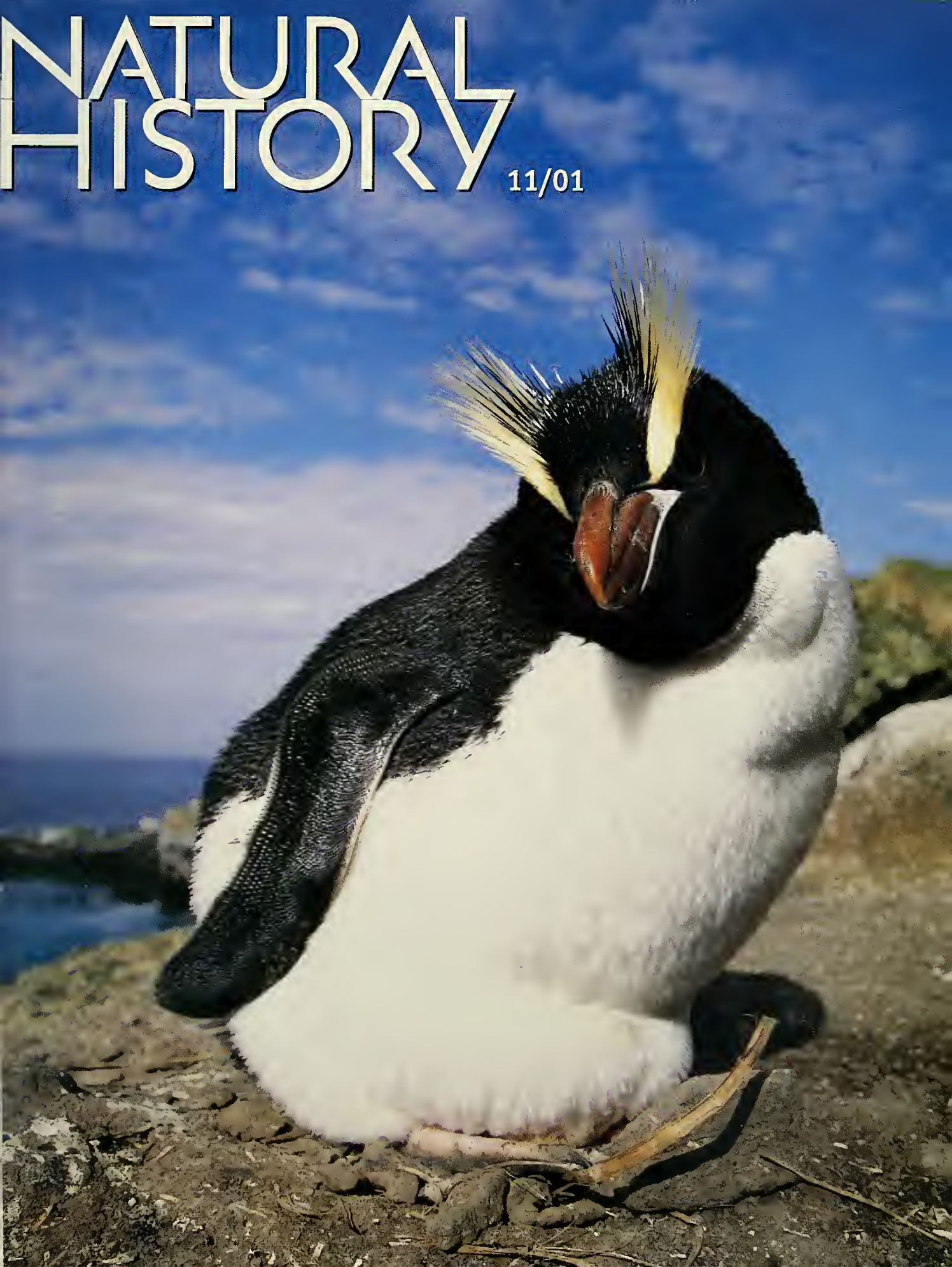
NATURAL HISTORY

11/01



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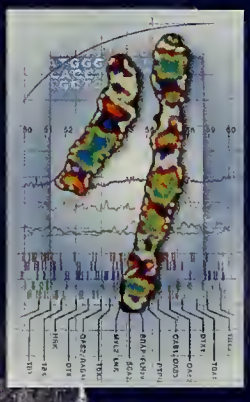
Three-time Tour de France winner Lance Armstrong, with his son Luke.



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NATURAL HISTORY

NOVEMBER 2001 VOLUME 110 NUMBER 9

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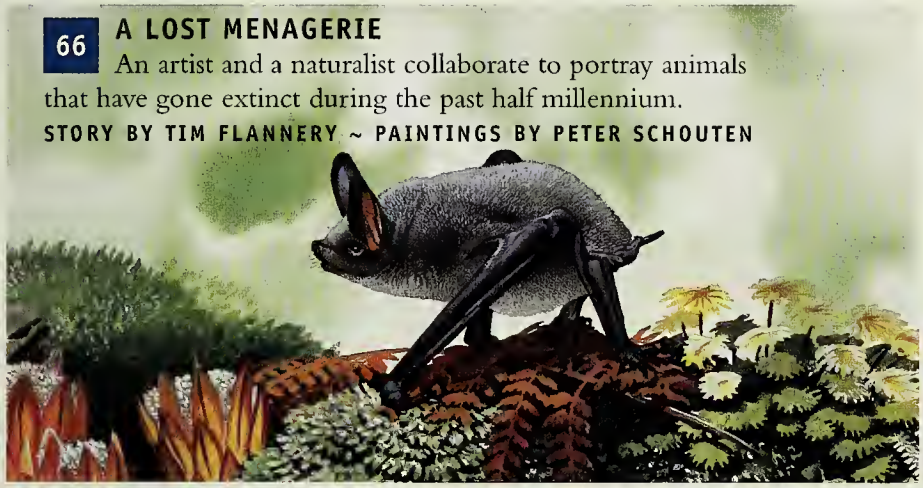

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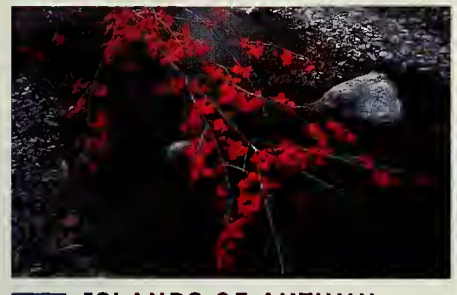

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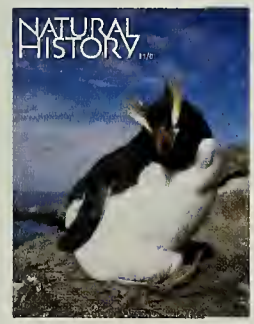

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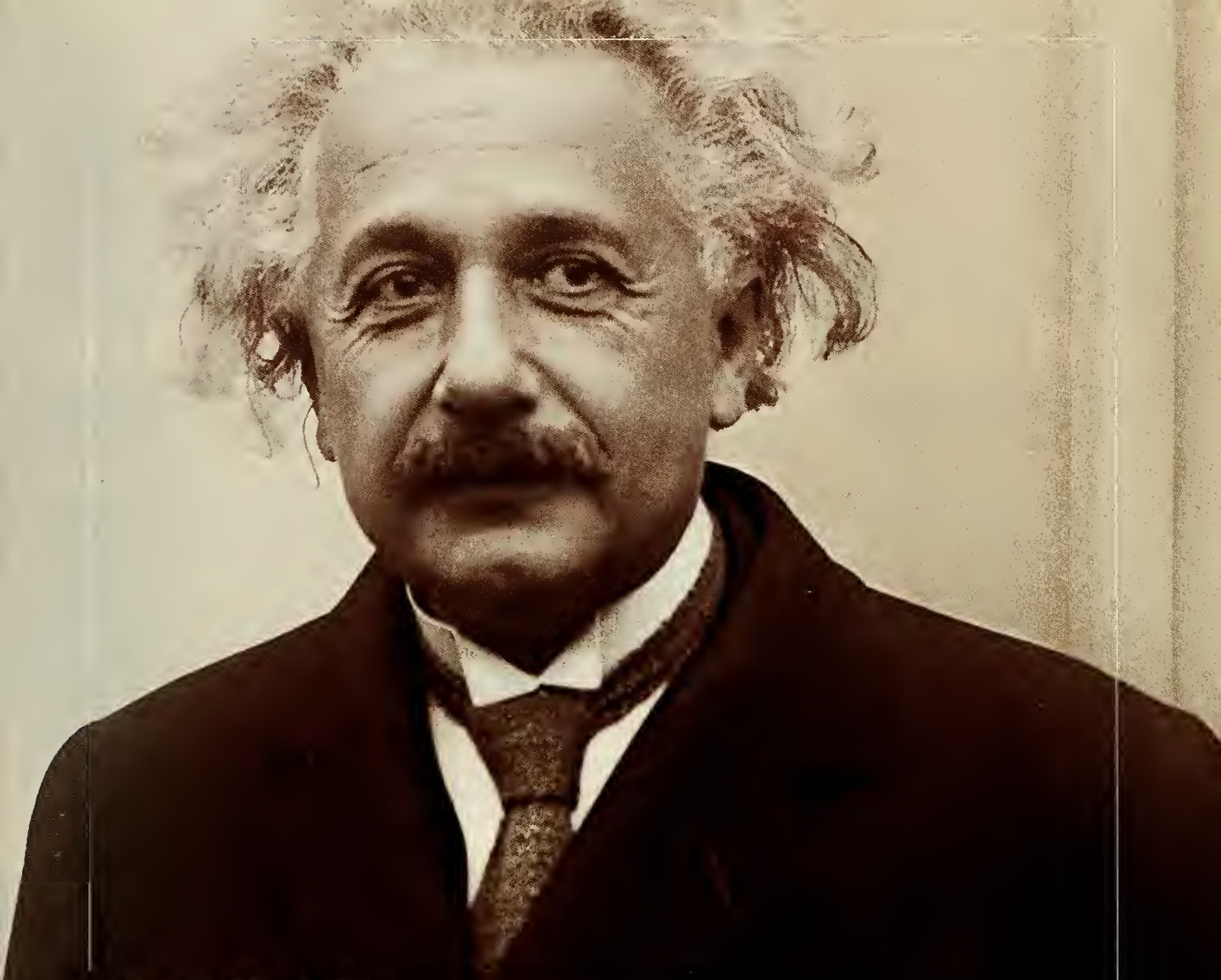

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UP FRONT

A Late Summer Day

"Last autumn the wild geese flew day after day across the path of the shells."
—Erich Maria Remarque, *All Quiet on the Western Front*

The American Museum of Natural History, where our offices are situated, is a hundred or so blocks north of the World Trade Center. On the bright, clear morning of September 11, a few members of the magazine's staff, on their way here from downtown and from Brooklyn, witnessed an attack that came quite literally out of the blue to demolish thousands of individual lives.

Neil deGrasse Tyson, director of the Museum's Rose Center for Earth and Space and author of our monthly column "Universe," is a member of the magazine family who lives in lower Manhattan. He bore precise, but not dispassionate, witness to the events of September 11 in an e-mail message sent to family and friends the next morning. Here is part of that message:

> *As more and more and more and more and more emergency vehicles descended . . . I hear a second explosion in WTC 2, then a loud, low frequency rumble that precipitates the unthinkable—a collapse of all the floors above the point of explosion. First the top surface, containing the helipad, tips sideways in full view. Then the upper floors fall straight down in a demolition-style implosion, taking all lower floors with it, even those below the point of the explosion. A dense, thick dust cloud rises up in its place, which rapidly pours through the warren of streets that cross lower Manhattan. I close all our windows and blinds. As the dust cloud engulfs my building, an eerie darkness surrounded us—the kind of darkness you experience before a severe thunderstorm. . . .*
>
> *I will never be the same after yesterday, in ways that I cannot foresee. . . . How naïve I was to believe that the world is fundamentally different from that of our ancestors, whose lives were changed by bearing witness to the twentieth century's vilest acts of war.*

Three weeks later, as the magazine goes to press, another spell of warm, bright weather temporarily envelops the city. From our balcony, we can see the occasional flock of birds moving south, and a security guard here told me that some of them are pausing to feed in the small park in front of the Planetarium. We are left to mourn, to carry on, to try to grasp what happened—and to look to the best of human science, anthropology, economics, history, literature, and philosophy to tell us why our species is capable of such things.

— *Ellen Goldensohn*

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LETTERS

Going Lightly

This hardly seems the time to be lighthearted, but I would like to comment on Neil deGrasse Tyson's amusing (and interesting) "Universe" article entitled "By Any Other Name" (7/01–8/01). I am a lifelong amateur astronomer and sometime philosopher of science, but I had never consciously taken notice of the curious fact highlighted by Tyson: that astronomical nomenclature is user friendly.

May I suggest an even simpler and better term for what he says astronomers call dark energy (the force now held accountable for the acceleration of the expansion of the universe)? I propose "levity." I think this would serve as an apt counterweight to its opposite, that heavy term "gravity."

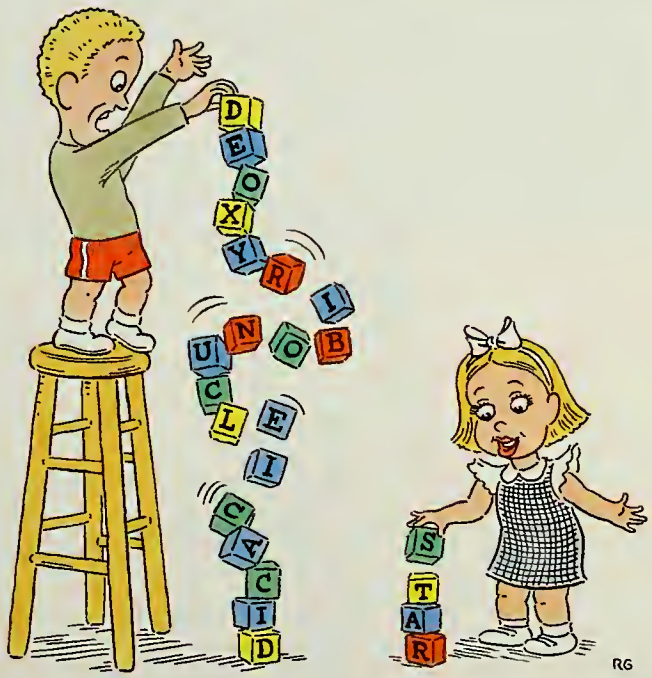
Joel Marks
West Haven, Connecticut

Speed Kills

I am writing to correct one of the statements in the note about eagles and trains that appeared in the "In Sum" column of 9/01. It is true that trains hit and kill eagles on the tracks between New York and Montreal, but not at 125 miles per hour. At present the only trains running that fast are traveling the Northeast Corridor, between Washington, D.C., and Boston.

Francis Mac Dowell
White Lake, New York

THE EDITORS REPLY: Our note was unclear; the original study mentioned an increase in bald eagle fatalities along the Hudson Valley of New York State but did not refer to any particular rail line when it cited the high velocities. According to Jerry Shook, of the New York State Department of Transportation, passenger trains on Amtrak's Empire Corridor, between New York and Albany/Schenectady, can reach 110 miles per hour, depending on the location and the track-signaling system in place. There are plans to increase the speed to 125 miles per hour as soon as tracks are upgraded to accommodate that speed. From Albany/Schenectady north to Montreal (on the Canadian Pacific Railway's main line), train speeds are considerably slower, reaching 70 miles per hour at a few points but mostly in the range of 50 to 60.



ROBERT GROSSMAN

"Bulletproof T-shirts, anyone?"

I have a question regarding the last sentence in Adam Summers's "Biomechanics" article on the properties of silk ("Got Silk?" 7/01–8/01). Is it true that twelfth-century Mongol warriors wore silk shirts that prevented enemy arrows from penetrating their bodies?

Daniel Marcus
Armonk, New York

THE EDITORS REPLY: According to Central Asia scholar Morris Rossabi, Daniel Marcus is absolutely right. Rossabi recommends a book by James Chambers, *The Devil's Horsemen: The Mongol Invasion of Europe,* for more information. Chambers writes: "The heavy cavalry wore a coat of mail with a cuirass made of oxhide or iron scales covered in leather, and the light cavalry wore either a cuirass of lacquered leather strips or else a quilted *kalat* [tunic] and no armour at all. Next to his skin every soldier was required to wear a long, loose undershirt made from raw silk. An arrow might pierce his armour and penetrate his body, but it would usually fail to cut through the silk and would instead carry the silk with it into the wound. . . . [B]y gently lifting the twisted silk around the wound, the Mongols could draw the arrow out, turning its head along the same route as the one by which it had entered, and thus leave the hole as neat and small as possible. . . . [T]he wound was not always as clean as the physicians might have hoped: . . . soldiers often kept on their shirts until they began to rot."

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CONTRIBUTORS

Braving seasickness, **Lloyd Spencer Davis** ("A Superlative Penguin," page 46) traveled to the remote Antipodes Islands to observe erect-crested penguins, which nest there. Davis is used to living at the ends of the earth; he has studied Adélie penguins in Antarctica and many other penguin species, including the yellow-eyed penguins of his native New Zealand. A senior lecturer in zoology at the University of Otago in Dunedin, Davis is also the director of a program in natural history filmmaking. He is the author of *Penguin: A Season in the Life of the Adélie Penguin* (Pavilion Books, 1993) and, hot off the press, *The Plight of the Penguin* (Longacre Press, 2001).

In 1980, intrigued by W. D. Hamilton's ideas on altruism, **Bernard J. Crespi** ("Altruism in the Outback," page 56) started looking for good self-sacrificing species to study. Twelve long years later, he found what he was looking for: social thrips in the Australian outback. A native of Illinois, Crespi is a professor in the Department of Biological Sciences at Simon Fraser University in British Columbia. Besides researching thrips, he studies speciation and asexuality in walking sticks and the phylogenetics of Galápagos Islands snails and of gall-inducing social aphids. In the future, he hopes to turn his attention to sociality in organisms even smaller than thrips, such as pathogenic bacteria. Illustrator **Utako Kikutani** is a frequent contributor to *Natural History*. Her work last appeared in the April 2001 issue ("Hot Times in the Bighorn Basin" and "Wyoming's Garden of Eden").

Photographer **Jack Dykinga** ("Islands of Autumn," page 62) believes that images can spur people to protect and preserve land that is threatened by human activity. Dykinga, left, also photographs places for beauty's sake alone, as was the case with his photoessay on big-tooth maples and other flora in southeastern Arizona. A Pulitzer Prize winner, he has produced both photographs and text for several books. **Wade C. Sherbrooke** is director of the American Museum of Natural History's Southwestern Research Station near Portal, Arizona. After sixteen years of living in the Chiricahua Mountains, he says he's still learning about their moods and complexities.

Tim Flannery and **Peter Schouten**'s portfolio of text and images ("A Lost Menagerie," page 66) is drawn from *A Gap in Nature: Discovering the World's Extinct Animals*, a four-year project (published this month by Atlantic Monthly Press) documenting animal species that have disappeared within the past 500 years. Flannery, left, is director of the South Australian Museum and the author of twelve books. Schouten is a Sydney-based freelance wildlife illustrator whose many honors include the Whitley Medal, for *Tree-Kangaroos: A Curious Natural History* (1996), another collaboration with Flannery (and others).

Born in Shanghai, art historian **Jay Xu** ("The Enigmatic Art of Sanxingdui," page 72) is the Foster Foundation Curator of Chinese Art at the Seattle Art Museum. He is the organizing curator of the exhibition "Treasures From a Lost Civilization: Ancient Chinese Art From Sichuan," which is touring the United States and Canada, and a principal contributor to the exhibition catalog, *Ancient Sichuan: Treasures From a Lost Civilization,* edited by Robert Bagely (Seattle Art Museum/Princeton University Press, 2001). A future project involves China's little-known southerly silk road to India and Burma.

Photographer and filmmaker **Gary W. Griffen** ("The Natural Moment," page 92), a producer of wildlife documentaries for Discovery Channel, routinely spends three years filming animals for each of his programs. He says he'll "do almost anything for a good shot," including traveling fourteen hours to stand in -30° F weather to film bull moose shedding their antlers. Griffen's latest film, *Moose: Spirit of the North Woods*, won the Gold Camera award in the Nature and Wildlife category at the U.S. International Film and Video Festival in Chicago, and his still work has been published by *Smithsonian*, *National Wildlife*, and *National Geographic*.

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AT THE MUSEUM

DAVID GRIMALDI

Primitive *Sphecomyrma freyi* worker ants in New Jersey amber

The Perfect Fossil

To a Museum entomologist, studying a Cretaceous insect exquisitely preserved in amber is a very close second to seeing the living thing.

By Henry S. F. Cooper Jr.

Just above the Hall of Saurischian Dinosaurs on the fourth floor of the American Museum of Natural History is the laboratory of entomologist David A. Grimaldi. Entering it, one finds microscopes and computers, a battered, overstuffed sofa and easy chair, and a row of cabinets with tiers of shallow drawers. These cabinets hold 15,000 pieces of translucent, orange-yellow amber containing fossils of ancient flies, ants, and mosquitoes that would have tormented some of the dinosaurs on the floor below. Amber is greatly compressed pitch or resin from various conifers as well as from some tropical broad-leaved trees. It very likely developed early in the Cretaceous Period (135–65 million years ago) as the trees' defense against an increase in herbivorous insects. It was to the trees what flypaper is to us—much the same color and, if anything, stickier.

Grimaldi studies insect fossils in both amber and stone. The stone fossils—mostly limestone—are the more abundant and cover a broader span in space and time. Fossils in amber date from no earlier than the Cretaceous and are limited to outcrops in a few places, such as Lebanon, Russia, Myanmar (formerly Burma), the Caribbean, and the east coast of the United States, from Martha's Vineyard to Georgia.

Some twenty years ago, while a graduate student at Cornell University, Grimaldi saw his first amber fossil. It immediately grabbed his attention. "I was amazed that more entomologists weren't studying amber fossils—I still don't understand it," he says. "You can study a cell's nucleus and mitochondria under an electron microscope, even its amino acids and maybe its DNA." His fascination hasn't diminished, and in 1996 he organized the Museum ex-

hibition "Amber: Window on the Past."

Insects are descended from marine arthropods, he explains, and first appeared on land less than 400 million years ago as small, wingless bugs resembling silverfish. Between 345 and 280 million years ago, the forests buzzed with giant dragonflies. But Paleozoic insects such as these (along with 98 percent of all other life-forms) became casualties of the unprecedented mass extinction at the end of the Permian, and gradually, from the Triassic to the Cretaceous, insects evolved into more familiar forms. Says Grimaldi, "The Cretaceous interests me because that is when a lot of modern insect families evolved—and angiosperms, or flowering plants."

From his cabinets, Grimaldi produces two small bits of Cretaceous amber, one encasing a tiny bee, the other a small cluster of oak flowers. They might have come from Central Park, accidentally frozen into a clear orange popsicle. The 65-million-year-old fossilized bee has changed his thinking quite a bit: "We never knew or surmised there would be a bee from the Cretaceous. It's still the only bee we've found." This bee proves that bees had already evolved by then, but judging from their absence in the earlier fossil record, they were not yet plentiful. Flowering plants, on the other hand, were abundant: they appeared in the beginning of the Cretaceous, 135 million years ago, and explosively radiated 35 million years later, eventually becoming the dominant form of multicellular plant life on Earth.

Not only bees but also moths, butterflies, and long-tongued flies are relatively scarce in the Cretaceous fossil record, raising interesting questions: What was pollinating the flowers and causing their proliferation? What was decomposing the carcasses, given the total absence of fossils of the larger flies, such as flesh flies and blowflies (whose larvae, which we call maggots, feed on carrion)? And finally, since termite fossils are rare, what decomposed all the Cretaceous plant matter? We don't know.

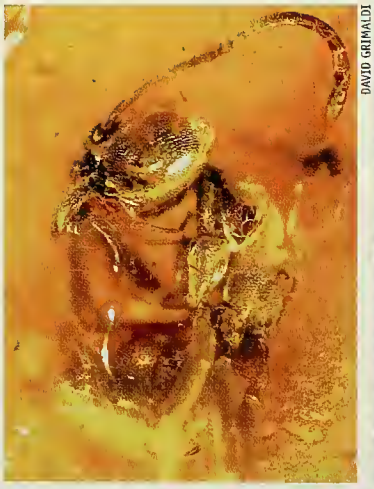
In another cabinet drawer is a 90-million-year-old ant from an amber deposit in New Jersey; this ant defended itself not by stinging but by spraying formic acid. Grimaldi believes the existence of this fossil suggests that ants may have evolved as early as 110 million years ago.

Ants, like termites, were rare and primitive in the Cretaceous, but they were already social. Some of Grimaldi's pieces of amber have several ants in them—an unlikely occurrence unless the insects spent a lot of time together. And after identifying worker ants in several of the fossils, he believes that ants had already begun to specialize into castes. In addition, many species of Cretaceous ants and termites display a variety of specialized structures, another feature of social insects.

"For years, people who have studied social insects like ants, termites, bees, and certain kinds of wasps have said that sociality was critical to a group's abundance and a driving force in its ecological success and diversity," says Grimaldi. "But apparently not, for ants just squeaked along for their first 50 million years of existence, even though they were social. For some reason, at the beginning of the Tertiary Period, around the Paleocene or the lower Eocene, they became abundant and diverse. And the studies I am doing with termites reveal the exact same thing."

If sociality wasn't responsible for social insects' success, what about the effects of the cataclysmic impact that marked the end of the Cretaceous and the beginning of the Tertiary, an interval often called the K-T boundary? After all, if the resulting cold and darkness killed off dinosaurs and allowed our own rare and primitive shrewlike ancestors to radiate, might it not have performed the same service for the ants, termites, bees, and wasps by getting rid of their competitors?

Grimaldi thinks not. The fossil record for insects just before and just after the K-T boundary is virtually nonexistent. There is evidence over the broader sweep of time, however, that these insects made it through unscathed—and that the insects that might have been their competitors did not go extinct. Grimaldi attributes the increase of social insects in the Tertiary to climate change, their own evolution, and the further evolution of flowering plants. Meanwhile, he continues to search for new amber deposits, certain they will offer a window on insects' past.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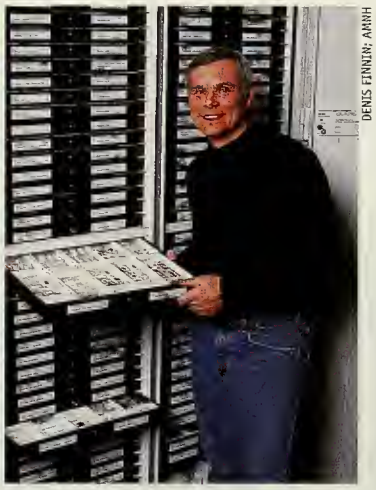
DENIS FINNIN; AMNH

***Kyromyrma neffi,* left, the oldest formicine ant. Right: David Grimaldi in his Museum lab.**

Henry S. F. Cooper Jr., a former staff writer for the New Yorker, *has been visiting the Museum since he was four years old, when his father sat him in a cavity of the Willamette meteorite.*

MUSEUM EVENTS

NOVEMBER 2 THROUGH 10
THE 25TH ANNUAL MARGARET MEAD

FILM & VIDEO FESTIVAL

This year's program celebrates the centennial of the birth of Margaret Mead (1901–1978), the Museum anthropologist in whose honor the international film festival was established. Among the featured films are *Cannibal Tours* (1988) and *Cunnamulla* (2000), by Dennis O'Rourke; *Shinjuku Boys* (1995) and *Runaway* (2001), by Kim Longinotto; the Papua New Guinea series (1983–92) and *Facing the Music* (2001), by Bob Connolly and Robin Anderson; and *The Belovs* (1992) and *I Loved You . . . (Three Romances)* (2001), by Victor Kossakovsky. Also highlighted are selections from the Jakarta International Film Festival. Visit www.amnh.org/mead for the screening schedule and descriptions of the films.


Dennis O'Rourke's *Cannibal Tours*

NOVEMBER 5
Lecture: "Parallax: The Race to Measure the Cosmos" (Distinguished Authors in Astronomy series). Alan Hirshfeld, of the University of Massachusetts Dartmouth's observatory. 7:30 P.M., Space Theater, Hayden Planetarium.

NOVEMBER 7 AND 14
A geological tour examines the granite and marble that make up AMNH's walls and facade: "Sensing the Museum Inside/Out." Sidney S. Horenstein, coordinator of the Museum's environmental public programs. 3:30–5:00 P.M. Meet at 77th Street entrance.

NOVEMBER 14, 15, 16, AND 20
Panel discussion: "DNA and Privacy." Bioethicist Peter Singer, of Princeton University; forensic DNA researcher and attorney Elisabeth A. Palladino, of Harvard University; and Susannah Baruch, director of legal and public policy, National Partnership for Women and Families. November 14, 7:00 P.M., Kaufmann Theater. Presented in conjunction with the exhibition "The Genomic Revolution" (on view through January 1, 2002, in Gallery 3). Workshops on genetics: November 15 and 16, 9:00–11:00 A.M. and 7:00–9:00 P.M.; follow-up explanation session, November 20, 7:00 P.M.

NOVEMBER 16, 17, AND 18
Symposium: "Taino Revivalism in the 21st Century: Cultural Heritage of Caribbean Indigenous Peoples" (Identities Beyond Borders series). Moderated by Gabriel Haslip-Viera, editor of *Taino Revival: Critical Perspectives on Puerto Rican Identity and Cultural Politics.* November 17, 2:00–5:00 P.M., Kaufmann Theater. Programs are presented throughout the weekend. For information, call (212) 769-5315 or check www. amnh.org/programs.

NOVEMBER 26
Lecture: "Solar Influence" (Frontiers in Astrophysics series). Astrophysicist Sallie Baliunas. 7:30 P.M., Space Theater, Hayden Planetarium.

NOVEMBER 27
Lecture on upcoming sky events: "Celestial Highlights." Joe Rao, columnist for the *New York Times* and *Natural History;* astronomers Steven Beyer, Hank Bartol, and others. 6:30 P.M., Space Theater, Hayden Planetarium.

DURING NOVEMBER
Field trips, walking tours, and workshops for children and adults, both inside and outside the Museum. For information, call (212) 769-5200.

For news from the Center for Biodiversity and Conservation, see research.amnh.org/biodiversity/center/newsletter/webletter.html.

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

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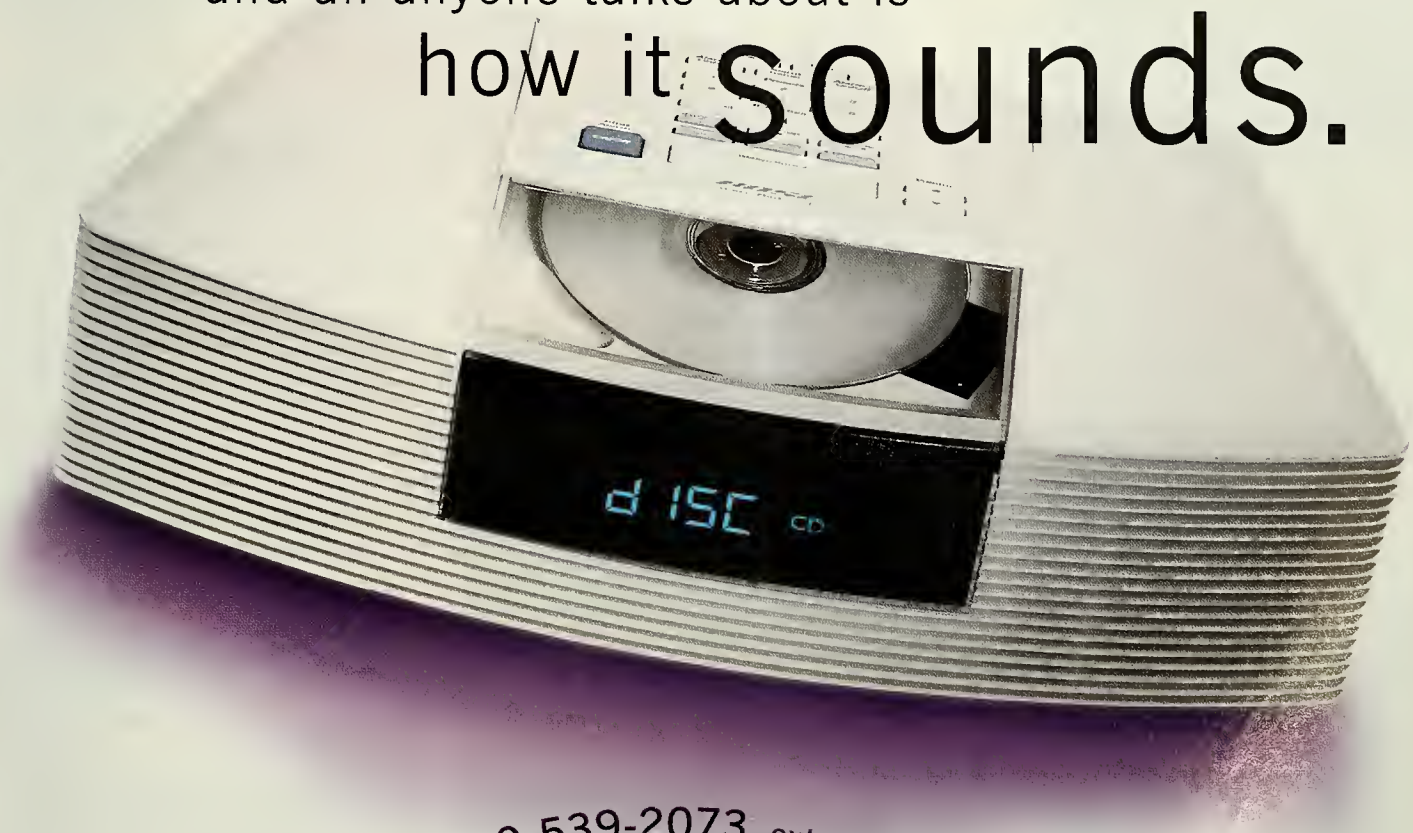

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FINDINGS

How to Stalk a Spitting Spider

On a mountain in the Philippines, the hunter risks becoming the hunted.

By Robert R. Jackson and Simon D. Pollard

Eye to eye and head to head,
This shall end when one is dead;
Turn for turn and twist for twist—
Hah! The hooded Death has missed!
—Rudyard Kipling, *The Jungle Book*

Rudyard Kipling's story of the battle between the mongoose Rikki-tikki-tavi and two cobras has a surprising parallel in the spider world. *Portia labiata,* a spider with the cunning of a mongoose, hunts and is hunted by *Scytodes pallidus,* a spider with the defenses of a spitting cobra. While Kipling set his story in an Indian bungalow and garden, our story takes place in a rainforest on the slopes of Mount Makiling, about forty miles southeast of Manila on the Philippine island of Luzon.

Having built its web in the cup of a partly folded leaf, *Scytodes* sits with its feet splayed on the strands of silk, "listening" for telltale vibrations that will signal the arrival of a possible prey or predator. It is oblivious to being watched by *Portia,* a clever jumping spider that views *Scytodes* as a potential meal. Surveying the surrounding vegetation with its keen eyes, *Portia* initiates a plan of attack that will thwart its target's formidable defenses. First it approaches the edge of the web and, using its palps (small, leglike appendages close to the mouth), softly plucks the web's silk lines. The finely tuned signal has the effect of bringing *Scytodes* into the open without provoking an attack. *Portia* then starts to climb toward a leaf directly above the web. Often losing sight of its prey, *Portia* spends twenty minutes detouring through the foliage to reach the optimal vantage point. Peering down on its intended victim, *Portia* situates itself so that it can land in a prime position to grab its prey from the rear. Then it leaps.

In an instant, the tables are turned. As *Portia* jumps, one of its legs touches a silk strand, spoiling its aim and alerting *Scytodes* to the presence of an intruder on the web. Whirling around to face the danger, *Scytodes* fires a stream of sticky glue at *Portia* from its mouthparts. The jumping spider is hopelessly trapped, pinned down by the glue. The web's resident spider delivers the coup de grâce by burying its fangs in *Portia*'s head and injecting venom. This time, the would-be diner has become dinner.

Both these species have a predilection for arachnid flesh but are otherwise quite different. Instead of constructing a web, *Portia* uses its eyes and brain to stalk and pounce. Unlike most spiders, *Portia* has eyesight that rivals our own; it is capable of seeing size, color, and shape. Web-building spiders such as *Scytodes* have much weaker eyesight and instead rely heavily on interpreting the signals from movement and variations in tension of the strands of their webs. *Portia* exploits this sensory system by manipulating the web silk in numerous and often subtle ways as it seeks to gain control over the other spider's behavior. Sometimes, perhaps expecting to catch a struggling prey insect, the duped *Scytodes* rushes into *Portia*'s waiting arms. At other times, *Portia* entices its victim out into the open to investigate and then positions itself for the kill.

While *Portia*'s advantage is its acute

ALL PHOTOGRAPHS BY ROBERT R. JACKSON

In this battle, the cunning *Portia* (top) has overcome *Scytodes,* the spitting spider.

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A female *Scytodes* carrying spiderlings on her back and an egg sac in her mouth is easy prey for a jumping spider.

eyesight, which allows it to monitor every move of its prey, *Scytodes*'s advantage is its headful of ammunition. Most spiders produce venom and all have fangs, but *Scytodes* has an additional weapon: Connected to the venom glands inside its disproportionately large head are glands that contain a sticky gum. By contracting muscles around these glands, *Scytodes* can fire a wad of venom-laced glue over distances of an inch or more within half a second, quickly paralyzing both prey and predators.

About 130 *Scytodes* species exist worldwide, and they are the only spiders that spit. *S. pallidus* is found in different parts of Asia, but as far as we know, the only ones whose standard fare is jumping spiders are those that live on and around Mount Makiling. They weave sparse, nonsticky webs on the large leaves of trees and shrubs. Jumping spiders are very common in the same habitat and often trip over *Scytodes*'s web lines, eliciting spitting attacks.

There are about 15 species of *Portia* in the world. All of them specialize in eating spiders—other jumping spiders as well as web builders. In the area of Mount Makiling, *P. labiata* is the only jumping spider that routinely gains the upper hand and overcomes *S. pallidus*. Part of its success appears to depend on its ability to stay out of the spitting spider's line of fire.

A *Portia* (right) in a *Scytodes* web

But *Portia* also exploits the maternal behavior of *Scytodes*. Female spitting spiders are unusual in the degree of care they give their offspring. The mother carries a cluster of developing embryos in an egg sac that she holds in her chelicerae (stout mouthparts ending in fangs). And while the juveniles of most web spiders disperse after the first molt, *Scytodes* spiderlings stay with the mother until they have molted three or more times. During this period of dependency, the mother brings prey to her babies, sharing the meal with them or allowing them to eat all of it.

Since spit comes from the fangs, a *Scytodes* mother carrying an egg sac in her mouthparts is effectively disarmed. To spit, she would have to release her hold, which she is reluctant to do. *Portia* can spot the difference between a *Scytodes* that is carrying an egg sac and one that is not. In laboratory experiments, we have found that when given a choice, a Mount Makiling *Portia* will go after an egg carrier. And even though making a detour is generally the safer way to approach a spider that spits, *Portia* tends to take a fast, direct path toward an egg-carrying *Scytodes*, seemingly because the risk is minimal. Upon killing a mother, *Portia* sets her aside and, as in a tale from Greek mythology, eats the eggs before feasting on the parent.

Natural selection has obviously favored *Portia* that tread carefully where *Scytodes* live and that exploit the vulnerability of egg-carrying females. In fact, Mount Makiling *P. labiata* reared in the lab with no experience of *Scytodes* also prefer egg carriers and approach them less cautiously, so the behavior must be innate. But not all members of this *Portia* species are equally streetwise.

About 200 miles north of Mount Makiling, in Mountain Province, *P. labiata* live in a *Scytodes*-free zone. There they hunt web-building spiders but are apparently oblivious to the special danger posed by the ones that spit. When tested in a lab, these *P. labiata* tried an array of signals on the *Scytodes* web, often provoking the intended victim to spit. They also failed to detour into positions from which they could attack *Scytodes* safely, from the rear. Instead *Portia* often tried to walk directly onto the web. It was usually a fatal mistake.

Robert R. Jackson is a professor of zoology at the University of Canterbury; Simon D. Pollard is Curator of Invertebrate Zoology at Canterbury Museum and a senior fellow at the University of Canterbury, both in Christchurch, New Zealand.

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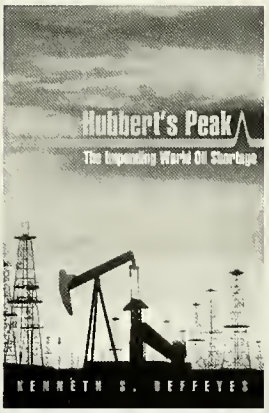

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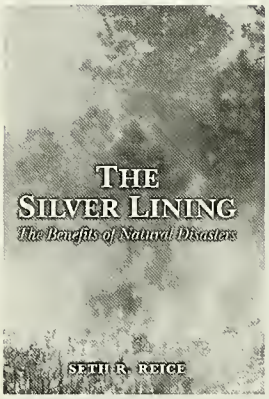

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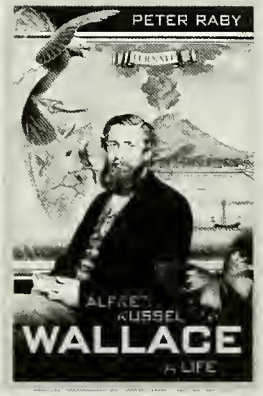

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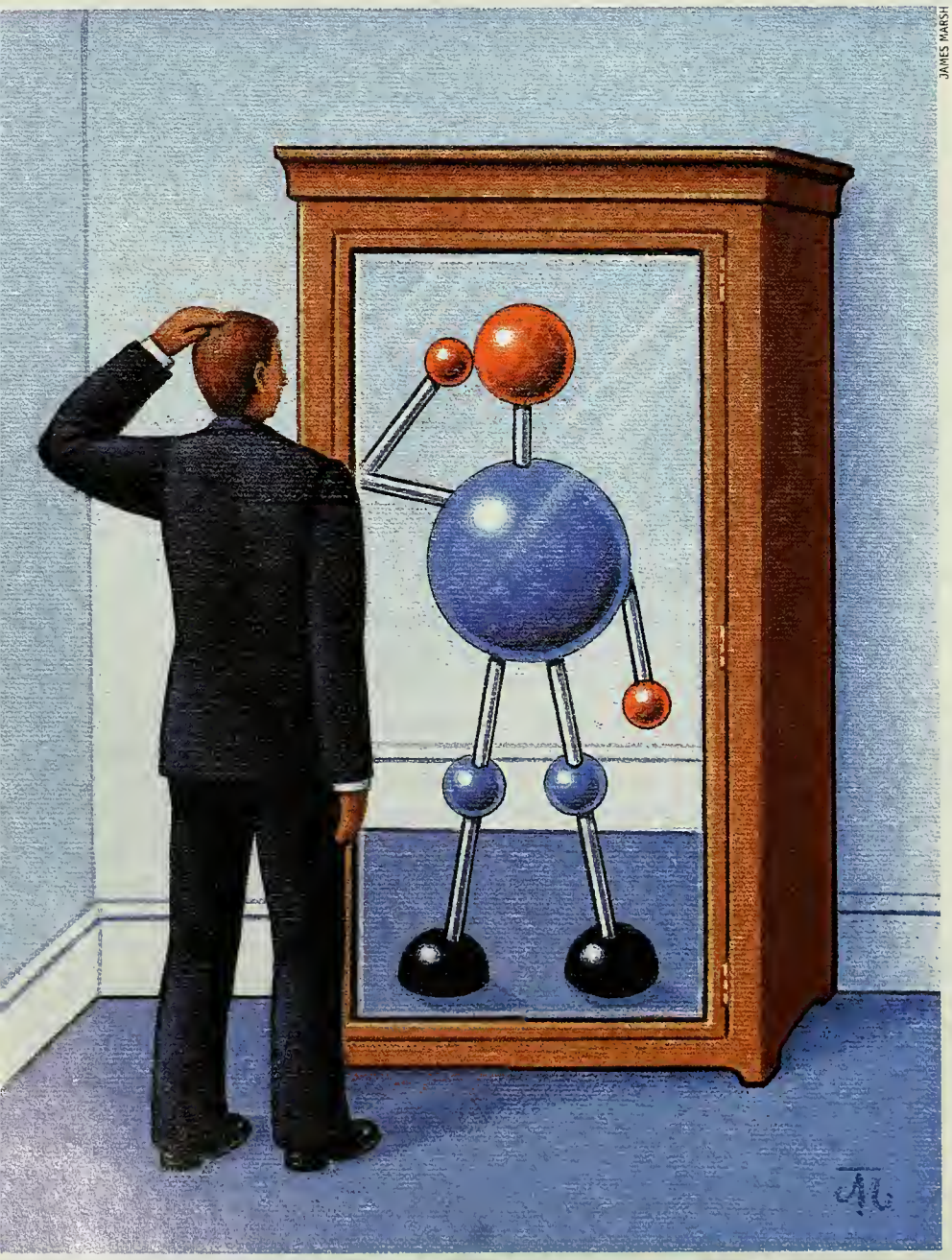
THE EVOLUTIONARY FRONT

Us and Them

Junk DNA raises the question, Whose life is it anyway?

By Carl Zimmer



JAMES MARSH

The February 15, 2001, issue of *Nature* was a peculiar one. Lodged in the middle of the journal was a kind of scientists' centerfold: a multipage foldout covered in long trains of tiny hatch marks, alphanumeric codes, and squiggly graph lines. Here, for the first time in print, was a rough draft of the human genome—what Francis Collins, head of the U.S. Human Genome Project (HGP), called "the first glimpses of our instruction book, previously known only to God."

It certainly gives one pause to look at this sprawling map and think about what it represents. It's even tempting to imagine we are peering at a biological version of the soul, the unique essence that determines us both as a species and as individuals. But be careful when you turn to your genome to search for your soul. Where you expect to find your true inner self, you will come face-to-face with a mob of strangers.

Researchers now estimate that the human genome contains roughly 40,000 genes—those stretches of DNA that make the proteins that a cell needs to survive. That's up from the figure of 30,000 published last February, but these 40,000 genes still constitute only about 2 percent of the full human genome. What's the other 98 percent? In the 1970s, when geneticists first began to look at it, they dubbed this extra material "junk DNA."

The implication of the nickname

was that there was nothing interesting or important about the stuff. It is true that a sizable portion of the DNA that isn't part of a gene fits this definition. Known as "pseudogenes," these segments of DNA are the mutated relics of genes that once encoded proteins. But a large portion of the junk DNA—amounting to about 40 percent of the human genome, in fact, according to an HGP estimate—actually has a life of its own.

An ordinary gene can duplicate itself only when a cell divides and makes a new copy of the entire genome. Certain kinds of junk DNA don't have to wait that long. Instead they may, for example, harness the cell to copy them in the form of a segment of RNA, the single-stranded version of the genetic code. Normally, RNA is used by the cell during the production of proteins. But in the case of some junk DNA, the cell uses this RNA to create another DNA copy of the junk segment, which it then inserts somewhere else in the genome. Researchers call such self-replicating pieces of junk DNA "transposable elements" because of the way they transpose copies of themselves into new places in the genome.

Why do some species have lean, mean genomes with hardly any junk, while others are overwhelmed by it?

The more researchers have studied transposable elements, the more these bits of DNA have come to seem like a collection of parasites that use the genome as their host. We tend to think of parasites as autonomous organisms—hookworms or lice, for instance—not as our "own" genetic material. But during the 1980s and 1990s, the metaphor of genetic parasites turned out to be very powerful. Parasites tend to follow certain evolutionary paths, and these genetic parasites are no exception.

Like other parasites, transposable elements can cause a lot of harm to their host—such as by pasting a copy of themselves smack in the middle of a gene. When it comes time for the cell to build a protein based on that gene, it may be unable to do so because the inserted DNA has turned the gene's code to gibberish. Researchers are discovering more and more forms of human genetic disorders—ranging from hemophilia to breast cancer—that have come about because a transposable element has hopped into an unfortunate place in the genome.

Another hallmark of parasites is that hosts often evolve defenses against them. Transposable elements appear to be no exception to this rule. In certain regions of our genome, for example, our DNA is capped with hydrocarbon molecules. This capping (called methylation) prevents the cell's DNA-copying machinery from locking onto the genetic material in those parts of the chromosomes. Researchers suspect that in many cases, methylation is the genome's way of fighting against the damage caused by transposable elements—by stopping them from reproducing.

In the May 10, 2001, issue of *Nature,* for instance, a group of Japanese researchers described their study of methylation in the genome of the thale cress plant *(Arabidopsis thaliana).* They found that if a certain gene mutated, the plant could no longer methylate its DNA. Freed from their prisons, the transposable elements in these mutants started replicating themselves and inserting these new copies into the genome. The resultant plants were nothing more than shriveled clumps. Thanks only to methylation, it seems, can the thale cress withstand its genetic parasites.

This discovery points up a conundrum that arises as much in connection with transposable elements as with conventional parasites: if they can be so harmful to their hosts, why haven't they driven their hosts extinct—and made themselves extinct in the process? Part of the answer comes from their evolutionary history. Transposable elements can spread gradually through a genome over millions of years, but eventually their success at self-replication wanes. Copying errors creep in and undermine their ability to replicate themselves; in addition, the host genome evolves an ability to suppress them. Most of the transposable elements in the human genome, it now seems, are already dead or about to give up the ghost.

Your genome is an ancient ecosystem in which hundreds of thousands of mysterious life-forms compete, cooperate, co-opt one another, and coevolve.

The only way a transposable element can escape this fate is to leave its host and find a fresh genome to invade. By comparing transposable elements found in an array of hosts, researchers have discovered that these genetic parasites can make astonishing leaps—from marine flatworms to beetles, for example, or from salmon to frogs—although no one knows for sure how they manage these migrations. Perhaps certain mutations turn the transposable elements into full-fledged viruses—nucleic acid molecules covered in protective protein shells. They can then exit their host, find a new one, and snuggle into its genome. Some of today's transposable elements might have once been free-ranging viruses, and some contemporary viruses may have had transposable elements as ancestors.

Through migration and proliferation, transposable elements have become inordinately successful, and that is how they have come to constitute 40 percent of our DNA, either as active copies or dead ones. Much of the remaining junk DNA in our genome may also turn out to be former transposable elements that have mutated beyond recognition. In certain species the proportions are even more staggering: 99 percent of the lily genome consists of transposable elements.

Despite what we know about transposable elements, can't we still salvage the notion of the genome as the biological soul? When I look at the map of the human genome, don't I still see "myself" in the genes that code for useful proteins—albeit a self that is besieged on all sides by these annoying parasites? The answer, it increasingly seems, is no. You can't draw a line in the genome between us and them.

One of the best places to see this fuzziness is in the arid canyons of Israel. The wild barley plants that grow there carry many copies of one family of transposable elements, called BARE-1. Alan Schulman, of the University of Helsinki, and his colleagues recently studied a single population of barley plants in one of these canyons. They found that the plants growing at the top of the canyon carried three times more BARE-1 copies than did the plants of the same species growing at the bottom, where conditions are less harsh. Similar patterns have emerged throughout Israel and surrounding countries. In other words, having a lot of BARE-1 copies somehow seems to allow barley to survive under arid conditions.

One possible explanation is that transposable elements make the genome physically big, which is sometimes a good thing. In 1978 Thomas Cavalier-Smith, then at the University of British Columbia, proposed that the sheer size of a genome can sometimes be an adaptation. Since then, this idea has been generating much controversy as it floats around the scientific community. Its main attraction is that it addresses a fundamental puzzle about DNA: Why do some species have lean, mean genomes with hardly any junk, while others are overwhelmed by it?

A species with a sizable genome may simply have had the bad luck to be attacked by a particularly nasty transposable element. But it's also possible that genomes of certain sizes may be favored under certain circumstances. Big genomes tend to be found in big, slow-dividing cells. As genomes expand, the cells they inhabit may have to expand with them to accommodate a larger crew of proteins employed in keeping the genome in good working order. Getting these bigger cells to divide may also be a bigger undertaking, and this would make them multiply more slowly.

Large, slow-dividing cells may outperform small, quick-dividing ones in some situations. If a plant can grow to a good size, it can capture more sunlight and make more seeds. But plants also need water to grow, and in Israel and the rest of the eastern Mediterranean region, winter is when the most water is available. Since the relatively cold temperatures slow down the chemical reactions involved in cell division, plants may grow by developing fewer, bigger cells instead of a lot of small ones. In the case of the barley plants, the climate at the top of the canyon is much harsher than the climate at the bottom, favoring bigger genomes and the bigger cells they bring. It's possible that similar tradeoffs have driven the evolution of different-sized genomes not just among plants but maybe among animals, fungi, and amoebas as well. So while

transposable elements may indeed be genetic parasites, they may end up helping their hosts.

Transposable elements also appear to play a crucial role in the evolution of the cell's "legitimate" genes. Genes can evolve only if they first mutate, and transposable elements create a significant fraction of a genome's mutations. Like other kinds of mutations, most of those caused by transposable elements are neutral or harmful, but some of them can do an organism good. Sometimes, for instance, these mobile genetic parasites drag a piece of a neighboring gene with them to their new home. In the process, they link two preexisting chunks of genes into a new combination that may quickly take on a new function.

Transposable elements themselves have even become vital parts of genes. About 500 million years ago, for example, a transposable element in the genome of early vertebrates was incorporated into a gene that became part of our immune system. This ex-parasite stopped using its DNA-splicing skills to replicate itself and instead began rearranging the genes that encode pathogen-recognizing proteins. Thanks to this transposable element, our immune cells can quickly generate millions of different-shaped proteins. Through a process much like natural selection, the cells with proteins that allow them to identify pathogens will survive and can then be made to alter their genes again to do an even better job. In other words, it is only thanks to an erstwhile parasite that we can fight off other parasites.

This example of an adopted transposable element is just one of hundreds that geneticists have uncovered, and the list keeps growing. These discoveries have left biologists groping for new kinds of metaphors to describe the genome. In a review article concerning transposable elements, published in the January 2001 issue of *Evolution,* biologists Margaret G. Kidwell and Damon R. Lisch sounded downright Zen. "Who are we and who are they, who is host, and who is parasite can be seen as a function of how selection is operating at any given time," they wrote, adding that in specific cases "these distinctions can become meaningless."

I highly recommend mulling over riddles like that one while you gaze at the map of the human genome. The self can be found everywhere and nowhere on that chart. Your genome is an ancient ecosystem, a jungle, a tangled bank of a river, in which hundreds of thousands of mysterious life-forms compete, cooperate, co-opt one another, and coevolve. In the words of the immortal Pogo, "We have met the enemy and he is us."

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

IN THE FIELD

A Turtle Out of Water

To freeze or not to freeze: a hatchling's dilemma

By Peter J. Marchand

ZIG LESZCZYNSKI: ANIMALS ANIMALS

Like the hatchlings of many other turtle species, this eastern painted turtle emerges into a cold world.

It was a sobering sight, one of those encounters that awakens you to the harsher realities of nature. The ground was dug up and strewn with white, leathery shells—remnants of about ten eggs, near as I could tell. From the tracks in the loose soil, I guessed that a skunk had discovered the buried trove about forty yards from the edge of a pond and, in a single feeding spree, had wiped out a snapping turtle's reproductive effort for the year. In a poignant way, this exemplified the perilous trial of aquatic turtles out of water. Superbly adapted to adult life in the pond, they are less well equipped for their start on land. And hungry predators aren't the only obstacle between turtles and the safety of water; many hatchlings in northern climes, emerging in the fall, are faced with the daunting task of surviving their first winter below ground, often exposed to freezing temperatures.

Had the snapping turtle's eggs escaped predation, the young would have moved to the pond as soon as they emerged from their nest in autumn. But hatchlings of many other turtle species remain at or close to their natal site during their first winter, digging themselves out the following spring and only then migrating to water. Some, such as the yellow mud turtle, burrow deeper into the soil shortly after hatching, finding safety below the frost line. In contrast, the ornate box turtle and northern populations of the painted turtle frequently overwinter in shallower soils and, when unable to avoid freezing, show a remarkable tolerance for the formation of ice in their body tissues.

Subjected to slow cooling, hatchling turtles may begin to freeze at a temperature slightly below 27°F, with ice first forming on the outer skin and then advancing slowly toward

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the body's core, eventually cutting off peripheral blood circulation. At 25°F, slightly more than half the water in the turtle's body may be frozen, and all vital signs cease. If the temperature drops no further, the hatchlings will recover completely upon thawing.

Remarkable as this freezing tolerance is, 25°F is close to the turtle's limit of survival in the frozen state; in order to withstand lower temperatures in nature, turtles must utilize another tactic. Through a process known as supercooling, they become chilled well below the normal freezing point of their blood plasma without undergoing ice formation. As long as the water in the turtle's body tissues remains liquid, no immediate harm comes of supercooling (the presence of ice in living tissues, rather than low temperature per se, is the primary cause of cell damage). But life is tenuous in this state, for if a supercooled animal is disturbed in any way, ice may form instantaneously, spreading rapidly throughout the body and resulting in a quick death. And disturbance isn't the only risk. The presence of any impurity in the bloodstream or gut of the animal can also "seed" ice by providing a nucleus or particle around which crystals can form more easily than they can in a pure liquid. Ice in the immediate environment of the animal is a danger, too, for nothing seeds ice crystals as readily as ice itself.

The surest way for a turtle to minimize the chances of flash freezing in the supercooled state is to avoid conditions that might serve to stimulate ice formation in body tissues. Hibernating in a dry place and evacuating the gut, so that neither external ice nor intestinal impurities pose a threat, are two possibilities. While the former is partly a matter of chance, painted turtles, it appears, do systematically empty their guts of soil particles and pieces of eggshell that are accidentally ingested during the hatching process and that might provide a nucleus for ice formation. Through this evacuation alone, hatchlings can greatly enhance their supercooling capacity. Northern populations of painted turtles are

Ornate box turtle, newly hatched

ultimately able to resist freezing to temperatures as low as -10°F.

Turtle hatchlings were once thought capable of producing ice-promoting, or ice-nucleating, proteins that facilitate harmless ice crystallization at temperatures slightly below 32°F. Hatchlings could thereby avoid the risks inherent in supercooling—a benefit if their winter surroundings remain above 25°F or so. But while ice-promoting substances are often present in blood samples taken from turtles, they apparently are contaminants and are not produced by the animal. Hatchlings raised in the laboratory, free of ice-nucleating particles, can supercool to much lower temperatures than turtles raised on natural soils. Sugars and alcohols like those that protect insects in winter may likewise be naturally induced in turtles in small quantities during freezing but do not seem to be produced and stored ahead of time in the animals' bodies. While turtle hatchlings in the wild may utilize either supercooling or freeze tolerance to get through winter, whichever strategy is employed seems to be a matter of environmental circumstances. If the hatchlings ingest bits of eggshell or bury themselves in soil containing ice crystals, they will freeze at relatively high temperatures and survive only if subsequent temperatures do not go too low. In the absence of ice nucleators, they will supercool to lower temperatures and, unless somehow disturbed, survive colder winters.

One misty evening, a couple of weeks after discovering the exhumed snapping turtle eggs, I happened upon two box turtles digging nest cavities at the side of a dirt road. A short while later I encountered a skunk working its way through the tall grass at the road's edge. Between predators and the prospect of freezing, it seemed to me that a turtle out of water stood on shaky ground, and I wondered why the young of all aquatic species don't bolt for the safety of the pond as soon as they are out of the shell, rather than digging in and overwintering on land. There is no clear answer to this puzzle. While natural selection has favored certain adaptive themes for all turtles, each species has evolved a balance of traits that best suits its overall needs. And in that balance hangs the fate of many hatchling turtles, suspended for months in the uncertain limbo of the supercooled state.

Peter J. Marchand is a research ecologist at the Catamount Institute on the north slope of Pike's Peak in Woodland Park, Colorado.

Distinctive Destinations

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Costa Rica

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Guanacaste's coastal waters offer a spectacular array of large marine life, from a tiny fluorescent damsel to a six-foot white tip reef shark to a giant manta.

AFTER LANDING IN COSTA RICA'S CAPITAL CITY OF SAN JOSÉ, head northwest to the Guanacaste area. From San José, take the Interamerican Highway toward Liberia, winding your way through breathtaking landscapes as you enter this magical region. The largest of Costa Rica's provinces, Guanacaste comprises a combination of lowland dry forests, vast windswept plains of golden waving grasses and tough flowering shrubs, impressive volcanic mountain ranges, cloud and rain forests, subterranean national parks, and of course, miles and miles of coastline.

From Playa Pan de Azucar down to Playa Conchal, sandy beaches abound, ranging in color from a rich coral to a pale gray. Costa Rica's shore presents the perfect opportunity to relax and bask in the sun or to walk along the waves searching for sea treasures. Marine birds and iguanas are abundant – and neither seem to mind sharing the beach with visitors.

If you're interested in more than beaches and tranquil waters, make a stop at a tropical and humid premontane transition forest, which can be found in Santa Rosa National Park or Rincón de la Vieja National Park. Rincón de la Vieja, named after an active volcano, was created in 1973 to protect the extensive flora, fauna, and watersheds around the area. Before arriving at the park's exciting fumaroles, known as Las Pailas, you can hike through thousands of trees and lush vegetation, stopping to gaze at myriad birds and butterflies. Fascinating mud cones of different sizes and shapes continually bubble before your eyes. Thirty-two rivers flow down the volcano, making the park's ecological importance impossible to overestimate. Because of the park's size and diversity, a thorough investigation takes at least two days. No lodging is available within the borders, but a variety of small hotels built in the traditional hacienda style can be found nearby.


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Mexico

As a winter chill enters the air in the north, an estimated 250 million monarch butterflies begin their annual journey south to Michoacan, Mexico. If you're planning a trip to Mexico this winter, don't miss this amazing feat of nature and beauty, a phenomenon that not even scientists entirely understand. Leaving Canada and the United States in late October or early November, the monarchs fly approximately 70 miles per day.

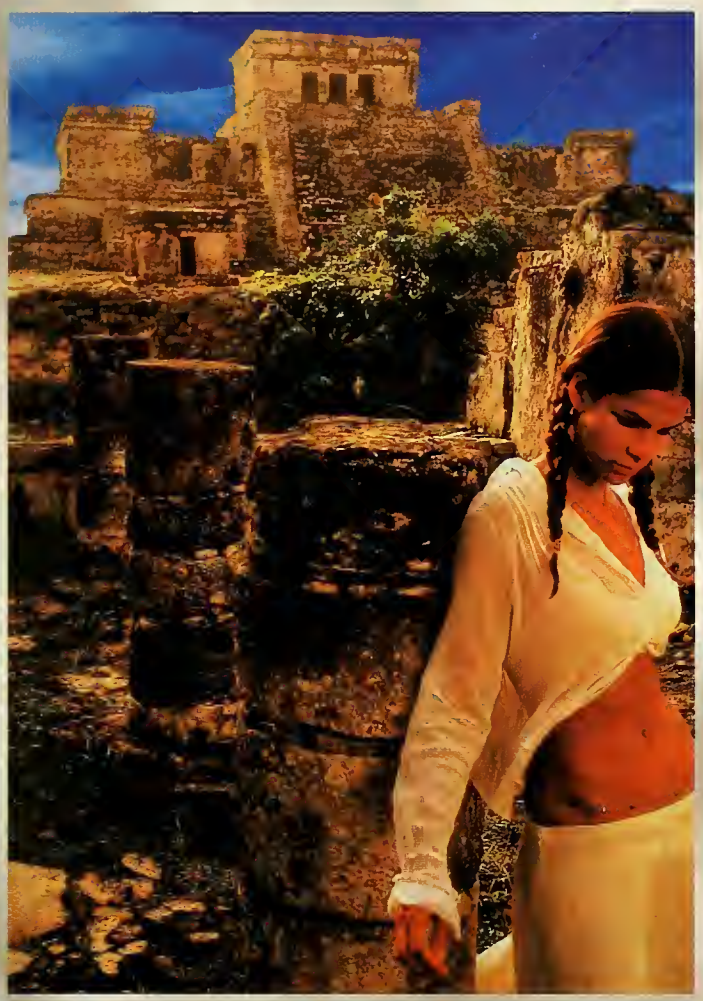
When you visit Mexico to see the monarchs, take some time to enjoy the unique orchitecture or join the notional celebration of the Days of the Dead.

DURING THEIR MIGRATION, the butterflies fly only during the day and feed at night. Adding to the intrigue of the monarch migration is the fact that no butterfly completes the entire round-trip migration, as its life span is only a few months. The butterflies in Michoacan are the offspring of the ones that left the previous spring.

The butterflies' final destination lies in the eastern mountains of Mexico surrounding Morelia, a charming colonial city at the center of several unique tourist destinations including Lake Patzcuaro, Janitzio, and Tzintzuntzan. Here, in the Oyamel fir forests, the monarchs spend their winter waiting for the spring by hibernating, forming massive colonies in the tall pines and firs. In a semi-dormant state they conserve energy over the winter for mating. The sight of so many butterflies is overwhelming in its splendor, with the trees transformed into a bright orange carpet.

Two butterfly reserves are open to the public. The largest one, Santuario de Mariposas El Rosario, or El Rosario Monarch Butterfly Sanctuary, is located in the mountains of the Monarch Butterfly Biosphere Reserve, three hours west of Mexico City. Here, the monarchs cluster together in the pine trees, often weighing down branches with their sheer mass.

Another reserve open to the public is the Sierra Chincua Monarch Butterfly Sanctuary, which is a short distance from the small mountain town of Angangueo. Sierra Chincua offers guided horseback riding tours, as trails tend to be a little rough. Angangueo and nearby towns such as Ocampo, Zitacuaro, and Maravatio celebrate the monarch butterfly in February during the Festival de la Mariposa Monarca, which is characterized by typical dances, music, and craft markets.



I was born thousands of years ago, and soon I taught the world to count the days by the sun, the months by the moon, and the years by the stars. **Today I am affectionately called México, and I am full of intrigue and wonder.**

I am ancient.

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Belize

FROM COROZAL IN THE NORTH TO TOLEDO IN THE SOUTH, Belize is known for its archaeological heritage and natural history, making it a favorite destination for many travelers. The country's significant marine environment includes the world's second longest barrier reef, as well as three major offshore atolls along the coastline. Visitors can visit numerous mangroves both offshore and along the coast. These ecosystems provide a tremendous wetlands environment in which birds, fishes, mammals, and reptiles all flourish.

Belize is also blessed with an outstanding archaeological heritage of Maya temples and palaces. The Maya occupation began as early as 1500 BC, and although it began its decline in AD 900, some Maya cultural centers continued to be occupied until contact with the Spaniards in the 1500s. Although large Maya cultural centers no longer exist, there is still a substantial Maya population residing within many small villages.

Arizona

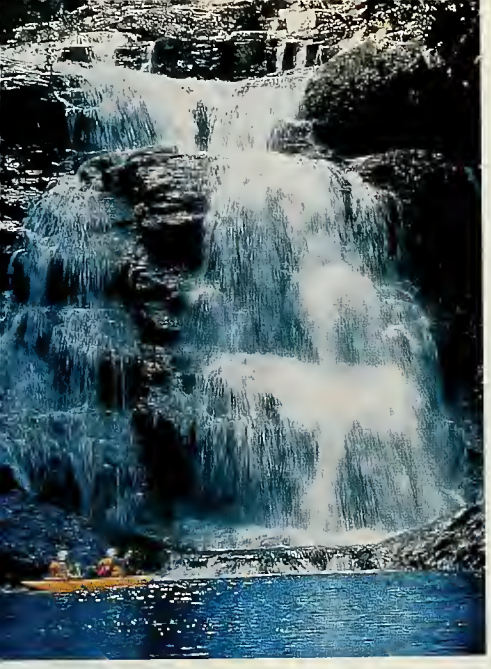
CLOSER TO HOME, Arizona offers some of the world's most awe-inspiring natural beauty. The cactus-dotted deserts, the cool pine forests surrounding Flagstaff, the red rocks of Sedona, the cosmopolitan sprawl of Phoenix, and the magnificence of Monument Valley are all part of the Arizona vacation experience.

Begin your trip in Arizona's northwest and north-central regions, home of the Grand Canyon, Sedona/Oak Creek Canyon, and the mountain community of Flagstaff. Each season brings a different palette of colors to Canyon Country and a new slate of vacation activities, from hiking and rafting to skiing and sledding.

For a taste of the culture of the Navajo and Hopi nations, visit northeastern Arizona, where you can experience the fascinating civilization and ceremonial artifacts of these Native Americans. In addition to being part of the famous point (Four Corners) where Arizona, Utah, Colorado, and New Mexico share a common border, the region is characterized by sweeping plateaus, towering mesas, and scenic canyons, and it is home to well-known attractions such as Monument Valley, Canyon de Chelly, the Petrified Forest, the Painted Desert, and Lake Powell.

The lofty mountain peaks, trout-filled streams, and thick ponderosa pine forests that distinguish the east-central Arizona region pleasantly surprise many first-time visitors to the state. Between November and March, the region is transformed into a winter wonderland for snow sports enthusiasts.

The traditional West comes alive in southern Arizona's Old West Country. From the cosmopolitan city of Tucson, home to stylish resorts and lively Western guest ranches, to the enchanting mining towns of Bisbee and Tombstone, this region is a perfect getaway from the everyday. Authentic nineteenth-century missions, country vineyards, bird-watching habitats, hiking, and colorful festivals are all part of the Old West vacation experience.



Although Belize is a relatively small country, with very low-lying land, it receives an abundance of rain during the winter season and supports 20 major river systems and smaller streams.

Arizona's Navajo Nation is home to the famed Antelope Canyon, carved from sand stone and renowned for its steep, rainbow-hued walls. If you're a photographer, a trip to Antelope Canyon is a must.

Swan Hellenic

Some people find that the perfect vacation includes a well-planned trip that is orchestrated by an expert. If you are such a person, then Swan Hellenic may provide just the vacation you are looking for. Swan Hellenic's discovery cruises offer an array of "must-see" destinations and little-known places that are off the well-beaten tourist track. All are special, and all include guided excursions and guest speakers on board to lecture from personal experience about a broad range of topics relevant to your cruise.

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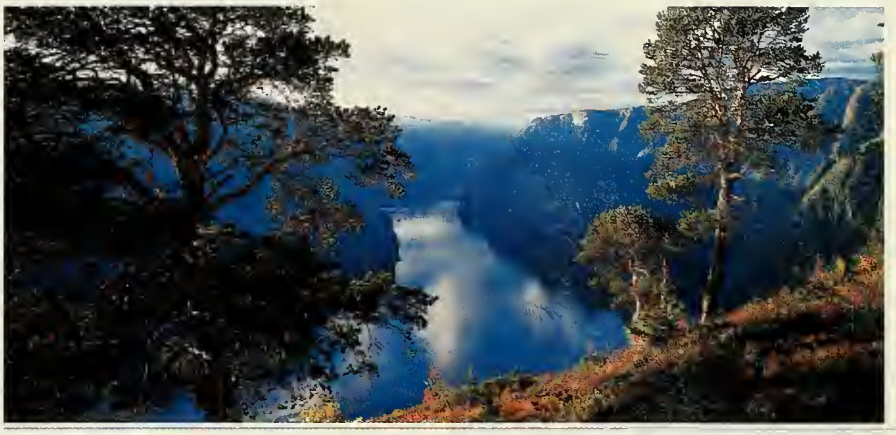
Norwegian Tourist Board



Norway's unique an d dramatic fjords, carved by glacial ice millians of years ago, wind their way from the coast to the inland areas of Norway. Many small towns lie along the fjords, a reminder that in days gone by, waterways were always a natural traffic thoroughfare.

Set foot in the fjords of Norway and you'll know at once that every moment of your visit will be memorable.

WHEN MOST PEOPLE THINK OF NORWAY, they usually think of Norway's most spectacular natural asset, the fjords. Formed millions of years ago, these craggy coastal inlets leave visitors awe-struck with their serene beauty. One after another, they cut into the country for miles, surrounded by mountains, glaciers, and waterfalls.

Begin your Norwegian journey in the charming coastal city of Bergen. Known as the Gateway to the Fjords, Bergen is a lively city with Old World charm and atmosphere. Its wooden houses, narrow alleyways, and busy harbor give it a unique atmosphere. Take the Funicular Railway to the top of Mount Floyen, or the cable car up Mount Ulriken, for one of the most spectacular sights in Norway – Bergen framed by the sea and fjords against a backdrop of mountains. Wander around the shops of historic Bryggen, a wharf that is now an UNESCO World Heritage site.

You'll get the best view of the fjords traveling by boat or ferry. Take a fjord cruise down the Lysefjord, Hardangerfjord, Sognefjord, Geirangerfjord, or one of the many other fjords. There are daily departures from many of the towns and villages in the region, and Bergen is an ideal base from which to explore. Many tourist offices in Bergen and around Fjord Norway will book accommodations and transportation and sell tickets for sightseeing tours and other activities.

Norway

Whether it's the pristine beauty and tranquility of our fjords, the vivid reminders of our Viking heritage, or the warmth of our native Sami people, there's not a more enchanting place for a vacation than Norway. Call **1-866-6-NORWAY** (866-666-7929) for more information, or visit **www.visitnorway.com/us**.

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Poconos

LOCATED IN THE NORTHEASTERN corner of Pennsylvania, the Pocono Mountains are only 90 minutes from New York City and less than 2 hours from Philadelphia. The region's 2,400 square miles of wooded peaks and valleys are filled with numerous lakes, rivers, and some of the loveliest waterfalls in the east. In the midst of all this natural beauty, you will find hundreds of attractions and places to stay, making the Poconos a perfect place to vacation this winter.

Enjoy downhill and cross-country skiing, ice-skating, and tobogganing in this winter getaway. Over 146 slopes and trails beckon, whether you're an expert skier or a beginner. To help families learn to ski, the major ski areas and resorts provide special Learn to Ski packages. Of course, not every attraction is found outdoors. Pocono resorts also offer nightly entertainment, indoor swimming pools and tennis courts, health clubs, and more.

FOR MORE INFORMATION on these distinctive destinations, visit their web sites.

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IN SUM

Don't Tread On It The Arctic's delicate tundra plants support large populations of animals such as caribou and provide nesting habitat for huge numbers of birds. The Bush administration's plan for oil drilling in the Alaskan wilderness, plus the advent of global warming, has environmentalists worried about the tundra ecosystem. New research shows that minor alterations caused by human intrusions into both the High and the Low Arctic landscapes may be just as detrimental as the more apparent, larger-scale menaces. Bruce C. Forbes, of the Arctic Centre at the University of Lapland in Finland, and colleagues recently summarized the results of numerous studies examining small-scale threats to the tundra of Alaska, Canada, Greenland, and Siberia.


Damaged tundra

BRUCE FORBES

The researchers compared the plant communities in undisturbed patches with those in patches that had previously suffered damage from humans but had subsequently been on the mend for several decades. They found that only the smallest, wettest patches of tundra recovered on their own from extreme injury—the sort that removes all aboveground plant matter. But even patches that retained an intact plant layer were often permanently altered.

Some of the most severe damage was caused by trucks, vans, and other heavy vehicles. Just one pass of such a vehicle during the summer months left ruts that drained the water from wetlands. The explosive growth of ecotourism has also wounded the habitat; hiking, for example, has compacted soils and destroyed vegetation. Willows, horsetails, and certain grasses have readily regenerated in these trampled areas, taking over where a formerly diverse plant community once flourished. The researchers warn that a series of seemingly insignificant disturbances will nibble away at species diversity, changing the sensitive landscape forever. ("Anthropogenic Disturbance and Patch Dynamics in Circumpolar Arctic Ecosystems," *Conservation Biology* 15:4, 2001)—*Kirsten L. Weir*

Nature's Candy Flowering plants have evolved many clever ways to get themselves pollinated; one of the best is to compensate pollinators with tasty treats. Among plants pollinated by birds, such rewards usually are given in the form of liquid nectar. Now Marlies Sazima, of the Universidade Estadual de Campinas in Brazil, and colleagues have discovered a novel plant prize: candy pellets.


Jelly-laden *Combretum lanceolatum*

MARLIES AND IVAN SAZIMA

The researchers studied *Combretum lanceolatum,* a shrub that grows along muddy riverbanks and ponds in western Brazil's Pantanal floodplain. They found that each of the shrub's flowers produces a single clear jellylike pellet, formed when the plant's inner wall swells and gelatinizes as it comes in contact with nectar. Oozing out of the flower's center, this mixture solidifies into a sweet gumdrop. Unlike liquid nectar, these floral confections aren't renewed after they've been eaten.

Over a total of eighty-seven hours, team members recorded twenty-eight species of birds, from eight families—most often parakeets, macaws, kiskadees, tanagers, and finches—dining on the sweets. Perched on the shrubs to collect the pellets, the birds often brushed against the showy greenish flowers, dusting their throats and breasts with pollen. Thanks to this reproduction strategy, the plant is spreading rapidly. ("The Sweet Jelly of *Combretum lanceolotum* Flowers [Combretaceae]: A Cornucopia Resource for Bird Pollinators in the Pantanal, Western Brazil," *Plant Systematics and Evolution* 227, 2001)—*Kirsten L. Weir*

Mutant Ninja Bacteria Drug-resistant bacteria—a worldwide problem resulting from the indiscriminate use of antibiotics—are particularly threatening in developing countries. Overuse of antibiotics has been shown to drive the evolution of mutant strains of bacteria immune to a broad spectrum of drugs, including penicillins, cephalosporins, and quinolones. Now scientists have found that these multiple-drug-resistant, or MDR, bacteria can find their way from an infected hospital patient's digestive system into hospital effluent and thence into community sewage systems.

V. Chitnis, of Choithram Hospital and Research Centre in Indore, India, and colleagues compared the bacterial concentration in the runoff from ten hospitals with that in sewage from eleven residential areas. They found that although effluent in Indore's residential areas had a higher overall bacterial count (which the team attributes to a lower concentration of disinfectants and antibiotics than is found in hospital runoff), the proportion of MDR bacteria in hospital samples was significantly higher. What's more, higher concentrations of resistant bacteria were detected, in some cases, more than a mile from the point where the hospital effluent had entered the municipal sewage system.

These MDR bacteria are able to proliferate because resistance plasmids—genetic elements found in bacterial cytoplasm—can be transferred from one bacterium to another by cell-to-cell contact. The result is that bacteria that have never been exposed to antibiotics can become resistant simply by coming into contact with MDR bacteria. If such resistance is transferred to any of the bacterial pathogens causing infections (such as cholera and dysentery) that are common outside the hospital setting, the researchers caution, "most of the presently available antibiotics will be futile against the infectious organisms." ("Hospital Effluent: A Source of Multiple-Drug-Resistant Bacteria," *Current Science* 79, 2000)—*Maria Ribaudo*

UNIVERSE

Radio Bubble

Alien couch potatoes? It's possible, thanks to escaping TV and radio signals.

By Neil deGrasse Tyson

In the opening scene of the 1997 film *Contact*, a virtual camera executes a controlled, slow pullout from Earth to the outer reaches of the universe. For this journey, you can decode Earth-based television and radio broadcasts that have escaped into space. Initially you hear a cacophonous mix of loud rock music, newscasts, and noisy static, as though you were listening to dozens of radio stations simultaneously. As the journey progresses out into space, and as you overtake earlier broadcasts that have traveled farther, the discordance lessens and the signals report historical events that span the broadcast era of modern civilization. Amid the noise, you hear—in reverse sequence—sound bites from the space shuttle *Challenger* disaster of January 1986; the Moon landing of July 1969; Martin Luther King's "I Have a Dream" speech, delivered in August 1963; President John F. Kennedy's January 1961 inaugural address; President Franklin D. Roosevelt's December 1941 address to Congress, asking for a declaration of war; and Adolf Hitler's speech given at the opening ceremonies of the 1936 Olympics. Eventually the human contribution to the signal disappears entirely, leaving a din of radio noise emanating from the cosmos itself.

Poignant. But in fact, this scroll of acoustic landmarks would not unfurl exactly as you hear it. If you somehow managed to violate an important law of physics by traveling fast enough to overtake a radio wave, few words would be intelligible, because you'd hear everything played backward. Furthermore, we hear King's famous speech as we pass the planet Jupiter—an audio-video moment implying that Jupiter is as far as the broadcast has traveled. In fact, King's speech passed Jupiter thirty-five minutes after he delivered it.

Contact's opening scene was nonetheless poetical and powerful, as it marked the extent to which we have presented our modern lives to the rest of the Milky Way Galaxy. The radio bubble, as it has come to be called, centers

on Earth and continues to expand at the speed of light in every direction, while its middle gets continuously refilled by modern broadcasts. Our bubble now extends nearly a hundred light-years into space. Its leading edge corresponds to the first artificial radio signals that ever escaped from Earth, and its volume now contains about a thousand stars, including Alpha Centauri (4.3 light-years away), the nearest star system to the Sun; Sirius (10 light-years away), the brightest star in the nighttime sky; and every sunlike star around which a planet has thus far been discovered.

Not all radio signals escape our atmosphere, however. The plasma properties of the ionosphere, beginning at more than fifty miles up, enable it to reflect back to Earth all radio-wave frequencies of less than about twenty megahertz. This allows some forms of radio communication, such as the well-known shortwave frequencies of ham radio operators and the BBC World Service, to reach thousands of miles beyond their transmitters' horizons. All the broadcast frequencies of AM radio are also reflected back to Earth, accounting for the extended range these stations enjoy.

But if you broadcast at a frequency that isn't reflected by Earth's ionosphere (or if Earth didn't have an ionosphere), your radio signals would reach only those receivers in its line of sight. Tall buildings give a significant advantage to radio transmitters mounted on their roofs. While the horizon for a 5'8" person is just three miles away, the horizon seen by King Kong as he climbed atop New York City's Empire State Building was more than fifty. After the filming of that 1933 classic, a broadcast antenna was installed there. An equally high receiving antenna could, in principle, be located fifty miles farther still, enabling the signal to graze the treetops at the fifty-mile horizon, thereby extending the signal's reach to a hundred miles.

The ionosphere reflects neither FM radio nor broadcast television, itself a part of the radio spectrum. Each of these travels no farther on Earth than the most distant receiver it can see, allowing cities that are relatively near each other to command separate audiences for their own television programs. For this reason, locally broadcast, unsyndicated TV and FM radio cannot possibly be as influential as AM radio, which may account for AM's preponderance of politically acerbic talk shows. But the real influence of FM and TV may not be terrestrial. While their signals are purposely broadcast parallel to the ground, part of every signal leaks straight up, crosses the ionosphere and travels through the depths of space. For these signals, the sky is not the limit. And unlike some other bands in the electromagnetic spectrum, radio waves have excellent penetration through the gas and dust clouds of interstellar space. For them, the stars are not the limit either.

As the signals move away from Earth, they get weaker and weaker, ever more diluted by the growing sphere of space through which they travel.

If you add up all the factors that contribute to Earth's radio signature—such as military radar; the total number of shortwave, AM, FM, and TV stations; the distribution of stations across the planet's surface; the energy output of each station; and the bandwidth over which the energy is broadcast—you find that television accounts for the largest sustained flux of radio signals emanating from Earth. One part of a TV signal's anatomy is skinny; the other is wide. The skinny, narrowband part is the video carrier, through which more than half the total energy is broadcast. A mere 0.1 hertz wide in frequency, the signal establishes the station's location on the dial (the familiar channels 2 through 13) as well as the existence of the signal in the first place. A low-intensity, broadband signal 5 million hertz wide surrounds the carrier at higher and lower frequencies and is imbued with modulations that contain all the program information.

As you might guess, the United States contributes more than any other nation to Earth's global television profile. An eavesdropping alien civilization would first detect our strong carrier signals. If the aliens continued to pay attention, they would notice periodic Doppler shifts (alternations between lower and higher frequencies) in these signals every twenty-four hours. They would also notice the signal getting stronger and weaker during the same time interval. The aliens might first conclude that a mysterious, though naturally occurring, radio loud-spot was rotating in and out of view. But if they managed to decode the modulations within the surrounding broadband signals, they would gain immediate access to elements of our culture.

Unlike sound waves, electromagnetic waves (including visible light and radio waves) do not require a medium to travel through. Indeed, they are happiest moving through the vacuum of space. So the time-honored flashing red sign in broadcast studios that says "On the Air" could justifiably read "Through the Space," a phrase that applies especially to the escaping TV and FM frequencies.

As the signals move away from Earth, they get weaker and weaker, ever more diluted by the growing sphere of space through which they travel. Eventually the signals drown in the ambient radio noise of the universe—noise from regions of star formation in the Milky Way, exotic galaxies, cosmic rays, and the big bang itself. These factors, more than any others, will limit the ability of a distant civilization to decode our way of life.

At current broadcast strengths from Earth, aliens using human technology would require a radio receiver 15 times the collecting area of the thousand-foot Arecibo radio telescope (the world's largest telescope) to detect a television station's carrier signal from a hundred light-years away. If they wanted to decode our programming information, and hence our culture, they would first need to compensate for the Doppler shifts caused by Earth's rotation on its axis and by its revolution around the Sun before they could lock onto a particular TV station. They would then need to have a detection capacity 10,000 times greater than that needed to detect the carrier. In radio-telescope terms, this amounts to a dish with a diameter about 400 times Arecibo's, or about seventy-five miles across.

Electromagnetic waves are happiest moving through the vacuum of space.

If technologically proficient aliens are indeed intercepting our signals (with a suitably large and sensitive telescope) and if they are managing to decode the modulations, then the basic features of our culture are surely befuddling the anthropologists among them. As they watch us becoming a radio-transmitting planet, their attention might first be flagged by early episodes of *The Howdy Doody Show*. Once they knew to listen, they could then audit episodes of *The Honeymooners* and *I Love Lucy* and learn how typical human males and females interact. They might then assess our intelligence from episodes of *Gomer Pyle* or *The Beverly Hillbillies* and then, perhaps, from *Hee Haw*. If the aliens didn't just give up at this point, and if they chose to wait a few more years, they would learn a little more about human interactions from Archie Bunker in *All in the Family*. After a few more years of study, their knowledge would be further enriched by the odd characters in *Seinfeld* and, of course, the prime-time cartoon *The Simpsons*. (They would be spared the wisdom of the hit show *Beavis and Butthead* because it existed only as a cable program on MTV.) These cherished sitcoms were among the most popular shows of our time, each sustaining cross-generational exposure in the form of reruns. Mixed in among our cherished sitcoms would be the extensive, decade-long news footage of bloodshed during the Vietnam War, as well as coverage of Nicaragua, Iraq, Bosnia, and other military hot spots around the planet.

After watching fifty years of television, the aliens could draw no other conclusion but that most humans are neurotic, death-hungry, dysfunctional idiots.

In this era of cable TV, even broadcast signals that might otherwise have escaped the atmosphere are now delivered via wires directly to our homes. If this trend continues, there may come a time when television is no longer a broadcast medium, causing our tube-watching aliens to wonder whether our species had gone extinct.

For better or for worse, however, TV signals are not the only ones from Earth that aliens might decode. Anytime we communicate with our astronauts or our space probes, all signals that do not hit the craft's receiver are lost in space forever, though the efficiency of such communication has been greatly improved by modern methods of signal compression. In the digital era, it's all about bytes per second. If you devised a clever algorithm that compressed your signal by a factor of ten, you could communicate ten times more efficiently, provided the person or machine on the receiving end of the signal knew how to undo your secret signal. Modern examples of compression utilities include those that enable fast modems, MP3 acoustic recordings, JPEG images, and MPEG movies for your computer.

The only radio signal that cannot be compressed is one that contains completely random information, making it indistinguishable from static. And the more you compress a signal, the more random it looks to someone who intercepts it. A perfectly compressed signal will, in fact, be indistinguishable from static to everyone except the person with the knowledge and resources to decompress it. What does all this mean? If a culture is sufficiently advanced and efficient, then evidence of its intelligence might just disappear completely from the highways of cosmic gossip.

Ever since the invention of electric light, human culture has also created a visible bubble. Our nighttime signature has slowly changed from tungsten incandescence to other sources of light, including neon from billboards and sodium from the widespread use of sodium vapor lamps for streetlights. But apart from the Morse code flashed by shuttered lamps from the decks of ships, we typically do not send visible light through the air to carry signals, so our visual bubble isn't interesting. It's also hopelessly lost in the visible-light glare of our Sun.

Rather than let aliens listen to our embarrassing TV shows, why not send them a signal of our own choosing, demonstrating how intelligent and peace-loving we are? This was first done in the form of engraved gold plaques affixed to the sides of four unmanned planetary probes: *Pioneer 10* and *11* and *Voyager 1* and *2*. All four plaques display pictograms conveying some basic science and our location in the Milky Way Galaxy. The two *Voyager* plaques also contain audio statements about the kindness of our species. Traveling at 50,000 miles per hour—a speed in excess of the solar system's escape velocity—these spacecraft are moving through interplanetary space at quite a clip. But compared

with the speed of light, they're ridiculously slow and won't get to the nearby stars for another 100,000 years. These probes represent our "spacecraft bubble." Don't wait up for them.

A better way to communicate is to send a high-intensity radio signal to a busy place in the galaxy, such as a star cluster. This was first done in 1974 when, as a test of the concept, the Arecibo telescope was used in reverse—to transmit rather than to receive. It sent the first radio-wave signals of our own choosing out to space. That message is now headed in the direction of the spectacular globular star cluster known as M13, among the stars tracing the constellation Hercules. The message contains in digital form some of what appeared on the *Pioneer* and *Voyager* plaques. In 25,000 years, when the signal arrives, those intelligent aliens living on M13's planets will know how smart we are.

But there are two problems: The M13 cluster has such a meager quantity of heavy elements (the raw materials of planets) that planets are probably rare among its stars. Furthermore, the globular cluster is so chock-full—it has about half a million tightly packed stars—that any planets it does have would have unstable orbits. A planet's gravitational allegiance to its host star would be challenged every time the star passes through the cluster's center.

In any case, the leading edge of our "on purpose" radio signals (which form directed radio cones instead of bubbles) is now twenty-seven light-years away. If intercepted, it may mend the image of us that the aliens would have deduced from our television shows. But this will happen only if they can somehow determine which signals come closer to what our cosmic reputation deserves to be.

Astrophysicist Neil deGrasse Tyson is the Frederick P. Rose Director of New York City's Hayden Planetarium and a visiting research scientist at Princeton University.

THIS LAND

Of Water and Wire Grass

A placid river meets a threatened prairie, and a botanist rejoices.

By Robert H. Mohlenbrock


DAVID ORTIZ

Cabbage palms

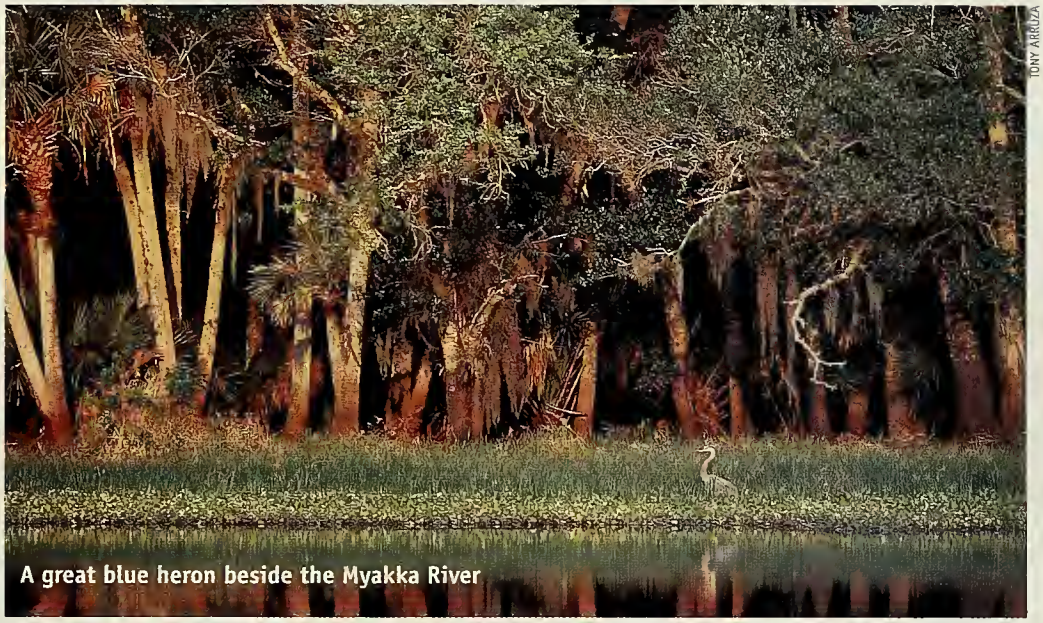
Rising near the former settlement of Myakka Head, the Myakka River of peninsular Florida flows roughly south toward the town of Port Charlotte, where it empties into the north end of Charlotte Harbor. Along the way, it rolls through the low flats of Myakka River State Park's 28,800-plus acres. One of Florida's largest, the park has precious reserves of disappearing native habitat, which are elsewhere being gobbled up by expanding cities.

The threats are not new. A century and a half ago dry prairie, covered with wire grass, carpeted much of the land from Lake Okeechobee southward, but settlers cleared the prairie and planted crops and a variety of exotic grasses. Little remains today of Florida's dry prairie; only three tracts cover more than 10,000 acres. The stretches surviving in Myakka River State Park—comprising about a third of the park's total area—are among the most extensive dry prairies remaining in southern Florida.

Crop plants and foreign grasses have not been the only causes of its disappearance. Before 1970, park management suppressed fires, thus allowing foreign shrubs (which burning would have eliminated) to invade the area. These aliens created too much shade for prairie plants that need full sunlight to survive. Now, however, controlled burns are helping dry prairies, which the Nature Conservancy designates as globally imperiled, to recover in the park.

One of the park's least threatened features is the lay of the land. A mountaineer would hardly call the topography spectacular: flat expanses, a lot of water, and a fair bit of

pockmarked Florida limestone define the local habitats. With the exception of the DeSoto Plain on the east side of the park, where a few sandy ridges climb to nearly forty-five feet above sea level, the land here sits about fifteen feet above sea level. In September, toward the end of the rainy season, water levels rise, often causing floods along the riverbanks and around the park's two lakes, the Upper and the Lower Myakka. For much of the year this water fills widespread marshes, which dry out only in late winter and spring. Visitors interested in wetland vegetation will have a field day in the habitats that border both lakes.



Where the river brings enough water to sustain trees, a variety of sylvan landscapes flourish. These include moist (mesic) flatwoods, scrubby flatwoods, forested wetlands, and oak-palm hammocks, which host tropical shrubs not found in temperate regions of the United States.

Whatever the fate of the areas surrounding Myakka River State Park, much of the land within is relatively pristine. However, considerable damage has been wrought along the park's main roads and wherever feral pigs roam, tearing up the soil and vegetation. On my family's first visit there, about thirty-five years ago, we encountered Rosie, a pig that seemed to relish visitors to her territory. Although everyone got a kick out of seeing Rosie root around and hearing her snort, she and her fellow swine were causing irreparable damage to parts of the park. Both the pigs and the roads have contributed to the proliferation of a number of weedy species.

Many park visitors, however, come for a look at the wildlife typical of the area rather than at the descendants of escaped farm animals. Roseate spoonbills sometimes visit the park and have been seen near the bridge over the Myakka River, and herons, egrets, and ibises flock there. Sandhill cranes are often present in the marshes near the Birdwalk, a boardwalk on the eastern shore of Upper Myakka Lake. Alligators abound.

The park is located about nine miles southeast of Sarasota. Nearly forty miles of trails make most of the habitats accessible to hikers, and the Visitor Center has exhibits on wildlife and their environments. Ranger-guided tours, fishing, biking, canoeing, and camping are also available.

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

For visitor information, contact:
Park Manager
Myakka River State Park
13207 State Road 72
Sarasota, FL 34241
(941) 361-6511
www.myakka.sarasota.fl.us

HABITATS

Dry prairie consists mainly of grass species, especially little bluestem, splitbeard bluestem, wire grass, bottlebrush threeawn, Indian grass, and


Wild coffee
KEN BRATE; PHOTO RESEARCHERS, INC.

slender beardgrass. Among the prairie wildflowers are blazing-star, pine lily, vanilla leaf, yellow-eyed grass, Saint-John's-wort, and silk grass (actually related to golden asters). Scattered shrubs include two kinds of low-growing blueberries and the dwarf live oak, which is less than a foot tall.

Invasive shrubs include saw palmetto, wax myrtle, gallberry, fetterbush, and staggerbush. Para grass, which cattle ranchers planted before the land became a park, has become well established, too.

Moist flatwoods occur, for the most part, as islands in the vast dry prairies, although larger, continuous moist flatwoods can be found in the southern part of the park. Where soils are well drained, longleaf pine dominates. Here at the southern end of its range, this pine is widely spaced, giving this habitat, with its more open understory, an appearance reminiscent of an urban park. In wetter soils, slash pine replaces most longleafs.

The presence of shrubs and ground plants in the flatwoods depends on the frequency of fire. One might find fetterbush, staggerbush, the two lowbush blueberries, dwarf live oak, and winged sumac—which also grows throughout the eastern United States. On the ground are dry-prairie plants, which include wire grass, little bluestem, and Florida paintbrush.

Summer wildflowers include meadow-beauty, marsh pink, wild pea, and round-leaved rattlebox (whose seeds, which are loose in the pod, rattle when the pods are shaken). In the autumn, net-veined aster and hollow-stemmed goldenrod add flashes of white and yellow, respectively.

Scrubby flatwoods standing on some of the well-drained sandy ridges at the park's highest elevations host three species of ten- to twenty-foot-tall oaks beneath a canopy of longleaf pine. Myrtle oak, turkey oak, and Chapman oak are often so densely spaced that few other plants can grow beneath them.

Oak-palm hammocks are home to the tall, beautiful cabbage palm, a hallmark of these fertile raised regions on the Myakka River floodplain. Large golden polypody ferns grow in the axils between the firm bases of the palm's leaf stalks and its trunk, which is also adorned with the shoestring fern. Trees well suited to the periodically inundated floodplain include live oak, laurel oak, American elm, and water locust. Tropical plants here include two species of wild coffee, pigeon berry or rouge-plant, prickly ash, marlberry, and colicwood. The wild coffee plants have strong-veined leaves like those of true coffee trees. Pigeon berry has a common relative—pokeweed, or pokeberry—found both in the temperate regions of the United States and in the park. The tropical prickly ash has a temperate equivalent called the toothache tree. Marlberry and colicwood belong to the strictly tropical family Myrsinaceae. Shrubs here are storax, beautyberry, and small-leaf viburnum. Frequent flooding and intense shade limit the herbaceous growth to a few species, although the hottentot fern is usually present.

Forested wetlands generally lie between oak-palm hammocks and the park's rivers and streams. Laurel oak, red maple, and swamp gum dominate. Swamp bay, loblolly bay, and swamp dogwood are plentiful; the Virginia chain fern and the swamp fern are almost always present. Jack-in-the-pulpit grows here and there.

Marshes, with maiden cane and wild millet grasses as two of the dominant species, also contain an assortment of sedges, rushes, and smartweeds. Two lovely blue-flowered lobelias are found here. Para grass has overrun some of the marshes.

Lakes and ponds have buttonbush, pickerel weed, bulltongue arrowhead, horned bladderwort, water milfoil, and water-shield growing in the water.


Little bluestem
RUTFORD AND SUSAN DAY; EARTH SCENES

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A Superlative Penguin

The least known, last studied, strangest penguin takes a scientist on a most uncomfortable journey.

Story and photographs by Lloyd Spencer Davis

One of five penguin species with distinctive headdresses, erect-crested penguins sport flamboyant golden "eyebrows." These birds nest on the Antipodes Islands and other remote bits of land in the remote South Pacific.

The Antipodes Islands are in the middle of nowhere. More precisely, they are three and a half days of vomiting southeast of my home in Dunedin, New Zealand. I am the sort of person who gets motion sickness on escalators, and as I lay strapped into my bunk on the *Breaksea Girl,* I asked myself over and over, "Why am I doing this?"

The answer was penguins. Of the world's sixteen species, all have been studied in detail except one. I was after the last, the erect-crested penguin. This penguin owes its anonymity more to its location than to any lack of cuteness or scientific interest. Erect-crested penguins breed on the Antipodes and on a similarly isolated group of islands nearly 200 miles to the north, the Bounty Islands. Both are home to little more than seabirds, seals, and shipwrecks.

Erect-crested penguins are, quite simply, the most striking of penguins. Upright parallel combs of blonde feathers sit incongruously above their eyes, like Marilyn Monroe's eyebrows on steroids, lending the penguins a feminine beauty. But what drew me most to these birds was that they were rumored to exhibit an extremely bizarre behavior. There had been only two prior attempts to study these penguins scientifically—one conducted about thirty years ago, late in the breeding season, and a more recent one lasting a mere five days, during the period of egg laying. The authors of this last study asserted, remarkably, that these penguins, which lay two eggs, deliberately eject the first egg from the nest soon after it is laid.


NEW ZEALAND
North Island
South Island
Chatham Islands
Snares Islands
Bounty Islands
Auckland Islands
Antipodes Islands
Campbell Island
0
500 Miles
JOE LEMONNIER

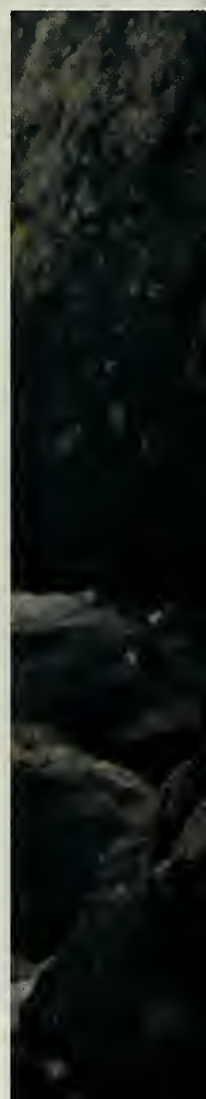
A colony of erect-crested penguins situated in the lee of a 600-foot-high cliff called Perpendicular Head, above. Right: A small greenish first egg is laid only to be neglected, while the big white second egg gets all the penguin parents' attention.

It was another twist to one of the stranger stories in the animal kingdom. The erect-crested penguin is one of five species known as crested penguins. All five lay two eggs but rear only one chick. Furthermore, in contrast to all other birds, they lay a second egg that is larger than the first, and it is the chick from the second egg that is most likely to survive. Biologists have long sought the answers to two questions: Why produce two eggs if only one chick can survive? Why is the second egg larger? I was, I told myself with each roll of the boat, in search of answers to such questions as much as I was after the "last" penguin.

Late during the fourth night I heard the anchor being let out, and mercifully, the wild pitching eased. I went up on deck to get my first glimpse of the place my two companions and I would be calling home for the next two months. In the morning gloom, I peered straight out at the 600-foot-high cliff aptly named Perpendicular Head. At its base, huge waves crashed relentlessly. I had never seen a place less likely to offer sanctuary, less likely to be called home.

Fortunately, not all the cliffs that surrounded the island were as high as this, but unfortunately, in the small cove that offered the only reasonable landing site, the waves were as fierce as those that pummeled Perpendicular Head. Despite the apparent proximity of the penguins, which I could make out as groups of dots at the base of the cliffs, at that instant they seemed very far away.

We had no alternative but to choose a much less desirable landing site, at Stella Bay. To call our approach a landing is really to glorify it; it was much more like a controlled crash. Wearing wet suits, Martin Renner (a former student of mine), Dave Houston (a biologist from New Zealand's Department of Conservation), and I jumped from a dinghy into the freezing water. A wave immediately slammed us into the rocks, cutting open my knee. We grasped kelp to anchor us, so as not to be taken out in the backwash, and clambered over its slimy fronds to the jumble of boulders that constituted the beach. We then had to wade back in and retrieve repeated dinghy-loads of gear that were tossed to us between one wave and the next: packs of clothes, boxes of food, drums of fuel, generators, scientific equipment, and wood for mending a hut constructed on the island about a century earlier to shelter castaways. By the time we had finished, we were all cut and bruised. After tossing us a box of sandwiches, the captain of the *Breaksea Girl* waved good-bye and steamed off to the northwest, leaving the three of us—the entire human population of the Antipodes Islands—in an enveloping drizzle.



Next we had to get our gear up a 70-foot-high cliff; carry it through waist-high tussock grass, which is just about impossible to walk through without falling over every few steps; and, finally, wade through a bog. It took us two full days of backbreaking work to lug all our supplies up to the hut.

While completing this task,

we were able to make our first casual observations of the penguins. Stella Bay is home to a colony of about 300 breeding pairs. At this stage, however, virtually all those present were single males, which typically arrive at the colony a week or more before the females. Why they should do so is not at all clear; it's not as if they have a swag of boxes and generators to hoist up to their nest sites before getting down to the business of courtship. The classic explanation is that they come early to secure a site before the females get there, but other penguins manage this without the need for the males to arrive so far ahead of the females. It is said that the males use this period to fight like gladiators for nest space, with the victors presumably getting the choicest sites. But we saw little evidence of this; there was hardly any fighting at all.

The rogue male fur seal grabbed a penguin and shook it so violently that its head came away from its body.

It would be wrong to assume from this that male erect-crested penguins are not territorial. They will defend their chosen site if they have to, even at their own peril. The biggest fight we observed was between a male fur seal and a male penguin. The fur seal lunged at the penguin on its nest, shook it vigorously, and tossed it about fifteen feet away. With a deep wound to its chest, the penguin made the mistake of returning to attack the big hairy intruder. This time the seal reached down, grabbed the penguin, and shook it so violently that its head came away from its body. To our surprise, the seal—supposedly a fish eater—set about devouring its foe. A quick check of the colony revealed five similar carcasses. This had been no crime of passion but the premeditated act of a serial killer. We envisaged this rogue seal slowly eating his way through the entire Stella Bay colony as the breeding season progressed. Fortunately for the penguins, two days later a group of elephant seals arrived, banishing the

Cry havoc: Like a bull in a china shop, a young elephant seal throws his weight around a nesting colony, causing alarm.

much smaller fur seals to the nether regions of the beach, and the carnage stopped.

We chose to study the penguins breeding in Anchorage Bay, in the lee of Perpendicular Head. Our main study colony was situated atop a rock stack, and from a knoll above it we were afforded an unimpeded view of all the nests—the perfect place to make observations. But first we had to measure and mark the penguins so that they could be recognized individually. Penguins really do all look alike.

Testosterone-driven behemoths, mature bull elephant seals battle savagely for dominance and mating opportunities. The penguins' courtship rituals are tame in comparison.

The birds proved to be remarkably unperturbed by our presence. We set up shop near the colony and began a processing operation. First I would catch a penguin, using a fishnet like those used to land trout. It was a relatively easy task to approach a penguin quietly and let the net fall gently over it, pulling the bird toward me as I did so. I had to be fairly deft with the next bit: grabbing the penguin around the ankles with my left hand and then quickly grasping the back of its neck with my right. These penguins have sturdier bills than most others. The top mandible ends in a vicious hook that is used to grasp fish but that is quite capable of ripping open your arm or any other part of your anatomy within striking distance. I would carry the penguin to Martin and Dave, who would weigh it; place a numbered stainless-steel band on the right flipper; and measure foot, flippers, bill, and crest. I then took a small blood sample from a flipper, and Mar-

Two giants reared up and faced each other, their noses quivering like jelly-filled socks, their mouths wide open.

tin photographed the crest. Finally, I painted both a letter and a number on its back in white enamel so the individual could be recognized from a distance. This was the key to our behavioral study, because it meant that we would never need to handle the penguin again. Each bird could be completely processed in this way in less than five minutes. In all, we marked 271 individuals before beginning to observe the colony continuously throughout the daylight hours.

The first thing we noticed was that not a lot happened. Even after all the females had arrived and most males were paired up, these guys were positively lethargic compared with other penguins I had studied. The most riveting thing to happen during the entire courtship period occurred on the shoreline in front of us.

A big bull elephant seal had been lying there sleeping when another cruised up like a submarine, inflating its huge proboscis and blowing bad breath in a deep growl. Our erstwhile beach companion raised its head and inflated its own nose. The seal in the water caterpillared up the stones, and the two giants faced each other, their bodies bent at right angles, their noses quivering like jelly-filled socks, their mouths wide open. For a while it seemed that they were going to do battle with their breath—the smell must have been lethal at such a point-blank range.

The intruder flung its head at our resident and bit the side of his body with its huge canine teeth. Our man was no slouch in this department either, and he struck back with a vicious blow to the intruder's back, tearing two parallel, foot-long cuts in its blubber. They continued to trade blows, thumping their chests together and biting each other's body. It seemed an evenly matched contest—until the resident received three unanswered strikes to his right side. Perceptibly, he changed. The intruder leaned more into him; he arched back further. Inch by inch, the intruder shuffled the resident out to sea. In the surf, our guy put up one last stand: bloody open mouths were held close together, and then a final lunge, a final bite, and it was all over.

Now *that* was competition. The mating game we were witnessing in the penguin colony was gentle and benign by comparison. I was used to observing the mating behavior of Adélie penguins in Antarctica, where the courtship period is a frenzy of fighting and fornicating. The erect-crested penguins, in contrast, just did not seem to have their hearts in it. They rarely fought, and whereas Adélie pairs copulate every three hours or so, erect-crested partners consummated their relationship only once every thirty hours. The blood samples we had taken revealed that the males had relatively low levels of testosterone, which might have explained their lack of both aggression and libido. But the females, too, were out of sorts. While female Adélie penguins will copulate within minutes of arriving at the colony and pairing up, female erect-crested penguins were likely to reject a male's initial advances. These penguins seemed to arrive at the colony only half ready to reproduce.

Four fur seals, relegated to the edges of Stella Bay by an incursion of elephant seals, take up vantage points on separate rock stacks.

We settled into a routine of observation stints to watch this protracted, if tame, courtship ritual for clues to the penguins' behavior. After the females had been at the colony for about two weeks, the first eggs were laid. While this signaled an exciting change for us, the penguins were much more blasé: to our surprise, neither mothers nor fathers were inclined to do much about it. Some attempted to incubate halfheartedly, but many simply stood beside the egg and ignored it. Another surprise was that the vast majority of the erect-crested penguins made absolutely no attempt to construct a nest. Other penguins collect stones or grasses to line their nests (ex-

cept king and emperor penguins, which incubate their single egg on their feet), but these birds were content simply to drop their eggs on bare ground or even on the tops of large rocks, often on steep slopes. Without a decent nest, any knock or bump was likely to send an egg rolling away.

In an experiment we conducted in a nearby colony, we created supernests, surrounding some rudimentary nests with large stones so that the first eggs could not roll away. But these survived no longer than those in control nests or in the main study colony. Although the first eggs remained within the vicinity of the nests, they were neglected: some rolled against the rocks, and many broke, probably after being trod on or pecked at.

While her mate is at sea feeding after a long fast, a female incubating her precious second egg is brutalized by a twosome that failed to breed successfully.

We found that about four of every ten first eggs are lost before the second is even laid, but the arrival of the second egg seals the fate of the first. I suspect this is largely for mechanical reasons. The first is not much bigger than a chicken's egg from a supermarket; the second is nearly twice that size. And while first eggs are pale green, second eggs are white. During the five or six days between the laying of the two eggs, the first one—if it survives that long—gets quite dirty as well. A female that has just laid her second egg responds more strongly to the stimulus of the large, bright white egg and will push it into her brood patch, a feather-free area of vascularized skin on her tummy. She will then attempt to draw in the small first egg, but it is like trying to sit on a football and a tennis ball at the same time—an awkward proposition exacerbated by the eggs' aspherical shape, which makes them prone to rolling unpredictably. Females seem to find it difficult to get comfortable. They stand up repeatedly, turning around in the nest and trying to adjust the eggs. Almost inevitably, the smaller of the eggs, being less snug against the female's body, will be dislodged and will roll away. At least another four of every ten first eggs are lost this way on the very day the second egg is laid. And the longest we observed any first egg to survive was six days after the second appeared. But this was not deliberate rejection, as claimed by earlier researchers. Females tested at a colony about half a mile away readily tried to retrieve and incubate a first egg that had rolled away if we replaced it within a few inches of the nest. The combination of parental neglect, differences in egg size, and poor nests seems to conspire against the prospects of the first eggs.

But simply knowing how first eggs are lost does not explain why the penguins persist in laying two eggs and why the second one gets all the attention. Some have suggested that crested penguins lay two eggs because the first is an insurance policy in case the second, larger one is lost. But for erect-crested penguins, at least, this scenario seems ludicrous: more than 80 percent of these so-called insurance policies are lost before or on the day the second egg is laid, and none of the remainder last for more than a week.

Often when one tries to decipher why animals do what they do, a good place to start is with food. Penguins can be divided into two broad groups: those that feed inshore and those that feed offshore. Crested penguins are of the latter kind, swimming just about as far as their flippers can take them to find food and rush it back to the chick. The costs of finding and transporting food over such distances make it unlikely that these penguins could ever bring back enough food to feed two offspring. So why bother laying two eggs? DNA evidence suggests that the ancestors of crested penguins laid two eggs. However, given the circumstances crested

penguins face, surely it would be to the females' advantage to reduce their clutch size by simply stopping their laying after the first egg.

For whatever reason, erect-crested penguins have a long courtship period of two weeks or more. That means that males and females are ashore, and unable to feed, for an extended period of time. While penguins are quite capable of dieting for phenomenally long periods, when it comes to producing the energy and nutrients needed for egg laying, fasting females must convert their reserves of fat and protein, since they can't use nutrients derived directly from food. The little work done on this suggests that erect-crested and other crested penguins depend more upon converting their reserves for manufacturing eggs than other penguins do.

Nests are rudimentary. These penguins are content to drop their eggs on bare ground or even on the tops of large rocks.

Conversion of fats and proteins for egg formation, like most of reproduction, is a hormone-mediated process. Hormones are like chemical postcards that the brain sends around the body to tell it what to do, and it seems crested penguins arrive at the colony with comparatively few of these missives getting delivered to their reproductive system. The synthesis of hormones can be influenced by external events, such as calls made by other penguins or the physical presence of eggs. Indeed, the social stimulation derived from the calling and courting of neighbors in the colony has been shown to hasten the development of eggs in crested penguins.

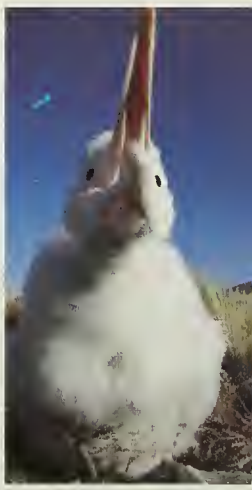
Our results seemed to confirm the benefits of breeding in a crowd. The size of both first and second eggs tended to increase as the colony filled up and became more boisterous. Very early breeding pairs tended to lose their first egg immediately, suggesting that the adults were not ready to care for it properly. The brood patches of both female and male crested penguins take several days to become fully vascularized and suitable for incubation; work by my students on yellow-eyed penguins, the crested penguins' closest living relatives, has shown that the presence of an egg stimulates the development of the brood patch.

As I sat atop the knoll, looking down at pairs of penguins hunkered down on and protecting second eggs, while all about lay the abandoned and broken shells of first eggs, it occurred to me that we were asking the wrong questions about their strange breeding behavior. The real question is not why they have two eggs but why they favor the second egg. Had the first egg been at least as likely to produce offspring as the second, it should have been a relatively simple matter to stop there and reduce the clutch to a single egg. But, of course, to take advantage of the better prospects of the second egg meant having a first one, too, no matter how superfluous that might be.

Could it be that the first is really just a primer for the birds' reproductive system? Had natural selection tilted the balance in favor of the second egg because females were then better able to mobilize their reserves to produce it, and both males and females were better prepared to care for it? If so, then crested penguins have little choice but to lay a first egg even if it has little prospect of producing a surviving offspring. All they can do is reduce its size and the energy they invest in it. To explain why crested penguins favor the second egg, then, is also to explain why they must persist with laying two eggs and why the first is smaller.

Crested penguins' breeding strategy has served them well enough for millions of years. But recently, in the face of environmental changes being wrought by humans all over the Southern Hemisphere, there are signals that all is not well in the crested penguin world: Major population crashes have been recorded for rockhopper penguins.

The islands are also a nursery for other Southern Hemisphere seabirds: A hungry wandering albatross chick sounds off, below, and a light-mantled sooty albatross sits tight on a nest, bottom.



Fiordland penguins are already among the world's rarest. Snares penguins seem to be holding their own but are limited to a single breeding area, making them extremely vulnerable to a local catastrophe. Only macaroni penguins (including a subspecies, royal penguins) appear to be in reasonable health. No truly accurate census of erect-crested penguins exists. However, just over a decade ago there were estimates of 110,000 pairs breeding on the Antipodes, while a few years later the population was estimated to be only half that.

My colleagues and I did not have the time or resources to census all the penguin colonies on the Antipodes, but we did survey and count breeding pairs in representative colonies on the main island. Antipodes Island is less than five miles in length and somewhat more than a mile across at its widest point. It is, however, a desperately hard island to traverse. Its cliffs forbid coastal access, leaving the interior—a tussock-covered plateau—as the only feasible route. The going was particularly tough and the results discouraging: our sampling indicated that the size of the various breeding colonies had fallen between 8 and 41 percent since the counts made three years earlier.

A female driven from her nest by attackers stands muddied and battered, below. Opposite page: A view of Perpendicular Head with an albatross aloft.

Albatrosses are distant cousins of penguins. On the cliffs above the colonies, we encountered nests of the light-mantled sooty albatross; on the plateau, huge wandering albatross chicks sat like white, fluffy lighthouses. Simple economics dictates that albatrosses, too, can never rear more than one of their gargantuan babies and so lay a single egg. However, the albatrosses' strategy has one major advantage over the penguins' when environmental changes affect the distribution and abundance of prey: Albatrosses can fly. Penguins, even offshore-feeding penguins, are much more constrained by how far they can go from the colony and are therefore much more susceptible to local perturbations in the ecosystem.

We do not know just where erect-crested penguins go to find fish, but because a chick must be fed frequently after it hatches, parents must be limited to foraging within a radius of less than seventy-five miles from the colony. The crested penguins' approach to chick provisioning also differs from other penguins'. Whereas in other species the parents take turns getting food for their newly hatched chicks, crested penguins strike a blow for female liberation, with the female being the sole breadwinner for the first two or three weeks, while the male stays at home to look after the chick.

During the period when the eggs are being incubated, erect-crested penguins are likely to travel

The poor females lay over the eggs, flippers spread-eagled, while the marauders meted out blows with flippers and beaks.

hundreds of miles on feeding trips that can last upwards of two weeks. The energy demands of fasting through courtship and producing eggs are high, and in other species of penguins, either the male or the female departs immediately for the feeding grounds after egg laying. Not crested penguins. Parents remain together at the nest for up to ten days or so after laying. This baffled us as we continued to monitor the study colony, because only one parent at a time can incubate the egg—and the male, especially, having already gone without food for about a month, must have been starving. Why should he continue to hang around?

When hunger did eventually force the males to leave (after they had lost some 40 percent of their original body weight), we witnessed yet another twist to this tale: neighboring males and unemployed birds—penguins that either had not bred or had failed to breed successfully—went around attacking the females left alone on their nests. The poor females lay prone over their second eggs, flippers spread-eagled, forehead tucked down onto the ground, eyes closed, while the marauders meted out a flurry of blows with their flippers and beaks. In several cases, a female was forced to abandon her nest, and the egg was broken. Could it be that their male partners had remained with them so long after egg laying to guard them?

As our time on the Antipodes drew to a close, I was beginning to see the erect-crested penguins not so much as the last penguins but as the oddball penguins. Instead of answers, we had found mostly more questions. To unravel their story further, it seemed unavoidable that we would need to return. And as I boarded the *Breaksea Girl* for the journey back to New Zealand, that thought alone was enough to make me ill immediately. □

Altruism in the Outback

For some tiny Australian insects, the willingness to die for one's home is a relative matter.

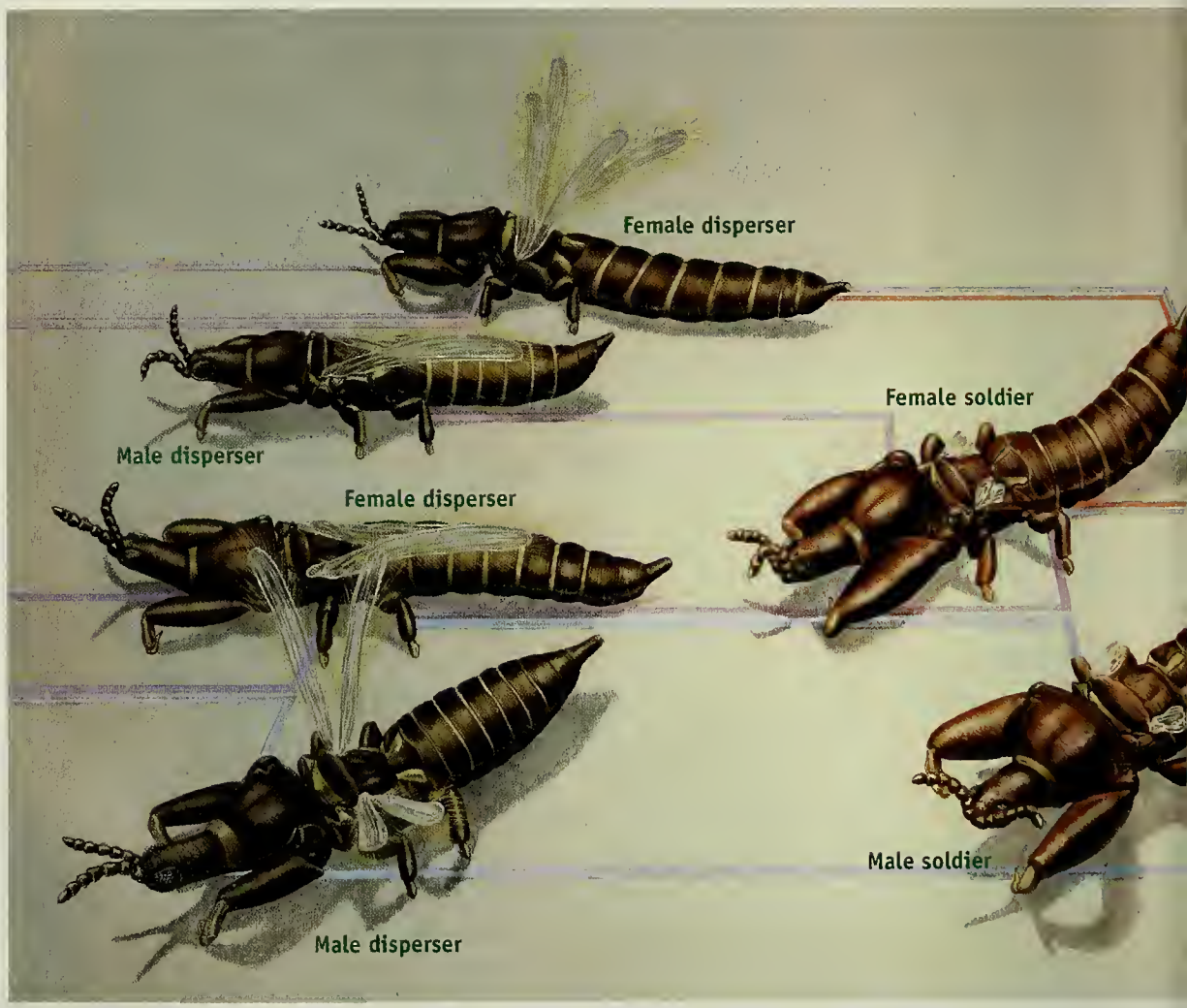
Story by Bernard J. Crespi
Illustrations by Utako Kikutani

In this cutaway of a gall, a female soldier (the large brown individual in the foreground, with the raised abdomen) grasps a black invader thrips. Also in the gall are other soldiers, eggs, larvae, and several of the soldier's long-winged siblings.

A whistle-blower risks her job by speaking out about threats to the environment, a soldier gives his life in defense of his homeland, a New York City firefighter dies in the collapse of the World Trade Center towers as he struggles to save the lives of strangers. Heroic actions like these fill us with deep emotion and pride in the altruistic possibilities of humanity. Yet we are not the only altruists. Termites rush to a breach in their nest and clamp their jaws onto the snout of a marauding anteater, almost guaranteeing their own death. A worker honeybee that stings us to defend her mother and other family members in the hive is doomed, for she cannot extract her barbed stinger from her victim without ripping out her innards in the process. Unlike the human examples, these animal altruists do not perhaps deserve to be called heroic, and they are acting only in defense of their own kin. But both pose a dilemma for evolutionary biology: how can self-sacrifice have evolved if the altruistic individuals so often bring about their own destruction?

For Charles Darwin, this paradox could be resolved by the idea that natural selection operates not only at the level of individuals but also at the level of families. He reckoned that just as farmers can retain a favored trait of domestic animals (such as well-marbled cattle flesh) by breeding relatives of the superior individual, natural selection can preserve and promote seemingly selfless traits of wild

animals—as long as genetic relatives benefit from the act. One hundred years after the *Origin of Species,* the late biologist W.D. Hamilton formalized Darwin's conjecture, developing what is now called kin selection theory. This theory predicts that, all else being equal, the degree of an individual's altruism toward family members should depend on how closely related they are genetically. Most of the time, the real world acts just as Hamilton predicted. But in many species, close relatives in social groups behave selfishly toward one another, and in some species in which groups are not made up of close relatives, altruistic actions are common. To understand how social behavior evolves, we must consider not only genetic relatedness but also aspects of habitat and ecology that may select for altruism.

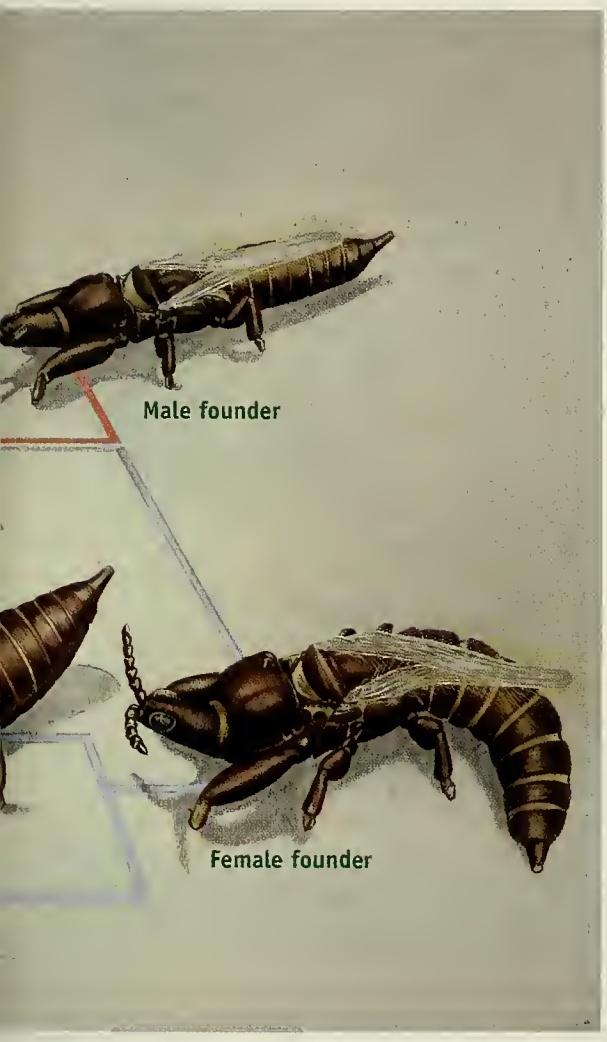


A pedigree shows that social thrips can produce tiny-winged soldiers, which never leave the gall in which they were born, as well as longer-winged individuals, which disperse to produce their own galls. Both dispersers and stay-at-home soldiers can reproduce.

With this goal in mind, I decided to study thrips, a group of punctuation-sized insects (in the order Thysanoptera) most commonly encountered as pests of houseplants. Among the approximately 5,000 described species are thrips ranging in size from 0.5-mm motes to 15-mm giants. All have sucking mouthparts with which they feed on green plant tissue, pollen, spores, or fungal mycelia. I chose to study these insects for two reasons. The first is that in thrips, as in the order Hymenoptera (ants, bees, and wasps), females develop from fertilized eggs and are diploid (having two sets of chromosomes, one from each parent), while males develop from unfertilized eggs and are haploid (having a single set, inherited from the mother). This haplodiploidy, as Hamilton was the first to point out, has important implications for the evolution of altruism. In haplodiploid species, females share 75 percent of their genes with their full sisters: 50 percent via their father (in these species, all the sperm produced by a male are genetically identical) and 25 percent via their mother (she has two alleles, or forms, for each gene, halving the probability of passing on any particular allele). Females can thus pass on their own

genes more effectively by helping to rear and protect full sisters (to which they are three-quarters identical) than by leaving home and producing their own offspring (only one-half identical).

My second reason for focusing on thrips had to do with ecology. About twenty species in the deserts of Australia occupy galls, plant tissues that have been modified by feeding insects to form a hollow cavity. Galls resemble nests, except that neither the mother nor her offspring have to leave to find food: they can get all they need by feeding on the gall's walls. Such all-in-one habitats are extremely valuable to their creators—perhaps worth dying for—and, I thought, would be likely to promote altruistic defensive behavior.



Thus, armed with collection records from the early Australian entomological pioneers, I drove far into the outback to an arid landscape dominated by vast stands of acacia shrubs inhabited by 3–4 mm thrips. Here, on various species of acacia, I found a diversity of gall forms: simple spheres, fat bean shapes, round and flat coin shapes, hemispheres like half a football, thin tubes, and spiky, purse-shaped pouches. The galls ranged in size from 5 mm wide and 15 mm long to 15 mm wide and 60 mm long. All were hollow, with walls 1–2 mm thick.

Over the next several years, I studied the life histories and behavior of the gall inhabitants. A single adult female induces a gall on a young leaf by sucking out the juicy, nourishing cell contents of the plant tissue. Through a mechanism not yet understood but perhaps involving a certain feeding pattern or the injection of chemicals by the thrips, the growing leaf develops a shallow depression at the feeding site. This deepens and closes over the female in a nascent gall. In some species, an adult male accompanies the female, mating with her and joining her in the developing gall, where they will both spend the rest of their lives. In other species, some females are virgins at the time of encasement.

Sometimes a female—presumably after failing to produce a gall on her own—tries to gain one by force. The resident and the challenger fight viciously, sometimes to the death, using forelegs armed with daggerlike "teeth." Rearing up like cobras, they lunge, grasp, and grapple with their forelegs, seeking to plunge their daggers into their opponent's most vulnerable spot: the thorax (the middle section of the insect's three-part body). Rival males may also engage in lethal fights for the privilege of being encased with a female. The stakes are high: females are fighting for their one chance at reproduction, shelter, and a lifetime supply of food; males are fighting for a mate (if they are successful, the only one they will ever have). In some dense populations of thrips, most galls eventually contain not only living, breeding thrips but also the shriveled dead bodies of vanquished rivals.

Female thrips can pass on their own genes more effectively by helping to rear their sisters than by producing their own offspring.

Once all the fighting is over and the gall is more or less closed (though still growing), the female begins to lay eggs on the gall's inner surface. Brood sizes range from about a hundred to more than a thousand, depending on the species. The eggs hatch after about two weeks, and the young larvae begin to feed on the walls of the gall. Juvenile thrips molt through two stages, or instars, before pupat-

ing. In some species, the second-instar larvae leave the gall through very small holes or cracks (located where the gall closed over the foundress) and apparently drop to the ground to pupate in deep cracks in the soil. In other species, the entire brood matures within the gall, dispersing after the gall dries up, drops from the plant, and opens.

But some young thrips follow a very different path. In six Australian species, some or all of the first individuals to develop in a brood never disperse. Instead they remain within the gall and defend it, often to the death, against invaders of other species (including other thrips, caterpillars, and fly and hymenopteran larvae). These "soldier" thrips, which may be male or female, have tiny, useless wings but greatly enlarged forelegs, armed with even bigger daggers than those of their pugnacious, winged mothers. When an incompletely sealed gall is breached—most commonly by a single, specialized, gall-usurping invader thrips—the soldiers rush headlong into the breach and attempt to grab the invader and pierce its cuticle. The invader (also heavily armed and well armored) generally manages to kill one or more of the defenders; sometimes it succeeds in killing them all. When that happens, the usurper proceeds systematically to execute the now defenseless larvae before it deposits its own eggs in the gall. Sometimes, however, the soldiers subdue the invader, enabling their siblings to complete their development in peace until they are ready to fly off and start galls of their own.

Both virginity and incest may have contributed to the evolution of soldiering and altruistic behavior in thrips.

The discovery of altruistic soldiers fits nicely with Hamilton's theory of kin selection, but it raises many more questions than it answers. For the past eight years, working with colleagues in Britain, Canada, and Australia, I have been employing an arsenal of methods to determine how and why soldiers evolved in Australian gall-breeding species. We have sequenced a portion of the mitochondrial DNA in all species of Australian gall thrips. Using the variation in the DNA sequences to construct an evolutionary tree for the group, we inferred that soldiers evolved only once in these thrips, early in their diversification. Other molecular studies—employing molecular markers known as microsatellites to estimate levels of genetic relatedness—enabled us to determine that in all six species that have soldiers, levels of genetic relatedness are sometimes exceptionally high. (Relatedness is partly a function of how often the foundress mates and how closely related she is to her mate or mates.) Thus, we can infer that relatedness was probably high when soldier thrips first evolved, which supports Hamilton's theory that genetic relatedness favors the evolution of altruistic behavior.

Our microsatellite data also indicate that five of the six species with soldiers are incestuous, with brothers and sisters mating in the gall. Soldiers mate with soldiers, and winged males mate with winged females before they disperse. This incest results in offspring that are genetically even closer. Another consequence is that the males in these species can be as highly related to gallmates as females are, which helps explain why there are soldiers of both sexes.

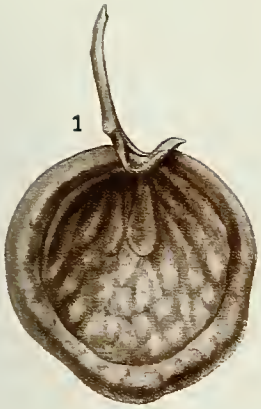
Many soldiers, of course, die in battle before having a chance to reproduce, but we found that, especially in the older species, female soldiers that are not killed defending their gall can lay considerable numbers of eggs. The ability of soldiers to reproduce may have eliminated one impediment to the evolution of altruism, because protosoldiers would not have had to give up on personal reproduction while developing specializations for gall defense. And haplodiploidy means that even unmated female soldiers can lay viable eggs (all of which will produce sons). Thus, both virginity and incest may have contributed to the origin of soldiering.

Comparing thrips with other altruistic creatures reveals a number of interesting parallels. Researchers studying bees and wasps often emphasize not only haplodiploid sex determination but also the importance of defense against natural enemies, such as ants and birds, in the evolution of sociality. And many species of gall-inhabiting aphids also have soldiers. Finally, thrips share features with termites—generally considered to be near the pinnacle of insect social life. In many termite species, for example, soldier castes are highly developed, and colony members never leave their nests of dead wood because, like gall aphids and gall thrips, they are able to feed off the walls.

A wide taxonomic gulf will forever separate thrips, aphids, and termites from their human observers. Nevertheless, a shared appreciation of the importance of a home—vital for protecting, nourishing, and raising a family—reminds us of our connection to even such tiny, distant relatives as these insects. □

Made-to-Order Galls

Australian thrips not only induce their acacia hosts to develop galls, they also seem to determine the galls' size and shape. Different species of thrips occupying the same kind of acacia, in fact, produce tremendously different galls (compare 9 and 10, for example). Closely related thrips species tend to make similar galls, regardless of the acacia species on which they find themselves (4 and 9, and 13 and 15, are two such pairs). Species that produce large broods tend to make relatively large, rounded galls, capable of housing up to a thousand thrips (3 and 17, for instance). Species that produce fewer young, as well as species with soldiers, tend to have smaller, more elongate galls. Examples of the latter are 10, 11, 13, and 15.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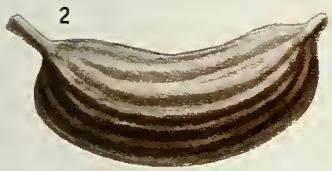
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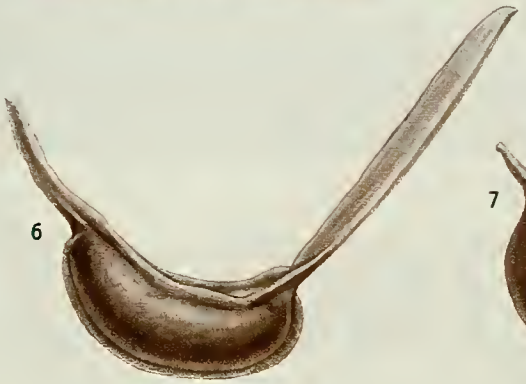
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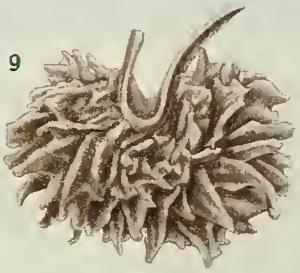
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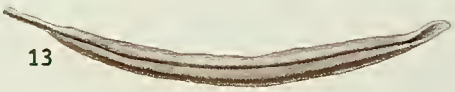
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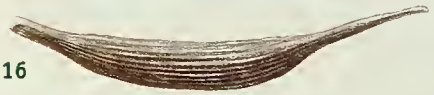
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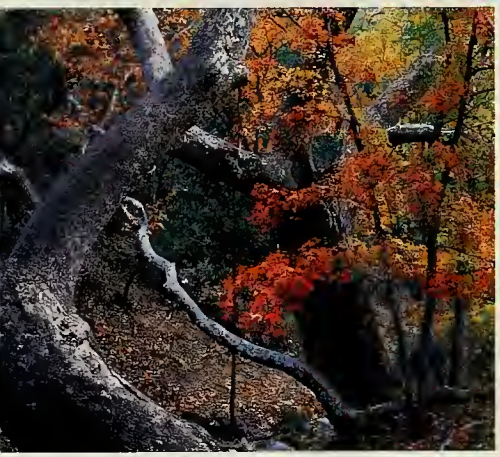
Photographs by Jack Dykinga
Story by Wade C. Sherbrooke



Amid the deserts of Arizona, maples blaze a trail.

Big-tooth maples splash their colors among Arizona sycamores in Ramsey Canyon, above. Agaves in Miller Canyon, right, grow cheek by jowl with the maples, which—unlike succulents—need plenty of moisture to survive.

In the Chiricahua Mountains of southeastern Arizona, I hike through narrow canyons in search of the crimson glory that maple trees bring to autumn. A strange quest, perhaps, here where the Chihuahuan and Sonoran Deserts meet? Only to the uninitiated. The Chiricahuas, Huachucas, and other "sky islands" are ecological isolates in a sea of desert; the clouds that hit these mountains drop up to forty inches of rain a year on them, whereas the surrounding desert receives only about twelve inches. Water trickling down the slopes into canyons supports the southernmost populations of the Rocky Mountain big-tooth maple, also called the western sugar maple.

I know I won't find maples in every canyon, so I choose carefully. Entering Cave Creek Canyon at the spot where its watercourse emerges, I start up the South Fork. Thanks to the summer rains, the beds and sides of the sky islands' watered canyons are home to many plants that could never survive outside in the desert valleys. The Cave Creek watercourse—so weak in the first days of fall that frequently it runs only below the surface—gives sustenance to sycamores, cottonwoods, and Arizona cypresses. I spot a few big-tooth maples as well; I'm

Islands of A

utumn

Crimson-leaved maple branches along a stream in Cave Creek Canyon, right. Below: Maples in Miller Canyon grow close to yuccas. Opposite page: In Cave Creek Canyon, ladybird beetles congregate on an apache pine.

on the right track. Glancing up, I also note a healthy covering of pine, fir, and spruce trees at the summit—a sign that enough rain falls throughout the year to nourish them.

As I move upstream, often hopping over boulders, the canyon narrows. Finally I am in the midst of a big-tooth maple forest. The roots of these water-loving trees have tapped whatever moist soil has accumulated on the bottom of this cut; a rich maple canopy blazes up along the canyon.

Onward I climb, upward, the workload telling on my body. Taking a breather, I observe at one point a quite different world just a few feet away from my red-leaved fastness: rock-rich, water-poor slopes. But even such eroded volcanic remnants are life-giving enough for some plants, and I see a healthy scattering of succulents—yuccas, agaves, sotols, prickly pears—as well as evergreen oak, small-leaved trees adapted to dry conditions.

Big-tooth maples need a more forgiving environment. Enough of them have found it here to blaze small trails of autumn color on the desert slopes of the sky islands. □

A Lost Menagerie

During the past 500 years, countless animal species have gone extinct, some to loud lamentation, others to little notice. Now the art and words of two men have brought to life dozens of the lost creatures, including this sampling—three mammals, a bird, and a reptile—that once lived in Australia and New Zealand.

Story by Tim Flannery ~ Paintings by Peter Schouten

It may seem a soul-destroying task to set about documenting, in words and pictures, the creatures that have perished in the past 500 years, but this project is one of the most exciting I have ever been involved in. That's because it has allowed me to glimpse, in my imagination at least, a tiny flicker of the wonder of this lost world. Over the four years of the project, my collaborator, Peter Schouten, created 103 life-size paintings. Each was a voyage of discovery: even photographs don't exist for most species we studied, and the few that are available are reproduced in black-and-white.

Because it was essential that Peter's images be as accurate as possible, we both made numerous trips to museums. There we would photograph, sketch, and take notes on the faded and distorted specimens. These records, along with other people's written accounts and sketches drawn from life, constituted our reference materials. On occasion, I would find myself descending into the vault of a European museum where rare and valuable specimens are housed. There a curator would unlock a cabinet and open a drawer to reveal, for instance, a stuffed bird skin that the great Captain James Cook himself had seen, the sole example of an entire species. On one memorable occasion at the University of Oxford, the famous head of a dodo (the only one left) was placed reverently in my hands; on another, I peered through an alcohol-filled jar at the sad remnants of a long-extinct fruit bat. To see or touch such specimens seemed to put me in direct contact with a rich, now vanished world.

Greater Short-Tailed Bat *(Mystacina robusta)*

Last record: April 1965. Distribution: prehistorically, North and South Islands, New Zealand; historically, small islands off Stewart Island, New Zealand.

New Zealand was home to only three land mammals before the arrival of the Maori, and all were bats. Two species belonged to a unique New Zealand bat family, of which the greater short-tailed bat was the larger member.

Short-tailed bats are the only bats as adept at scrambling along the ground as they are at flying. They have pouches on the sides of their bodies for their wings to fold into. With their wings hidden away, they can race through burrows or scrub with the alacrity of shrews and mice.

In historic times, greater short-tailed bats were known only from one dubious South Island record and from colonies on several small islands off Stewart Island in the far south. There the bats used the burrows of seabirds as roosts. They flew slowly, never rising more than ten feet off the ground. They fed on nectar from flowering plants and were probably also partly carnivorous, hunting nestlings as well as scavenging fat and meat from muttonbirds caught and left out to dry overnight.

The very last refuges of these bats were on Solomon and Big South Cape Islands, which remained rat-free up to a remarkably late date. The bats thrived there as recently as 1962 or 1963, until the arrival of black rats aboard fishing vessels.

Pig-Footed Bandicoot *(Chaeropus ecaudatus)*

Last record: 1901. Distribution: inland Australia.

The pig-footed bandicoot was one of the very strangest of marsupials. The size of a kitten, it had long, slender limbs, with each hind foot bearing a single, elongated toe like a tiny horse's hoof, and each forefoot bearing two digits that resembled miniature cloven hoofs. It had a peculiar gait, being likened by a nineteenth-century naturalist to "a broken-down hack in a canter, apparently dragging the hindquarters after it."

Pig-footed bandicoots were never common, although the species was rather widespread. They appear to have been principally vegetarian, taking grass seeds in the wild, although in captivity they ate lettuce, bulbs, and grasshoppers. By day they sheltered in a grass nest, from which they emerged in the evening to feed.

Gerard Krefft, a member of the 1856–57 Blandowski expedition to the junction of the Murray and Darling Rivers, brought along a drawing of a specimen to show Aborigines that this was the animal he was eager to procure. Unfortunately, the only drawing he could obtain was of a specimen that had lost its tail, and his Aboriginal helpers brought him any number of common bandicoots with their tails removed. Eventually they arrived with two living pig-footed bandicoots. Krefft, who was on short rations, studied them for some time before he killed one and ate it. He recorded that "they are very good eating, and I am sorry to say that my appetite more than once overruled my love for science."

The Australian nation came into existence through federation in 1901, the same year that the last pig-footed bandicoot specimen was secured. Interviews with Aborigines living in remote regions, however, suggest that the species survived long after this, finally becoming extinct in the western desert as late as the 1950s. Just which factors—the changed fire regime; the introduction of foxes, cattle, sheep, and cats—were responsible for the extinction of this strange creature remains unclear.

Kawekaweau *(Hoplodactylus delcourti)*

Last record: 1870. Distribution: North Island, New Zealand.

Maori legend has it that a giant lizard, known as the kawekaweau, once inhabited New Zealand, the land that the Maori call Aotearoa. The last person to catch one was a chief of the Urewera tribe, who found it living under the loose bark of a dead tree in central North Island in 1870. He described it as being brownish, with red stripes, and as thick as a man's wrist. But no specimen was kept, and the kawekaweau came to be considered by biologists as a legendary or fantastical creature. Then, in 1986, researchers published an article announcing the "discovery" of an ancient stuffed lizard skin, mounted on a plank, that had lain unrecognized in a museum in Marseille, France, for well over a century. No one knew how it came to be there or even when it was collected, for it had no label. The scientists who examined it were amazed: it was by far the largest gecko they had ever seen, being half again as long as the largest previously known species. They eventually surmised that it was a specimen of the kawekaweau, the only one to have survived to give credence to the old Maori tales.

The kawekaweau, which has not been recorded as a living creature for 131 years, must have been an important predator. Since large geckos often consume a broad range of foods, it may have also eaten plants and even served as a pollinator in New Zealand's ecosystem. Unfortunately, it vanished before anything could be learned of its biology. The causes of its extinction remain unclear, but it is likely that rats, weasels, and cats played a role in its demise.

Slender Bush Wren *(Xenicus longipes)*

Last record: 1972. Distribution: North, South, and Stewart Islands and nearby islands, New Zealand.

The slender bush wren was a small bird with poor powers of flight. Although it belonged to a group that comprises the most ancient of songbirds, it was largely silent, emitting only faint rasping sounds as it foraged for insects with its long, slender bill. It built its nests in cavities among tree roots or in fallen logs or clumps of ferns. Both parents incubated the eggs. In habits and ecology, slender bush wrens were more like mice than like birds, and in New Zealand, which lacked mammals except for a few bats, they may have evolved to fill the ecological niche occupied elsewhere by small rodents.

The slender bush wren was rarely seen on North Island at the time of European contact; the last specimens were collected there in about 1850. The birds persisted on South Island until about 1968. Their final stronghold, however, was Big South Cape Island, but when rats reached there in 1962, the wrens rapidly declined.

Broad-Faced Potoroo *(Potorous platyops)*

Last record: about 1875. Distribution: southwestern Australia.

The tiny broad-faced potoroo survived for just thirty-six years after the establishment of Western Australia's Swan River colony, where the city of Perth now stands. Almost nothing is known of its biology. The collector John Gilbert recorded all of our firsthand knowledge of the marsupial (one of a group known as rat kangaroos) in one sentence: "All I could glean of its habits was that it was killed in a thicket surrounding one of the salt lagoons in the interior." It seems to have inhabited a scrubby belt of vegetation between the forests of the southwest and the arid interior.

Just twelve specimens were ever collected. The Australian Museum in Sydney was the only museum in the world to preserve (in spirits) any complete bodies, but in 1913 the museum decided to turn those specimens (which it had held since the 1860s) into study skins. The bodies—with all their potential to inform us about the animal's diet, parasites, organ adaptations, and DNA—were simply thrown out.

It seems likely that either the cessation of Aboriginal burning—done to attract game species and clear the land—or the arrival of cats caused the extinction of the broad-faced potoroo. This creature vanished long before foxes became common in Western Australia or land clearing there by European settlers became widespread. □

Bronze trees and masks evoke the spirit worlds of a lost civilization in China.

The Enigmatic Art *of* Sanxingdui

By Jay Xu

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Images such as the head on the opposite page and the life-size figure above have no parallels elsewhere in China.

The Red Basin, which falls mostly within southwestern China's Sichuan Province, is an isolated land of plenty. Since antiquity, its fertile soil, mild weather, and abundant water from tributaries of the Yangtze River have made the area rich in vegetation and game and hospitable to human settlement. Yet the basin is surrounded by mountains and high plateaus. "The road to Shu is harder than the road ascending to the blue sky," the eighth-century A.D. poet Li Bo famously said, describing the journey there from the north (Shu was then the common name for the region, now known in China as the Sichuan Pendi). Even today, despite highways and railroads, land travel to and from the basin is not always easy.

When I first visited the Red Basin in 1988—as a student of early China and a young assistant curator then working in the Shanghai Museum—I, too, traveled there from the north. The train ride was sometimes excruciatingly slow; on occasion the train all but ground to a halt as it climbed up a mountain. In places the tracks were laid on narrow paths hewn along precipitous slopes that overlooked river torrents below. Tunnel often followed upon tunnel. In earlier times, the challenging topography was a barrier to contact with other regions, especially the middle Yellow River Valley, 600 miles to the northeast, home to China's first two historic dynasties, the Shang (ca. 1500–1050 B.C.) and the Zhou (ca. 1050–221 B.C.). The period of the Shang and Zhou dynasties largely defines what archaeologists call the Chinese Bronze Age (ca. 2000–300 B.C.). These two powerful societies cultivated such crops as millet, rice, and wheat; established large cities; practiced warfare; and manufactured jade implements and bronze vessels used in making offerings to ancestors. The Shang also developed writing, which the Zhou refined and made more extensive use of, but the records they left behind barely mention Sichuan. Among the surviving examples are inscriptions incised on "oracle bones" (the shoulder blades of cattle and the bottom shells of turtles, used in divination) and dedications to deceased ancestors, impressed on bronze vessels.

The early people of the Red Basin left no written record of their own, further shrouding the region in obscurity and creating a common perception that it was a cultural backwater for most of the Bronze Age. In the last century, however, mainly the past few decades, this impression has gradually been changing, thanks mainly to findings at an archaeological site called Sanxingdui. Located in the

Adapted from *Ancient Sichuan: Treasures From a Lost Civilization*, edited by Robert Bagley, published by the Seattle Art Museum in association with Princeton University Press.

Sanxingdui has yielded more than one ton of bronze, gold, jade, and stone.

Chengdu Plain on the western edge of the Red Basin, the site is surrounded by lush but rather nondescript farmland, far from the bustle of modern life. On the April day when I first saw the site, the yellow rape flowers were in full bloom, and the place made me feel vibrant and sleepy at the same time. Little did I know that the striking objects that had been unearthed there would become a major focus of my professional life.

Hints that the locale was important in the past had surfaced as early as 1929, when a local farmer found a pit containing several hundred jade and stone artifacts. An archaeological field survey in 1951 revealed that such ancient cultural remains were distributed over a considerable area. Between 1980 and 1985, researchers unearthed jade implements, a pottery kiln, and extensive house foundations, indicating that a settlement of substantial size existed there from about 2500 to 1000 B.C.

SICHUAN PROVINCIAL INSTITUTE OF ARCHAEOLOGY

The 1,300 artifacts in Sanxingdui's Pit 2, above, were placed in distinct layers and topped by 67 elephant tusks. Right: The ancient settlement was located in a fertile, well-watered area.

Beginning in 1985, archaeologists uncovered remnants of what seemed to be the boundaries of a city—pounded earthen walls from 20 to 30 feet high, 130 feet thick at the base, and narrowing to 60 feet at the top. These had been constructed starting in about 2000 B.C. Evidently the city once had at least three walls—on the east, south, and west sides—surrounding an area of at least one and a half square miles, huge for the time. Some archaeologists think that a wall once also existed on the north side but that it was washed away after the settlement was abandoned.

While such formidable walls may suggest a defensive purpose, functional weapons are conspicuously absent at Sanxingdui (by contrast, the weapons found at the Bronze Age sites in northern China testify to the Shang and Zhou concern with military defense). With their gently sloping sides, Sanxingdui's walls may instead have been dikes for flood control. Among the cultural deposits found near the walls (which contained pottery fragments and other broken artifacts) are layers of blackish silt: possible deposits from floods.

Investigations both inside and outside the city walls have revealed the foundations of a number of buildings. The largest—a 2,000-square-foot complex with several rooms—might have served as a gathering place and ritual center. Elsewhere the remains of workshops and kilns suggest a large population requiring the services of specialized artisans. At its height, in about 1200 B.C., the entire settlement covered almost five square miles.

What has primarily thrust this civilization into the consciousness of historians of China, however, is the excavation of two pits containing more than one ton of wealth in the form of elephant tusks and artifacts of bronze, gold, jade, and stone. They were accidentally discovered by workers from a local brickyard who were digging clay to make bricks. These pits lie inside the city's south wall—although when they were excavated, in the summer of 1986, the layout of the settlement was still far from clear. During my visits to the site beginning in 1988 and through discussions with the archaeologists working there and other experts, I collected information about these finds. But their implications did not become completely apparent until 1998, with the publication of the formal ex-

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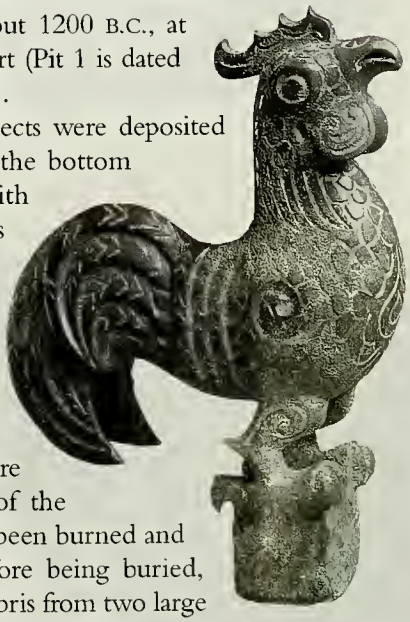
cavation report by the team led by Chen De'an, Sanxingdui field station director of the Sichuan Provincial Institute of Archaeology.

The bronze artifacts include fifty or so life-size heads, a life-size standing figure, and more than twenty masks. A few of these are partly covered in gold, a material rarely used elsewhere in China at this time. The countenances range from human to somewhat animal-like to simply weird; most are done in a unique style, with sharply cut, striking features and exaggerated eyes. Equally unprecedented finds are several bronze trees (distinct from money trees, artifacts found in second-century A.D. tombs in Sichuan and other provinces of western China), the tallest one ornamented with birds, flowers, pendants, and a dragon. The excavations have also yielded a small number of conventional bronze vessels that resemble those from other regions and enable archaeologists to determine that both pits were created in about 1200 B.C., at most several decades apart (Pit 1 is dated slightly earlier than Pit 2).

These and other objects were deposited in layers. For example, the bottom of Pit 2 was lined with pieces of the bronze trees and with small bronzes, cowrie shells, daggers, and other implements of jade and stone. The middle layer consisted of the larger bronzes, while elephant tusks were strewn on top. Much of the material in the pits had been burned and deliberately broken before being buried, suggesting that it was debris from two large

More than thirteen feet high, an ornamented bronze tree, left, was found in pieces and later partially restored. Below: The rooster from Pit 2 is the most realistic image found at the site.



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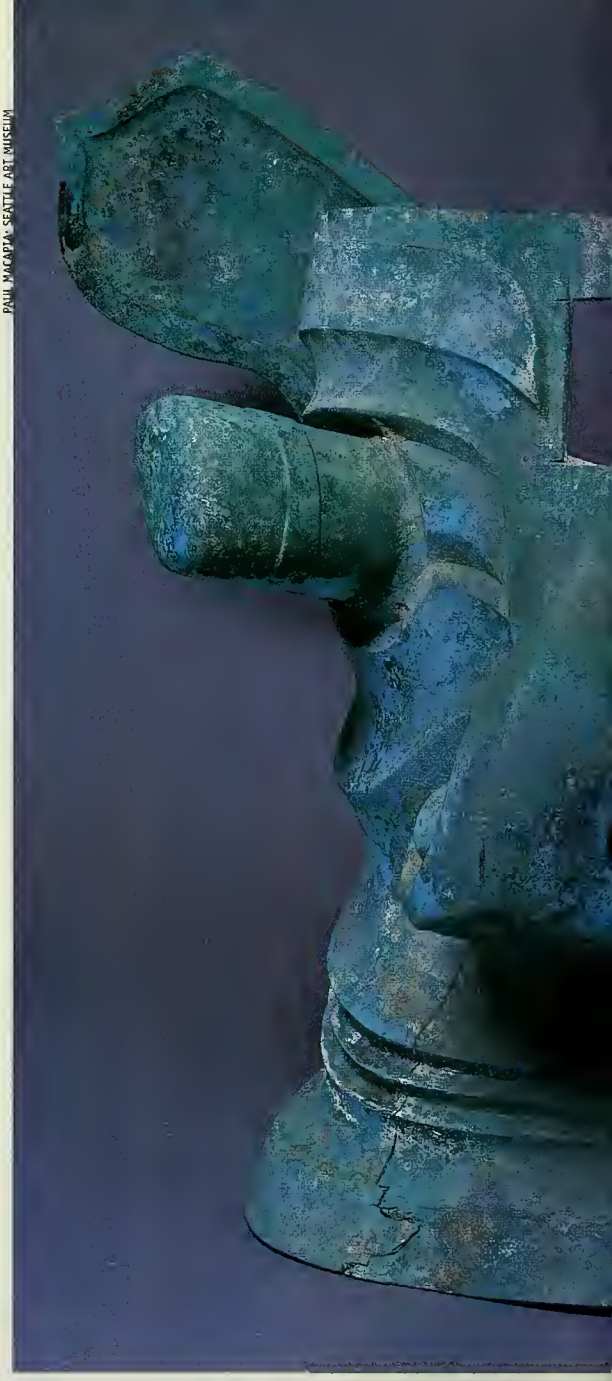
The ancient city was one of China's largest.



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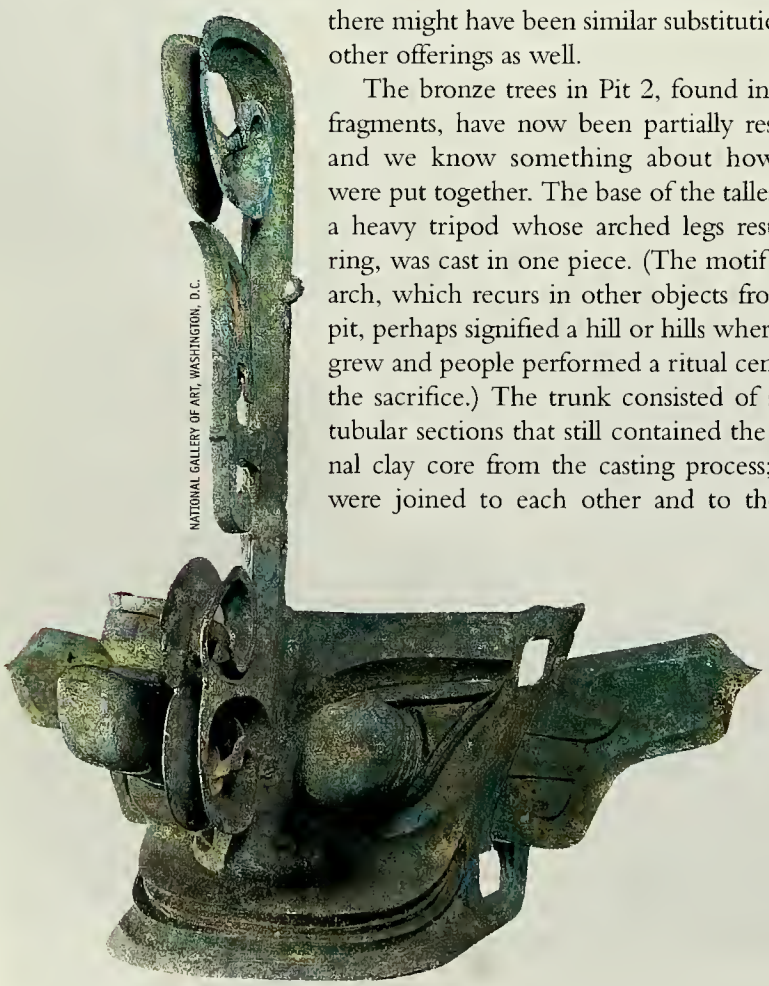
Below: A bronze mask's telescopic pupils and floppy ears—and the fantastic spiraling excrescence above its nose—suggest a creature with acute sensory powers.

sacrifices. Perhaps burning and breaking were ways of "killing" symbolic objects—items made specifically for ceremonial rituals or for sacrifices—so that they could succeed in making the passage from this world to some supernatural realm (the bronze daggers, for instance, are too flimsy to have been of practical use).

Pit 1, the earlier pit, contained many animal bones (mostly pig, sheep, cattle, and buffalo) as well as wood ash and bamboo ash. Pit 2 held more conspicuous testaments to wealth, such as bronze heads, masks, human figures, trees, birds, and even models of what might be temples or altars. Differences between the contents of the two pits might reflect an increase in the city's wealth, the growth of its bronze and jade industries, or changes in the ritual procedures themselves. Possibly the bronze trees sacrificed in the later pit were a replacement for actual trees sacrificed in the earlier one, and there might have been similar substitutions for other offerings as well.

The bronze trees in Pit 2, found in many fragments, have now been partially restored, and we know something about how they were put together. The base of the tallest tree, a heavy tripod whose arched legs rest on a ring, was cast in one piece. (The motif of the arch, which recurs in other objects from this pit, perhaps signified a hill or hills where trees grew and people performed a ritual central to the sacrifice.) The trunk consisted of several tubular sections that still contained the original clay core from the casting process; these were joined to each other and to the base with separate pours of metal. The same technique was used to assemble nine curving, bifurcated branches, each with a dozen or so separate components. The tips of the branches end in small sprigs that suggest leaves and fruits, and on these perch small birds. A dragon figure occupies one side of the tree, its forequarters resting on the base and its undulating, ropelike body (part of which is now missing) extending upward.



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Sanxingdui's human figures and masks constitute the earliest significant collection of such imagery anywhere in China. The life-size figure, which stands on a three-foot-high pedestal, has thick arms that end in oversize hands evidently de-

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Left: Among the outsize artifacts in Pit 2 was a bronze mask nearly four feet wide. A marble *ge* blade, above, was ornamented at its tip with the incised figure of a bird.

signed to hold some object (now missing), such as an elephant tusk. The details of sumptuous clothing, including a feathered headdress, are carefully modeled, while the feet are depicted as bare. The facial features, now cloaked in the same green patina as the rest of the figure, may have originally been enlivened by colors: black for the eyebrows, pupils, and hair; red for the lips, nostrils, and ear hollows. Traces of such highlights survive on other heads and smaller figures from this site.

Most of the representations of human heads are made on the same scale as this complete figure and are given similar facial features; their necks end in a correspondingly V-shaped neckline. Possibly the heads were originally mounted on posts serving as rudimentary "bodies," which may have been concealed by rough approximations of garments or even dressed in real silk robes. A gathering of such figures, with their painted faces and their feathered headdresses, would have been an impressive sight.

Traces of coloring survive on some of the bronze masks as well. These come in various sizes, and the holes in their sides suggest that they could have been attached to posts or buildings. Many appear human, but the largest three, ranging from thirty to fifty-four inches wide, have animal-like ears and monstrously protruding pupils.

In nearby Jinsha, archaeologists have recently found new deposits.

Whatever the exact nature of the offering ritual, it was quite different from those performed during the same period at Anyang, the capital of the Shang rulers. There we find pits containing a number of human skeletons interred together, with few or no burial goods (oracle-bone inscriptions found elsewhere in Anyang mention sacrifices of several hundred human victims). The skulls are often either missing or found buried without bodies, indicating beheading; in some cases there are signs of struggle, suggesting that some victims were buried alive. Since oracle-bone inscriptions from Anyang often mention battles with enemy states and the taking of prisoners who were then sacrificed, archaeologists conclude that these skeletons are probably those of war captives. The paucity of grave goods suggests that whoever the victims were, they were people of low social standing.

Large animals were also sacrificed at Anyang, but the offerings there seldom included bronzes or jades—artifacts that were abundant in Sanxingdui. The only known sculptural images of men and gods are a few tiny jade figurines, while the bronzes are mostly elaborately ornamented ritual vessels. Considering the practice of human sacrifice at Anyang, one can speculate that the bronze heads at Sanxingdui might, in some sense, have been a substitute for live victims. Judging by their rich costumes, however, the Sanxingdui images were not of war captives or an underclass. Perhaps the offerings represented self-sacrifice by the local elite.

While these two societies differed fundamentally in religious and artistic practices and were separated by mountain barriers, they nevertheless flourished within a common sphere of cultural interaction and trade. Cowrie shells—valued items that probably came from the Indian Ocean—appear in large quantities at both Anyang and Sanxingdui. The style of certain carved jade objects, such as blades, is remarkably similar. The bronzes usually differ in style but were cast at both sites by means of ceramic molds fashioned in multiple sections. In addition, the bronze alloy itself includes the same unusual lead isotope. Lead mines in Yunnan Province, south of Sichuan, most likely supplied the foundries in both regions.

Although the two sacrificial pits remain the most dramatic finds, fieldwork continues at Sanxingdui. And to my happy surprise, while I was visiting the site last February, news broke that a new site—clearly related to Sanxingdui—had just been found about twenty-five miles to the southwest, in the village of Jinsha, outside Chengdu. A bulldozer had hit a deposit of bronzes, jades, and a few gold items; many of them are similar to those from Sanxingdui. More than a thousand objects have been salvaged so far, though no large sculptures like those at Sanxingdui have emerged.

Along with other recent finds in the middle Yangtze River Valley—such as the tomb of Xin'gan in Jiangxi Province (dating from about 1200 B.C. and discovered in 1989) and the unique large bronze bells found in Hunan Province (dated 1200–1000 B.C. and excavated over the past few decades)—the discoveries from Sanxingdui and Jinsha have begun to decisively change the picture of a Shang empire surrounded by less civilized societies. After nearly a century of archaeological investigations, we can discern a broader panorama of Bronze Age China, with highly developed cultures not only in the north but also in the south. □

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Using gold foil, below, an artist fashioned the rounded ears, lithe body, clawed feet, and stripes of a tiger. Opposite page: The ceremonial headgear of this sixteen-inch-tall bronze figure represents the head of a winged animal.

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REVIEW

Field Trials

Naturalists have a bent for writing intriguing memoirs. This year has seen a bumper crop.

By Steven N. Austad

During a particularly foul time in the bush—I'm not sure whether it was while I lay immobilized on a moldering sleeping bag because of a foot so swollen it looked like a lumpy red soccer ball or when I discovered that the pungent peanuts in the chicken casserole I had so lovingly prepared were really hundreds of overcooked beetles—I began to giggle a little deliriously at the thought that someday all this might sound like a whopping fine escapade. Field biology is, after all, nine parts tedium and trouble to one part insight and adventure. The accumulated evidence of these four field memoirs, each in its own way a gripping read, suggests that I was probably having a whopping fine escapade after all.

BILL WEBER

Amy Vedder, Nyungwe Forest, Rwanda

The most traditionally autobiographical book of the lot—and the only one in which scientific discovery plays a major role—is *Captivating Life.* John Avise pioneered the use of molecular biological techniques to address key questions of evolution and behavior: whether a regional particularity in bird plumage really deserves species status, whether sea turtles return year after year to the beach where they were born. I remember quite well that in my graduate student days we derisively referred to his ilk as cell smashers and gel jockeys, who, instead of laboring to observe animals week upon week with poised notebook, simply showed up one day, took a few snips of tissue, and disappeared back into the laboratory. But they were the ones getting the best answers to the big questions—something for which I am just now beginning to forgive them.

Beyond the Last Village is ostensibly about working to set up a conservation program in Myanmar (formerly Burma) but is in reality a highly personal account of Alan Rabinowitz's love affair with wild places and the people and animals that live there. Dominating the story is a trek into the Himalaya of northernmost Myanmar, where no Westerner has ventured for years and where exotic mammals with exotic names like muntjac, goral, serow, and takin still haunt the forest, one step ahead of local hunters. Rabinowitz hoped to find remaining pockets of additional charismatic fauna—elephants, tigers, and rhinoceroses—and to set up a biological reserve to protect them, but he soon learned that these large mammals had disappeared.

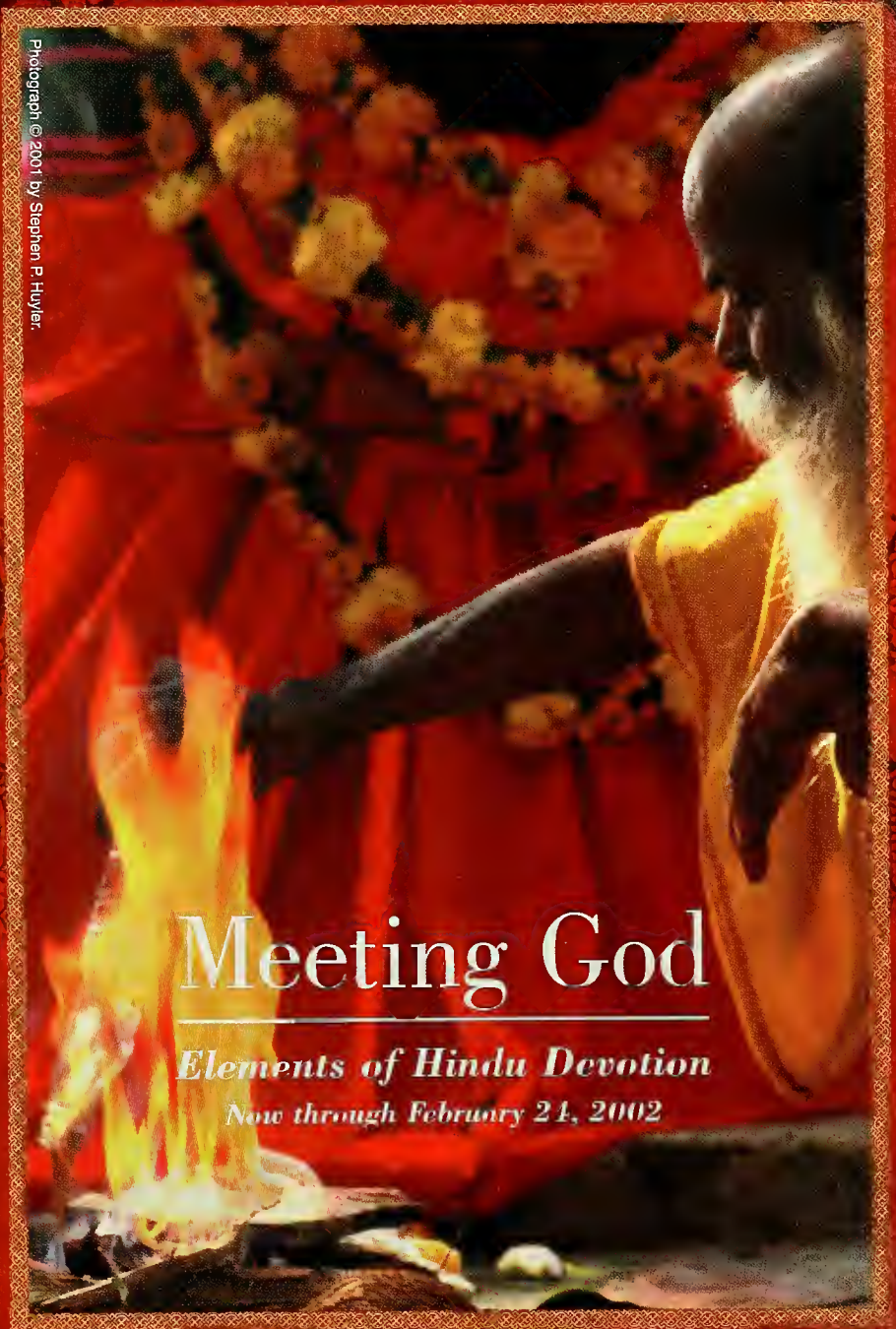
According to this finely observed account, he learned most about the animals by querying hunters and listening intently to what they had to say. This gift for listening led him to discover that the local economy is based largely on salt. The local people don't really need to hunt wildlife, because their gardens and livestock provide sufficient food. But salt, which both humans and livestock need to survive, is nonexistent in the area, so traders bring salt from China across mountain passes and exchange it for the organs of wild animals, used in traditional medicine. This knowledge allowed Rabinowitz to work out a strategy whereby he ensured regular supplies of salt and the people could stop hunting (see "The Price of Salt," September 2000).

Captivating Life: A Naturalist in the Age of Genetics, *by John C. Avise (Smithsonian Institution Press, 2001; $24.95)*

Beyond the Last Village: A Journey of Discovery in Asia's Forbidden Wilderness, *by Alan Rabinowitz (Island Press, 2001; $25)*

In the Kingdom of Gorillas: Fragile Species in a Dangerous Land, *by Bill Weber and Amy Vedder (Simon and Schuster, 2001; $27.50)*

A Primate's Memoir: A Neuroscientist's Unconventional Life Among the Baboons, *by Robert M. Sapolsky (Scribner, 2001; $25)*



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For me, the most haunting accounts here are about the people: government officials whose personal quirks can make or break his project; the Taron "pygmies," all but extinct because of persecution, inbreeding, and despair; a mother so desperate to save her ill baby

that she gives up the infant to Rabinowitz's Burmese colleague.

Bill Weber and Amy Vedder's *In the Kingdom of Gorillas* is an account of their work with mountain gorillas in Rwanda. In 1973, en route to their Peace Corps posting in eastern Congo, the newly married couple was detained in Uganda by troops under orders from the bloodthirsty tyrant Idi Amin. Despite this inauspicious beginning, they developed an appreciation for the people and cultures of Africa that led eventually to their decade-long involvement in a Wildlife Conservation Society project on gorillas in the subalpine forests of neighboring Rwanda.

At first, the most difficult 500-pound gorilla they had to contend with was Dian Fossey, international media star, who loved the gorillas and had suffered mightily to study them. By the time Weber and Vedder met her, she had dissolved into alcoholism and paranoia to such a degree that she was harming gorilla preservation efforts more than helping them. Offering Weber a gun as he set off to census the remaining gorillas for the first time, Fossey instructed him, "If you see anyone in the park, shoot them." A previous worker had taken her at her word, shooting and paralyzing a suspected poacher, which led his friends and family to kill five gorillas in retaliation.

Later, Weber and Vedder came up against AIDS and unparalleled ethnic violence, which devastated their project, their Rwandan friends, and the region itself. They provide a vivid portrait of a land desperately trying to put itself back together. The gorillas survive.

Mountain gorillas also fascinated Robert Sapolsky, but, as he writes in *A Primate's Memoir,* he joined a baboon troop in Kenya's Serengeti Plain instead. The year was 1978, when I, too, made my first trip to Africa and was fleeced on the streets of Nairobi by probably some of the same con artists (with their eye for American pigeons) whom he describes. Rarely have I encountered a scientist who became so attached to his study animals, giving them biblical names and roles and fleshing out descriptions of their individual personalities the way he might his childhood chums. Which makes it all the more horrifying when, after twenty years of increasingly intimate acquaintance, his baboon friends begin dying, one after another, for preventable reasons that he can do nothing about. A tale of deep humanity played out between two primate species, the book resonates with humor but also with the outsize emotions: sorrow and fear and joy.

Steven N. Austad is a professor of zoology at the University of Idaho and the author of Why We Age: What Science Is Discovering About the Body's Journey Through Life *(John Wiley and Sons, 1997).*

nature.net

Natural Borders

By Robert Anderson

I love maps, especially maps that convey information about our world in a novel way. I was therefore happy to find at Wild World (www.nationalgeographic.com/wildworld) a pair of interactive maps created by the National Geographic Society in collaboration with the World Wildlife Fund.

The first map, "Global 200," shows 200 regions (on land and in the seas) for which conservation efforts are crucial because they are home to the richest, rarest, and most endangered biological communities. I was surprised to learn that Los Angeles, where I live, is right in the middle of one of these special places—47,000 square miles of California chaparral and woodlands. This relatively small and highly threatened area is one of just five spots on Earth with a Mediterranean climate. Together, these regions harbor 20 percent of the world's plant species. Rainforests aren't the only places in critical need of help.

The second interactive map, "Terrestrial Ecoregions of the World," shows the world's landmass divided into ecoregions—867 of them—instead of into the usual political demarcations. These entities are distinguished by shared ecological features of climate and of plant and animal communities. You can quickly find yours by typing in your zip code. My ecoregion (a subdivision of the area described above) is California coastal sage and chaparral, or NA 1201. When I clicked on it, I got an overview of the flora and fauna, and I learned that the protected patches of my ecoregion are generally too small to conserve intact natural communities. More information was available via a link to the World Wildlife Fund's scientific report.

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

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BOOKSHELF

Aquagenesis: The Origin and Evolution of Life in the Sea, *by Richard Ellis (Viking/Penguin, 2001; $25.95)*
With a sense of exuberance and wonder, marine artist and writer Richard Ellis investigates the evolution of sea life, especially land animals that have returned to an aquatic existence—such as whales, seals, manatees, and penguins. He manages the daunting task of compressing 300 million years of evolution into a very readable book.

The Evolution Explosion: How Humans Cause Rapid Evolutionary Change, *by Stephen R. Palumbi (W. W. Norton, 2001; $24.95)*
Whether in TB's resistance to antibiotics or the diamondback moth's immunity to the deadly pesticide known as Bt toxin, the force of human-driven natural selection is abundantly evident. Harvard biologist Palumbi looks at our species' impact on evolution and the ways we ourselves continue to evolve.

The Botany of Desire: A Plant's-Eye View of the World, *by Michael Pollan (Random House, 2001; $24.95)*
Linking the destinies of apple, tulip, potato, and cannabis species to our own, this entertaining and informed book celebrates how plants, animals, and microbes respond with "so many different and unexpected answers to the deep pulse of their genes and the wide press of their surroundings."

Hubbert's Peak: The Impending World Oil Shortage, *by Kenneth S. Deffeyes (Princeton University Press, 2001; $24.95)*
Geologist M. King Hubbert proved correct in his 1956 prediction that U.S. oil production would peak in the early 1970s. Now analysts have applied Hubbert's method to global oil output. They estimate that between 2004 and 2008, supplies will begin a permanent decline. This is a sobering look at fossil fuels and alternative energy sources.

World Atlas of Coral Reefs, *by Mark D. Spalding, Corinna Ravilious, and Edmund P. Green (University of California Press, 2001; $45)*
Enormous, spectacular, and dense with overwhelmingly diverse life, the planet's tropical reefs are visible even from space. This exhaustive, area-by-area assessment of an increasingly threatened ecosystem includes text, photographs, tables, and splendid, up-to-date maps.

Great Waters: An Atlantic Passage, *by Deborah Cramer (W. W. Norton, 2001; $27.95)*
The origins, organisms, and movements of the vast Atlantic Ocean (which covers 32 million square miles and reaches depths of 12,000 feet) are illuminated by an author who spent a decade researching the scientific literature and many weeks aboard a research vessel visiting "the rough, chilly Gulf of Maine" as well as "the calm, weedy Sargasso."

Life Script: How the Human Genome Discoveries Will Transform Medicine and Enhance Your Health, *by Nicholas Wade (Simon & Schuster, 2001; $24)*
By decoding the 3 billion DNA "letters" spelling out all the genes that create and maintain the human body, the Human Genome Project will open up new ways to pinpoint the genetic causes of disease, permit individualized diagnostics, and lead to new treatments.

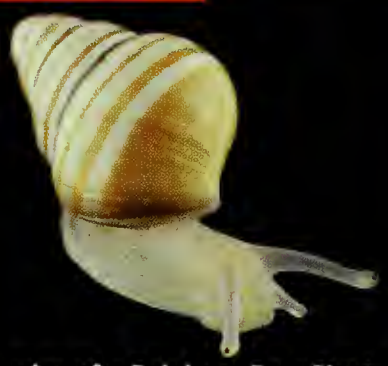
Platypus: The Extraordinary Story of How a Curious Creature Baffled the World, *by Ann Moyal (Smithsonian Institution Press, 2001; $21.95)*
In 1799 a strange Australian specimen, "a small amphibious animal of the mole kind," arrived at the Royal Society of London. "Neither fish nor fowl, bird or reptile," this monotreme puzzled scientists for a century before its biology—especially its antediluvian sensory system—was understood.

This Cold Heaven: Seven Seasons in Greenland, *by Gretel Ehrlich (Pantheon Books, 2001; $27.50)*
Writer and poet Ehrlich traveled to the "world's largest island" in 1993 and fell in love with it. Her heroes, the Inuit people (who reached Greenland thousands of years ago), have created a "cold-adapted, boreal culture, a single entity [that] stretches 6,000 miles across ice caps, pressure ice, barren lands, rivers, mountains, fjords, and frozen oceans."

The Tapir's Morning Bath: Mysteries of the Tropical Rain Forest and the Scientists Who Are Trying to Solve Them, *by Elizabeth Royte (Houghton Mifflin, 2001; $25)*
Barro Colorado Island is a living ecological laboratory located in the middle of Gatun Lake (part of the Panama Canal system). It has been administered by the Smithsonian Institution since 1923. As the author accompanies researchers counting seedlings or sorting insects, she muses on the evolutionary and ecological questions raised by the fieldwork.

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

PHOTOGRAPHY



DAVID LITTSCHWAGER AND SUSAN MIDDLETON

Remains of a Rainbow: Rare Plants and Animals of Hawai'i, *by David Littschwager and Susan Middleton (National Geographic, 2001; $50)*

National Collector's Mint announces a limited release of the ...

2001 U.S. GOV'T "AMERICA UNITED" SILVER EAGLE DOLLAR

To benefit the victims and families of the September 11, 2001 attack on America

WASHINGTON, D.C., Corp. ID Center, Thursday, 8:55 AM - Today history is being made. America is uniting as it has not done since the Japanese attacked Pearl Harbor 60 years ago.

In response to the terrorist attack on the World Trade Center and the Pentagon the morning of September 11, 2001, thousands of men and women came forward to help rescue efforts. Hundreds of businesses volunteered their services.

In that spirit, the National Collector's Mint is releasing the "America United" Silver Eagle Dollar, a Brilliant Uncirculated 2001 U.S. Government Silver Eagle, with the Twin Towers of the World Trade Center standing proudly in full color across its obverse as the Stars and Stripes flies above them.

For each "America United" Silver Eagle Dollar purchased, National Collector's Mint is making a $7.00 donation to the United Way's September 11th Fund, providing immediate and long-term aid to victims and their families. We expect to lose money. But, after their sacrifices, helping victims and their families is more important. In fact, it's the only thing that's important.

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The "America United" Silver Eagle Dollar is a statement of your commitment to support America's struggle against the shadowy enemy. Each coin is a legal tender Silver Eagle Dollar, the biggest, heaviest and purest silver coin ever minted by the U.S. Government. The full-color image of the World Trade Center and the American flag appears across its obverse, with the never-to-be-forgotten date of the attack, September 11, 2001. Beneath this brilliant image, Lady Liberty strides toward us out of the dawn. On the reverse is the great heraldic eagle. Emblazoned across it stands the American flag in full-color, and the legend, "God Bless America."

Advance Discount Price

The issue price of your "America United" Silver Eagle Dollar was originally set at $49.00. But, in order to raise funds as quickly as possible, and to put as many of these precious coins into the hands of Americans who want to memorialize this tragedy, and proclaim our unity, the issue price of this pure silver masterpiece has been cut to just $29.95.

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CELESTIAL EVENTS

Outta Sight

Once in a while, Jupiter's moons take a walk.

By Richard Panek

An artist's vision of Jupiter hovering above the ice spires of Callisto, one of the planet's four Galilean moons. The three other moons are to Jupiter's right.

If Galileo had first looked at Jupiter through a spyglass powerful enough to discern the planet's moons a few evenings earlier or later than January 7, 1610, what he might have seen was this: Jupiter. *Just* Jupiter.

Instead, what he famously observed on the night of the 7th was Jupiter accompanied by a distinctive arrangement of "stars"—three pinpoints of light in a curiously straight line, two on one side of the planet, one on the other. Galileo looked at Jupiter again the following evening; this time he found the three stars all to one side of Jupiter. At first he suspected that the planet had changed position relative to the stars, even though such repositioning would have contradicted standard predictions for Jupiter's trajectory. Over the following week, however, Galileo not only located a fourth star accompanying Jupiter but also began to suspect that what was jumping around wasn't Jupiter; it was the mysterious "stars" themselves—the four bodies that today we know as the Galilean moons.

Of all the revolutionary discoveries Galileo made in his first months of using a telescope to study the night sky—including mountains on our own Moon and multitudes of stars invisible to the naked eye—it was this observation that prompted him to rush these findings into print. The presence of moons orbiting Jupiter didn't decisively validate Copernicus's 1543 hypothesis that the planets go around the Sun (Galileo's observation of the phases of Venus would soon do that; see "Celestial Events," June 1999). But it did demonstrate that Earth, dragging along its own Moon, isn't the only body in the universe that serves as a center of motion.

The Galilean moons aren't always visible to us. Each disappears from view when it passes behind (is occulted by) the planet. And when one of them passes in front of (transits) Jupiter, the two bodies can't be distinguished from each other with even quite sophisticated amateur instruments. Certainly Galileo's primitive telescope would have been inadequate to the task.

The occultations and transits of Io, the Galilean moon closest to Jupiter, begin about every twenty-one hours and last just over two hours. Callisto, the moon farthest from Jupiter, disappears, or nearly so, every eight and a third days for about four hours—"nearly so" because from our perspective, its orbit often takes it just above or below Jupiter rather than across it. Between these two extremes falls Europa, which vanishes every forty-two hours, and Ganymede, every three and a half days. The simultaneous disappearance of two Galilean moons isn't all that unusual. The disappearance of three at the same time, however, is.

Unusual but not irregular. Every six months or so, the three innermost moons vanish from sight simultaneously for a few minutes at a time. These disappearances can occur four, five, or more times at three-and-a-half-day intervals (the length of time between an occultation and a transit of Ganymede, the outermost of these three moons).

By a quirk of fate, Galileo began his historic observations of Jupiter on January 7, 1610, smack in the middle of one such spate of disappearances. Five evenings earlier, for an observer who happened to be where Galileo was (in Padua) at the very time that Galileo would soon begin his daily studies of the planet through his optic

tube ("the first hour of night"), three of Jupiter's moons would have been out of sight. The fourth and farthest, Callisto, would have been distant enough in its orbit that Galileo might very well have overlooked it or, at any rate, failed to associate it with the planet. This precise celestial arrangement happened to repeat itself on January 6, though not at a time of day when Jupiter would have been above the horizon for an observer in Padua. On January 9, when the same circumstances recurred, Galileo in fact attempted to observe Jupiter—but cloud cover obscured his view.

Another such spate of disappearances is currently coming to an end. For an observer in New York, the moons Europa, Ganymede, and Io disappeared at about 5:00 A.M. on October 18 and remained out of sight right through sunrise. The same three moons disappeared again on October 21, but Jupiter was below the U.S. horizon at the time. On November 8, three Galilean moons will vanish once more, with Callisto—usually the distant straggler—among the missing. Ganymede will be the odd moon out, though by a distance from Jupiter of less than fifty arc seconds, or about 1/37 the width of our full Moon. So for virtually any amateur observer, the four Galilean moons will pass temporarily out of sight that day, beginning about 16:30 Universal time.

Not, alas, in New York, where the disappearance will occur at 11:30 A.M. And not in Padua, where Jupiter will be below the horizon. But if you happen to find yourself in Hawaii in the predawn hours of November 8, you'll be able to witness a sight that even Galileo never got to see, although it was one he thoroughly expected to find when he looked through his primitive telescope on January 7, 1610: *just* Jupiter.

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

THE SKY IN NOVEMBER

By Joe Rao

Mercury descends from its excellent morning viewing position of late October. It gradually drops lower into the bright morning twilight, hovering less than 1° from Venus through November 7. Also close by is the first-magnitude star Spica, a blue gem. During the first five days of November, Venus, Mercury, and Spica form a trio. Mercury is visible 2° to the lower left of Venus on the 11th, increasing to 4° by the 17th. Mercury slowly brightens during this interval, reaching magnitude -0.9. In the third week of November, the planet drops deep into the morning twilight and is lost in the glare of the Sun.

Venus rises almost due east about one and a half hours before sunup on the 1st. Spica is close to Venus the first week of November; Mercury lingers nearby through midmonth. On the 3rd, Venus passes 3.5° north of Spica. A thin crescent Moon is visible above Venus and to the lower left of Spica on the morning of the 13th. Venus sinks deeper into the dawn twilight throughout the month.

Mars, in Capricornus throughout November, can be found in the southwestern sky at dusk, setting just before 10:30 P.M. local standard time (LST). It starts the month at magnitude +0.1 and dims to +0.4 by the end.

Jupiter glimmers above the eastern horizon by 9:00 P.M. LST at the beginning of November and by 7:00 P.M. LST at month's end, reaching its highest point in the sky during the predawn hours. Late on the night of November 5–6, the Moon passes 1.5° north of Jupiter.

Saturn dominates the constellation Taurus this month. It rises about two hours after sunset early in November but only fifteen minutes after sundown by the 30th. On the evening of November 3 it hovers close to the Moon. On the 30th the ringed planet is occulted by the full Moon for much of North America; it disappears at roughly 7:30 P.M. LST in the East and 5:00 P.M. LST in the far Southwest.

The Moon is full twice in November for those in the eastern time zone—on the 1st at 12:41 A.M. and on the 30th at 3:49 P.M. Last quarter comes on the 8th at 7:21 A.M. The Moon is new on the 15th at 1:40 A.M., and first quarter comes on the 22nd at 6:21 P.M.

The Leonid meteor shower should reach a peak over North America on the morning of November 18 between 5:00 and 5:30 A.M. Try to get an unobstructed view of the sky far from city lights. The meteors will be radiating from the sickle of Leo. Keep alert for brilliant fireballs or exploding meteors. This year's shower may include a brief outburst of up to 2,500 meteors per hour. If the weather cooperates, you might see more "shooting stars" than you ever have before. Eight hours later—when it's daytime in the Western Hemisphere—an even grander Leonid display, with possible rates of up to 15,000 per hour, is expected over eastern Asia and western Australia. To learn more about the display, go to www.hometown.aol.com/theleonids.

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

BIOMECHANICS

Sand Dune Two-Step

The need for speed may bring these lizards to their (hind) feet.

Story by Adam Summers ~ Illustration by Sally J. Bensusen

As the sun rises over the Mojave Desert, its pale yellow light casts every irregularity into stark relief. Countless pockmarks and minute tracings on the surface of the dunes provide evidence of a busy night for kangaroo rats and sidewinders—the scuffling of tiny feet, the swishing of curved bodies, and the occasional mad sprint to escape a predator. But one small patch of the Kelso Dunes in the southeastern area of the desert is strangely lacking in such sandy signs, having been blown smooth by biologists wielding gas-powered leaf blowers. These researchers are testing out their theories of lizard locomotion.

Among the most astonishing residents of the dry and apparently barren Kelso Dunes is the Mojave fringe-toed lizard *(Uma scoparia)*. This small, finely checkered lizard is active during the day, skittering across the sand in search of invertebrate prey. Occasionally it disappears in a flash as it deftly burrows into the sand. For a real show, try catching one of these lizards. It races away in a sudden burst of speed, its front end lifting off the ground like a hot rod, its forelimbs weakly pawing the air. As the four-inch-long creature dashes off at thirteen feet per second, its hind limbs windmill like the legs of a cartoon character making a fast getaway, and its long toes flare, each bearing an expanded row of scales that provide traction in the sand.

Scientists assume that being fleet of foot boosts evolutionary fitness by helping an animal avoid becoming someone's dinner for long enough to produce lots of offspring. As a result, a great deal of research has been conducted on the relationship between speed and such variables as leg length; how long feet stay in contact with the ground; and the degree to which the legs are splayed, as in lizards, or held underneath the body, as in mammals (except for the duck-billed platypus). So, using a lizard-sized treadmill and high-speed cameras, Bruce Jayne, of the University of Cincinnati, and Duncan Irschick, of Tulane University, have been gathering sprinting data for the Mojave fringe-toed lizard as well as for its close relative, the zebra-tailed lizard *(Callisaurus draconoides)*.

In the laboratory, the researchers determined the top speed of both species and also when they use two legs and when they use four. The longer-legged zebra-tailed lizard—which, like its relative, is diurnal but which inhabits a wider range of terrains, from fine sand to the hardpan of desert washes—runs much faster than the fringe-toed lizard, even on loose sand, where the researchers had expected the latter's toe cleats to be a significant advantage. And oddly, though the researchers assumed that running on two legs would be quicker than running on all four, they found that after the first few seconds of movement, when both species can run bipedally, there was little difference in speed between the two modes of locomotion. Running on two legs may facilitate quick acceleration or may simply be an unintended consequence of it.

Laboratory studies like these are useful for purposes such as understanding the mechanics of a rapid, sprawling gait or making an evolutionary comparison between species. However, Irschick and Jayne wanted to know how the lizards perform outside the contrived conditions of a biology lab. In the field, they wondered, are the animals content to creep around most of the time, sprinting only when necessary, or do they regularly dart from place to place?

To circumvent the problems of exposing high-tech electronic equipment to sand and extreme heat, Jayne and Irschick borrowed a tactic from Sherlock Holmes: they measured the footprints left by lizards and then compared the prints with data from the laboratory experiments.

In their early experiments on the dunes, the researchers simply walked up to lizards and observed the animals as they sped off. They found that on gentle slopes, both species were just as likely to run uphill as they were to run down or across, so long as the direction was *away*. On steeper slopes, the zebra-tailed lizards tended to run across the hill, presumably because uphill would be slower and downhill more apt to result in a tumbling fall. While both species ran on two feet at first, as they did in the lab, it turned out that the fringe-toed lizard resumed quadrupedal running after just a few upright steps, while the gangly zebra-tail remained bipedal for nearly half the escape strides.

The smoothed patch on the Kelso Dunes is one of several sites in the Mojave where Jayne and Irschick have set up a more ambitious experiment so that they can study locomotion in a community of lizards behaving naturally, unobserved and undisturbed. For this experiment, the researchers deploy their leaf blowers at night and then retreat, leaving behind a blank slate ready to record the animals' movements. The lizards are active for several hours during the relative cool of morning and again in the early evening. When the sun is high, they seek cover in burrows or under vegetation. At this point the researchers, braving the heat (up to 115° F), examine the dunes to measure the lizards' tracks.

Over the course of several weeks, the research team measured more than 5,000 footfalls in more than 300 trackways. Calculating the slope of each path and the speed of the animal that made it, they found that the fringe-toed lizard moves remarkably quickly when covering longer distances. In the lab, the lizards displayed a range of speeds, but in the field they preferred just two speeds: an exhausting dash across open ground and a slow, aerobically sustainable walk when foraging near cover. Surprisingly, they rarely ran on two legs out in the Mojave when no six-foot-tall researchers were there to alarm them; the need for rapid acceleration may arise less frequently in the wild than it does on treadmills in a laboratory. In one intriguing trackway, the footfalls of a fringe-toed lizard were paralleled by the prints of a roadrunner, a lizard-eating bird. After several feet, the lizard tracks disappeared abruptly: evidence of a well-timed dive under the sand or perhaps an indication that no matter how fast the lizards are, they do not always win the race.

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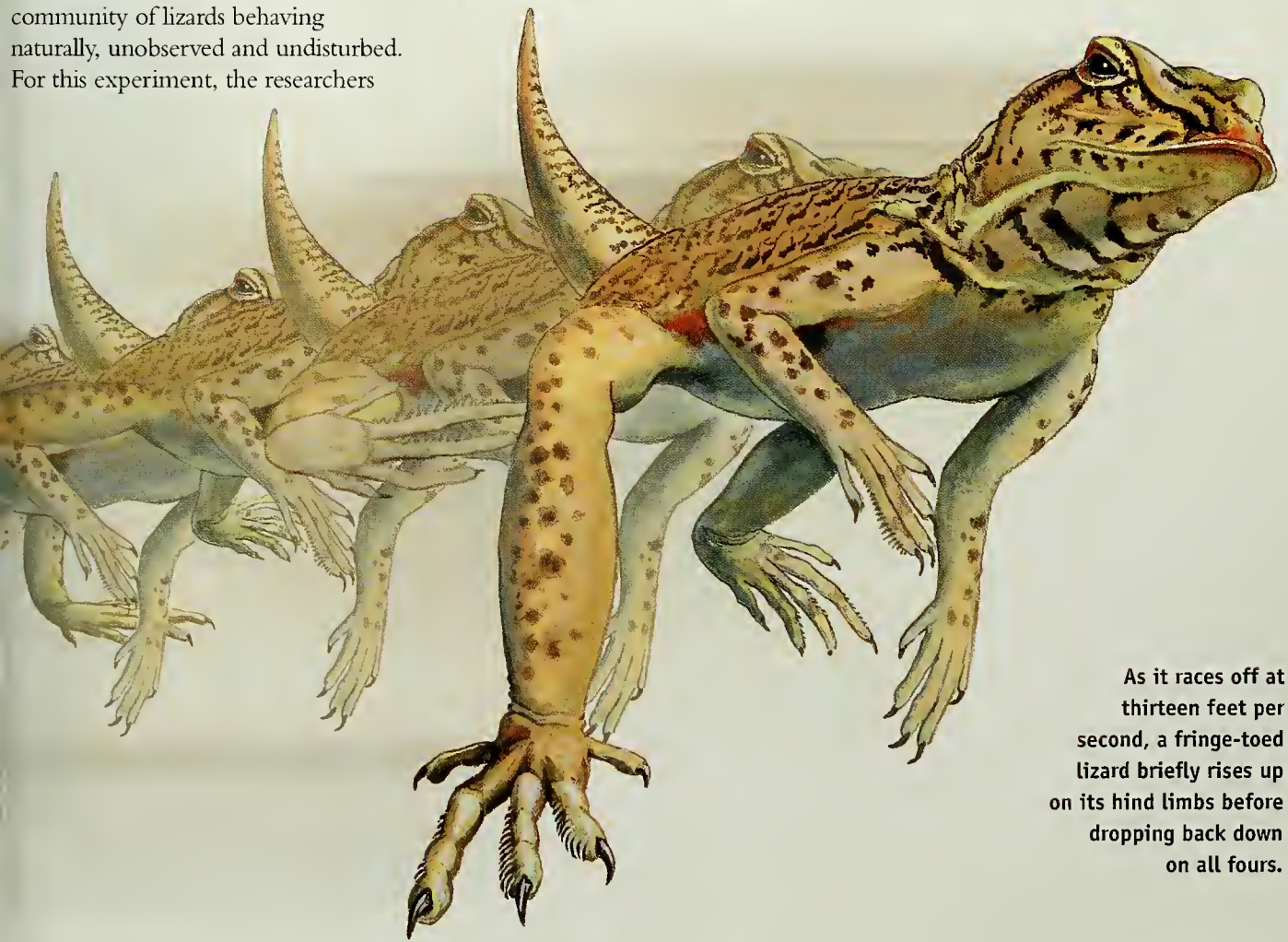


As it races off at thirteen feet per second, a fringe-toed lizard briefly rises up on its hind limbs before dropping back down on all fours.

Stuffin'

Photograph by
Gary W. Griffen

By the end of the nineteenth century, North America's indigenous wild turkey had dim prospects of survival. Once so common that colonial markets sold the bird for two cents a pound, this relative of the pheasant was relentlessly hunted and its forest habitats cleared for agriculture. It seemed that only the smaller-brained, domesticated turkey, bred for centuries by Native Americans in Mexico, would survive. But as acres of farmland gradually returned to forest, the wild turkey repopulated its former range in thirty-nine states and extended its range into all other states except Alaska, thanks mainly to "capture and release" programs.

Ground-dwelling omnivores, turkeys walk miles foraging for nuts, insects, and other edibles. While hens usually travel together, toms (males) roam either in separate flocks or alone. In spring they seek out hens, enticing them with spectacular displays of gobbling, feather fluffing, and quill buzzing. Sometimes a male travels with a group of females, mating with as many as possible.

In late April or early May, hens nest on the ground, where they lay about a dozen eggs over a two-week period. After twenty-eight days, the poults hatch and immediately begin to follow their mother closely. Just before sunset each evening, the hen flies up to a tree's lower limb and calls to the poults, which fly up and scramble for places next to her, even clustering on her back or neck if they cannot crowd beneath her wings for warmth.

This brooding hen was photographed in the Taconic Range in New York State, near the Connecticut border. Although the youngsters are favored targets of owls, snakes, opossums, coyotes, and foxes, mother turkeys have been successful in rearing enough of them to ensure the triumphant comeback of the wild turkey.—*Richard Milner*

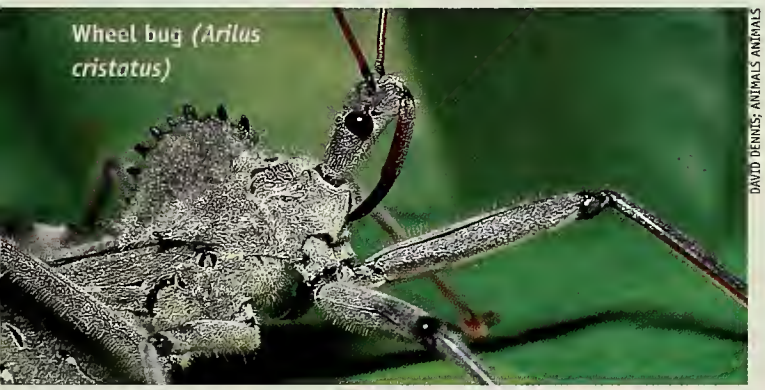
ENDPAPER

The LAST DAYS *of an* ASSASSIN

By Elizabeth Cator

On the midsummer morning I took it captive, the wheel bug was clinging to the stem of a swamp milkweed, its lethal beak plunged deep into the limp body of a monarch caterpillar. I picked the stem and carried it home. Since monarch caterpillars are notoriously toxic, I expected the wheel bug to die.

A wheel bug *(Arilus cristatus)* is both fearsome and comical. None of its parts match: spindly legs on a hulk of a body; a disproportionately small head; front femurs like massive biceps; a fantastic, cogwheel-like toothed semicircle erupting from its back. Years ago I found one lurking on a sumac at



Wheel bug *(Arilus cristatus)*

DAVID DENNIS; ANIMALS ANIMALS

the edge of a field. Its gray body black in the shadows, it sat motionless until I reached out a finger (an unwise move), prompting it to back slowly away. A shy, retiring insect, I thought, and was surprised to learn that it belonged to the family of assassin bugs and could have stabbed me.

My captive assassin, imprisoned in a bucket roofed with cheesecloth and set in a sheltered corner of the patio, went on feeding. Next morning I found it clinging to the underside of the cheesecloth, looking as lively as a wheel bug gets. I wondered what else it would eat and threw it a tobacco hornworm on a tomato leaf. It seemed not to notice, yet some hours later I saw that it had climbed down and was creeping toward the somnolent hornworm.

Millimeter by millimeter, with many long pauses, the wheel bug advanced. The whole time, one of its long, jointed antennae swept the air in a wide arc. The tip grazed the hornworm's head, more than an inch away. Provoking no response, the antenna tapped segment by segment along the body until, with a jerk, the hornworm began to crawl—not away but fatally forward. It was the wheel bug that then moved back, cautiously edging around to position itself directly in front of the advancing hornworm. Still the restless antenna swept and tapped. It tapped the hornworm's last segment; at once the wheel bug reared up on its two pairs of stiltlike hind legs, raised its burly forelegs beside its head, and stood like a trestle as the hornworm inched underneath. This is how the monarch must have died, in an event both random and inevitable: the grasping forelegs snapping down, the tarsal hooks sinking in, the curved needle-beak plunging, jerking up, plunging again. There was no struggle. A drop of green fluid fell to the floor of the bucket as the wheel bug began to suck up the nutritious innards of its prey.

The banquet lasted many hours; by evening, the hornworm's desiccated skin hung from the tomato leaf and the wheel bug was back on its cheesecloth ceiling.

It continued to thrive. I scattered leaf litter on the floor of the bucket and threw in another hornworm, then a squash bug, a bluebottle fly, a spiny orb weaver, a daddy longlegs, a bald-faced hornet, a wolf spider, and various unidentified larvae. Most were live, some were stunned, and a few were dead; many must have been exotic fare, but the wheel bug rejected only a yellow jacket (dead) and a stinkbug (live)—evidence, perhaps, of some gustatory standards, however low. Between meals the wheel bug hung motionless, sometimes for days, on the cheesecloth.

So it went until early November. After the frost the wheel bug retired to the leaf litter, where it lay fasting but made no attempt to burrow in and hibernate.

Then something mysterious happened. All summer I had seen no other wheel bugs, but now one appeared over the kitchen door. Slightly larger than the captive, it was some thirty feet from the bucket when I first noticed it. I never saw it in motion; from time to time I noticed that it was no longer where I had last seen it. Day by day, it made its way across the ceiling, down the wall, and eventually to the bucket's cheesecloth roof. The journey lasted two weeks.

For days neither wheel bug stirred. The captive lay on the leaves, the newcomer on the top of the cheesecloth. When I touched either one, a leg slowly lifted and then froze. One morning there was no response from either bug. With tarsi still hooked to the cheesecloth mesh, the newcomer was dead. Down on the leaves, the captive, too, had died.

Insect lives are short and surprising. My wheel bug not only survived a meal of poison caterpillar and months of imprisonment but appeared, at the end of its life, perhaps to have attracted a suitor. Or so I imagined. But for this slow and deliberate couple, time had simply run out.

English-born Elizabeth Cator is an embroiderer. She watches bugs in Hartwood, Virginia.

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