Yosemite Valley). The walls and floor of the lower reaches of the Dry Valleys are indeed shaped like a U, but to the practiced eye the U looks too wide and too shallow to have been solely glacial.

The most telling evidence of how the valleys did form occurs at high elevations, where geologists have discovered remnants of flat surfaces interrupted by steep-walled valleys. The latter valleys appear to be relics of river erosion 55 million years ago, when the climate was semiarid and Antarctica had no ice. In those days, in a sense, Antarctica did not exist at all. It was still attached to Australia as part of a larger continent known as Gondwana. There are places on Earth today that may bear a close resemblance to the Antarctic landform back then. One of them is the Colorado Plateau of southern Utah and northern Arizona, where seasonal rivers and streams have carved sinuous valleys with flat floors and steep semicircular walls.

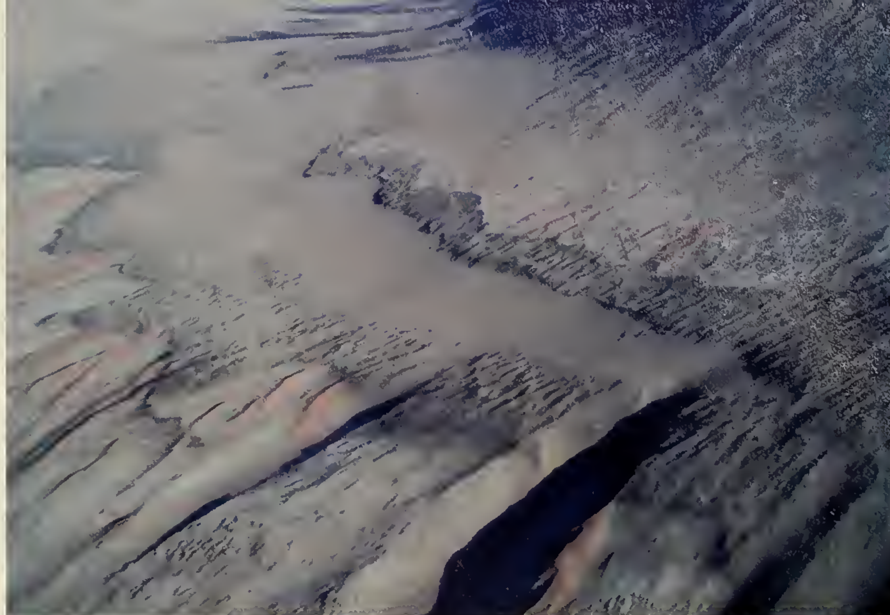
The Antarctic ice cap began to form much later than the valleys did, about 34 million years ago. The fundamental cause was the opening of the Drake Passage, the part of the Earth's great Southern Ocean that separates Antarctica from South America. The newly circumpolar ocean established a circumpolar current that blocks the southerly flow of warm water and thermally isolates Antarctica from the rest of the world. In contrast to the Arctic, which is highly sensitive to global climate change, the Antarctic climate has remained relatively stable for millions of years.

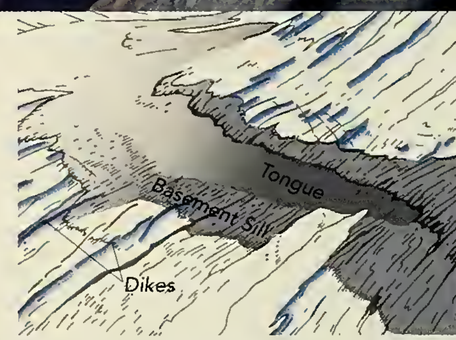
Early on, glaciers did cover much of the Dry Valleys. The glacier traces are hard to miss: rock surfaces have been scoured smooth, and rocky, gravelly debris known as glacial till has been scattered throughout the high valleys. But by about 14 million years ago, the glaciers—except for the small, cold-based glaciers of today—had largely disappeared from the valleys. How do geologists know? On some of the surfaces high above the valley floors, delicate volcanic ash deposits, some as old as 13.6 million years, lie just beneath the desert pavement—the loose rock and gravel too heavy for the wind to have blown away. Those regions of the Dry Valleys have remained hyperdry, hypercold, and glacier-free, at least since the ash fell.

I don't mean to suggest that nothing has happened "recently." Low parts of the valleys were flooded by the sea: nine-million-year-old sediments, typical of the sediments at the bottoms of fjords, remain in the floor of Wright Valley. Similar deposits, aged between 6 million and 3.4 million years, occur in Taylor Valley. Since then, the region has been uplifted—and so the major valley floors are now mostly a few hundred feet above sea level. There was also a period of glacial advance, about 3 million years ago, when the Taylor and Wright glaciers expanded into the lower parts of their valleys and left deposits of till as their calling cards. At various times, sea ice has also invaded the lower valleys. In brief periods of relative warmth, glacial meltwater accumulated behind this ice to form small, temporary lakes. Their sites are marked today by local beds of sediment in the valley floors. Yet none of these events fundamentally altered the landscape; the vista we gaze on today has remained largely unchanged for at least 14 million years.

In today's valleys, the Ferrar dolerites occupy four massive sills, each between 330 and 1,150 feet thick, interconnected by a series of dikes [*see illustration on this page*]. The intricacy of the array is accompanied by a wide variation in the composition of the rocks—a variation presumably related to the way the magma solidified. Unlike water, which freezes at a single temperature, magma freezes over a temperature interval. Most basaltic magmas are completely molten at 2,200 degrees F (1,200 degrees C) and do not become completely solid until the temperature falls to about 1,650 degrees F (900 degrees C). As the magma cools between those two temperatures, different minerals crystallize, or freeze out, at different temperatures. These minerals are not the same in composition as the magma itself. Therefore, as crystals form and sink or otherwise separate from the magma, the composition of the residual magma changes.

In a cooling basaltic magma, the first mineral to crystallize is usually olivine, a magnesium silicate (Mg_2SiO_4) that also includes some dissolved iron. In the case of the Ferrar dolerites, the first to freeze out was orthopyroxene ($MgSiO_3$ with about 15 percent dissolved iron). Because orthopyroxene—and, for that matter, olivine—both have a higher proportion of magnesium than magma does, the magnesium content of the residual magma falls as these minerals crystallize. As cooling continues, plagioclase (a mixture of two kinds of aluminum silicates) and the pyroxene mineral augite (a magnesium silicate mixed with some iron) form.





Tongue of orthopyroxene-rich basalt, embedded in the Basement Sill, is exposed in Wright Valley; its position is shown in schematic diagram at right. The tongue has been eroded by wind and is now covered with sand that makes it look smooth. The reddish striations above and below the Basement Sill are basaltic dikes that predate the sill. When the sill intruded, it cut through those dikes.

The distribution of orthopyroxene proved to be our most telling clue for understanding the Ferrar dolerites. Looking closely at the rocks, we could see clear differences among the sills. Some are made up of dense, black, homogeneous basalt, with no visible mineral grains. Others have varying abundances of orthopyroxene crystals suspended in otherwise fine-grained rock. In consequence, the rock varies from 3 percent to 12 percent magnesium, depending entirely on the proportion of orthopyroxene.

Marsh and his students have meticulously mapped those proportions. The maps show that orthopyroxene crystals are distributed within the sills in great tongues, sometimes extending for tens of miles along the sills. The orthopyroxene-rich tongues are thickest—occupying perhaps half the height of a sill—where the sills appear to have filled from their feeder dikes, and they thin from the filling points toward the more distant parts of the sills.

Given the high melting point of orthopyroxene, its distribution into tongues suggests it froze out of the melt deep in magma chambers, before it reached the sills. Crystals of the mineral were then carried in suspension by the upward-moving magma and forced toward the center of the flowing slurry.

When the flow of magma intruded between layers of rock as a sill, the liquid began to solidify at the sill margins. The "solidification front" then proceeded inward as the basalt continued cooling. Meanwhile, the suspended orthopyroxene crystals, most of which were now near the center of the sill, slowly settled into the lower part of the magma in which they were suspended. When the solidification front moved entirely through the sill, it preserved the tongue-shaped distributions of orthopyroxene crystals we see today in the valley walls.

Elsewhere in the world, geologists have studied vast bodies of well-layered igneous rocks. Some of those rocks hold important deposits of metals such as platinum, for reasons that may be related to the rock-layering process. The layering has thus engaged the attentions of several generations of earth scientists, who continue to wonder not only about ore deposits, but also about the larger lessons the layered rocks may hold. In the Dry Valleys of Antarctica, where the Ferrar dolerites solidified rapidly, geologists have caught the layering process in the act. Thanks to the fortuitous circumstances that keep the landscape free of ice, the Dry Valleys are among the planet's best places to study how various kinds of rocks form, and even how the deep Earth organizes itself. □

In the Heat of the Night

An assassin bug's sensory journey

By Graciela Flores

In rural areas of Latin America, adobe houses with thatched roofs are fixtures of the landscape. The houses are crisscrossed by crevices that serve as hideouts for insects. In the evenings, as the sun goes down, masses of intertwined heads, legs, and antennae start to disentangle. One by one, the insects come out and start their nightly search for blood. They are called kissing bugs or assassin bugs in English, but in Latin America they have many regional names. In my home country of Argentina, we call them *vinchucas,* a word derived from Quechua (a family of languages dating back to the Incan Empire), which means "those who let themselves fall."

These insects are bloodsuckers, and when searching for a blood meal they honor their Quechuan name: because they are such bad fliers, they let themselves drop from walls and ceilings. Once on the floor, or while crawling down the walls, the insects skillfully navigate the intricate micro-landscape of odors, shadows, and temperatures they encounter. When a vinchuca finds a host—a dog, say, or a sleeping human—it swiftly locates a blood vessel. Next, it extends its proboscis, a beak neatly folded under its head, and pierces the skin of its victim. As it feeds, the bug injects a cocktail of analgesics, anticoagulants, and vasodilators that help the blood flow smoothly and painlessly.

Slowly, the vinchuca grows, as Charles Darwin described with disgust after being attacked by one in Argentina, from "flat as a wafer to a globular form," as it becomes "bloated with blood." While still feeding, the insect releases urine and feces on the skin of the host, making room in its abdomen for the enormous amount of incoming blood. [*See photographs on page 34.*]

The vinchuca's excretions can harbor a protozoan known as *Trypanosoma cruzi*—the cause of Chagas' disease. The *T. cruzi* parasites come, in turn, from another animal, and get sucked up when the insect feeds on that infected host. Thus the vinchuca acts as a carrier, or vector, for *T. cruzi.* When a healthy bite victim scratches at a vinchuca wound, any *T. cruzi* parasites in the droppings can slide inside the victim's open skin, and eventually move through the bloodstream to colonize heart muscle and other body tissues.

Symptoms of Chagas' disease vary dramatically, particularly in the early stages. Some people never develop side effects, whereas others experience fever, rashes, and fatigue a few weeks after being bitten. About a quarter of the infected population suffer from serious heart or digestive disorders, which only develop decades after the initial infection. Of the some 20 million people in Latin America now infected with *T. cruzi*, about 50,000 die every year. Those figures make Chagas' disease one of the most widespread and economically devastating tropical diseases in the world. And for poor countries, in which substandard housing is widespread, the total economic loss due to Chagas' disease is staggering.

Vinchucas are relatively unknown in big cities, simply because urban housing does not offer them appropriate refuges. As a city dweller myself, I did not encounter a vinchuca until I became a graduate student in the Laboratory of Insect Physiology, at the University of Buenos Aires. There I was part of a team trying to answer some of the many outstanding questions about vinchucas. As my colleagues and I immersed ourselves in the study of the insect and pooled our results, we were able to reconstruct the insect's sensory trip from its refuge to its host.

In common usage, the term "vinchuca" can refer to many species. We concentrated on one, *Triatoma infestans*, which thrives in the arid north of Argentina and lives almost exclusively in human dwellings. When we started our research, the behavior of *T. infestans* was not well understood. The director of our laboratory, Claudio R. Lazzari, had surveyed the species' behaviors during his own graduate work, with the insect physiologist Josué A. Núñez, also of the University of Buenos Aires. From Lazzari, Núñez, and a few other insect physiologists, we knew that *T. infestans* could home in on an animal's blood vessel even in a pitch-dark room. But we did not know how it accomplished the task. Odors, chemicals, and heat all clearly played a

Vinchucas spend their days crowded together in refuges such as the cracks of adobe houses in rural areas. The interior of one such house is shown impressionistically on these two pages. At dusk, the internal clocks of the vinchucas set the insects on their nightly search for a blood meal.

role, but we were clueless about exactly how the insects exploited that information. So we divvied up the various aspects of the vinchucas' biology and behavior among the members of our team. I focused on the thermal sense—to me, the most fascinating sense of all.

By day, the vinchuca remains in a sleeplike state known as akinesis. At dusk, however, the insect is activated by an internal biological clock, which regulates most of its behaviors. The newly awakened vinchuca raises its antennae—its sensing instruments—and, usually, grooms them: a mesmerizing process. Standing steady on its four rear legs, the insect lifts both front legs and unhurriedly draws first one antenna, then the other, through small combs on the inner sides of the two front legs. Now it is ready to go.

Vinchuca (Rhodnius prolixus), *the species first studied in the 1920s for its response to heat, feeds on a human host. The insect starts out "thin as a wafer," as Charles Darwin noted, left, but balloons in size and empties its bowels as it fills with blood, right.*

As the last hints of daylight disappear, the insect starts randomly walking, moving its antennae smoothly up, down, forward and backward. Every so often, though, the insect pauses, and the smooth, sweeping antenna movements become jerky, resembling the old semaphore method of flag signaling. The vinchuca is sampling the air.

The vinchuca's antennae are remarkable structures. Less than a third of an inch long in adults and even shorter in the larvae, the antenna is the seat of thousands of so-called sensilla, the insect's sense organs [*see illustration on opposite page*]. Each sensillum is a sensory unit made up of one or more neurons, plus supporting cells that nourish them. The sensilla endow the insect with senses of heat, smell, and touch. Taken together, the antennae and their sensilla are the insect's window on the external world.

The wandering vinchuca, antennae waving, has entered an odor plume. Mists of molecules bump into the insect. Some of the molecules penetrate the insect's cuticle through minute pores and reach the olfactory sensilla just beneath. Warm-blooded animals are an endless source of odors, and their high temperatures help disperse chemicals by creating local convection currents.

One of the best indicators that a good source of blood is nearby is a gas that, to us, is odorless: carbon dioxide. Most blood-sucking insects, including mosquitoes and vinchucas, however, *can* smell carbon dioxide, and they rely on that cue in their search for a host. My colleagues discovered that an internal clock controls the sensitivity of vinchucas to carbon dioxide. It turns out that the insect's sensitivity is highest in the first hours of the night, at the start of their journey. Vinchucas have olfactory receptors for dozens of other scent molecules as well as for carbon dioxide.

Upon detecting a promising odor, the vinchuca adopts a new tactic: it travels "upwind," against any local currents of air, to get closer to the source. As it follows the current, the insect gauges its direction with motion-sensitive hairs, known as mechanoreceptors, which are abundant on the antennae. In a new state of alert, the vinchuca closes in on its intended host, and as it does, it enters an undulating landscape of temperatures.

For all the vinchuca's sensitivity to smell and touch, heat is the ultimate stimulus that prompts it to bite. We devised a way to demonstrate that behavior in the laboratory. We heated a piece of metal to the surface temperature of a warm-blooded animal—about ninety degrees Fahrenheit (thirty-two degrees Celsius)—and brought the metal within range of a vinchuca's proboscis. Immediately the vinchuca extended its proboscis and repeatedly tried to bite the metal. Furthermore, when we cooled the metal to below ninety degrees Fahrenheit, no other stimulus we presented could induce the vinchuca to extend its proboscis. Even if the insect hadn't eaten for forty days, we could not get it to bite a cool surface.

My colleagues were able to come up with only one way to circumvent the vinchuca's virtually automatic response. They placed a miniature copper rod, warmed to the temperature of a warm-blooded animal, near the vinchucas' antennae, and tricked the insects into drinking cold blood. It is hard to imagine a clearer, simpler demonstration of how important thermal sensilla are to the insects' feeding routine. Odors from a potential host initially attract vinchucas, but heat is the only stimulus both necessary and sufficient to get them to bite.

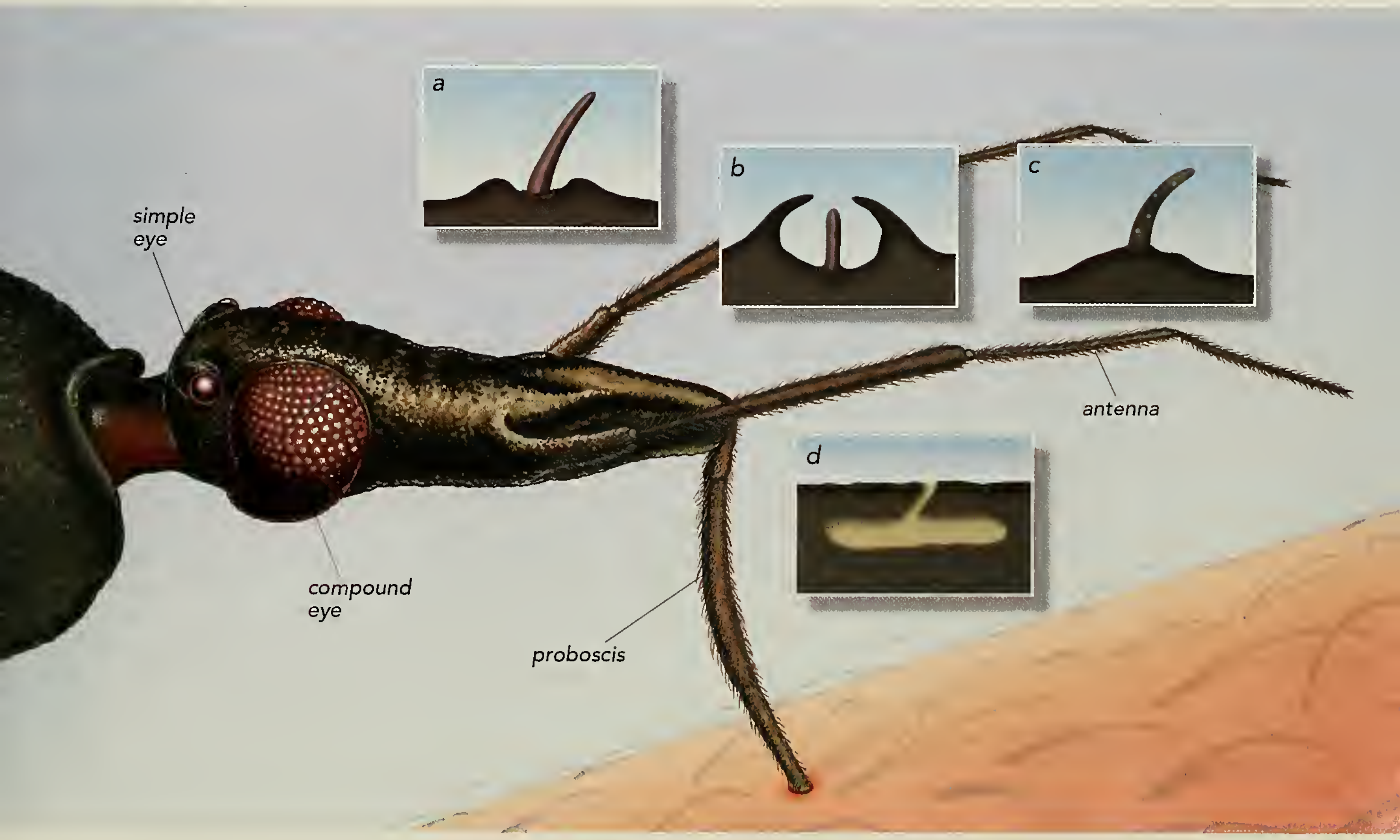
A current of warm air has now reached the insect's sweeping antennae. As the thermal sensilla absorb the heat, they warm up. Vinchucas, like most animals, can detect heat through conduction or through rising air currents. Amazingly, though, the insects can also sense radiant heat—known as infrared radiation.

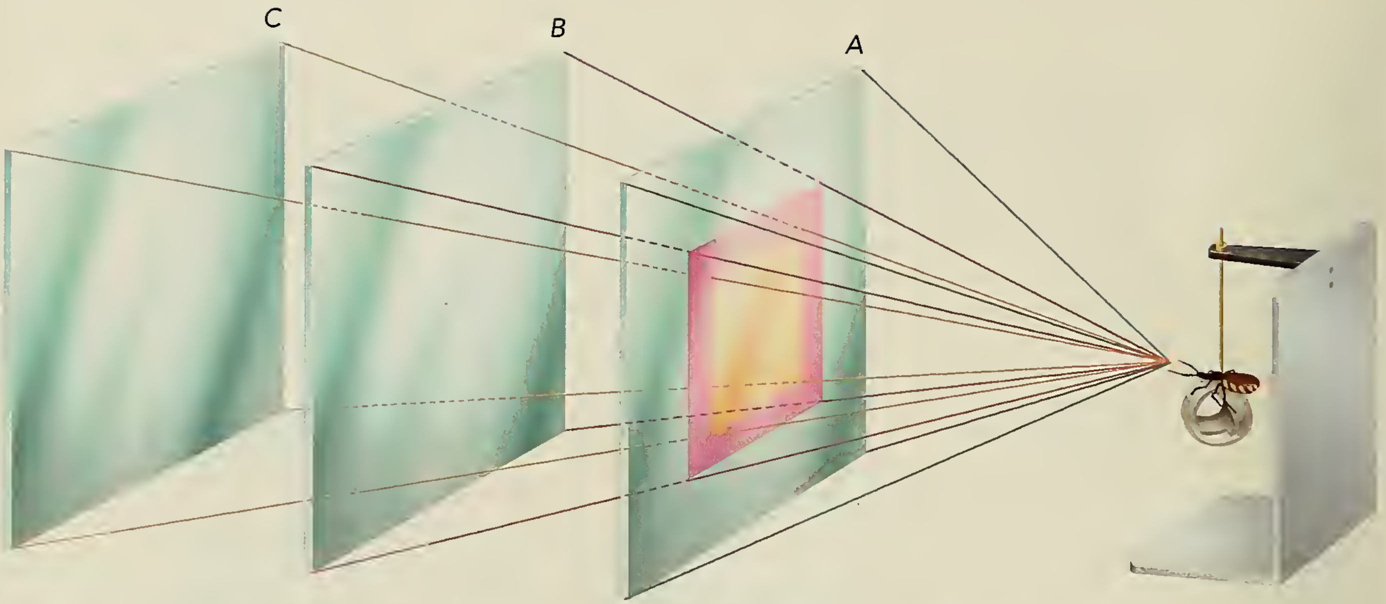
Lazzari and Núñez discovered that capability when they placed windows, impenetrable to infrared radiation, between the insects and a source of heat—which was, again, a miniature metal rod at the right temperature. All the vinchucas' usual responses to heat disappeared, but were duly restored when the experimenters replaced the infrared-opaque window with a window transparent to infrared rays. The insects could detect temperature changes as small as 0.0072 degree F (0.004 degree C)—which makes them among the most thermally sensitive animals known. Only a few other animal species are known to be sensitive to radiant heat, including boas, pit vipers, pythons, and the jewel beetle *(Melanophila acuminata)*—an insect able to detect forest fires from nearly fifty miles away.

Thousands of sensilla cover the vinchuca's antennae: mechanoreceptors (a) give the insect a sense of "touch;" thermoreceptors (b) respond to heat; chemoreceptors (c) bind to scent molecules; and the solitary cave organ (d)—one per antenna—may help the insect detect infrared radiation.

Vinchucas are also unusual in that their antenna carry a kind of sensillum observed in only a few other blood-sucking insects: the "cave organ." Since its discovery in the 1950s, the function of the organ has been a mystery. It is a pit (hence its name) lined with hundreds of thin, short hairs that have no pores. Each antenna, moreover, has only one cave organ, in sharp contrast with other kinds of sensilla that number in the hundreds. Lazzari showed that the cave organ responds to heat but not to odors, and suggested that it might be acting as an infrared receptor. But there is still no clear-cut evidence supporting the hypothesis.

Studying the vinchuca's response to heat requires a love for the minuscule—and good craftsmanship as well. In our laboratory, everyone created the tools he or she needed. That rule was mainly driven by the bug-size devices that had to be custom-made for each experiment. But it also stemmed from a tradition in entomology, inherited from such early investigators as the English entomologist Vincent B. Wigglesworth. Wigglesworth began his studies on another vinchuca vector of Chagas' disease, *Rhodnius prolixus*, in the 1920s, and became the first to study its response to heat. He soon encountered a problem that many others have faced as well: As an insect walks,





Experimental apparatus for testing a vinchuca's responses to heat is shown schematically. The insect was tethered to a stand and allowed to walk in place, while it held on to a rounded, tetrahedral Styrofoam object called a spangenglobus. *Warm metal plates of equal size and temperature were placed at various distances (A, B, C), and smaller plates, subtending the same angles as the plates at distances B and C, were placed at distance A (pink and yellow rectangles). The insect spread or closed its antennae as the plates varied in distance or size, just as if it were "measuring" the angle of each plate from its point of view. Thus, with an independent estimate of distance, the vinchuca could also estimate the true size of its potential host.*

the amount of heat reaching it constantly changes. How, then, can the experimenter maintain a constant distance between the insect and the heat source, and thereby control for the heat reaching the insect, without stopping the insect from walking?

The problem was ingeniously solved more than half a century ago. The German behavioral biologists Bernhard Hassenstein and Werner Reichardt devised the celebrated—in the world of entomologists—*spangenglobus.* The device is essentially a miniature tetrahedron that has been "inflated" into a more nearly spherical shape about three quarters of an inch in diameter. The tetrahedral framework is made of a light material such as balsa wood or, in our case, Styrofoam. The back of the insect, in turn, is glued to a rod that suspends the insect directly beneath a fixed frame. Because the spangenglobus weighs about the same as the insect does, the insect can grab the spangenglobus with its legs and walk, just as if it were walking upside down and gripping a ceiling with enough force to support its own weight. To the insect, then, holding on to the surface of the spangenglobus as it walks is indistinguishable from walking upside down on a solid surface. Like Lewis Carroll's Red Queen, the insect walks and walks, only to stay in the same place.

The tetrahedral shape also has a clever purpose. Because three edges come together at each vertex, whenever the insect walks up to a vertex, it faces a choice of two ways to proceed, left or right. If the experimenter presents a stimulus on the right different from that on the left, and notes which way the insect turns, the animal's behaviors can be studied in detail.

I inherited my spangenglobuses from Lazzari: ten hand-carved hollow Styrofoam balls. I guarded the little treasures with zeal and kept them together with ten custom-made acrylic boxes, ten diminutive copper pincers, a miniature brush made of my own hair, and a few solid aluminum plates that served as heat sources. With this basic homemade tool kit I studied the vinchucas' responses to heat. We later acquired more sophisticated gadgets, but the first experiments, the ones conducted with the most primitive tools, were by far the most interesting.

With the spangenglobus, Lazzari had tested the behavior of blinded vinchucas—their eyes had been covered over with paint—when he confronted them with pairs of metal plates at different temperatures. He found that the insects walked toward temperatures close to that of a warm-blooded animal, away from plates that were hotter, and were unaffected by the ones at room temperature. This result might seem obvious, but it is not. It has an important implication: the insects can estimate the temperature of a distant object. Furthermore, in Lazzari's experiments the vinchucas never raised their proboscises in an attempt to bite the warm metal plate: they "knew" it wasn't close enough, even though their eyes were covered.

In another experiment, this time with unrestrained, freely walking—but still blind—vinchucas, I observed that once the insects reached the heat source, they repeatedly tried to bite and pierce the metal; they all extended their proboscises when they were about half an inch from the source, even though they could not see it. Did that imply that they could estimate distance as well as temperature? Abundant evidence suggested they could; it was time to ask how.

To answer that question, think about what happens to the thermal sensilla. When confronted with a heat source, the sensilla receive a given amount of heat, which fires neurons. But that information, by itself, is not enough to discriminate sources at different temperatures, because a distant—or small—hot source could produce the same local warming as a closer—or larger—cool source. Thermal sensilla alone cannot distinguish those two conditions, but vinchucas certainly can.

The insects might be recognizing two characteristics of the heat source: distance and size, and "computing" a third characteristic, its actual surface temperature. Vinchucas could gauge distance—we had ample evidence of that. But I was determined to find out about their ability to discern size. If they could estimate the first two of these variables, then, given the basic physical and geometric circumstances, maybe they could "calculate" the third.

Spreading their antennae helps vinchucas estimate the size of a host.

The antenna movements of a walking vinchuca, which I knew in great detail, gave me an idea. Confronted with a warm source—or with the hand of the experimenter, for that matter—a vinchuca walks toward the potential blood meal, opening and closing its antenna. Perhaps those antenna movements, which expose the thermal receptors to the heat source, were also enabling the vinchuca to estimate the size of the source.

I devised two tests for my hypothesis. In the first, I put heat sources of various size at a fixed distance from the insect; in the second, I put a single heat source at various distances [*see illustration on opposite page*]. In both experiments, I filmed the vinchucas on the spanglobus as they reacted to heat, and digitized the positions of the antennae every second. From the filmed positions I determined the angles between the antennae and compared them from test to test. To my amazement, I found that the antenna aperture changed with both the size of the source and the distance between the source and the insect.

When I plotted the angular values, it became clear that the position of the antennae simply, and consistently, followed the apparent size of the source from the insect's point of view—regardless of the actual size or distance of the source. In other words, when two plates subtended the same angle—one big and far away, the other small and nearby—the antennae also made the same angle with each other. The pieces of the thermal puzzle were beginning to fall into place: the variable of size might be accounted for.

Let's go back to the vinchuca once more and reconstruct the last part of its journey. The insect, attracted to a host by its smell, enters the thermal domain. Close enough to perceive the host's heat through thermal receptors, it turns and faces the source of heat. Scanning the air, it follows the edges of the heat source with its antennae, whose position is being closely monitored by mechanoreceptor hairs. These hairs bend when the antennae move, and report the antenna position to processing centers in the brain. The insect thus estimates the apparent area, or size, of the heat source.

The amount of heat from a given source increases as the vinchuca gets closer to that source, but the increase is not proportional to the distance. Instead the heat is inversely proportional to the *square* of the distance. If the vinchuca walks to within half its initial distance from the heat source, the insect gets four times as much heat as it got at first; if it takes a few more steps, to a quarter of its initial distance, the heat increases to sixteen times its initial level. We think such rapid changes in heat play a key role for the insect in determining its position with respect to the heat source. For example, a vinchuca might measure the amount of heat received in two different parts of its body, say, the head and the rear end. By comparing the amount of heat received at those two points, it could estimate the distance to the heat source and thus assign a value to the second variable.

Knowing the area and the distance, the vinchuca could "derive" the third, and crucial, variable: the actual temperature of the heat source. If it fell in the known range of temperatures of a warm-blooded animal, the vinchuca might as well try for a meal.

Thus ends a bug's trip from its refuge to a host, a trip aided by amazing sensory instruments. It is a journey repeated endlessly by millions of vinchucas every evening, across Latin America. In spite of the vinchuca's superior homing skills, this journey would not be possible without a proper refuge during the day. And yet, in many countries, the straightforward approach of improving housing conditions—filling in nooks and crannies—remains only a dream, and the insects continue to have free reign on their nightly forays. ☐

Unhappy Trails

Forensic examination of ancient remains sheds new light on the emergence of Florida's Seminole Indians.

By Christopher M. Stojanowski

On January 30, 1838, the Seminole war hero Osceola died of malaria while in captivity at Fort Moultrie, South Carolina. The several hundred Florida Indians under his leadership had been waging guerrilla-style warfare against United States forces for a few years. Three months earlier, with expenses and military casualties mounting, the U.S. Army General Thomas S. Jesup, under the pretense of offering peace negotiations, had lured Osceola to Saint Augustine, Florida. When Osceola approached, Jesup's soldiers had captured and imprisoned him. The intention had been to break the spirit of his group of renegades and expedite the removal of all the Seminole to lands west of the Mississippi, designated as Indian Territory. The members of the other major tribes inhabiting the southeastern U.S. had already been forced to make the journey. They were the Chickasaw, Choctaw, Creek, and—remembered for the infamous "Trail of Tears"—the Cherokee. But the Seminole were not about to give up. What was known as the Second Seminole War would last another four years.

Seminole leader Osceola posed proudly even in captivity, as shown in this lithograph from an 1838 portrait by George Catlin. Osceola and his followers had been resisting relocation out of Florida under the terms of the 1830 Indian Removal Act.

The First Seminole War, from 1817 until 1818, had also been fought between U.S. forces and Seminole bands, even though at the time Florida still belonged to Spain. Among the U.S. justifications for the incursion was the unwillingness of the Seminole to return fugitive slaves to settlers' plantations. By the time the war ended, many Indian towns in Florida had been burned by General Andrew Jackson, the future president, whose scorched-earth campaign against the Indians also led Spain to abandon their troubled colony.

Following a period of uneasy peace, warfare had erupted again in 1835. The causes of the Second Seminole War were numerous, but central was the refusal of the Seminole to relocate, as prescribed by the 1830 Indian Removal Act. By the end of the war, in 1842, several thousand Seminole had complied with the removal. But some hundreds remained in Florida. Their leader, Billy Bowlegs, was finally defeated in the Third Seminole War (1855–1858), and he consented to lead his people to Indian Territory. The ethnic cleansing of Florida was all but complete; as few as 200 Seminole lingered on, deep in the Everglades, far removed from American contact.

But who were the Indians known as the Seminole, who clung so tenaciously to their homeland? At the time of European contact, in the early 1500s, the tribes in what is now Florida and southeastern Georgia included, among others, the Apalachee, Calusa, Guale, Ocale, Potano, Tequesta, Utina, and Yustaga. Those populations had roots going back thousands of years. But no tribe named "Seminole" existed. The term itself did not even come into general use until about 1760, and it is thought to be a derivative of the Spanish word *cimarrón,* meaning "wild" or "untamed."

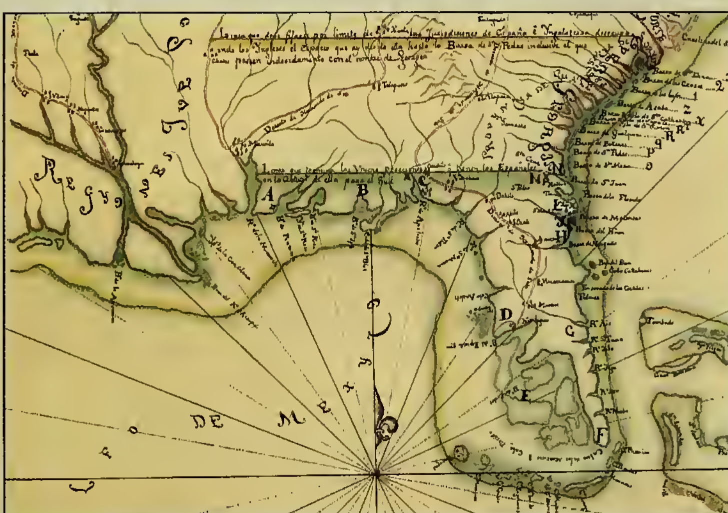
The standard account of Seminole origins is that after two centuries of disease, European conflict, and harsh colonial policies, Florida and southeastern Georgia were essentially devoid of indigenous groups. The region was then repopulated during the mid-1700s by Creeks from central Georgia and Alabama. Those Creeks that settled in Florida then became culturally distinct and began to be called Seminole. Ac-

Seminole Tommie Jumper wears garb typical for tribesmen living in Florida in the late nineteenth and early twentieth centuries, including turban, scarves, and flowing shirt. Jumper was a descendant of Indians who eluded relocation to what is now Oklahoma. The author has investigated the biological origins of the Seminole, a tribe that did not exist in name at the time of European contact.


TOMMIE JUMPER

cordingly, Florida's native populations are typically divided into two groups, pre-Seminole and Seminole, in recognition of their disjunctive histories.

That, at any rate, is what the evidence from historical documents and archaeology shows. But another line of evidence can be brought to bear on the question of Seminole origins: bioarchaeology, the study of human remains excavated from cemeteries and other archaeological sites. Ample physical remains exist for the crucial time period covering the transition from the last of the original indigenous tribes to the advent of the Seminole. In my research I have sought to reconstruct genetic relationships and how they changed among the principal groups, and I have sought to relate my observations to events known on independent historical or archaeological grounds. The results bring into doubt the "common knowledge" that native Floridians fall neatly into pre-Seminole and Seminole groups.



Map depicting the Spanish claim over what is now the southeastern United States was made in 1742 by the Spanish army royal engineer Antonio de Arredondo. The image, a detail of a 1914 copy of the map, shows that some areas were in dispute, but that Spain recognized other areas as legitimately occupied by England and France under a 1670 treaty.

The first people to reach what is now Florida, between 12,000 and 10,000 years ago, were nomadic hunters and gatherers whose ancestors migrated from Asia into the Americas several thousand years earlier. Some of the earliest known archaeological sites in Florida are also among the most unusual anywhere in the New World, because they are wet sites where anaerobic conditions have preserved organic material that normally decomposes. For example, at Windover Farms, near the eastern coast, outside of Titusville, a burial pond dating from between 7,000 and 8,000 years ago has yielded—in addition to more durable artifacts such as bone, antler, and stone tools—textiles, human brain tissue, and botanical remains from stomach contents, representing medicinal concoctions and "last meals."

Archaeologists distinguish several cultural areas that, by about 2,000 years ago, were the precursors of the groups encountered by the first European explorers in Florida and Georgia. Most groups practiced some form of horticulture, tending early New World domesticates such as squash, sunflower, and maize. Where available, fish and shellfish, as well as terrestrial animals, were an important part of the diet.

The first European credited with setting foot in the Florida peninsula is Juan Ponce de León, who explored the coast in 1513. He claimed the peninsula—and much of the surrounding territory as well—for Spain, naming it La Florida, because he discovered it in the Easter season (also known as *pascua florida*, or the feast of the flowers). Other explorers followed, including Pánfilo de Narváez and Hernando de Soto, but it wasn't until the 1560s, when the French began to position forts along the southeastern coast of North America, that Spain established a permanent colony. In 1565 the Spanish naval officer Pedro Menéndez de Avilés expelled the French and founded the city of Saint Augustine.

As part of his royal charter, Menéndez was charged with converting La Florida's indigenous populations to Catholicism. This task was taken over in 1573 by the Franciscans. During the next 125 years, the friars expanded their reach, converting numerous populations living along the coast of what are now Georgia and northern Florida, throughout north-central Florida and adjacent southern Georgia, and in the Florida panhandle. At the height of missionary expansion, during the 1600s, dozens of missions served tens of thousands of converts.

The Spaniards placed their missions in three main regions serving three major groups of Native Americans: the Timucua, the Guale (pronounced *wally*), and the Apalachee [*see map on opposite page*]. The Timucua lived along the northern Atlantic coast of the Florida peninsula, throughout the north-central interior, and in what is now southeastern Georgia. Although they were somewhat unified linguistically, speaking a dozen or so dialects of one language family, they were politically divided into as many as fifty distinct chiefdoms. The Guale, who lived along a narrow strip of the Georgia coast, and the Apalachee, who lived in the panhandle, were both well-defined chiefdoms. They were linguistically distinct from the Timucua and from each other. The Apalachee were the most settled of the three groups, cultivating maize and other crops in a well-defined territory bounded by the Aucilla and Ochlockonee rivers. Other indigenous groups lived outside the zones proselytized by the missionaries, particularly in the south of the Florida peninsula.

The process of cultural extinction initiated by the Spaniards was stepped up beginning around the mid-1600s, as English colonies became established to the north of Spanish territory. Instigated by the English but carried out by their indigenous allies (mainly Creeks), raids were conducted, mostly against the Guale, to obtain slaves. Then, early in the 1700s, English colonial forces assaulted the Spanish missions. By 1706 the missions outside Saint Augustine had been abandoned or burned, and many Indians had been killed or captured as slaves. A minority of Indians remained Spanish loyalists and retreated to the protection of Saint Augustine, while others fled to seek French protection in Louisiana, or disappeared into the wild frontier that was central Georgia and Appalachia. The diaspora effectively ended thousands of years of regional cultural continuity in northern Florida and coastal Georgia.

Spain established a colonial presence principally in what are now northern and central Florida and southeastern Georgia. There the Spaniards distinguished three regional groupings of indigenous peoples: the Apalachee and the Guale were each well-defined chiefdoms, but the Timucua were divided into as many as fifty separate chiefdoms.

From the early 1500s onward, historical sources document, in increasing detail, the effects of European contact on the indigenous peoples of La Florida. Such sources, however, are neither unbiased nor sufficient in themselves. Complementing the historical data are the resources of archaeology and my own specialty, bioarchaeology.

Bones, and details of their shape, including signs of injuries and muscle attachments, can shed light on a population's diet, disease experience, and even life activities. Teeth offer similar information: cavities, tartar, and dental malformations indicate something of the general health of individuals in the past. My research focused not on health, however, but on two other kinds of data: demographics and microevolutionary change. My hope was to reconstruct patterns of genetic relationship and document how those patterns changed through time.

The task of the demographer is to determine the size of populations and identify their members by age and sex. For the indigenous populations, I relied on existing estimates, which are based on human remains and other evidence from archaeological sites and, for the postcontact period, on historical sources as well. All the estimates are subject to error, but they do provide a baseline for comparative purposes.

Microevolution, by definition, is any change in gene frequencies within populations of a single species. Such changes appear over short periods of time, whereas macroevolutionary changes, such as the rise of new species, take longer. My approach to microevolutionary research is to measure skeletal remains, because they are widely available and measurement is nondestructive—two issues that arise in designing studies based on prehistoric DNA.

The skeletal collections at my disposal came from cemeteries previously excavated by archaeologists as long ago as the 1940s. For some cemeteries only the enamel, or white portion, of the teeth was preserved; the tooth roots, as well as the rest of the skeletons, had decayed in the acidic clay soils. Thus, I focused my sampling, measurements, and analyses on dentition, whose form, fortunately, is strongly influenced by genetics.

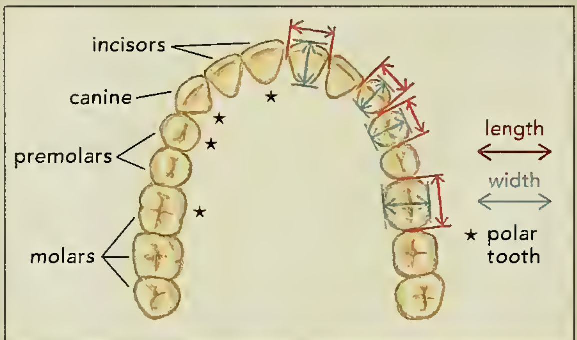
Because the populations I was examining were confined to a relatively small region, and the remains of only fifteen or so generations were present, it was unlikely that any genetic changes I might find would have had enough time to evolve through natural selection. I was not looking, as paleoanthropologists do, for evidence of long-term adaptive trends, such as the evolution of increased brain size. The genetic variation I would see would reflect patterns of migration and the process of genetic drift.

Migration, as geneticists define it, encompasses not only the literal movements of new individuals into or out of a group, but also any changes in mating (or marriage) patterns that redistribute genetic variation across the landscape. For example, if neighboring groups previously married only among themselves, but then begin to intermarry, the variety of genes in each group will increase, and the variation in genes will become more homogeneous, or evenly spread, across the two groups.

Genetic drift arises by chance alone; through purely random processes, the individuals in a group in one generation may not reflect the full range and proportion of traits in the preceding generation. Drift is comparable to the kind of sampling error that pollsters have to take into account, and the smaller the population, the greater the likelihood it will show up. For example, if only one person in a small group had all the genes for red hair, and he or she perished in an accident (in no way attributable to having red hair—which would be an example of natural selection), the group would lose the trait of red hair. Genetic drift tends to reduce genetic variability when populations are declining and migration between populations is limited. As a consequence, data on the genetic variability in a population can provide an independent way of estimating changes in population size through time.

The dental features I measured were the length and width of tooth crowns for all four types of teeth—incisors, canines, premolars, and molars [*see illustration on this page*]. From these measurements I could also calculate the ratio of length to width, which is one aspect of tooth shape. Tooth size and shape are both strongly influenced by genetics. In all, I examined 1,300 individuals, enough to have reasonable samples of people living in the Apalachee, Guale, and Timucua regions for three discrete time periods: late precontact (A.D. 1300–1400), early mission period (1600–1650), and late mission period (1650–1706).

I was primarily interested in two kinds of analysis. First, I explored how genetic variation changed in each of the three population groups with time. My reasoning was that if variation was declining, so was the size of the population, because the smaller the population the greater the effect of genetic drift in reducing variation. Conversely, if variation was increasing, population was increasing as well, most likely because previously separate lineages or ethnic groups were gathering together for mutual support. Second, I estimated the overall level of genetic variability within the region as a whole—combining all three population groups—and compared genetic variability from one period to the next.



Tooth length and width, defined as shown in the illustration, as well the ratio of length to width, an aspect of tooth shape, are determined largely by genetics. To study genetic variation and relatedness among populations of Native Americans, the author examined teeth from archaeologically excavated human remains. The teeth least subject to nongenetic variation, known as the polar teeth, were measured. For the upper jaw (shown), the polar tooth in each case—incisor, canine, premolar, molar—is the most forward in the mouth; in the lower jaw, however, the second incisor is measured.

The demographic data showed that the stresses of the postcontact period were almost overwhelming for all three populations, yet the Apalachee appear to have weathered them better than the Guale or the Timucua. The Apalachee population dropped by more than 70 percent, from a precontact total of 30,000 to about 8,000 by the time the Spanish missions were abandoned in the early 1700s. But by the mid-1600s, the Guale had already declined from several thousand to several hundred, and the Timucua from more than 150,000 to less than a thousand.

The trends in genetic variability evident in my samples of the Guale differed sharply from those of the Apalachee, and partly explain the striking contrast in the fate of the two groups. Among the Guale, variability increases as colonization begins, then declines rapidly after 1650. In contrast, among the Apalachee, variability does not change with initial colonization, but it increases dramatically after 1650. What caused the difference? Historical sources vaguely note that epidemics ravaged the eastern coast of Florida and Georgia early in the 1500s—essentially upon contact; similar epidemics may not have exacted as severe a toll among the Apalachee until much later, perhaps a century later.

The sudden, early increase of genetic variability among the Guale reflects immigration, apparently by outsiders showing up in their territory. Most likely, Guale groups that had suffered heavy losses from the epidemics, as well as from conflict with the Spaniards, were drawing together and being joined by other decimated groups. The subsequent decline in variability in the region, the result of genetic drift, is a signal that their numbers then steadily fell. In contrast, the Apalachee were still in an earlier phase of transition by the time the missions fell and their population was dispersed.

The overall level of biological interaction among the three ethnic groups in precontact times proved relatively high. Intergroup warfare, which often resulted in the capture of women and children by the victor of a violent encounter, helped ensure genetic mixing. Intergroup marriage and sexual unions undoubtedly also took place as a result of other forms of ceremonial and social interaction.

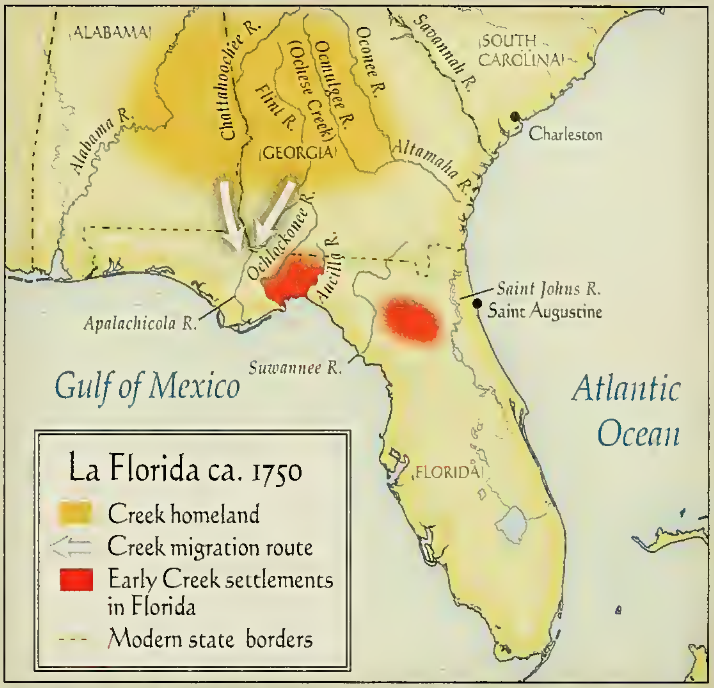
During the early mission period, the Indians in all three regions were converted to Catholicism and united under the banner of Spanish authority. Paradoxically, however, the genetic differences among the three regions become more pronounced, not less. By restricting small-scale intertribal warfare and, perhaps less intentionally, by interfering with other forms of social interaction, the Spaniards may have reduced the degree of genetic mixing. Ethnic boundaries—and therefore, perhaps, genetic ones—may also have been shored up because the different groups were competing for access to European power and prestige.

After 1650, the region-to-region differences shrink dramatically, a sign that mating had expanded across language and ethnic boundaries. The remnant Christian populations had become a single biological population.

Three factors account for that unification. First, as local village populations fell to critically low levels, people were forced to bend traditional rules regarding who was a suitable mate. Second, people were often choosing to migrate over longer distances. Such population shuffling was hastened by Spanish attempts to repopulate strategically important missions. Finally, after 1650, England began competing intensely with Spain for New World dominance, encouraging indigenous allies to carry out slave-raiding expeditions against the Spanish-affiliated tribes. In that context, I suggest, the tribes in Spanish Florida minimized their internal ethnic, cultural, and linguistic differences.

The resident groups in La Florida still were identifiable as Apalachee, Guale, and Timucua. What is most interesting, though, is that from a biological perspective, a new, more homogeneous indigenous population was emerging in Spanish Florida. That nascent population, never named—and hence invisible to us today—was then widely scattered when the missions were destroyed. The only Native American groups that still retain their original identity today descend from a few Apalachee who, at that time, fled to the French Louisiana territory.

With Florida's tribal areas vacant, the stage was set for repopulation by Creeks, who lived in central Georgia and Alabama. Made up of fractured populations that had congregated in the Deep South sometime in the 1600s, the Creeks spoke a variety of languages. They constituted a new confederacy, not



By 1750, the indigenous landscape of La Florida had dramatically changed. All the original tribes were gone, and their lands were being settled by Creeks migrating southward along the Flint and Chattahoochee rivers. The Creeks in Florida eventually became recognized as a distinct people, the Seminole. Before those migrations, however, the Creeks themselves had arisen from a conglomeration of various groups that had sought refuge in central Georgia and Alabama. The author's data suggest that an important constituent of the Creek population actually descended from some of La Florida's original tribes.

an indigenous tribe that had existed for thousands of years in their region. Even their name was not indigenous: they were referred to by English traders as the Indians living near Ochese Creek (now called the Ocmulgee River); later they were simply called "Creeks." During the early to mid-1700s, some Creek groups, principally from central Georgia, moved down the Flint and Chattahoochee rivers into Spanish Florida [*see map above*]. With time, the Florida communities, separated from the Georgia Creeks by several hundred miles, evolved into the Seminole, a distinct tribe that, like the Creeks themselves, did not exist in name in precontact times.

My own research does not dispute the arrival of Creeks from Georgia as the ultimate origin of the Seminole. But my findings give a new perspective on the biological origin of the Creeks, and by extension, the Seminole. The numbers of Apalachee, Guale, and Timucua dropped during the mission period, and the typical assumption is that disease was at the root of the declines. But those unhappy with the presence of the friars or Spanish military, or unhappy with the increasingly unreasonable labor quotas levied by the secular government in Saint Augustine, may have simply fled the sphere of Spanish influence. What that suggests is that the "Creeks" in the Georgia interior may have included ethnic Apalachee, Guale, and Timucua, a nuanced distinction simply ignored or unrecognized by contemporary European chroniclers.

Another clue is the location of the earliest settlements chosen by the Creeks—or what I would call the proto-Seminole—who moved into Florida. The impetus for the move has been well documented. In part, it was an outcome of the Yamasee War of 1715, between the Yamasee and the English in South Carolina, which worsened relations with the English. At the same time, the Spaniards invited the Creeks to settle in central and northern Florida, where they could serve as a buffer between Saint Augustine and

Chief Outina (center) and his warriors, depicted in this scene of sixteenth-century Florida by the Flemish artist Theodor de Bry, belonged to one of the original tribes the Europeans encountered in the region. The Spaniards referred to this and other tribes that spoke similar dialects as the "Timucua."

the English colonies. Finally, the rich Florida resources made the region inherently attractive.

A glance at a map of the earliest settlements that were destined to be Seminole, however, reveals that the incoming groups were settling areas formerly inhabited by Christian Indians, primarily Apalachee and Timucua. In my view, then, another major factor affected the choice of settling area: the political influence of the elite Christian, pro-Spanish Indians that had left La Florida and interbred with Creek elites. There is even some historical documentation that ethnic Apalachee had intermarried with Creek elites in Georgia. Although they were only a minority of the Creek population, the Apalachee may have been a key component. Their descendants could have harbored ties to the traditional homeland, vacant for only two or three generations.

If I am right, the genesis of the Seminole as an ethnic group does not begin with the movement of an outside population into Florida, but with events that took place a hundred years earlier. Gene flow between previously separate groups was the first step in forging a new identity. It was followed by the dissolution of earlier ethnic labels and the shared experience in the Creek confederacy of Georgia. The subsequent shared experiences in Florida and increasing isolation from the Creek confederacy remaining in Georgia promoted the emerging Seminole identity. Political unification, in the 1800s, then came in response to American demands for a Seminole governing council. The U.S. government's purpose was to hasten the Seminole's removal to lands west of the Mississippi. After three wars, that goal was nearly accomplished.

With the exception of the small community of Apalachee descendants who live today in Louisiana, the ethnic groups inhabiting Florida at the time of the first European contact have been consigned to history, their languages no longer spoken, their customs no longer practiced. The legacy of the Guale is particularly limited, perhaps reflecting their early and rapid decline in the wake of the epidemics. Prominently but erroneously—because the Apalachee lived along the coastal plain—their tribal name is commemorated in the East's great mountain range, the Appalachians. The Timucua language family lives on in various modern place names, such as the city of Ocala and Tomoka State Park, both in Florida. The images of the Timucua themselves—albeit fanciful in many respects—come down to us in the engravings of the sixteenth-century Flemish artist Theodor de Bry [*see illustration on this page*]. The engravings were based on the drawings of Jacques Le Moyne de Morgues, an artist who accompanied the brief French occupation of La Florida.

Members of the Creek and Seminole tribal confederacies who complied with the provisions of the Indian Removal Act and endured the hardships of Indian Territory are represented by their descendants enrolled in the federally recognized Muscogee (Creek) and Seminole nations of Oklahoma. The descendants of the small number of Seminole who eluded capture in the Florida swamps are now several thousand strong. They formed a constitutional government and achieved federal recognition in 1957. A closely related, but much smaller renegade group, the Miccosukee Tribe, has enjoyed separate federal status since 1961. Like most up-to-date tribes, they all have Web sites that recount their histories, asserting, one by one, remarkable stories of survival. □

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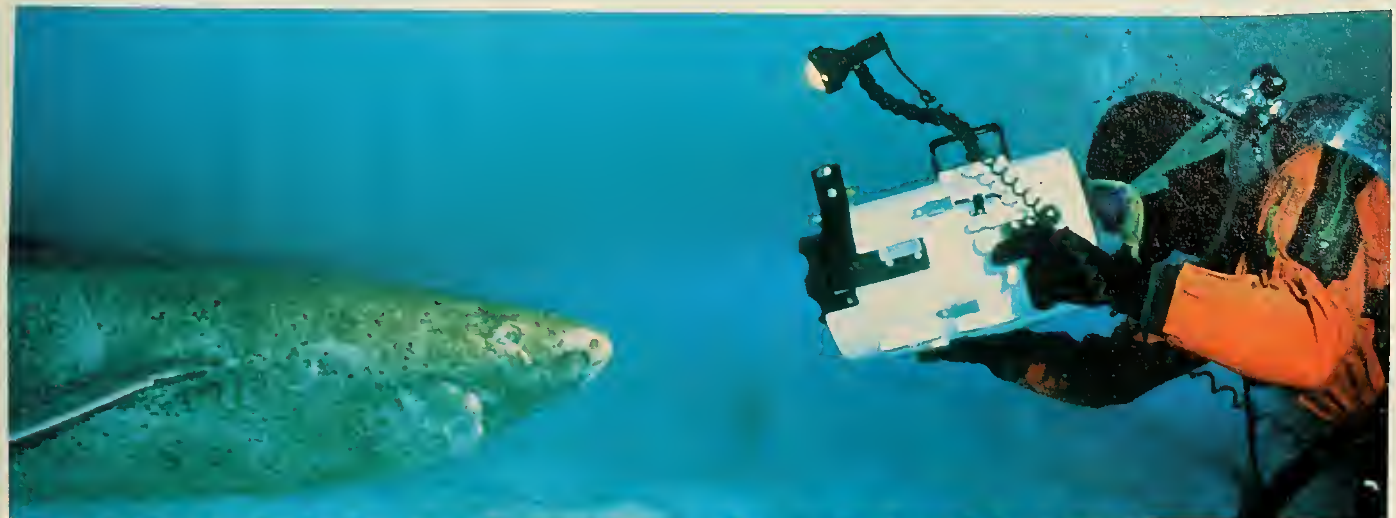

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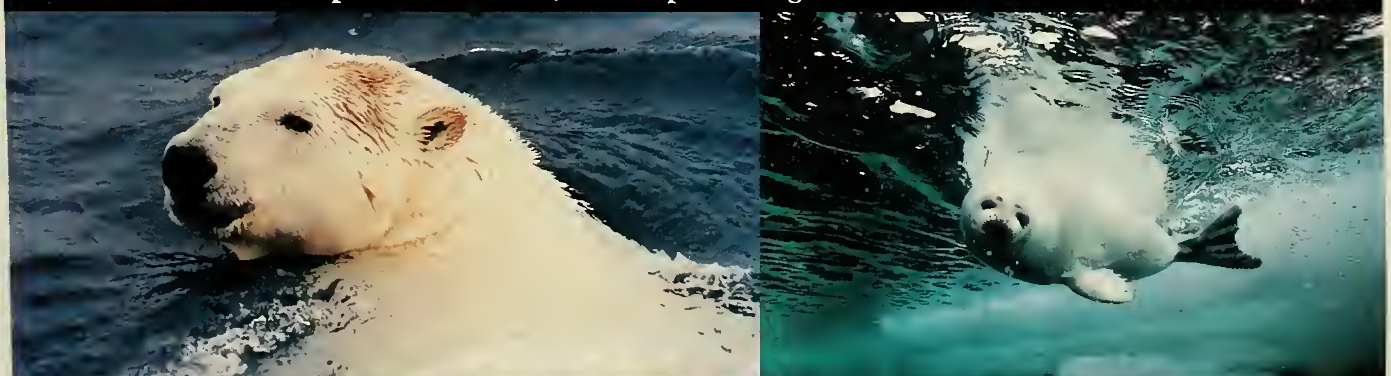

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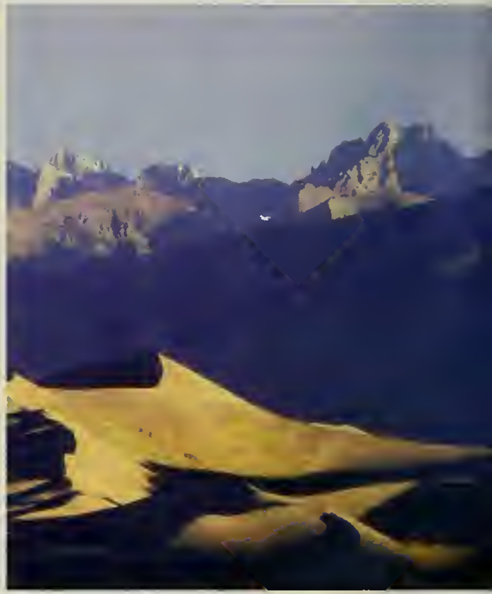
Sand Trap

Confined to a mountain valley, windblown sand has piled up into towering dunes.

By Robert H. Mohlenbrock



Bordered by the Sangre de Cristo Mountains (background), windblown sand dunes rise as high as 750 feet above the San Luis Valley floor.

More than a hundred miles long and fifty miles wide, the San Luis Valley lies within the Rocky Mountains of south-central Colorado and northern New Mexico, bordered on the west by the San Juan range and on the east by the Sangre de Cristo range. Dominated by rubber rabbitbrush and grasses, the valley shares its name with San Luis Creek, a stream that flows through its northern half. The more prominent waterway, however, is the Rio Grande, which originates in the San Juans and flows through the southern part of the valley. The configuration of the two mountain ranges and the ceaseless action of wind and water have bestowed upon the valley the tallest sand dunes in North America.

Prairie sunflowers brighten the sand sheet, a relatively flat zone adjacent to the dune field.

Rising as high as 750 feet above the valley floor, they are the centerpiece of the Great Sand Dunes National Park and Preserve.

Through volcanic action the San Juans began to form about 35 million years ago, and the Sangre de Cristos were rapidly uplifted beginning about 19 million years ago. Rain, wind, and—beginning about 1.6 million years ago—ice-age glaciers chiseled away at the peaks. Sand, gravel, and clay were washed into the valley, leaving behind lakes containing sand and silt. During dry periods, these lakes shrank or disappeared, and prevailing southwesterly winds blew clouds of sand from the dry lakebeds across the valley. Sand grains too heavy for the wind to carry beyond the crest of the Sangre de Cristos accumulated near the base of the mountains. Occasional strong northeasterly winds also helped trap the sand in the valley and pile it into dunes.

The dunes cover about thirty square miles on the eastern side of the valley, in a region near its midpoint. One reason they are so concentrated here is that several small streams help capture and return sand blown out of this zone. In the dune field, the sand is continually shifted back and forth by the wind, and vegetation has a hard time taking hold. Plants that do become established often get buried. Blowout grass and lemon scurf pea are two species that can send out roots and rhizomes several feet into the shifting sands, thus ensuring better stabilization. South and west of the dune field is a flatter, more vegetated zone known as the sand sheet, and today that is the main source of additional windblown sand.

Dunes come in various shapes. Barchans are crescent-shaped dunes that creep slowly across the landscape as sand is blown over the top and slides down the leeward side. The windward side is the convex side of the crescent. Barchans can also join end to end to form transverse dunes—rows of sand that run perpendicular to the direction of the wind.

Parabolic dunes are formed when the wind causes a blowout, that is, begins to gouge sand out from around a patch of vegetation that has weakened its grip. The excavated sand is slowly blown forward, but the sand on either side of its path remains stabilized by other vegetation. The forward-moving pile forms the "nose" of a parabola, while the anchored vegetation left in place on either side forms two trailing arms, of-

ten stretching behind for long distances. Star dunes, with arms that extend from a central point, form where the winds pummel the sand from several directions.

The dunes were first protected in 1932 by the establishment of Great Sand Dunes National Monument, which embraced fifty-nine square miles. The monument remained essentially the same size until 2000, when Congress authorized an expansion to create the Great Sand Dunes National Park and Preserve. The first major addition was the transfer of about sixty-five square miles of the Rio Grande National Forest to form the national preserve. The preserve extends up the slopes of the Sangre de Cristos, providing numerous niches that enhance the biological diversity in the preserve. Streams and small marshy areas within the park provide additional habitats for plants.

Although the winds are continually reshaping the dunes, they have not wrought substantial changes in living memory. Forest Service scientists E. Durant McArthur and Stewart C. Sanderson compared photographs of the area taken in 1936 with conditions in 1990 and found that the dune masses were relatively stable. They did note, however, that nearby marshlands and scattered ponds had become dramatically smaller.

FOR VISITOR INFORMATION, CONTACT:

Great Sand Dunes National Park and Preserve
11500 Highway 150
Mosca, Colorado 81146
719-378-6300
www.nps.gov/grsa/

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

Habitats

Dune In the dune field, mainly where it grades into the sand sheet, the most common plants are blowout grass, Indian rice grass, and lemon scurf pea. Other species are burr ragweed, crown-leaf evening primrose, hairy bugseed, rush skeleton plant, and Russian thistle (a nonnative invader). The vegetation in the sand sheet is made up primarily of grasses known as sand dropseed and sandhill muhly. Among the other species are broom groundsel, James' catseye, narrow-leaf gromwell, narrow-leaved penstemon, needle and thread, nodding buckwheat, rubber rabbitbrush, and yucca. Prairie sunflower brightens the sand sheet with vivid yellow from late July through early September.

Streambank Large and small creeks are lined with such trees as coyote willow, narrow-leaf cottonwood, quaking aspen, and thinleaf alder. Skunkbush, trumpet gooseberry, and Woods' rose are shrubs that occur here and there along the streams. Among the grasses and herbs are Kentucky bluegrass, nodding brome, slender wheatgrass, starry false Solomon's seal, and western yarrow.

Marsh Most of the wetland species are commonly found in marshes in many other parts of the country. Among them are American manna grass, bluejoint grass, common spikerush, common three-square, cowbane, field horsetail, fringed willow-herb, hardstem bulrush, marsh hedge nettle, marsh skullcap, needle spikerush, pinkweed, Rocky Mountain iris, swordleaf rush, valley rush, two species of buttercup, and two kinds of arrowgrass. Blue lettuce, Douglas' knotweed, Nevada bulrush, and scratchgrass have a more restricted distribution, westward from western Kansas and Nebraska.

Mountainside The predominant trees are Douglas fir, piñon pine, Ponderosa pine, Rocky Mountain juniper, and white fir. Such species as golden currant, mountain mahogany, ocean spray, roundleaf snowberry, and wax currant make up the fairly rich shrub community. A grassy ground layer of blue grama, littleseed ricegrass, mountain muhly, and mutton grass is punctuated by wildflowers that include beardtongue, dainty gilia, Fendler's ragwort, flatspine stickseed, hairy golden aster, hoary aster, James' buckwheat, pygmy flower rock jasmine, sanddune wallflower, tall tumble mustard, and three-toothed groundsel.

By Laurence A. Marschall

Out of Eden:
An Odyssey of Ecological Invasion
by Alan Burdick
Farrar, Straus and Giroux, 2005;
$25.00

Standing in a lush forest on the Pacific island of Guam, science writer Alan Burdick is haunted by an eerie silence. Not a single warble, tweet, or chirp can be heard—nothing but the faint buzz of insects, the passing hum of a distant airplane, and the hushed rustle of the wind. Guam's songbirds have all vanished, victims of the brown tree snake. An exotic predator native to Australia, New Guinea, and nearby islands in the eastern Pacific, the snake arrived unannounced in a military vessel sometime around 1949. Such birds as the bridled white-eye, the Guam flycatcher, and the Mariana fruit dove, once widespread on the island, now exist only as stuffed museum specimens or illustrations in birders' guidebooks. Even some nonavian natives—the Mariana fruit bat, for instance—are rapidly disappearing under the attack of the resourceful reptile.

Guam may be an extreme case of a habitat devastated by a hungry immigrant. But it is not uniquely vulnerable just because it is a small, isolated island. In 1988 the zebra mussel, once confined to the lakes and rivers of Europe, hitched a ride to Lake Erie, presumably in the ballast tanks of a visiting freighter. Today zebra mussels flourish throughout the Great Lakes, and can be found in the Mississippi River and its tributaries, as far south as New Orleans. Native clam populations in the Great Lakes have been decimated, and other species that compete for food with the mussels are in sharp decline. Accumulations of zebra mussels clog municipal water systems, and have even been known to sink navigational buoys by their combined weight alone.

Burdick points out that nowhere on the planet does nature survive in an Edenic state, unaffected by nonnative invasions: American gray squirrels now live in the British Isles; Asian longhorned beetles, which infested New York City maple trees in Brooklyn in the mid-1990s, now threaten the trees of Central Park; visitors to Hawai'i who marvel at the variety of flowers in the tropical island paradise are likely to be admiring plants that are visitors there, too: most species of lowland flora in Hawai'i were introduced by settlers in the past few centuries.

Box elder infested with Asian longhorned beetles (inset)

Burdick implies that even the "pure" Edenic state is a human invention. Would we know one if we saw it? And if we did, would returning to it be environmentally sound? Invasion is a process inherent in global ecology. Siberian woolly mammoths made their way over the Bering land bridge to the New World long before mercantile ships made the journey. Insects and worms hitchhike the ocean on bits of flotsam, coming ashore wherever the winds and currents take them. The capacity of plant and animal life to spread over the globe is what made it possible for newly emerging landmasses to develop their own indigenous forms of flora and fauna in the first place. Without invasive species, volcanic islands would have remained as barren as they were when they emerged, millions of years ago, from the floor of the sea.

What's more, people are hardly latecomers to this process. The Polynesian settlers of Hawai'i brought the first pigs to the islands; centuries later, British soldiers carried the first cattle there. Settlers in the New World were diligent both in exporting American indigenous plants back across the Atlantic, and in bringing the plants and animals of their European homelands to American soil. Modern air and ocean transportation has only accelerated the process.

Burdick began this book, I sense, in an attempt to uncover nature at its "purest." He found that it was difficult, perhaps impossible, to define ecological purity at all. In most cases, the leakage of species from one habitat to another has been going on for so long that ecologists have no way of knowing what an "indigenous" ecosystem might look like. Moreover, whether an invasion is benign or clearly devastating, such as that of Guam's brown tree snake, it may be impossible to reverse. One lesson of Burdick's odyssey is that there is no such thing as a "state" of nature—only a continuous dynamism that challenges our ability to understand, preserve, and manage.

The Golden Spruce: A True Story
of Myth, Madness, and Greed
by John Vaillant
W.W. Norton & Company, 2005;
$24.95

To the Haida people of the Queen Charlotte Islands, it was known as K'iid K'iyaas, "the elder spruce." It was not the tallest tree in the forest, though it was still a giant by most standards, standing 165 feet tall and measuring more than twenty feet around at its base. At about age 300, it was not the oldest tree in the tribal area, either, for the Queen Charlotte Islands, which lie off


I DON'T KNOW YOUR FAMILY. YOU DON'T
KNOW MY NAME. BUT I'D RESCUE
YOUR KIDS IN A HEARTBEAT.

"Golden Spruce," now gone, was once a beacon of the forest.

the central coast of British Columbia, are still home to some of the most ancient stands of timber on the continent, even after nearly a century of logging. What was remarkable about the spruce was its color: a lambent yellow, caused by a rare genetic mutation that affected its ability to make chlorophyll. The unusual brightness of its foliage among the dense greenery of the Northwest rainforest made it seem to glow with its own inner light, and visitors not familiar with the Haida mythical name always referred to it as the Golden Spruce.

For as long as anyone could remember, the Golden Spruce had stood not far from the shore of the Yakoun River, which runs through the center of Graham Island. A local timber company had set aside a small area of uncut timber around the tree, partly as a recreational resource and partly as a gesture to environmentalists. But sometime between January 20 and January 23, 1997, the Golden Spruce came down, crushing the undergrowth around it and hitting the ground with one end hanging over the bank of the Yakoun. Although no one saw it fall, the cause was soon evident: someone had killed the spruce by carefully slicing into it with a chain saw at strategic points around the trunk, cutting nearly all the way through and leaving a hinge of wood just thick enough at its core to keep it upright. Like the living dead, the tree was poised to crash to the ground with the slightest breath of wind.

The arbocide, it soon emerged, had been perpetrated by one Grant Hadwin, a fortyish logger and surveyor from the mainland who had become increasingly upset with the environmental effects of the big timber industries on coastal forests. In a message he sent to the local newspapers, Hadwin referred to the spruce as the "pet plant" of the logging companies. Speaking to reporters, he claimed to have no animosity to the native Haida, who venerated the tree. Nor, he insisted, was he insane. Insanity, to Hadwin, was the notion that protecting a few isolated patches of wildness would make up for the wholesale rape of old-growth forests. "When society places so much value on one mutant tree and ignores what happens to the rest of the forest, it's not the person who points this out who should be labeled."

But few people saw it that way. To the Haida, the felling of the spruce was comparable to the destruction, for New Yorkers, of the Twin Towers. Throughout Canada, timber barons and environmentalists alike condemned the wanton destruction and called for swift justice. But Hadwin never went to trial. A few days before his scheduled appearance, he set out from the mainland in a kayak, presumably intending to paddle across the treacherous Hecate Strait to his court appearance on Graham Island. A few months later the remains of the kayak and a few of his personal possessions were found on an Alaskan beach, 450 miles from his point of departure. Hadwin's disappearance, like his strange and desperate act of protest, remains cloaked in the mists of the Northwest Coast.

It's impossible not to compare Hadwin to Christopher McCandless, the protagonist of Jon Krakauer's nonfiction book *Into the Wild,* who died in the Alaskan wilderness while pursuing another personal dream of environmental integrity. Vaillant's book is cut from the same cloth. As it moves smartly from scene to scene, with a literary style that betrays its origin as a *New Yorker* magazine feature, the author wisely refrains from indulging in futile speculation about Hadwin's inner life. Instead, he gives the reader arresting descriptions of an exotic landscape, along with illuminating discourses on plant genetics, the timber business, and the clash between native culture and corporate capitalism. His book is one to ponder and to savor.

The Elements of Murder: A History of Poison
by John Emsley
Oxford University Press, 2005; $30.00

My idea of bliss in the dog days of summer is a comfortable lawn chair, a cool drink, and a stack of murder mysteries. For those with similar criminal fixations, here's a thick book of nonfiction that might also fill the bill: a natural and social history of poisons, by the former Science Writer in Residence at the chemistry department of the University of Cambridge. John Emsley's book includes more than anyone but a fiend would want to know about the uses and abuses of antimony, arsenic, lead, mercury, and thallium, along with information about a host of elements less commonly ingested but, under the proper circumstances, no less deadly: barium, chromium, selenium, and tellurium among them.

The danger of these poisons, well known to pathologists, is that their effects can be both cumulative and insidious. When such toxic elements are environmental, particularly when they occur in one's everyday surroundings, one can be slowly poisoned without ever becoming aware that something is wrong. Substances now considered highly poisonous were once even prescribed as

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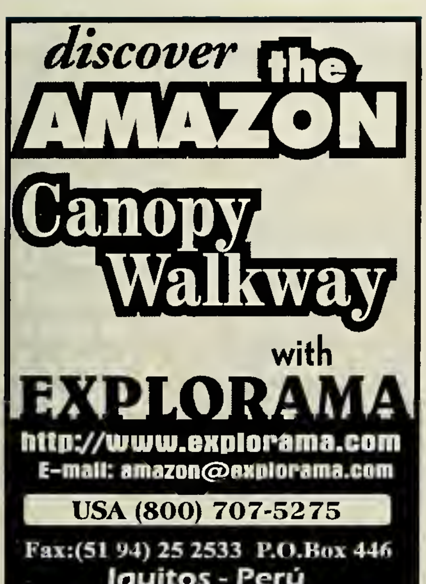
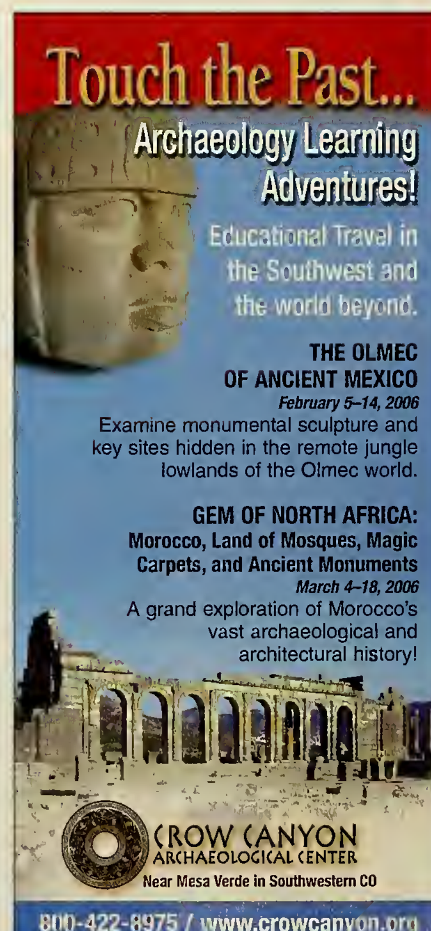




home remedies, simply because they had no apparent negative effect and their medicinal effect was beneficial. Calomel, a chloride of mercury, was used well into the 1950s as a so-called teething powder for babies, since it was known to soften the gums. The babies' relief, unfortunately, was a mild case of mercury poisoning. At its most severe, mercury poisoning causes teeth to fall out. Because mercury also attacks the nervous system, even the low doses in the teething powder no doubt affected the mental development of millions of smiling babies. And smiling adults, too: President Lincoln supposedly ingested mercury in the pills he took as a laxative, which may have led to his reported propensity to mood swings.

J.J. Grandville, personification of ciguë *(hemlock), ca. 1847*

That same treacherous subtlety makes poison the weapon of choice for many murderers, especially the ones who want to conceal the very existence of a crime. Has the skin on your palms and the soles of your feet been thickening lately? Have you been weary, overly irritable, losing appetite and weight? Are your eyes red and watery? Check that elderberry wine your maiden aunts have been serving you, or those bonbons that keep coming from a secret admirer. You have all the signs of chronic arsenic poisoning.

Then again, if you're losing your hair, watch out! It may be more than bad genes—especially if your body has that tingling feeling, or your hands and feet feel numb from time to time, or you're having trouble sleeping. Someone who would profit from your demise may have read *The Pale Horse,* a classic Agatha Christie, whose villain used thallium salts to knock off his victims.

Thallium ions are dead ringers for potassium ions, one of the metals essential to health. Thallium, however, does not function quite the same way potassium does. When too much thallium circulates in the blood, it invades all the organs of the body, impairing their operation, destroying hair follicles, muscles, and nerves. Because it takes time for thallium to get into the cells, large doses may produce no immediate effect. But because it is not readily excreted, thallium continues to build up long after the fatal flagon has been drained. By the time the victim begins hallucinating, turns gray-skinned, becomes paralyzed, and dies, it may be impossible to identify who did the dastardly deed, or when.

The list of the famous who may have been poisoned by one of these devious toxins is a long one, from Pope Clement II to Mozart. Emsley has dug up the dirt on these and a rogue's gallery of lesser-known cases. Today, with analytical techniques that can routinely sniff out minute amounts of toxins, villains can no longer count on getting away with the perfect murder. But if the golden age of poisoning is gone (replaced, to be sure, by other forms of mayhem), in Emsley's book it's still very much alive.

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

Chill Out

By Robert Anderson

Summer heat getting you down? Then imagine setting your time machine for a geologic era more than half a billion years ago, when the entire globe, not just the polar regions, was enveloped in ice. Average surface temperatures reached minus fifty-eight degrees Fahrenheit. Geologists have been kicking the "snowball Earth" hypothesis around for more than a decade, ever since the discovery that glacial features occur in Precambrian rocks over a wide area of the planet. According to the theory, Earth was exposed to as many as four freeze-over episodes, each followed by melting brought on by volcanoes [*see "The Longest Winter," by Gabrielle Walker, April 2003*]. Some scientists think the catastrophic climate swings may have sparked the so-called Cambrian explosion, the geologically sudden evolution of complex animal life on Earth.

Try the snowball Earth theory on for size by listening first to a five-minute audio explanation that covers the basics, at the North Country Public Radio online site (go to www.northcountrypublicradio.org/news/natural.php and scroll down to "Natural Selections: Return to Snowball Earth"). Or go straight to a lengthy but informative text, "'Snowball' Scenarios of the Cryogenian," posted in 2002 on an impressive Web site called "Palaeos: The Trace of Life on Earth" (www.palaeos.com/Proterozoic/Snowballs.html).

To get a good sense of the extreme climatic fluctuations conjectured by the theory, visit the site of the "Paleomap Project" (www.scotese.com/). From the menu at the top left of the page, click on "Climate History." Scroll down here to the chart titled "Ice House or Hot House." Earth's climate history is a fascinating topic, and the National Oceanic and Atmospheric Administration has posted information about it in a highly accessible form, organized as a time line (www.ngdc.noaa.gov/paleo/ctl/resourcebeyond.html). On the home page, scroll down to view a time chart of Earth's ice ages. You can click on "About CTL," on the menu at the top of the page, to learn how best to take advantage of the site's many resources.

In the 550 million years since the end of the Precambrian era, geologic processes have melted, twisted, reoriented, deeply buried, or destroyed much of the oldest rock record. Yet through painstaking detective work, geologists have assembled an accurate map of the continents at the time of the Cambrian explosion. To view a map titled "Late Precambrian Supercontinent and Ice House World," return to the "Paleomap Project" (www.scotese.com/), and from the list at the left of the home page, click on "Earth History." Once there, click "Precambrian" on the menu at the left of the page.

Joseph L. Kirschvink, a geologist at Caltech specializing in paleomagnetics, coined the term "snowball Earth" in 1992. At his Web site (www.gps.caltech.edu/users/jkirschvink), you can access information about past and present projects of Kirschvink and his laboratory group. One fascinating feature of his site is an animated reconstruction of continental displacements at about the time of the Cambrian explosion (scroll down the page and click on the blue hypertext "iitpw.mov").

The Internet is also the place to go for dissident views. At the Web site of NASA's Goddard Institute for Space Studies (www.giss.nasa.gov/research/briefs/sohl_01/), you'll find an article by two geologists at Columbia University. They simulated climatic conditions during the late Precambrian era, and found that, even in worst-case scenarios, with reduced solar radiation and low levels of greenhouse gases, the oceans would have remained ice free near the equator. They dubbed their model "slushball Earth."

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

feel strongly that including those primitive Asian taxa in their study would have produced results supporting an Asian origin for the group.

As for *Deinosuchus,* that animal was undoubtedly one big, mean crocodilian, but to our knowledge, paleontologists have yet to recover stomach contents that include juvenile tyrannosaurs.

Mistaken Identity?

Adrienne Mayor's supposition, presented in her article "Tales From the Badlands" [5/05], that fossils may have influenced human legends and myths, is certainly reasonable. But I found some of her supporting evidence unconvincing. On page 56, the picture of the enormous New Mexican bird snatching up a "human" was particularly troubling. I would suggest that the image actually shows a wading bird with a frog. The downward-curving bill of the bird, the small head, and the swollen knees are all accurate depictions of a wader. The supposed human is articulated more like an amphibian than a mammal.

Early New Mexican artists were superb at depicting natural history, so I doubt they would represent humans so oddly. Why was this image interpreted by Ms. Mayor as predation on people?

John M. Marzluff
University of Washington
Seattle, Washington

Adrienne Mayor notes that Native American tribes mistook prehistoric dinosaur remains for the remains of the monsters that populated their myths. But they may not have been the only ones to misidentify the remains.

The Lewis and Clark expedition recorded an incident on September 10, 1804, that has never been explained. Their journals state that when passing through present-day South Dakota, the party "found the back bone of a fish, 45 feet long, tapering to the tale [*sic*]." These men, with backgrounds in surveying, were not given to exaggeration, so there is little reason to doubt their measurements. Lewis and Clark seem also to have mistaken the remains of a prehistoric reptile or dinosaur for those of a fish.

Bruce Meyers
Paulsboro, New Jersey

ADRIENNE MAYOR REPLIES: The petroglyph mentioned by John M. Marzluff is located at Puerco Pueblo in Petrified Forest National Park, which is in Arizona, not New Mexico, as the photo caption incorrectly states. Some viewers have agreed with Mr. Marzluff that the carving depicts a frog in the beak of a wading bird. The long beak might support this view, but the large size of the frog seems unrealistic.

Other viewers have argued, though, that the victim appears to be a struggling human carried by a giant bird. Teratorns, which are now extinct, were large raptors that co-existed with humans in North America and snatched up prey with their long beaks. I chose this rock art because I learned that a Hopi elder had associated the drawing to old Hopi traditions about giant birds that used to swoop down and fly off with Hopi children. His comments are documented in my book.

Bruce Meyers is correct in pointing out that Lewis and Clark's measurements of the immense spine and ribs were probably accurate. At the time of the discovery, in 1804, dinosaurs were unknown. The locality and dimensions of the South Dakota "fish" have led paleontologists to guess that the creature was a long-necked plesiosaur or a serpentine mosasaur. Fossils of both of these Mesozoic marine reptiles are abundant in that region.

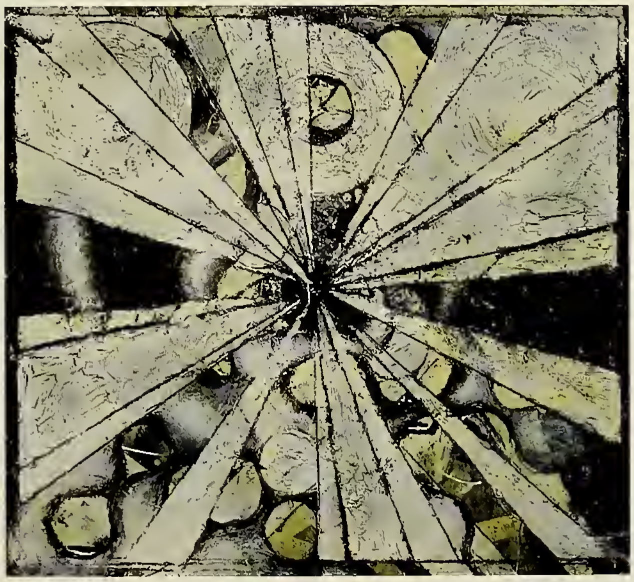
Natural History *welcomes correspondence from readers* (nhmag@naturalhistorymag.com). *All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

Not Dead Yet

A dying star is caught flaring briefly back to life.

By Charles Liu

When most people see a constellation referred to as Sagitta, their first inclination is to add four letters to make the word "Sagittarius." Not so fast. The latter is indeed the famous archer, one of the twelve constellations of the zodiac. But Sagitta, the arrow, is an ancient constellation in its own right. Its stars form a diminutive but distinct flechette, sandwiched between Aquila, the eagle, and Vulpecula, the fox. According to some versions of sky lore, Sagittarius accidentally shot the wayward Sagitta while aiming at nothing in particular. Others say the Greek hero Hercules fired Sagitta at a vulture that was tormenting the captive Titan Prometheus.



John R. Thompson, *The Center Cannot Hold*, 1993

Of course, none of our ancestors who recounted those myths had the slightest clue about the real identity of the remarkable objects that make up these celestial stick figures. Near the outstretched arm of Sagittarius, for instance, lies the center of our Milky Way, some 25,000 light-years from Earth. There, invisible to all but the most specialized telescopes, lurks a black hole millions of times the mass of the Sun [*see "Peering at the Edge of Time," by Fulvio Melia, June 2003*]. Sagitta harbors nothing quite so dramatic. Yet one of its stars has achieved a kind of minor celebrity as a stellar corpse that has apparently risen from the dead.

About a billion years before a sunlike star "dies," or stops generating energy via nuclear fusion, it becomes a red giant, growing dramatically to a hundred times its original

(Continued on page 58)

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(Continued from page 55)
diameter. Then, as the red-giant phase ends, the star blows off its outer layers, giving rise to an expanding gas cloud called a planetary nebula [*see "Ghosts of Suns Past," by Charles Liu, March 2004*]. The planetary nebula, in turn, swells in size and drops in density for at most another 100,000 years, exposing the remaining stellar core at its center. That core becomes a white dwarf—the most common celestial cadaver visible in the sky. The white dwarf usually radiates its leftover heat into space for billions of years, and it slowly fades to black.

Some soon-to-be white dwarfs, however, seem to heed the counsel of Dylan Thomas: "Do not go gentle into that good night." According to the theory of stellar evolution, the temperature in the stellar core can fluctuate wildly, and sometimes spikes as high as tens of millions of degrees. For a little while at least, the core may even flicker back into stellar life as a giant star, generating new energy with new flares of nuclear fusion.

Alas, such a "born-again" giant can't last long, because the core is, in essence, running on fumes. Without a substantial fuel source to sustain fusion, a nuclear re-ignition of this kind runs out of gas within a few centuries, and the star heads back toward white dwarfhood. But during its brief return to fusion-powered life, its interaction with the surrounding cloud of gas creates a fascinating astronomical laboratory for the study of stellar and interstellar processes.

> *A "born-again" giant can't last long.*

The star FG Sagittae, a highly variable star in Sagitta, seems to be a case in point. FG Sagittae lies at the heart of a planetary nebula called He 1-5. In the past thirty years the star's temperature has dropped from more than 30,000 degrees Fahrenheit to less than 10,000 degrees, though its brightness has changed erratically from year to year. As with an old, grease-choked diesel engine struggling to start back up, the star's efforts to restart nuclear fusion create puffs of thick smoke—carbon atoms coughed up from the fading stellar core. The smoke absorbs the star's radiating heat and periodically obscures the visible light it emits. To see through the haze and examine the goings-on near the star's surface, astronomers must look at its radiation in less obscured wavelengths, such as infrared light.

A research team led by Robert A. Gehrz of the University of Minnesota in Minneapolis has now done just that. Recently the team published the results of twenty years of monitoring the infrared properties of FG Sagittae with three telescopes equipped with infrared photometers—in effect, photon counters. One instrument is in Minnesota, one in Arizona, and one in Wyoming.

Gehrz and his colleagues discovered that, though the star's overall brightness and temperature have changed dramatically through the years, one component of the FG Sagittae system has been shining more or less steadily at a temperature of about 1,200 degrees F (650 degrees Celsius). That's roughly hot enough to melt aluminum, but substantially cooler than the core of any star undergoing active nuclear fusion. Gehrz and his colleagues conclude that, besides giving rise to clouds of obscuring gas, FG Sagittae is powering a strong stellar wind peppered with carbon dust. They think this dust, originating from the star's surface, has been glowing continuously for the past decade. On the basis of the measured amount of emitted infrared radiation, Gehrz's team estimates that the wind is carrying between 1.5 and 7.5 quadrillion (1.5 to 7.5×10^{15}) tons of stellar material away from FG Sagittae each second—or about eight to forty Earth masses each year.

Sooner rather than later the current burst of new nuclear fusion will cease, and FG Sagittae will change from a born-again giant into a dead-again one. The dusty stellar wind will cease. The stellar core, no longer obscured by a thick, dusty blanket, will turn once more into a hot white dwarf. If, as theoretical models predict, the stellar renaissance of FG Sagittae lasts a few hundred years, the wind will deposit thousands of Earth-masses' worth of carbon-rich matter into the star's surroundings. The carbon atoms, as they cool down, could become seeds for the buildup of interstellar dust grains—which, in turn, could seed the formation of asteroids, moons, planets, and perhaps eventually even life as we know it. Maybe the astronomers of the twenty-fourth or twenty-fifth century will look toward FG Sagittae and see, in its surroundings, the potential makings of a new and distant earth.

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

By Joe Rao

Mercury, still near the much brighter Venus after their close encounter late last month, shines in the western evening twilight at magnitude 0.1 as July begins. Mercury is less than a degree to the left of Venus; the two planets can be found just above the west-northwestern horizon about forty minutes after sunset. During the following two weeks the pair slowly separates, as Mercury appears to pivot around and below Venus. By the evening of the 13th, Mercury lies three and a half degrees directly below Venus, but Mercury appears only about half as bright as it did at the start of the month, so I recommend looking through binoculars to find the planet. After midmonth Mercury fades rapidly from the evening sky.

On August 5 Mercury reaches inferior conjunction, passing between Earth and the Sun. Thereafter the planet rushes up for a good dawn apparition during the latter half of the month. By the 17th Mercury has brightened to first magnitude and rises seventy-five minutes before sunup. On the 23rd the planet reaches its greatest western elongation, eighteen degrees from the Sun. At that point Mercury rises ninety minutes before the Sun and has brightened further, to magnitude zero.

Venus has been playing coy for a couple of months now, but the planet consents to showing itself ever so slightly longer in the twilight, as the summer progresses. Although always bright, the planet remains low in the sky all summer, as seen from midnorthern latitudes. On July 22 binoculars will help show Venus's close pairing with the star Regulus, the little king, in the constellation Leo, the lion. The planet and star are just a bit more than one degree apart, though the planet is much the brighter of the pair.

Venus's apparition in August is scarcely changed from what it was in June and July. The planet does make an approach to Jupiter.

Mars continues to approach Earth, and so it brightens dramatically in July and August. On July 1 the Red Planet, brilliant at magnitude −0.1, is exactly one astronomical unit—92.9 million miles—from Earth. Mars crosses the constellation Pisces, the fish, this month. On the 1st Mars rises nearly due east just before 1 A.M., and it rises about two and a half minutes earlier each night thereafter.

During August the distance from Earth to Mars shrinks to 62 million miles. Mars's brightness more than doubles as a result; it shines like a yellow-orange jewel, at magnitude −1; only one star, Sirius, shines brighter. Mars briefly passes through the constellation Cetus, the whale, from August 2 through the 5th, before moving into the constellation Aries, the ram, for the rest of the month. At the beginning of August Mars rises just before midnight in the east-northeast, and by the 31st it's rising before 10:30 P.M.

Jupiter is low in the west-southwest at dusk as July begins, and just gets lower (and sets earlier) as the month goes on. Jupiter remains in the constellation Virgo, the virgin, as it was in June, and the planet is moving eastward toward the constellation's brightest star, Spica, with each passing night; planet and star are separated by about fourteen degrees as July commences.

In early August Jupiter sets about an hour after dark, and just at the end of evening twilight as August ends. The planet continues moving eastward against the stars toward Spica; the gap between them closes to six degrees by the 31st. More notable—and noticeable—is the approach of Venus to Jupiter. On the 1st the two planets are separated by more than thirty degrees, but by the 31st they are within one and a half degree of each other.

As July commences, sky gazers might be able to see Saturn about forty minutes after sunset, just above the west-northwestern horizon; the planet is about seven degrees to the lower right of Mercury and Venus. Thereafter Saturn is swallowed up in the evening twilight.

The planet is not visible again until mid-August, when it appears in the east-northeast just before sunrise. A good time to look for Saturn comes on the morning of August 18, when it passes five degrees above Mercury.

In July the Moon wanes to new on the 6th at 8:02 A.M. It waxes to first quarter on the 14th at 11:20 A.M. and to full on the 21st at 7:00 A.M. Our satellite wanes to last quarter on the 27th at 11:19 P.M.

On the night of July 17th a waxing gibbous Moon occults, or hides, the bright reddish star Antares. The occultation is visible from parts of the far western and southern United States. Elsewhere, Antares seems to pass close to the Moon's upper limb. The best views come between about 8 P.M. and 9 P.M. on the 17th in the Pacific time zone, and between about 1 A.M. and 2 A.M. on the 18th in the Eastern time zone.

In August the Moon wanes to new on the 4th at 11:05 P.M. It waxes to first quarter on the 12th at 10:38 P.M. and to full on the 19th at 1:53 P.M. It wanes to last quarter on the 26th at 11:18 A.M.

The Earth reaches aphelion, its farthest point from the Sun, on July 5 at 1:00 A.M. The Sun is 94,512,036 miles away.

The Perseid meteor shower comes every August. This year it peaks during the predawn hours of the night of August 11th. The meteors are fast and bright, and they often leave persistent trails. From a location free from bright lights and tall objects, an observer might see some fifty to a hundred shooting stars an hour. The meteors are called Perseids because they appear to shoot away from the constellation Perseus, a hero of Greek myth. Because the Perseids usually make their display around August 10, which the Roman Catholic Church recognizes as the feast of Saint Lawrence, they have been referred to as the fiery "tears" of Saint Lawrence.

Unless otherwise noted, all times are eastern daylight time.

Young Naturalist Awards 2005

A research-based essay contest for students in grades 7–12 to promote participation and communication in science


ALLISON HOLCOMBE

Now celebrating its eighth year, the Young Naturalist Awards recognizes the accomplishments of students who have investigated questions in the areas of biology, Earth science, or astronomy.

Every year, scientists from the American Museum of Natural History travel far and wide on expeditions to learn more about the natural world. Following in that tradition, students throughout the United States and Canada are invited to embark on their own expeditions, but their research can be conducted as close to home as their backyard or a local pond or stream.

After identifying a question, students plan how they will gather information, conduct outside research to learn more about their topic and possible methodologies, observe their subjects, and record their findings. Finally, their data analysis leads to conclusions that either answer the original question or lead to further inquiry.

Included here are descriptions of and excerpts from the winning essays. Full-length versions of the winning essays and information on how to enter the contest are published on the Museum's Web site at www.amnh.org/youngnaturalistawards.

The Pantano Wash: Investigating an Ecosystem, by Daniel Fried (Tucson, Arizona; Grade 7)

Intrigued by a local wash, Daniel decided to explore this ecosystem to learn how plants survive during flash floods.

"Most people have heard the old saying, 'When it rains, it pours.' This is literally true where I live in southern Arizona. Over time, huge dry riverbeds have been carved out of the earth by the water. They are dry most of the time, but during a rainstorm they fill up with water. During the rainy season, the washes can have up to 15 or 16 feet of water in them, flowing very swiftly. You might think that this would kill any plants in the wash, but grass, bushes, and trees are able to survive and even thrive in this harsh environment."

The Effects of *Hedychium gardnerianum* on the Surrounding Soil and Native Flora in Volcano, Hawaii, by Mali'o Kodis (Volcano, Hawaii; Grade 7)

Kahili ginger, an invasive plant, is a threat to the Hawaiian rain forest. Mali'o investigates this plant further.

"Ever since I can remember, Kahili ginger *(Hedychium gardnerianum)* has been an enemy of my household. It dominates the ground cover and blocks out sunlight. I grew up assuming that I was doing a very good deed for the environment by depleting the ginger population. I never once wondered, is ginger truly bad for the environment? Maybe it actually helps native plants."

Exploring Earthworms' Influences on a Miniature Ecosystem, by Rémy Robert (New Orleans, Louisiana; Grade 8)

Among the lush variety of plants and creatures in her backyard, Rémy encountered several species of worms.

"The other day, in my backyard, I slapped a mosquito that had just landed on my knee and looked out at the spectrum of paper-thin, satin-soft flowers; the bouquets of long, glossy green ginger leaves; and the young live oaks. My mind


R. MICKENS/AMNH

shifted—the wide stretch of grass seemed big to me. How big must it seem to one of the white, microscopic grains-of-sand-with-legs crawling around on the fig ivy?"

Does Effluent Water Affect the Ecosystem in Fountain Hills, Arizona? by Christina Silvestri (Fountain Hills, Arizona; Grade 8)

The town of Fountain Hills, Arizona, uses recycled wastewater to fill a local lake. Christina decided to explore the lake's cycles.

"On my way to school each day, I pass the Fountain Hills Fountain and park. Effluent water is recycled wastewater, used to fill the lake and water the park. At times the lake is full of animal and plant life, at other times the water is gloomy, looking as if nothing could survive. I wondered why the town uses effluent water in a public area. I decided to investigate."

Tidal Pools: Bacterial Variability and Marine Life Stability, by Allison Holcombe (Coto de Caza, California; Grade 9)

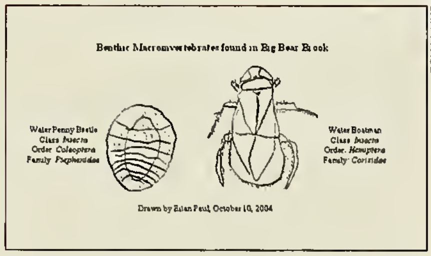
Allison sought to find out how ocean temperature and bacterial counts might affect tidal pool marine life.

"Despite their adaptability, tide pools are quite susceptible to the whims of humankind. Storm drain runoff after a significant rain can raise bacterial counts. El Niño weather patterns can change feeding patterns for much of the native marine life. Even the changing of the seasons may cause ambient ocean temperatures to fall. Thus, the formation of my hypothesis for this expedition depends on the flux of the temperatures of the ocean, as well as the resultant change in bacterial counts."

Impact Study of Grovers Mill Pond and Dam Reconstruction on Big Bear Brook, by Eitan Paul (Princeton Junction, New Jersey; Grade 9)

When plans to reconstruct Grovers Mill Dam were announced, Eitan wondered what impact the reconstruction would have on a local body of water.

"In the 1800s early settlers in the area built a 400-foot-long earthen dam to trap Big Bear Brook for their grinding mill. Over the years, silt and sediment have spilled into the pond, creating an

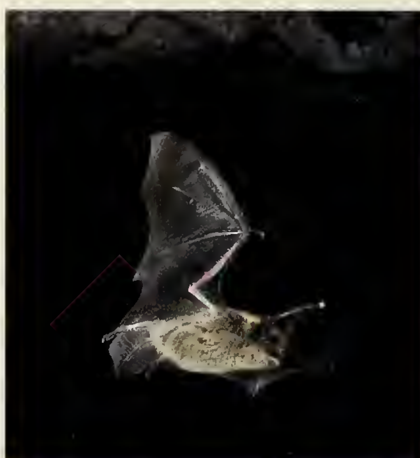


EITAN PAUL

over-vegetated ecosystem resembling thick green muck. This eutrophication has greatly reduced the amount of dissolved oxygen available to aquatic organisms. The rehabilitation of Grovers Mill Pond and Dam got underway, and I wondered what impact the reconstruction might have on Big Bear Brook."

The World through a Bat's Ear, by Sarah Bayefsky-Anand (New York, New York; Grade 10)

Sarah's curiosity about bats led her to study how they adjust their echolocation calls in cluttered environments in order to orient themselves.


SARAH BAYEFSKY-ANAND

"During my fieldwork, I had watched little brown bats fly adroitly in the open and in cluttered situations, so I predicted that these bats would adjust their calls according to the setting in which they operated. I hypothesized that in response to the degree of clutter, these bats would adjust the features of their calls, shortening the duration and the intervals between calls and increasing the frequency for shorter wavelengths."

The Dance of the Moons, by Elliot Alexander (McMinnville, Oregon; Grade 10)

PEOPLE AT THE AMNH

Stephanie Fotiadis
Graphic Designer, National Center for Science Literacy, Education and Technology


S. KIM/AMNH

Stephanie Fotiadis

The work that Stephanie Fotiadis does is seen by millions of kids, parents, and teachers every year, but Stephanie herself remains behind the scenes. As the Web Designer for the National Center for Science Literacy, Education and Technology for the past five and a half years, she has guided the look of innovative educational Web pages. "At the Museum, I really feel like I am creating something that benefits people, which is rewarding."

Stephanie has primary responsibility for the creative direction of the National Center's Web sites, including Ology, Resources for Learning, and the Young Naturalist Awards. She is also a key member of the production team for each of these projects. "The work we do here is so diverse and interesting. We interact with so many people at the Museum and deal with such an array of subject matter—every day I learn something new."

Outside the Museum, Stephanie is an avid tennis fan and a New York City restaurant connoisseur. She has used her skills to produce a tennis Web site as well as to teach an html seminar in Harlem.

Intrigued by Jupiter and its moons, Elliot observed and recorded the positions of the moons so that he could construct an accurate model of the inner Jovian system.

"I traveled about 50 feet for my field trip. But I looked over 300 million miles. There is one place in the solar system that puts on a show over a time span of days or even hours—Jupiter and its satellites. First discovered by Galileo in 1610, the four innermost moons of Jupiter seem to shuttle back and forth. At certain times a change is visible over an hour or less. Since it runs fast, I could measure it in a relatively short period of time."

Troubled Waters: A Six-Month Longitudinal Study of the Spanish Fork River System, by Shannon Babb (Highland, Utah; Grade 11)

June suckers are a species of fish found only in Utah Lake. Concerned about their dwindling numbers, Shannon decided to investigate the water quality of the rivers that feed into the lake.

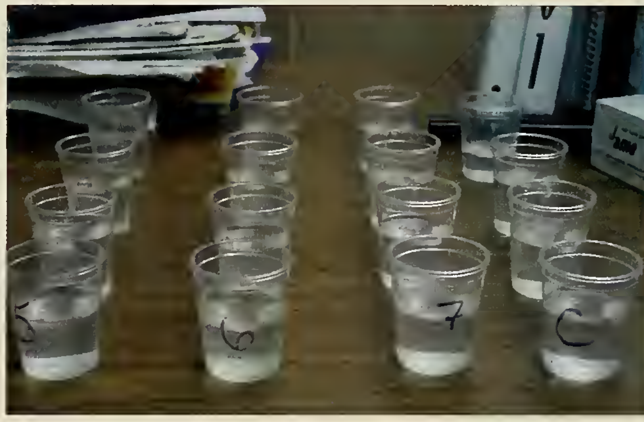
"For the past three years I have been comparing the water quality of


SHANNON BABB

the rivers flowing into and out of Utah Lake. I have been studying the rivers to figure out which one has the worst water quality. I discovered that the Spanish Fork River was the most polluted, [yet] only 12 miles upstream, where the Spanish Fork River flows through Spanish Fork Canyon, the river appears to be healthy."

Environmental Effects of Industrial Runoff on *Daphnia magna*, by Mauree Gibson (West Point, Iowa; Grade 11)

Years of improper hazardous-waste



MAUREE GIBSON

disposal at an Iowa munitions plant have led to a contaminated water supply and serious health problems for people living nearby. Mauree wanted to find out what effects the industrial runoff has had on local creeks.

"Over the past three years, I have tested water quality using *Daphnia magna,* freshwater invertebrate crustaceans that are frequently used in water toxicology research because of their ability to signal stressful levels of pollution. *Daphnia magna* has a light-sensitive eye, meaning that the eye will track a moving light source. This knowledge helped me to establish a measurement of reflex, providing a measurement of the effect of environmental stress on the nervous system."

Got Cats? Get Worms! by Eric Kimbrough (Prairieville, Louisiana; Grade 12)

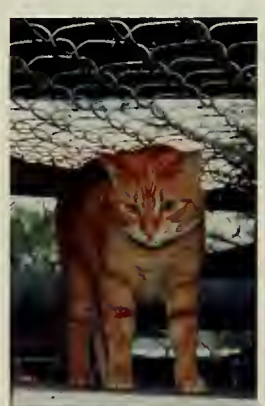
His dislike for cleaning out his cats' litter boxes led Eric to experiment with worm composting, with amazing results.

"The ultimate purpose of my experiment is to find an environmentally friendly solution to animal wastes. Our cats live happily in a very large, specially equipped pen, but I still hate to clean the four smelly litter pans. For years I've observed worms in the compost piles in the woods behind our house. Why not borrow some worms from the woods and have them clean the cat pans for me? Having worms clean up cat mess is my idea of how work should be done."

A Search for Variable Stars in Two Northern Open Clusters: NGC 381 and NGC 637, by Morgan MacLeod (Cumberland, Maine; Grade 12)

Armed with a ten-inch telescope and a charge-coupled device camera, Morgan searched the heavens in hopes of finding variable stars in open-star clusters.

"Over the past two years, I investigated variable stars with amateur telescopes and charge-coupled device cameras. First, the light curves of known variable stars were plotted using a charge-coupled device attached to various camera lenses. Then the charge-coupled device was attached to the telescope for greater photometric accuracy, and a poorly understood variable star named v377 Cas was observed. This research demonstrated that amateur equipment could be extremely effective in collecting photometric data."




ERIC KIMBROUGH

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Dinosaurs: Ancient Fossils, New Discoveries and its accompanying education and public programs are made possible by Bank of America.

This exhibition is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Houston Museum of Natural Science; California Academy of Sciences, San Francisco; The Field Museum, Chicago; and North Carolina Museum of Natural Sciences, Raleigh.

Major funding has also been provided by the Lila Wallace-Reader's Digest Endowment Fund.

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A lush photographic journey from the Andes to the Amazon to the Chaco. Captions in English and Spanish.

This exhibition is made possible by the generosity of the Arthur Ross Foundation.

GLOBAL WEEKENDS

Indigenous Peoples' Day
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An afternoon of films, lectures, and performances in recognition of the United Nations' International Day of the World's Indigenous Peoples

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, and the New York City Council. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

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With author Vicki Croke

The Ape in the Tree
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With paleoanthropologist Alan Walker

Art/Science Collision: The Coney Island Museum
Tuesday, 7/26, 7:00 p.m.
With curator Aaron Beebe

FAMILY AND CHILDREN'S PROGRAMS

DR. NEBULA'S LABORATORY

Dino Adventure
Saturday, 7/23, 2:00–3:00 p.m.

Planetary Vacation
Saturday, 8/13, 2:00–3:00 p.m.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

The Grand Tour
Tuesday, 7/5, 6:30–7:30 p.m.

Dynamic Processes in the Universe
Tuesday, 8/2, 630–7:30 p.m.

This Just In...

July's Hot Topics
Tuesday, 7/19, 6:30–7:30 p.m.

August's Hot Topics
Tuesday, 8/16, 6:30–7:30 p.m.

Celestial Highlights

The Dog Days of Summer
Tuesday, 7/26, 6:30–7:30 p.m.

The Summer Triangle
Tuesday, 8/30, 6:30–7:30 p.m.

PLANETARIUM SHOWS

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

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Messing About

By Dru Clarke

"Do you know [said Mole], I've never been in a boat before in all my life. Is it so nice as all that?"

"Nice [said Rat]? It's the *only* thing. Believe me, my young friend, there is *nothing*—absolutely nothing—half so much worth doing as simply messing about in boats. Simply messing."

—Kenneth Grahame, *The Wind in the Willows*

The pond near our farmhouse swells and recedes with the seasonal rains, but the last downpour had not swelled it by much. From where I was standing I could make out a thick ring of sodden weeds that enclosed a smaller circle of deep water.

But the water was deep enough to float my boat, and my custom-made canoe, which weighed in at a scant thirty-one pounds, was relatively easy to haul out to the pond and trundle across the gooey muck. Sukey, my smallest and best dog, hopped into the bow and looked around smartly, eager to play the double role of ballast and tracker. One push with the kayak paddle and we slid over the flotsam of reeds and into open water. My other two dogs took off to greet us at the other side of the pond. We were seriously messing about.

Arthur Rackham, *King Log*, from *Aesop's Fables*, 1912

The natives, however, weren't nearly as thrilled about our activities as we were. By my quick calculation, anywhere between one and two dozen northern green frogs abruptly scattered. A chorus of froggy "Eeeks!" gave voice to the general havoc. From every direction frogs leaped, skidded, and dived toward the safety of deeper water. Rocketing from the shoreline at least twelve feet behind me, one skimmed the surface like an artfully skipped stone before disappearing underwater. Another performed a clean, no-splash dive—a 9.8 Olympic qualifier. A third simply jumped straight up and fell, completing a comic cannonball.

After a moment the frogs burped to the surface, a wet circle of improbable profiles. I pondered the evolutionary forces that might have led them, despite their shared musculature and reflexes, to develop such a suite of diverse escape maneuvers. Hearing the commotion, the mares and foals in a nearby pasture galloped to the water's edge. They stood dumbly gazing, then lowered their heads to drink, keeping wary eyes on the floating phenomena. The frogs, apparently accustomed to such interlopers, were unfazed.

Anxious for some action, Sukey and I paddled over to a pole that was poking out of the water. Atop the pole, perched like some cartoon gargoyle, was a huge northern green. As we floated around it in circles, the frog remained "on post." Perhaps, in its dim amphibian brain, it thought we couldn't see it. We weren't about to let on that we could.

It wasn't long before I began to predict the frogs' underwater routes by watching the wakes left by the powerful thrusts of their hind legs. Their predators, too, I mused, must look for similar clues. When a bumper crop of frogs turned up one year in our garden pool, a mob of foraging black-crowned night herons discovered them. Raucous cries from those joyous opportunists tipped us off to the garden party. They dined on every last frog, as if each one were an irresistible, delectable hors d'oeuvre.

As the pond shrinks in the summer heat, and the frogs become more densely packed around it, a similar fate may await these northern greens. A more diverse gathering—bobcats, coyotes, foxes, raccoons—may attend the next garden party. We'll probably miss that one, but we'll be back next summer to do some more messing about.

Dru Clarke *taught marine science and ecology in secondary school for thirty-one years. She lives in Kansas. Clarke last wrote for "Endpaper" in September 2003.*


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