NATURAL HISTORY

12/06–1/07

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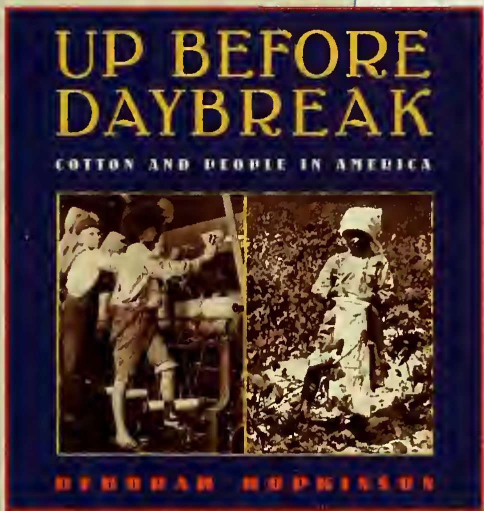

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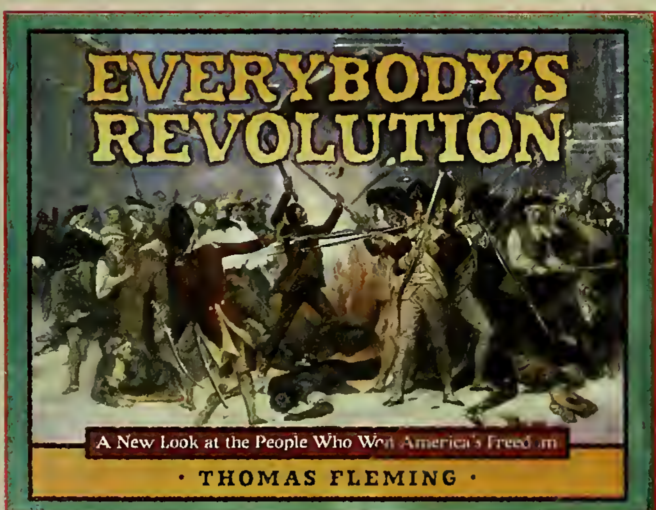

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DECEMBER 2006/JANUARY 2007 VOLUME 115 NUMBER 10

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Male kori bustard,
Ngorongoro Crater, Tanzania
Photograph by Christophe Ratier

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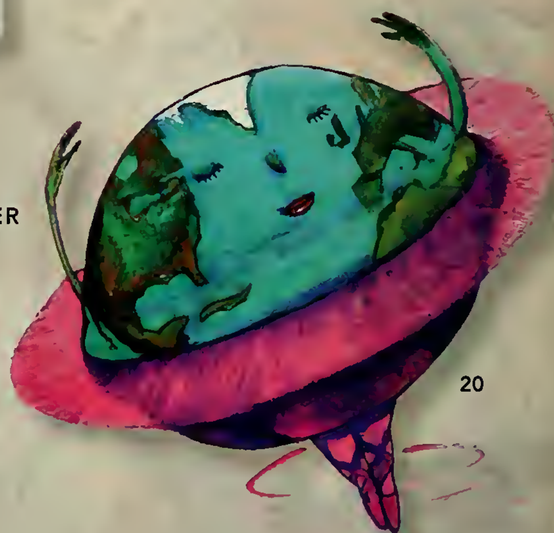

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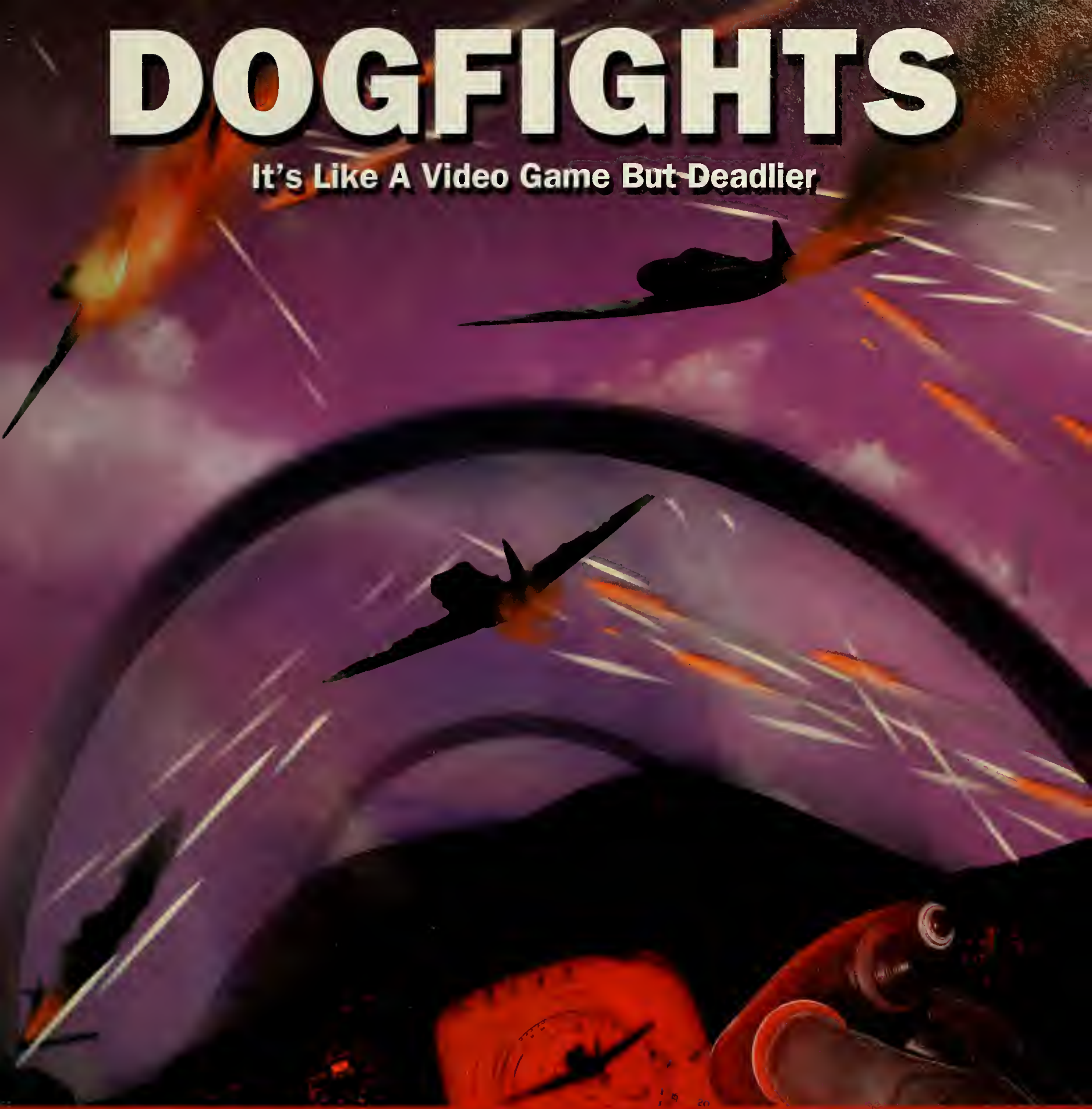

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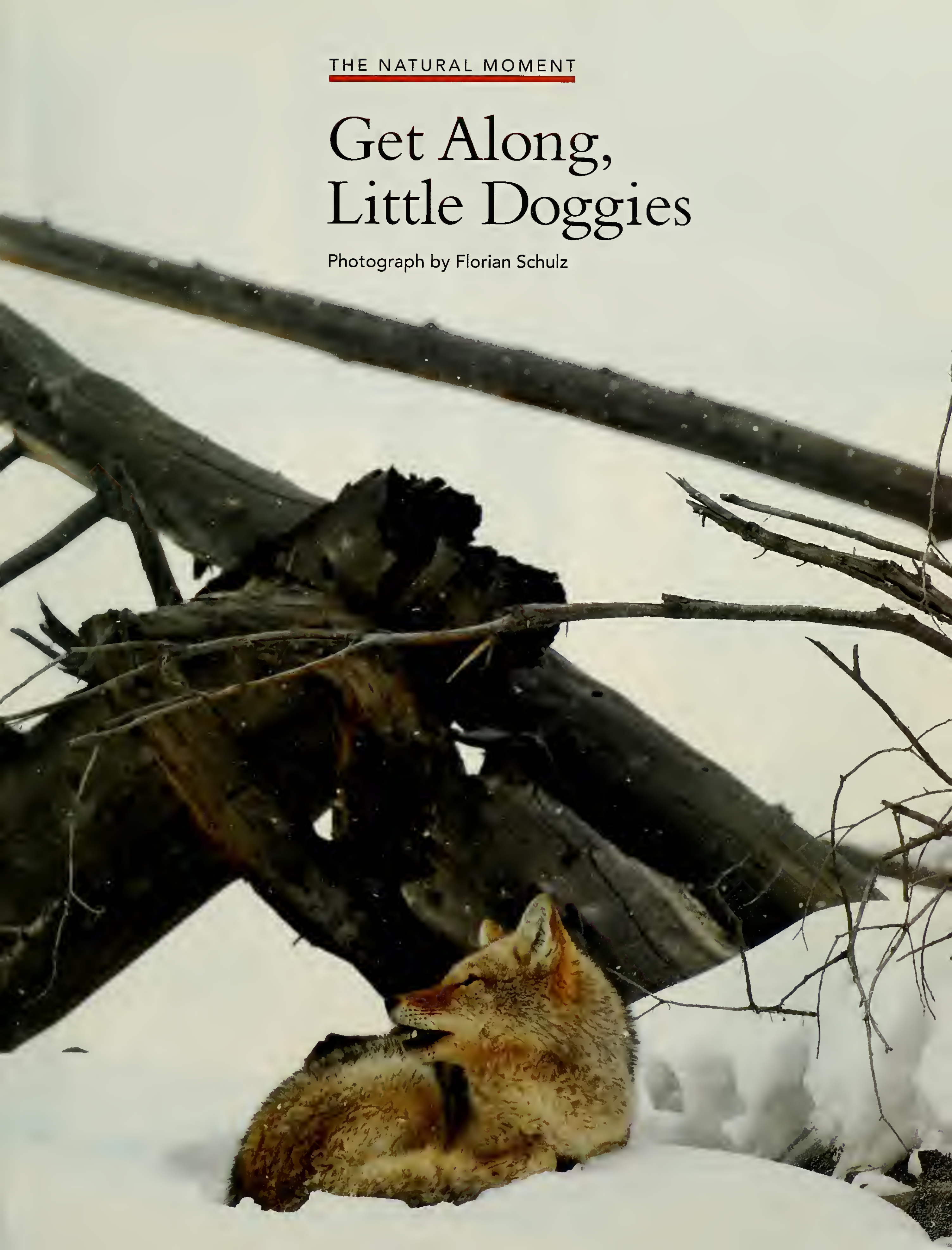
Get Along, Little Doggies

Photograph by Florian Schulz



THE NATURAL MOMENT

◄ *See preceding two pages*

Last winter a pair of coyotes, napping on a fresh pallet of snow in Yellowstone National Park, were roused by the far-off howl of a fellow coyote. The male stood up, shook the snow off his fur, and bayed loudly in response, while the female stayed curled in a ball. Then, according to photographer Florian Schulz, she added a more mellow call to the chord, aimed at her lusty partner.

Coyotes are perhaps the most vocal wild mammals in North America, particularly from January until March, when they couple up to mate. But their sounds—howls, yips, and so-called yip-howls—changed throughout Yellowstone in January 1995, when gray wolves were brought back into the area. The coyotes certainly had something to cry out about: their population was swiftly halved. Even a scrawny wolf is three times heavier than the average, thirty-pound adult coyote, and preys easily on coyote pups.

Coyotes are adaptable, though; they have struck a balance with the larger canines in Yellowstone and even benefit from their leftovers. Particularly when the snow is deep, the wolves seem to leave more scraps from their winter kills, making the season easier for scavengers: magpies, ravens, . . . and coyotes.

Schulz had waited nearly an hour for the coyotes in his picture to stir. His snowy vantage point was near the Lamar River in the northeast corner of the park. When the animals finally broke the chilly silence, Schulz, his toes thoroughly numbed, was grateful for the wake-up call. —*Erin Espelie*

UP FRONT

The Long View

Our annual double-month issue that brackets the holidays takes the long view this year—26,000 years long. That's the time the Earth needs to do its impersonation of the one-second wobble of a spinning toy top beginning to slow down (see "Turn, Turn, Turn," by Donald Goldsmith, page 20). One consequence of the Earth's slow wobble—more properly known as precession—is that the North Star (Polaris) was not always, and will not always be, the navigator's friendly beacon of the north. Goldsmith reminds historians, archaeologists—and re-enactors—that if they hope to evoke the ancient world, they must remember that the Egyptians, the Greeks, and their contemporaries looked on a sky whose north pole was closer to the rather dim star Thuban, in the constellation Draco, the dragon, than to our familiar Polaris. Our descendants in the 140th century will find north easily by looking for Vega, a bright "summer" star usually too low on the horizon this time of year to be visible (at reasonable hours of the night!) at mid-northern latitudes.

By those standards, the birthdays whose 300th anniversaries we're gearing up for in this issue are recent history. Carl Linnaeus and Georges-Louis Leclerc, the Count of Buffon, the two leading "natural historians" of the eighteenth century, were both born in 1707. As Richard Conniff tells the tale ("Happy Birthday, Linnaeus," page 42), the two could hardly have been more divergent in background, or scientifically more at odds: Linnaeus, the provincial, self-promoting Swede, pious and gregarious, the man with one great idea whose name resonates in "Linnaean" taxonomy today; and Buffon, the sophisticated Frenchman, politically adroit, confidante of the rich and powerful, brimming with ideas, yet now virtually forgotten. Each was the other's greatest enemy. Linnaeus will get by far the *Panthera leo*'s share of the attention in this year's celebrations; but Buffon, Conniff argues, deserves at least equal honors for his scientific depth and his adherence to the evidence from nature.

• • •

To me and maybe to you, it's comforting, in the bleak midwinter, to contemplate the life that goes on ceaselessly beneath the frozen soil. In his article "Dig It!" (page 36), Robert R. Dunn takes us on an eye-opening voyage into that flourishing underground ecosystem, where he finds an astonishing diversity of burrowing activity. Dunn also reports that biologists have found wonderfully creative ways to study life in the soil. One investigator put marine worms in a kind of transparent gelatin, which approximated the density of sediment; then she flooded the gelatin with light. The force made by the worms at various points along their bodies as they burrowed through the gelatin caused differences in how the light was reflected. So by watching the worms and their "light shows," she could tell a lot about the ways they move.

• • •

Neil deGrasse Tyson returns to us in our next (February 2007) issue with a fascinating tale of neutrinos, the "little neutral ones" from the depths of space that ceaselessly zip through our bodies. Until then, we wish you a joyous holiday season and a peaceful New Year.

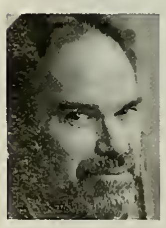
—Peter Brown

CONTRIBUTORS

Although based in southern Germany, the nature and wildlife photographer **FLORIAN SCHULZ** ("The Natural Moment," page 4) spends much of his time abroad. During the past few years, largely under the sponsorship of the Blue Earth Alliance, he has traveled extensively through the northern Rocky Mountains. One result is an award-winning book, *Yellowstone to Yukon: Freedom to Roam* (The Mountaineers Books, 2005). The photograph of two coyotes featured in these pages is another. More of Schulz's photographs of the Rockies are on display at the American Museum of Natural History in New York City, through January 15, 2007, as well as on his Web site, www.visionsofthewild.com.

Never people to take life easy, the husband-and-wife team **TIM** and **LAUREL OSBORNE** ("Big Bird," page 30) began their long-term research project on the kori bustards of Namibia in 1997, after Tim retired from his job as a management wildlife biologist in Alaska. The move from the colder clime, however, was a welcome change. The two met in the early 1970s in California, where Tim earned a master's degree in biology at Humboldt State University, in Arcata, and Laurel did graduate work in zoology at the University of California, Berkeley. They married and went to Africa, where Tim did a stint working for the Zambian National Parks. Ultimately, however, he focused his work on Alaska's caribou, moose, and wolves, while Laurel raised two girls and the occasional orphan moose calf. In Namibia the two own a wildlife farm on the border of the Etosha National Park. There they run a lodge while continuing their investigations in the parklands and elsewhere in Namibia, now focusing on two smaller bustard species.

An assistant professor of zoology at North Carolina State University in Raleigh, **ROBERT R. DUNN** ("Dig It!" page 36) says he became interested in burrowing animals while digging for ants with a spade, because it led him to appreciate the seeming ease with which some creatures move through the soil. A frequent contributor to *Natural History,* Dunn's earlier article about army ants, "Impostor in the Nest" (June 2003), was based on a field season chasing army ants as they poured into and out of the soil. "I spent many days," he recalls, "wishing I had the forearms of a mole or were the size and shape of a worm." Another focus of his work is the evolutionary, ecological, and biogeographic consequences of dispersal of seeds by ants, the subject of his most recent article for this magazine, "Jaws of Life" (September 2005).



At work on a historical book about the discovery of life on earth, **RICHARD CONNIFF** ("Happy Birthday, Linnaeus," page 42) began with Linnaeus "because the story starts with him." A resident of Connecticut, Conniff routinely pursues his craft in unroutine circumstances, from tea in the members' dining room at the House of Lords to the driver's seat in a demolition derby. He is the author of five books about human and animal behavior, most recently *The Ape in the Corner Office: Understanding the Workplace Beast in All of Us* (Crown Business, 2005). He has also written widely about wildlife, culture, and other topics for a variety of major national magazines. Conniff won the 1997 National Magazine Award for Special Interests, and the 2000 John Burroughs Award for Outstanding Nature Essay.

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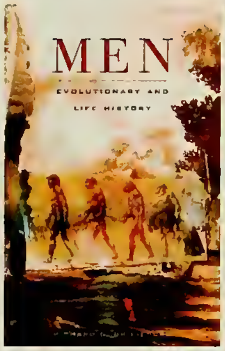

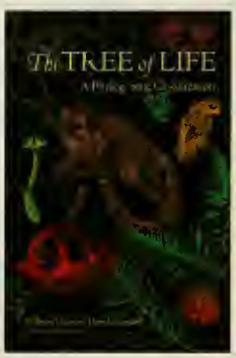

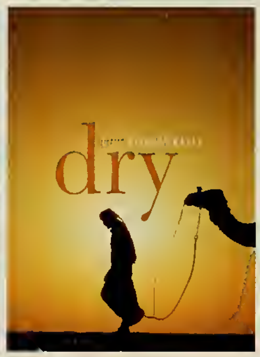

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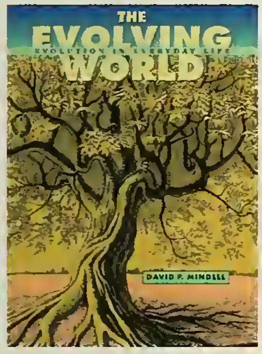

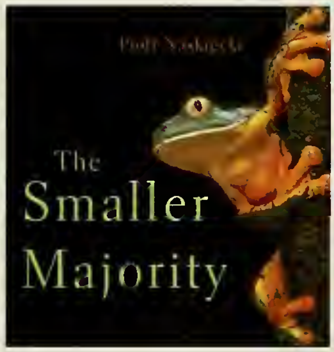

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—Gaden S. Robinson, TIMES LITERARY SUPPLEMENT

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Jaws—or Lips?

R. Aidan Martin and Anne Martin ("Sociable Killers," 10/06) claim to differ with my theory that white sharks avoid feeding on people because they prefer fattier prey. But the Martins offer no reason a shark would not eat a human it has bitten—out of "curiosity"—except to say the shark may be fought off.

In fact, there are many cases in which white sharks have not eaten incapacitated humans. An abalone diver off northern California was seized by the head and carried in the jaws of a white shark before being released; the diver swam ashore. In two other cases a shark carried a surfer underwater by the ankle or leg, then let the victim go. Such observations led me to suggest that white sharks be called Lips, not Jaws. Like primates, they handle large food items gently in their lips, tasting them before deciding to eat them.

White sharks also reject other lean but vulnerable species. Sea otters commonly float up on the shores of Monterey with bite wounds and embedded fragments of shark teeth, yet a sea otter has yet to be found in a white shark's stomach.

Crude experiments supplement such anecdotes. The rib cage of a northern elephant seal, with the fatty layer removed, was presented to a white shark off San Francisco. The shark bumped the carcass once, but after several minutes left it uneaten. Yet when chunks of seal fat were put in the water at the same place and time, the sharks readily ate them. More carefully controlled experiments are needed; they will, I believe, support my hypothesis.

A. Peter Klimley
University of California
Davis, California

In the twenty-five years I've lived in far northern California there have been at least a dozen nonfatal white-shark attacks on local surfers. One man was sitting on his board in five or six feet of water, when a white shark in the ten-foot range swam under him, circled back, and grabbed him by the thigh. He was dragged under, but the shark let go immediately.

About a week later I launched my kayak through the surf a few yards from where the attack had occurred. "Time to go trolling!" I joked to myself. Not ten minutes later there was a tremendous bang at the back of the boat, and I was dumped overboard. Underwater, I saw a white shark about ten feet long turning back toward me. I was still holding my kayak paddle, and aimed a blow at the shark's head. I don't know if I actually hit it, but the next thing I knew I was on the surface. I swam to shore, remembering something John E. McCosker, a biologist at the California Academy of Sciences in San Francisco, had said in a television program—that white sharks attack to disable their prey, then circle until it stops struggling.

Matt Hinton
Trinidad, California

"Hon, look what I did with your fruitcake!"

R. AIDAN MARTIN AND ANNE MARTIN REPLY: A. Peter Klimley suggests that white sharks reject humans as food because they are too lean, but most shark attacks on humans are very different from predatory attacks. The 85 percent of victims who survive often report that the animal moved slowly and methodically, and that the wounds from the initial (and often only) strike were minor compared with the damage typically inflicted on prey. White sharks are highly curious, and they gently "feel" objects with their teeth and gums. We believe they rarely consume humans because their encounters are usually motivated by curiosity rather than hunger.

Mr. Klimley has suggested that fat helps maintain the white shark's body warmth. But though a pound of dietary fat carries twice the calories of a pound of protein, the useful energy from protein, or heat liberated by its digestion inside the animal, is superior. Pound for pound, protein not only generates the same amount of metabolic heat as fat, but protein also "burns" more slowly, spreading the heat out longer and so maintaining body temperature more effectively. In addition, the importance of marine mammals in the white shark's diet has been exaggerated, partly because of observer bias (it is relatively easy to observe attacks on seals) and partly because gut-content analysis is limited (fish remains are relatively delicate and inconspicuous). Fourteen quantitative studies show that almost 75 percent of the white shark's diet is low-fat food (fishes, squids), and slightly more than 20 percent comes from marine mammals.

Matt Hinton recounts a neat story! White sharks may employ the "bite, spit, and wait" tactic when tackling large and powerful prey, such as northern elephant seals, but with smaller and more agile prey they typically do not delay between attacking and feeding.

(Continued on page 67)

Running Man

Persistence hunter and his quarry

Couch potatoes may disagree, but people are fairly well built to run in the heat. We sweat more per unit of body surface area than any other animal, and our upright posture exposes less body surface to the sun than would walking on all fours, and more surface to the cooling wind. On the hunt, those traits give people a distinct advantage over most quarry. In fact, Australian Aborigines and various Native American and African groups have traditionally practiced "persistence hunting," chasing antelopes or other game in the midday heat, often for hours, until the animals overheat and collapse.

During the past twenty years, Louis Liebenberg, an animal tracker and the owner of CyberTracker Software in Cape Town, South Africa, has observed the only persistence hunters still left, the !Xo and /Gwi bushmen of the central Kalahari in Botswana. He reports a success rate as high as 80 percent—and a meat yield that beats hunting with bow and arrow, club, or spear. Only hunting with dogs proved superior.

Conditions have to be just right: the days must be long and hot, and the terrain must slow down the quarry. Furthermore, the hunters must be terrifically fit—the runs Liebenberg observed lasted as long as six-and-a-half hours and covered as many as twenty-two miles. And the hunters' tracking skills must be exquisite; finding and following the quarry every time it bolts out of sight or mingles with a herd is no easy task—teamwork helps. But done right, Liebenberg says, persistence hunting is so effective that it may have helped select for the excellent thermoregulatory system, bipedal posture, and long strides that we all possess. Perhaps sadly, the practice is dying out, though the physical skill endures in those who shun couches and run for fun. *(Current Anthropology)* —*Stéphan Reebs*

No Joy in Mudville

The freshwater mussels of North America are in trouble. Of 300 native species, some 70 percent are extinct, endangered, or declining. Invasives such as the zebra mussel have been, er, muscling them out of lakes and streams; development and pollution are also threatening their habitats. Now the beleaguered bivalves must add yet another peril to their list of woes: a new study shows that the widely prescribed antidepressant Prozac, a common pollutant, interferes with their reproduction.

Like other drugs, Prozac often ends up in lakes and streams after being excreted and making its way through a wastewater-treatment plant. Fluoxetine hydrochloride, its active ingredient, boosts the concentration of the neurotransmitter serotonin in the brain.

To test its effect on mussels, Rebecca M. Heltsley, a biologist at the National Institute of Standards and Technology in Charleston, South Carolina, and several colleagues placed female eastern elliptio mussels in tanks of water laced with serotonin, or with fluoxetine hydrochloride at various concentrations, some matching the levels that commonly occur in bodies of freshwater. All the mussels were carrying larvae; within forty-eight hours, mussels in each tank had prematurely released their larvae, which were often too immature to survive. The greater the concentration of fluoxetine hydrochloride, the more larvae were released. Better filtering of sewage would give freshwater mussels a less depressing outlook, says Heltsley. (Presented at the national meeting of the American Chemical Society, September 2006)

—*Rebecca Kessler*

Litter Bugs

You may feel more secure when your skeletons are hidden in the closet, but a young assassin bug is safest when the carcasses of its victims are conspicuously arrayed across its back. Investigators have interpreted such "corpse camouflage" as a strategy to help vulnerable juveniles of certain assassin-bug species, which prey on other insects, avoid predation themselves. Sensing nothing but a pile of corpses and other debris, a predator—perhaps a gecko or an adult assassin bug—moves on.

Now Christiane Weirauch, an entomologist at the American Museum of Natural History in New York, has figured out how the juveniles don their camo: they have minute brushes on their hind legs with which they sweep corpses, soil, sand, or plant material onto their backs. "Glue," which oozes from hairlike structures on their backs, sticks the debris in place. When a juvenile molts to a larger—but still juvenile—size, it retains its leg brushes and glue, but it must renew the camouflage. Once it molts to its adult stage, though, both brushes and glue disappear, and the assassin bug faces the world camouflage-free. *(American Museum Novitates)* —*Mary Knight*

Female hawksbill turtle lays eggs.

Baked Eggs

All sea-turtle eggs can develop into either male or female hatchlings; which gender depends on the temperature of the sand where the eggs are buried to incubate. Now, it seems, tourist development is leaving so much hot sand in its wake that batches of sea-turtle hatchlings are tipping heavily female—which could contribute to the endangerment of the various species.

Stephanie Jill Kamel and Nicholas Mrosovsky, both zoologists at the University of Toronto, studied hawksbill-turtle nesting sites on the Caribbean island of Marie-Galante in Guadeloupe. Among hawksbills the "pivotal" temperature is 84.6 degrees Fahrenheit: nests in warmer sand give rise mostly to females; nests in cooler sand yield mostly males. In many sea-turtle populations female hatchlings heavily outnumber the males, which could impair reproduction. But could nest location explain it?

Not surprisingly, Kamel and Mrosovsky determined that sand amid low-growing vegetation is

Migratory dragonfly, radio-ready for takeoff

Four-Winged Migration

Think of a migratory flier, and chances are a bird comes to mind. But at least nine species of dragonfly in North America head south in the fall, too. Until recently, though, migratory dragonflies could not be tracked because radio transmitters were too big for them to carry. A new study has changed all that, and determined that dragonflies and birds abide by some of the same rules of flying.

Martin Wikelski, an ecologist at Princeton University, and several colleagues glued minute, custom-made radio transmitters to the undersides of fourteen dragonflies known as common green darners, which the investigators captured in New Jersey. Then they tracked the darners for twelve days by car and light aircraft. The insects, like birds, began their flights only after several nights of plunging temperatures (a herald of winds from the north that assist their southward journey). Also like most birds, the dragonflies alternated days of flying and resting, stayed put on overly windy days, and avoided crossing large bodies of water.

Unlike birds, though, dragonflies that fly south in the fall probably do not come back in the spring; instead, investigators think, their progeny use the return ticket. Future studies, perhaps aided by satellite tracking and longer-lasting transmitters, may solve some enduring mysteries. For example, Wikelski showed that the dragonflies advanced thirty-six miles in six days, but no one yet knows how far the little migrants ultimately travel, or their final destination. *(Biology Letters)* —*S.R.*

Enemy at the Gates

Plants have pores on their leaves called stomata, which let carbon dioxide in and oxygen and water vapor out during photosynthesis. That function would seem to make each stoma a portal for invaders, too, such as disease-causing bacteria. Indeed, botanists have long assumed that plants cannot bar entry to pathogens, and so must fight them internally. But a new study shows that stomata function more like the portcullis of a medieval city: plants close them when under attack, and invaders pry them open to gain entry.

Maeli Melotto and Sheng Yang He, both plant biologists at Michigan State University in East Lansing, and three colleagues deposited virulent bacteria on the leaves of *Arabidopsis* plants, then observed that most of the stomata closed tight within two hours. The plants, they determined, detect and respond to certain molecules on the surfaces of the bacteria. Thus the "portcullises" are probably the plants' first line of defense against bacterial invaders. But the bacteria kept up the attack, producing a chemical called coronatine that forced the stomata to reopen within a few hours. (Remarkably, the plant biologists also noted that the bacteria selectively swarmed open stomata.)

Pea-leaf stomate, magnified 100X

How have such a dramatic defense and counterattack remained unknown until now? It was simply a case of misguided assumptions. So prevalent has been the idea that stomata can't prevent invasion that investigators studying plant disease often injected pathogens directly into the leaves, thus bypassing the stomata entirely. *(Cell)* —*S.R.*

warmer than the hawksbills' pivotal temperature, and so the nests there are likely to produce females. Sand in the shade of forests high on the beaches is cooler, and so friendlier to males. Trouble is, when Caribbean beachfronts under development are cleared of their native forest, palm trees are often planted instead. Kamel and Mrosovsky found that the sand beneath palm trees gets as hot as it does in deforested areas—3.6 degrees warmer than under native forest, and well above the hawksbills' pivotal temperature. Palm-fringed beaches could therefore produce few or no males—and spell more problems for the hawksbills. *(Ecological Applications)* —*S.R.*

New Planets on the Block

Planets outside the solar system keep popping up in the Milky Way. Two "exoplanets" were discovered 26,000 light-years away, the farthest yet detected—by a team of astronomers led by Kailash C. Sahu of the Space Science Telescope Institute in Baltimore. The team also identified fourteen more possible exoplanets in the same region. Another two exoplanets were identified by a team led by A. Collier Cameron of the University of St. Andrews in Scotland. The new discoveries bring the total number of known exoplanets to more than 200.

Most of those have been inferred from periodic wobbles in the motion of their parent stars, which can be detected from shifts of their spectra. The wobbles could be caused only by the gravitational pull of an unseen giant planet.

But detecting the spectral shifts is tricky, and the four new exoplanets, as well as the fourteen candidates, were all discovered with a much more efficient technique. Telescopes are programmed to search for stars that dim at regular intervals; the dimming could result when an orbiting planet transits, or partly eclipses, the star. The method is so rapid that instruments can repeatedly scan millions of stars for the telltale sign.

All four newfound exoplanets are gas giants, like Jupiter, and at least that big. Unlike Jupiter, though, they are so close to their central stars that they orbit in periods of between forty-three hours and four days (Jupiter orbits the Sun every twelve years). Sahu estimates that some six billion more exoplanets are scattered across the Milky Way, just waiting to be detected. *(Monthly Notices of the Royal Astronomical Society; Nature)* —*S.R.*

Don't Blame the Sun

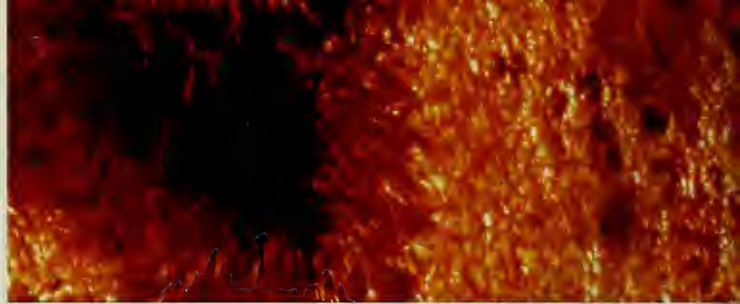
The theory that the Sun, not human activity, is responsible for most of the warming of the Earth in the past century has been debated for many years. According to that theory, the Sun has increased in brightness, and the brightening accounts for most of the warming. A new study puts the theory to rest.

Astrophysicists Peter Foukal of Heliophysics, Inc., in Nahant, Massachusetts, and Hendrik C. Spruit, of the Max Planck Institute for Astrophysics in Garching, Germany, together with two colleagues, analyzed records of variation in solar luminosity caused by changing dark and bright areas on the Sun—sunspots and faculae.

The team began by examining twenty-five recent years of precise solar-luminosity records gathered by radiometers on spacecraft. To peer further back in time, they scrutinized historical records of sunspots and faculae from the past century, as well as isotope ratios in the Greenland and Antarctic ice sheets, which register changes in solar activity for the past 1,000 years. They correlated those data with reconstructions of how temperatures have varied in the Northern Hemisphere during the past millennium, giving a fine-grained picture of the effects of changes in the Sun's brightness on climate.

The Sun did get brighter during the past 200 years, they discovered, but only by about 0.04 percent. That variation, they conclude, is far too small to have contributed substantially to the accelerated global warming observed since the mid-1970s. Although other solar traits—variable ultraviolet rays or solar winds, for instance—may yet be discovered to play a role, people burning fossil fuels are responsible for the bulk of the recent warming. *(Nature)*

—*Graciela Flores*



Sunspots (dark areas) and faculae (bright areas) dot the solar surface.

Warm-Weather Friend

Good news is rare in research on global warming, but here's a hopeful discovery. Certain species of coral may be able to cope with warming seawater with a little help from their microscopic friends.

In return for a safe place to live, in the tissue of hard coral, single-celled algae of the genus *Symbiodinium* supply their hosts with photosynthesized sugars, and help calcify the coral's hard skeleton. When rising sea temperatures kill the algae or cause them to become toxic to their hosts, hard corals suffer bleaching and may die. But some corals harbor several strains of *Symbiodinium*, which differ in their response to light and temperature, and in some of their metabolic products. Investigators suspected that the algal strains might also alter the thermal tolerance of their hosts.

Acropora millepora

To test that idea, Madeleine J.H. van Oppen, a marine geneticist, and Ray Berkelmans, a coral ecologist, both at the Australian Institute of Marine Science in Townsville, transplanted colonies of *Acropora millepora*, a common Indo-Pacific hard coral, from their home waters on Australia's Great Barrier Reef to warmer sites on the reef. They also tested the colonies' thermal tolerance in the laboratory and genetically identified the strains of algae living inside. After a year, the investigators discovered, the transplanted corals increased their heat tolerance, a direct result of shifting the strain of *Symbiodinium* that dominates their tissues. Apparently, the corals initially take up an assortment of strains; if a strain with low heat tolerance is lost during high-temperature stress, a more heat-tolerant strain takes over.

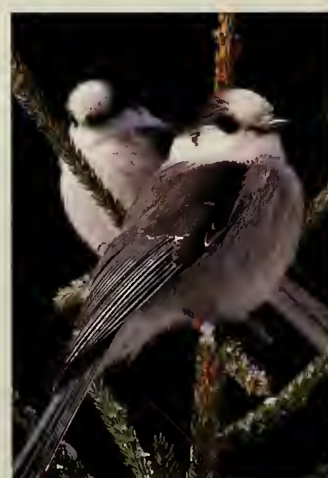
Will hard corals survive the next century's hike in sea temperatures, predicted at between one and three Celsius degrees? Shuffling their *Symbiodinium* strains will probably not be enough to save the corals, say van Oppen and Berkelmans. But it may buy enough time to save them by reducing emissions of greenhouse gas. *(Proceedings of the Royal Society B)*

—G.F.

Broken Refrigerator

In the forests of Ontario, Canada, rising temperatures have caused a decline in gray jays and may eventually eliminate the species in the southern parts of its breeding range.

Thomas A. Waite, an ecologist at Ohio State University in Columbus, and Dan Strickland, a naturalist at Ontario's Algonquin Provincial Park, analyzed population data collected between 1980 and 2006 in the park, which stands at the southern edge of the gray jay's range. Waite and Strickland discovered that in the past twenty-five years the gray jays' breeding season has advanced by about a week. More disturbing, the number of nestlings has declined, on average, by half a bird, and the overall population has plummeted by half. Moreover, Waite and Strickland determined statistically that warm fall temperatures, which have risen by about five Fahrenheit degrees in the past thirty years, probably caused those changes. But how?



Gray jays

Most likely by affecting the food supply: the team found that the breeding of gray jays that received food from people throughout the winter was unaffected by fall temperatures. To prepare for winter, a gray jay hoards hundreds of times its body weight in perishable food—as many as fifty pounds of berries, fungi, insects, and vertebrate flesh. The stores are particularly important because the jay breeds before winter's end. Warm autumns could cause the stored food to rot, Waite and Strickland hypothesize, which would probably delay and compromise breeding. *(Proceedings of the Royal Society B)*

—G.F.

Photo by Craig Chesek/AMNH

A Love Affair with the American Museum of Natural History

Professor William Thierfelder of Dowling College in Oakdale New York has recently named the American Museum of Natural History as the sole beneficiary of his retirement fund. Recently, he wrote a love letter to the Museum, part of which said:

"I have written poems, gotten the idea for the next story, and created lesson plans for my courses in just about every nook and cranny of the Museum. And in recent years, I've been able to take members of my classes at Dowling College to experience first hand the Museum's many wonders.

So it was only 'natural' to name the Museum as the sole beneficiary of my retirement fund. When I pass on to the Beyond—and get to spend quality time with Stephen Jay Gould and other icons of the Museum—my legacy gift will help the Museum to continue its mission. I couldn't think of a better way to say thank you to a place that has been the hive of my continuing education and the source of my never-ending zest for life and the remarkable planet on which we live."

If you would like more information about giving a legacy gift, or a gift that provides you income for life, call or e-mail the Office of Planned Giving at (212) 769-5119 or plannedgiving@amnh.org.

AMERICAN MUSEUM OF NATURAL HISTORY

ARIZONA

Charles Loloma, Hopi
Bracelet, 1975
Heard Museum Collection
On view in **HOME: Native People in the Southwest**

WHETHER YOUR INTEREST LIES IN ART, BOTH ancient and contemporary, Western history, architecture, or Native American culture, Arizona has something for everyone. San Ignacio de Tubac, a presidio ("fort"), was established in 1752 to protect the missions in the area. Tubac, the oldest of the three Spanish forts in Arizona, located forty-five miles south of Tucson, is now a park and museum highlighting the contributions of American Indians, Spaniards, Mexicans, and Anglo-Americans to Arizona's history and development. Tumacácori National Historic Park, fifty miles south of Tucson, protects three Spanish colonial mission ruins in southern Arizona: Tumacácori (1691), Guevavi (1691), and Calabazas (1756). These missions were established in the Pimería Alta by Father Kino and other Jesuits, and later expanded upon by Franciscan missionaries. The adobe structures are on three sites, with a visitor center at Tumacácori. Visitors can tour the mission church, cemetery, museum, and outlying structures and grounds.

The Phippen Museum of Western Art, founded by George Phippen, the first president of the Cowboy Artists of America, celebrates the "unique heritage, mythology, and influence of American Western Art." Located in Prescott, the museum sponsors an annual Western Art Show and Sale on Memorial Day weekend that brings together the finest works of western sculptors and painters.

Arizona's storied past, reaching back thousands of years, is celebrated in museums, parks, and cultural attractions

More than seven decades of history have transformed the internationally acclaimed Heard Museum in Phoenix into what *USA Today* describes as "the nation's most prestigious private Indian arts center." One of the best places to experience the native cultures and art of the Southwest, the Heard Museum boasts ten spacious exhibit galleries and beautiful outdoor courtyards. See exhibits of the Southwest's land and people from prehistoric times to the present; large displays of Indian jewelry, mostly from Navajo, Hopi, and Zuni craftspeople; and a kachina collection ftom Hopi and Zuni tribes that fills an entire room. The Heard Museum also features large collections of Southwest pottery, weavings, basketry, and paintings.

In 1937 Frank Lloyd Wright purchased land in northeast Scottsdale and, along with his apprentices, took on the task of building Taliesin West as a "winter" camp. Wright saw Taliesin West *(right)* as a bold new architectural concept for desert living. Today Taliesin West is a National Historic Landmark as well as the home of the Frank Lloyd Wright School of Architecture.

With such a vibrant blend of cultures and traditions, you'll soon discover why a visit to Arizona is a truly unforgettable experience.

For your free Arizona travel packet, visit arizonaguide.com or call 1-866-891-3638 toll-free.

Turn, Turn, Turn

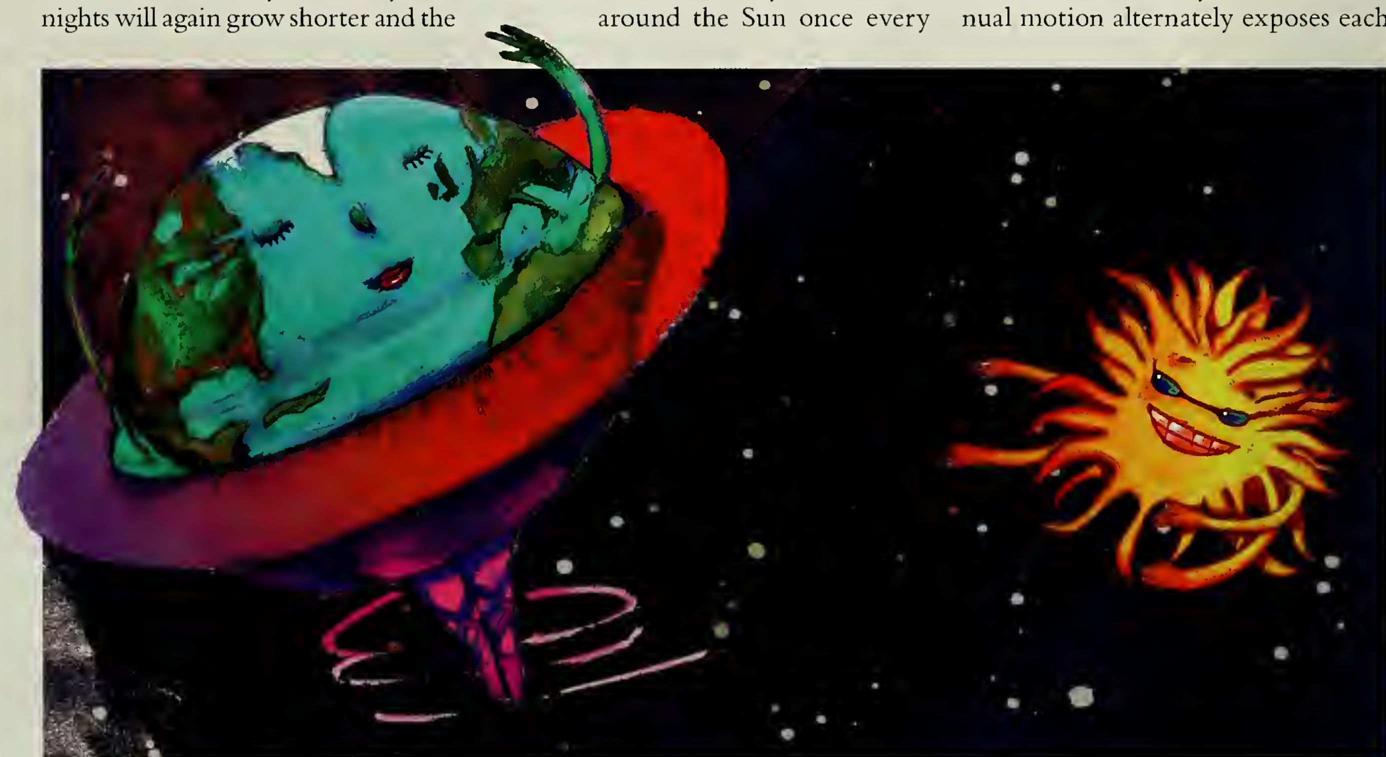
In addition to its daily spin and its annual trip around the Sun, the Earth wobbles—affecting the seasons, the "north star," and human history.

By Donald Goldsmith

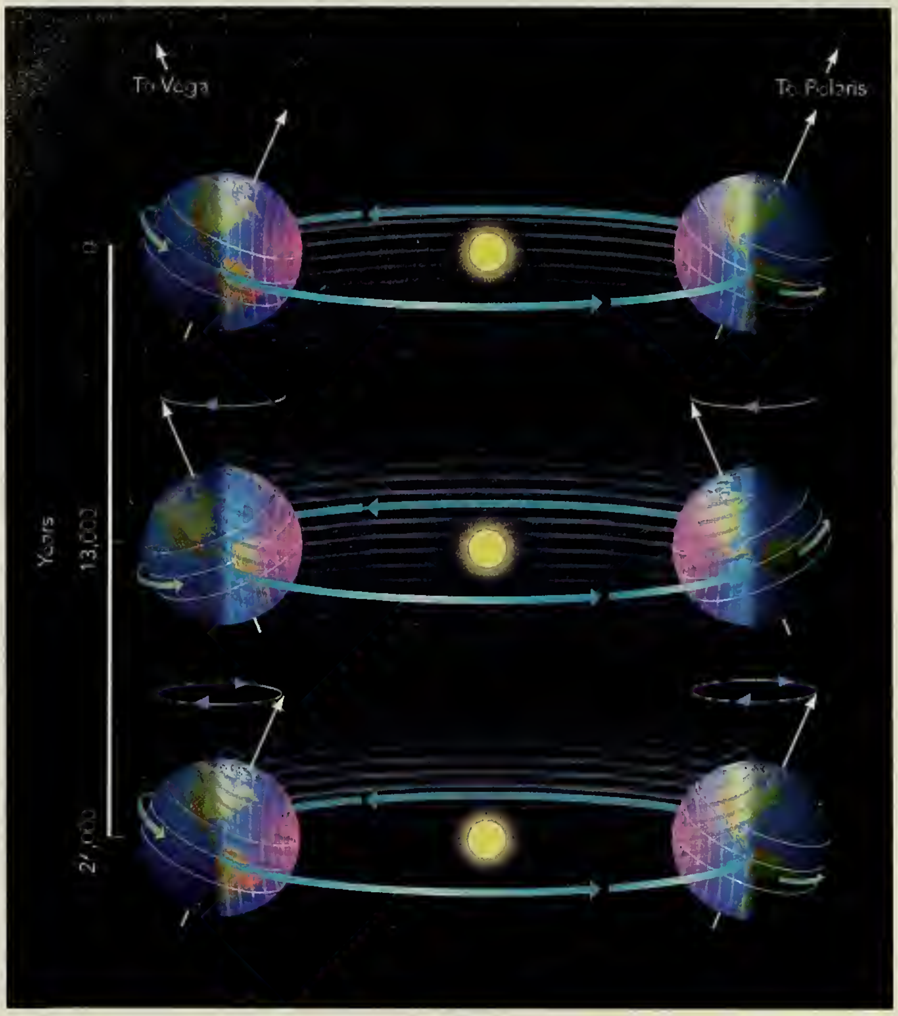
Winter brings the year's longest nights—extra hours of darkness in which to watch the stars wheel their ways around our basic point of reference in the sky: a star named Polaris. Known today as the North Star (for its unique status as the star most closely aligned with the projection of the Earth's north pole on the sky), Polaris seems to stay steady no matter how long the dark night. The explorers who first sailed between continents clung to it for orientation in their travels. And yet, as surely as the nights will again grow shorter and the seasons will change, Polaris will lose its role as our north star. A slow cycle of the heavens will eventually bring Polaris back to its familiar role—but not for another 26,000 years, and not before other stars have taken their turn as celestial beacons for the stargazers of the distant future.

Centuries of effort by the world's finest thinkers have led to a basic understanding of why the winter nights are cold and dark. Today most schoolchildren know that the Earth rotates on its axis once each day and revolves around the Sun once every year—discoveries that long ago shook the very core of human understanding and led to the abandonment of the idea that the Earth lay at the center of the cosmos. Those two rhythms rule our lives: the Earth's daily spin produces sunrise, sunset, and the alternation of night and day. Our planet's annual trip around the Sun takes us through the cycle of seasons, winter to spring to summer to fall.

And just how, exactly, does spring emerge from winter every year? Not, as many believe, because the Earth's elliptical path takes us closer to the Sun. Changes in the distance between Earth and Sun have only a modest effect on the seasonal cycle. Instead, seasonal variations arise because the Earth's axis of rotation, the imaginary line through the north and south poles, does not stand upright with respect to the plane of the Earth's orbit around the Sun. The rotation axis tilts by about 23.5 degrees from perpendicular. It also maintains a constant orientation in space—in other words, with respect to the stars—throughout the course of a year. So our annual motion alternately exposes each



Our twirling Earth, bulging at the equator from its spin, slowly wobbles in space as the Sun's gravity tries to pull it upright.



Earth undergoes three periodic motions: its daily rotation, its yearly revolution around the Sun, and a slow precession, or wobble, of its rotation axis. The wobble causes the axis to sweep out an inverted cone in space above the Northern Hemisphere. The axis traces a complete circle on the sky every 26,000 years [see illustration on page 24]. Polaris and Vega each serve as "north star," at intervals of 12,000 to 14,000 years.

hemisphere, northern, then southern, then northern again, to more direct sunlight.

That direct sunlight, as the Sun rises higher and stays longer in the sky, causes summer in the hemisphere that tilts toward the Sun and winter in the hemisphere that tilts away. (The higher Sun and the longer days make roughly the same contribution to the seasonal differences, though of course the two effects are closely intertwined.) On two days of the year, the spring and fall equinoxes (which fall on or close to March 21 and September 22 each year), the Earth's rotation axis tilts neither toward nor away from the Sun. On those two days, day and night have equal lengths all over the world. In fact, if our planet's rotation axis were perpendicular to the plane of its orbit, rather than tilted, day and night would be equal throughout the year, and there would be no seasons to celebrate.

Lurking within the faithful cycles of day and night, winter and summer, is a third cyclical motion, which arises from the Earth's daily rotation and interacts with its annual revolution. That motion is called precession. It is, in essence, an almost imperceptibly slow wobble that creates a subtle and intriguing wrinkle in time. To visualize precession, imagine a top slowing down as it spins on the floor. Before it stops spinning entirely, it begins to wobble, its rotation axis rolling in various directions. As the axis changes direction, it sweeps out the shape of an upside-down cone, perpendicular to the floor; that motion is precession. There is, of course, one big difference between the top and the Earth: the precession of the top can take less than a second; the precession of the Earth takes almost 26,000 years.

Compared with twenty-six millennia, time scales measured in decades or even in centuries are so brief that for most practical purposes, the Earth's axis continues to point in the same direction. Today, north in any season can be determined by noting the position of Polaris. In the long run, however, the spatial orientation of the Earth's rotation axis does change. Every 26,000 years (more accurately, every 25,785 years), the two points on the sky directly above the Earth's North and South Poles—the extended ends of the axis of rotation—trace out complete circles on the background of stars. The radius of each circle is equal to the tilt of the rotation axis, 23.5 degrees. Thus the rotation axis changes only its orientation, while maintaining a constant angle to the Earth's orbital plane [*see diagram on this page*], as it sweeps out an inverted cone in space.

In spite of the glacial rate of precession, you can't fully understand ancient history or archaeology without taking account of the fact that Polaris has not always pointed the way north. Four-and-a-half millennia ago, when the Egyptian pharaoh Khufu built the Great Pyramid, Polaris was nowhere near the "north celestial pole," the point that lies directly above the Earth's north pole at any particular time. In those days, astronomical observers relied on a much fainter star, Thuban, in the constellation Draco, the dragon, to serve as the north star; they may even have oriented the galleries of the pyramid on the basis of Thuban's position.

One and a half millennia later, at the time Homer composed the *Odyssey*, precession had left Thuban relatively

Circular trace (blue) on the map of stars shows how the direction of the Earth's rotation axis precesses, or wobbles, with time, as seen from Earth. Today's north celestial pole—the point directly above the Earth's north pole—lies close to the star Polaris. In Egyptian times, roughly 4,500 years ago, the star Thuban served as the north star, and in about 12,000 years the north celestial pole will pass near Vega.

useless as a north star. Homer's wandering hero Odysseus had to do his best with the Big Dipper—the seven bright stars of the constellation Ursa Major, or big bear, which then, as now, lay relatively close to the north celestial pole: "For so Kalypso, bright among goddesses, had told him to make his way over the sea, keeping the Bear on his left hand." In fact, the constellation would have moved around the sky quite a bit during the night, making Odysseus's navigational task considerably more difficult than Kalypso's directions imply. Still, the Big Dipper was a rough-and-ready indicator of the way north [*see illustration above*].

The discovery of precession, like Homer's great poem, was a signal achievement of ancient Greek culture. The Greek astronomer Hipparchus, who lived during the second century B.C., is justly famous for being the first to note its effects. Hipparchus made his breakthrough not by observing the position of the north celestial pole, but rather by noting some of the other changes caused by precession. High among them are the times of the year when the Sun reaches particular points on the sky, as it seems to move among the constellations, blocking some of them from view. (Astronomers now realize, of course, that it is the Earth that moves.)

Even as the orientation of the Earth's rotation axis wobbles, or precesses, the Sun continues to take its yearly lap around the sky, along the path called the ecliptic. Although ancient astronomers could not see the stars that happened to lie behind the Sun at various times of year, their excellent record keeping enabled them to accurately reconstruct which constellations provided a "house" for the Sun at any given moment.

There were twelve such houses, which match the familiar constellations, or signs, of the zodiac; together they form a band around the sky that includes the ecliptic. In the zodiacal system for keeping track of the year, created by astronomers in ancient Mesopotamia, each time the Sun entered a new house heralded the beginning of a new month. Every new year, moreover, began on the spring equinox when, as the Mesopotamians had determined, the Sun blocked the constellation Aries from sight.

But Hipparchus noted that something had happened during the two millennia since the Mesopotamian system had been codified: the Sun no longer occupied its specified position on the first day of spring. Instead, he determined, the Sun was reaching its marks along the ecliptic progressively earlier, by one day every seventy-two years. Because precession changes the times of the year of the spring and fall equinoxes—which we also measure by the visible seasonal changes on Earth—the effect acquired its full title: "precession of the equinoxes." If you could wait for 365 times seventy-two years—approximately 26,000 years—you would find that the equinoxes take place once again at their original times of the year, because one full cycle of precession had finished. Nowadays on the spring equinox, the Sun is near the first point in the constellation Aquarius, which leads some astrologers to refer to our epoch as the "Age of Aquarius."

How seriously do you read your horoscope? If you think the Sun's position in a particular constellation has important effects in determining birth signs, yours is wrong! Astrologers codified their basic principles roughly three millennia ago, and so precession has slipped the Sun's location at any particular time of year by about one and a half zodiacal constellations. If the horoscope column says that you are a Libra, for instance, you are actually a Virgo or even a Leo (assuming you judge by the Sun's actual position along the ecliptic at the time of your birth).

Conventional astrologers deal with that awkward fact by arguing that astrology has codified the meaning of the times of the year, not the location of the Sun against the backdrop of constellations in the zodiac. A minority sect, known as "new age astrologers," insists that conventional astrology requires wholesale revision, precisely because of precession. Both groups agree, however, that in the 230th century, more or less, the two systems will once again coincide in their predictions and their accuracy.

For astronomers, the chief effect of precession appears in star charts, which record the coordinates of celestial objects. Those coordinate systems usually designate a particular position on the sky—say, the Sun's position at the time of the spring equinox—as their primary reference point. But precession continuously slides that point along the ecliptic, and—since most coordinate systems depend on the orientation of the Earth in space—it also changes the orientation of the coordinates that astronomers measure from that point. As a result, astronomers must attach a particular "epoch" to the coordinates they use; today the standard epoch is January 1, 2000 (before that, it was January 1, 1950). Computers can readily make the small adjustments needed to update an object's coordinates from the current epoch to the present time; once fed into a telescope's tracking system, the updated coordinates enable astronomers to work unfettered by precessional effects.

From the 130th through the 150th centuries, when Vega becomes the north star, no one will have trouble finding north.

Even in less meticulous circles, though, precession still rears its wobbly head. It affects the calendar, which must correct for the slippage in time that Hipparchus first noted. Our Gregorian calendar incorporates precession by changing the usual rule for leap years: It omits the leap day in every century year, such as 2100, that is not evenly divisible by 400.

What causes precession? The answers are gravity, angular momentum, and the fact that the Earth has a bit of a belly around its midsection, a bulge at the equator. The bulge itself arises from the Earth's rotation, which tends to fling the planet's central regions outward. The gravity of the Sun and the Moon attract the bulge, and tend to make the Earth "stand up straight," attempting to make its rotation axis perpendicular to the plane of its orbit. (The plane of the Moon's orbit around the Earth happens to nearly coincide with the plane of the Earth's orbit around the Sun, so both the Moon and the Sun act in nearly the same way on the bulge.)

If the Earth did not rotate, or if it rotated extremely slowly, the two objects would indeed set the Earth's rotation axis nearly upright. But because the Earth rotates rapidly, the net effect of the Sun's and Moon's gravity on the Earth's bulge drives precession. Draw the vectors, do the math, and you find that the forces give rise to a 26,000-year circle, never changing the amount of tilt but continuously varying the Earth's orientation in space.

Polaris, which has acted as the north star since the time of Columbus, will continue to serve us well for many more centuries; in fact, the north celestial pole on the sky will move even closer to Polaris during the next 150 years. Eventually, however, the celestial pole will wander on, and Polaris will no longer work as a good north star. Our descendants will labor under virtually the same handicap that our brethren in the Southern Hemisphere have for centuries. Bereft of a south star, they have been forced to compensate by using the Southern Cross as a pointer toward the south celestial pole.

In about 11,800 years, just over halfway through the cycle of precession from now, the northern end of the Earth's rotation axis will point almost directly at the extremely bright star Vega. In those navigationally favorable times, from the 130th through the 150th centuries (more or less), no one will have trouble finding the way north on a clear starry night [*see illustration on page 22*].

Do other planets precess? Certainly, provided they, too, are not spinning perpendicularly to their orbital planes, and provided they have equatorial bulges gravitationally affected in the same way that the Sun's gravity affects the Earth. Although astronomers have never directly measured the precession of any planet except our own, an observer on, say, Mars could detect the same kind of precessional changes that we find for Earth.

But the rotation axis of a tilted spinning object is not the only thing that precesses. If an orbit is not perfectly circular, its long axis can change its orientation in space, giving rise to a precession of the entire orbit. For example, the Moon's orbit around the Earth undergoes just such a precession, historically called the "regression of the Moon's nodes." The full cycle of precession lasts 18.6 years, which explains why eclipse "seasons" also vary over an 18.6-year cycle.

Another important example of orbital precession affects the elliptical orbit of Mercury. Astronomers who studied the orbit during the nineteenth century observed a relatively large precessional effect. They calculated that the gravity of the other planets could account for more than 90 percent of the observed precession. But try as they might, a small fraction of the total remained unexplained—forty-three seconds of arc per century. Since each of the 360 degrees in a full circle is equal to 3,600 seconds of arc, the unexplained precession of Mercury's orbit seemed trivial.

But that "trivial" amount turned into a key piece of confirming evidence for Einstein's general theory of relativity. Einstein's theory makes a precise prediction of the amount of precession of Mercury's orbit, by calculating how much the Sun bends

(Continued on page 60)

BIOMECHANICS

The Jaws That Jump

Trap-jaw ants have smashed the record for fastest predatory strike on Earth, with mandibles that double as spring launchers.

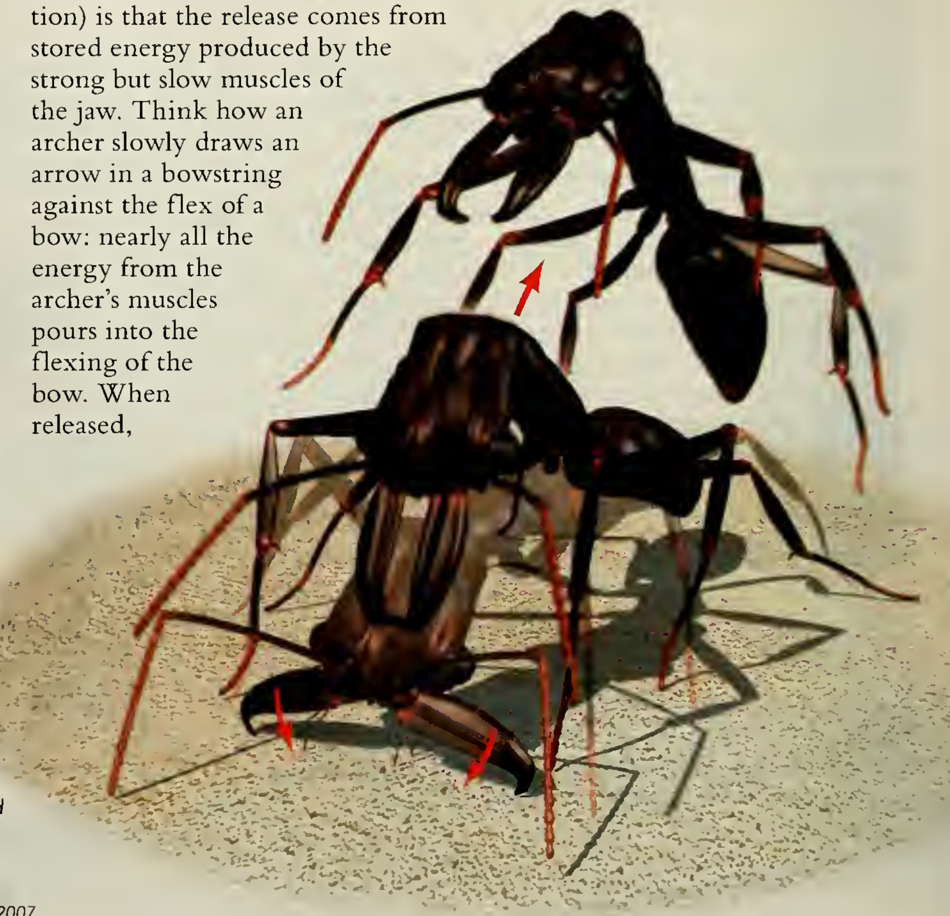
By Adam Summers ~ Illustrations by Tom Moore

Dressed in shorts and wetsuit booties, I was out for a late evening walk in south Florida. Suddenly I felt a dozen little stabbing pains in my foot. Thinking I must have stepped in a stinging nettle, I carefully backed one foot out of range, but the stinging got worse, not better. A flashlight revealed the true source of my misery: my foot had landed squarely in a nest of Argentine fire ants. To this day I bear the scars of their assaults.

Recently I was reminded of just how powerful ants can be when inflicting damage on intruders. A team of biomechanists has studied the incredibly speedy bite of a group of Central and South American ants. The team clocked the bite as the fastest on the planet—and discovered that it also gives the ants the unique ability to jump with their jaws, adding to an impressive array of already known defenses.

Trap-jaw ants nest in leaf litter, rather than underground or in mounds. There they often feed on well-armored and elusive prey, including other species of ants. As they stalk their dinner, the trap-jaws hold their mandibles wide apart, often cocked open at 180 degrees or more by a latch mechanism. When minute trigger hairs on the inner edge of the mandible come in contact with something, the jaws snap shut at speeds now known to reach 145 miles per hour. No passerby could outrace that. The astoundingly high speed gives the jaws, despite their light weight, enough force to crack open the armor of most prey and get at the tasty meat inside.

The key to the jaws' speed (and their even more amazing acceleration) is that the release comes from stored energy produced by the strong but slow muscles of the jaw. Think how an archer slowly draws an arrow in a bowstring against the flex of a bow: nearly all the energy from the archer's muscles pours into the flexing of the bow. When released,



Trap-jaw ant propels itself nearly straight into the air by hitting its mandibles—which are already cocked open—against the ground. The action triggers a latch mechanism that suddenly releases the energy stored in the open mandibles; they close against the ground with a force 400 times the ant's body weight, launching the ant forcefully upward (see trajectory in red on opposite page).

the energy stored in the bow wings the arrow toward its target much faster than the archer could by throwing the arrow like a javelin. The biomechanics of energy storage is the bailiwick of Sheila N. Patek and Joseph E. Baio, both biomechanists at the University of California, Berkeley. They teamed up with two ant experts, Brian L. Fisher of the California Academy of Sciences in San Francisco and Andrew V. Suarez of the University of Illinois at Urbana–Champaign, to look at the trap-jaw ant *Odontomachus bauri*.

Fisher, Suarez, and other field biologists had already noted that catching *O. bauri* was like grabbing for popping popcorn—and very hot popcorn at that, because a painful sting goes with an ant's trap-jaw bite. The insects bounced around in a dizzying frenzy and propelled themselves many times their body length when biologists or smaller intruders approached them. Patek and Baio made high-speed video images of their movements, and discovered that the secret of their self-propulsion was the well-executed "firing" of their mandibles. They also observed that mandibles started to decelerate before they meet—possibly to avoid self-inflicted damage. Most important, the ants had two distinct modes of aerial locomotion [*see illustration below*].

In the so-called escape jump, an ant orients its head and jaws perpendicular to the ground, then slams its face straight down. That triggers the cocked mandibles to release with a force 400 times the ant's body weight, launching the insect ten or more body lengths nearly straight into the air [*see illustration on opposite page*]. The ant doesn't seem to go in any particular direction, but the jump is presumably fast and unpredictable enough to help the insect evade, say, the probing tongue of a lizard. Not only can the jumping ant gain height and sow confusion, but it may also get to a new vantage point from which to relaunch an attack.

The second kind of jaw-propelled locomotion is even more common than escape jumping. If an intruder enters the ants' nest, one of the ants bangs its jaws against the intruder, which triggers the trap-jaw and propels the interloper (if small enough) in one direction, out of the nest, and the ant in the other. Often the force sends the ant skimming an inch off the ground for nearly a foot. The attack, for obvious reasons, is known as the "bouncer defense." In the wild, gangs of defending ants team up to attack hostile strangers, sending them head over heels out of the nest.

From an evolutionary point of view, the trap-jaws are an intriguing story. The ants clearly evolved an entirely new function, propulsion, for a system that was already useful—chewing up prey. Several lineages of trap-jaw ants have independently hit on the tactic of storing energy in their jaws to penetrate well-defended prey. In *Odontomachus*, the horizontal, bouncer-defense jump could have arisen out of attempts to bite intruders, but the high, escape jump—with jaws aimed directly at the ground—must have arisen from a different, perhaps accidental kind of behavior. Such a serendipitous event would have been a rare instance in which banging one's head against the ground got good results.

O. bauri is a member of a large group of trap-jaw ants whose bodies and trap-jaws come in a variety of sizes. That should enable Patek and Suarez to determine the evolutionary history of the jumps, as well as which body parts make for the best jumping. Fortunately, no one has any plans to allow these little beauties to gain a foothold in south Florida. Otherwise my next set of scars might go a lot farther up my leg.

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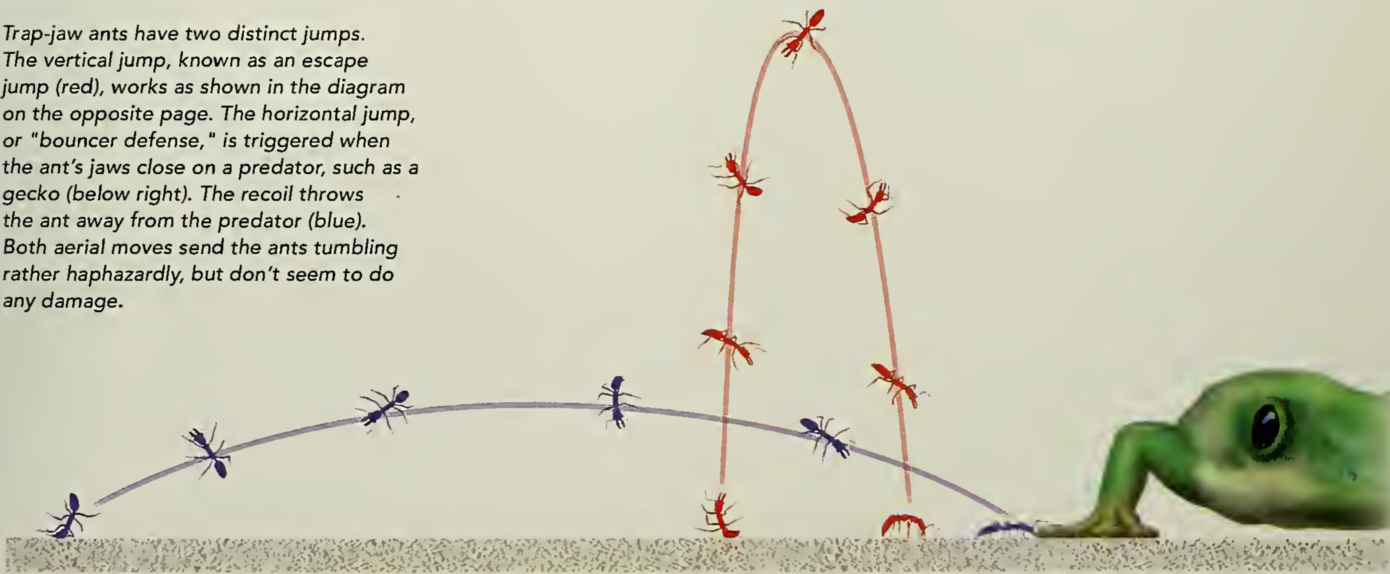
Trap-jaw ants have two distinct jumps. The vertical jump, known as an escape jump (red), works as shown in the diagram on the opposite page. The horizontal jump, or "bouncer defense," is triggered when the ant's jaws close on a predator, such as a gecko (below right). The recoil throws the ant away from the predator (blue). Both aerial moves send the ants tumbling rather haphazardly, but don't seem to do any damage.



NATURAL HISTORY
DECEMBER 2006/
JANUARY 2007

Big Bird

The kori bustard, the world's heaviest flyer, depends on the rain on the Namibian plain for its breeding success.

By Tim and Laurel Osborne

We stood under a broiling sun in the middle of Halali Plain, a sea of baked earth and yellowed, knee-high grass in Etosha National Park, in northern Namibia. A hundred feet away, paying us no mind, stood a large male kori bustard, the world's heaviest flying bird. We attached a parabolic microphone to a tape recorder, aimed the instrument toward the bird, and listened while we recorded his low, booming call. With each call, the kori inflated his esophageal pouch with air until his neck was four times its usual thickness, its patch of white feathers fluffed out like a cheerleader's pom-pom. When he finally released the air, out came a six-note series of booms, each a half-second apart, concluding with a bill snap: a deep, resonant kori mating call. He took thirty seconds to reinflate his pouch before calling again.

Suddenly a dust cloud appeared near a herd of blue wildebeests that had been grazing peacefully 500 yards away. One of us (Laurel) scanned the commotion with binoculars. Three cheetahs were chasing newborn wildebeest calves. Torn between completing the recording session and watching the rare sight of predation in action, the other of us (Tim) finally put the microphone down and picked up binoculars. We both watched as the adult wildebeests in the herd, which was now on the run, stopped, turned, and faced the oncoming cheetahs. Outnumbered and confronted by fifteen powerful wildebeests, the cheetahs skidded to a halt.

Meanwhile, hot on the heels of the cheetahs, came a dozen jackals and two hyenas, already anticipating the kill. Cheetahs lose many of their prey to hyenas, and once they saw the advancing scavengers, they abandoned the wildebeests and ran, straight toward the kori bustard. The kori—no fool he—took one look at the three charging cheetahs and trotted rapidly away through the grass, putting an end to our recording session. The cheetahs bounded off the scene, while the scavengers headed back the way they came, ending the drama.

We weren't too disappointed by the kori's disappearance. Witnessing a sequence of interactions among no fewer than five large animal species—six, including us—had been well worth the disruption. Besides, it was October, and the kori-bustard mating season (which is also the rainy season) had just begun; it would continue until the following March, and so there would be plenty of other chances to record the boom calls of the male koris, belted out to entice females to tryst on the African plains.

Two years earlier, in February 1997, we had begun studying the life history of the kori bustard, having "retired" to Namibia

Female kori bustard hunts for insects in the grasslands of Etosha National Park, Namibia.

from Alaska, where Tim had worked as a wildlife biologist. Most investigators who come to Africa prefer to study endangered "charismatic megafauna"—cheetahs, lions, rhinoceroses, and the like. Although kori bustards are not ferocious, fuzzy, or even particularly threatened, they certainly are mega: they stand four feet tall and have a wingspan of nearly nine feet. The males weigh in at thirty pounds or more. And anyone who has observed the males' striking mating displays and rowdy battles knows that they are charismatic.

Strangely enough, despite their charms, no one had ever bothered to study them in depth before we took up the task. After one week we were the experts in Etosha National Park; after one month, the experts in Africa; after two months we became the undisputed world experts on kori bustards. During the past ten years we have come to know a great deal about the behavior and reproductive life of this remarkable yet overlooked bird, whose fortunes are intertwined with the changing seasons and weather patterns of its African habitat.

Along with twenty-four other bustard species, all large-bodied, ground-dwelling birds of the African, Australian, and Eurasian plains, the kori is a member of the Otididae family. Its closest relatives are its three genus mates, *Ardeotis arabs,* the Arabian bustard of North Africa, *A. australis,* the Australian bustard, and *A. nigriceps,* the endangered great Indian bustard. All four have long bills and backward-projecting crests on their heads. Courting males all give "balloon" displays, just as "our" kori did when it made its boom call, by inflating their esophageal pouches. That accentuates the bases of their white neck feathers, making them visible from afar.

The kori bustard is divided into two subspecies. The one we study, *A. kori kori,* ranges throughout parts of Angola, Botswana, Mozambique, Namibia, South Africa, and Zimbabwe. The other, *A. kori struthiunculus,* lives in the East African nations of Ethiopia, Kenya, Somalia, Sudan, Tanzania, and Uganda [*see map on page 33*]. The total population of *A. koris* is unknown, but the species (that is, the two subspecies together) has been declining in parts of South Africa and elsewhere, largely as a result of habitat loss. For the most part, however, koris seem to be doing fine and remain a common sight throughout most of their ranges, including Etosha National Park.

We were fortunate to have started our study of their life history in 1997: the rains were plentiful that year, and most of the females produced young. We had planned to catch the birds, radio-tag them, and follow their daily peregrinations. At first we could only catch adult males, because they cannot fly farther than half a mile. We flushed them and ran them down on foot after they landed. But the method was not successful with the smaller, lighter females, which can fly long distances and disappear out of sight. (Koris usually fly only when escaping a predator or moving to a nearby location. Mostly they walk instead, at about two miles an hour.)

We caught five males and attached radio tags to them—small devices slightly larger than two double-A batteries, which are fitted to a kori like a backpack. We then tracked the birds every day for as long as three years—until they died or the tag's batteries ran down. We learned that after the breeding season ends in March, the males move off the plains and into the woodlands. We had hoped to determine the size of their home ranges, but we soon discovered that the ranges are anything but consistent: our five koris covered between seventeen and 245 square miles.

The males return to the plains to breed every year in late October or early November. Like many birds, kori bustards breed in a lek—an area where males congregate to display, to squabble, and once

Dominance competition between two male kori bustards in Tanzania erupts into a shoving match. Male posturing and dominance displays during the breeding season often lead to combat.

females arrive, to court. Koris are unusual in that the males gather long before the females arrive, often in late December. That leaves two months for the boys to compete with one another for dominance and for a prime location within the lek. Typically, a kori lek includes six or seven males, each about 500 yards apart. They strut around with tail raised, neck ballooned, and head crest erect [*see photograph on cover of this issue*], pausing now and then to sound their booming call.

One alpha male rules each lek. He maintains his dominance by slowly patrolling his domain. When he approaches other males, most of them show submission: they lower their tail feathers, deflate their neck, drop their crest, and run away. In other words, they impersonate females, then scram. If, however, an approached male holds his ground and maintains his display posture, a fight ensues. The birds circle each other, slowly closing the distance between them. Then they lock bills, shoving breast to breast, sumo-style, for as long as twenty minutes, until one bird breaks away and flees, the victor in hot pursuit. The chases sometimes go on for more than half a mile. The alpha male then returns to the lek to strut his stuff, and the loser slinks back later.

It would seem an obvious advantage for a male to weigh as much as possible to win such pushing bouts, but within Etosha National Park, the presence of numerous predators selects for males that are light enough to get airborne rapidly. The heaviest male kori on record, at forty-eight pounds, lived in a farming area devoid of predators, but the heaviest bird we found in Etosha weighed only thirty-four pounds.

To test male dominance we commissioned a taxidermist to make a slightly larger-than-life fiberglass model of a male kori in display posture. We named him Gronk, after the noise koris make when they are harassed: a low, growl-like bark. We tried Gronk out on several males and soon discovered that he was more than large enough to qualify as an alpha. Most males, when they caught sight of him, assumed the submissive posture and fled. But when we placed Gronk some 200 yards away from a known alpha male, the alpha immediately approached and started circling, challenging his fiberglass rival. Because we were keen to radio-tag him, we had set up a capture net nearby. So before he could actually attack Gronk, we herded him into the net. The incident made us wonder, though: would the lek hierarchy have been upset if the alpha had made contact with Gronk?

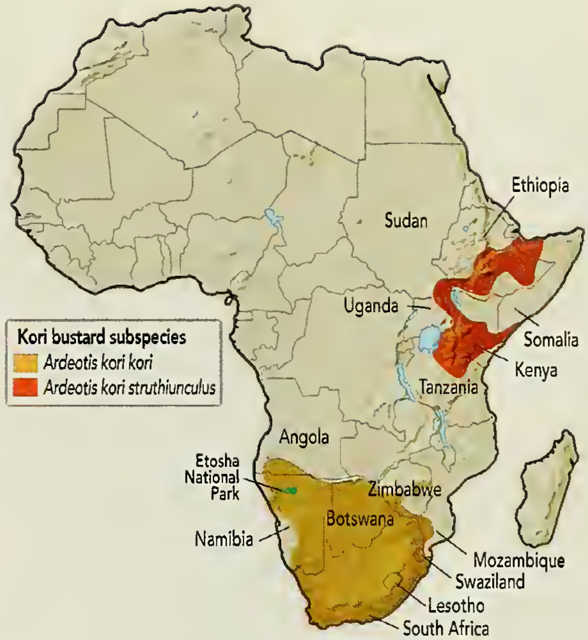
Kori bustards can actively suck water when they drink, as the female in the photograph demonstrates. Most other bird species must fill their mouths, then tip their heads up to swallow.

We decided that would be the first and last time we set up Gronk for an alpha male.

The scientific literature on koris, such as it is, is full of references to "pairs" of kori bustards that feed each other during courtship and share incubating duties on the eggs. Yet in our first year we saw no pairs at all until July, when we spotted a female with her single male offspring; he weighed thirteen pounds and towered over his mother by six inches. When the female turned to feed a tender morsel to her big baby boy, she engaged in the "courtship feeding" described in the literature.

After that observation, we were not surprised to find that kori bustards are polygamous, and that males mate with as many females as possible. The males strut around the lek, stopping to emit their booming calls. Near sunset, the females approach the lek on foot, feeding as they go. The males advance on the females. If a female is receptive to a male, she approaches him and lies down a few feet away. He then straddles her from the back and pecks repeatedly at her head for ten to fifteen minutes. The mating itself lasts just a few seconds, after which the couple parts and never associates again—until perhaps the next mating season.

Before we arrived, the Etosha park staff had never seen a kori-bustard nest or small kori chicks. After observing kori mating behavior in the February of our first study season, we had expected females to



remain on the plains to nest. But they were strangely absent. Not until April did the first female reappear on the plains, and she arrived with a chick that was already quite large. Where was her nest? Where had she raised her chick? The only way to find out was to capture and radio-tag some females, something we had, so far, been unable to do.

We set up a salmon gill net, a hundred yards wide, that we had brought with us from Alaska. Then we slowly herded the mother and her large

Bushmen in Botswana display a captured kori bustard. The bushmen traditionally eat both the meat and eggs of the bird, whose wing-span can reach nearly nine feet.

chick toward it. The mother saw the net, but she was more interested in watching her chick, so she made the mistake of putting her head through the mesh and was soon entangled. We had our first female! We equipped her with a radio tag in hopes of tracking her to her nest the following year. That season we captured and radio-tagged eight more adult females with the gill net.

We tracked the females almost every day and discovered that their home ranges were better defined than the males', covering as many as thirty-four square miles. Surprisingly, an adult female with her young was often accompanied by a subadult female. The association typically lasted just a few days or a few weeks, and then the pair would split apart, never to reunite. We assumed that the birds benefited somehow from the loose associations—perhaps assisting each other on lookout duty for predators.

That first year in the park we located seventy adult females accompanied by chicks: thirty-five had a single chick, thirty-three had two chicks, and two had three chicks. (A mother kori with three chicks had never before been recorded.) We also managed to radio-tag fourteen chicks from nine untagged mothers. Predation on the chicks was high: after a year, eleven of the fourteen—almost 79 percent—had been killed. We wondered if our radio tags or the identification tags we attached to their wings might have attracted predators. So we measured the mortality rate of the untagged chicks that accompanied our nine radio-tagged females. It was similar: 75 percent. Finally, based on our knowledge of how various predators kill, we were able to infer that black-backed jackals and leopards took nearly three-fourths of the kori chicks, and that caracals, lions, and martial eagles probably ate the rest.

On one memorable occasion, we got expert assistance from three San bushmen. We showed them three adjacent sites where kori bustards had been killed. At the first site, they walked around humming to themselves. At the second site they showed us where a leopard had taken a steenbok in addition to the kori. At the third site they were ready to explain what they saw. A female leopard and her cubs had lain in the shade on one side of a tree in the morning while they ate the kori. Then, in the afternoon, they had moved around to the shade on the other side to finish off their kill. The mother had been killing, killing, killing to feed her cubs, but they were growing big now, the San trackers concluded, and she would soon stop killing on the cubs' behalf.

On the way back to our truck the San trackers commented with a laugh that Laurel, who had worn boots all day, walked with her toes crossed. She does; they could tell from the way she walked. Philip E. Stander, a biologist then on the staff of Namibia's Ministry of Environment and Tourism, once asked the same three bushmen to reconstruct 560 known leopard kills. The bushmen turned out to be correct in 98 percent of their reconstructions, without ever having seen the leopards.

Once we had radio-tagged both females and chicks, we began to learn the secrets of kori-bustard life. We finally located six females on nests. But the nests were in thick woodland, not on the plains where we had expected them to be. Two of the females had walked from the plains, where we had seen them near displaying males, to nest in a woodland fifteen miles to the south. We found that kori nests—really just dirt patches scraped free of vegetation—are usually on the east side of a small tree for afternoon shade, and on top of a slight rise to ensure proper drainage. Females and their young remain together until the chicks are eleven months old, then part ways.

During our second year in the park, 1998, the rains were late and poor; only one of our nine radio-tagged females laid an egg. We could find only one other female with a chick in the entire park. The area over which the females wandered was much greater than it had been in the preceding, rainy year: they covered as many as 160 square miles, compared to at most thirty-four the year before. It was the same story in 1999. Then, in 2000, we had double the rainfall of either of the preceding two years, and located thirty-nine females with chicks. Clearly, rainfall was highly influential in determining the kori's breeding success, but how did the two factors fit together?

The Etosha Ecological Institute, home to the government's scientific body in the park, uses satellite data to track fires and determine vegetation growth. The institute staff have also combined the satellite data with direct measurements of grass biomass to determine how the vegetation cover in the park fluctuates from month to month during the rainy season. In 2001 we began comparing the institute's data to the bustards' breeding success, and discovered a strong trend: once 25 percent of the ground is covered by vegetation, the birds breed. In some years, the rains make breeding possible in late December, some years in March, some years never.

In Namibia, we determined, insects make up the bulk of the kori bustards' diet. But without good grass cover, the insect population cannot provide the female koris with the nutrition they need for breeding. The females spend 95 percent of a twenty-three-day incubation period on their eggs. Thus, before laying, the females need to build up enough fat to sustain them through the long incubation.

Their nutritional state determines when they show up in the lek. If the rains are plentiful, they arrive in late October; if the rains are poor, they arrive much later. But if the rains come too late, their chicks are born during the spring dry season, when food is again scarce, resulting in a poor crop of chicks. We thus identified the chain of events driving the kori bustard's breeding: rains bring grass, which feed insects, which fatten female koris, so they can breed successfully.

As for the males in the leks, their boom calls coincide with the rains, and they call only when the rains are sufficient. In some years they call from November until March. In other years the calls echo from late October until January, then cease. In those years, the males abandon the plains, and risk missing the females altogether.

World's heaviest flying bird seldom flies long distances; kori bustards travel primarily by walking. Female koris, such as the one in the photograph, are lighter than the males, and thus better able to fly. The photograph was made in Kenya.

After a decade of observation, the ups and downs of the koris' breeding success have come to remind us of nothing so much as a college fraternity party. The male koris call, strut, push, shove, and fight, not unlike frat boys getting a keg of beer and starting a party early, before the girls arrive. The female koris don't show up until they are nice and plump, not entirely unlike college girls who arrive at the party only after they are primped and ready. During rainy years, the party is a hit, and many young are born. But if the rains are late or sparse, then by the time the girls make an appearance, the boys are long gone and the party is a bust.

Such is the rocky love life of the kori bustard in the semiarid and unpredictable habitat of Etosha National Park. □

Dig It!

An air-lubber surveys the pleasures and perils of the burrowing life.

By Robert R. Dunn

Peter J. Nicholson sneaked out of his Australian boarding school bedroom one night and ran into the nearby forest. The moon was slight and the clouds were heavy, but he knew where he was going. Once there, he took out his flashlight and lowered himself headfirst into the burrow of a common wombat.

The common wombat is a chubby marsupial that can weigh as much eighty pounds. It lives in an underground nest, or den, served by a network of tunnels collectively as long as a hundred feet, and all wide enough—between twelve and twenty inches—to accommodate the animal's hind end. By midnight, it is safe to say, Peter was the only fifteen-year-old boy from Canberra testing his girth against that of a wombat.

Everything was going well until the passage through which Peter was crawling began to narrow. Because Peter's explorations were secret, no one would know where to look for him if he turned up missing. Who would think to check a wombat hole? And the threat of burial was real. Peter had previously found the remains of wombats that had been trapped in their own tunnels. Dirt fell on his back. Deep beneath the forest, he began to worry. When tunnels cave in, animals that are effective diggers can escape. Those that aren't, become part of the soil.

Artist's impression of how Peter J. Nicholson, a young Australian teenager, explored the burrows of the common wombat. Nicholson's explorations as a boy in the early 1960s led to the first detailed documentation of the animal's underground world.

Soil is built of broken-down things—mountains, trees, decayed bodies. The agents of the breakdown are the elements, and also the animals that plow through the earth. But moving through earth is not like moving through air. Earth is denser, more complexly structured, more reluctant to allow passage, and more apt to close in upon you. When people walk, air moves forward and around them. Belowground, wombats and other mammals cannot just push forward. They must dig.

The wombat, for its part, is a rather ordinary burrower. It claws at the earth with its powerful forelegs and spends part of its time aboveground. Truly subterranean animals rarely leave the earth. We only glimpse hints of their presence. We see tunnels in our lawns. We find a mole in the road, after it has tumbled out of an embankment. We sink a spade into the soil and pull up worms. We turn a stone, and a blind ant struggles to disappear. Worldwide, among mammals alone, more than 280 species in eleven families spend most of their lives underground. Still, most underground creatures are insects, worms, or other invertebrates (as are most creatures generally). When Peter looked around him in the wombat's hole, he couldn't help but notice other subterranean life. It must have scurried over, under, and around him.

A digging animal has a few necessities if it is to make headway. It needs to dig. And it needs to do something with the dirt it has dug—dump it out or at least compact it. Those two simple steps, with a few twists, can create complex underground structures, ranging from a few inches to many hundreds of yards in length. Almost all animals' burrows feature two kinds of spaces, chambers and tunnels. (Earthworms mostly make tunnels; ants make lots of chambers.) On top of that basic structure, there are many additional adjustments to prevent collapse, to make it hard for a weasel (for instance) to get in, to prevent carbon dioxide from building up to toxic levels, to store food, and to dispose of waste. But the basics are dig and remove.

Many unrelated lineages of animals have converged on similar body types and lifestyles that make tunneling easier. In almost every case, their adaptations involve a suite of losses (such as reductions in eyes, external ears, and girth) as well as gains (heightened senses of smell and touch, longer incisors, stouter forelimbs with longer, sharper claws). Peter Nicholson possessed none of those adaptations, but he

did have a trowel. To dig his way through the tight tunnel, he hacked away at the earth with his trowel, pushed dirt down beneath his belly, and kicked it behind him.

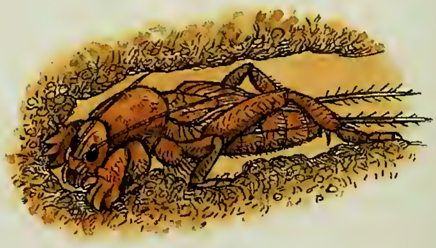
Underground life is at least superficially unappealing. There is no light. It is hard to move. It is hard to detect and find food. Nothing comes easily. But there must also be advantages to being underground, even if it is only to escape the lumbering creatures above. Among the mammals living underground are bamboo rats, moles, marsupial moles, mole rats, pocket gophers, tuco-tucos, voles, and the like, each an independent evolutionary foray into the subterranean ecosystem.

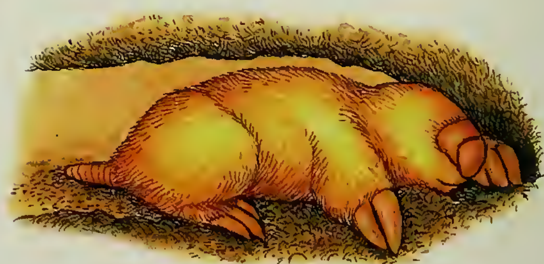
So predictable are the adaptations for life underground, that in 1974 the zoologist Richard D. Alexander of the University of Michigan predicted the existence of a kind of social mammal not then known to exist. On the basis of his knowledge of social insects, Alexander made twelve predictions about the hypothetical mammal. It would live somewhere in Africa; it would have a morphologically distinct queen; it would live on tubers; it would engage in "cooperative reproduction"; and so on. Alexander then went looking for the predicted creature and helped discover and study it in the semideserts of Ethiopia and Kenya. The animal is now known as the naked mole rat *(Heterocephalus glaber)*.

Naked mole rats are best known for their behavioral adaptations—who can ignore a mammal with a queen? But they also have anatomical adaptations for their underground lifestyle. They dig by lifting their head and then bringing their incisors down on the soil in front of them. Most of the digging is done at night, accompanied by low squeaking sounds—mole rat work songs.

As the incisors chip away, the mole rat also scrapes with its forelimbs and pushes the dirt under its belly and out behind itself. Naked mole rats and other members of the genus *Heterocephalus* occasionally even form digging chains. One mole rat shovels dirt back to a second mole rat, which, in turn, pushes the dirt farther back to others, until the last in line expels the soil outside [*see illustration on page 41*].

One obstacle that Peter, the wombat, the mole rat, and most other mammals quickly encounter when digging is their size. It's not just that the bigger you are, the more you have to excavate. A wider and more muscular animal exerts more force, but beyond some optimal (and typically small) size, that greater force does not translate into more force per unit area, or pressure. An elephant can pound mightily





Many burrowing animals dig with their limbs, among them (clockwise, from lower left) the northern carmine bee-eater of eastern Africa, the Atlantic puffin, the northern mole cricket of the central and eastern United States, and the marsupial mole of western Australia. Particularly robust forelimbs have evolved in the marsupial mole and the mole cricket. The birds rely on their beaks to loosen soil, which they then kick out with their feet. The animals are not all drawn to the same scale.

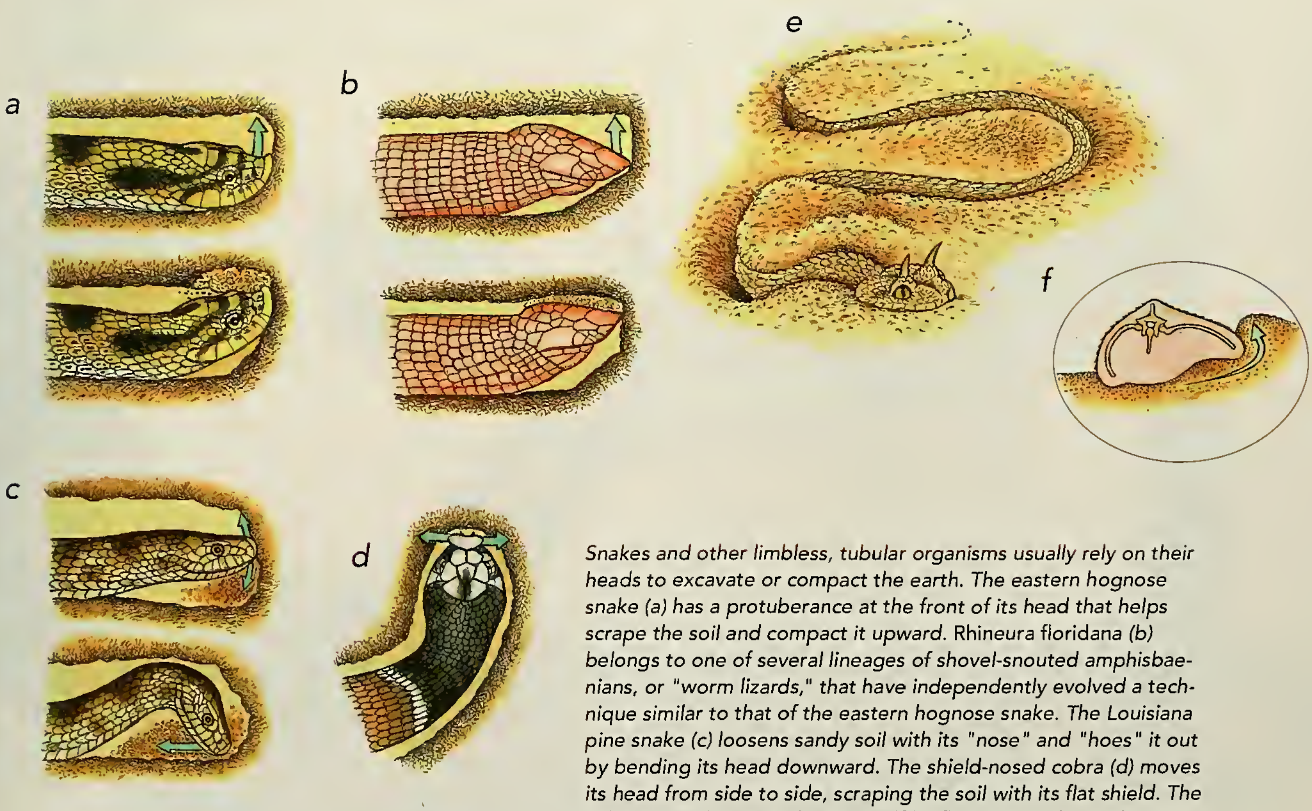
on the ground, but the pressure its foot exerts is less than that exerted by a mole rat's teeth. Smaller and thinner animals can even push their way through the soil with their heads. In addition, where the texture of the soil is not uniform, they can often find ways between and around roots, stones, and other hard obstacles that would block a larger animal.

But if narrower bodies are easier to shove through the messy ether of soil, why are most subterranean mammals kind of, well, plump? One of the answers may be that mammals must maintain a near-constant body temperature. Long, narrow bodies have more surface area relative to their volume than do plump bodies, and so they lose heat faster. The same holds for birds, which also maintain a near-constant body temperature. Although no birds are subterranean, several species, including kiwis, many penguins, and shearwaters, do dig burrows for nesting.

Turn that logic around, and you begin to understand what kinds of animals tunnel more easily beneath us. When animals do not have to produce their own heat, it is less energetically costly to have a tubular body. And so animals shaped like the probing ends of roots have evolved repeatedly: in snakes, in a lineage of amphibians, in no fewer than four groups of lizards, and, of course, in worms and many other invertebrates. The dark landscape of soil is populated with many miniature, elongate writhing beasts—mole crickets, sand gropers, and many kinds of tunneling larvae. Like roots, they find their way chemically. They probe the soil for soft spots. They move and leave a hollow trail behind them.

One major advantage of having a body shaped like a tube is that relatively little dirt must be moved out of the way to advance, and the dirt need not even be moved so much as compressed. But tubular life is not without its disadvantages. Imagine you are twenty feet below ground in a hole barely wider than your body. All around you is earth and darkness. You must move forward without limbs.

So how do they do it? The pine snake loosens sandy soil at the end of the tunnel by scraping with its "nose" and then bends its head down to "hoe" the sand out of the hole. The eastern hognose snake has a small protuberance on the front of its head that acts as a small spade. The shield-nosed cobra wiggles its flat nose while moving its head from side to side. In amphisbaenians, a group of lizards, limblessness has evolved several times. Some are shovel-snouted, such as *Rhineura floridana*, which loosens dirt with its nose, then scoops it up with its head and presses it against the roof of the tunnel (it has an enlarged scale on the top of its head, which may facilitate that



Snakes and other limbless, tubular organisms usually rely on their heads to excavate or compact the earth. The eastern hognose snake (a) has a protuberance at the front of its head that helps scrape the soil and compact it upward. Rhineura floridana *(b) belongs to one of several lineages of shovel-snouted amphisbaenians, or "worm lizards," that have independently evolved a technique similar to that of the eastern hognose snake. The Louisiana pine snake (c) loosens sandy soil with its "nose" and "hoes" it out by bending its head downward. The shield-nosed cobra (d) moves its head from side to side, scraping the soil with its flat shield. The Saharan sand viper (e) buries itself by flexing its side, as shown in the cross section of its body (f), and twisting to scoop out sand.*

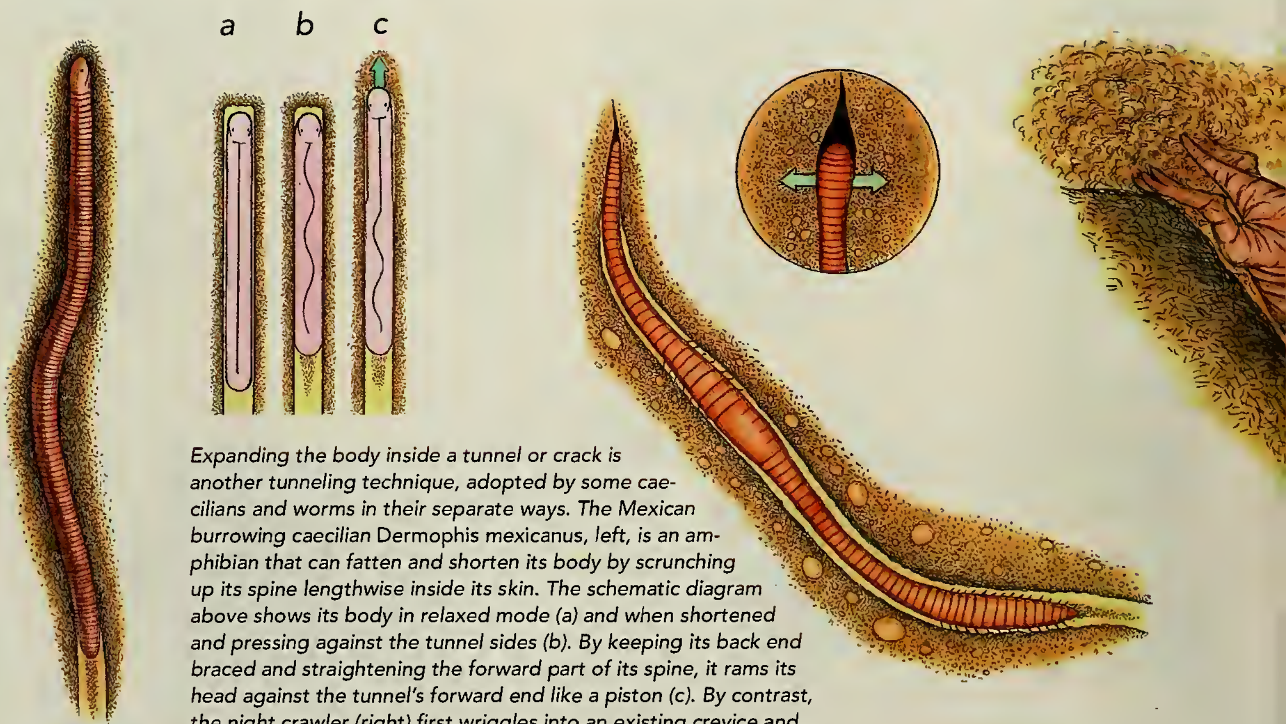
movement). Keel-headed amphisbaenians scoop dirt side to side. Round-headed amphisbaenians ram straight into the soil, but precisely how they do so has yet to be studied.

Some legless animals that move through soil do not burrow forward so much as straight down. The Sahara sand viper commonly sinks into the hot desert sands to surprise prey, avoid predators, and perhaps to regulate body temperature. Instead of tunneling with its head, however, the snake remains entirely horizontal. Its secret trick is to expand one side of the body and twist at the same time. The expanded side then acts like a kind of shovel, scooping sand out from beside and beneath the snake [*see illustration on preceding page*].

Trapped in a hole precisely their own width, many animals—including humans—would die. So even for animals that lack arms and legs, the tunnels they dig generally offer them some elbow room and legroom (for want of better terms). But some legless animals can so contract and expand their bodies, or sections of them, that they can pass through a hole substantially narrower than their most expanded girth.

Among such shape-shifters are some species of caecilians, which are snakelike (or, less flatteringly, wormlike) amphibians. At least one of those caecilians, *Dermophis mexicanus*, fattens and shortens its body by scrunching up its spine lengthwise inside its skin [*see illustration below*]. In essence, the animal turns its skin into a kind of second tunnel, and its skeleton presses against both skin and earthen tunnel. Then, keeping its hind end anchored against the tunnel wall, the caecilian releases its front end and throws its body forward while simultaneously compressing the soil by repeatedly raising and lowering its head [*see "Biomechanics: Squeeze Play," by Adam Summers, September 2003*]. Its skeletal muscles straighten the spine, while other muscles squeeze it into a narrower, longer shape. The combined muscular forces create a hard-driving, pistonlike digging stroke—a motion that has evolved hand in hand with a toughened nose and a thick skull.

Earthworms also push forward through holes no wider than they are, but their main digging force is lateral. Contrary to popular opinion, worms do not simply eat their way through the soil. (If they have the choice, they eat leaves, which they painstakingly pull into their tunnels from the soil surface.) To move, an earthworm pushes the front of its body into whatever crack is before it and then expands its body laterally by shortening itself. The expansion widens the hole and opens up additional cracks it can follow. The technique is known as "crevice burrowing." It is perhaps the best animal imitation of the narrow end of a digging plant root. Like a knife or a sharp stick, small crevice-burrowing worms can exert much more pressure against the soil than big worms can—hence the relative rarity of the latter.



Expanding the body inside a tunnel or crack is another tunneling technique, adopted by some caecilians and worms in their separate ways. The Mexican burrowing caecilian Dermophis mexicanus*, left, is an amphibian that can fatten and shorten its body by scrunching up its spine lengthwise inside its skin. The schematic diagram above shows its body in relaxed mode (a) and when shortened and pressing against the tunnel sides (b). By keeping its back end braced and straightening the forward part of its spine, it rams its head against the tunnel's forward end like a piston (c). By contrast, the night crawler (right) first wriggles into an existing crevice and then expands laterally (detail), compacting the soil around it.*

Recently Kelly M. Dorgan, a graduate student in oceanography at the Darling Marine Center of the University of Maine, in Walpole, Maine, reported yet another way of moving forward. Dorgan put marine worms in a kind of transparent gelatin, at about the same density as sediment, so that she could watch how they moved. She and her co-workers also flooded the gelatin with light; the force the burrowing worm exerted on the gelatin at various points along its body caused differences in how the light was reflected. Dorgan and her team were able to quantify those differences, thereby getting a good picture of how the creature burrows.

Their results show that the marine worm moves forward by extending its mouth—or technically, its pharynx. The animal extrudes its pharynx into a crack, exerting the greatest force at the crack's rim. The crack widens the way split wood spreads under the force of a wedge.

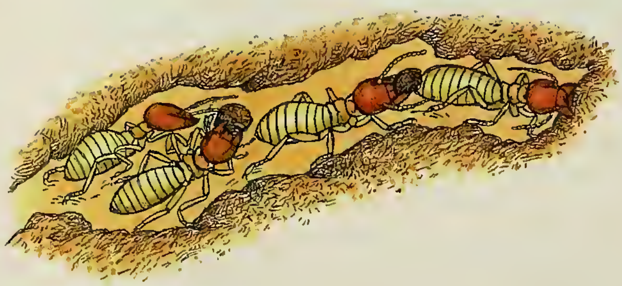
For all of the organisms I've discussed so far, the soil is a barrier that must be carved away, chewed up, or pushed to the side. But for the smallest organisms, the soil is an ether. As solid as it seems, soil is between 40 and 60 percent air. Small animals, such as mites and springtails, simply pass from air pocket to air pocket. Ants and termites are perhaps the smallest organisms that still dig, excavating dirt by the mouthful. Some kinds of termites and ants (including army ants) live their entire lives underground. Not coincidentally, those species lack eyes and are narrow-bodied. Army ants and subterranean termites can dig, but more often than not they just pass belowground among air pockets too small for us to notice.

As Peter Nicholson's wombat tunnel narrowed and its collapse became ever more likely, the young explorer might well have been alarmed. But discovery beckoned more insistently than reason. Determined to push on, he struggled through the narrow part of the tunnel and went even deeper before coming back to the surface. There, he carefully noted and sketched what he had seen.

Peter made many other forays underground, at times even coming face-to-face with the wombats. The result, the most complete study of the burrows of common wombats that had ever been done, earned first prize as a science project. His story is true; it is told in James Woodford's delightful book, *The Secret Life of Wombats.*

Peter eventually graduated from his boarding school and went on to become a businessman. But—a true amateur—he never tired of watching animals. When Woodford was writing *The Secret Life of Wombats,* Peter welcomed the chance to go back to see the creatures. Within minutes, he began to move some dirt and lower himself into a hole. He made it to the first turn in the tunnel but then had to come back up. Like Alice after her visit to Wonderland, Peter had grown too big. His secret world had sealed shut, as though all of it had been a dream. □

Naked mole rats, whose social structure resembles that of an ant colony, sometimes form chains to move excavated soil out of a tunnel. The lead animal (below right) chips its way forward with its upper canines. African termites of the species Macrotermes natalensis *(right) carry soil particles to the surface in their mandibles. There they cement the particles into an ever-growing mound.*



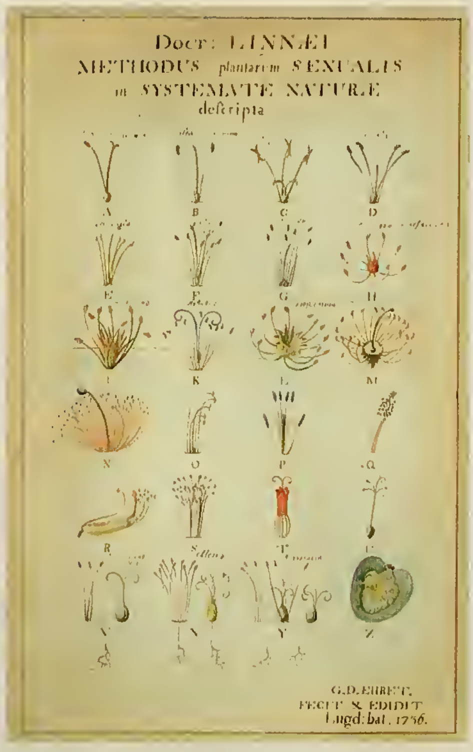
Happy Birthday, Linnaeus

The great biological classifier celebrates his 300th birthday in 2007, while Buffon, born the same year and Linnaeus's greatest rival, has been forgotten. Are we celebrating the wrong birthday?

By Richard Conniff

"Come and stand here," said a guide in a room on the second floor of the house where the naturalist Carl Linnaeus lived with his wife, five children, several monkeys, parrots, and a pet raccoon. The house, in Uppsala, Sweden, is now the Linnaeus Museum. "Do you feel the way the floor is worn away under your feet?"

Linnaeus stood on this spot to lecture his students, in a corner of the room where the professorial elbow naturally eases back onto the carved mantle. By all accounts, he was a charismatic teacher, both ribald and full of religious fervor for the wonders of the natural world. The words Linnaeus spoke here inspired nineteen of his students to undertake voyages of exploration to the far corners of the Earth. He called them his "apostles," praised their every "immortal" discovery, and saw half of them die overseas in the service of his mission. His ideas would also prove indispensable to later explorers, from Captain James Cook and Charles Darwin to biologists of the present day.



Linnaeus's sexual system for classifying flowering plants appears in the 1736 edition of his Species Plantarum. *Linnaeus first assigned the flowering plants to classes according to the number of stamens, or male parts, of each flower, and further differentiated each class into orders according to the number of pistils, or female parts.*

Linnaeus was, of course, the inventor of the system by which every living species gets its two-part scientific name, its genus and its species. *Homo sapiens,* for instance, was a name Linnaeus coined. People today tend to take his system for granted, and scientific names such as *E. coli* and *C. elegans* have become part of the common language. Of Linnaeus himself, even biologists specializing in natural history generally know little or nothing.

But for those who had struggled to make sense of the world before Linnaeus, the system he invented was cause for jubilation. "When Linnaeus started," says Thierry Hoquet, a science historian at the University of Paris X-Nanterre, "natural history was a mess, and people needed guidelines. Do you know in Greek mythology the story of how Ariadne fell in love with Theseus, and gave him a ball of thread to help him find his way out of the Minotaur's Labyrinth? Linnaeus gave us the thread."

Having followed that thread myself, I wanted to know more about Linnaeus. A good way to do it, it seemed to me, was to look not just at Linnaeus, but also at his underappreciated French rival, Georges-Louis Leclerc, Comte de Buffon, whose encyclopedic *Histoire naturelle* became one of the best sellers of the eighteenth century. Both men were born in 1707, and so both are rapidly approaching their 300th birthdays. And both struggled with the same fundamental questions, which still trouble biologists today: What exactly is a species? Where does one species end and another begin? How do species and habitats affect each other?

Both Linnaeus and Buffon were towering figures in their day, and each despised the other. Linnaeus regarded himself as anointed by God to bring order to the chaos of creation. Buffon, who was in many ways the deeper thinker, questioned the very idea of creation and provided crucial scientific evidence against Biblical assumptions about the age of the Earth. Linnaeus focused his relentless energy on naming species and organizing them into groups. Buffon ridiculed the whole idea of imposing order on nature, preferring instead to focus on how species behaved and how they related to one another.

And yet with the questions they asked, Linnaeus and Buffon together launched one of the greatest intellectual quests in history—to understand life on Earth in all its diversity. In place of the animal folklore that earlier naturalists had complacently repeated since Roman times, they demanded specimens and eyewitness accounts. When they began their work, the number of species known to science was no more than a few thousand. Today, it numbers about 1.7 million. Linnaeus will get much of the credit for that, in tercentennial events around the world in the coming year. But as I learned about Buffon, whose own tercentennial will be largely ignored, I began to wonder: could it be that we're celebrating the wrong birthday?

The known world at the start of the eighteenth century did not include Antarctica, nor much more than a glimpse of the coast of Australia. But every ship coming home from Africa, Asia, and the Americas seemed to carry some bizarre new creature: an opossum appeared on the crowded London quays, an iguana in Antwerp, a chambered nautilus shell in Paris. How did such creatures live? Where did they fit in the scheme of creation? How did they affect ideas about our own species? Naturalists caught in the tide of strange new life-forms had no language or methodology for discussing such questions. They could not agree on how to name the plants and animals in their own backyards. How could they possibly make sense of species at the opposite ends of the Earth?

Linnaeus was hardly an obvious candidate to provide the answer. He was a provincial, descended from four generations of Lutheran parsons in the Swedish countryside. But he was a careful observer of plants and animals, and compulsively organized

Botanical expedition to Lapland, where Linnaeus acquired the costume depicted in this 1775 lithograph, helped establish Linnaeus's image as an explorer and proved critical to his success. Linnaeus portrayed his expedition as a perilous adventure among dangerous natives, though he probably spent only a few weeks among the Sami people there.

about recording his observations. He was also ambitious and spectacularly egotistical ("Nobody has been a greater botanist or zoologist," he once wrote). By the age of twenty-five he had already completed an expedition to Lapland, sponsored by the Royal Society of Science in Uppsala. He later depicted his journey as a perilous adventure among dangerous natives in uncharted regions. But in her 1999 biography, *Linnaeus: Nature and Nation*, the historian Lisbet Koerner of Imperial College London concludes that he probably spent no more than a few weeks among the Sami people there. He also claimed double the distance he actually traveled,

Siegesbeck protested that Linnaeus wa[s]
Linnaeus responded by giving the nam[e]

Cherubs and a trumpet-bearing angel weave garlands about the image of Linnaeus in this adulatory, 1806 portrait by Francesco Bartolozzi. The religious iconography reflects Linnaeus's Bible-based beliefs, an integral part of his scientific approach. Like most of his contemporaries, Linnaeus rooted his definition of species in the plants and animals with which the God of Genesis populated Eden.

possibly because he was being paid by the mile.

His image as an explorer proved critical to his success. In Amsterdam, London, and Paris, he dressed in a showy variation on the native costume of the Sami. Together with his buoyant personality, the figure he cut gained him entrée with the leading scientists of the day. He quickly impressed his new friends with his ideas about the classification of species, which he published as *Systema naturae,* at the age of twenty-eight.

The Linnaean system incorporated three important innovations, none of them completely original. First, Linnaeus classified flowering plants according to the number of stamens and pistils, the male and female parts, in each flower. Such a simplistic sexual system was, he knew, artificial (other botanists soon replaced it with a reliance on a broader range of traits). But it instantly opened up the botanical world to anyone who could look into a flower and count. Second, he devised precise rules for describing any species, which, again, even beginners could follow. And third, he gradually introduced his binomial system. A species that used to suffer under the name *Arum summis labris degustantes mutos reddens* became instead simply *Arum maculatum.*

Linnaeus shrewdly served up this new system with a lyrical dollop of sexual innuendo. He described flower petals as "the bridal bed," perfumed and hung with "precious bed-curtains," awaiting "the time for the bridegroom to embrace his beloved bride." He spoke blithely of two brides in bed with one husband (two pistils and one stamen).

Sex undoubtedly attracted newcomers to the charms of botany, and the simplicity of the Linnaean system gave them confidence in their identifications. The French philosopher Jean-Jacques Rousseau later celebrated the Linnaean system as a source of "great pleasure," because the layperson was no longer confined to making isolated observations. Testimonials of delight and gratitude arrived from around the world. By the time he was thirty-three, Linnaeus was already boasting that scholars abroad regarded him on a par with Newton and Galileo.

Then, as now, Uppsala was a college town of pink-, cream-, and ochre-colored buildings arranged around a pretty little river, the Fyrisån. The garden where Linnaeus practiced his craft as a botanist and as a professor at Uppsala University occupies much of a city block in the middle of town, with his house on one corner. From here, Linnaeus used to lead regular collecting excursions into the local countryside joined by as many as 300 people at a time. With his characteristic passion for order, Linnaeus organized them into platoons. They armed themselves with butterfly nets and carried their trophies home pinned to their hats. Kettle drums and hunting horns announced their jubilant return at the end of the day, accompanied by cries of "Long Live Linnaeus!"

From the start, Linnaeus also attracted critics. The German botanist Johann Georg Siegesbeck protested that Linnaeus was turning innocent flower gardens

...rning gardens into beds of harlotry. ...iegesbeckia to a foul-smelling weed.

into beds of harlotry. Linnaeus, who suffered criticism poorly, responded by giving the name *Siegesbeckia* to a small, foul-smelling weed. Another vocal critic, though not on sexual grounds, was the French naturalist Buffon.

The Jardin des Plantes in Paris is today an enclosed compound of rose gardens, tree-lined alleys, and museums about the natural world. Georges-Louis Leclerc, a son of provincial bourgeoisie, assumed the powerful title of administrator here in 1739, when he was just thirty-two. During the next half-century, he more than doubled the size of the Royal Botanical Garden, as it was then known, to its present sixty-four acres. He also laid the foundations for what was to become the Muséum national d'Histoire naturelle, one of the finest natural history museums in the world. Leclerc was a talented administrator, politically adroit, a confidante of everyone from Benjamin Franklin to King Louis XV. But the key to his reputation was his writing, which made him internationally famous as Buffon—later Comte, or Count, of Buffon—a name taken from a small Burgundy village near his country home in Montbard.

From 1740 on, Buffon spent half the year in Montbard ("Paris is hell," he wrote). Here Buffon set out to catalogue the king's collection of natural artifacts, taking on his new task with such enthusiasm that he eventually wrote thirty-six volumes of his encyclopedic *Histoire naturelle.* It became an attempt to synthesize everything then known about the animal and mineral worlds. The *Histoire naturelle* was an immediate best seller—and remained a pillar of French literature until Buffon's lofty prose fell out of favor in mid-twentieth century.

What made Buffon different was not just his style, but also his scrupulous avoidance of religious or supernatural explanations. Linnaeus and most other contemporaries still rooted their definition of species in the plants and animals created by God to populate Eden. Buffon, by contrast, thought it was absurd to imagine God being "very busy with the way a beetle's wing should fold." He defined a species scientifically, as a group of animals breeding together over time.

Such departures from orthodoxy angered religious authorities, who presented Buffon with a list of fourteen "reprehensible statements." Buffon dutifully signed a declaration of his faith in Scripture. ("It is better to be humble than hung," he remarked.) But he left his "reprehensible statements" unaltered.

Books, a globe, and a few animals serve as decorative elements in this 1769 portrait of Buffon, in contrast to the religious imagery in the painting of Linnaeus on the opposite page. Unlike Linnaeus, Buffon scrupulously avoided religious and supernatural explanations. Buffon suggested that animals were not immutable forms created by God, but rather adapted to their habitats.

Buffon's keen interest in habitat and behavior anticipated sciences such as ecology and ethology, which were still 200 years in the future. And though he had no inkling of evolution, he wrote about how species could be transformed by their habitat. He believed, for instance, that a cold, wet climate caused animals in the Americas to be smaller. (His friend Thomas Jefferson, then the American ambassador to Paris, gently corrected this error by presenting the Royal Botanical Garden with the hide of a moose.) Buffon's aim was to incorporate particular observations about animals into general theories about the natural world, and it earned him a reputation as "the Pliny and the Aristotle of France." Given the egos involved, a clash with the "Newton and Galileo" of Sweden was inevitable.

Buffon struck the first blow in the mid-1740s, attacking Linnaeus for imposing an artificial order on the disorderly natural world. He gleefully pointed out absurdities in the groups Linnaeus had proposed. Did tulips really belong with barberries? Or elm trees with carrots? Linnaeus had mistakenly grouped those species together because he did not realize that a particular trait—the number of pistils and stamens, for instance—could evolve independently even in the most distantly related species. It was even worse in zoology. On the basis of dental structure, for instance, humans and monkeys both turned up in the order Anthropomorpha. But so did two-toed sloths. "One must really be obsessed with classifying to put such different beings together," Buffon wrote.

Buffon thought it was absurd to imagine God being "very busy with the way a beetle's wing should fold."

Linnaeus dismissed his antagonist as a "hater of all methods," who delivered "few observations" and much "beautiful ornate French." He quoted the Bible ("And I have cut off all thine enemies out of thy sight") to prophesy that the "Frenchman named Buffon" who "always wrote against Linnaeus" would suffer the wrath of God.

Buffon's objections to the Linnaean system arose partly from sincere belief. "Nature moves through unknown gradations and consequently she cannot be a party to these divisions," he wrote, "because she passes from one species to another species, and often from one genus to another genus, by imperceptible nuances."

He was highlighting a problem that bedevils biologists to this day. The Linnaean system, even in its modern form, is far from perfect. New evidence routinely obliges taxonomists to move species from one genus to another, or even to an entirely different order. At times, the revised groupings can seem as absurd as the ones Buffon lampooned. Buffon was also correct in arguing that the Linnaean system is often arbitrary. Taxonomic "splitters" tend to recognize new species on the basis of relatively small differences. Taxonomic "lumpers" group them together on the basis of traits they have in common. Then they fight.

But if the system Linnaeus invented is so flawed, why has his reputation endured? Partly it's because binomial identification has proved so convenient. And partly it's because Linnaeus was extraordinarily lucky. Although he was thinking about God and creation, he developed a rudimentary hierarchy of classification that would prove congenial, a century later, to the new evolutionary thinking of Darwin. His timing was also impeccable. He provided a coherent system of classification just as the age of discovery was revealing the overwhelming richness of plant and animal life.

Buffon, meanwhile, proposed no alternative way of coming to grips with the abundance of new species. He made the mistake, as absurd as anything in Linnaeus, of putting human beings at the center of the animal world, and his *Histoire naturelle* paid inordinate attention to species that were useful and familiar to us. Perhaps Linnaeus was a mere collector and classifier, as Buffon argued. And maybe he lacked Buffon's insight into ecology and animal behavior. But Buffon somehow missed a point all modern scientists understand: Classification is the essential first step. You need to know what species you are looking at, before you can begin to talk about how they behave.

The attack on Linnaeus mainly hurt Buffon himself. According to Phillip R. Sloan, a historian of science at the University of Notre Dame, the *Histoire naturelle* was quickly translated into most major European languages. But it was twenty-five years before the first translation appeared in England, where the cult of Linnaeus was particularly devout. (Even in the eighteenth century he was celebrated there as "the immortal Linnaeus.")

But does Buffon deserve to be forgotten? His relative obscurity, like the immortality of Linnaeus, also turns out to be largely a matter of luck.

From Montbard, I walked along a canal to a collection of handsome stone buildings with red tile roofs, just outside Buffon's namesake village. It's an old forge where, late in life, Buffon conducted a series of remarkable experiments. He had his workers take molten balls of iron of various size and composition from the smelter and carefully measure how long it took them to cool down. His theory was that the Earth originated as a fireball, gradually solidifying as it cooled. By scaling up from iron balls to the size of the planet, he hoped to estimate the age of the Earth. His numbers

Le Jardin des Plantes, the most important botanical garden in France, is depicted around 1805. In his half-century as its administrator, Buffon more than doubled its size. According to one story, Buffon's son was sent to the guillotine during the French Revolution by former neighbors that Buffon père had evicted in the course of expanding the garden.

ranged from 10 million years to as little as 75,000 years, the estimate he published when his "Epochs of Nature" finally appeared in 1778.

Geologists now know that the Earth is billions of years old. But Buffon's work was the beginning of the end for the biblical belief that all creation dated back just 6,000 years. According to the late Stephen Jay Gould, "Epochs of Nature" was "the most important scientific document ever written in promoting the transition to a fully historical view of nature."

The forge is now a museum, but amazingly, the exhibits make no reference whatever to the experiments Buffon conducted there. And that seems to be Buffon's fate in history. His ideas, though essential in their day to the advancement of science, were consigned thereafter to oblivion.

Thierry Hoquet, the author of a recent book about Buffon, credits him with four important ideas in the history of science: the understanding of geologic time, the definition of species on biological terms, the role of habitat in shaping species, and the conviction that species can transform over time. Those ideas all stand up to modern scrutiny. But they are relatively complex, and buried in a prodigious stream of other ideas.

Buffon's reputation also suffered for political reasons. He died in 1788, a year before the French Revolution, which, unsurprisingly, had little regard for such a close ally of the king. Buffon's son went to the guillotine. At least the revolutionaries understood the value of Buffon's work well enough to found the Muséum national d'Histoire naturelle on the collections he had largely assembled. But one of the early zoologists there, Georges Cuvier, set out to turn natural history into a scientific discipline. And clearing the path to professionalism meant pushing Buffon and the kind of amateur naturalists he had inspired into the dustbin.

But even Cuvier later conceded that Linnaeus and Buffon together possessed the essential tools for rapidly advancing the scientific study of nature: "Linnaeus knew with precision the distinctive traits of creatures; Buffon comprehended in a glance some of their most remote relations." Without both, natural science as we know it would not exist.

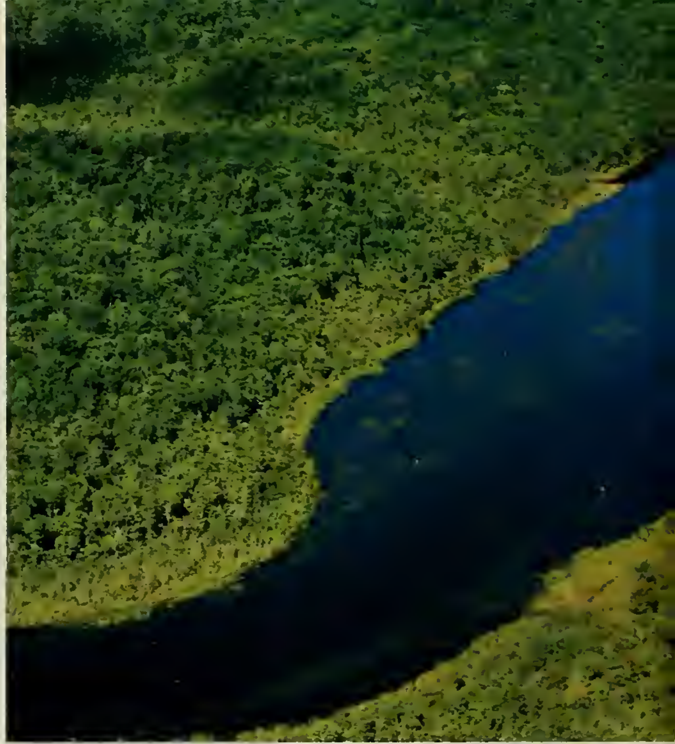
At the Jardin des Plantes, a bronze statue of Buffon presides in casual splendor over the gardens and the natural history museums he helped make great. One day this past summer, a worker—an unwitting agent of the cult of Linnaeus—set up a sprinkler directly in front of the statue, so that it seemed to be spitting indifferently onto Buffon's ruffled blouse. But then the pressure went off, and for a little while, the image of Buffon glistened again under the Paris sun. □

THIS LAND

Salt of the Earth

Hidden among Florida's sand pine scrublands is a diverse host of other habitats.

By Robert H. Mohlenbrock



Visitors to central Florida who drive through Ocala National Forest without leaving the main roads may get the impression that the region is one giant sandy area with scattered pine and shrubby thickets. That habitat, known as sand pine scrub, certainly dominates, but if you poke around a little further, you'll find natural springs, clear streams suitable for canoeing, hundreds of lakes of every size, cypress swamps, longleaf pine savannas, wet prairies, and other natural attractions. Although Ocala is the only national forest in the continental United States with subtropical conditions, there is also a hardwood habitat at its northern end, whose tree species are common to areas much farther north.

Large shell middens, or ancient trash heaps, beside some of the springs, creeks, and rivers show that Native Americans lived in the region for thousands of years before the first Europeans arrived. Spain claimed Florida in the sixteenth century, but abandoned the claim two centuries later, and Florida entered the Union in 1845. Pats Island, within Ocala, has more recent historical interest. The name designates an isolated forest, not an actual island: here a swath of longleaf pine is surrounded by a sea of sand pine scrub. Marjorie Kinnan Rawlings, who stayed at Pats Island in October 1933 with two local residents, Calvin and Mary Long, based her Pulitzer Prize–winning novel, *The Yearling*, in part on her hosts' experiences. Although the "island" is now uninhabited, visitors can walk the Yearling Trail, off Florida Highway 19.

Coontie plant, a species of cycad

You can sample a variety pack of the region's habitats about eight miles to the north of Pats Island, near the town of Salt Springs. The springwaters rise in a pool and meander four miles southeast as Salt Springs Run, before they empty into Lake George. They originate in a fairly shallow aquifer kept warm by the mild climate, not geothermal activity. They maintain the pool at about seventy-two degrees year round. The water is not only warm, but also salty. One theory is that it originated as ancient seawater that entered the aquifer in Pleistocene times, between 1.8 million and 12,000 years ago, when sea levels were often high. Another possibility is that it has penetrated inland from thin salt beds and from seawater that has been concentrated in tidal lagoons.

HABITATS

Sand pine scrub Distinguished by two- to three-inch-long needles in clusters of two, sand pines rise between thirty and sixty feet high. Beneath them grow bluejack oak, Chapman's oak, and sand live oak. Farkleberry, with acrid fruits, dominates the shrub layer. Other common woody species are dwarf palmetto, garberia, Jackson vine, and woody goldenrod. Lichens, popularly referred to as deer moss, form light gray, crumbly mounds across the sandy soil, which is so dry in places that prickly pear cactuses also appear.

Moist hammock American holly and southern magnolia, two evergreens popular as ornamentals, are the signature trees. In spring, the magnolia puts out ten-inch-wide white flowers; they are followed by cone-shaped fruits containing red seeds. American holly blooms during the summer, its small, whitish flowers paving the way for red berries. Common shrubs are American beautyberry, coastal plain staggerbush, and rusty staggerbush. Dwarf palmetto and Jackson vine are also common. Partridgeberry, with its little round leaves, provides the ground cover.

Pond pine flatwoods The five- to nine-inch-long needles

Salt Springs Run, looking west

Swimmers and snorkelers can gain access to the pool in the forest's Salt Springs Recreation Area, near the town. The facilities also include a campground, picnic shelters, restrooms, a concession stand, fishing piers, and boat ramps. But to explore the forest habitats, look for the Salt Springs Trail, a two-mile loop that begins along the east side of Florida Highway 19, about a mile south of the campground. Dropping almost imperceptibly downhill from its starting point, the trail goes through a sand pine scrub habitat, a moist hammock (a tract of forested land that rises above adjacent marshland), a pond pine flatwoods, and an extensive bayhead—a swampy forest dominated by several species of bay trees.

Although distinguished by different species of trees and shrubs, all of the habitats merge into one another to some degree. Eastern diamondback rattlesnakes live in the area, so it is safer to keep to the trail. In the wettest part of the bayhead, the way is elevated on a boardwalk. The halfway point is an observation deck that overlooks Salt Springs Run.

Notable at the beginning of the trail are two specimens of coontie *(Zamia floridana)* that the Forest Service has planted. The species is a native of the sand pine forest, but it has become rather rare. It stands about three feet tall and has long, stiff leaves that resemble palm leaves. The seeds are orange and about an inch long, borne in cones about the size of hand grenades (in fact, the cones look a bit like hand grenades). Coontie is one of only eleven genera and about 140 species of cycads that remain in the world today. The cycads, which are related to conifers, were the dominant plants on Earth when the Jurassic dinosaurs roamed, between 200 million and 146 million years ago.

The coontie plant grows from a large underground stem that is filled with a starch known as Florida arrowroot. From the time of early Indian occupations until the early European settlers, the underground stems were dug, prepared, and eaten. At one time several commercial coontie mills were operating in central and south Florida. The starchy product is said to have a vanilla flavor; the journal of an early settler describes it as "giving a very sweet cookie, or you can boil it up sort of like grits and make a breakfast cereal out of it." Unless the underground stems are properly prepared, though, they are poisonous.

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www.fs.fed.us/r8/florida

of the pond pine grow in groups of three, and they are conspicuous on the trunk as well as on the branches. The trees grow sixty feet tall. Sweet gum and wild olive trees also live in this habitat. Switch cane, a bamboo-like grass, stands as high as twelve feet; slender woodoats is a grass that grows in clumps. Yellow jessamine climbs over the vegetation.

Bayhead This swampy forest is dominated by four species of bay trees. The leaves of red bay and swamp bay, both in the laurel family, have a spicy aroma when crushed. Sweet bay, a kind of magnolia, has white-backed leaves. Loblolly bay, in the tea, or camellia, family, has leaves that resemble the leaves of magnolias, but edged with small teeth. Other common trees are dahoon, red maple, and swamp tupelo. The understory is made up of cinnamon fern, marsh fern, netted chain fern, royal fern, and stinking camphorweed. A high-climbing vine is laurel greenbrier.

Streamside Growing on the bank of Salt Springs Run is Jamaica swamp sawgrass, a coarse sedge with sharp teeth along the edge of its narrow blades. Largeleaf marsh pennywort and southern cattail are rooted just offshore.

Best Books for Young Readers, 2006

By Diana Lutz

FOR THE VERY YOUNG

Discovering Nature's Alphabet, by Krystina Castella and Brian Boyl (Heyday Books; $15.95)

This elegant alphabet book was inspired by a tree in the shape of a Y at Joshua Tree National Park. Noticing the tree, the authors, a husband-and-wife team, challenged each other to find the forms of other letters in nature. They found a C in a seedpod on snow, an S in a sinuous cactus, and a P in the tail of a gecko on a wall. Five years and 2,000 photographs later they had finished this quiet but elegant earth-art alphabet that combines the fluid forms of script letters with the engaging irregularities and rough textures of living things.

Slippery, Slimy Baby Frogs, *by Sandra Markle (Walker & Company; $16.95)*

There's a reason most eggs have shells. Frogs—whose eggs are shell-less—have to struggle to keep their eggs moist. If the egg's thick, protective jelly coat dries out, oxygen can't get through to the developing embryo inside. Foam-nest frogs moisten their eggs, Sandra Markle explains, by secreting a sticky liquid that they whip into bubbles with their hind legs, and then laying their eggs in the foam, which hardens around them and prevents them from drying out. Trapped inside the bubbles of foam is a supply of oxygen for the growing baby frogs. Other frogs pee on their eggs periodically or stuff them into pouches on their backs, where they are moistened by mucus secreted by the skin. Those are only a few of the fascinating frog facts in Markle's new book. In her acknowledgments she thanks four frog experts and seven wildlife photographers. By drawing on such a depth of expertise, she has produced a photo essay that works on two levels: it enthralls children even as it entertains knowledgeable adults.

Marvelous Mattie: How Margaret E. Knight Became an Inventor, *by Emily Arnold McCull (Farrar, Straus and Giroux; $16.00)*

The machine that cuts, folds, and glues the square-bottomed paper bags at your local grocery has lately enjoyed a minivogue, appearing in many publications, including the magazine I edit. *Marvelous Mattie* is a picture book about the woman who invented it—and roughly ninety other ingenious devices. She got an early start, supplying her brothers with acrobatic kites and racing sleds. By the time she was twelve she had invented a guard to prevent heavy metal shuttles from flying off automatic looms and beaning nearby workers. *Marvelous Mattie* takes her story up to the invention of the paper-bag machine, the theft of her paper-bag patent, the ensuing courtroom battle, and her ultimate triumph. In charming watercolors, red-nosed, plaid-panted men goggle at the slim-waisted, rosy-cheeked Mattie like sailors at a mermaid. But small drawings at the bottoms of the pages, meant to be Mattie's notebook sketches, can be hard to understand.

Extreme Animals: The Toughest Creatures on Earth, *by Nicola Davies; illustrated by Neal Layton (Candlewick Press; $12.99)*

In the past ten years the science press has been full of stories of extremophiles. That usually means oddball bacteria that can withstand extremes of temperature, *p*H, or radiation. But I've always wondered just how much interest people really have in such single-celled creatures, marvelous as they might be. *Extreme Animals* broadens the picture to include larger, more familiar animals that can lay claim to various incredible qualities or stunts of endurance.

Nicola Davies begins with a contest that pits the Arctic musk ox, the bowhead whale, the emperor penguin, the polar bear, and the sea otter against one another for the title of world's

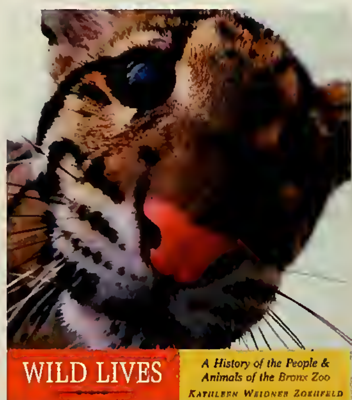
warmest coat (you don't know who wins, do you?). Wood frogs, ice fish, and springtails vie for the honor of having the most potent antifreeze (the springtails win). The camel gets a consolation prize because its body temperature yo-yos more than any other mammal's. Other extreme lifestyles get Davies's attention, but she saves the ultimate prize for last: the water bear, or tardigrade, is crowned toughest creature on Earth.

Davies writes in a kid-friendly, conversational tone with flashes of humor, but the occasional detail or the reference to scientific experiment show that she knows her material. The informal cartoons by Neal Layton (which include scratched-out mistakes) convey the fun of finding out cool stuff about animals.

FOR INTERMEDIATE READERS

Wild Lives: A History of the People & Animals of the Bronx Zoo, *by Kathleen Weidner Zoehfeld (Alfred A. Knopf; $18.95)*

When William T. Hornaday, the first director of the Bronx Zoo, learned that the American bison, or buffalo, was on the verge of extinction, he was deeply concerned—so much so that he organized a collecting expedition to Montana. There he killed two buffaloes from the only herd he could find, but because their hides were too "scruffy and tattered," he had to mount a



second expedition the following fall, when he succeeded in finding and killing several animals suitable for stuffing. *Wild Lives* is full of such wild contradictions, which continually ensnared the directors and curators at the Bronx Zoo as they struggled to improve zookeeping practices.

"The problem, for the most part," writes Kathleen Weidner Zoehfeld, "was not lack of intelligence or compassion, but lack of knowledge." Who would have guessed that buffaloes, when imported to the Bronx, would suffer gas from the rich New York grass? Who knew that gorillas prefer the stems and inner linings of banana peels to the bananas themselves? But people learn. Hornaday was ashamed of killing the buffaloes, and went on to establish a herd at the Bronx Zoo from which many of the animals now in public herds are descended. Providing hope without pandering, *Wild Lives* is an honest and intelligent discussion of the difficulties of caring for animals appropriately outside their native habitats.

The Hero Schliemann: The Dreamer Who Dug for Troy, *by Laura Amy Schlitz; illustrated by Robert Byrd (Candlewick Press; $17.99)*

Everyone knows there was something slightly off about Heinrich Schliemann's discovery of the ancient city of Troy. Few of us, though, are sure just what it was. Laura Amy Schlitz explains that the problem was Schliemann himself, who was seemingly driven by a childhood of almost Dickensian misery to turn his life into a drama-filled story. While still young, he traveled to California to give a brother a proper burial. While still there, he wrote a "vivid eyewitness account" of the San Francisco fire of 1851 (even though he wasn't in the city), and "glued it into his diary so cunningly that it looks like one of the diary pages." As Schlitz wryly puts it, "This was a bizarre thing to do."

As he dug his way through Troy and Mycenae, Schliemann continued to change the details of his life, all for a better story. In the end he built his own "Palace of Troy," where he lived with his wife and children. "It con-

tained not one stick of comfortable furniture," his daughter Andromache [*wince!*] complained.

In the standard account of the discovery of Troy, Schliemann is awkwardly cast as an early archaeologist. In Schlitz's carefully researched, sophisticated, and far more amusing account, Schliemann's obsessions and his inability to distinguish fact from fiction bring him into focus as the monomaniac he was.

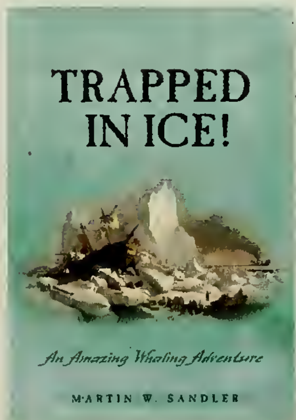
The Jumbo Book of Outdoor Art, *written and illustrated by Irene Luxbacher (Kids Can Press; $16.95)*

In *The Jumbo Book* you can find instructions for freezing frost patterns permanently into paper, sculpting a mask that looks like an animal's skull, or making a flip book of a banana rotting. Inspired by the ideas of teachers at an arts school in Toronto, Canada, *The Jumbo Book* is a mad, happy jumble of observation, art, science, and imagination. Raw materials for the projects include bark, dead flowers, grass seed, leaves, twigs, and old vegetables.

The book also gives recipes for making art materials from nature, such as dyes from beets and pigments from soils. Even the paper can be customized. Kids can make lovely bubble paper by floating paper on bowls of soap bubbles tinted with tempera; marbleized paper by floating paper on oil and colored water; and aged paper by rubbing it with wet tea bags. All the projects in the book have clearly passed the kid test: not only will children be able to do them, they will want to do them.

Trapped in Ice! An Amazing True Whaling Adventure, *by Martin W. Sandler (Scholastic; $16.99)*

In 1871, thirty-nine ships filled with 1,219 men, women, and children sailed into the Arctic Ocean in pursuit of the bowhead whale. Thirty-two of the ships' captains ignored the warnings of the Inuit, who paddled out to the ships to warn the whalemen that the weather was more severe than normal. The ships remained in the north until they became pinned against the coast near Point Belcher (close to the northernmost part of modern Alaska) by enormous ice packs. Knowing that either their ships would be crushed between heaving blocks of ice or food would run out, the captains voted to attempt a desperate escape in small whaleboats.



To his credit, Sandler manages to tell the story by incorporating the men's own words, quoting from ships' logs and sailors' diaries. The whalemen are almost comically laconic ("Spotted seven whales," one wrote in a logbook. "Gave chase. One whaleboat stove in. Three whales taken. So ends the day."). But occasionally they rise to eloquence. "Tell them all," said one of the captains who stayed south, when he heard of the fleet's plight, "I will wait for them as long as I have an anchor left or a spar to carry a sail."

FOR ADVANCED READERS

With a Little Luck: Surprising Stories of Amazing Discoveries, *by Dennis Brindell Fradin (Dutton Children's Books; $17.99)*

I didn't expect much from this book, which describes the lives of eleven scientists; most biographies for children are painfully pedestrian. But I read Dennis Brindell Fradin's book with increasing pleasure. Who knew that as an old man Newton liked to take bubble baths, blowing soap bubbles through a pipe and watching them burst? Who knew that Horace Wells, one of the discoverers of anesthesia, became addicted to breathing anesthetic gases, went mad, sprinkled acid on two women, and killed himself?

Who knew that in the nineteenth-century Vienna of Ignaz Philipp Semmelweis, "the father of infection control," pregnant women knelt and begged to be admitted to the second of two maternity clinics, the one staffed by midwives rather than doctors, because they were much less likely to die there? Who knew that Sir Alexander ("Alec") Fleming filled outlines of dancing ballerinas traced onto agar with colonies of pigmented bacteria and called them "germ paintings"? Who knew that the man who got the Nobel Prize for the discovery of pulsars said that Jocelyn Bell, the woman who found the pulsars, was "a jolly good girl" who was "just doing her job."

In Fradin's world, people are often ill, suffer writer's block, don't have a telescope when they need one, are called liars when they are telling the truth, turn desperate, run mad, and suffer grotesque deaths. All this, of course, is horribly interesting. Fradin takes every opportunity to bring children (or their dogs) into the story, but the main thing is that he tells stories that will make the scientists live in children's imaginations.

Team Moon: How 400,000 People Landed Apollo 11 ***on the Moon,*** *by Catherine Thimmesh (Houghton Mifflin; $19.95)*

"Fate has ordained that the men who went to the moon to explore in peace will stay on the moon to rest in peace. These brave men, Neil Armstrong and Edwin [Buzz] Aldrin, know that there is no hope for their recovery." No, this isn't a sentence from an "alternative-history" novel. It is a speech prepared

for President Nixon in the event the *Apollo 11* lander became stranded on the Moon.

If you think you know the story of the Moon landing, *Team Moon* might surprise you. Catherine Thimmesh puts the drama back into the familiar story by interviewing engineers rather than astronauts, and by focusing on the engineering problems behind the scenes instead of on the show the astronauts were putting on TV. Error messages kept cropping up during the lander's descent to the Moon. Fuel supplies ran so low that mission control was afraid the lander would crash. The temperature of a plugged fuel line soared close to the flash point. The crises continued as the capsule headed back to Earth: at the last minute an engineer discovered that the system set up to sanitize the film shot on the Moon might melt it instead. Extensive research and original interviews inform this enthusiastic account of the first lunar landing, which gains

authenticity by quoting the engineers directly even when they're speaking Engineering rather than English.

The Printer's Trial: The Case of John Peter Zenger and the Fight for a Free Press, *by Gail Jarrow (Calkins Creek Books; $18.95)*

One of the cornerstones of the American free press is the 1735 court case that first distinguished American from British libel law. In British law, anyone who printed criticisms of the government could be accused of seditious libel—whether the criticisms were true or false. In fact, writes Gail Jarrow, the libel was considered more serious if the published statements were true, for the perverse reason that readers would be more likely to believe them.

The case in question opened when the British colonial government arrested a barely literate printer named John Peter Zenger for printing anonymous attacks on William Cosby, the lavishly corrupt British governor of New York and New Jersey. Zenger was charged, even though he didn't write the attacks, because he was the only one who could be identified. At trial, Zenger's lawyer, the brilliant Philadelphia attorney Andrew Hamilton, ignored British law and argued, over the protestations of the judge, that the jury should decide whether the "libels" were true.

Jarrow's method matches the sophistication of her topic. A typical two-page spread includes a primary document and explanatory caption on the left-hand page, and the author's narrative on the right. But don't be fooled by all the primary documents into thinking the book is dry and scholarly. They record political shenanigans so outrageous that even Jon Stewart and Stephen Colbert would sputter and gasp.

DIANA LUTZ keeps an eye on children's literature for her daughter Emily, and her roundup of the year's books for children on science and nature is a regular feature of our end-of-year issue. She is also the editor of Muse, *a science magazine for young people ten and older.*

This year, give the gift of inspiration.
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And for the Coffee Table

By Laurence A. Marschall

Pollen: The Hidden Sexuality of Flowers, *by Rob Kesseler and Madeline Harley (Firefly Books; $60.00)*
Seeds: Time Capsules of Life, *by Rob Kesseler and Wolfgang Stuppy (Firefly Books; $60.00)*

Artist and visual arts professor Rob Kesseler and two plant biologists at the Royal Botanic Gardens in Kew, England, have combined talents to capture the polymorphic world of botanical sex. Artfully framed blowups, in coffee-table format, command full-page status throughout, with occasional diagrams and concise text blocks lending an element of scholarly analysis to the often abstract beauty of the micrographs and photographs.

But the images also convey a remarkable sexual tension. In the pollen book, one can almost feel the sensuality in a close-up of lily anthers, languishing under the weight of their thick coating of fertile powder. The offspring of this floral licentiousness, on display in the matching volume, *Seeds,* are even more bizarre. That book illustrates the wide range of strategies for seed dispersal, from multi-armed hooked spheres that catch on passing fur, to delicate, winged laceworks that float on the wind.

If plants could read, they might be appalled to see their sex lives explored so up close and personal, but we human beings can only marvel and delight.

Wild Borneo: The Wildlife and Scenery of Sabah, Sarawak, Brunei, and Kalimantan, *by Nick Garbutt and J. Cede Prudente (The MIT Press; $34.95)*

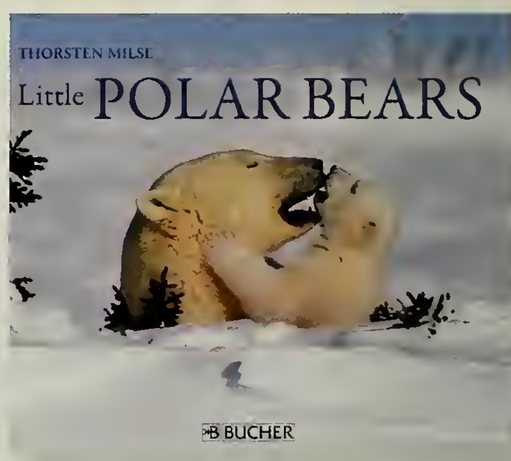
Borneo, a short hop southeast of the Malay Peninsula, may be the third-largest island in the world (after Greenland and New Guinea), but it's unknown territory to most Westerners. Now, thanks to the collaboration of writer-photographer Nick Garbutt and photographer J. Cede Prudente, a land that still hosts the orangutan and the world's smallest elephant may become more familiar to English-speaking couch potatoes.

One of the book's memorable photographic sequences depicts the visible life cycle of the gargantuan flower *Rafflesia,* a parasite on jungle vines. After living for a year or so as a reddish-brown bud that resembles a cabbage plant, the flower unfolds virtually overnight into a stinking blossom that can reach three feet across and weigh more than ten pounds. Then, after a week of display and pollination, it disintegrates, leaving behind a puddle of glutinous black goo. So rare is the sight of a flowering *Rafflesia* that Borneans have been known to charge admission when one appears on their property.

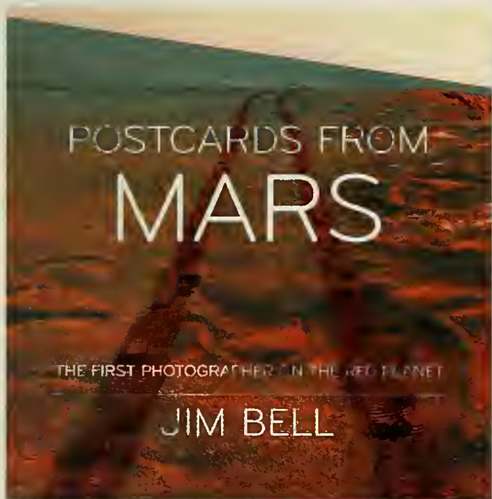
Among many other photographic pleasures are portraits of splay-nosed, pot-bellied proboscis monkeys, pitcher plants big enough to digest rats, and a variety of unlikely "flying" creatures, from frogs to colugos to lizards. There are even two species of flying snake—which, I am certain, look far less threatening in photographs, placidly embracing branches and leaves, than wriggling, eerily airborne, through the jungle canopy.

Little Polar Bears, *by Thorsten Milse (Bucher; $45.00)*
The World of the Polar Bear, *by Norbert Rosing (Firefly Books; $45.00)*

It's ironic that the word "cuddly" seems so apt in describing Earth's largest land predator, yet that's the impression one gets from these two magnificent picture books. Both show polar bear mothers and cubs sleeping together, moms caressing their young, and cubs playfully roughhousing in the snow. In one idyllic scene, the German nature photographer Thorsten Milse has captured a diminutive cub hitching a ride on its mother's back, while two siblings tussle nearby. In another, Milse's compatriot Norbert Rosing has caught a fox tugging fearlessly at the hind leg of a bear, "perhaps to urge it to go hunting."



If the images seem to depict a peaceable kingdom, that's not far from the truth—both books record expeditions to Canada's remote refuge for polar bears, Wapusk National Park, a vast territory east of the Churchill River along the southwestern shore of Hudson Bay. The books also neatly complement each other, despite some unavoidable overlap. Milse focuses on mothers and cubs, and even seems to have crept into their dens (unoccupied, one hopes) to give readers a bear's-eye view of the world outside. Rosing takes a broader, ecological perspective, shooting Arctic landscapes along with portraits of sleepy foxes, snow-rimed musk-oxen, and herds of sunbathing walruses. The creatures may be polar and the land frigid, but the work of these two fine photographers is warm and radiant.



Postcards From Mars: The First Photographer on the Red Planet, *by Jim Bell (Dutton; $50.00)*
Saturn: A New View, *by Laura Lovett, Joan Horvath, and Jeff Cuzzi (Abrams; $40.00)*

As you read this review, a pair of wheeled rovers, Spirit and Opportunity, are crisscrossing the Martian desert, as they have since early 2004. About a billion miles farther from Earth than the rovers, the *Cassini* spacecraft is orbiting Saturn, well into the third year of its scientific mission to examine the planet, its rings, and its satellites. On the surface of the largest of those satellites, Titan, is the probe *Huygens,* released by *Cassini* on Christmas Day, 2004; *Huygens* parachuted through Titan's dense clouds to reveal a chilly world marked by river channels and what might be lakes of liquid methane and nitrogen.

Those two unmanned space missions have produced many tens of thousands of images, of which only a small selection could be reproduced in these handsome books. Even this sample, however, is awe-inspiring. The exquisite detail of the Mars photographs owes a lot to a panoramic imaging system designed by *Postcards* author Jim Bell and his co-workers. On a number of the landscapes here, the tracks of the rovers can be seen converging towards the Martian horizon like lanes on a highway—a roadway made by alien explorers on a strange planet. The images of Saturn, which show the planet's rings and moons from a range of distances and perspectives, convey a sense of loftiness and grandeur that contrasts with the intimacy of the Mars shots.

When many of us were young, not that long ago, Mars and Saturn were unknown and unknowable, just distant smudges of light seen through a telescope, darkly. These books celebrate the newly discovered beauty of extraterrestrial worlds, and the ingenuity of the teams of scientists and engineers who have brought the solar system into our living rooms. Alas, current budget priorities at NASA, mandating travel to Mars at the cost of unmanned scientific missions, do not augur well for many sequels to these glorious volumes.

100 Caterpillars: Portraits from the Tropical Forests of Costa Rica, *by Jeffrey C. Miller, Daniel H. Janzen, and Winifred Hallwachs (Harvard University Press; $39.95)*
Butterflies of the World, *photographs by Gilles Martin; text by Myriam Baran (Abrams, New York; $35.00)*

The intricate coloration of butterflies and moths, so aesthetically pleasing to the eye, is an adaptation that enables the insects to rest unnoticed on bark, on flowers, or in the leaf-strewn shadows of the forest. Other patterns come into play when camouflage fails: Brazil's owl butterfly looks so much like a predator when the false eyes on its rear wings are exposed that hungry birds instinctively flee in panic.

Both of these books do justice to their photogenic subjects, but in different ways. *100 Caterpillars* showcases the richness of a single UNESCO World Heritage Site, the *Area de Conservación Guanacaste* in northwestern Costa Rica. The uniformly posed caterpillars, arranged as an inventory of species, look like so many fat worms in Mardi Gras drag. Matching photographs and descriptions of their adult forms occupy the second half of the book.

In contrast, Gilles Martin's *Butterflies* samples the entire world of butterflies and moths—and does so with panache. He has snapped his subjects in a variety of natural settings, giving the photographs a sense of texture and depth of field that is frequently exhilarating. What's more, Myriam Baran's text bubbles with gossipy facts and surprises, adding dimensions the camera cannot capture. The yellow and steel-blue caterpillar of the death's-head hawk moth, for instance, looks terrifying enough in Martin's close-up, but when threatened, Baran informs us, it can shriek like a cornered mouse.

Lasting Light: 125 Years of Grand Canyon Photography, *by Stephen Trimble (Northland Publishing; $40.00)*
Yosemite: Art of an American Icon, *edited by Amy Scott (University of California Press; $65.00/cloth, $34.95/paper)*

There's a photograph by Ernst Haas in Stephen Trimble's book that took my breath away. Photographed from what must have been the bow of a boat running the Colorado River rapids, it shows the steep walls of the inner canyon in shadow, converging straight ahead to a narrow gap where the river plummets through. Beyond the gap, in brilliant sunlight, is another wall of schist, and beyond that, another, suggesting the bends in the river that go on for miles. The print is exquisite, of course, but what strikes one most is the sense of power evoked by the river-level perspective, and the perfect sense of timing reflected in such a brilliant rendering of motion, light, and shadow.

The Canyon, next to Yosemite perhaps, is America's dearest and most-visited natural wonder. But though the place is familiar, the presentation in this book is fresh and exciting. Trimble has assembled a gorgeous sample of the work of forty-seven Canyon photographers, from Timothy H. O'Sullivan's first wet-plate landscapes of 1871, through the work of such well-known masters as Ansel Adams, the Kolb brothers, and Eliot Porter, to lesser-known contemporary artists such as Mike Buchheit, Liz Hymans, and Gary Ladd. There's plenty of backstory in the text, explaining how at least some of the photographic magic is achieved.

Amy Scott's book on Yosemite includes equally striking landscapes and related artworks in a variety of media, ranging from such early paintings as Albert Bierstadt's otherworldly 1868 painting *Sunset in the Yosemite Valley,* to David Hockney's photo-collage *Merced River, Yosemite Valley, Sept. 1982.* Essays by six art historians and museum curators, a historian, and an ethnographer inform the works.

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.*

 (Continued from page 26)

space (and time) in the neighborhood of the planet. The theory's prediction corresponded almost exactly with the observed precession, and played a crucial role in gaining rapid acceptance among scientists for Einstein's revolutionary hypothesis.

So if anyone asks you why you should care about precession, be prepared to answer with confidence and pride. Not for any reason linked to daily life, for eclipses and star charts remain the provinces of astronomers. Rather, precession turns out to describe a deep truth about the cosmos, worth understanding in its own right.

If your questioner demands more than that, ask him or her to consider what the discovery of precession could have meant to earlier civilizations. In their book *Hamlet's Mill,* two historians of science, Giorgio de Santillana and Hertha von Dechend, speculated that precession was known not only to Hipparchus in the second century B.C., but also to the Babylonians, many centuries earlier. Such a discovery must have been mind-boggling:

[Precession] became the vast impenetrable pattern of fate itself, with one world-age succeeding another, as the invisible pointer of the equinox slid along the signs, each age bringing with it the rise and downfall of astral configurations and rulerships, with their earthly consequences.

Then ask: Could precession really have seemed so impressive to our ancestors? Have we become so indifferent to the cosmos since they looked to the skies and expounded a host of explanations that we have lost our sense of wonder? And if so, are we better or worse off than they were, adrift in space on our rotating, revolving, precessing planet?

DONALD GOLDSMITH is the author of twenty books on astronomy, including Connecting with the Cosmos *(published by Sourcebooks in 2002). He is the co-author, with Neil deGrasse Tyson, of* Origins: Fourteen Billion Years of Cosmic Evolution *(Norton, 2004).*

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EXPLORER GUIDE

nature.net

The Good Earth

By Robert Anderson

The soil underfoot rarely gets its due. As a geologist, I viewed soil—when I considered it at all—as an impediment, an annoying, transient layer hiding the interesting bedrock beneath it. Nevertheless, when I worked at the American Museum of Natural History, I was repeatedly drawn to a diorama of a forest floor that reveals the hidden world of soil in oversize detail. Under a blanket of giant, decaying oak leaves and an acorn the size of a watermelon, a cutaway displays a burrowing earthworm as big as a python, as well as an unfamiliar collection of arthropods and fungi—all busily building soil for the next generation of trees (you can see it at www.amnh.org/learn/musings/SP02/mind.html).

The conservationist Les Molloy described the wonder I felt, in his book *The Living Mantle: Soils in the New Zealand Landscape:*

> For only rarely have we stood back and celebrated our soils as something beautiful, and perhaps even mysterious. For what other natural body, worldwide in its distribution, has so many interesting secrets to reveal to the patient observer?

Because of soil's economic importance, it's hardly surprising that the U.S. Department of Agriculture has a page devoted to those who have written in praise of dirt (soils.usda.gov/education/resources/k_12/quotes). USDA also has a primer on soil biology (soils.usda.gov/sqi/concepts/soil_biology/biology.html); the first chapter outlines the vital importance of the subterranean food web.

The Bureau of Land Management has a good site on the biological communities living in western "biological soil crusts" (blm.gov/nstc/soil). Click on the "Just for Kids" button on the left of the screen for a kid-friendly version. "Soil," we are told, delightfully, "is the top layer of the Earth's surface, like frosting on a birthday cake!" NASA, not to be left out, has a "Soil Science Basics" page (soil.gsfc.nasa.gov/basics.htm) that gives students an appreciation for the time it takes nature to create an inch of decent soil (about 500 years), and for the fraction of our planet's entire surface that is arable land (about 10 percent). Students who want to explore the underground microcosm at its smallest scale should visit the "Microbe Zoo," a creation of the Center for Microbial Ecology at Michigan State University (www.commtechlab.msu.edu/sites/dlc-me/zoo/index.html). Click on "DirtLand" and then "Root Cellar" to learn about the rhizosphere.

The Field Museum in Chicago has a wonderful exhibit devoted to life in the soil (www.fieldmuseum.org/undergroundadventure). On the Web you can tour the exhibit virtually, which gives a good sense of what visitors experience when they walk through the subterranean world in the museum, enlarged to make them feel less than an inch tall. The Smithsonian Institution in Washington, D.C., is working on a major soil exhibit, scheduled to open in 2008. Go to soils.org/smithsonian/index.html and click on the movie in the upper right, or "Learn about the Exhibit" to see what the museum is planning.

My favorite Web site on the subterranean world, however, is Thomas E. Loynachan's "Soil Biology Movies" (www.agron.iastate.edu/~loynachan/mov). A professor of agronomy and microbiology, Loynachan has sixteen videos on his site, with commentaries that show soil creatures in action. Perhaps the most fascinating of the lot are the nematode-trapping fungi, the Venus flytraps of the mushroom world. Another intriguing site is the "Rhizosphere Image Gallery," where soil scientists photograph the underground with a special "root camera" to observe what's going on below the surface (ic.ucsc.edu/~wxcheng/wewu/index.html). It gives you a sense of why life in the soil remains mysterious.

Thomas Jefferson penned more than one self-evident truth: "Civilization itself rests upon the soil."

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

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By Joe Rao

Just before sunrise from December 7th until the 14th, Jupiter (magnitude –1.7), Mercury (–0.6), and Mars (1.5) cluster low in the east-southeast sky. The best time to look for this intriguing pre-Christmas gathering is around 6:30 A.M. local standard time—though the group's low altitude and proximity to the Sun will probably make it impossible (or nearly so) to see Mars with the unaided eye. The trio becomes most compact on the 10th—the three planets fit inside a one-degree circle. On that morning, they resemble a small arrowhead pointing west, with Mars at the tip of the arrow.

By the 20th, Mercury is rising even later, just forty-five minutes before the Sun does, and so it becomes hard to see. The planet reaches superior conjunction, behind and roughly in line with the Sun, on January 7th, and then bolts back into view late in the month in the evening sky. By the 27th you might glimpse Mercury with the naked eye low in the southwest, between about thirty and forty minutes after sundown. Use Venus as a guide; you will see Mercury about eight degrees below and to the right of the bright planet (your clenched fist held at arm's length measures roughly ten degrees of arc).

During December Venus begins to climb up out of the sunset's glow in earnest and returns, at magnitude –3.9, to reclaim its role of brightest evening "star." Look for Venus with binoculars shortly after sundown very low in the southwest. On December 1st the planet is just four degrees above the southwest horizon at sundown (as seen from around forty degrees north latitude); it touches the horizon about a half-hour later.

By New Year's Day Venus is eleven degrees high at sunset and remains up for more than an hour. Come the end of January, this interval increases to almost two hours, and Venus is still about nineteen degrees above the horizon at sunset. Don't expect any good telescopic views of the planet just yet, though. Even with good magnification, Venus remains a dot of dazzling light, just barely out of round.

From late December until next May Mars rises soon after the beginning of morning twilight. On New Year's Day, when it lies 222 million miles from the Earth, Mars is a dim, +1.5-magnitude object low in the southeastern sky. That makes it somewhat fainter than the ruddy star Antares, which is nearly ten degrees above the Red Planet and to its right in the constellation Scorpius, the scorpion. During January the planet moves twenty-four degrees eastward, from the constellation Ophiuchus, the serpent holder, into the constellation Sagittarius, the archer. In fact, Mars nearly keeps pace with the Sun. With a large telescope, you might be able to resolve the planet into a tiny disk.

By the end of December, Jupiter is rising a few minutes before 5 A.M. local standard time, and by the end of January it's coming up about ninety minutes earlier. Jupiter has moved from the constellation Libra, the scales, where it spent much of 2006, into the richly starred region of Scorpius's head. Then, on January 29th, the largest planet officially moves into Ophiuchus.

Saturn is in the constellation Leo, the lion. At the start of December it rises out of the east-northeast shortly after 10 P.M. local standard time and reaches its highest point in the south just before dawn. By the end of January the planet rises before 6 P.M. and is highest in the sky around 1 A.M. By dawn it drops low toward the west-northwest horizon. During December and January a thirty-power telescope is enough to reveal the famous ring system, which appears tipped at about twelve-and-a-half to thirteen degrees toward Earth.

The Moon is full on December 4th at 7:25 P.M. It wanes to last quarter on the 12th at 9:32 A.M., and to new on the 20th at 9:01 A.M. The Moon waxes to first quarter on the 27th at 9:48 A.M. In January, the Moon returns to full on the 3rd at 8:57 A.M., then wanes to last quarter on the 11th at 7:45 A.M. and to new on the 18th at 11:01 P.M. First quarter falls on January 25th at 6:01 P.M. The Moon occults, or glides in front of, the Pleiades star cluster for observers in North America and Europe on the night of December 3–4. Unfortunately, the Moon is nearly full that night, making it hard to observe the occultation even with a good telescope.

The Geminid meteors, which peak on the night of December 13–14, could be the best shower of the year. You might see as many as seventy-five slow, graceful Geminids an hour. The meteors appear to radiate from a spot in the sky near the stars Castor and Pollux, in the constellation Gemini, the twins, which will be fairly high in the northeast sky by 10 P.M. local standard time. On the night of December 12–13 the Moon, which is just past last quarter, rises at about 12:30 A.M., which leaves about two and a half hours of dark skies for good meteor watching. Conditions improve thereafter, as moonrise is delayed by about an hour with each passing night and the Moon continues to wane. Before the Geminid maximum, small, faint meteors dominate the shower. During and after the peak period, bright meteors and fireballs appear.

The Sun arrives at the Solstice, its southernmost position in the sky, at 7:22 P.M. on December 21st. Winter begins in the Northern Hemisphere; summer in the Southern Hemisphere.

Earth reaches perihelion, its closest approach to the Sun, at 3 P.M. January 3rd. Our planet is 91.4 million miles from the Sun.

Unless otherwise noted, all times are eastern standard time.

LETTERS

(Continued from page 12)

Sensory Trade-off

In his article "Broken Pieces of Everyday Life" (10/06), Sean B. Carroll suggests that trichromatic vision is tied to reduced olfactory perception. "The fraction of fossil olfactory receptor genes," he writes, "is significantly higher in all species with full color vision" (such as the Old World primates). But Mr. Carroll skips over the fact that some reptiles equipped with full color vision also have excellent olfactory perception.

Mr. Carroll also states: "Because decaying genes accumulate multiple defects, their inactivation cannot readily be reversed." Yet, New World howler monkeys appear to have "recaptured" color vision.

Herb Windolf
Prescott, Arizona

SEAN B. CARROLL REPLIES: The observations I report about the fate of olfactory-receptor genes in various primates with color vision are based on data from DNA. How such genetic change unfolded in reptiles is not known in such detail. According to Kurt Schwenk of the University of Connecticut, in Storrs, in some reptiles with full color vision, olfactory perception is excellent, in others it is reduced. The species' lifestyles likely maintain differing pressures on the olfactory system.

The howler monkey does indeed have full color vision, but acquired it millions of years later than our Old World ancestors did, by independently duplicating an opsin gene. The fossil opsin gene was not repaired. In the howler monkey, by the way, the proportion of fossil olfactory receptor genes is high, independently exemplifying how acquiring color vision can lead to reduced olfaction.

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

Origami Holiday Tree

The orange elephant has arrived from Pune, India. So have the blue and cream-colored pachyderms and the silver giraffe. From across the country and around the world, the safari gathers, fantasy folds that make the shapes of lions and tigers and bears—and birds and butterflies and Burmese pythons.

The Origami Holiday Tree is back, an annual tradition, with a safari theme for 2006 and more than 300 intricate and astonishing paper examples of biodiversity. The American Museum of Natural History's entirely original tree decorations are largely the work of OrigamiUSA, a 1,600-member organization headquartered at the American Museum of Natural History.

Beginning in late spring and gathering momentum through November, volunteers fold, experiment, and fold some more. Magical creatures alight from all over as a folder in Hawaii, another in California, some international enthusiasts, and about 40 local OrigamiUSA members deliver their fragile ornaments for the 14-foot tree.

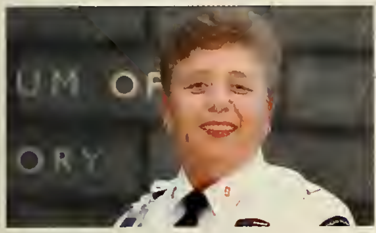
The Origami Holiday Tree can be viewed through January 1, 2007, in the Theodore Roosevelt Memorial Hall on the Museum's lower level. OrigamiUSA volunteers will be on hand throughout the holidays to teach visitors of all ages the art of paper folding. Try your skill and take home a purple bunny (easy) or a plaid camel (harder) as a handmade souvenir of your holiday visit to the Museum.

R. MICKENS/AMNH

Previous Origami Holiday Tree themes have included "Flight," "Winter," and "Under the Sea." This year's "Safari" theme proves just as festive.

PEOPLE AT THE AMNH

Maria Diana
Lieutenant
Department of Security and Safety


R. MICKENS/AMNH

You might say Maria Diana was born to handle crowds and kids. Twelfth in a family of 13 children, she is happiest working Halloween when the halls are jammed with double strollers, or the Friday after Thanksgiving, the single busiest day in the Museum's year.

Maria started 20 years ago when Museum security included groundskeeping, and today her job can be best described in one word: diplomacy. That can mean nudging parents changing diapers in front of dioramas to use the changing tables in restrooms; quieting rowdy teens, reminding them they are "in a museum, not a park"; patiently explaining for the umpteenth time where the nearest bathroom is; or—in response to the second most common question—the way out.

Maria's duties also bring her into contact with politicians such as President George W. Bush, who appeared at a reception at the Museum the day he opened the United Nations in September 2003—an event that included Colin Powell and Pervez Musharraf. She is no stranger to movie stars either, recently working security for filming *Night at the Museum*, a comedy with Ben Stiller and Robin Williams.

Having emigrated to the United States as a teenager, Maria still has relatives in her native Italian province of Caserta, including a cousin who works in the Royal Palace there, famous more recently as an interior location in several episodes of *Star Wars*. His job? Security.

Last Chance!

Don't miss these three wonderful exhibitions, now in their final weeks:

Voices from South of the Clouds
Villagers in southwestern China use evocative photographs and storytelling to document their world. Through January 2.

Lizards & Snakes: Alive!
A fascinating display of 60 live specimens from around the world. Last day, January 7.

Yellowstone to Yukon
Spectacular photos chronicle the effort to provide wildlife unimpeded access to natural ranges in the North American West. Ends January 15.

The Museum at Your Fingertips
WWW.AMNH.ORG

With a few clicks at your computer, immerse yourself in all the Museum has to offer without leaving home. Simply visit www.amnh.org for detailed information about public programs, cutting-edge scientific research, and more, including our permanent and special exhibitions.

For example, a link to www.amnh.org/gold offers a sparkling exploration of our newest exhibition, *Gold*. Here, through multimedia, glittering images, and descriptive text, you can preview the exhibition's features to be sure you won't miss favorites when you visit in person. Or, after your on-site experience, use the link to take a virtual tour and learn more.

Can You Guess What This Is?


AMNH

Students in classrooms around the country took their best guesses to decipher this mystery photo in a recent issue of Scholastic's ***Science World***® and ***SuperScience***® magazines, which featured an article about American Museum of Natural History scientist Julie Feinstein and her fascinating work as the Collections Manager of the Museum's frozen tissue lab.

The article, which invites readers to peer into cryovats preserving the DNA of a wide range of animal species, is part of the second year of Science Explorations, an award-winning partnership between the American Museum of Natural History and Scholastic. The partnership promotes science literacy among students in grades 3 through 10 through newly developed content both in magazines and online.

Upcoming Science Explorations articles in ***Science World***® and ***SuperScience***® will investigate flora and fauna deep in the Vietnamese jungle, and—in a feature complementing the Museum's big summer exhibition—unravel the science behind mythic beasts like dragons and unicorns.

Students, parents, and teachers looking to dig deeper into the coolest science topics can visit www.scholastic.com/scienceexplorations for multimedia activities, a virtual library, Web quests, and more, all part of Science Explorations.

Still wondering about the photo above? Go to http://ology.amnh.org/mystery_photo/frozen to see if you were right!

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY

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D. FINNIN/AMNH

Keros cups from Peru

EXHIBITIONS

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Through August 19, 2007

This glittering exhibition explores the captivating story of the world's most desired metal. Extraordinary geological specimens, cultural objects, and interactive exhibits explore and illuminate gold's timeless allure.

Gold is organized by the American Museum of Natural History, New York (www.amnh.org), in cooperation with The Houston Museum of Natural Science. This exhibition is proudly supported by The Tiffany & Co. Foundation, with additional support from American Express® Gold Card.

The Butterfly Conservatory

Through May 28, 2007

Visitors mingle with live, free-flying butterflies in a tropical environment.

Lizards & Snakes: Alive!

Through January 7, 2007

Live lizards and snakes are the center of attention in this engaging exhibition. Fossil specimens, life-size models, and interactive stations complement the more than 60 live animals representing 26 species.

Lizards & Snakes: Alive! is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with Fernbank Museum of Natural History, Atlanta, and the San Diego Natural History Museum, with appreciation to Clyde Peeling's Reptiland. *Lizards & Snakes: Alive!* is made possible, in part, by grants from The Dyson Foundation and the Amy and Larry Robbins Foundation.

Voices from South of the Clouds

Through January 2, 2007

China's Yunnan Province is revealed through the photography of its indigenous people.

This exhibition is made possible by a generous grant from Eastman Kodak Company. The presentation of this exhibition at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Yellowstone to Yukon

Through January 15, 2007

Spectacular photographs emphasize the diverse flora, fauna, and geology of the Yellowstone to Yukon corridor—an area connecting habitats so that wide-ranging animals can travel unimpeded by human structures and developments.

This exhibition was developed by the American Museum of Natural History's Center for Biodiversity and Conservation in concert with the Yellowstone to Yukon Conservation Initiative and the Wilburforce Foundation and is made possible by their support. Additional generous support provided by the Woodcock Foundation.

GLOBAL WEEKENDS

Kwanzaa Spirit 2006

Saturday, 12/30, 12:00 noon–5:00 p.m.

In an afternoon of song, dance, and spoken word, this festival salutes 40 years of *Nguzo Saba,* Kwanzaa's seven principles.

Living in America: The Allure of Gold

Three Sundays, 1/14, 21 & 28 1:00–5:00 p.m.

Trace the enduring influence of this glittering symbol of wealth, power, and beauty with performances, discussions, and films for adults and families.

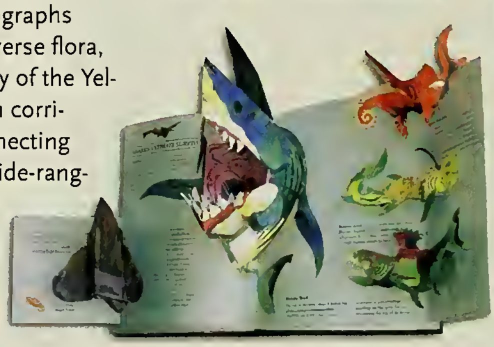
Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, the New York City Council, and the New York City Department of Cultural Affairs. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick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

LECTURES

Encyclopedia Prehistorica: Sharks and Other Sea Monsters

Sunday, 12/3, 2:00 p.m.

With pop-up creators Robert Sabuda and Matthew Reinhart.



Encyclopedia Prehistorica: Sharks and Other Sea Monsters. Copyright ©2006 by Robert Sabuda and Matthew Reinhart. Reproduced by permission of the publisher, Candlewick Press, Inc., Cambridge, MA

To the Ends of the Earth

Tuesday, 12/5, 7:00 p.m.

With photographer and explorer Gordon Wiltsie.

GORDON WILTSIE

Hanging camp at Great Sail Peak, Baffin Island, Canada, 1998, in *To The Ends of the Earth*

21st-Century Challenges in Mining Gold

Wednesday, 12/6, 7:00 p.m.

Panel discussion moderated by James D. Webster, AMNH.

Newton's Alchemy

Thursday, 1/11, 7:00 p.m.

With science historian William Newman.

Adventures in the Global Kitchen: Golden Sake

Tuesday, 1/16, 7:00 p.m.

Learn and taste with sake experts.

Volcanic Activity and Formation of Gold Deposits

Thursday, 1/18, 7:00 p.m.

With economic geologist Jeffrey W. Hedenquist.

The Upside of Down

Thursday, 1/25, 7:00 p.m.

With conservationist Thomas Homer-Dixon.

ROSE CENTER FOR EARTH AND SPACE

Sets at 6:00 and 7:30 p.m.

Friday, December 1

Stefon Harris Presents "African Tarantella . . . Dances with Duke"

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

Friday, January 5

Visit www.amnh.org for lineup.

Aglow in the Dark: Art/Science and Bioluminescence
Thursday, 1/25, 7:00 p.m.
Panel discussion with scientists and artists.

FAMILY AND CHILDREN'S PROGRAMS

Wild, Wild World: Wolves
Saturday, 12/9, 12:00 noon–1:00 p.m. and 2:00–3:00 p.m.
Live animal program.

Wild, Wild World is made possible, in part, by Mortimer B. Zuckerman.

NEW ASTRONOMY PROGRAMS
Twinkling Stars
Two Tuesdays, 12/5 & 12, 4:00–5:30 p.m. (Ages 4–6, each child with one adult)

Elemental Universe
Saturday, 12/9, 11:00 a.m.–3:00 p.m. (Ages 10 and up)

Frosty Adventures
Saturday, 1/20, 11:00 a.m.–12:30 p.m. (Ages 4–5, each child with one adult) or 1:30–3:00 p.m. (Ages 6–7, each child with one adult)

GOLD SUNDAYS
Gold Myths
Sunday, 12/3, 11:00 a.m.–12:30 p.m. (Ages 4–6, each child with one adult) or 1:30–3:00 p.m. (Ages 7–9)

Gilding with Gold Leaf
Sunday, 12/10, 11:00 a.m.–12:30 p.m. (Ages 4–6, each child with one adult) or 1:30–3:00 p.m. (Ages 7–9)

All about Alchemy
Sunday, 12/17, 11:00 a.m.–12:30 p.m. (Ages 4–6, each child with one adult) or 1:30–3:00 p.m. (Ages 7–9)

Gold leaf suspended in a bottle

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME
Virtual Universe
Is it a Planet?
Tuesday, 12/5, 6:30–7:30 p.m.
A New Year for the Milky Way
Tuesday, 1/2, 6:30–7:30 p.m.

This Just In...
December's Hot Topics
Tuesday, 12/19, 6:30–7:30 p.m.
January's Hot Topics
Tuesday, 1/16, 6:30–7:30 p.m.

Celestial Highlights
Wheels in Wheels
Tuesday, 12/28, 6:30–7:30 p.m.
Sparkling Winter Jewels
Tuesday, 1/30, 6:30–7:30 p.m.

LECTURES
The Cosmic Landscape
Monday, 12/11, 6:30–7:30 p.m.
With string theorist Leonard Susskind.
Postcards from Mars
Monday, 1/29, 6:30–7:30 p.m.
With Mars scientist Jim Bell.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions
Journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic formation of our universe. Narrated by Robert Redford.

AMNH

The formation of our Moon in *Cosmic Collisions*

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

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

Presented in association with MTV2 and in collaboration with renowned artist Moby.

INFORMATION

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

TICKETS AND REGISTRATION

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

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Fearful Symmetry

By Shaily Menon

It's a warm afternoon in southern India, and the bus is hot and dusty. After six bumpy hours on rough mountain roads with numerous hairpin turns, my bones are weary. And frankly, I'm feeling sorry for myself. After years in the classroom and the library, I was ready at last to conduct my doctoral research on lion-tailed macaques, an endangered species. But my plans to spend two years in a remote, pristine forest were foiled. Forty-three of my study subjects live in a pale ghost of the original forest, a small fragment surrounded by plantations and degraded by logging. I began my work here three months ago, but I'm still feeling cheated. What can such marginal territory possibly offer by way of discovery or adventure?

Henri Rousseau, *Tropical Thunderstorm with a Tiger* (detail), 1891

I hop off the bus, returning to the study site after a trip to the herbarium in the nearest city, Coimbatore. My tracker, with his rough-hewn machete and keen forest instincts, awaits me at the bus stop. We head to the forest fragment, a 160-acre island in a sea of tea and coffee plantations, to search for the macaques.

Lion-tailed macaques are black monkeys with distinctive shaggy, gray manes and tufted tails. They live only in rainforests in the southern part of the Western Ghats, the mountain chain that parallels India's western coastline, and many of them, like my study group, remain trapped in small forest fragments. The loss of habitat threatens them with extinction. My task is to document their behavior and how they manage to survive under such diminished conditions.

The tracker and I walk along an overgrown trail, craning our necks to catch a telltale movement or sound: the loud crash of branches as a monkey jumps across a gap in the trees or the soft call-and-response "coos" of monkeys keeping in touch. For an hour or more we hear only the insistent, chattery warning calls of Malabar giant squirrels. Finally, we notice a flurry of activity in a distant group of trees. We have found the monkeys—but something is amiss.

Several are barking and lunging toward the undergrowth, their typical response to a predator. I wonder aloud if a village dog has strayed into the forest. Few, if any, of the monkey's natural predators survive here. The tracker tells me about some buzz he heard at the bus stop. The week before, defying common sense, a guard at a nearby tea estate approached a sleeping tiger and prodded it with a stick. The tiger, rudely roused from slumber, promptly mauled the guard, killing him. A companion of the guard lived to tell the tale. Some villagers last saw the tiger entering this forest fragment.

I ponder the tracker's story as we walk in silence toward the monkeys. From a tiger's point of view, a tea estate has little to recommend it as habitat. Nor has a frayed forest fragment, where food is scarce and territory cramped. What tiger would linger here, when distant, ample forests beckon? I shrug off the possibility. Our footsteps slow as we arrive at the trees where the monkeys are behaving strangely. We move cautiously through the thick undergrowth, which obscures our vision and blocks our path.

Then we hear it. A low, quietly menacing growl emanates from a patch of vegetation, five feet to the right. Tensing, the tracker halts in his tracks and tightens his grip on his rusted machete. Close on his heels, I freeze. We glimpse streaks of orange burning through the green undergrowth. In that moment of surging adrenaline, silence borders on cacophony and stillness on frenzied motion. Self-preservation, primal and raw, urges flight: turn back, tear through the undergrowth. But another impulse, intensely conflicting, impels me to stay, to prolong the moment, to step forward and behold the tiger's fearful symmetry.

The tracker senses my indecision. He catches my eye and gestures with his fingers to turn around and walk away quietly. Self-preservation prevails. I walk swiftly and more deliberately than I ever have before, humbled and awed. My research has begun in earnest, and I have much to learn.

Shaily Menon is an associate professor of conservation biology and chair of the biology department at Grand Valley State University in Allendale, Michigan.