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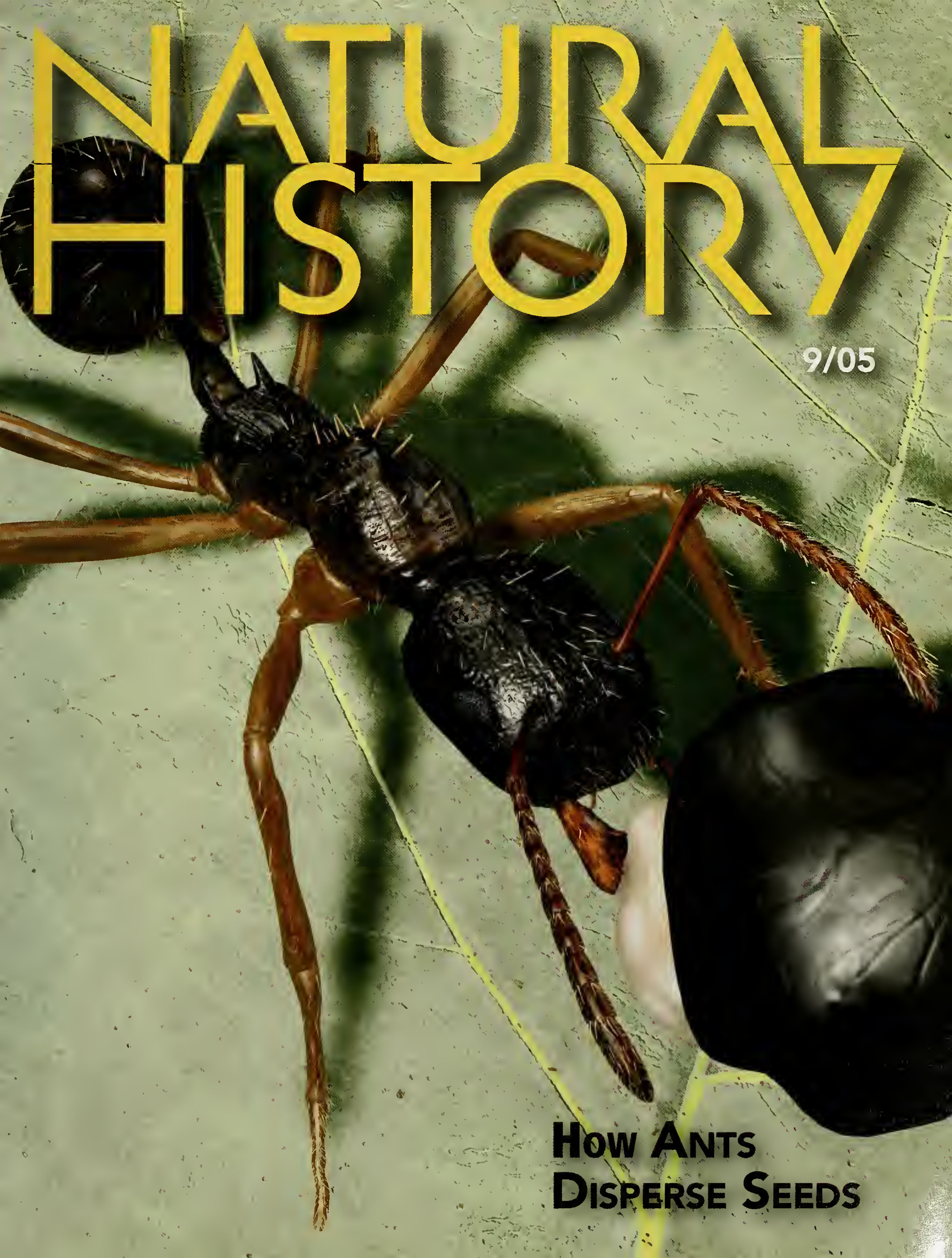

How Ants Disperse Seeds

NATURAL HISTORY

SEPTEMBER 2005 VOLUME 114 NUMBER 7

FEATURES

ON THE COVER:
Artist's rendition of an ant *(Aphaenogaster rudis)* carrying a seed of the wildflower *Corydalis flavula* by its elaiosome, a nourishing seed appendage

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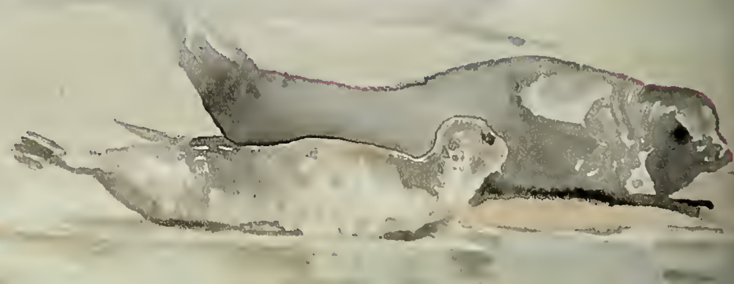
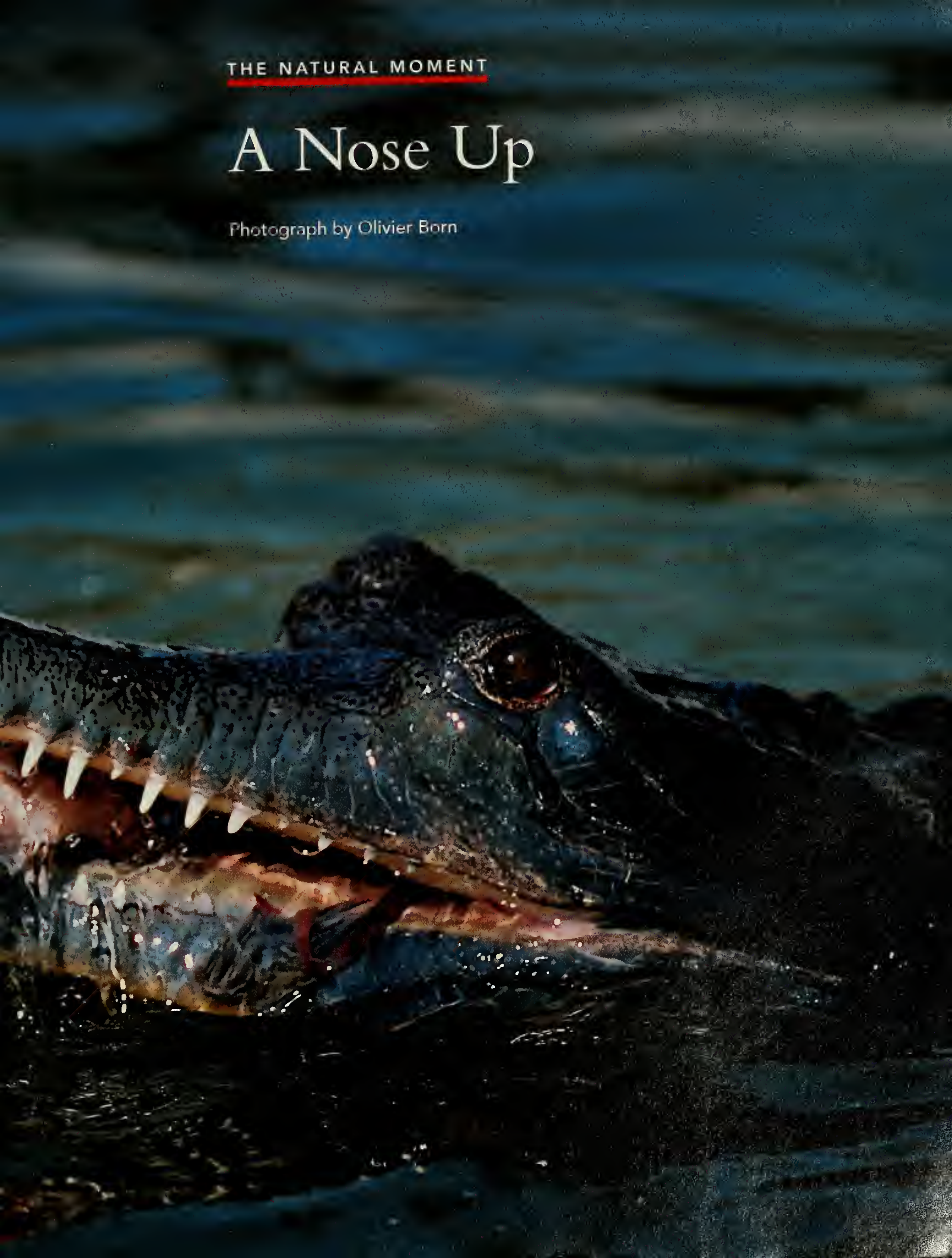


A Nose Up

Photograph by Olivier Born



THE NATURAL MOMENT

◄ *See preceding two pages*

Snapping up a fish in its narrow jaws, a male gharial *(Gavialis gangeticus)* in south-central Nepal thrusts his snout—a schnoz to make Cyrano envious—into the air. The most conspicuous part of its nose, though, the bulbous appendage at the end, serves not to enhance smell but rather to woo the opposite sex. The bulb is a healthy cartilaginous growth called a *ghara,* which develops only in males, beginning around the age of ten. During mating rituals, gharials buzz their honkers loudly and blow streams of underwater bubbles at their "Roxanes."

People, too, have bought into the ghara's come-hither powers. Poachers harvest the males' bulbs for sale as an aphrodisiac, and such poaching, along with habitat degradation and egg plundering (again, for human tonics), has brought gharials to the brink of extinction. The rare species is the only member of its taxonomic family, a branch of the order Crocodylia. The two other families in the order—the alligators and the crocodiles—are in less dire straits.

With help from the likes of the breeding center in Nepal's Royal Chitwan National Park, where photographer Olivier Born made this picture, gharials are growing in number. But political unrest has recently undermined the sanctity of Royal Chitwan. So in the spirit of reptilian reconnection ("See you later, alligator; after a while, crocodile!"), one should probably add: "Fare you well, gharial!" —*Erin Espelie*

UP FRONT

Prove It!

Bobby R. Harrison took part in the first confirmed sighting of an ivory-billed woodpecker in the United States in fifty years. By his own admission ("Phantom of the Bayou," page 18), the experience of rediscovering a bird long presumed extinct was so emotionally overpowering that Harrison broke down and cried; ever since, he's been known as Sobbin' Bob. Harrison was one of seventeen coauthors of a paper, announcing the reappearance of the ivory-bill, in the journal *Science* this past June; the news has become the biggest bird story of the year. Yet shortly before we went to press, Harrison's vivid first-person account seemed in danger of unraveling. Three respected biologists were questioning the evidence that the bird still existed.

Now Harrison has been vindicated. New audio recordings of a bird calling are so clear that even the skeptics have become convinced the sound is an ivory-bill. The Cornell University Laboratory of Ornithology has promised *Natural History* that the recordings are being posted on the Web (birds.cornell.edu/ivory) around August 28, after we go to press.

• • •

The ivory-bill aside, stories in *Natural History* are not usually the stuff of the evening news. So it's curious to find a second item in the mainstream news so pertinent to the topics we cover. President Bush has apparently endorsed the idea that "intelligent design" should be taught as a full-fledged theory, on a par with evolution.

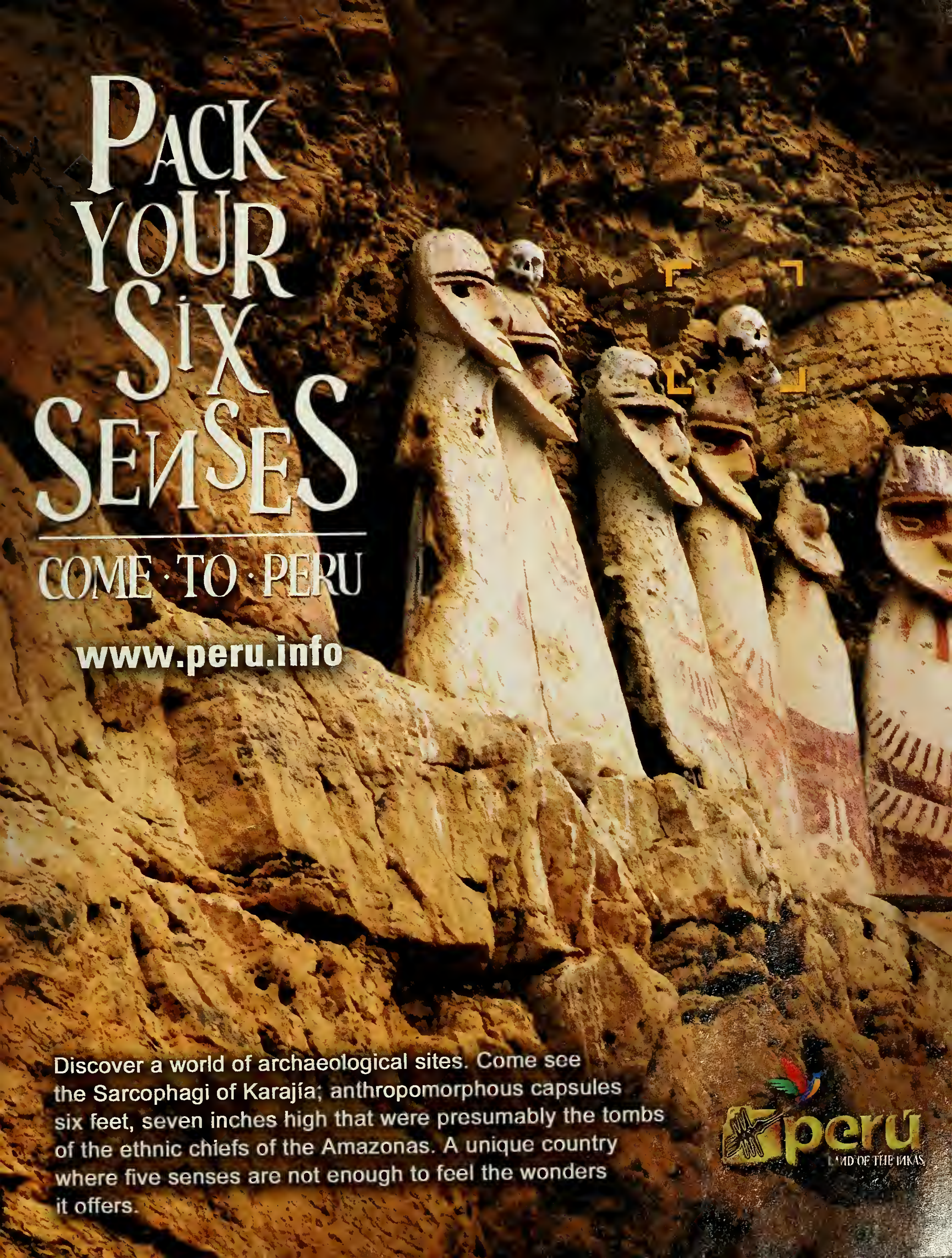
This is not the place to lay out claims and counterclaims about how life originated on Earth; we plan to do that, soon enough. But it is worth saying why intelligent design has utterly failed to engage the scientific community. The problem is not that it is wrong; the problem is that it can't be tested, proved, refuted, or falsified. Intelligent design doesn't risk *being wrong.* That's what makes it a matter of faith, not science.

Our cover story this month, Robert R. Dunn's article on ants, seeds, and convergent evolution ("Jaws of Life," page 30) offers an instructive illustration of the point. The seeds of vast numbers of plant species have small appendages that seem suited only for attracting ants. To an ant, the appendage is baby food. To a seed, the ant is a means of dispersal. So is each encounter of ant with seed the result of intelligent design? Maybe—how could you ever prove it wasn't?

But get down on your hands and knees with Dunn, turn over a rock, and watch the behavioral details unfold. Each step is no more deliberate than the falling of a stone, yet the steps taken together, over millions of years and uncounted trillions of ants and seeds, have given rise to a complexity that would be easy to mistake for an act of will. The mere existence of complexity, though, is no proof that it was intended: complexity can arise from the commonest elements. As a team manager in the 1988 movie *Bull Durham* says, with deep irony, about baseball: "[It's] a simple game. You throw the ball, you hit the ball, you catch the ball."

• • •

Our popular "Universe" columnist, Neil deGrasse Tyson, is taking a well-earned break from the lineup. Neil returns to our pages next month. —Peter Brown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LAND OF THE INKAS

CONTRIBUTORS

OLIVIER BORN ("The Natural Moment," page 4) earned a degree in photography from the School of Applied Arts in Vevey, Switzerland, in 1995, and is based in Lausanne, his birthplace. His work has appeared in several European magazines, including *Animan, National Geographic–France, Terre & Nature,* and *Terre Sauvage.* He specializes in animals with scales or hard shells.

"I became interested in ants as a boy, by kicking the nests of thatch ants and watching the ants boil out," confesses **ROBERT R. DUNN** ("Jaws of Life," page 30). His more recent investigative techniques, he says, have become a little more refined. An assistant professor of zoology at North Carolina State University in Raleigh, Dunn investigates such questions as, Do patterns of species diversity and extinction in insects differ from those in vertebrates? How many species are there on Earth? "At the surface, we are asking questions we might have answered with the tools of a century ago," Dunn remarks, "but for the most part, they remain unanswered."

A former editor at *Scientific American* and *American Scientist* magazines, **BRIAN HAYES** ("Ghosts in the Machines," page 36) writes on science, mathematics, and technology. His article is adapted from his book *Infrastructure: A Field Guide to the Industrial Landscape,* which will be published in October by W.W. Norton & Company, Inc. "The genre of my work is the nature guide," Hayes says, "even though the subject matter is everything that *isn't* nature." In the past two decades he has been exploring the technological elements of the environment in a deliberate effort to understand them, much as a naturalist would study a meadow or a woodland. "It seems important," Hayes says, "to try to make sense of the world we've built for ourselves."

Although he has since worked at many other sites, **ZHANG JUZHONG** ("The Magic Flutes," page 42) began his archaeological career at Jiahu, in Henan province in eastern China. The finds from the excavation of that Neolithic site have never ceased to inspire him: What discovery can compete, after all, with bone flutes that can still be played after 8,000 years? A professor in the department of history of science and technology and archaeometry at the University of Science and Technology of China, Zhang is currently investigating the lives of the people who once inhabited the ancient site. **LEE YUN KUEN,** Zhang's co-author, first saw the bone flutes of Jiahu in 2000, and was fascinated by the possibility of "hearing" the distant past—an unexpected dimension in archaeological experience. Lee is a research associate in the department of anthropology at Harvard University. A scholarly article by Zhang, Xiao Xinghua, and Lee describing the bone flutes in the journal *Antiquity,* won the Antiquity Prize for best article of 2004.

Zhang

Lee

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P.O. Box 5000, Harlan IA 51593-0257.

Natural History (ISSN 0028-0712) is published monthly, except for combined issues in July/August and December/January, by Natural History Magazine, Inc., in affiliation with the American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024. E-mail: nhmag@naturalhistorymag.com. Natural History Magazine, Inc., is solely responsible for editorial content and publishing practices. Subscriptions: $30.00 a year; for Canada and all other countries: $40.00 a year. Periodicals postage paid at New York, NY, and at additional mailing offices. Canada Publications Mail No. 40030827.

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Ladies First

In their article "Dance of the Sexes" [6/05], Sharon T. Pochron and Patricia C. Wright ask why female lemurs are dominant over males in most groups of lemurs. I venture that the answer is found in the authors' own observation: "By the end of her lifespan, a female sifaka will rarely have more than one daughter that survives to reproduce." Anything that adversely affects the fecundity or the reproductive longevity of a female puts the entire species at risk. Under those circumstances, I would imagine that any animals that failed to behave this way are long gone.

Hans J. Berliner
Carnegie Mellon University
Pittsburgh, Pennsylvania

Well, I was looking for a yes-man, but a toady will do just as well.

Sharon Pochron and Patricia Wright seem guilty of an all-too-common form of anthropomorphism. They state: "None of those mating males is likely to know whose baby the female is having." Doesn't this leave the reader thinking that male lemurs associate the sexual act with fatherhood?

I doubt any species besides the modern human realizes that sex leads to offspring.

Russ Agreen
Denton, Maryland

Sharon Pochron and Patricia Wright propose that female dominance is adaptive because threats of food shortages necessitate that females maintain feeding priority over males.

My fieldwork in Mantadia National Park, Madagascar, examined the feeding ecology of another lemur species in which the females are dominant, *Propithecus diadema*. Females did not eat significantly more fruit seeds than males did, but they did eat more flowers. Thus both fruit seeds and flowers may be essential to female health and reproduction.

Joyce A. Powzyk
Wesleyan University
Middletown, Connecticut

Sharon T. Pochron and Patricia C. Wright reply: Hans J. Berliner points to the very core of the group-selection debate of the past forty years. If selection is so strong that every individual's selfishness would adversely affect the reproductive success of the group, one might expect the scenario he proposes. But there is no clear consensus on how to distinguish group selection from selection operating on the individual. Female dominance could be viewed as an evolutionary strategy benefiting the survival of certain groups, but the presence of infanticide suggests that there is plenty of room for individual levels of "selfishness."

Russ Agreen is absolutely correct. Many biologists, including us, use a kind of shorthand when discussing animal behavior. We did not mean to imply facultative decision-making on behalf of the lemur. Instead, we expect that the infants of males that preferentially invest in their own offspring are more likely to survive to reproduction than the infants of males that treat all offspring alike. A male would not remember past matings, but he might rely on such cues as an infant's odor or his familiarity with its mother when deciding how to treat an infant.

As Joyce A. Powzyk writes, the foods that drive female dominance in one lemur species or group may not drive it in others. We would argue that whereas the food type underlying female dominance may not be universal, the concept of fighting for high-quality foods is. For example, we would be surprised if dominant females fought for mature leaves or unripe fruit, because both are costly to digest and provide fewer calories than other foods. Perhaps flowers in Mantadia National Park provide more calories for a given effort than other foods there.

Losing Sight

Luis and Monika Espinasa's article, "Why Do Cave Fish Lose Their Eyes" [6/05], brought to mind a zoology instructor who offered the following alternative explanation: In any fish population, mutations give rise to fish with defective, degenerate, or absent eyes. Outside caves, such fish are at a severe disadvantage, and so the mutations are eliminated. In the cave environment, however, fish without eyes might enjoy an advantage, because eyes are delicate organs and susceptible to injury. Eyes would be at risk as fish collided with their surroundings in caves.

Steve Miller
Santa Fe, New Mexico

The Espinasas assume that cave fish "lost" their eyes. But did they? Are eyeless fish the outcome of regressive evolution? Couldn't developmental plasticity—in which identical genotypes develop differently, depending on their environment—also account for the phenomenon?

Glen D. Dillon
Pahrump, Nevada

Luis and Monika Espinasa reply: Steve Miller suggests that an alternative driving force behind the selection for eye loss and blindness in cave fish could be related to the prevention of injuries that may cause infectious diseases. Although multiple factors probably play a role, our experience does not support this hypothesis in the case of *Astyanax*. Both the eyed and the blind morph of *Astyanax* inhabit a cave whose water is contaminated by the droppings of a large community of bats. Yet even in this unhygienic cave, eyed fish survive quite well and are not out-competed by the blind morph, presumably because of the abundance of food.

Glen D. Dillon's question—would eyelessness occur in fish if they were hatched and raised in complete darkness?—has been addressed with *Astyanax* in the laboratory. The answer was no. Those results confirm that blindness in cave fish is genetic, the product of regressive evolution.

Do the Hop

In "Bird's-eye View" [5/05] Matthew T. Carrano and Patrick M. O'Connor examined modern birds to gain a better understanding of the birds' dinosaur ancestors. But has anyone ever considered whether theropods might have "hopped" like birds, and if these hops could have been a preliminary aid to the motion of flying? A related question occurred to me from my reading Laurence A. Marschall's review of *Birdsong: A Natural History* [6/05]: did dinosaurs have a syrinx, which would have enabled them to make bird sounds?

Sondra F. Messina
Fresh Meadows, New York

MATTHEW T. CARRANO REPLIES: Some paleontologists have theorized that, based on the anatomy and orientation of theropod hip bones, the particularly bird-like theropods may have been hoppers. More recent work, however, suggests that those dinosaurs were still primarily walkers and runners. Some dinosaurs may have jumped or hopped occasionally, but the characteristic hopping of many small songbirds is probably a specialized feature of advanced birds, not something they inherited from their dinosaurian ancestors.

Similarly, dinosaurs almost certainly lacked a syrinx. The structure is highly specialized only in certain kinds of songbirds, and it was missing in the small theropod *Scipionyx*, the only dinosaur fossil for which traces of a trachea have been preserved. It was probably missing in the earliest birds as well.

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

Tsunami Postmortem

According to the most reliable recent estimates, the monstrous earthquake that rocked the northwest coast of Sumatra and the nearby Andaman and Nicobar island groups on December 26, 2004, released the energy-equivalent of a 250-megaton bomb, shaking every point on Earth's surface half an inch or more. It also launched a tsunami at more than a million coastal dwellers, killed nearly 300,000, and wrecked many fragile local economies. So just what took place in the Earth's crust to generate such force and cause such devastation? Four dozen earth scientists—among them Charles J. Ammon of Pennsylvania State University in University Park; Roger Bilham of the University of Colorado in Boulder; Thorne Lay of the University of California, Santa Cruz; and Jeffrey Park of Yale University—have now given a detailed answer to that question.

Along the coast of Sumatra and the islands to its north, the Indo-Australian tectonic plate is steadily pushing northward and, at the same time, thrusting under the Eurasian plate. The two plates are converging here at a rate of an inch or two a year, building up immense stresses at the boundary. Large earthquakes have been recorded here since 1797, though none so massive as the one late last year.

Earthquake of December 26, 2004, led to slippage (jagged, bright-red line) along a thousand miles of the boundary between the Indo-Australian tectonic plate, which pushes steadily northward (red arrows), and the Eurasian plate. The quake caused a devastating tsunami in the Indian Ocean. In March 2005 an adjacent segment (orange line) of the plate boundary ruptured.

On that morning the plate boundary, which is normally locked up by the pressure and friction of the rock masses, gave way near the northern tip of Sumatra, about twenty miles below the surface of the sea. It was almost as if a zipper had suddenly become unzipped. Within the next minute, a sixty-mile stretch of seafloor north of the initial rupture slipped rapidly beneath Sumatra. In the next eight or nine minutes the rupture raced northward for nearly a thousand miles along the plate boundary. The seafloor instantly buckled: above the rupture a vast area rose up several feet, while areas to the east and west of the rupture sank. This contortion of the seafloor displaced millions of tons of seawater, initiating the tsunami.

Then, as vibrations spread through the surrounding rock, the rate at which the two plates had been slipping past each other slowed dramatically. About half an hour later the slippage stopped. Altogether, the total displacement of the seafloor made for an event of magnitude 9.3 (by some estimates)—so powerful that its vibrations triggered small earthquakes as far away as Alaska. But its effects did not stop there: This past March, another 200-mile-long segment of the plate boundary failed, adjacent to the December rupture. Around the world, detectable vibrations continued for months. Even the global sea level is now half a millimeter higher than it was before the temblor. (*Science* 308:1126–44, 2005)

—*Dave Forest*

Flipper Fashion

Not long ago in Shark Bay, off the coast of western Australia, a female bottlenose dolphin broke a chunk of sponge off the seafloor and wore it as a mask over her snout while she probed the sediment for fish. Today "sponging" is a foraging fad among dolphins in Shark Bay—but, with one exception, exclusively among females. Moreover, though the Shark Bay dolphins adopt a dozen foraging tactics, sponging is the only one that involves a tool.

Biologists have resisted giving the label "culture" to the perpetuation of the practice of sponging. But Michael Krützen, a molecular ecologist formerly at the University of New South Wales in Sydney, Australia, and his colleagues maintain that the term fits, and they've ruled out alternative explanations. Both spongers and nonspongers forage in deep water, so sponging is not a response to habitat. And samples of nuclear DNA from adult spongers rule out the possibility that a propensity for sponging is a genetic trait.

The only remaining explanation, Krützen and his colleagues argue, is that sponging is socially learned—the first established example of the cultural transmission of tool use in marine mammals. But if it's social learning, it remains (almost) all in the family: according to an analysis of the spongers' mitochondrial DNA, all but one of them are descended from a single matriarch. Thus they most likely learned the practice from a female relative, probably Mom. The single sponging male examined by the investigators is kin, and would have spent the same amount of time with his mother as a daughter would have. So why don't other males sponge? That's still a puzzle. (*PNAS* 102: 8939–43, 2005)

—*Graciela Flores*

The latest in foraging attire

Color Coordinated

Honey possum on mature *Banksia* flower

To see color, your retina has to have cone cells; the more kinds of cones it has, the more colors you can differentiate. Like us, several species of Australian marsupials have three kinds of cones. One such animal, the honey possum—a wee creature that tips the scales at less than a tenth of an ounce—feeds exclusively on the nectar and pollen of colorful flowers, particularly those of the tree *Banksia attenuata*. And one of the possum's cones is sensitive to a much longer wavelength—a redder color—than the corresponding cone in other marsupials.

Petroc Sumner, a neuroscientist at Imperial College London, and two biologist colleagues measured the composition of light reflected by the flowers and leaves of fifteen species of plants in the possum's habitat, figured out what would register on every possible kind of cone, and computed the ideal cone sensitivity for a honey possum to have. It turns out that the possum's oddly tuned cone is perfect for distinguishing the mature, yellow flowers of *B. attenuata* from the similarly shaped, but green, immature ones and the brown, senescent ones. Makes sense: instead of climbing all over a tree just to reach a nectarless flower, the possum can judge from a distance whether the climb is worth the effort. (*Journal of Experimental Biology* 208: 1803–15, 2005) —*Stéphan Reebs*

Female Radicals

It's hardly news that women, on average, live longer than men. So, in fact, does the average female of many other mammalian species. José Viña and several other biochemists at the University of Valencia in Spain have long been investigating the physiological causes of this common gender gap.

Inside each animal cell, within the minuscule structures called mitochondria, oxygen reacts with the by-products of digested food to yield energy. Few animals can live without oxygen, which, alas, also forms oxidants—compounds that strip electrons from other essential molecules, thereby disabling them. Fortunately, animal cells produce various antioxidants, which neutralize most oxidants. But the oxidants that survive, especially the very reactive ones known as free radicals, can damage DNA.

According to one popular theory, aging is the result of a lifelong buildup of damage caused by free radicals. One culprit is hydrogen peroxide (H_2O_2), which is commonly produced from and also transformed into more potent free radicals, and so its presence signals trouble. Viña and his colleagues recently determined that the mitochondria in females have only about half as much hydrogen peroxide as the ones in males. Furthermore, they discovered that female hormones—estrogens such as estradiol—are to thank for this healthy restraint. Estradiol binds to a receptor in the cell membrane and triggers a cascade of cellular reactions that activate genes and eventually give rise to more antioxidants.

So what's a guy to do? Because estrogen could cause feminization in males, gulping estradiol pills is probably not the solution. But Viña and his colleagues have been investigating plant compounds that resemble estrogens. One such compound in soybeans lowers hydrogen peroxide in isolated human cells; within the coming decade, tests of the compound in people are expected. (*FEBS Letters* 579:2541–45, 2005) —*S.R.*

The Birth of Left and Right

In spite of its many symmetries, the body is subtly asymmetric: the heart, for instance, lies to the left of center and the liver to the right. But how does the asymmetry arise? Investigators in the laboratory of Nobutaka Hirokawa, a cell biologist at the University of Tokyo, have discovered that the rapid gyrations of cilia, or microscopic hairs, on the underside of eight-day-old animal embryos are responsible.

Embryos manufacture protein-rich fluids filled with chemical cues. As the cilia whip around clockwise (the direction is always clockwise because of the cilia's asymmetric internal structure), they circulate the fluids. Stem cells pick up the cues and act accordingly. Surprisingly, the cilia's gyrations don't create a tornado-like vortex of fluids. Instead the result is a linear, leftward flow.

By doing some fancy camera work with fish, mouse, and rabbit embryos, Hirokawa's group discovered that the fluids flow leftward because the cilia sprout off-center from a domelike membrane, and so the axis of the cilia's gyrations tilts toward the embryo's rear end. During the right-to-left phase of its clockwise swing, each cilium is perpendicular to the membrane and pushes fluid unimpeded toward the surface of the embryo. The "recovery" phase of the swing, which begins in a trough, close to the surface of the embryo, gives less of a push to the fluid. Consequently, the proteins don't get distributed evenly, the chemical cues vary, and asymmetry develops. (*Cell* 121:633–44, 2005) —*S.R.*

The Palace on Wheels

There is something indefinable about India that makes westerners who have been there yearn to return. Perhaps it is the vastness of the country and its timeless quality. Perhaps it is the multiplicity of peoples and cultures that strikes a hidden chord in us, for whom this land seems so alien and yet so fascinating. Or perhaps it is the way that humans and nature are so closely linked, co-existing in a way that seems intrinsically impossible. There are some places in a lifetime that simply must be visited, and India is one of them.

In 2001, we chartered The Palace on Wheels, India's premier train, for a journey to the foremost wildlife and tiger preserves of India. Peter Matthiessen, George Plimpton, and Robert Bateman were on that trip, and all agreed it was one of the best trips of their lives. As a group, we saw 11 tigers, plus a marvelous variety of birds and mammals. We repeated this trip in 2004 with equal success, and are proud to offer it again in March 2006. Please contact us for our detailed itinerary and video.

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Flash of Insight

Physicists once thought gamma rays—the most energetic form of electromagnetic radiation—originated primarily from distant celestial sources. But new technology has been registering gamma rays in Earth's own atmosphere, at a rate of at least fifty bursts a day. Now Steven A. Cummer, an electrical engineer at Duke University in Durham, North Carolina, and his colleagues have analyzed twenty-six of those so-called terrestrial gamma-ray flashes (TGFs) and discovered another big gamma-ray surprise.

A process called runaway breakdown seems to set off TGFs: A cosmic ray, or high-speed atomic nucleus, strikes an ordinary air molecule within a strong electric field. The collision energizes and dislodges one of the molecule's electrons, which the electric field then accelerates to nearly the speed of light. The highly energetic electron strikes other air molecules, energizing yet more electrons. When a beam of such energetic electrons collides with an atom, gamma rays burst forth.

It used to be thought that TGFs were generated far above thunderstorms, immediately after a very strong bolt of lightning. What Cummer and his colleagues found, however, is that TGFs *precede* lightning bolts by a split second, and are associated with lightning several hundred times weaker than anyone expected—or even with no lightning at all. To the investigators, the link with moderate lightning implies that TGFs develop at surprisingly low altitudes: near the tops of thunderclouds, rather than some twenty miles above them, as had been predicted. And so runaway breakdown, they say, seems to be connected to the cause of *both* lightning and TGFs. Apparently not only gamma rays, but also lightning itself, are still a bit of a mystery. (*Geophysical Research Letters* 32: L08811, 2005) —*Rebecca E. Kessler*

You Talking to Me?

For people, it's second nature to refer to a friend or family member by name, but there's scant evidence that other animals do the same. Some species do communicate information on the whereabouts of food or the presence of a predator, and animals can clearly recognize individual members of their own group. But even dolphins, clever as they are, have apparently not invented tags for one another.

But spectacled parrotlets, brilliantly colored Central and South American birds, may be a different matter. Ralf Wanker and two other biologists at the University of Hamburg in Germany report that, in an experimental setting, the birds made different "contact calls" for different members of their family. Furthermore, they responded more often to recordings of calls that had originally been directed toward them rather than toward another family member. That is strong evidence, say Wanker and his colleagues, that some nonhuman species label their social companions individually. People will just have to learn that spectacled parrotlets are not all called Polly. (*Animal Behaviour* 70: 111–18, 2005) —*Nick W. Atkinson*

Spectacled parrotlets

Clues to Shoes

When did people become the only animals that regularly wear shoes? The oldest well-dated surviving footwear—North American sandals made of plant fibers or leather—is 9,000 years old. Earlier shoes have decayed; their existence must be extrapolated from figurines, footprints, and remnants of burial goods. To peer farther into footwear's past, says Erik Trinkaus, a physical anthropologist at Washington University in Saint Louis, one must look at feet. A bare foot in direct contact with the ground depends more on the four small toes for traction and weight distribution than it does when supported by a shoe. Thus the small toes of the habitually unshod become stronger and bigger than those of the habitually shod.

Trinkaus examined toes from the remains of Neanderthals between 75,000 and 40,000 years old, Middle Paleolithic modern humans about 100,000 years old, and Upper Paleolithic modern humans between 28,000 and 20,000 years old. He found that, compared with the remains of several groups of recent humans whose footwear habits are known, Neanderthal toes were several times more robust than modern toes. Robustness declined most rapidly between the Middle Paleolithic and the midpoint of the Upper Paleolithic. As early as 28,000 years ago, Trinkaus concludes, people had begun to wear shoes on a regular basis. (*Journal of Archaeological Science* 32:1515–26, 2005) —*Caitlin E. Cox*

NATURALIST AT LARGE

Phantom of the Bayou

The author's thirty-year personal quest to find the ivory-billed woodpecker culminates in the first confirmed North American sighting of the elusive bird in more than fifty years.

By Bobby R. Harrison

The author, a lifelong birder, and his canoe (top left) sport bottomland camouflage, the better to capture the elusive ivory-billed woodpecker on video. Ivory-bills during the 1930s, when J.J. Kuhn (above) was the warden of the Singer Tract in Louisiana, appear to have been less wary than the ones the author has recently sighted.

"It had a long neck, and the head—it had a red topknot that came to point, and it had a big white bill—it looked real cartoonish." Gene Sparling, a kayaker from Hot Springs, Arkansas, was on the phone, eagerly describing his encounter with a woodpecker on February 11, 2004, in the Arkansas bottomlands. Sparling had been kayaking on the bayou when the bird "flew overhead and landed on a cypress tree less than seventy feet in front of me." He thought he had seen a "superlarge" pileated woodpecker, "with white in the wrong places." But every feature he described seemed to fit another bird, the ivory-billed woodpecker, a bird many people thought had gone extinct in the mid-twentieth century. When he said "cartoonish," goose bumps popped up on my arms, and the little bit of hair I still have on my head stood on end. I had never heard anyone use the word "cartoonish" to describe an ivory-bill, but it was perfect.

That was the moment I began to think Gene's superlarge pileated might instead be the ghost bird I had sought for more than three decades. At the time of Gene's call, I had already been preparing to check out a lead on an ivory-bill sighting in Louisiana. Now Arkansas was looking like a better destination.

Eleven months earlier, another report had come in about a bird in Arkansas whose description matched that of the ivory-bill. That bird, from the White River National Wildlife Refuge, was reportedly a large black woodpecker with a prominent white shield on its lower back. The shield was divided into two parts, as if the wings were held slightly apart to reveal a black back underneath. The crest was red. But the sighting, like Gene's, was similar in another respect to a host of such sightings in the past few decades—they were always made by a single individual, with no corroborating witness. In other words, there was no proof that the bird they saw was really an ivory-bill.

I e-mailed Tim Gallagher, longtime editor of Cornell University's *Living Bird* magazine and a friend of mine for almost twenty years, my plans had changed, I told him, and I was going to Arkansas. His curt reply: "Pick me up in Memphis. I'm going with you."

The ivory-billed woodpecker once ranged over a wide swath of the southeastern United States, from the Carolinas westward to Houston, Texas, and as far north as southern Illinois, as well as in Cuba. For a woodpecker, it had an unusual way of grasping a tree—it would place both feet wide apart and then brace itself with its long, recurved tail as it pounded the bark with both beak and body. A series of such thumps, delivered sideways from left and right, would loosen the bark to uncover the larvae of wood-boring beetles that made up the bulk of the ivory-bill's diet.

The colorful scarlet crest of the male and its cream-colored bill made ivory-bill heads popular adornments on the headgear of the Native Americans. When Europeans arrived, they too became enamored of the birds' decorative value. In the early nineteenth century, the killing of ivory-bills increased dramatically, primarily because of demand for the heads as curiosities. By 1901 a law was passed to prohibit such "collecting," but by then the species was facing an even more difficult challenge: the loss of habitat as a result of unchecked logging. In 1942 the American ornithologist James T. Tanner, who conducted extensive research and the only field study ever done of the ivory-bill, concluded that habitat loss, rather than collecting, posed the greatest obstacle to the continued existence of the bird. "Shooting of a few birds," Tanner wrote, could serve only as "the final cause for their extinction." By his estimate, only twenty-four of the birds remained.

Soon after Tanner published his study, the birds were thought to have gone extinct in the U.S. By midcentury, visitors to the cypress swamps and pine forests of the Southeast no longer heard the distinct call of the ivory-bill (which sounded like the blasts of a toy trumpet) or its unique double knocks as it slammed its beak and body against the bark. (You can hear the ivory-bill on the Web [www.npr.org/programs/re/archivesdate/2002/march/]. Scroll down and click on "Listen to the only known recording of ivory-billed woodpeckers, captured in 1935 in a forested area of Louisiana known as the Singer Tract.") In 1948 the Singer Tract, where Tanner did much of his fieldwork, was cleared of its stands of trees, and apparently of its ivory-bills, for agriculture. Only sporadic sightings of ivory-bills in Cuba were made after that, the last of those in 1987. The last positive sighting in the U.S. took place in 1944. No one wanted to believe the birds were gone for good, but no one could prove otherwise.

Specimen of a male ivory-billed woodpecker, in the collection of the American Museum of Natural History, New York.

Nine days after Gene filled me in on his sighting, Tim and I were in a canoe in the Cache River National Wildlife Refuge in east-central Arkansas, on Bayou DeView, following Gene through a narrow strip of swamp that spanned only half a mile in its widest spots, where he had spotted his mystery bird. On our second day in the bayou, February 27, we began to see some very large cypress trees.

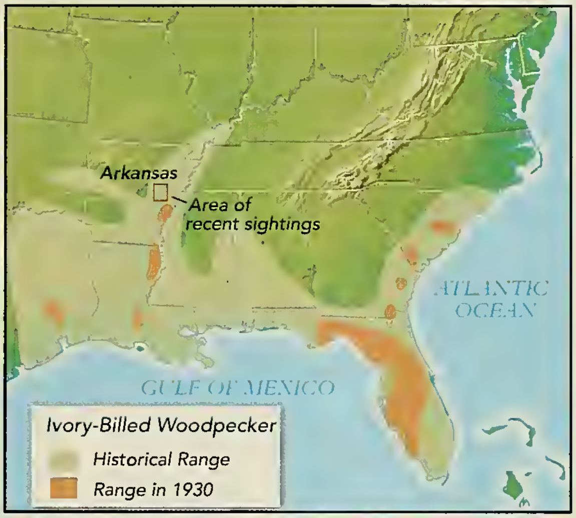
We spent the morning drifting down the bayou, looking for signs of feeding by ivory-bills and, of course, for ivory-bills themselves. By noon I was ready for lunch; portly people like me prefer our meals on time. With a few powerful strokes, Gene pulled

ahead to find dry land for a lunch break. As Tim and I drifted slowly downstream, we scrutinized every bird we saw. At the end of a large lake, we re-entered the main slough and made a turn to the southwest.

About 200 feet down the slough, at about 1:15 P.M., I saw a black bird, larger than a crow, perhaps twenty inches long. Appearing about forty degrees off the starboard bow, it was in powered flight, moving toward us through the trees. With my peripheral vision I detected that Tim was looking at the same bird, so initially I said nothing. It was flying like a duck—fast, with shallow, rapid wing beats. In fact, it reminded me of a pintail duck in the way its primaries, the ten outermost feathers of the wing, seemed to do all the flying. The inner portion of the wing hardly moved at all, yet the primaries seemed to quiver, making the wing look stiff and inflexible. I am an experienced birder, yet I had never seen such a bird before.

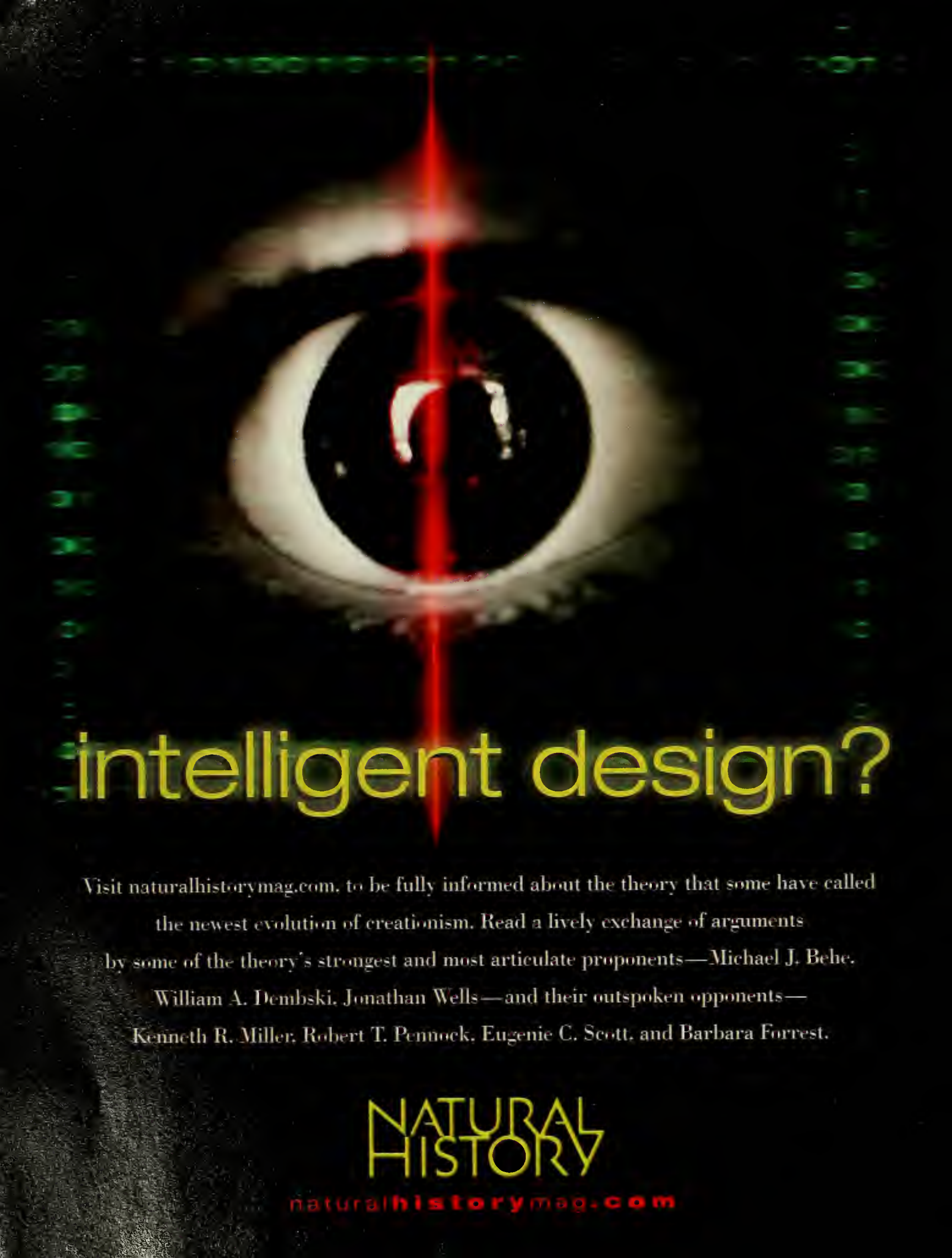
As the bird flew through the trees at the bayou's edge, it tilted its body from right to left about eighty degrees, with its back toward us. The light was at an angle that perfectly illuminated the bird's back, revealing the wing pattern diagnostic of an ivory-billed woodpecker: The bird was the blackest black I had ever seen. The body and the leading edge of each wing close to the body was a soft black. The primary feathers were also black, but had a gloss to them. The secondaries—the feathers closest to the body on the trailing edge of the wing—were snow white; the white extended beyond the secondaries into the three innermost primaries at an angle of about forty-five degrees. The pattern made the wings appear long and narrow. The black back of the bird separated the two wings from each other. The bird was unmistakably an ivory-billed woodpecker.

As the bird turned to reveal its back, Tim and I both shouted, in unison: *"Ivory-bill!"*



Both of us were in a state of shock. We jerked backward, and I began trembling; we almost fell out of the canoe from our reaction. Meantime, the bird swooped upward and flared its wings and tail as if it was going to land on a nearby tree. When Tim and I yelled "ivory-bill," the bird almost stalled in flight. In an instant it recovered, flying farther into the tree line on the east side of the bayou. It landed on a tree, still within easy sight. After a brief pause, it stopped momentarily on another tree. I whispered to Tim, "Keep watching it; I'm getting the camera." As Tim watched, the bird landed on yet another tree, again for only a second. Then it was gone.

Quickly we hauled the canoe ashore and began to follow on foot, but the muck and mire made a chase on land impossible. Two hundred feet into the forest, our bird had vanished. But Tim and I were still in shock. Tears were streaming down my face, and I was weak in the knees. Tim likewise moved nervously, his skin as white as if the blood had been drained from his body. With a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trembling voice he said, "I don't know about you, but that's a lifer for me." We laughed, and then I realized we had just become the first two qualified people since 1944 to see an ivory-billed woodpecker at the same time. When we got back to the canoe I sat down on a log, put my head in my hands, and began to weep, saying over and over, "I saw an ivory-bill, I saw an ivory-bill."

As I sat there, I realized that perhaps all those who had claimed to have seen it would now be vindicated. Emotion overwhelmed me—the phantom bird had been rediscovered. This time two people had seen it together. The phantom was not extinct, but very real and very much alive.

When we got back to the canoe I sat down on a log and began to weep, saying over and over, "I saw an ivory-bill, I saw an ivory-bill."

Our sighting launched a U.S. search of unprecedented intensity, leading to more than fifteen additional sightings and a pair of videos that support the contention that the ivory-billed woodpecker is not extinct.

That is not to say there are not unbelievers. A recent news article on the front page of *The New York Times* titled, "Mystery Woodpecker Flies By, Upending Life of a Bird Lover," outlined the critics' complaints. One argument is that the first video, made by M. David Luneau Jr., an associate professor of electronics and computers at the University of Arkansas at Little Rock, on April 25, 2004, is not absolutely clear, at least not to the average viewer.

You may not be able to draw a portrait from any of its frames, but what do show absolutely clearly in Luneau's video are the body and wing proportions of a bird in flight, the number of wing beats, and the consistency of white in the trailing edge of the wings. Those characteristics rule out the possibility that the bird on the video was another, similar bird, such as the lesser pileated woodpecker.

Another common objection is that repeated sightings must take place, with all possible field markings recorded. Most ornithologists who are familiar with ivory-bills base their knowledge on Tanner's monumental work. Yet Tanner observed only eight pairs of birds between 1937 and 1939, and his study was conducted in a forest tract where hunting had not been permitted for more than fifteen years. The birds there were relatively tame and very vocal. Ornithologists who read Tanner's account expect ivory-bills surviving into the twenty-first century to have the same traits.

Earlier descriptions such as the ones given in articles in *The Auk, The Wilson Bulletin,* and *The Oologist,* however, suggested ivory-bill behavior was a little more diverse. Numerous accounts tell of the ivory-bill's wariness, its facility in hiding, and its reluctance to call. Why the discrepancy? Birds that were hunted avoided humans. Birds that lived in areas where hunting did not occur, such as the birds in Louisiana's Singer Tract, where Tanner conducted the bulk of his study, were unafraid. Ivory-bills that were docile and vociferous fill museum specimen cases around the world; the ones that were wary and less vocal survived to pass on those genetic traits. The ivory-bills in eastern Arkansas are the wariest creatures I have ever encountered.

The reason the ivory-bill is not seen regularly is no doubt that the bird has such a large home range. According to Tanner, ivory-bills need six square miles of suitable habitat per bird. The area where Tim and I discovered the bird is not prime habitat, so the home range of the bird we saw must be greater than six square miles.

After our initial sighting on February 27, I spent another fourteen months in the swamp searching for ivory-bills and trying to document my successes. Dur-

Joshua Caez, male ivory-bill, 2005

ing that period I had four more encounters with the ghost bird. Three of my sightings have been within 400 feet of one another. Nevertheless, that does not indicate a pattern to the bird's movements or a predictability in finding it, because the sightings were months apart.

During one of my encounters, on September 4, 2004, I managed to capture an ivory-bill on video; as of this writing, that recording of the bird has not been widely released. Although it is brief and of poor quality, it shows an ivory-bill flying past a decoy that I had placed on a tupelo tree to attract a living counterpart. The bird is seen flying away from the camera at an angle of about forty-five degrees. Although the bird is behind foliage throughout most of the video, it is visible in an opening just before it passes out of the frame. Frame-by-frame images bring out the wing pattern of an ivory-billed woodpecker.

During the flyby, which lasts just a quarter second, the wings flap three and a half times, or roughly fourteen beats a second. In real time the wing beat appears to have a shallow range of movement, but the actual stroke is deep, covering an angle of at least 120 degrees. A frequency of fourteen wing beats a second explains why the wing movements I have seen appear rapid and shallow when the bird is in powered flight, and the high frequency also accounts for the description in the historical literature of the ivory-bill's pintail-like flight. Fourteen beats a second is too fast for the eye to see, so fast that the wings appear to quiver instead of flap. The movement creates the illusion of a shallow range of movement during powered flight. The video also shows a second flyby, thirty-three seconds after the first one, suggesting that the ivory-bill was responding to the decoy.

Even before making the video, I had spent much of the summer of 2004 in

(Continued on page 52)

Breaking Point

Not unlike a slab of cooling rock, DNA "cracks" under pressure in roughly predictable patterns.

By Adam Summers ~ Illustrations by Tom Moore

It's said that the legendary Finn MacCool created the Giant's Causeway—thousands of steplike stones on Ireland's northeast coast—in order to reach Scotland and thrash an upstart rival. As a child living in Dublin, I was fascinated by this myth. As an adult, I am intrigued by the true origin of this geologic formation: black basaltic rock that cracked into uniform columns after a volcanic eruption, 60 million years ago. And as a biomechanist, I am delighted that the same physical phenomena that led to the Giant's Causeway can also explain information exchange at the opposite end of the size spectrum, across strands of DNA.

DNA does not remain quietly coiled in the nucleus of a cell. Instead, it goes through cycles of unraveling and compaction, most dynamically during the process of meiosis. Meiosis is a kind of cell division that produces gametes—sperm cells and egg cells—from germ-line cells; no topic brings on cold sweats in biology students quite like it.

Human nuclear DNA is organized into twenty-three pairs of chromosomes, one member of each pair from an egg cell of the mother and the other member from a sperm cell of the father. The genetic information in a pair of chromosomes is not identical, but (with the sole exception of the two sex chromosomes in the male) the genes on both chromosomes are homologous, being arrayed in the same order. For example, a gene for eye color occurs on both members of one of the pairs of chromosomes, but one copy might code for blue eyes and the other for brown eyes.

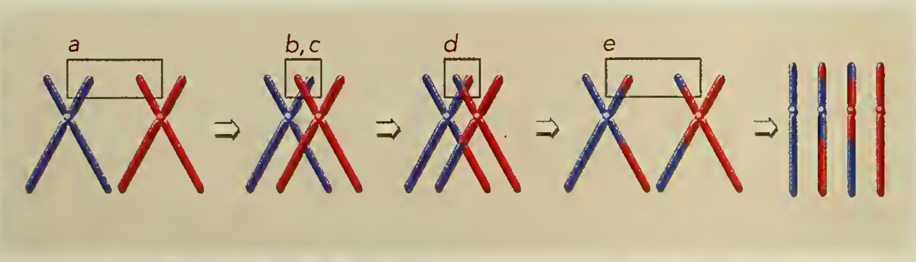
When a germ-line cell undergoes meiosis, the forty-six individual chromosomes perform a complicated dance in which the DNA is first replicated and, ultimately, divided up into four gamete cells—each with just twenty-three chromosomes. The part of the process immediately following replication, a part that is key to genetic diversity, is what makes the heart of the biomechanist beat faster.

After replication, chromosomal DNA and the proteins closely associated with it "condense," or compress, and the new and old copies of each chromosome form a tightly wound X-shaped package (not to be confused with the X chromosome). Each X shape then finds its genetically similar partner. Together, the twenty-three pairs of Xs line up along a central axis of the cell.

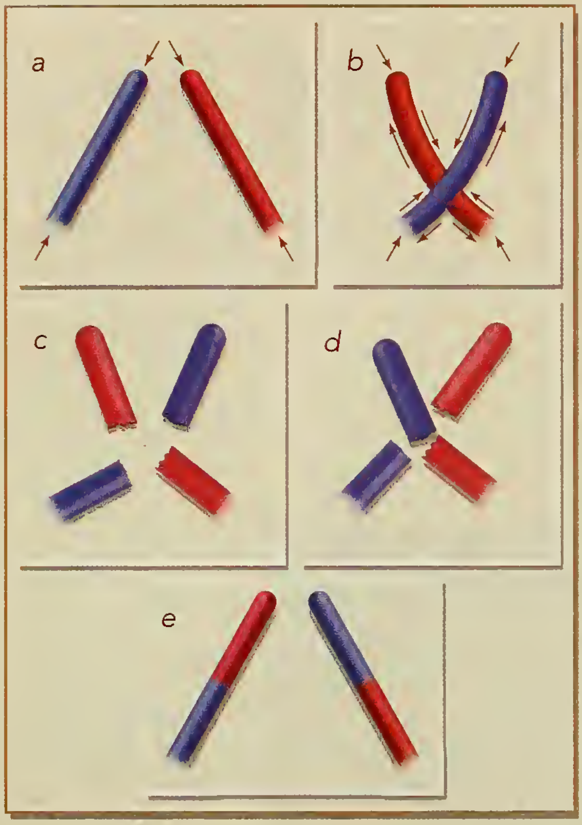
The next step is "crossing over," one of the hallmarks of meiosis: the pairs of Xs become entangled. A region on one chromosome (on an arm of one of the Xs) appears to cross over, and stick to, the homologous region on one of the chromosomes that make up the other X shape in the pair [*see illustration on this page*]. Wherever crossover occurs, DNA is exchanged between the two chromosomes.

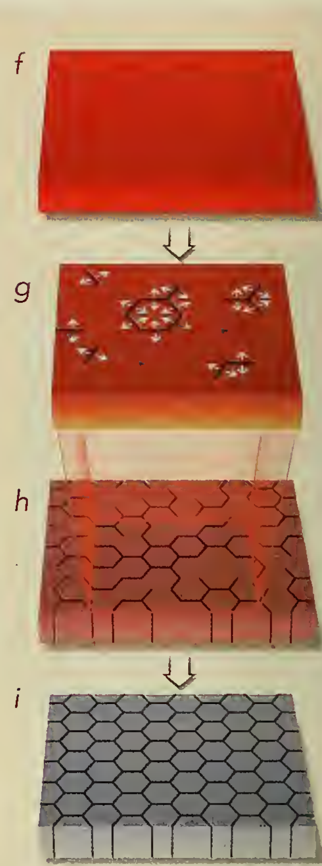
Once the genetic exchanges have taken place, the four chromosomes that make up a pair of Xs separate from one another. Thus, the chromosomes that wind up in the nucleus of a new gamete are distinct from the chromosomes in the parent cell; this outcome makes crossing over a major source of genetic variation among offspring. Later, if an egg and sperm happen to combine, the cell that results, called a zygote, contains the original complement of twenty-three pairs of chromosomes—half of every pair coming from the egg and the other half from the sperm.

Each human chromosome, on average, has about two crossover sites. Geneticists thought the location of those sites was determined by so-called chaperone molecules, or perhaps simply by random encounters. But Nancy Kleckner, a molecular biologist at Harvard University, and her colleagues have supplied convincing evidence that crossovers are also the



Crossover of genetically similar pairs of chromosomes during meiosis, as shown in the diagram, gives rise to diverse gametes. Each chromosome is replicated, and the original plus its copy are compressed into the shape of an X. Thus each genetically similar chromosome pair leads to two X shapes (red and blue Xs above). Homologous, or genetically similar, regions of the Xs then become entangled and interchange, giving rise to four new chromosomes.
The interchange of chromosomal material, such as the sequence shown within the labeled boxes of the diagram, may be caused by mechanical stress and breakage, as detailed in the corresponding boxes of the diagram on page 28.





Proposed mechanism of chromosome breakage during meiosis is shown schematically at left; the panels are labeled so as to correspond with the crossover steps in the diagram on page 26. Compression along a chromosome (a) leads to bending (b) and eventually to breakage (c), which relieves local stresses and so inhibits breaks close to the first. The broken DNA can then recombine (d), giving rise to a new pair of chromosomes (e). A similar effect governs the cooling of molten basalt (diagrams at right). Because molten rock cools more rapidly at its surface than it does at depth (f), surface rock contracts more quickly. As cracks form to relieve the resulting surface stresses (g), each crack gives enough local stress relief that further cracks only form some distance away (h). The result is a uniform hexagonal pattern, such as the one exhibited by Ireland's Giant's Causeway (i).

by-products of mechanical processes.

At least one crossover is needed for proper assortment of chromosome pairs, yet the location of the crossover site is not the same in every cell that undergoes meiosis. In other words, there are no preset sites for crossovers in any given chromosome. Another odd fact of crossover distribution leads back to the Giant's Causeway: it turns out that every crossover lowers the chances that a second crossover site occurs nearby. Something about a crossover seems to inhibit the formation of neighboring crossovers.

The Giant's Causeway started off as a thick layer of volcanic ejecta. As the lava solidified and cooled, it contracted, but the surface layers, exposed to the air, cooled faster than the deeper layers. Hence the surface layers also contracted faster, setting up a tensile stress that could be relieved only by cracking along the surface.

Once a crack formed, though, it relieved tension in the surrounding area, preventing other cracks from forming immediately nearby. At some distance from the first crack, however, the tension would still be high enough to cause another crack to form. The differential cooling led to the hexagonal pattern of cracking visible today [*see illustration above*]. Stress relief provided by a crack explains the appearance of myriad structures, from the crackling of old paint to the crevices that plague Vermont roadways.

But what generates stresses in a chromosome analogous to the stresses in cooling lava? Kleckner proposes several factors that could be acting in concert. First, during the meiotic cycle, the chromosomes condense into more tightly looped skeins of DNA. That compression could set up stresses simply by confining the DNA to a smaller space—possibly causing the DNA to stiffen as well. Second, because DNA is also replicating during meiosis, there is simply more DNA trying to fit into the constant volume of the cell nucleus. Chromosomes might be pushing against the walls of the nucleus—or against each other—so hard that they buckle under the stress.

Kleckner and her colleagues tested a theoretical model, which predicted where such mechanical stresses would cause "cracks" along a chromosome, against maps of observed crossover points—and found the model to hold true. Furthermore, micrographs of chromosomes show clear evidence of stress buildup. Some are twisted like phone cords; others have sharp flexures from buckling.

If there were not enough stress built up in a chromosome to ensure at least one crossover event, chromosome pairs would not separate properly. That possibility alone is a powerful selective force for a stressful environment. In this case it is important to crack, as they say, under pressure.

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Jaws of Life

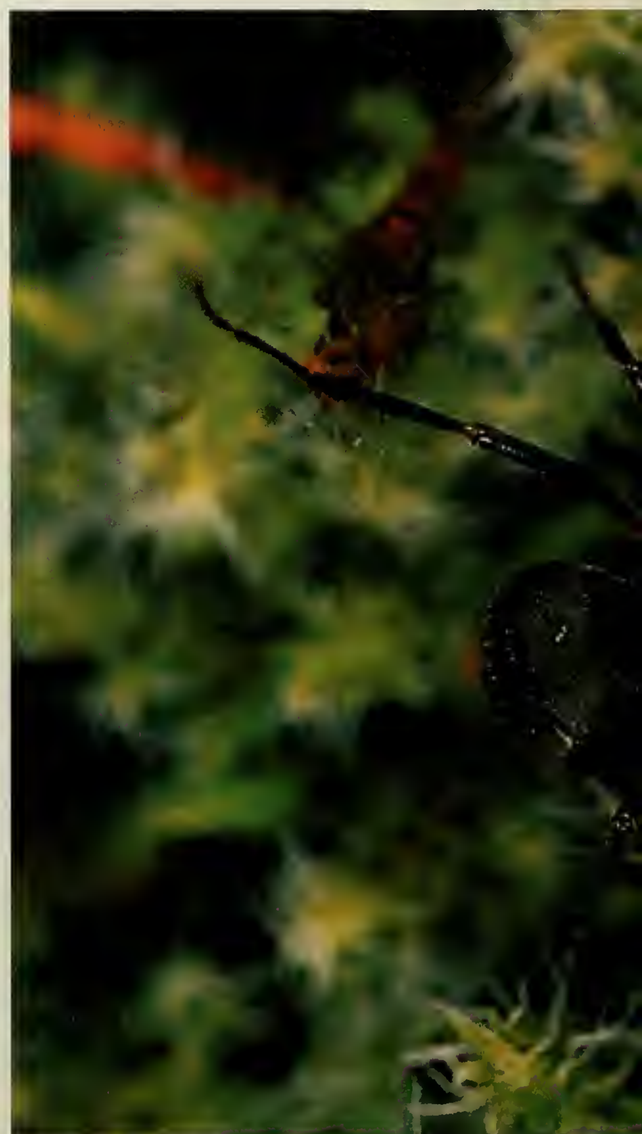
Thousands of plant species place their fates in the mandibles of ants.

By Robert R. Dunn

I displaced a rock in Tennessee. Underneath, huddled at one edge of the exposed dirt, was a colony of ants. The slender ants moved slowly in the cool spring morning, and I had a long look at them before they vanished down their hole. The queen was fat and glamorous. Around her were tiny, silver eggs, chubby larvae, and pupae folded like mummies inside translucent cases. At the edge of the colony, surrounded by a small pile of ant garbage—heads, legs, and other shiny but unidentifiable parts—were two seeds. How had the seeds found their way into the ants' tunnels?

With patience and the fortitude to sit still when an ant clambers over you, you might easily learn the answer for yourself. The first thing to do is to turn over the next rock, or poke into a nearby log. Rocks and logs are windows into the secret life of the soil; the views are fleeting but, at least to children and biologists, mesmerizing. Over many seasons of rock-turning and log-poking, I have found thousands of ant colonies, many containing seeds. Among the seeds have been dozens of plant species, including bedstraw, buttercup, fairy bells, green and gold, ornamental onion, silverleaf, violet, woodrush, and Wright's nutrush. You, too, will find them, in small piles, inside ant colonies or on the small hummocks of garbage deposited neatly nearby. If you live in eastern North America, you might discover the seeds of half the species of forest and meadow flowers, perhaps even more.

As long as you replace the rocks carefully, the ants will resume their normal activity when you leave, and you can revisit the same stones at a later date to check the fate of the seeds. On my own return later that same spring, the seeds that had looked forlorn and abandoned were germinating, rising out from under the rock I had turned. Trilliums and violets emerged in small clumps from between ant



European wood ant of the species Formica rufa, *which feeds on insects, honeydew from aphids, and other delectables, carries a seed of the wildflower* Corydalis cava, *a plant in the same family as poppies. The ant's mandibles grasp a white structure that is part of the seed—an oily and edible appendage known as an elaiosome.*

heads and cricket legs. If I could have scanned the entire forest, I would have seen seedlings poking out of hundreds of ant colonies in every green acre.

By all appearances, ants love gardening—but why? What do they get in return for their effort? Are they particular about which seeds they bring home? And what consequence, if any, does winding up in ant garbage have for the plants? We biologists have tracked the fate of perhaps a million seeds to address these questions (ours is a ridiculous but delightful profession). We still don't have all the answers, but we have learned that vast numbers of plant species throughout the world attract ants to their seeds and encourage their six-legged associates to carry them underground. And the benefits—whatever they are—appear to be great, as far as the plants are concerned. How else to explain that such disparate lineages of plants have evolved such ant-friendly seeds? That kind of independent "invention," known as convergent evolution, is a sign of a trait's evolutionary value. But it may not be at all obvious exactly what that value is.

As Yogi Berra once said, you can observe a lot just by watching. The easiest way to know what your ants are up to is to find a patch of trilliums or violets with mature fruit, get down on the ground, and watch the fate of the falling seeds. My experience in New England is that passersby will ignore me, even if I am lying across their trail. Some hikers have actually stepped over me. In the Smoky Mountains, by contrast, I've found that people tend to expect an explanation. When I tell them I'm studying, or just watching, ants, by far the most common response is, "Ants? I have ants in my kitchen!"—which everyone seems to think is hilarious. In any case, once you are settled, with your geographically appropriate response to passersby in mind, just watch the seeds. When the seeds fall, the ants will come.

In some species, the ants work in groups: a dozen or so tug a seed in the right direction—back to the nest—while one ant usually pulls the wrong way. In other species, a single ant may carry a seed on its own, hefting it between its two mandibles. Biologists have spent thousands of hours following seeds to their fates. In one day a hundred years ago, the Swedish naturalist Rutger Sernander watched a single species of ant lug 366 seeds, belonging to six different plant species. Assuming, as Sernander did, that the ants are active for about eighty "favorable days" a year, the annual total handled by that colony alone comes to more than 29,000 seeds. On your day of ant-watching, though, you might be content to follow just one seed or two.

What you will find is that ants are being tricked into gardening. Trilliums and thousands of other plant species have evolved seeds with a small, fatty appendage, known as an elaiosome, from the Greek *elaios,* "oil," and *so-*

ma, "body." When Sernander experimentally removed the fatty appendages from seeds in 1901, the ants were no longer as interested in collecting the seeds. Plants produce elaiosomes to woo ants. The ants seize the seeds with their mandibles, almost always by the elaiosomes, and carry them to their nest. Once in the nest, the ants feed the elaiosomes to their ravenous larvae and throw the otherwise intact seeds into their garbage, where, with luck, they germinate. The small garden of seedlings that issues from a well-tended garbage pile can be as dense as that in any planter box. In one ant garbage dump I counted 857 seeds of twenty different plant species; each had been carried and disposed of, one at a time.

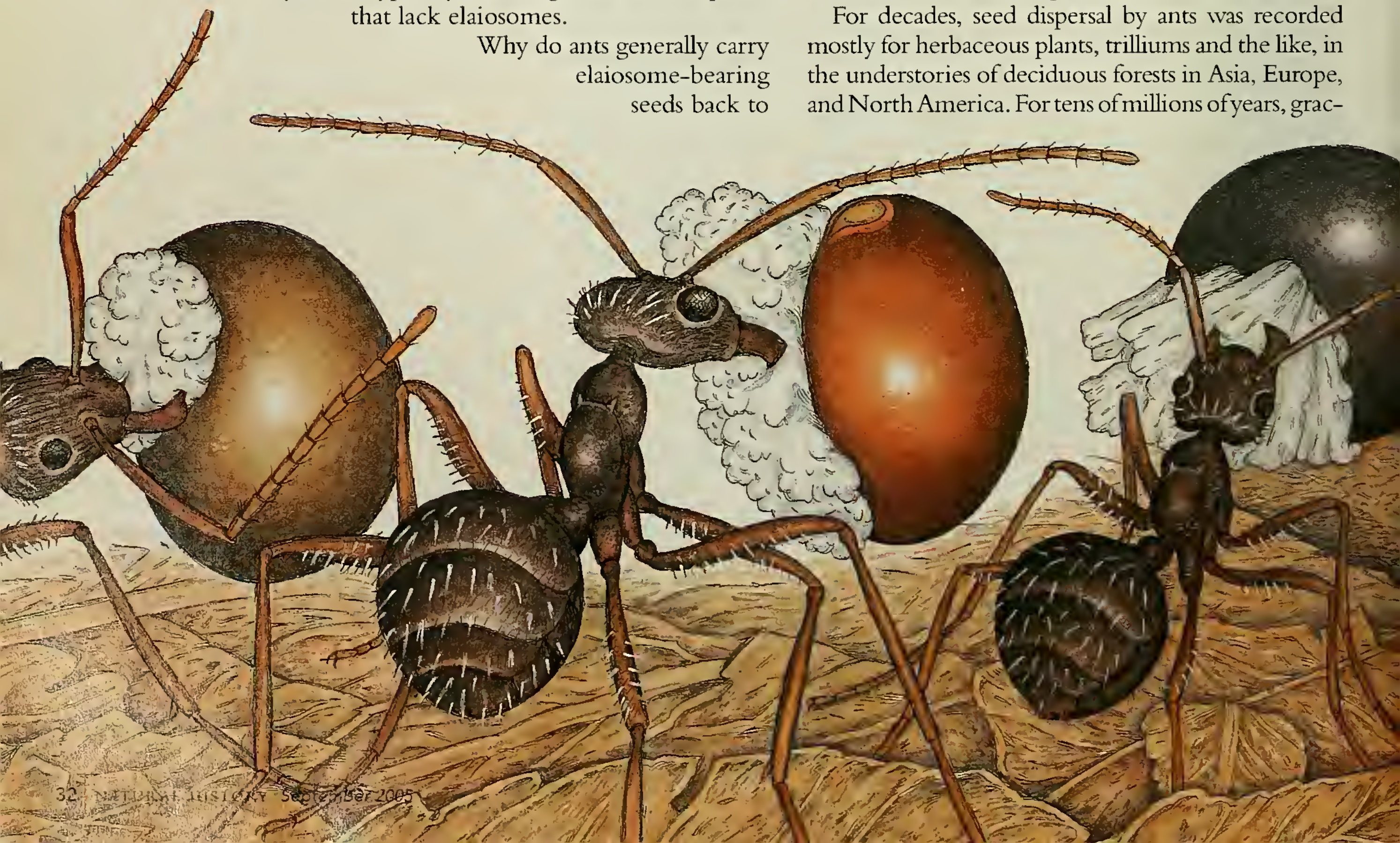
For a seed, getting dispersed by ants is like trying to get out of town on the local city bus. You often circle back to where you started.

In any given region, between five and ten species of ants might be expected to handle seeds in this way; you can check that on your own as you lie on your belly waiting for the next seed to fall. Most such ants are omnivores, generalists to which the elaiosomes represent just part of a diet that includes such delicacies as aphid poop, cricket wings, rival ants, and springtails. Other ants that consume elaiosomes are primarily predators on other insects, including other ants. Some ants, known collectively as harvester ants, do consume seeds, but the seeds they eat are typically those of grasses or other plants that lack elaiosomes.

Why do ants generally carry elaiosome-bearing seeds back to their nests, instead of removing the elaiosomes where they find them? The question was one of the first to be raised when the transport of seeds by ants was first discovered, and it remains largely a mystery. One suggestion is that elaiosomes contain chemicals that mimic dead insects. The ants, mistaking the elaiosomes for dead insects, would then carry the seeds back to the nest whole, as they often do with their prey. But that answer just raises another question: Why do ants carry insects back in one piece? Maybe the booty is less likely to fall into the mandibles of competing predators. But biologists really don't know.

Even less apparent is what plants are getting in return for proffering elaiosomes. Inducing ants to carry its seeds may be just a plant's way of moving around. Most plants, in fact, need help of some kind to disperse their seed—from bats, birds, primates, rodents, or wasps, or simply from the wind or the waves. Only with outside aid can their seeds reach new and possibly more auspicious surroundings. For similar reasons, some flies ride birds. Some lice ride flies. Bacteria ride in clouds (the late British zoologist William D. Hamilton famously suggested that some bacteria can actually trigger clouds to form so as to better disperse themselves).

For decades, seed dispersal by ants was recorded mostly for herbaceous plants, trilliums and the like, in the understories of deciduous forests in Asia, Europe, and North America. For tens of millions of years, grac-

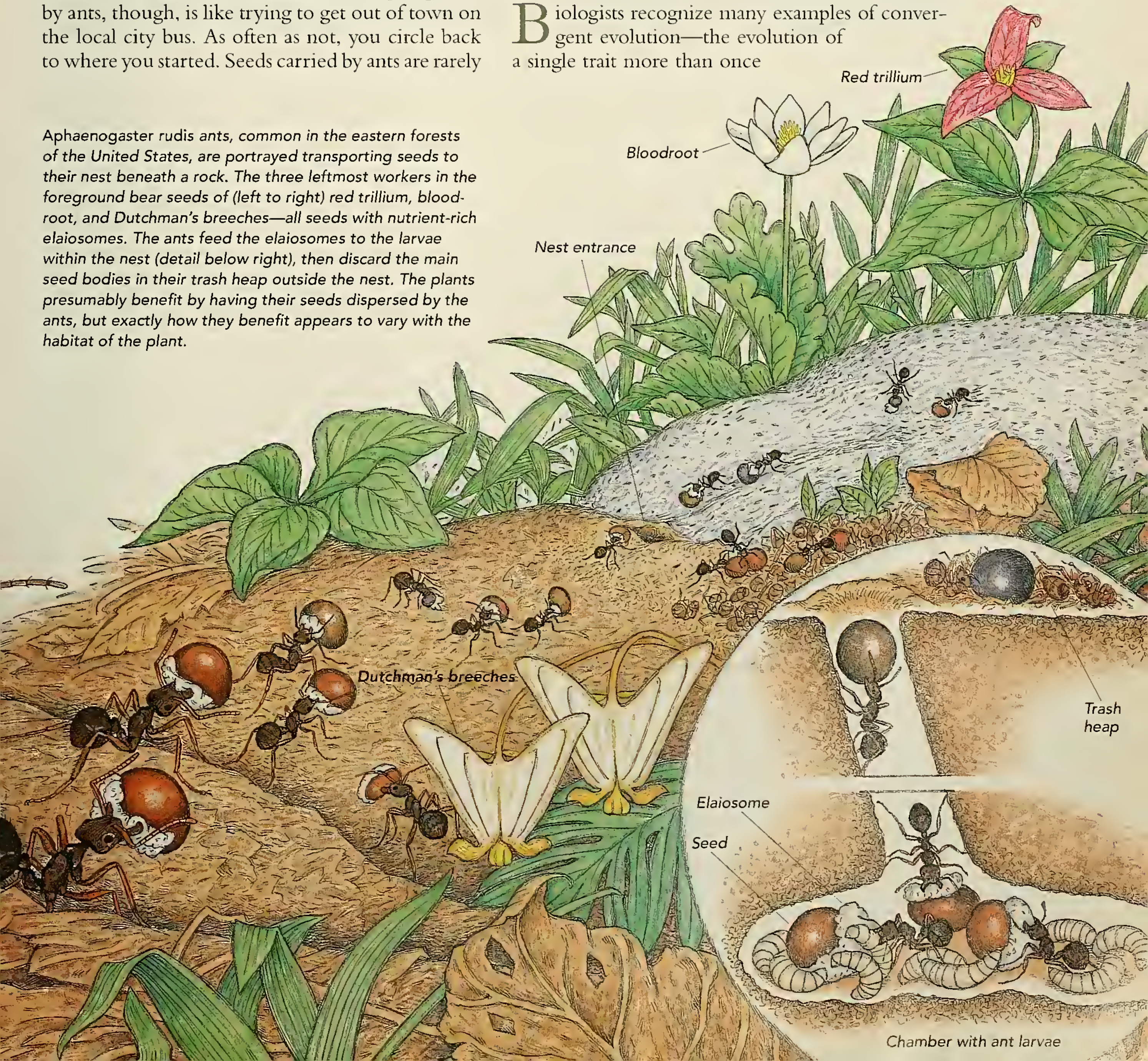


ile species of the ant genus *Aphaenogaster* and husky species of *Formica* hefted billions of seeds in each of these ecosystems. What do understory herbs have in common that makes their seeds more likely to be dispersed by ants than, say, the seeds of trees? It could be that the understory itself is not home to many other effective dispersers. Birds, for instance, might have trouble finding seeds on the forest floor—though they can be quite effective at dispersing tree seeds. Wind might not be strong enough to carry seeds effectively beneath the protection of the forest canopy.

But seed dispersal by ants also poses an entirely different kind of puzzle. Most modes of dispersal—bats, birds, wind—can ferry seeds far from their parents, to new and better habitats. Getting dispersed by ants, though, is like trying to get out of town on the local city bus. As often as not, you circle back to where you started. Seeds carried by ants are rarely taken more than a few feet from where they fall.

The issue wouldn't be so troubling if seed dispersal by ants had evolved just once or twice. But recently two of my collaborators at Curtin University in Perth, Australia, and I discovered that elaiosomes, and the dispersal of seeds by ants, have evolved at least eighty-six and perhaps several hundred times around the globe. In eastern North America alone, elaiosomes have evolved again and again, in various families of plants. In the Liliales (the group that includes the lilies) alone, ant dispersal may have evolved independently at least eight times. And the lilies aren't unique. Euphorbias do it. Violets do it. Grasses do it. Even some cacti do it.

Biologists recognize many examples of convergent evolution—the evolution of a single trait more than once



Aphaenogaster rudis ants, common in the eastern forests of the United States, are portrayed transporting seeds to their nest beneath a rock. The three leftmost workers in the foreground bear seeds of (left to right) red trillium, bloodroot, and Dutchman's breeches—all seeds with nutrient-rich elaiosomes. The ants feed the elaiosomes to the larvae within the nest (detail below right), then discard the main seed bodies in their trash heap outside the nest. The plants presumably benefit by having their seeds dispersed by the ants, but exactly how they benefit appears to vary with the habitat of the plant.

independently. In South America, anteaters evolved long sticky tongues that enable them to feed on ants and termites. Other ant- and termite-eating animals—armadillos in North America, echidnas in Australia, pangolins in Africa—evolved similar traits: a thick hide, long nose, and long tongue. (I can personally attest that pangolins and anteaters, at least, also converged on nearsightedness so extreme that it makes them likely to bump into you in the forests of the night.) Flight has evolved independently no fewer than four times. Singing has evolved dozens of times. Each instance of convergent evolution tells a story about what works on Earth and the few good ways to do a job.

Still, few cases are known in which a trait has evolved independently as many times as the evolution of elaiosomes. Such evolutionary repetition is good evidence that, again and again, they have proved advantageous, and in ways more consequential than hitchhiking three feet from a mother plant.

Ants are as constant as the elements. For millions of years plants and animals have evolved to take advantage of them.

But what are those advantages? Perhaps the seeds in ants' nests are better protected than the seeds of other species: from the elements, from predation, from pathogens. All of those hypotheses have some support. In North America, however, research has focused most closely on the suggestion that ants' nests are more fertile than surrounding soils. Or, to put the matter pungently, the grass is always greener over the septic tank. And sure enough, studies show that, at least in North America, ant garbage is richer in nitrogen and phosphorus than are the surrounding soils. Thus ants, the evidence suggests, were the first composters.

If the compost hypothesis is correct, plants that live where nutrients are poor should be more likely to entrust their seeds to ants. Epiphytes—plants that reside on other plants, such as on the branches of trees in the tropical-forest canopy—as well as plants that live in tropical-rainforest understories, inhabit such nutrient-poor zones. Ant-dispersed species have been found in both of those environments. Ant dispersal should also be common in the low-nutrient, but highly biodiverse, heathlands of Australia and South Africa. In 1975 the Norwegian botanist Rolf Y. Berg of the University of Oslo estimated that as many as a fifth of all Australian plant species are dispersed by ants. (My Australian collaborators and I now think the proportion may be as high as a third.) Soon thereafter, similar results emerged from the fynbos of South Africa, another semiarid, nutrient-poor, shrubby habitat. As many as a third of all plant species in the fynbos are dispersed by ants.

In 1688, long before Berg ever visited Australia, Gulliver encountered ant-dispersed Australian plants during his travels—or at least, the real-life model for Jonathan Swift's fictional Gulliver did. William Dampier, a buccaneer-naturalist who could write about the elegant legs of a flamingo in the morning and burn a village in the afternoon, was one of the first Europeans to document the natural history of Australia [*see Laurence A. Marschall's review of* A Pirate of Exquisite Mind, *"Bookshelf," June 2004*]. When Dampier landed in western Australia, he and his crew were looking for water and fruit (many were suffering from scurvy). They could locate no source of freshwater, and instead of fruit found only small unpalatable seeds. Little did they know the explanation for their bad luck was that the ants in the ecosystem did the work of carrying seeds. The "fruit" was everywhere, in the form of seeds with elaiosomes, but Lilliputian, unsuitable for pirates.

But the advantages of ant composting to plants may not be as straightforward as they seem. In 1986 Barbara Rice and Mark Westoby, both now ecologists at MacQuarie University in Sydney, Australia, examined the nutrient content of Australian ant garbage. They found no evidence that seeds dispersed by ants in Australia land in more nutrient-rich soils than the seeds not transported by ants. The reason may be that Australian ant colonies move more often than their North American counterparts, and so they do not accumulate as much garbage. Biologists weren't quite back to square one, but close. Something else was going on.

Australia burns. South Africa burns. For millions of years the two ecosystems have burned as often as every seven years. After a fire, plants must regrow from their burned stems or, more often than not, sprout anew from seeds. In the heathlands, with such frequent fires (and dependable rains), plants have evolved to germinate only following fires, because then they can take advantage of the pulse of nutrients deposited in the soil by ash. In many, perhaps most, Australian and South African ant-dispersed plant species, exposure to the smoke or some other aspect of a fire is what triggers the seeds to germinate. In the years between fires, essentially no seeds germinate. With fewer nutrients available, the seeds would be unlikely to grow into mature plants in time to produce seeds before the next fire.

How Would You Like Your Eggs?

The eggs of some stick insects, like the seeds of many plants, have nourishing appendages that encourage ants to pick them up and carry them away. The appendage of an insect egg is called a capitulum, and ants can remove it without damaging the egg. In the photograph above, for instance, eggs from the Central American stick-insect genus *Bacteria* are shown, magnified roughly fifteen diameters; the brown, knobby protruberances are the capitula.

The parallels between the elaiosomes of plant seeds and the capitula of insect eggs were first highlighted in 1992 by Mark Westoby and Lesley Hughes, both ecologists at MacQuarie University in Sydney, Australia. They gave seeds with elaiosomes and stick-insect eggs with capitula, along with several control items, to various ant species in southeastern Australia. The ants removed the seeds and eggs at a similar rate, treated them similarly, and threw them together into their garbage piles. The apparent advantage for the eggs is that, buried in the debris, they are less likely to be parasitized by wasps.

Perhaps it is appropriate that stick insects, which as adults mimic sticks, start out by living the lives of seeds.

Many plant groups in such fire-prone ecosystems have evolved seed-bearing cones that, when mature, remain on the plants instead of falling immediately to the ground. Such delayed seed release is termed serotiny. In fire-prone habitats, the seeds of serotinous species are stored in the canopy until their cones are opened by fire. Ant dispersal may be another way plants have found to safely store their seeds until the next fire. In that case, ant dispersal would serve not to provide compost to plants, but to protect them from predation, pathogens, and perhaps even desiccation. Some seeds in ant colonies may remain viable for as many as twenty years.

The hypothesis that ant dispersal is relatively advantageous in fire-prone ecosystems needs further testing. But short-term experiments in South Africa, done by Caroline Christian and Maureen L. Stanton, both ecologists at the University of California, Davis, suggest that seeds buried by ants are less likely to be killed by fungal pathogens than are seeds in the soil. My collaborators and I have also determined that where the diversity of serotinous species is high, the diversity of ant-dispersed species is also high. Our finding suggests that the same factors have driven the evolution of both modes of dispersal.

But if fire can explain the evolution of ant dispersal in South Africa and Australia, fire is obviously not a factor in tropical-rainforest understories and canopies, or even on the floors of forests like the ones I ramble through in the Smoky Mountains. Perhaps here, too, seed storage is more important than biologists have generally realized.

Yet storage is unlikely to be the whole story. Maybe it is just wrongheaded to search for a single, general explanation for the evolution of ant dispersal everywhere. Scientists like the elegance of simple explanations, but reality doesn't necessarily comply.

Biologists will debate the relations between ants and seeds for decades to come. Over beers at the end of the workday, even my collaborators and I disagree. Perhaps the only general conclusion is that whenever, for whatever reason, a plant species can benefit by entrusting its seeds to ants, the ants will be ready, willing, and able to do their bit. Ants are as constant as the elements, unwavering, little changing in their tastes, a fixture of the environment for millions of years. Against that background, plants and animals have evolved to take advantage of them for myriad tasks. If you drop it, they will come. □

The Ghosts in the Machines

Why does the industrial landscape seem so alien and forbidding?

By Brian Hayes

One winter afternoon a few years ago I was standing by a highway outside Gallup, New Mexico, admiring the scenery. The vista before me was a classic of the American West: red sandstone buttes rising from a valley floor, made redder still by the setting sun. It was the kind of landscape we all know from films and paintings and postcards. But this particular vista had something more. In front of the cliffs—and in fact rising to greater heights—were several cylindrical spires that I recognized as petroleum distilling columns, the kind of equipment that dominates the skyline of oil refineries. Off to one side were dozens of gleaming white storage tanks, some of them spherical, some lozenge shaped. The towers and tanks belonged to a plant for converting liquefied petroleum gas into propane and other products.

Many viewers of this scene would consider the industrial hardware in the foreground to be an intrusion, a distraction, perhaps even a desecration of the landscape. But it was the propane plant, rather than the scenic buttes, that had induced me to pull off the interstate and pull out my camera. For the past twenty years I have made a project of documenting the industrial artifacts that are so much a part of the modern landscape—from the most mundane bits of infrastructure (fire hydrants, manhole covers, traffic stoplights, utility poles) to those titanic installations that transform the terrain (landfills, mines, power plants, steel mills). Often I find myself making a pilgrimage to places that other people go out of their way to avoid, and I struggle to get an unobstructed photograph of the very things that everyone else tries to crop out of the frame.

At Gallup, I found the propane works interesting and worth a stop, but even I had to ask: Why *here*? The man-made elements of the scene—the cylinders and spheres and other simple geometric shapes—seemed to clash with the softer natural landforms, as irreconcilable as stripes and plaid. Couldn't they have

Wingate Fractionator Plant, outside Gallup, New Mexico, is a facility owned by the ConocoPhillips Company for processing liquefied petroleum gas. The plant lies near routes that reflect centuries of human travel by foot, covered wagon, stagecoach, railroad, and automobile. To the modern eye, however, the placement against the natural landscape appears jarring. The photograph was made by the author.

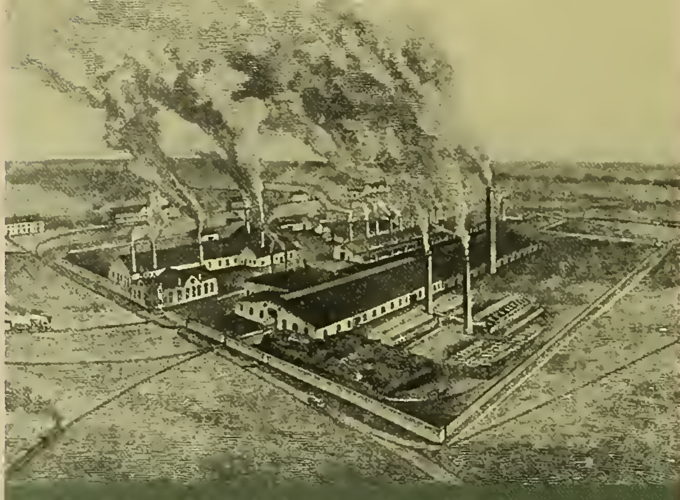
found a better place to put all that? History may provide a partial answer. The plant, at the terminus of a pipeline that originates ninety miles to the northeast, appears to have been located for convenient access to major east-west routes over which the gas products can be distributed—the railroad and Interstate 40. Before the highway and railroad were built, a stagecoach line followed the same route, which crosses the Continental Divide. Running parallel, thirty miles to the south, is the scenic road, State Highway 53, also known as the Ancient Way. That route follows a trail that, centuries before the arrival of Europeans, connected the pueblos of the Zuni and Acoma peoples. In other words, this landscape has been put to human use for a very long time. Still, the petrochemical gear seems to fall into another category, not just more conspicuous than earlier signs of human habitation, but also more menacing.

The clash of values goes beyond aesthetics. After all, everyone knows that nature is good and good for you, whereas industry is ugly, evil, and dangerous. The mention of nature brings to mind majestic landscapes: the Grand Canyon, Yellowstone, Yosemite. The mention of industrial technology brings to mind a long list of disasters: Love Canal, Three Mile Island, Bhopal, Chernobyl. In the presence of nature we hold our breath in hushed reverence; in the presence of industry we hold our nose.

It was not always thus. A few centuries ago, nature was often portrayed as savage, hostile, and cruel. Mountains and forests were barriers, not refuges. The lights of civilization were a comforting sight. We took our charter from the book of Genesis, which grants mankind dominion over the beasts, and we felt it was both our entitlement and our duty to tame the wilderness, fell the trees, plow the land, dam the rivers. In the most extreme version of this ideology, everything on the planet was put here explicitly for human use. At the opposite extreme, today, the Earth-first faction urges us to treat the entire planet according to the campsite ethic: carry out what you carry in, and leave no trace of your passage.

The crossover between those two sensibilities seems to have come sometime in the nineteenth century, when millions of people were leaving behind a rural life for jobs in factories, mills, and mines. That was the epoch when Henry David Thoreau decamped to Walden Pond (but couldn't escape the locomotive's whistle), and when John Muir became a

voice crying out for the wilderness. At the same time, however, others were still celebrating rather than lamenting the conquest of nature. In 1887 the American writer William Makepeace Thayer published an exuberant travel guide, *Marvels of the New West,* whose title page promises "marvels of nature, marvels of race, marvels of enterprise, marvels of mining, marvels of stock-raising, and marvels of agriculture." Five of those six marvels refer to products of human activity (the "marvels of race" are archaeological relics). Even the chapter on marvels of nature bears a strong human imprint. The engravings that illuminate those pages show canyons, peaks, and craggy rock formations, but there is very often a railroad line running through the middle of it all.



Smelter in Argo, Colorado, for recovering gold and silver, is portrayed in this engraving, published in William Makepeace Thayer's 1887 travel guide, Marvels of the New West. The guide reflected the exuberant aesthetic sensibilities of a growing nation, extolling the products of human activity—including agriculture, mining, and railroad construction—as much as the natural landscapes that made up their backdrop.

The modern resolution of those conflicting impulses is a curious one. Obviously we live in a world where technology has triumphed, where most citizens spend the better part of their days interacting with machines: automobiles, computers, televisions, automated bank tellers, self-service gas pumps. Even those who go out to seek the wilderness are likely to take along a cell phone and a GPS receiver.

And yet there has never been more wariness of industrial development and more skepticism about its benefits. There's so much to worry about: antibiotics, hormones, and pesticides in the food supply; declining fisheries; genetically modified crops and livestock; greenhouse gases and global warming; mad cow disease; mercury and sulfur emissions from coal-fired power plants; the accumulating radioactive wastes from nuclear power; the slash-and-burn destruction of tropical rainforests. We fear that our own wastes will overwhelm us. We complain that automobiles are choking our cities, and their exhaust fumes are choking us—but, we suspect, if the petroleum to fuel all those SUVs runs out, the practical consequences will be even more dire. All in all, the values people hold—or claim to hold—are closer to those of Thoreau and Muir than to the industrial boosterism of William Thayer. Yet the high-tech world is the one we choose with our dollars and our actions.

In the middle of my long journey through the industrial landscape, I made a discovery that may help to explain a little about this strange ambivalence toward technology and industry. I had an epiphany in a parking lot.

I was visiting a railroad facility known as a hump yard. The basic function of the place is much like that of a post office sorting room, but the scale is a good deal larger because the items being sorted are not letters but 150-ton freight cars. Trains from various cities converge on the yard, where the cars are separated and reshuffled into new trains, which then depart for other destinations. Engines push a long line of cars slowly up a hill, ascending at a walking pace. At the crest of the "hump," the cars are uncoupled one by one and allowed to roll down into a "bowl," where many tracks fan out to the left and right [*see photograph on opposite page*]. A series of switch points directs each car to whatever track holds the correct outgoing train.

The hump yard I visited was a big place, a hub of the national rail network, covering hundreds of acres of land. When I drove through the entrance gate, I wasn't surprised to find a parking lot with space for at least 200 cars. But the lot was empty except for a dozen cars and pickup trucks huddled near the entrance to the main building. The superintendent who was showing me around soon explained. At one time, he said, the yard employed a large number of brakemen, who rode along on each of the freight cars to control the speed as the cars rolled downhill. There were also switch operators, who steered the cars onto the right tracks. And inside the building was a roomful of clerks, who handled the paperwork that accompanied every freight car on its trip across the country.

All those workers are gone now. The role of the brakemen has been taken over by mechanical "retarders," rail devices that control the speed of a passing car by squeezing the flanges of the wheels. The motion of the cars is measured by a radar gun much like the one that police use to catch speeders; a computer then adjusts the retarders accordingly. Computers also control the switches that guide the cars to the right tracks. And the paperwork, too, is a thing of the past; like most other business transactions today, freight manifests are handled by electronic communication. The room that used to house the clerks is as empty as the parking lot.

What struck me that morning was just how lonely a place the industrial landscape has become. It's not just railroad freight yards. I found the same haunting depopulation almost everywhere I looked. On the docks of a cargo port, gangs of longshoremen used to swarm over a ship to load or unload it; now most of the work is done by one artful crane operator, perched high overhead, placing 60,000-pound containers in a ship's hold or on a dock at the rate of two a minute. Where miners used to toil underground, drilling and blasting, the earth is now ripped open by gargantuan shovels and draglines; these machines, too, are controlled by one worker in a high glass booth. Telephone switching centers, once filled with the voices of hundreds of operators, are silent, dark, and deserted. On the plains of Kansas a solitary farmer in the cab of a magnificent tractor plows and plants a thousand acres of land.

Fifty years ago "automation" was a hot topic, a subject for academic studies, newspaper editorials, congressional hearings, and presidential commissions. The prospect of replacing human labor with machines seemed at once attractive and forbidding. According to one view, automation would liberate us from drudgery, giving people the time and economic freedom to cultivate higher callings; we would become a society of poets and scholars at leisure. The other side asked: If our jobs are taken by sleepless machines, how shall we live?

At the time these competing visions of the future were being vigorously debated, most people probably believed neither of them. The idea that automation might either displace or liberate some large fraction of the workforce was one of those world's-fair fantasies that would always remain just beyond the horizon, like the car that drives itself.

Now automation is a reality, even though the word itself is seldom spoken anymore, and the debate over its threats and promises has faded from memory. Entire categories of jobs have all but disappeared. Elevator operators, typesetters, and airplane navigators have followed milkmaids and lamplighters into oblivion. It has all happened with remarkably little fuss. The marauding Luddites of nineteenth-century England smashed the power looms that threatened their livelihood, but the recently displaced bank tellers have not been sabotaging ATMs. Neither the utopian nor the dystopian vision of an automated future has quite come to pass. We have not yet become a nation of poets and scholars, but neither are there vast armies of the dispossessed and unemployed roaming the streets begging for bread. Perhaps we don't yet know

Hump yard in Linwood, North Carolina, is a facility for sorting freight cars to make up trains. Such yards once employed hundreds of workers; today most of the work is done electronically and automatically, supervised by a small crew in a control tower. The photograph was made by the author.

all the social and economic consequences of automation, or of the related trends designated by the current buzzwords "outsourcing" and "globalization."

But one effect is clear: the depopulation of the industrial landscape has made it seem an otherworldly place, disconnected from our everyday lives.

Farms, mines, factories, mills, and ports were not always such lonely places. Millions labored there. Today, in contrast, most of us do our work in offices, stores, restaurants, hospitals, or classrooms. Only 8 percent of U.S. jobs are classified as "production occupations," a category that takes in everything from assembly-line workers and machinists to nuclear reactor operators. (The category doesn't include farmers, but they have almost fallen off the charts anyway, making up less than one-half of 1 percent of all workers.) Few Americans of the younger generation have ever seen the inside of a coal mine or a steel mill.


Toyota automobile manufacturing plant near Georgetown, Kentucky, is situated outside the town and far from any large city. Such out-of-sight, out-of-mind locations are typical of many manufacturing sites today. The aerial photograph was provided by Toyota Motor Manufacturing, Kentucky, Inc.

The changing geography of industry has added to the sense of isolation. Industrial districts were once planted in the heart of the city—or else the city grew up around them. The automobile assembly plants in Detroit, the flour mills in Minneapolis, and the stockyards in Chicago were all urban institutions. The steel mills of Pittsburgh and Cleveland were surrounded by the homes of the people who worked there. New York City's garment district was in the middle of one of the most densely populated neighborhoods on the continent.

Today, by mutual consent, industries get as far away from people as they can. The "industrial park," a term whose linguistic oddity has worn off over the years, is explicitly designed to buffer factories and warehouses from residential areas. Or consider the new generation of automobile manufacturing plants, such as Toyota's immense factory near Georgetown, Kentucky: they are miles out in the countryside, off by themselves, with only a few farms for neighbors. Baltimore's Inner Harbor is another instructive example: The wharves of the neighborhood were once the economic engine that drove the rest of the city. The area is still a moneymaker, but the wharves have been replaced by hotels, restaurants, a convention hall, a ball park, and an aquarium. Baltimore remains a major port, but the ships unload in newly built facilities situated miles from the Inner Harbor.

It's a familiar refrain: people want electricity but no power lines, gasoline but no refineries, cell-phone service but not the cell-phone antenna tower. I once spoke with the aggrieved and exasperated operator of a stone quarry. When he began digging his pit, it was on the distant outskirts of a city, but it had since been engulfed by suburban development. Nearby homeowners wanted to shut down the quarry because of the noise, the dust, and the truck traffic. The owner objected that he was there first, indeed that stone from his quarry had built the foundations of the houses. The new residents' intolerance was unfair and irrational, he complained.

The manager of a garbage-burning incinerator told me that the acronym NIMBY, for "not in my back yard," has been superseded by the more extravagant terms BANANA ("build absolutely nothing anywhere near anybody") and NOPE ("not on planet Earth"). Needless to say, there is another side to the argument, starting with the principle that people should have a voice in the decisions that shape their own environment. On a local scale, decisions about where to build landfills, sewage plants, and highways are a severe test of the democratic process. More often than not, the nastier bits of infrastructure wind up on the poorer side of town. The same thing can happen on a national or global scale, when richer cities or countries find ways to export their wastes and other problems.

As industry retreats to the margins of society, queasiness about technology is fueled in part by people's isolation from the means of production. Because the mills and factories and power plants are places we never enter, they begin to seem alien, exotic, mysterious—and often sinister. We don't know what goes on behind the chain-link fence of a refinery or a smelter or a paper mill, or what comes out of the smokestacks, and therefore we suspect the worst. The owners of the plant—and often the workers, too—feel besieged by a hostile and uncomprehending public; they respond by closing the gates and building the fences higher. Their secrecy, naturally, tends to confirm public suspicion that they must have something to hide. And maybe they do. It is a spiral of distrust and animosity.

Perhaps there is still some hope of reconciliation, but it will take a while. Not all industrial artifacts evoke fear or disgust. Lighthouses, for instance, have a certain romance about them, and Dutch windmills are considered highly picturesque. Tugboats have inspired cheerful children's books. Railroads have their rail fans, who prowl the freight yards like paparazzi. Some of the old water-powered mills along New England's rivers, where generations of workers toiled for paltry wages, have been turned into upscale restaurants and shops. Quaker Oats mills and silos in Akron, Ohio, have been converted into a hotel. A former steel mill in Duisburg, Germany, has been converted into a new kind of industrial park—one where children play among the ruins of blast furnaces.

Those examples suggest that fondness and quaintness come with age—or better yet, with obsolescence. Hence that propane plant outside Gallup may look rather different to future generations. In fifty years—or maybe it will take 150 years—we'll be looking back on the brief but glorious age of petroleum in the same way we now look back with both horror and nostalgia on the age of whale oil. Those towers and tanks beneath the red rock buttes will be lovingly restored as historical artifacts; the buttes would look bereft without them. □

This article was adapted from Brian Hayes's forthcoming book, Infrastructure: A Field Guide to the Industrial Landscape. *Copyright ©2005 by Brian Hayes, and used with the permission of the publisher, W.W. Norton & Company, Inc.*

Steel mill, once the locus of humming industrial activity, now lies shuttered in Bethlehem, Pennsylvania. People may someday view such industrial infrastructure as picturesque, as they do the windmills and lighthouses of yesteryear. The photograph was taken by William Thomas Cain.

The Magic Flutes

Nine thousand years ago, Neolithic villagers in China played melodies on instruments fashioned from the hollow bones of birds.

By Zhang Juzhong and Lee Yun Kuen

Long ago in Jiahu village, an acclaimed musician passed away at the mature age of thirty-five. People who had appreciated his music flocked to the funeral ceremony. The musician's body was dressed in his finest clothing, and a turtle shell was tied to his right shoulder. In life he had often worn the shell: with a few pebbles placed inside, it rattled as he danced to his own music. One of the musician's two surviving sons, young men in their late teens, directed several helpers as they lowered the body into the rectangular earthen pit dug the day before. Then, kneeling in the grave, he separated the head from the torso with a stone ax, and carefully turned the head to face northwest—a customary treatment for special people of the time.

Leaning over the edge of the grave, the musician's other son then passed down the sixty or so offerings. His brother put the three-legged cooking pot, along with a jar and a vase containing provisions for the afterlife journey, near the head. Arrows and barbed harpoons were placed near the right leg; milling stones, awls, chisels, knives, and other offerings were set to the left of the body. Finally, the musician's two flutes, each crafted from the hollow wing bone of a red-crowned crane, were tucked on either side of his left leg. Then the son climbed out of the grave, and six or seven helpers started the backfilling with stone shovels.

We hope the reader will indulge the small license we have had to take in telling this tale. Our story is consistent with the abundant physical remains, but the burial took place long before history was written down. Yet, unlike most tales based on archaeological reconstruction, this one concludes with an episode that almost sweeps away the fog of the intervening centuries and brings the dead to life. In May 1987, more than 8,000 years after it had last been touched by human lips, one of the musician's two flutes was played again. The room was dead silent as Ning Baosheng, the flutist of the Central Orchestra of Chinese Music in Beijing, held the bone instrument at a forty-five-degree angle to his mouth. One by one, he tested the holes. The assembled archaeologists and musicians were amazed by the sound produced by a flute of such great antiquity. The tones seemed so familiar. In Europe, archaeologists have discovered the remains of even more ancient flutes, also fashioned from animal bone, but none in playable condition.

Bone flute, one of two discovered in a grave excavated at the site of Jiahu, in central China, is tested by one of the authors (Zhang). The grave dates from the early Neolithic, or New Stone Age, about 8,000 years ago, when people began living in villages and cultivating crops.

Jiahu is the name of a modern village in central China and, by extension, the name of the ancient flute-owner's village, or at least its archaeological remains. The setting is the upper valley of the Huai River, which flows east between the Huang He (Yellow River) to the north and the Chang Jiang (Yangtze River) to the south [*see map on next page*]. The site was discovered in 1961 by Zhu Zhi, an administrator of cultural resources, who plucked pottery shards and other material remains from the walls of wells and gullies. Archaeological excavation began in 1983, when the site was threatened by local development.

Chinese archaeologists cannot possibly excavate all sites threatened by development, but they consider Jiahu special. The artifacts collected even at

Excavated grave, thought to be that of a musician, shows by the positioning of the two bone flutes close to the remains that the instruments were among the prized possessions of the deceased. One flute was found intact; the other was broken in three pieces. Examination of the broken flute showed that it had been carefully repaired in antiquity.

Archaeological site of Jiahu takes its name from the present-day village nearby. The site is known to have been occupied from 9,000 until 7,800 years ago, and then from 2,000 years ago until the present. Further excavations may show that the settlement was occupied at other times as well.

the surface are as much as 9,000 years old, dating from the early Neolithic, or New Stone Age, when people first began to rely on domesticated crops and animals. Moreover, little was known about this stage of prehistory in this part of China. Six seasons of fieldwork, lasting between several weeks and several months each, were conducted between 1983 and 1987. A second round of excavations started in 2001 and is still under way.

At the outset, however, no one expected to find anything as exotic as a flute. Indeed, by the middle of the fourth season of excavation, in early May 1986, the archaeologists were beginning to feel bored, as the same arrowheads, harpoons, milling stones, spades, vessels, and other utilitarian artifacts surfaced over and over again.

Then one of us, Zhang, the director of the excavation, was approached by Yang Zhenwei, the field director, who was excavating a grave designated only by its field label: M78 (in the convention of Chinese archaeology, M designates a burial, because *mu* is the Chinese word for grave). Two bone tubes, each with seven small holes drilled on one side, lay within the collection of artifacts. Neither Yang nor Zhang dared utter a word about what was racing through their minds. Although the two artifacts bore a striking resemblance to a modern Chinese folk instrument—a kind of upright bamboo flute—nothing like that had ever been discovered in China from so early a time.

The finds were unprecedented but, as it turned out, not unique. Another flute was discovered in another grave the next day, and another in still another grave. Then they just kept coming. By the end of the first series of excavations, in June 1987, twenty-five specimens had been discovered. Seventeen were intact, or nearly so, six were broken or fragmented, and two were half-finished. All were made from the ulna—a wing bone—of the red-crowned crane [*see illustration on opposite page*]. The naturally hollow bones were first cut to a length of between seven and ten inches, then smoothed at the ends, polished, and finally drilled on one side to make a row of between five and eight holes.

Among the flutes was M282:20, the twentieth object documented in grave M282, and the basis for the vignette at the beginning of our story. That flute was found in pristine condition and was the first to be tested. During more recent seasons of excavation, Zhang's team has uncovered still more flutes from the burials, bringing today's total to thirty-three. And more tests have been conducted on the playable flutes. Those instruments have now afforded some insight into the evolving musical knowledge and skills of people who lived millennia before the first written records of music. At the same time, we must admit that their motives for playing music and their "ear" for appropriate musical composition and sound are still steeped in mystery.

The musical cultures of the past, like the ones of today, did not exist in a vacuum. Jiahu's location was apparently quite favorable because Neolithic people occupied the site almost continuously from 9,000 years ago—near the dawn of agriculture in China—until 7,800 years ago. The archaeological work at the site to date has yielded fifty house foundations, 430 storage pits, eleven pottery kilns, 439 burials, and thousands of artifacts made of bone, pottery, stone, and other materials. The stratigraphy of the site shows that it was occupied again in historical times, beginning in the Han Dynasty (second century B.C. to second century A.D.), and continuously thereafter down to the present. The intervening time is still a blank, but so far only 5 percent of the site has been excavated; further work could well show additional periods of occupation.

One surprising discovery is that the villagers grew *japonica* rice, a short-grain subspecies. Many scholars have believed that rice cultivation began with the long-grain *indica* subspecies, a crop domesticated in the tropics and subtropics 6,000 years ago. The short-grain type arose—or so the thinking went—as the crop spread to the cooler, more northerly latitudes. The early appearance of *japonica* rice in the north, together with some equally early finds of both subspecies in the lower Chang Jiang valley, has complicated that picture.

Apart from cultivating rice, the Jiahu villagers hunted and fished, taking carp, crane, deer, hare, turtle, and other animals. They also collected a broad variety of wild herbs, wild vegetables such as acorns, water chestnuts, and broad beans, and possibly wild rice. And they possessed domesticated dogs and pigs.

Living conditions in an ancient community are reflected not only in the artifacts unearthed, but also in the inhabitants' skeletal remains. Factors such as diet, disease, and mechanical stress leave indelible marks on bones. Barbara Li Smith, a forensic archaeologist at Harvard University, examined the skeletons of 248 individuals recovered in the excavations. She concluded that the villagers enjoyed reasonably good health. The Jiahu life expectancy, or average age at death, was about forty years, longer than usual for Neolithic farmers. Bone lesions from infectious disease or parasitic infection are rare. Osteoarthritis, a sign of bone degeneration with age or of the mechanical stresses of repetitive motion, appears in 38 percent of the skeletons.

As for more serious health problems, more than two-thirds of the skeletons show signs of iron-deficiency anemia. The tip-off is the presence of spongy lesions in the skull: marrow in the skull, compensating for the anemia, expands to make additional red blood cells. Anemia may reflect infection, but people whose dietary staple is grain often have a high incidence of iron-deficiency anemia simply because grain is deficient in iron.

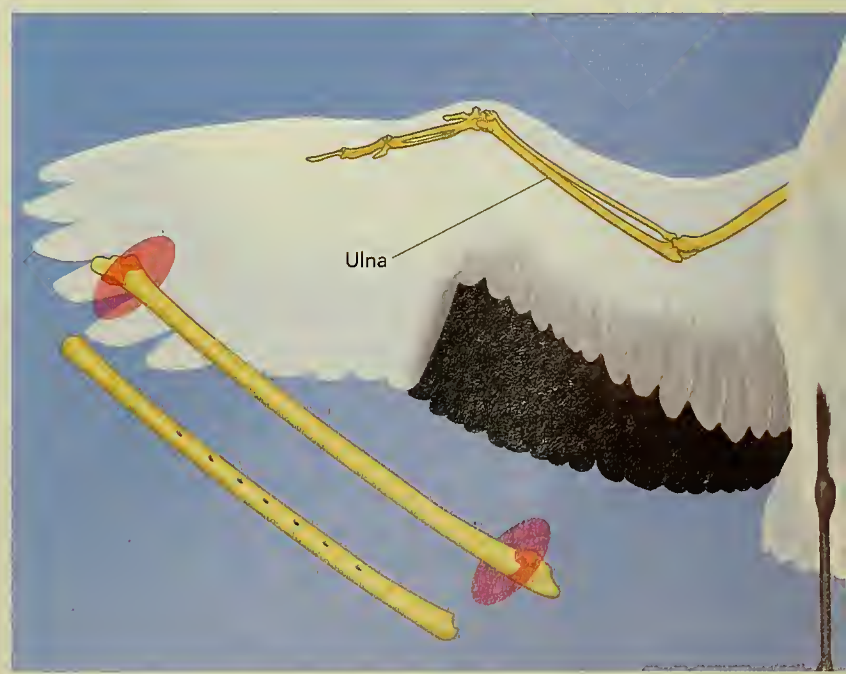
To learn more about the Jiahu diet, archaeologists examined the ancient pottery vessels. The vessels' contents had long since decayed away, but pottery is quite porous, and the hope was that residues trapped and preserved in the minute holes might be detectable with the right kinds of high-tech equipment. Patrick McGovern, a biomolecular archaeologist at the University of Pennsylvania Museum of Archaeology and Anthropology, analyzed potsherds of sixteen jars and vases. He extracted organic chemicals from thirteen of them, finding signs of rice, honey, and grape or hawthorn fruit.

McGovern concluded that many of the pottery jars and vases were used for fermenting and storing wine or beer. The ancient villagers not only fed themselves well, but also made alcoholic drinks from surplus grain. Besides being intoxicating, McGovern maintains, alcohol may have been healthful, because it kills many disease-causing microorganisms. The villagers also offered wine or beer to the dead, placing jars and vases in many of the graves.

The excavation at Jiahu uncovered the remains of 439 juveniles and adults, buried in pits, and 32 infants, buried in urns. Some pits contained just one individual, others as many as six. The multiple interments usually represented the reburial of skeletal remains from earlier burials, though in a few cases one new, or primary, interment was added. No one knows how the individuals buried together may have been related, but they were mixed in sex and varied in age.

In thirty-seven primary burials, the skull, mandible, or other bones of the extremities are missing from the skeleton; cut marks show that they were removed when the bone was fresh. Either the individual died of the cuts, or the parts were removed soon after death. In a dozen or so examples, such as the body of the musician in grave M282, body parts were severed, but the parts remained in the grave. We think that the various manipulations of the skeletons were reserved for important members of the society, simply because they involved more labor. Their purpose at Jiahu remains obscure, but in prehistoric Europe, some human bones seem to have been circulated among the graves and the living population, presumably because they were valued or venerated.

The flutes discovered so far all came from graves, usually graves that were fairly rich in burial goods. We and our colleagues have tested the tones of six flutes that are still playable. Those tests can tell us something about the musical scales that the in-



Bone flutes were fashioned from the ulna (one of the wing bones) of the red-crowned crane. Such bones are naturally hollow.

struments could have produced, and from the scales we can infer something about the complexity of possible melodies. In addition, the site was occupied in three distinct phases, from 9,000 until 8,600 years ago, from 8,600 until 8,200 years ago, and from 8,200 until 7,800 years ago. A comparison of flutes from those three periods can tell us whether the scales and possible melodies became more sophisticated with time.

A flute makes a sound because the player causes the column of air in its tube to vibrate. In a vertical flute, the customary way to set the air in motion is to rest the upper end of the tube against the lower lip and blow across the opening—much the way one makes an open bottle hum by blowing across

Three of the nearly three dozen bone flutes excavated from Neolithic burials in Jiahu are pictured (top to bottom): a six-hole flute from the early phase of occupation, between 9,000 and 8,600 years ago; a seven-hole flute from the middle phase of occupation, between 8,600 and 8,200 years ago; and an eight-hole flute from the late phase of occupation, between 8,200 and 7,800 years ago. After archaeologists temporarily repaired the eight-hole flute with Play-Doh, the tones of all three could be compared.

its rim. The angle and strength of the player's breath affect both pitch and sound quality, but what mostly determines pitch is the length and volume of the column of vibrating air. When the instrument is more than a simple tube, such as a flute with finger holes, the player can manipulate the size of the air column by covering or uncovering the finger holes.

Skilled musicians can get complex sounds and a variety of pitches out of an instrument by only partly covering the holes or by opening and closing them according to relatively complex patterns (known as cross-fingering). Without knowing the playing techniques of the ancient musicians, though, we were limited to testing the pitches that could be made with simple fingering. We measured the frequency of each pitch with an electronic sound-analyzing instrument called a Stroboconn.

Only two flutes have been recovered from the earliest phase of settlement; both came from the grave of an adult male. One has five holes, and so it can produce six discrete pitches, one for each hole, plus the pitch produced by the entire length of the instrument, when all the holes are covered. In two cases, however, notes are repeated an octave apart, so the musical variety is somewhat restricted. If you try constructing a scale, you wind up, in a sense, with only four notes, separated by wide gaps. Nevertheless, even such a simple scale shows that the flute players sounded more than single notes, and if one assumes that Jiahu musicians used cross-fingering and other means to vary the pitch, they could have played fairly elaborate pieces of music.

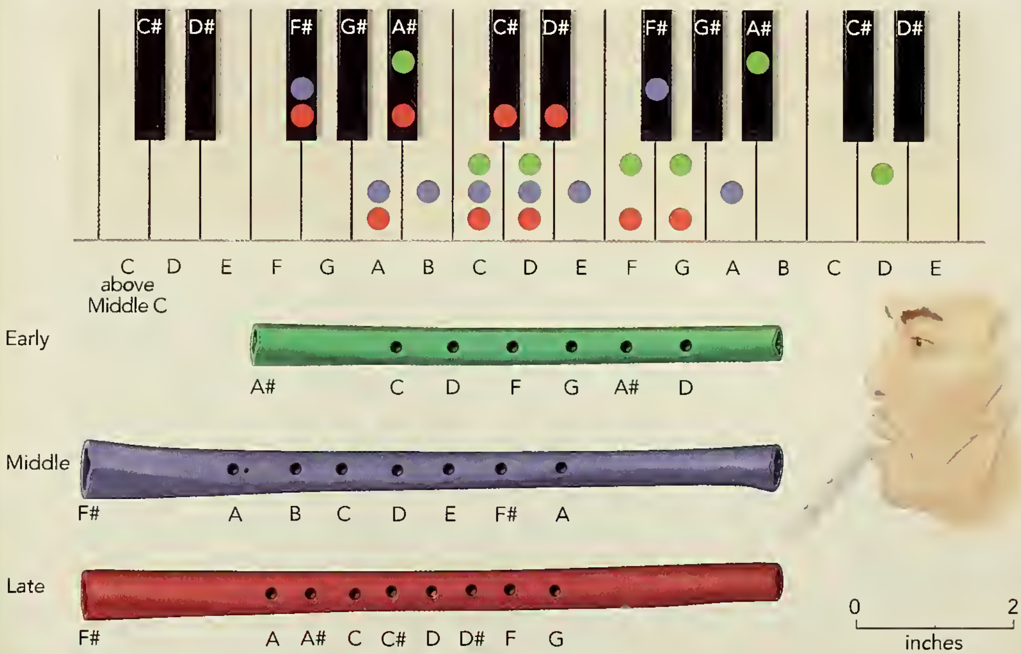
The second flute from the earliest phase of settlement has six holes [*see photograph at left*]. This flute can play seven discrete pitches, but again, in two cases, notes are repeated an octave apart. Thus the flute gives ready access to a five-note scale—an intriguing discovery in itself, given that a pentatonic, or five-note, scale is the basis of Chinese folk music even today. The presence of a five- and a six-hole flute in the same grave indicates that different musical scales probably coexisted during this phase of settlement in Jiahu.

About two dozen flutes were unearthed from the second phase of Neolithic settlement. Fifteen of them were intact or could be reconstructed. One of those has only two holes, but the others all have seven. Three of the seven-hole flutes are still playable, including the two that were found in grave M282, the burial of our now-famous musician.

Those two flutes alone are quite revealing. One of them, as we noted earlier, is in pristine condition, and the other, though broken into three sections in antiquity, had been carefully repaired. The ancient repair involved drilling fourteen tiny holes along the breakage lines and then tying the sections together with string, traces of which are visible. Modern laboratory technicians re-repaired the flute with glue, and to everyone's satisfaction, its tones could still be tested.

Thanks to the additional hole, each flute can play eight pitches, and despite some differences, the range of pitches and the intervals between them are similar. Those similarities led us to propose that the repaired flute was made first, and was highly esteemed by its owner. After the breakage and repair, we think, it was used as a model to cut the second flute. A tiny hole just above the bottom hole of the second flute is a telling clue [*see photograph on this page*]. We believe it was a test hole, drilled in an effort to match the pitch of the repaired flute, but the pitch it gave proved too high. The bottom hole was therefore drilled a bit farther from the mouth, and perhaps the little hole was plugged up. During our pitch analysis, the small hole had to be closed for the flute to produce the "right" tone.

The latest Neolithic deposits yielded seven flutes. One of them, with eight holes, is still playable. By that time the flute makers and players had become much better experienced with the acoustic capabilities of their wind instruments. They knew that by adding more holes and structuring the pitch intervals closer together, they could increase the variety of melodic structures in their music. In addition, the flutes became more standardized in pitch, presumably so that compositions could be played in a more consistent musical scale, perhaps for ensemble playing.



Approximate pitches produced by the three flutes in the photograph on the opposite page are given for each hole on each instrument. (A pitch is sounded by covering all the holes except the one corresponding to the labeled note; when the player covers all the holes, the pitch sounded is shown at the bottom end of the instrument.) Keys of the piano keyboard at the top are color coded to indicate the approximate pitch of each flute tone.

More evidence for the tuning of Neolithic scales has turned up at Zhongshanzhai, a site about eighty miles northwest of Jiahu and contemporaneous with the third phase of Jiahu settlement. A six-inch section of a bone flute unearthed from Zhongshanzhai has ten holes, arranged in a staggered pattern along two parallel rows. The holes are so close to one another that there is no room for comfortable fingering. Tonal tests show that the intervals between adjacent pitches closely approximate the half step (the interval, for instance, between a white key and an adjacent black key on a piano). This flute was very likely a tuning instrument, rather than one used for performing.

Unfortunately, the actual tunes played by musicians so long ago are beyond the reach of our archaeological tools. And we may never know why there were so many flutes in Jiahu. Some archaeologists speculate that the flutes were related to shamanistic rituals. If that were the case, our counts of flutes and burials imply that there was one shaman for every twenty people in the community—an unusually high proportion of ritual specialists for a farming village.

We think the music played a less esoteric role. Certainly it was an important element of community life. Given the availability of alcoholic drinks, we like to think the people of Jiahu enjoyed festive times.

Another mystery is why the villagers of Jiahu selected the wing bones of the red-crowned crane to craft their flutes. In Chinese legend, the Yellow Emperor cut flutes from bamboo, and bamboo may also have been used to make flutes at Jiahu and other Neolithic sites. But bamboo does not normally survive burial for thousands of years, so we archaeologists can be grateful for the choice of bone.

Standing nearly five feet tall, possessing an eight-foot wingspan, and bedecked with snow-white plumage accented with black and red, the red-crowned crane is an inspiring bird. The dance ritual of the male and female during courtship and pair-bonding is one of the most entertaining spectacles in the world of birds. It is replete with bows, leaps, extensions of the wings, and other dramatic gestures. The couple also performs a duet of loud, ringing calls between dances. Music is often inspired by the animal world. Did the musicians of Jiahu intend to imitate the crane's calls in their music? If so, perhaps they sought a magical assist by making flutes out of the birds' very bones. □

By Laurence A. Marschall

Grand Canyon: Solving Earth's Grandest Puzzle
by James Lawrence Powell
Pi Press, 2005; $27.95

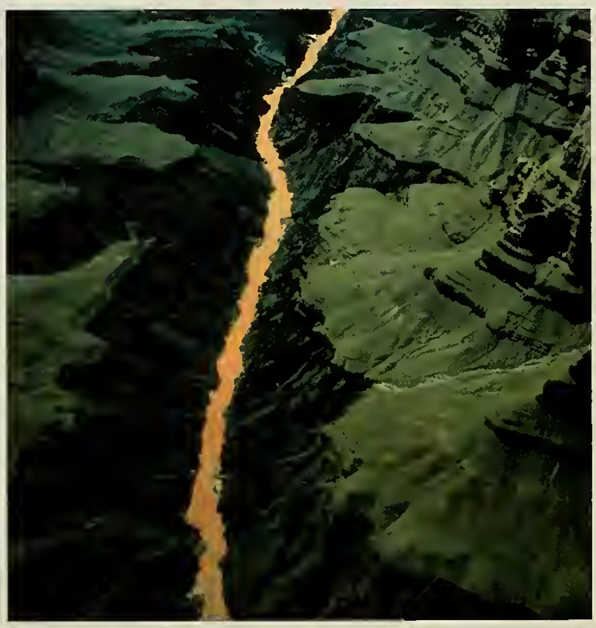
There are many passages in his classic, *Tertiary History of the Grand Cañon District,* published in 1882, in which the geologist Clarence Edward Dutton abandoned the customary reserve of the scientist to describe what lay before him:

> Reaching the extreme verge the packs are cast off, and sitting up on the edge we contemplate the most sublime and awe-inspiring spectacle in the world.

Geologically, however, the Grand Canyon is also one of the most perplexing spectacles in the world. Dutton knew that, in principle, a record of its past lies exposed in the layers of rocks that so marvelously pattern its walls. But just how to read that record has been a matter of continuous debate ever since John Wesley Powell led the first expedition through the deep gorges of the Colorado River in the summer of 1869.

Visitors nowadays get a general picture of the accepted scientific explanation from guidebooks and park rangers. The canyon's upper sedimentary layers, they will tell you, were laid down in a series of lakes or shallow seas that covered the region for hundreds of millions of years. They will also tell you that, surprisingly, the canyon itself is much younger than its rocks, dating back only five or six million years. Once a meandering river, the Colorado carved a canyon when the entire region that is now northern Arizona, Colorado, and Utah was uplifted by tectonic forces to form the so-called Colorado plateau. As the land rose, the rushing Colorado cut down through it, just as a rotary saw blade cuts a narrow kerf into a log that is being lifted up into a sawmill.

As the river cut through the first 3,000 feet of rock, the canyon walls eroded and slumped into the rushing waters. Each collapse exposed a new wall, leading to cycles of erosion and collapse that opened a wide expanse of spectacular vistas, some measuring fifteen miles from rim to rim. But when the river encountered resistant igneous rocks, it cut more slowly and laboriously, leaving an inner canyon so narrow that, from many of the rim overlooks, the river below cannot be seen at all.



A muddy Colorado River cuts through the ancient inner gorge of the Grand Canyon.

James Lawrence Powell (no relation to John Wesley), a former director of the Natural History Museum of Los Angeles County, ably recounts how explorers and geologists slowly came to understand that sequence of events. Many of the puzzles they initially faced arose from the nascent state of geology in the 1800s. Mechanisms of erosion were so dimly understood that some geologists found it hard to believe a river could cut through a mile of rock in any reasonable length of time. And what is more, the global plate motions that led to volcanism and uplift in the West were not even dreamed of when the Canyon was first discovered. Thus it seemed possible at first that the Colorado had cut down through a preexisting plateau, rather than slicing through the land as it rose.

A broad consensus about the origins of the Grand Canyon emerged as geology became more sophisticated, but like so much of science, the devil remains in the details. When it comes to the exact origin of this or that stretch of the gorge, for instance, substantial disagreement persists to this day. Modern geologists worry about conflicting evidence that the age of the canyon varies along its course, older in the upstream parts than it is downstream. Is it possible that, long ago, the Colorado River flowed through what is now the northeastern part of the canyon, but exited via the southeast and into the Gulf of Mexico? Or did it flow out the northwest, through a region now called the Kaibab Plateau and off into Utah and points west? Or is it possible that parts of the Colorado flowed underground for a while?

No book can adequately convey the grandeur of the canyon, but Powell's well-crafted account makes one appreciate just how it came to be so grand.

A Perfect Red: Empire, Espionage, and the Quest for the Color of Desire
by Amy Butler Greenfield
HarperCollins, 2005; $26.95

In the highlands of southern Mexico, near the city of Oaxaca, lives an insect no bigger than a lentil, known to modern biologists as *Dactylopius coccus,* or, more commonly, the cochineal. The female, which is the more common form of the bug (a female's life span is twice as long as a male's), is a wingless parasite whose ideal of domesticity is to stick her proboscis deep into the flaplike leaf of a prickly pear cactus. There she remains, motionless, sucking nutrients from her host for the

rest of her life. Tiny and nondescript, the cochineal would be easy to overlook—except for one remarkable characteristic. Crush one, and your fingers turn as red as arterial blood: the insects are filled with a pigment, which also goes by the name cochineal, that is one of the strongest and most colorfast red dyes ever discovered.

Native peoples of Mexico have used cochineal to color fabrics and feathers for millennia. The earliest conquistadors in the 1500s, who knew only the brownish madders and russets of the Old World, were dazzled by these Aztec reds; nothing back home could match their fiery intensity. Soon galleons were transporting wholesale quantities of the dried bugs to dyers in the great textile centers of Europe. Farmed, harvested, and dried by natives on small family plots, cochineal insects helped color the silks and wools of Hapsburg royalty and, not incidentally, brought the glitter of wealth to a growing merchant class. As trade with the New World increased, cochineal became the standard dye for a wide variety of uses, from the red coats of British soldiers, to the red tints of artists' paints and the coloring of pastry icings. By 1850, millions of pounds of cochineal—the equivalent of hundreds of billions of insect carcasses—were traveling across the Atlantic each year.

Mark Rothko, *Red on Maroon*, 1959

For centuries Spain enjoyed a monopoly on the source. Cochineal husbandry is a tricky business. The little bugs were hard to establish anywhere except in their native habitat. And Spain so effectively kept outsiders out of its New World colonies that, even into the 1700s, most Europeans did not even know whether the desiccated granules marketed as cochineal were originally plants or animals.

Writer Amy Butler Greenfield, who comes from a family of dyers, has mined the rich history of cochineal for wonderful stories about the biology of insects, the sociology of fashion, and the economics of colonialism. Among her more memorable characters is Nicolas-Joseph Thiery de Menonville, a French lawyer and naturalist, whose personal mission was to steal the secret of cochineal from Spain.

Thiery masqueraded as a physician, and through an elaborate series of ruses managed to enter Mexico, trek to Oaxaca (whose location he did not even know when he set out), and spirit away several chests of insect-infested cactus leaves from under the noses of customs authorities. In September 1777 he arrived in French-controlled Saint-Domingue (later Haiti), where he set up a garden to cultivate the delicate creatures for his homeland. Thiery died before he could establish an economically viable industry, but later biopirates eventually managed to break the Spanish monopoly.

By that time, however, synthetic dyes, developed in the late 1800s, were putting an end to the dominance of cochineal. Thanks to the wonders of chemistry, it became possible not only to re-create cochineal's active agent, carminic acid, but also to create hues never seen before in nature. Cochineal is still produced in a few places to meet the demands of the natural food and fiber market, but it no longer has the power to color the destinies of great nations.

Silent Snow:
The Slow Poisoning of the Arctic
by Marla Cone
Grove Press, 2005; $24.00

Flying over the Arctic, where few signs of human habitation and even fewer belching factories break the vast expanses of rock, open water, and snowy ice, one would scarcely believe that this is an environmentally wounded landscape. Yet according to Marla Cone, an environmental journalist, the Inuit residents of Qaanaaq, a village on the northwestern coast of Greenland, have the highest levels of toxic contaminants of any population on Earth. In the 1990s, Cone writes, many Greenlanders carried such high loads of mercury and PCBs that "their bodies, in technical terms, could have been declared hazardous waste."

That the contaminants are chemicals seeping northward from the temperate, industrialized nations is no surprise. Yet, paradoxically, the pollution problem in the Arctic is not the sheer level of contaminants in the air and water. Smog in the air on Baffin Island is insignificant compared to the smog in Los Angeles; the Bering Strait is, by and large, far purer than Lake Erie or the Black Sea. No, what makes matters particularly difficult in the circumpolar Arctic—Siberia, Alaska, Northern Canada, Greenland, and Lapland—is that the traditional diet of the inhabitants places them at the very top of the food chain.

Toxic chemicals, carried by wind, runoff, and ocean currents, work their way into northern oceans, where they are taken up by the zooplankton that flourish there. These minute creatures are eaten by larger fish, and those by still larger fish, which in turn become lunch for polar bears, seals, walruses, and whales. At each link in the chain, the concentration of pollutants increases. By the time native peoples eat these mam-

Caribou meet in Prudhoe Bay, Alaska, against the backdrop of an oil refinery.

mals, persistent pollutants have become so concentrated that each bite is the equivalent of drinking from a toxic spill. Sea otters from the Aleutian Islands, for instance, carry twice the load of PCBs as similar creatures on the California coast, and tests have shown high levels of toxins in beluga whales, polar bears, seabirds, seals, and sharks, to name just a few.

Cone's accounts of hunting and fishing expeditions with various peoples of the far North lend sensitivity and authenticity to their plight. They are aware that restricting the intake of particularly polluted species may be part of the solution to their problem. But no one, either native or southlander, seriously believes that Inuit hunters should abandon blubber for the blandishments of Velveeta and Wonder Bread. The ancient hunt is too much a part of native life, binding families and communities together in a way that contemporary consumerism never could.

The traditional diet, moreover, rich in omega-3 fatty acids (the kind that aid cardiovascular health), protein, and vitamins, is ideal for the rigors of the climate. Non-local foods are expensive and, by and large, harmful to both individual and social health. Imported foodstuffs, in fact, high in sugars, saturated fats, and carbohydrates, have already begun to affect the rates of obesity, heart disease, and diabetes in the Arctic. And the increased reliance on a cash economy for food, shelter, and entertainment has brought with it a familiar litany of social problems: increased levels of depression, alcoholism, and crime.

Thus the peoples of the North find themselves on the horns of a classical dilemma. On the one hand, environmental toxins threaten the health of future generations. Mercury from whale meat has already had a measurable effect in lowering the IQs of schoolchildren in Denmark's Faroe Islands; ecotoxins may even be killing off polar bears, one step down the food chain. On the other hand, abandoning the northern lifestyle seems no less damaging to a society that has, until lately, succeeded so well.

Cone's title, not incidentally, harks back to Rachel Carson's landmark *Silent Spring*, first published in 1962. Four decades after Carson's call to action, *Silent Snow* reminds us once again of the delicate interdependence of people and nature. The plight of northern peoples is, ultimately, linked with the personal and political choices everyone makes, whatever they eat, and wherever they live.

LAURENCE A. MARSCHALL is the W.K.T. Sahm professor of physics at Gettysburg College in Pennsylvania. He is the 2005 winner of the Education prize of the American Astronomical Society.

(Continued from page 24)

the swamp, coping with scorching heat and swarms of mosquitoes. Yet, despite the discomforts, I was happy to be there, because on June 9, 2004, the misery paid off. On that date I saw an ivory-bill swoop from one tree to another, a distance of sixty-eight feet. Its wings were extended, and never flapping.

I had a clear view of the bird from behind as it swooped upward to land. The white secondaries of each wing were clearly visible, separated by the black back of the bird, and they reached all the way to the trailing edge of the wings. I could easily see the bird's black tail, back, neck, nape, and crown. The nape came to a point and seemed to have a tonal value darker than the neck and crown. A female? That was my first thought. If so, it is the first evidence of a living female, and it signals the possible existence of a breeding pair. But finding a roost and nest will be the only sure way to tell whether Bayou DeView shelters a burgeoning population of ivory-bills.

One thing is certain, though. Somehow, the phantom bird has squeezed through the species bottleneck wrought by humanity. Extensive logging and collecting challenged the ancestors of every one of the ivory-billed woodpeckers that is out there today. My own belief is that the ancestors of the current birds got through the bottleneck because they were wary and less vocal than their peers, whose distinctive sounds gave away their positions as clearly as if they had been located by a GPS satellite. The quieter ivory-bills retreated to darkened corners of the remaining bottomland, keeping their songs to themselves. In so doing, their descendants have genetically continued the toned-down performance, enabling them to live on unnoticed for more than half a century.

Bobby R. Harrison is a lifelong chaser of the ivory-billed woodpecker, a birder, and a noted bird photographer. He is an associate professor and the director of the art program in the Department of Communications at Oakwood College in Huntsville, Alabama.

Heat Demons

By Robert Anderson

My interest in thermodynamics was recently rekindled while reading a copy of Basil Mahon's *The Man Who Changed Everything: The Life of James Clerk Maxwell.* Outside the physics community, he has never been celebrated the way Newton or Einstein are. Yet in the mid-1800s he brought his genius to bear on an extraordinary range of problems, from the composition of Saturn's rings, to color vision, to thermodynamics—a field initially driven by the quest for more efficient steam engines. (The Web site www.clerkmaxwellfoundation.org/ offers a concise biography.)

I was particularly intrigued by Maxwell's "demon," an imaginary creature the Scottish physicist dreamed up as a thought experiment to illustrate how, in principle, one might get heat to flow from cold to hot without adding energy—in violation of the second law of thermodynamics. A demon who could *see* molecules, Maxwell thought, might act as a gatekeeper, allowing only fast-moving molecules into a hot region on one side of the gate and only slow-moving molecules into a cold region on the other side. On the Internet I found two sites where you can play the demon's little game. At absolutist.com/online/demon/, you have to register to play (for free), but it's more fun than playing at the site of Sitabhra Sinha, a professor at India's Institute of Mathematical Sciences (www.imsc.res.in/~sitabhra/research/persistence/maxwell.html), where no registration is necessary.

At a site run by a group called Physics and Astronomy Online (www.physlink.com/Education/AskExperts/ae280.cfm), I found a wonderful formula for remembering the three laws of thermodynamics, attributed on that Web site to the English scientist and writer C.P. Snow: One, you cannot win; two, you cannot break even; three, you cannot get out of the game. It sounds remarkably like a trip to Las Vegas.

The second law, despite Snow's succinct summary, is particularly hard for many people to grasp. Yet its implications are enormous. To be slightly less succinct, the second law states that disorder increases with time, which in turn implies that whenever energy changes from one form into another, some usable energy is lost. A Web page titled "Energy Flow in Nature" (www.backyardnature.net/ecoenrgy.htm) gives a brief illustration of how, because of the second law, energy is lost in a food web every time it passes from one consumer to another.

An online slide show created by Mark C. Benfield of Louisiana State University in Baton Rouge (zooplankton.lsu.edu/web_2008/energy_flow_web/energy_flow.htm) illustrates how removing energy from an ecosystem can have dire consequences. In the 1970s, conservation efforts had led to the recovery of sea-otter populations off the west coast of North America. Then climate change and overfishing reduced food supplies—energy—for seals and sea lions that live in the deep ocean, causing those populations to crash. That forced orcas, or killer whales, which normally feed on seals and sea lions, to approach the coast and eat the sea otters. By the late 1990s the sea otter population had fallen by almost 90 percent of its 1970 level.

Some people maintain that evolution violates the second law, because it leads to increasingly complex, or more highly ordered, organisms. The Internet is full of sites that take this apparent inconsistency as proof that the theory of evolution is wrong. Other sites, however, unravel the misconception. Brig Klyce, for example, on his Web site (panspermia.org/seconlaw.htm), provides a history of the use of thermodynamics in biology. If your appetite is whetted for even more about that fascinating topic, check out a site developed by Frank Lambert, a professor emeritus of biology at Occidental College in Los Angeles (www.2ndlaw.com/evolution.html). Or you can go back to playing Maxwell's demon.

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

Finding the Forest despite the Trees

Two new galaxies, hidden among the stars

By Charles Liu

Ross Bleckner, *Blue Hands and Faces*, 1994

About fifteen years ago, a group of leading astronomers judged that the time was right for a new map of the sky. The map would tap revolutionary techniques and technology, including electronic cameras that collect light far faster than photographic film; computerized telescopes that aim and capture images supereffectively; and global computer networks that process, analyze, and store massive amounts of data.

Today, this magnum opus of cosmic study, called the Sloan Digital Sky Survey (SDSS), is well on its way to completion. To date, the database released to the public includes more than 8,000 gigabytes of images, 672,000 spectra, and 180 million catalogued objects (to take a look, visit the project's SkyServer Web site at http://cas.sdss.org). The survey has already led to major advances in just about every area of astronomy, including the detection of nearby dwarf stars, distant quasars, and the origins of structure in the universe.

The latest discovery to join the SDSS hit parade comes from a pair of studies led by Beth Willman, an astrophysicist at New York University's Center for Cosmology and Particle Physics. Willman and her colleagues have scoured the Sloan database for signs of small, faint dwarf galaxies hiding in the outskirts of the Milky Way. Now, it appears, they've found two.

You might think that the closer a galaxy lies to our own Milky Way, the easier it would be to see. That's certainly the case for larger galaxies, such as the Andromeda Galaxy or the Magellanic Clouds, which you can see with the naked eye. It's also true for smaller galaxies with bright cores of densely packed stars, such as the dwarf elliptical galaxy known as Messier 32, which can readily be detected with a small telescope. But a dwarf galaxy much closer to the Milky Way than Messier 32, made up mostly of faint (and old) stars, blends right into the foreground of the hundreds of billions of stars in the Milky Way. Furthermore, a nearby dwarf galaxy takes up a much larger patch of sky than a distant one, and so it doesn't stand out as a distinct object.

How, then, do astronomers distinguish the stars in an old dwarf galaxy from a pesky bunch of foreground stars in the Milky Way? One way is to compare the stars' colors. Any given star in the sky can emit any proportion of blue light to red light, depending on its age, mass, and chemical composition. But stars don't just shine in a rainbow of random colors. Instead, a complex interplay of nuclear fusion and gravitational collapse creates predictable distributions of star colors. In fact, if you plot the color and brightness of the stars in a given galaxy on a graph, the points lie on clearly distinguishable "sequences," "clumps," and "branches" that can identify the galaxy almost like a fingerprint.

With a computerized algorithm designed to pinpoint unusual color distributions, Willman and her colleagues scanned the Sloan for regions of the sky with unusually dense clusters of stars and unusual color. Then they studied those regions further, searching for distinct stellar populations that would indicate the presence of a galaxy other than the Milky Way. In particular, they sought a branch of aging giant stars attached to a main sequence. In two instances they seem to have succeeded. In the direction of the constellation Ursa Major they identified fifty stars—in a patch of sky about a quarter the size of the full Moon—that appear to follow a redder branch than Milky Way stars. A little to the southeast of that patch, they identified another group of about sixty stars whose branch is bluer than that of the Milky Way.

How can Willman and her colleagues be so sure they've found two whole new galaxies, when they based each identification on just a few dozen stars? First of all, their star-counting results are statistically very robust: the odds that either group of stars is just some kind of random blip in the run of Milky Way stars are much less than one in a billion. More important, the two teams followed up those initial

(Continued on page 58)

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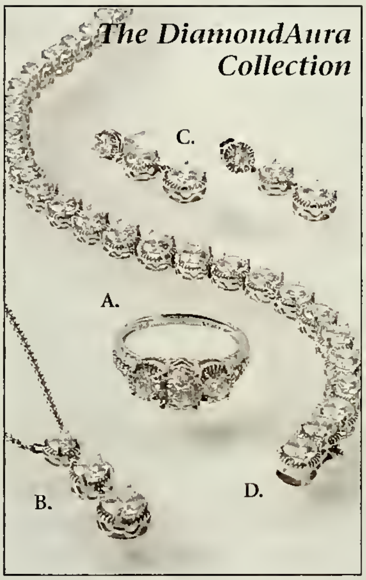

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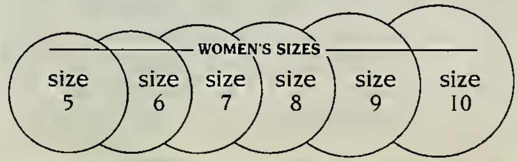

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 (Continued from page 54)

findings by taking more images of the two areas with other telescopes. After further analyzing the colors and brightnesses of the objects in the two star fields, they've concluded that the first, redder region includes a faint dwarf galaxy about 330,000 light-years from the center of the Milky Way. The bluer region contains an even fainter object, about 150,000 light-years from the Milky Way center.

The two new objects are, respectively, a few thousand and a few hundred light-years across—truly tiny compared to the 100,000 light-year diameter of the Milky Way. They're also among the faintest Milky Way companion galaxies ever seen. The blue one is so faint—far less than a millionth the luminosity of the Milky Way—that it may be more accurate to call it a star cluster than a dwarf galaxy; its very existence further blurs the distinction between the two classes.

The burning question is, how many more minigalaxies are out there? Computer models that incorporate current theories of galaxy formation predict that dozens or perhaps hundreds of them could be orbiting the Milky Way. If the theories are correct, the two newly found objects may be the first of many more, stealthily camouflaged by the multitude of stars in our own galaxy, just waiting to be found.

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

THE SKY IN SEPTEMBER

By Joe Rao

Mercury, shining at magnitude −1.2, can be glimpsed with the naked eye during the first week of September, even though it is barely above the eastern horizon at middawn. On the morning of the 4th the first-magnitude star Regulus can be seen just over one degree (two full-Moon diameters) to the lower right of Mercury. The planet reaches superior conjunction on the 17th, making it invisible in the solar glare as it passes behind the Sun.

Venus and Jupiter will make for an eye-catching pair low in the west-southwestern sky shortly after sunset as September begins. The two appear less than one and a half degrees apart on the 1st, and then gradually separate throughout the month. Venus moves off to the east, while Jupiter slowly descends ever deeper into the sunset glow. Venus was languishing low in the dusk all summer, but now it manages to stay above the west-southwestern horizon during midtwilight.

Actually, Venus still sets an hour and a half after sundown, as it has all summer, but because twilight shortens as summer wanes, Venus shines in a dark, purple sky before disappearing.

Dazzling Mars has become the "star" of late night as it approaches opposition. This month the Red Planet rises earlier each week; at the beginning of the month it rises around 10:20 P.M., but it's up by about 8:40 P.M. on the 30th. During this period its distance from us decreases from 61 million to 49 million miles, so the planet doubles in apparent brightness, from magnitude −1.0 to −1.7. The best time to view Mars is about 4 A.M., when it is high in the south.

Jupiter should be visible to the naked eye on most clear evenings, at least during the first part of the month. Look for it low in the west-southwestern sky half an hour after sunset. It finally disappears in late September.

Saturn is about one degree from the pretty Beehive Star Cluster, in the constellation Cancer, the crab, during most of the month. The planet shines at magnitude 0.3. On the 15th it rises at about 2:45 A.M.; as the month progresses, it continues to climb in the morning sky. By month's end it is nearly forty degrees above the eastern horizon at the beginning of morning twilight.

The Moon is new on the 3rd at 2:45 P.M. It waxes to first quarter on the 11th at 7:37 A.M. and to full on the 17th at 10:01 P.M. The full Moon that occurs closest to the autumnal equinox is called the harvest Moon, because it provides extra hours of light during the height of the autumn harvest. The Moon wanes to last quarter on the 25th at 2:41 A.M.

The Equinox takes place on the 22nd at 6:23 P.M. The Sun crosses the projection of Earth's equator on the sky and passes into the Southern Hemisphere. Autumn begins in the Northern Hemisphere, spring in the Southern Hemisphere.

Unless otherwise noted, all times are eastern daylight time.

EXPLORER GUIDE

Evolution of the Insects

You might learn to love insects after perusing a new 768-page reference book coauthored by Museum scientist David Grimaldi. It is the first comprehensive synthesis of *all* aspects of insect evolution. Dr. Grimaldi has traveled to 40 countries on six continents, collecting and studying recent species of insects and conducting fossil excavations.

Evolution of the Insects, by Dr. Grimaldi, Curator in the Museum's Division of Invertebrate Zoology, and Michael S. Engel, Assistant Professor in the Division of Entomology, University of Kansas, is a stunning accomplishment. Published by Cambridge University Press, it chronicles the complete evolutionary history of insects—their living diversity, relationships, and 400 million years of fossils.

Introductory chapters include the living species diversity of insects, methods of reconstructing evolutionary relationships, basic insect morphology, and the diverse modes of insect fossilization and major fossil deposits.

Major sections cover the relationships and evolution of each order of hexapods, or six-legged creatures. *Evolution of the Insects* also chronicles the main episodes in the evolutionary history of insects: their modest beginnings in the Devonian, the origin of insect wings hundred of millions of years before those of pterosaurs and birds, the effect of mass extinctions and the explosive radiation of angiosperms on insects, and how insects evolved the most complex societies in nature.

© D. GRIMALDI, M. S. ENGEL, CAMBRIDGE

Mantis in 20-million-year-old amber

The book is replete with 955 photo- and electron micrographs, drawings, diagrams, and field photos, many in full color. Many of the incredibly intricate line drawings are by Dr. Grimaldi, who was torn between science and art careers early on.

Along with open-minded insect avoiders, *Evolution of the Insects* will appeal to anyone intrigued by insect diversity, from professional entomologists and students to collectors and naturalists.

D. FINNIN/AMNH

At the Museum's DinerSaurus Café on 4, opened in conjunction with the exhibition *Dinosaurs: Ancient Fossils, New Discoveries*, visitors can dine on any of several surviving theropod dinosaurs, such as chicken and turkey. The menu also features the cuisine of Liaoning Province, China, where many of the striking fossils in the exhibition were unearthed. Kid-friendly items such as dinosaur-shaped chicken nuggets and cookies are also served.

D. FINNIN/AMNH

The American Museum of Natural History is an educational destination for over 400,000 New York City schoolchildren who visit for free every year. Groups are guided through the Museum's halls by instructors who teach classes and lead hands-on activities on a wide range of topics—from the Age of Dinosaurs to world cultures. A host of programs for children from pre-K through high school rounds out the Museum's educational offerings.

Living with Nature:

Consumer Choices for Children

Thursday, September 22
6:00 p.m., Resource Fair
7:30 p.m., Panel Discussion

We all have a role to play in meeting the challenges of the biodiversity crisis—the accelerated loss of animals, plants, and habitats caused primarily by human activities. In February 2004 the American Museum of Natural History's Center for Biodiversity and Conservation (CBC) inaugurated a series of public programs aimed at identifying ways people can help sustain nature through everyday choices. Topics for the programs have both strong implications for biodiversity and relevance to our day-to-day life. Last fall, the *Living with Nature* program explored food choices as a link to good health and a tool for conservation.

This fall, the series focuses on children. On Thursday, September 22, a resource fair beginning at 6:00 p.m. will provide information on sustainable activities, toys, parties, school and art supplies, and holiday fun for kids. At 7:30 p.m., a panel of experts, moderated by **Eleanor Sterling**, Director of the CBC, will explore how to nurture meaningful values and environmental stewardship in children in the face of an increasingly consumer-driven society. Panelists include:

- **Louise Chawla**, child development specialist and International Coordinator of UNESCO's Growing Up in Cities program
- **Julie Fox Gorte**, Director of the Calvert Social Research Department
- **Juliet Schor**, author of *Born to Buy: The Commercialized Child and the New Consumer Culture*
- **Betsy Taylor**, Founder and President of the Center for a New American Dream

Living with Nature: Consumer Choices for Children is geared to adults and children 12 and up. This event is FREE and open to the public. Registration is recommended. Please visit http://cbc.amnh.org/ or call 212-496-3423.

The *Living with Nature* program series and publications are underwritten by an anonymous Museum Trustee.

PEOPLE AT THE AMNH

Carl Mehling
Fossil Amphibians, Reptiles, and Birds Collections Manager, Division of Paleontology

ERICH ROSE

Carl Mehling

Carl Mehling remembers the date he found his first fossil: May 28, 1977. A family trip to Pennsylvania stopped at a Devonian coral reef site, and he's been hooked ever since.

Now, almost three decades later, Carl is in charge of the fossil amphibians, reptiles, and birds collections. He likens his role to that of a librarian—of fossils. He handles scientific loans, visitors, and public inquiries. "I think acting as a liaison to the public is an extremely important service. If we lose this connection, we simply become an ivory tower."

A native of Queens, Carl frequented the Museum as a child and into his teens. Even when he went away to college, he kept his goal of working at the Museum in mind: he majored in paleontology and art, and during breaks from school, volunteered at the Museum. "I combined paleontology and art with a mind to work in collections. There is an artistry to my job, to record-keeping, archiving, and appreciating the preservation of objects."

Carl has identified some spectacular finds, including a primitive bird fossil and a fossil walrus skull that was later donated to the Museum.

Museum Events

C. CHESEK/AMNH

A life-size biomechanical model of an *Apatosaurus* skeleton is among the highlights of the exhibition *Dinosaurs: Ancient Fossils, New Discoveries.*

EXHIBITIONS

Dinosaurs: Ancient Fossils, New Discoveries
Through January 8, 2006
Discover the most current thinking on the mysteries of dinosaurs: what they looked like, how they behaved, and how they moved, as well as why—or even whether—they became extinct.

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

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

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

Voices from South of the Clouds
Opens September 17
This engaging exhibition reveals China's Yunnan Province through the eyes of the indigenous people themselves, who use photography and statements about their work to chronicle their culture, religion, and daily life, as well as their interaction with the local environment.

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

Vital Variety: A Visual Celebration of Invertebrate Biodiversity
Ongoing
This exhibition of extraordinarily beautiful close-up photographs highlights the importance of the immense diversity of invertebrates, which play a critical role in the survival of humankind.

FIELD TRIPS AND WORKSHOPS

Fall Bird Walks in Central Park
Eight-week sessions start 9/7, 9/8, and 9/9.
Observe the fall migration of birds in Central Park. Learn how to use field marks, habitat, behavior, and song to assist in identification.

Animal Drawing
Eight Thursdays, starts 9/29
The celebrated dioramas, dinosaur skeletons, and other distinctive features of the Museum serve as the setting for an intensive after-hours drawing class.

FAMILY AND CHILDREN'S PROGRAMS

Visit the Space Station!
Saturday, 9/17
11:00 a.m.–12:30 p.m. (Ages 4–5, each child with one adult)
1:30–3:00 p.m. (Ages 6–7, each child with one adult)
Kids fascinated by astronauts will see what a day might be like living, working, and playing aboard the International Space Station.

Space Explorers: Myths and Constellations of the Fall Sky
Tuesday, 9/13, 4:30–5:30 p.m.
Begin the evening with a hands-on activity designed to prepare you for an in-depth lecture under the stars of the Hayden Planetarium.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe
Telling Time
Tuesday, 9/6, 6:30–7:30 p.m.

This Just In...
September's Hot Topics
Tuesday, 9/20, 6:30–7:30 p.m.

Celestial Highlights
Autumn Wonders
Tuesday, 9/27, 6:30–7:30 p.m.

LECTURE

Warped Passages
Monday, 9/26, 7:30 p.m.
With Lisa Randall

COURSES

Matter and Motion
14 Thursdays, 9/1–12/15
6:30–8:30 p.m.
This college-level introduction to the cosmos explores the basic physics of the universe and how it applies to the frontier of modern astronomical research.

Stars, Constellations, and Legends
Four Wednesdays, 9/28–10/26
6:30–8:30 p.m.
Enjoy the best night sky in New York City—inside the Hayden Planetarium. Learn to locate the stars of each season, whether you do your gazing from midtown Manhattan or the middle of nowhere.

Relativity 101
Four Wednesdays, 9/28–10/26
6:30–8:30 p.m.
Participants will gain an understanding of relativity that goes deeper than metaphor.

AMNH

PLANETARIUM SHOWS

SonicVision
Fridays and Saturdays, 7:30, 8:30, and 9:30 p.m.
Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

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

The Search for Life: Are We Alone?
Narrated by Harrison Ford
Made possible through the generous support of Swiss Re.

Passport to the Universe
Narrated by Tom Hanks

LARGE-FORMAT FILMS

LeFrak Theater
For films and showtimes, visit www.amnh.org or call 212-769-5100.

IMAX films at the Museum are made possible by Con Edison.

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.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

STARRY NIGHTS

Live Jazz

ROSE CENTER FOR EARTH AND SPACE
Friday, September 2

Enjoy jazz and tapas on the first Friday of every month. Visit www.amnh.org or call 212-769-5100 for lineup.

Starry Nights is made possible, in part, by Constellation NewEnergy and Fidelity Investments.

Become a Member of the American Museum of Natural History

As a Museum Member, you will be among the first to embark on new journeys to explore the natural world and the cultures of humanity. You'll enjoy:

- Unlimited free general admission to the Museum and special exhibitions, and discounts on Space Shows and IMAX films
- Discounts in the Museum Shops and restaurants and on program tickets
- Free subscription to *Natural History* magazine and to *Rotunda*, our newsletter
- Invitations to Members-only special events, parties, and exhibition previews

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

Monomoy

By Scott Weidensaul

Sometimes, a place you've heard about but never visited takes on an almost mythic quality, and so Monomoy was for me. For years I'd heard about this remote and wild group of shifting islands in Nantucket Sound that had once been part of the mainland, forming an eight- or nine-mile-long peninsula that jutted south from the "elbow" of Cape Cod. Now almost all traces of Monomoy's more settled past were said to have vanished beneath the dunes. The surrounding waters were dangerous. Today—or so I imagined—only birds came to call.

Such preconceptions, romanticized by distance and a lack of firsthand experience, seldom withstand close scrutiny. When at last one goes to these places, the daydreams are replaced by a more pedestrian reality. When I finally visited Monomoy, I knew that there was no way it could measure up to my expectations.

Except that it did.

It was a calm day in the middle of September, with a heavy fog over the sound, so that the run down from Chatham was cold and dreary, the swells looking oily in the gray light. No one on the boat said much on the way out.

But as the captain throttled back, signaling that despite the wall of featureless white we must be getting close to South Monomoy, we emerged from the mist into soft sunshine. Before us lay a long, low ripple of sand, golden white in the hazy sun, with dune grass like brushstrokes in a Japanese painting. Flocks of shorebirds rose on fast wings, calling, but my eyes were on the water.

All around us were seals—not the pudgy little harbor seals I am used to seeing, but huge gray seals with heads like horses, Roman-nosed, massive, each seven or eight feet long. The seals were everywhere—dozens of them on the beach, caterpillaring into the surf with blubber rippling, and dozens more swimming around the aluminum skiff that would land us.

We waded ashore, and the kid with the skiff gunned the outboard and planed back through the curious seals to the big boat, now once more enshrouded in the mist. With the boats gone, the outside world vanished, and the enchantment was complete. I felt like a child playing hooky—not from school, but from my own century.

A fierce spring storm in 1958 bulldozed the channel that first severed the peninsula from the mainland. An infamous blizzard in 1978 split the new island into three, and after that Monomoy became a vastly wilder place, in ways both concrete and spiritual: recognized as a place apart by animals as well as people.

Gray seals, hunted for bounty in New England waters as late as the 1960s, finally gained federal protection in 1972. A decade later, they began to appear in increasing numbers in Nantucket Sound. At first they were merely seasonal visitors, but they soon became successful inhabitants.

The islands also serve as a landing spot for thousands of migrating birds. When we arrived, it was past the peak of the fall shorebird migration, but there were still hundreds of sandpipers and plovers resting and feeding on Monomoy. As we ambled along the beach, they rose and fell before us, an undulation of wings and movement that lasted for hours. Higher, against the pale green-gray dune grass, stood four buff-breasted sandpipers, the color of fresh biscuits, with buttery legs. They stood poised for a moment, then sprang into the pellucid air on long wings, making a quiet little trill as they flew south, out into the ocean and the waiting fog.

Today the channel separating Monomoy from the mainland may be closing again. If its storied isolation ends, how will its character change? There will be more visitors. The seals could find their patience tested. But in the end, the keenest loss may be the one that nurtures the daydreams, the Monomoy that lies somewhere, out there: splendid, empty, and remote.

SCOTT WEIDENSAUL lives in the Pennsylvania Appalachians. This essay is adapted from his forthcoming book Return to Wild America: A Yearlong Search for the Continent's Natural Soul, *which is being published in November by North Point Press.*