

# NATURAL HISTORY

10/01











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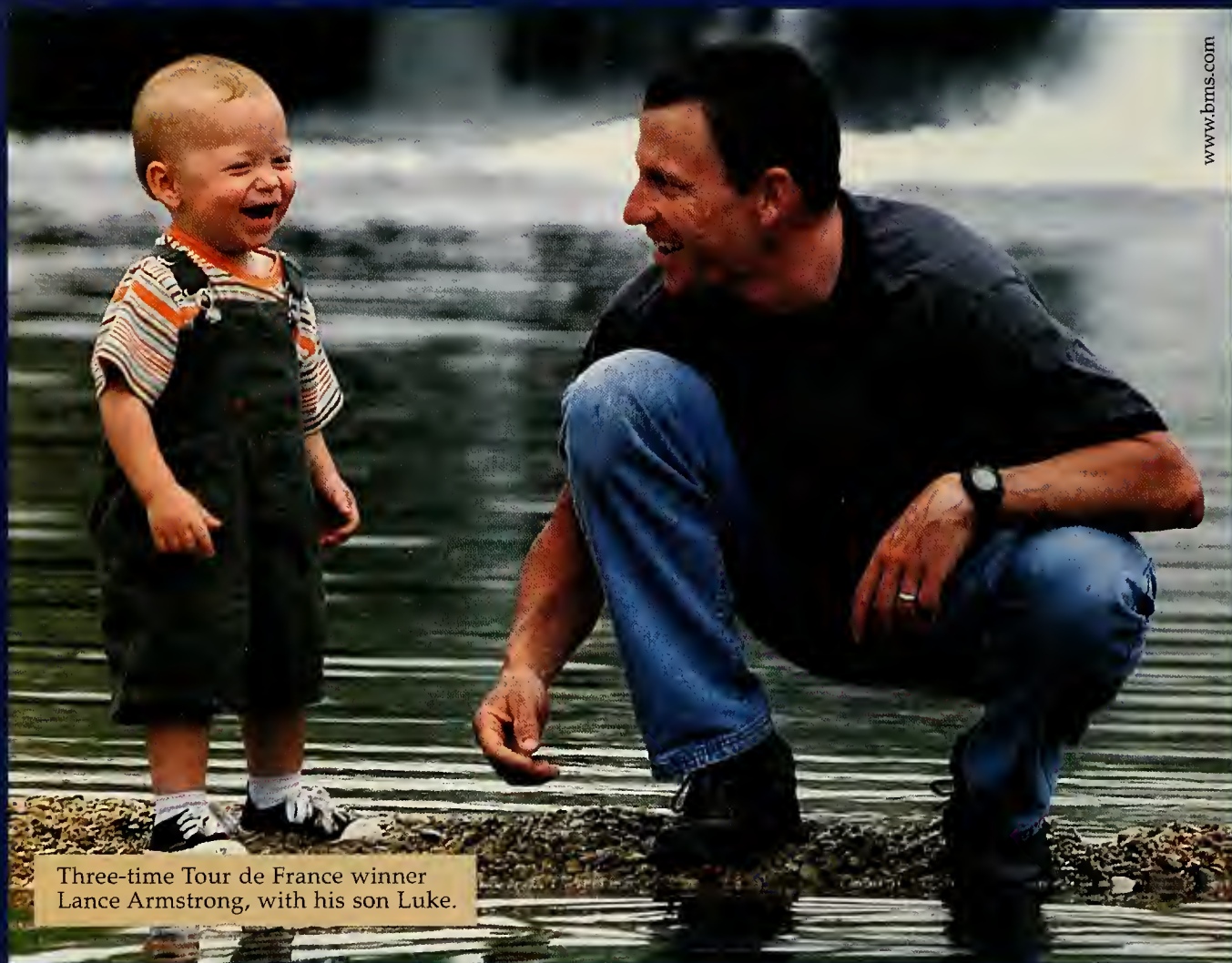
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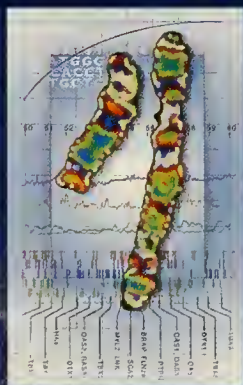


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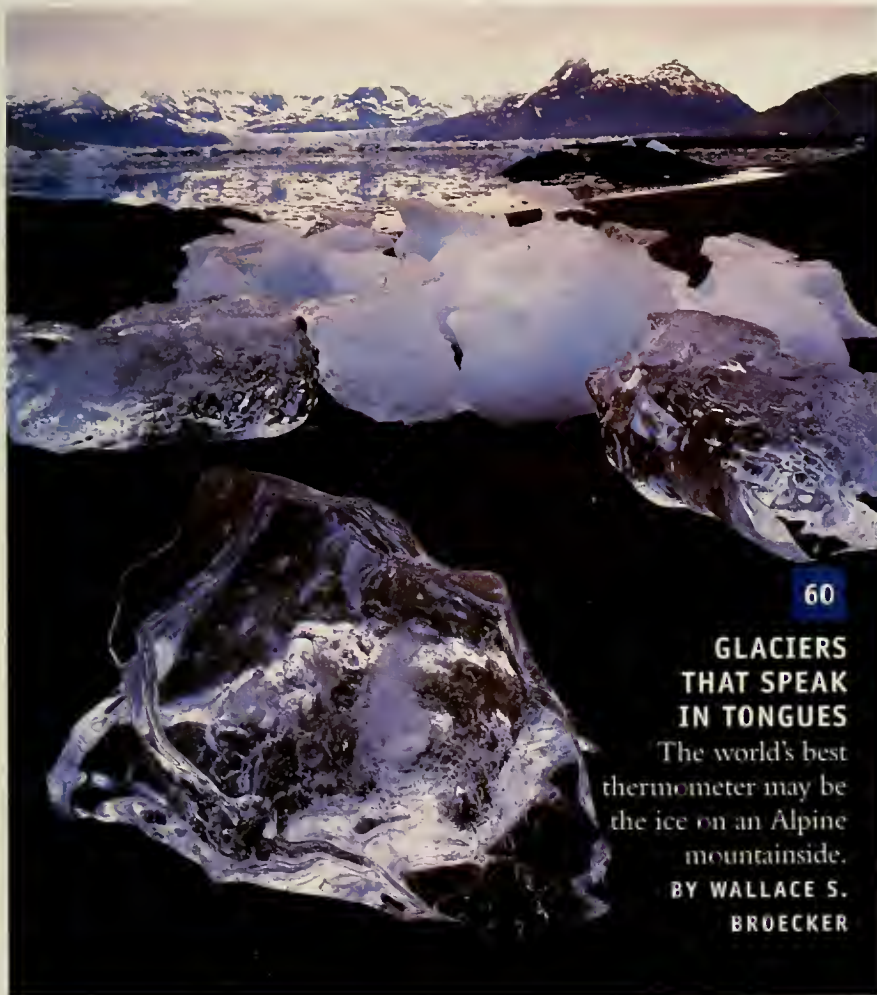
# NATURAL HISTORY

OCTOBER 2001

VOLUME 110

NUMBER 8

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PHOTOGRAPH BY DENIS FINNIN; AMNH



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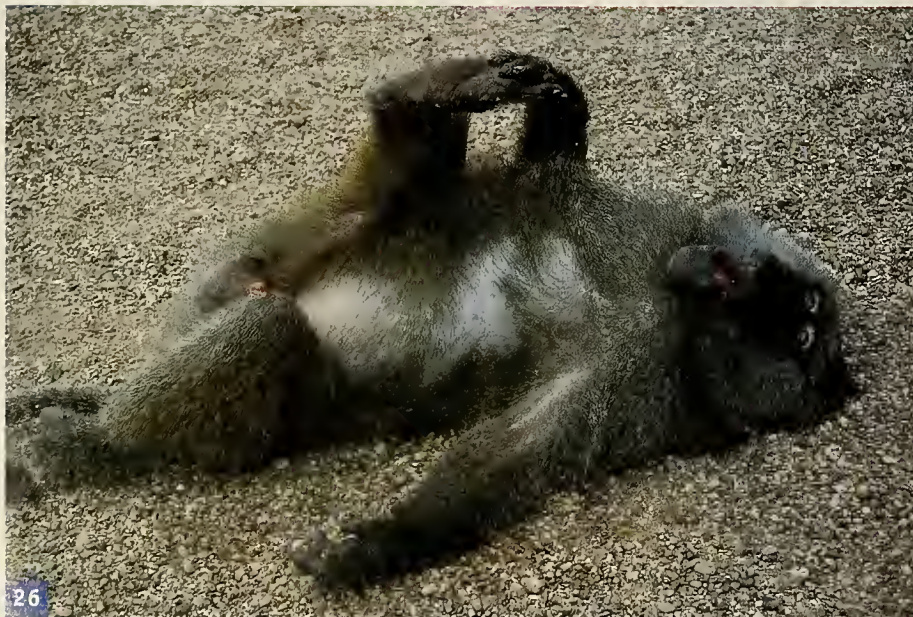




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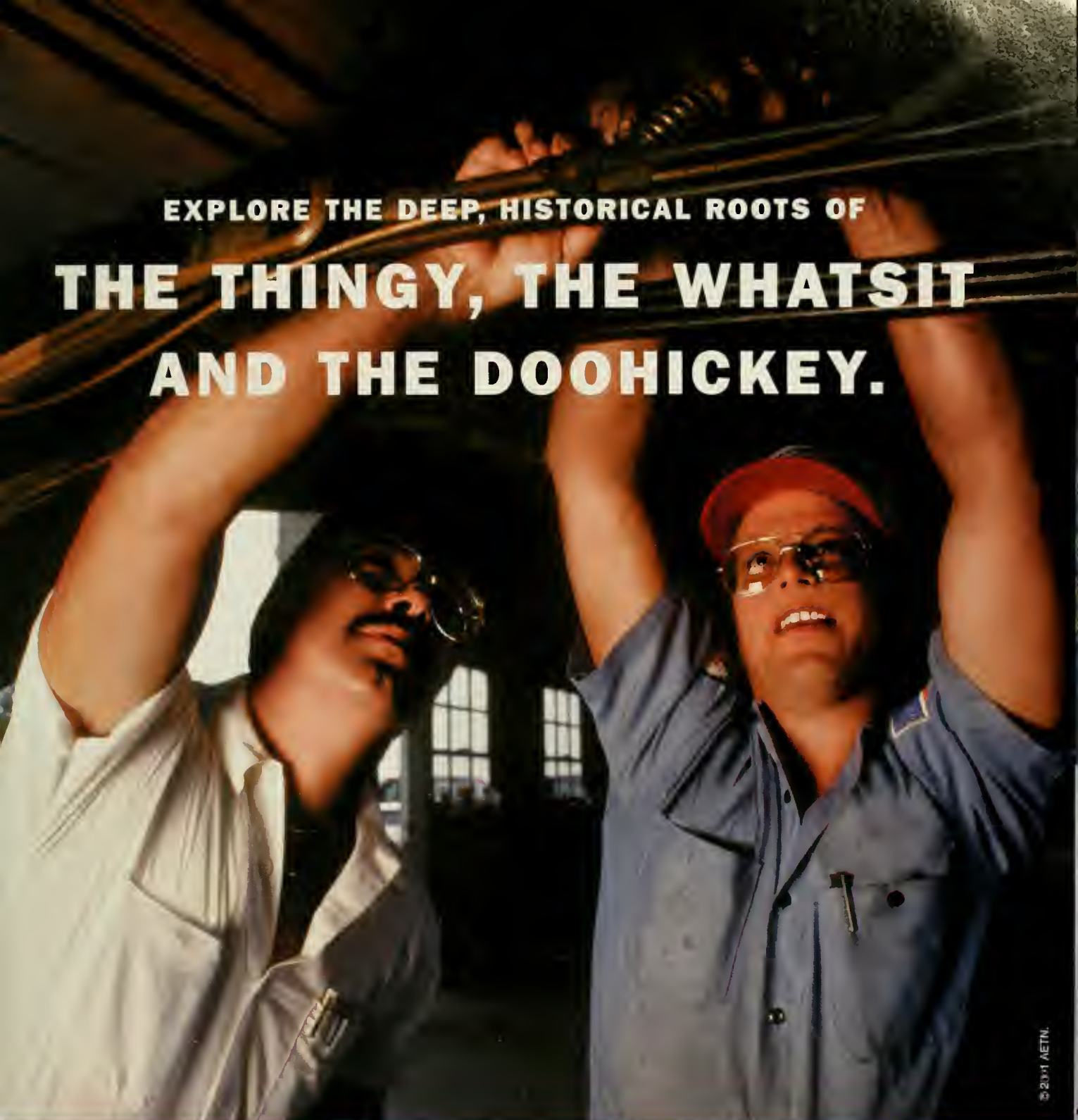
**90 ENDPAPER**

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## UP FRONT

## Time Travelers

"What seest thou else in the dark backward and abysm of time?"

—William Shakespeare, *The Tempest*

As a mid-twentieth-century schoolchild, I thought of the First World War as a distant event. I placed all the historical figures of previous centuries in more or less the same category, the remote past, which included everyone from Moses to Abraham Lincoln. My perceptions changed as I aged, of course. At my fiftieth birthday, I realized that the entire history of the United States had occurred within a span that amounted to little more than four of my lifetimes. The nineteenth century was a temporal stone's throw from my parents' childhood and, therefore, from my own life. From the vantage point of my middle age, certainly Abraham Lincoln and maybe even Louis XIV had become my contemporaries.

Working at *Natural History* has altered my perspective far more radically. Scientists' tales of fossils and shifting tectonic plates have taught me a new kind of history. Bacteria were the ancients, dinosaurs a late development, mastodons born yesterday.



Switzerland's Grindelwald Glacier, 1794

MUSEUM HARBODDWE N.E. WROCLAWTU, WROCLAW

Lincoln's birthplace in Kentucky once lay under a shallow tropical sea filled with brachiopods and trilobites; the Des Moines area emerged quite recently from beneath a glacier.

More than other scientists, natural historians—the geologists, paleontologists, evolutionary biologists, and others who write for these pages—are time travelers. And more than other people, they are aware that present reality

represents a mere moment, a freeze-frame in a long drama of upheaval and transformation. This month, in "Glaciers That Speak in Tongues" (page 60), geochemist Wallace Broecker addresses the question of humanity's contribution to global warming. Scientists cannot yet identify this contribution with precision, he explains, because to do so requires that they first establish the dynamics and natural baseline of Earth's recent temperature variations. By "recent," Broecker means the Holocene Epoch—just the past 11,000 years or so. Lately, he tells us, his colleagues have been finding a record of these climate patterns in surprisingly simple things—reddish grains of sand, bits of wood washed out from under mountain ice. Janus-like visionaries, these climatologists look backward to help us predict the future.—Ellen Goldensohn

## NATURAL HISTORY

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## LETTERS

**Osage (Orange)  
Can You See?**

I was surprised to see the picture caption in Connie Barlow's "Ghost Stories From the Ice Age" (9/01) about Osage orange trees being confined to a few river valleys in eastern Texas. The tree is common to this part of the Ozarks and has been at least since white settlers arrived. The wood was supposed to have been used by Native Americans for their bows.

T. B. Clark  
Berryville, Arkansas



Osage orange tree

A tree and fruit that looked just like your picture of Osage orange were certainly to be found smelling up Milledgeville, Georgia, where I grew up. Maybe you should check there for Pleistocene horses, too.

James F. Minter  
New York, New York

The Osage orange, called hedge apple in Missouri, is found all over the Ozarks of southern Missouri. There is

a belief that putting the fruits in your kitchen will keep roaches away. I tried it once. It did not work.

H. M. White  
via e-mail

Connie Barlow writes that the Osage orange tree is rare. However, many rows of old Osage oranges can be found in New Jersey. This species, characterized by thorns and dense growth, was at one time widely planted by farmers in the East to form impenetrable living fences, similar to Old World hawthorn hedgerows. As the trees grew, farmers pruned them to force the plants into hedge forms. After the farms were abandoned, the hedges resumed their natural, treelike growth.

Norman Fine  
Sewell, New Jersey

CONNIE BARLOW REPLIES: The letter from Norman Fine contains the seed of the answer to all those who protested that the geographic range of Osage orange is far wider than I stated in the article. After European settlers arrived, Osage orange became exceedingly popular as a "living fence," and its range was expanded by human plantings until barbed wire became cheaply available.

This was especially so in the prairies and plains, where a scarcity of trees made wooden fencing impractical. Botanists have surmised that the post-glacial native range of Osage

orange was probably restricted to the Red River region, where Arkansas, Texas, and Oklahoma meet. A year ago, an archaeologist exploring the Indian trade in Osage orange for bow wood proposed that the native range may have been even more restricted—to just a few tributaries of the Red River in eastern Texas. (See Frank F. Schambach, "Spiroan Traders, the Sanders Site, and the Plains Interaction Sphere," *Plains Anthropologist* 45:171, 2000. Or see my book *The Ghosts of Evolution* [Basic Books, 2001] for the full story.)

Hawthorn (genus *Crataegus*) is native to both the Old and the New World, with the eastern United States boasting the richest diversity of species.

**Buffalo Grass**

"Ghost Stories From the Ice Age" fascinated me. The flora of this country also includes ghosts from the nineteenth century: plants that coevolved with the American bison. Among these are three-awned grasses of the genus *Aristida*, with long bristles, or awns (well designed for penetrating the coat of a bison—or one's wool socks), and running buffalo clover, *Trifolium stoloniferum*. After the buffalo disappeared from the midwestern landscape, the clover itself became very rare and was once even thought to be extinct.

Bill Shepherd  
Little Rock, Arkansas

**Color Question**

In "The Proof Is in the Plumage" (7/01–8/01), on a feathered dromaeosaur from China, one of Mick Ellison's close-up photographs on page 61 reveals some fairly conspicuous red paint applied above the dromaeosaur's humerus. Close inspection also shows black paint in two photographs. Both the red and the black paint have been cleaned up in the large photograph on page 60. It seems unlikely that the bright scarlet color is simply an accidental property. Was the fossil acquired with this curious red paint upon it?

Jordan Moar  
Waterloo, Ontario

PHOTOGRAPHER MICK ELLISON REPLIES: Farmers in China's Liaoning region have been collecting fossils in the area for decades. Specimens are rarely found in one unbroken piece, and the process of reconstituting them is akin to completing a jigsaw puzzle. The excavators often highlight parts of the fossil with grease pencils or other markers, presumably to indicate how one piece might fit with another. For the cover of the issue and the photograph on page 60, the dromaeosaur's "tailoring" marks were digitally removed.

Natural History's e-mail address is [nhmag@amnh.org](mailto:nhmag@amnh.org).



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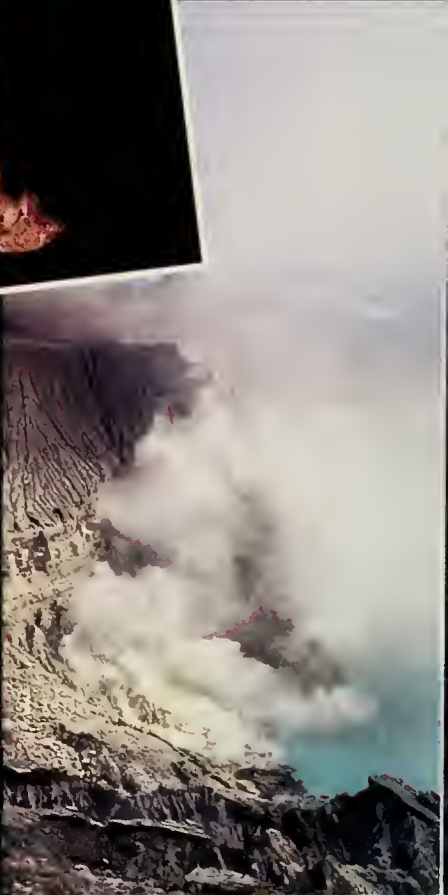
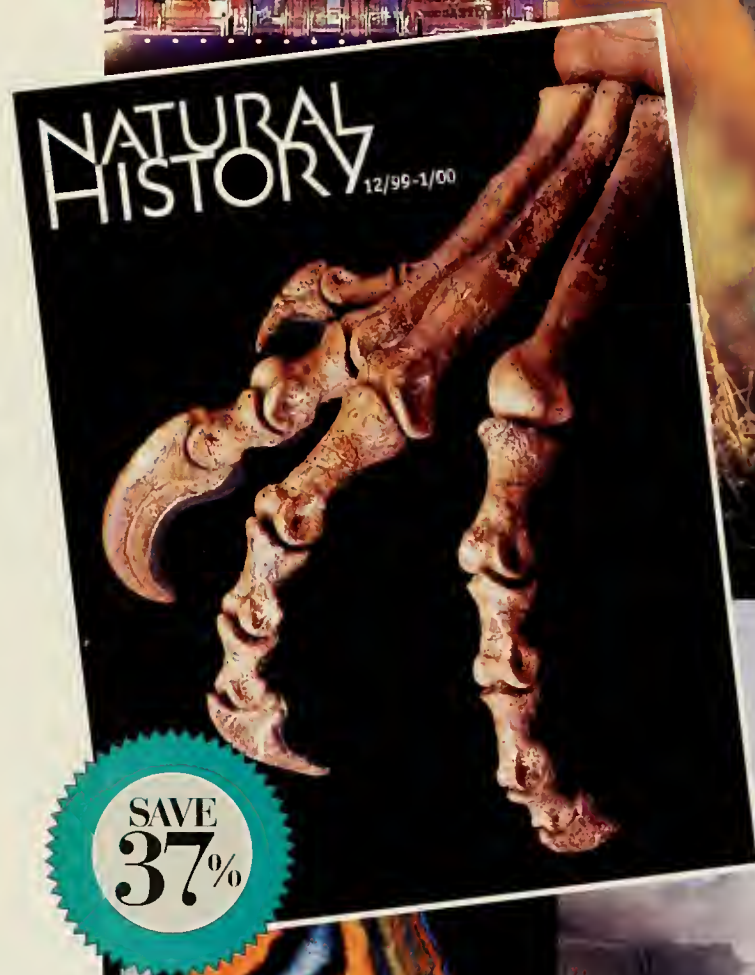
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## CONTRIBUTORS



**Sue Hubbell** (“Engineering the Apple,” page 44) did not plan to write another book after her last one (*Waiting for Aphrodite: Journeys Into the Time Before Bones*, Houghton Mifflin, 1999). But as she worked in her woodlot and built stone walkways around her Maine house, she began to reflect on her “proclivity for rearranging bits of the world.” This realization led her to investigate “a few animals and plants whose genetic identity we have tinkered with to varying degrees”—dogs, corn, silkworms, lions, cats, rats, and apples. Unraveling the history we have shared with these organisms, as well as the unintended consequences of our experiments with them, became another book, *Shrinking the Cat: Genetic Engineering Before We Knew About Genes*, published this month by Houghton Mifflin.



**Fred Bruemmer** (“Sea Hunters of Lamalera,” page 54) has been a writer and photographer since 1952 and a contributor to *Natural History* for almost as long. Over the years, he has been drawn back again and again to the Arctic and has written several books on aspects of Arctic life. Bruemmer, who lives in Montreal, has spent considerable time among subsistence sea hunters, including walrus hunters in Little Diomed Island in the Bering Strait, narwhal hunters in Greenland, and sperm whale hunters in the Azores. Lamalera, on the Indonesian island of Lembata, was a natural destination for him, he says, because of “the boats, the hunt, and the animistic link between hunter and prey.”

A recent visit to the Alps provided **Wallace S. Broecker** (“Glaciers That Speak in Tongues,” page 60) with a firsthand glimpse of new evidence of past climate changes. Guided by Swiss glaciologists, he and the others in the visiting field team found fifty samples of ancient peat and wood that had washed out from beneath the glacial ice—signs that vegetation once grew in areas now frozen over. The Newberry Professor of Earth and Environmental Sciences at Columbia University’s Lamont-Doherty Earth Observatory, Broecker is the author of a text on the evolution of Earth, *How to Build a Habitable Planet* (Columbia University Press, 1998). Among his previous articles for *Natural History* is “Global Warming on Trial” (April 1992).



As a child, **John J. Wiens** (“Shape Shifters,” page 70) kept dozens of pet reptiles and amphibians in his bedroom. When the number got out of hand, he packed up and moved into a different room, bequeathing the bedroom to the animals. Now, as an associate curator at the Carnegie Museum of Natural History in Pittsburgh, he has an entire three-story building full of herpetological specimens at his disposal. For many years, Wiens has been fascinated by the evolution and diversity of lizards and snakes, and he says that studying how one turns into the other is a perfect way to combine his interest in both groups. He plans to extend his studies of the evolution of body form to salamanders and to skinks, the group of lizards in which a snakelike body plan has evolved most frequently. Wiens’s other research interests include reproductive strategies in tree frogs and the evolution of herbivory in South American lizards.



**Theo Allofs** (“The Natural Moment,” page 88), a resident of Canada’s Yukon Territory, has traveled the world photographing wildlife. During late December 1999 and January 2000, he positioned himself in the midst of a large colony of flying foxes not far from Brisbane, Australia, where he took this month’s photograph of a little red flying fox. Despite his concealment in a blind, Allofs reports, the fruit-eating bats knew he was there and were not upset by his presence. But when they returned from foraging to roost above him in the trees, he was “bombarded by hundreds of ‘fruitcakes.’” Whenever Allofs poked his camera out of the blind, the lens hood instantly became coated with bat droppings. To see more of his work, visit [www.theoallofs.com](http://www.theoallofs.com).



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## AT THE MUSEUM

# Columbus's Pearls

*The discovery of vast oyster beds in the New World generated a "pearl rush" whose bounty flooded European markets.*

*By Neil H. Landman, Paula M. Mikkelsen, Rüdiger Bieler, and Bennet Bronson*

Inspired by greed, a messianic desire to convert the world to Christianity, and fierce competition with the oceangoing Portuguese, King Ferdinand and Queen Isabella of Spain sponsored the Genoese explorer Christopher Columbus in an "enterprise of the Indies": finding a new route to the riches of the Orient. Under the contract, Columbus, as Admiral of the Ocean Sea, was granted authority over all the lands he discovered, as well as 10 percent of the value of all goods obtained. In turn, the monarchs made a list of what they expected. By chance or design, pearls were the first item on this list.

Columbus set sail westward in 1492, made landfall in the Bahamas, and then explored the coasts of Cuba and of Hispaniola (the island comprising modern-day Haiti and the Dominican Republic). After establishing the settlement of La Navidad on Hispaniola, Columbus returned to Spain in triumph, with gold, cotton, and Indians to be baptized, but without pearls. Not until his third trip, in 1498, when he reached the South American mainland, did Columbus finally find the long-sought supply of pearls—in what is now Venezuela, along the Gulf of Paria near the mouth of the Orinoco River. Noticing that the women at one Indian village there wore bracelets of "pearls or baroque pearls of high quality," Columbus bartered for these orna-

ments with needles, buttons, scissors, and broken majolica plates and asked about the source of the pearls. The natives gestured to the north and west.

He sailed on, passing the islands of Cubagua and Margarita, sites of what would ultimately become known as the Pearl Coast, the richest pearl grounds in

## "Pearls"

**An exhibition on the natural and cultural history of pearls opens at the American Museum of Natural History on October 13, 2001, and runs through April 14, 2002. Organized by AMNH in collaboration with the Field Museum in Chicago, "Pearls" is made possible through the generous support of Tasaki Shinju.**

the Americas. By coincidence, he gave Isla de Margarita that name—the Greco-Latin word for "pearl"—to honor Infanta Margarita of Austria, who was engaged to marry the heir to the Spanish throne. Once back in Hispaniola, Columbus became so embroiled in mediating colonial politics that he sent two ships back to Spain on their own, carrying letters that mentioned nothing about the Venezuelan pearls.

His returning sailors, however, privately sold the pearls they had acquired,

and the news of this reached the Spanish court. Possibly suspecting that Columbus had kept other pearls for himself and disgruntled with his inept handling of the political situation on Hispaniola, his transport of slaves to Spain, and his reported cruelty to the sailors and West Indian natives, Ferdinand and Isabella had Columbus put in chains and returned to Spain in 1500. Released the following year, Columbus embarked on his fourth and last voyage in 1502. This time he followed the east coast of Central America, stopping en route in what are now Panama and Honduras but returning to Spain in 1504, again without pearls.

By the time Columbus died in 1506, his voyages had already initiated a "pearl rush" that was to last for the next 150 years. The first to profit were his sailors, among them Peralonso Niño, former pilot of the ship *Santa María*, who in 1499 received royal permission to explore the Pearl Coast, in clear contravention of the agreement giving Columbus exclusive authority. The chronicler Peter Martyr d'Anghiera, chaplain to Ferdinand and Isabella, recorded that Niño brought back "96 pounds of pearls, some as large as hazelnuts, very clear and beautiful, though poorly strung."

At about the same time, Alonso de Ojeda, who had sailed on the first expedition, somehow obtained Colum-



bus's map of the South American mainland and, accompanied by a then-unknown Italian, Amerigo Vespucci (whose account of the voyage would later give the continent his name), returned to the Pearl Coast. He landed on Isla de Margarita and explored Aruba, Bonaire, and Curaçao before moving on to Hispaniola and the Bahamas, obtaining about sixty pounds of pearls.

The quest for pearls soon expanded. Vasco Núñez de Balboa of Spain sailed still farther west, crossing the Isthmus of Panama in 1513. Upon reaching the Pacific coast, he encountered natives wearing pearls. When asked about the source of these riches, the chief responded that the best pearls came from Tararequí in the Gulf of Panama, now called the Archipiélago de las Perlas. As word of Balboa's discovery spread, other Spaniards headed for the Gulf of Panama and returned with sackfuls of pearls. Like those from Venezuela, most Panamanian pearls were destined for Spain.

Once the supply of pearls available through trade was exhausted, the Spanish began organizing pearl-harvesting ventures involving the use of slaves as pearl divers. When Christopher Columbus's son Diego became governor of Hispaniola in 1508, he established the first permanent pearl-fishing settlement on Isla Cubagua. Pearl fishing quickly expanded into other areas of the region, including Isla de Margarita and Isla Coche and eventually all the way to Cabo de la Vela in present-day Colombia. In 1535 Gonzalo Fernández de Oviedo y Valdés, in his *Natural History of the West Indies*, gave the most complete description of pearl diving in the region at that time:

*Many Indians working in groups . . . leave the island of Cubagua . . . and go out in a dugout or boat early in the day to where they think they will find a large quantity of pearls. There they anchor the boat, in which one Indian remains, and he keeps the boat as still as he can. The others dive to the bottom. After some time, an Indian*

*diver's feet want to rise—it is only with difficulty that the worker can remain on the bottom any length of time. Under such conditions, the Indians use two large stones tied together with a cord, which they place over their shoulders, one on each side, and enter the water. . . . When he wants to rise to the surface, he merely drops the stones.*



**Isabel de Valois, wife of Philip II of Spain, in a pearl-encrusted gown**

*will return to the surface and deposit in the boat the oysters in which the pearls are found. He rests a while, takes a bite to eat, and once more he enters the water to stay as long as he can, finally returning with more oysters. . . . Sometimes when the sea is rougher than the pearl fisher would like—and also because naturally when a man is working underwater at a great depth, a*

Working conditions were extremely harsh. Diving bosses, known as *rancheros* or *patrones*, employed teams of four to seven divers per canoe under the supervision of a major-domo. They dived to depths of eight fathoms (forty-eight feet). A diver did not last long on the Pearl Coast, especially in the early years. In 1516 Spain's new king, Carlos V, responding to appeals by the priest Bartolomeo de Las Casas for more humane treatment of the Indians, issued regulations including the maximum hours and depth of diving per day and the minimum requirements for food and lodging. These rules were ignored often enough that further royal edicts became necessary. One such edict imposed the death penalty on anyone forcing a free Indian to become a pearl diver:

*Because report has been made to us that, owing to the pearl fisheries not having been conducted in a proper manner, deaths of many Indians and Negroes have ensued, We command that no free Indian be taken to the said fishery under pain of death. . . . If, however, it should appear to them that the risk of death cannot be avoided by the said Indians and Negroes, let the fishing of the said pearls cease, since we value much more highly (as is right) the*

DETAIL OF PORTRAIT BY ALONSO SANCHEZ COELLO, KUNSTHISTORISCHES MUSEUM, VIENNA. PHOTOGRAPH BY ERICH LESSING; ART RESOURCE





In a 1594 engraving, Theodor de Bry depicted pearl fishing off the islands of Margarita and Cubagua. The area was a primary source of pearls in the sixteenth century.

*preservation of their lives than the gain which may come to us from the pearls.*

Many millions of Venezuelan pearls were collected in the first half of the sixteenth century, virtually flooding European markets. From the ports of Santo Domingo, Cartagena, and Havana, vessels laden with their precious cargoes of pearls and gold set sail for Spain, a trip fraught with danger from several sources. Some ships sank at sea in tropical hurricanes. Other ships were preyed upon by pirates, whose numbers increased during the sixteenth century. Seville became the center of the pearl market, a position Venice had claimed in previous centuries. Garcilaso de la Vega wrote that pearls from the West Indies were so abundant in Seville "that they were sold in a heap in the India [custom] house . . . just as if they were some kind of seed."

Pearls, a symbol of wealth and power, became an obsession among the elite. Without serious competition from other gems (sophisticated faceting techniques for precious stones were not developed until the mid-seventeenth century), pearls were unrivaled. In Europe, enriched by the loot of the Age of Discovery, conspicuous consumption rose to unprecedented levels.

Portraits of European royalty at the time display a wealth of pearls on clothing and in jewelry. Alonso Sánchez Coello's portrait of Isabel de Valois, third wife of Philip II of Spain, carefully renders the large pearls adorning her headdress, necklace, and belt and sewn along her collar, bodice, and shoulders. In another portrait, Catherine de Medici, queen of France in the mid-sixteenth century, is shown with round white pearls on her dress, in addition to a pearl headdress, necklace, and earrings. One of the most famous pearls

from American waters is La Peregrina (often called "The Incomparable"). This pear-shaped white gem, weighing about ten grams, was reputedly a wedding gift from Philip II of Spain to his second wife, Mary I of England. Over the centuries, it passed through a succession of royal hands and, in 1969, was sold at auction to British actor Richard Burton, who gave it to his then wife, Elizabeth Taylor. She still possesses the jewel, although a few years ago she allegedly lost it in the plush white carpet of a hotel room, finding it eventually in her dog's mouth.

As the sixteenth century drew to a close, the known pearl beds of the Americas were increasingly depleted. Between 1513 and 1540, the number of pearls taken from Cubagua alone approached 120 million. Allowing one

pearl per ten pearl oysters, this would mean that 1.2 billion oysters were harvested on that part of the Pearl Coast in just twenty-seven years, or approximately 40 million pearl oysters per year. Few species can recover from this kind of assault.

In the succeeding 400 years, there have been attempts to resuscitate the Venezuelan pearl industry, but most such endeavors have proved unsuccessful. Pearls are still occasionally found in oysters off the coast of Venezuela, however, a reminder of a time when Spanish ships plied those waters in search of pearls and the New World supplied the Old with an abundance of riches.

*Neil H. Landman, of the American Museum of Natural History, is lead curator of the exhibition "Pearls," with co-curators Paula M. Mikkelsen, also of the American Museum of Natural History, and Rüdiger Bieler and Bennet Bronson, of Chicago's Field Museum.*





  
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## MUSEUM EVENTS

### OCTOBER 2

Lecture: "Evolution: The Triumph of an Idea." Carl Zimmer, author of the companion volume to the PBS *Evolution* series and columnist for *Natural History*. 7:00 P.M., Kaufmann Theater.

### OCTOBER 3

Panel discussion: "Genetic Enhancement and Gene Therapy." Historian David Rothman, oncologist Eric Juengst, and legal scholar Dorothy Nelkin. 7:00 P.M., Kaufmann Theater.

### OCTOBER 4, 8, 11, AND 15

Lectures: "Floral Diversity Past and Present," October 4, and "Ecological Biodiversity and Plants," October 11 (Biodiversity and Plants series). William Schiller, Museum botany lecturer. 7:00 P.M., Linder Theater. (The series is repeated on October 8 and 15 at 2:30 P.M.)

### OCTOBER 4, 11, AND 15

Lectures in conjunction with the exhibition "Meeting God: Elements of Hindu Devotion": Curator Stephen P. Huyler; Mary McGee, director of Columbia University's Dharam Hinduja Indic Research Center; and others. 7:00 P.M., Kaufmann Theater. (October 4: Additional lecture by Stephen P. Huyler, AARP series, 2:00 P.M.; exhibition viewing, 6:00–7:00 P.M.)

### OCTOBER 4, 11, AND 18

Lectures: "Sources of Information and Basic Geological Principles," October 4; "Rocks and Their Features," October 11; and "Landscape Classification and Geological Structures," October 18 (Geology for Travelers series). Geologist Sidney S. Horenstein. 7:00 P.M., Linder Theater.

### OCTOBER 6

Exhibition opening: "The Butterfly Conservatory: Tropical Butterflies Alive in Winter." Hall of Oceanic Birds. Through May 27, 2002.

### OCTOBER 10, 16, 23, AND 30

Lectures: "The Hudson: A Visual Journey," October 10; "Navigating Through History: Boats on the Hudson River," October 16; "The Hudson River Estuary: A Spawning Ground and Nursery," October 23; and "Bridges and the Creation of Greater New York," October 30 (Beyond Henry Hudson/AARP series). Historian Roger Panetta, of Marymount College, and Museum natural science instructor Uta Gore. 2:00 P.M., Kaufmann Theater.



KEN HEYMAN

**Focus on the family: *Portrait of a Danish Mother and Child*, from the Margaret Mead Centenary Exhibition, which opens in the Akeley Gallery on October 27**

### OCTOBER 13, 17, 23, AND 25

"Pearls," an exhibition in Gallery 4, opens on October 13. Lectures: "All About Pearls: Their Nature and Culture," Neil H. Landman, curator of the exhibition, and co-curator Paula M. Mikkelsen, October 17; "Pursuing the Dragon: The Mystery of the Orange Pearls of Vietnam" (AARP series), gem collector Benjamin Zucker and author James Traub, October 23; and "Understanding and Appreciating the Queen of Gems—The Pearl," Antoinette Matlins, author of *The Pearl Book*, October 25. 7:00 P.M., Kaufmann Theater.

### OCTOBER 15

Lecture: "The Universe at Midnight" (Distinguished Authors in Astronomy series). Astronomer Ken Croswell. 7:30 P.M., Space Theater, Hayden Planetarium.

### OCTOBER 18

Lecture: "In the Company of Gorillas." Biologist Amy Vedder, director of the Wildlife Conservation Society's Africa Program. 7:00 P.M., Kaufmann Theater.

### OCTOBER 21

Children's workshop and exhibition visit: "Pearls: Legend and Lore." Artist and art historian Ita Aber. 10:30 A.M.–1:30 P.M. Venue to be announced at registration. (For ages 10 and 11.)

### OCTOBER 27

Exhibition opening: "Margaret Mead Centenary Exhibition." Photographs by Ken Heyman, from Mead and Heyman's *Family* (1965). Akeley Gallery. Through May 2002.

### OCTOBER 29

Lecture: "Quasar Absorption Lines: Seeing Ghosts in the Universe" (Frontiers in Astrophysics series). Astronomer Jane Charlton. 7:30 P.M., Space Theater, Hayden Planetarium.

### OCTOBER 30

Lecture: "The Evolution Explosion." Biologist Stephen Palumbi. 7:00 P.M., Kaufmann Theater.

### DURING OCTOBER

Latin American and Caribbean heritage celebration: "Identities Beyond Borders." Free films, lectures, and performances. Leonhardt People Center. For a complete schedule, call (212) 769-5315.

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A woman with dark hair, wearing a green patterned dress and a dark headscarf, is sitting on a wooden floor. She is looking down at an open book she is holding in her hands. The background is a dark, textured wall with some vertical lines, possibly from a stage set or a wall in a theater.

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## IN THE FIELD

# A Squirrel's Glide to a Long Life

*Longevity secrets of a fly-by-night mammal*

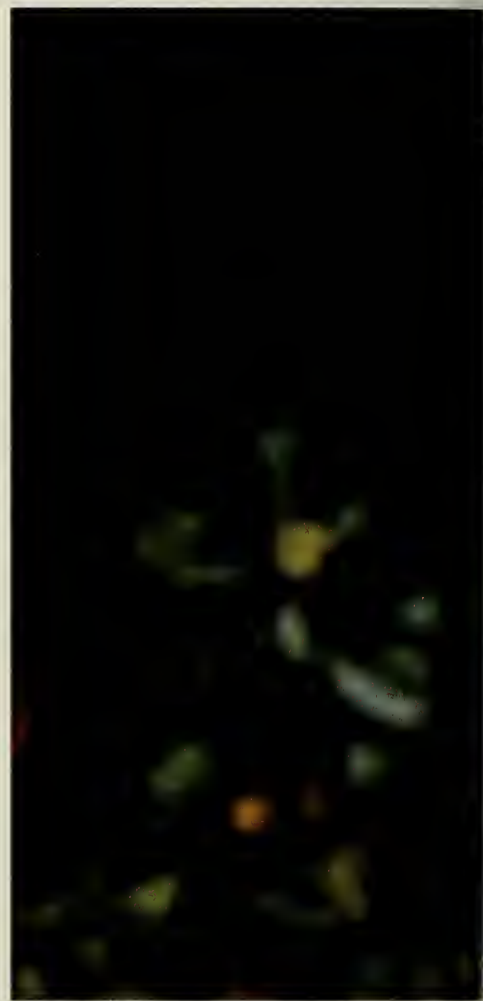
By Peter J. Marchand

An hour or so after sundown, my students and I stepped outside our lodge in the White Mountains of New Hampshire to look at the night sky. The October evening was settling in crisp and clear, the brighter stars already showing through the waning twilight. We were gazing upward, hoping to see a meteor or two, when a shadowy silhouette caught my eye. I turned just in time to see a flying squirrel glide into the darkness of the forest understory. Turning our attention to the woods, we all stood motionless, straining to see the squirrel again. Soon another one appeared, and then another, emerging to forage. It was their time, and we were in the right place.

I couldn't tell for sure whether we were watching northern flying squirrels (*Glaucomys sabrinus*) or the smaller southern flying squirrels (*G. volans*). The ranges of these species overlap along the Appalachian Mountains from the southern United States to New England, and it is difficult enough to tell these squirrels apart in daylight, let alone in the dark. Ecologically, however, they behave much the same, and taken together the two species are quite possibly the most common of all squirrels in the eastern United States, even in wooded parks and urban residential areas. When times are good for flying squirrels, they may number as many as eleven per acre in the spruce-fir and hardwood forests of the Appalachians.

For most other squirrels in the wild, this would be a veritable crowd, but flying squirrels break nearly all the rules with their gliding locomotion, their strong dietary preference for underground truffles, and their unusual longevity. For *Glaucomys*, eleven is mere company.

Numbers, in fact, contribute significantly to the success of these gregarious little squirrels. Weighing only two to four ounces and staying active all year, they have little natural resistance to the cold they may encounter even in the southern Appalachians. But what these animals lack in size and insulation, they make up for in sociability. To cope with winter's chill, flying squirrels huddle together in grass-, moss-, or bark-lined tree cavities. While congregations of about ten are the norm, groups may swell to twenty or even fifty individuals, particularly among southern flying squirrels. And the benefits are considerable. I once slipped a small temperature probe into a tree cavity that I knew was being used by flying squirrels. Weeks later, on a cold January day, I checked on the cavity with my students. As I expected, the temperature in the nest was well above that of the outside air. (Differences of thirty or more degrees are commonly reported.) While we were standing below the tree hole, watching our remote recorder, the temperature suddenly shot up ten degrees, due to a burst of unseen squirrel activity, and



then settled back down. My students had much fun speculating on the nature of this heat-generating action. Although it was a few weeks early for reproductive behavior, cavity sharing may indeed have benefits beyond simply staying warm.

It is not by their social habits alone, however, that *Glaucomys* achieve their relative abundance. They also age more slowly than do other squirrels and, with a life span of ten or more years, live longer than expected for a small mammal—as much as 50 percent longer than, say, ground squirrels of comparable size. This longevity may be tied to their exceptionally low metabolism. Joseph Merritt, of the Carnegie Institute's Powdermill Biological Station in western Pennsylvania, recently found that the average resting metabolic rate of





JOE MERRITT

A leap in the dark: A southern flying squirrel deploys its broad, rudderlike tail and its gliding membranes, which stretch from wrist to ankle. These squirrels' large eyes enhance night vision.

southern flying squirrels was 38 percent lower than expected, based on previous studies of similar-sized mammals. Other tree squirrels occupying the same geographic range as flying squirrels typically have rates at the opposite end of the spectrum—up to four times higher than predicted for their body mass.

While it may seem intuitive that aging and metabolism would be related, this is not necessarily the case among other long-lived animals. Although many reptiles seem to support the “live slow, live long” notion, animals such as hummingbirds can also reach a relatively great age, despite their high metabolic requirements. Perhaps other life-history traits—flying or gliding, for example—favor longevity. Birds in general, excepting poor flyers such as grouse and turkey, have life spans two

or three times longer than mammals of comparable size. And among mammals, bats live the longest relative to body size. In fact, most of the world's gliding mammals appear to outlive their earthbound counterparts by a significant margin. For flying squirrels in particular, the combination of gliding, nocturnal habits, and tree-cavity nesting may confer significant advantages by reducing their vulnerability to predation. And in the evolutionary game, safety, rather than low metabolic rate, could make the difference.

Last fall I accompanied Joe Merritt on his rounds at the Powdermill reserve. For twenty years Joe has weighed, marked, and released flying squirrels that enter live traps attached to tree trunks. This time, in the space of only an acre or so, he caught three

new, unmarked southern flying squirrels. Judging by their weight—all three were less than two ounces—these young squirrels were from a pair's second litter of the summer, born in August. Already, however, they were adept gliders and had become familiar with their territory. As Joe released the first one, it climbed quickly up a tall, straight yellow poplar. At a height of nearly seventy feet, it turned face

downward and launched unhesitatingly into a long, graceful glide across a stream. The squirrel clearly knew just where it wanted to go. Steering with all four limbs and using its tail as a rudder, it navigated toward and landed directly on its target: the trunk of a dead white oak. It scampered forty feet up the oak, then disappeared under a slab of loose bark that more than likely concealed a nest cavity. It was a treat to observe this nocturnal creature in broad daylight, and my thoughts immediately went back to that evening in New Hampshire when my students and I felt so privileged to have caught just a glimpse of this very common but seldom seen tree squirrel.

*Peter J. Marchand is a research ecologist at the Catamount Institute in Woodland Park, Colorado.*



## UNIVERSE

# Between the Planets

*The emptiness of interplanetary space has been much exaggerated.*

By Neil deGrasse Tyson

From a distance, our solar system looks empty. If you enclosed it within a sphere large enough to contain the orbit of Neptune, then the volume occupied by the Sun, the planets, their moons, and all asteroids would take up little more than one-trillionth of the space. When viewed close-up, however, the space

between the planets contains all manner of pebbles, chunky rocks, ice balls, dust, streams of charged particles, and far-flung probes. The space is also permeated by monstrous gravitational and magnetic fields.

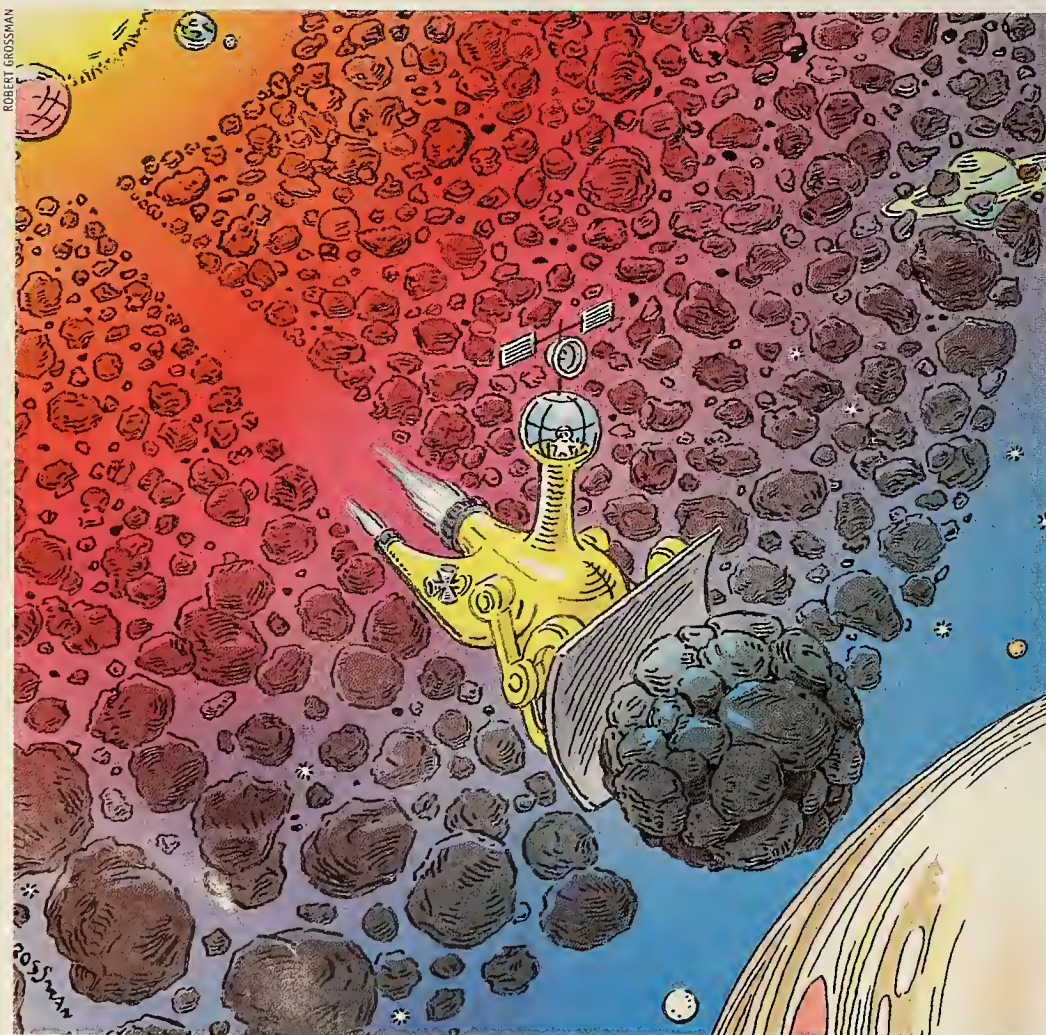
Space is so not-empty that Earth, during its eighteen-mile-per-second orbital journey, plows through hun-

dreds of tons of interplanetary debris per day—much of it no larger than a grain of sand. Nearly all of it burns in Earth's upper atmosphere, slamming into the air with so much energy that it vaporizes on contact. The larger, golf-ball-sized pieces of debris heat fast but unevenly and often shatter into smaller pieces before they vaporize.

Still larger pieces get their surfaces singed but otherwise make it all the way to the ground intact. You'd think that by now, after 4.6 billion trips around the Sun, Earth would have vacuumed up all possible debris in its orbital path.

But things were once much worse. For half a billion years after the formation of the Sun and its planets, so much junk rained down on Earth that the energy from the impacts sustained a heated atmosphere and a molten surface.

One hunk of junk in particular was quite substantial—it's what led to the formation of the Moon. The unexpected paucity of iron and other high-mass elements in the Moon (deduced from lunar samples returned by Apollo astronauts) indicates that the Moon most likely burst forth from Earth's iron-poor crust and mantle when our





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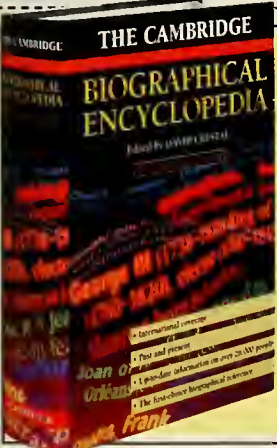
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planet had a glancing collision with a wayward, Mars-sized protoplanet. The orbiting flotsam resulting from this encounter coalesced to form our lovely, low-density satellite. Apart from this newsworthy event, the period of heavy bombardment that Earth endured during its infancy was not unique in the solar system: all the planets and other large bodies sustained similar damage, with the airless, uneroded Moon and Mercury preserving much of the cratered record from this period.

Not only is the solar system littered with the detritus of its formation, interplanetary space also contains rocks of all sizes that were thrust from Mars, the Moon, and probably Earth as the ground recoiled from high-energy impacts. Computer studies of meteor strikes demonstrate conclusively that surface rocks near ground zero can get thrown upward with enough speed to escape a celestial body's gravitational tether. Meteorites originating from Mars turn up so often on Earth that scientists have concluded that as much as a thousand pounds of Martian rocks may rain down on us each year. Perhaps the same amount reaches Earth from the Moon. Indeed, we didn't have to go there to retrieve Moon rocks, although we didn't know this during the Apollo program. Plenty come to us, even if they are not of our choosing.

If Mars ever harbored life—billions of years ago, when its surface was wet with liquid water—then unsuspecting bacteria stowed away in the nooks and crannies (especially the crannies) of the ejected rocks could have traveled to Earth for free. We already know that some varieties of bacteria can survive long periods of hibernation as well as the high doses of ionizing radiation to which traveling microorganisms would have been exposed en route to Earth. So the existence of space-borne bacteria is neither a crazy idea nor pure science fiction. The concept even has an important-sounding name: panspermia. If Mars spawned life before Earth

did, and if simple life traveled from Mars on an ejected rock and seeded Earth, then we may all be descendants of Martians. Awareness of this fact may also obviate environmentalists' fears about astronauts sneezing on the red planet's surface, spreading their germs on the alien landscape.

Most of the solar system's asteroids live and work in the main asteroid belt, a somewhat flat zone between the orbits of Mars and Jupiter. Often drawn

*Meteorites of Martian origin are regularly discovered on Earth. As much as a thousand pounds of rocks from the red planet may rain down on us each year.*

by artists as a region of cluttered, floating rocks in the plane of the solar system, the asteroid belt's total mass is less than 5 percent that of the Moon, which is itself not much more than 1 percent the mass of Earth. Sounds insignificant. But accumulated perturbations of the asteroids' orbits continually feed a deadly subset of objects, perhaps a few thousand, whose eccentric paths intersect Earth's orbit. A back-of-the-envelope calculation demonstrates that most of them will hit our planet within the coming 100 million years. Those larger than about a mile across will bang into Earth with enough energy to destabilize our ecosystem and put most land species at risk of extinction. That would be bad.

Asteroids are not the only space objects that pose a risk to life on Earth. The Kuiper belt is a circular, comet-strewn swath of real estate that begins just beyond the orbit of Neptune, includes Pluto, and extends perhaps as far again from Neptune as Neptune is from the Sun. The Dutch-born American astronomer Gerard Kuiper advanced the idea that frozen leftovers from the formation of the solar system reside in the cold reaches of space beyond Neptune's orbit. Without a massive planet to fall upon, most of these comets will orbit the Sun for billions

more years. Like their counterparts in the asteroid belt, a subset of Kuiper belt objects travel on eccentric paths that cross the orbits of other planets. Pluto and its ensemble of siblings called Plutinos cross Neptune's path around the Sun. Other Kuiper belt objects plunge all the way down to the inner solar system, crossing planetary orbits with abandon. One of these is Halley, the most famous comet of them all.

Far beyond the Kuiper belt, extending halfway to the nearest stars, lives a spherical reservoir of comets called the Oort cloud, named for Jan Oort, the Dutch astronomer who first deduced its existence. This zone is responsible for the long-period comets, whose orbital periods last far longer than a human lifetime. Unlike Kuiper belt comets, Oort cloud comets can rain down on the inner solar system from any angle and any direction. The brightest comets of the 1990s—comets Hale-Bopp and Hyakutake—both emerged from the Oort cloud and are not coming back this way anytime soon.

Not everything that fills interplanetary space is visible. If we had eyes that could see magnetic fields, Jupiter would look ten times larger than the full Moon in the sky. Spacecraft that visit Jupiter must be designed to remain unaffected by this powerful magnetic field. As English physicist Michael Faraday demonstrated in the 1800s, if you pass a wire across a magnetic field, you generate a voltage difference along the length of the wire. For this reason, electric currents can be induced within fast-moving metal space probes. These currents happen to generate a magnetic field of their own that interacts with the ambient magnetic field in such a



way as to retard the space probe's motion. This might be the cause of the mysterious slowing-down of the two *Pioneer* spacecraft as they exit the solar system. Neither *Pioneer 10* nor *Pioneer 11*, both launched in the early 1970s, has traveled as far into space as our dynamic and kinematic models predicted they would have by now. If we subtract the possible effects of leaky fuel tanks and space dust en route, the best explanation for this pokiness becomes magnetic interaction—in this case, with the Sun's field.

Once upon a time, there were fifty-six moons among the planets in the solar system. When I woke up one morning in 1995 to learn that another four had been discovered around Saturn, I decided I would no longer keep count. All I care about now is whether any of them would be fun places to visit or study. By some measures, the solar system's moons are much more fascinating than the planets they orbit. In Jonathan Swift's 1726 classic, *Lemuel Gulliver* learns from the cloud-dwelling scientists of Lagado that Mars has two Moons. Problem is, these two potato-shaped bodies were not discovered until a century and a half later. Earth's Moon is about 1/400 the diameter of the Sun, but it's also 1/400 as far from us, making the Sun and the Moon the same size in the sky—a coincidence not shared by any other planet-moon combination in the solar system, and one that allows for uniquely photogenic total solar eclipses. Earth has also tidally locked the Moon, leaving it with identical periods of rotation on its axis and revolution around Earth. Wherever and whenever this locking happens, the moon shows only one face to its host planet.

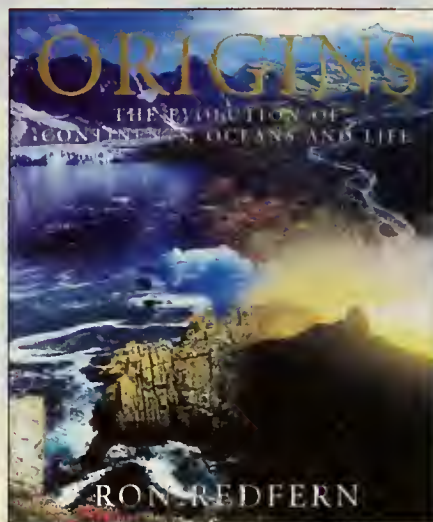
Jupiter's system of moons is replete with oddballs. Io, Jupiter's closest satellite, is tidally locked and structurally stressed by its interactions with Jupiter and with the planet's other moons—which pump enough heat into the little

orb to render its interior rocks molten. Io is the most volcanically active place in the solar system. Jupiter's moon Europa suffers from the same heating mechanism, which has melted its subsurface ice, leaving a liquid ocean below. (An artist coworker of mine once asked whether alien life-forms from Europa are Europeans. The absence of any other plausible answer forced me to say yes.) Close-up images of the surface of Miranda, one of

Uranus's moons, reveal badly mismatched patterns, as though the poor moon had blown apart and the pieces were hastily glued back together. The origin of these exotic features remains a mystery but may be due to something simple, such as the uneven upwelling of ice sheets.

Pluto's lone moon, Charon, is so large and so close to Pluto that the two bodies have each tidally locked the other, making their rotation peri-

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ods as well as their periods of revolution identical.

By convention, planets are named after Roman gods, and moons are named after lovers, friends, and enemies of the Greek counterparts of these Roman gods. The classical gods led complicated social lives, so there is no shortage of characters to draw on. The lone exception to this rule applies to the moons of Uranus, which are named for assorted protagonists in English Lit. Astronomer Sir William Herschel was the first person to discover a planet beyond those easily visible to the naked eye, and he was ready to name the new planet after the king under whom he faithfully served. Had Sir William succeeded, the planet list would read: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Neptune, and George. Fortunately, clearer heads prevailed and the classical name Uranus was adopted some years later. But his original suggestion—to name the moons after characters in William Shakespeare's plays and Alexander Pope's poems—remains the tradition to this day. Among Uranus's nearly two dozen moons we find Ariel, Cordelia, Desdemona, Juliet, Ophelia, Portia, Puck, and Umbriel.

Streaming toward objects in the solar system is the solar wind. The Sun loses material from its surface at a rate of 200 million tons per second (which happens to match closely the flow rate of water through the Amazon basin). Most of this material takes the form of high-energy charged particles. Traveling up to a thousand miles per second, they fly through space and are deflected by planetary magnetic fields. The particles spiral down toward the planets' north and south magnetic poles, colliding with gas molecules and leaving the atmospheres aglow with colorful auroras. The Hubble Space Telescope has spotted auroras near the poles of both Saturn and Jupiter. On Earth, the aurora borealis and aurora australis (the northern and southern lights) serve as

intermittent reminders of how nice it is to have a protective atmosphere.

Earth's atmosphere is commonly described as extending a couple dozen miles above Earth's surface. Satellites in "low" Earth orbit typically travel between 100 and 500 miles up and complete an orbit in about ninety minutes.

*Satellites in low orbit can be dragged down by scattered molecules of atmospheric gas. Only intermittent boosts of power prevent a fall back to Earth.*

While you can't breathe at those altitudes, some atmospheric molecules remain—enough to slowly drain kinetic energy from moving satellites. To combat this drag, satellites in low orbit require intermittent boosts lest they burn up in the atmosphere. The most sensible way to locate the edge of our atmosphere is to find where its density of gas molecules equals the density of gas molecules in interplanetary space. By this definition, Earth's atmosphere extends out thousands of miles. Orbiting high above this level—23,000 miles up, one-tenth the distance to the Moon—are the communications satellites. At this special altitude, where interference from Earth's atmosphere is not a factor, the satellites take twenty-four hours to complete one revolution around Earth. With an orbital speed that precisely matches the rotation rate of Earth, these satellites effectively hover, which makes them ideal for relaying signals from one part of Earth's surface to another.

Newton's laws specifically state that although the gravity of a planet gets weaker and weaker the farther you travel from it, at no point does the force of gravity reach zero. The planet Jupiter, with its mighty gravitational field, slings out of harm's way many comets that would otherwise wreak havoc on the inner solar system. Jupiter acts as a gravitational shield for Earth, allowing us 100-million-year stretches of relative peace and quiet. Without

Jupiter's protection, terrestrial life would have had a hard time becoming interestingly complex, remaining at risk of extinction from a devastating impact.

Nearly every probe launched into space has exploited the gravitational fields of planets. The *Cassini* probe, for example, now en route to Saturn, was

launched from Earth on October 15, 1997, and has since been gravitationally assisted twice by Venus, once by Earth (on a return flyby), and once by Jupiter. As with a multicushion billiard shot, trajectories from one planet to another are common. Our tiny probes would otherwise not have enough speed and energy to reach their destinations.

I am now personally accountable for some of the solar system's interplanetary debris. In November 2000 the main-belt asteroid 1994KA, discovered by David Levy and Carolyn Shoemaker, was named Tyson 13123 in my honor. While I enjoyed the distinction, there's no particular reason to get big-headed about it; plenty of asteroids have familiar names, such as Jody, Harriet, and Elliot. There are even asteroids out there named James Bond, Merlin, and Santa. Passing the 20,000 mark, the asteroid count might soon challenge our capacity to name these objects. Whether or not that day arrives, I enjoy a curious comfort knowing that my chunk of cosmic debris is not alone as it litters the space between the planets, joined by a long list of other chunks named for real and fictional people.

I'm also glad that at the moment, my asteroid is not headed toward Earth.

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







## NATURALIST AT LARGE

# Coming Home

*Under the tutelage of baboons, a scientist learns to appreciate her animal self.* By Barbara Smuts



BARBARA SMUTS: ANTHRO-PHOTO FILE

Gombe Stream National Park, Tanzania: Bofu, an adult male baboon, takes a break.

I've joined chimpanzees carousing in the hot, rugged hills of western Tanzania, baboons strolling across the golden grasses of highland Kenya, gorillas munching their way through the foggy mountains of central Africa, and dolphins gliding through the aquamarine Indian Ocean. In all these worlds I felt at home. I loved the freedom, the feel of the sun, the smell of the air, the tranquillity of dusk, the beauty of my animal companions.

Over the past thirty years, wild ani-

mals and places have taught me things about human nature—and about my own nature in particular—that I could never have anticipated back when I chose to become a biologist. At first, I approached wild primates as subjects to be studied. The places they lived and hunted were “habitats” that I needed to know about simply because they influenced the animals’ behavior. Although I loved these creatures (and their surroundings), between us lay an uncomfortable gap—an outgrowth of

my scientific orientation. Then something started to happen that would help bridge the gap. Slowly, imperceptibly at first, another identity began to assert itself within me, an identity I will refer to as “the animal,” though really it requires no name. It is simply myself.

During my first two years in the field, my scientist self and my animal self lived together without speaking. The animal didn't in any way interfere with the scientist's activities; in fact, she often helped. She noticed things that



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the scientist missed, such as the tension in the air before a male chimpanzee began to display or the longing of a female baboon for her male friend. She knew these things not in words but with a keen, intuitive awareness. Later, back at the university, I began to reflect on the animal. I wondered who she really was, and I wondered what I might learn about other animals and my fellow humans from examining this aspect of myself. I wanted to know the animal better, for both scientific and personal reasons. But to know her better, I had to evoke her more often and more intensely. The scientist would have to move over and make more room for the animal.

When I returned to the field, I gave some time over entirely to the animal. The scientist conducted observations of foraging baboons; the animal joined

*The baboons were expert guides, and I abandoned myself to their far superior knowledge.*

the baboons on exciting adventures to unexpected places: same journey, more fun. On my own, I could easily have become lost in this vast place with no trails, no signs pointing homeward, and no people. But I was lucky; the baboons were expert guides, and I abandoned myself to their far superior knowledge. They taught me things like how and when to scan the horizon for predators, shortcuts to water sources, the best places to find mushrooms and ripe fruit, the coolest places for naps, and the location of rock overhangs for shelter from the rain. I was regaining the kind of knowledge that belonged to my ancestors, and I was doing so in the place where, several million years ago, humans first evolved. It felt like coming home.

Nevertheless, in the early days I tried to understand my animal self in scientific terms, focusing especially on what I knew about human evolution. Comparing my upright stance to the baboons'

four-footed gait, I tried to figure out the advantages of bipedalism. When I froze in the morning and burned in the sun later the same day (my baboon field site near Gilgil, Kenya, was more than a mile above sea level), I wondered why we humans ever lost our protective coat of hair. Gradually, however, my awareness shifted from the thoughts filling my head to moment-to-moment reality. With each step, I could feel how I was designed to flourish in the wild. My eyes, like yours, are made to scan for bright-colored fruit and for predators moving in the distance. My ears are made to notice a rustle in the grass or the faint cry of a baby. My feet are made to feel the texture of the ground. My hands are made to grasp and to caress, my arms

to throw and embrace, my heart to beat fast or slow in response to the matrix of sounds, sights, and scents in which I am enveloped. And my whole being is made to stay open every moment to every sensory nuance.

Over time, my animal self grew more confident. The animal wanted to do things she was made for: walking for miles in a slow, steady rhythm; snacking on seeds and fruit throughout the day; sleeping through the heat of the afternoon. Because I was designed to do such things, I tended to do them rather well and with great enjoyment. Nowadays when I travel by foot in wild places, I rarely need to stop and think, "Where should I go? What should I eat? Is it time to make camp for the night?" Instead I respond from moment to moment, surrendering gently to instinct—not as mindless, reflexive action but rather as action rooted in the certainty of knowledge, deep and old.

The actions of wild animals stem

from this place of deep knowing. A chimpanzee may respond to a leopard's threat with a highly inventive act that no chimpanzee has ever used before, but the awareness of the need to re-



Gilgil, Kenya: The author and a baby baboon

spond quickly and defensively arises without effort, without pause. Similarly, a mother baboon knows how to nurse and comfort her baby without instruction. Even when skills depend greatly on experience, on learning, the learning itself is guided by ancient knowledge about what to learn and how to learn it. This kind of knowledge exists in all of us, waiting to be recognized and used.

Trusting such deep knowing is, I'm convinced, a good way to live. Of course, the wild animals I lived with got grouchy, went hungry, and suffered fear and pain and loss. But these creatures seemed quite happy most of the time. Each morning as baboons descend from their sleeping places, all troop members, but especially females and young, enthusiastically greet one another with gentle pats, hugs, and other affectionate touching. Sometimes a greeting turns into play, as when a saucy adolescent female ends her hello to an adult male with a somersault flourish. As the day heats up, baboons are given to taking long breaks in attractive locales, where they indulge their passion for lying in the shade with a foot or two in the air. This is a favorite time for grooming, which seems to relax the groomee the way a good massage relaxes us. Every now and then, someone emits a deep, satisfied sigh. Off and on, a chorus of



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soft grunts ripples gently among the baboons, as though they concur about the agreeableness of their situation.

When I first went to the field, I viewed these siestas as valuable opportunities to gather data on who slept near whom. Later, I would sometimes lie around with them instead. Later still, I would sometimes lie around without them (that is, they were present but busy eating). Once I fell asleep surrounded by 100 munching baboons, only to wake up after half an hour—alone except for an adolescent male napping by my side. We blinked at each other and then he led me back to the rest of the troop, miles away.

By associating with baboons (as well as with chimpanzees, gorillas, dolphins, and others) and surrendering to my animal self, I learned how satisfying it can be just to be. This lesson has changed me, irrevocably. Although I still function as a scientist and enjoy doing so, the work no longer feels intrinsic to my identity. My identity now feels paradoxically both firmer and more fluid, more entwined with my surroundings.

We humans (at least in the West) tend to consider autonomy and community as opposite states of being, but I suspect that baboons, and perhaps many other animals, experience themselves as both distinct agents and a part of something bigger. There can be no doubt that baboons are distinct individuals—highly idiosyncratic characters, in fact, each and every one. I can recall Alex's long-limbed lope and Virgil's throaty bark. Each baboon has favorite foods (one alpha female, Dido, was crazy about mushrooms), favorite ways to take a nap (Boz liked to wrap his arms around a suitable-sized bush, leaning into it like a lover). Many had peculiar habits: Himalaya, a lusty female, used to capture the attention of a potential suitor by bending over and peering at him upside down, from between her legs; Triton, a young adult male, carried around scraps of rabbit fur gleaned from recent kills to hurl at

the rumps of estrous females who ignored him.

I relished the animals' individuality because it made them so interesting to be with. In so doing, I developed a greater acceptance of and appreciation for my own idiosyncratic nature. I could see aspects of myself, both "good" and "bad," reflected in individual baboons. I identified with one mother's gentle treatment of her infant but also with another mother's impatient shove when the kid got in the way. I had no impulse to condemn "bad" traits in the baboons, because I could see clearly how each individual's distinct nature depended on a unique configuration of strengths and weaknesses. I began to try to apply the same accepting attitude toward myself.

### *Once I fell asleep surrounded by 100 baboons, only to wake up alone except for an adolescent male.*

This was difficult when I thought in terms of my culturally constructed, specifically human identity; easier when I thought of myself as just another primate. In the same way, upon returning to civilization I tried to judge other people less. Again, this proved easier when I remembered that they, too, are just other primates, doing the best they can in a world ever more alien to their animal natures.

Although every baboon (or chimpanzee or dolphin) is a distinct, highly individuated self, each seems to exist simultaneously as self-in-community or even as self-in-communion. When the baboons responded to an intrusion into their home range by a neighboring troop, they could move as one toward the enemy, like a well-trained army. But they also expressed community when they were well fed and facing no threat. Gathering on their sleeping cliffs at night, the group would sing a song of gentle grunts, with the deep voices of the adult males, the softer voices of the females, and the high-pitched voices of the young blending in a harmony that

seemed to express their delight at being part of a close-knit group.

Sometimes their sense of community seemed to move beyond the boundaries of their ordinary lives. I treasure one memory in particular. A troop of baboons in Gombe Stream National Park, Tanzania, were traveling to their sleeping grove late one afternoon, moving slowly down a stream punctuated by smooth boulders and still pools. Without any perceptible signal, everyone stopped and then sat, alone or in small clusters, gazing into the pools. Even the perpetually noisy, scrappy juveniles fell into silent contemplation. Half an hour later, again with no signal I could detect, they resumed their journey, in what felt to me

like an almost sacramental procession. I was stunned by this mysterious expression of what I have come to think of as a baboon *sangha* (spiritual community).

A rhythm of change lies at the center of this account. My relationship with the natural world began with a longing to be in nature, a longing stemming in part from a sense of separation from nature. Over time, the feeling of separation dissolved. I discovered that I am as intrinsic a part of the wild landscape as are the baboons, and I learned that my body, like theirs, harbors the wisdom of the ages. This wisdom connects me to everyone and everything else, reminding me that every habitat is someone's dearest home. All of it is alive, and all of it deserves reverence.

*Barbara Smuts, author of Sex and Friendship in Baboons (Harvard University Press, 1999), teaches animal behavior in the psychology department of the University of Michigan. Her current research interests include greeting behavior in wild baboons and social play among domestic dogs.*



A toucan bird with a large, colorful beak is perched on a branch in a lush green forest. The bird has a black body with a yellow and red throat. The background is filled with dense green foliage and tree branches.

taking *flight*

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# costa *rica*



*If you're looking for an autumnal vacation that's a little more exciting than leaf peeping, take flight and join the fall migration to peek at some of the most breathtaking beauty in the world. You can take flight to Central Park in New York City and watch the hawks migrate south from Belvedere Castle, or you can take flight to Latin America and the Caribbean to find a colorful quetzal in Costa Rica. A birding vacation is the perfect fall getaway, a chance to experience nature's riches in a new and exciting way.*

Christopher Columbus first gave Costa Rica her name: "rich coast." With only 20,000 square miles, Costa Rica is rich in biodiversity and natural beauty. The government has protected 30 percent of its territory in national parks and forest preserves, allowing visitors to take advantage of this incredibly rich coast. And with almost 850 species of birds, Costa Rica has long been famous among bird watchers.

Visitors usually fly into Costa Rica's Juan Santamaría International Airport, located in the capital, San José. Although San José was founded in the mid-1600s, it didn't become the nation's capital until the 1820s, after Costa Rica's independence from Spain. Make sure you spend at least a day in this bustling colonial city before heading out to explore the rest of the country. Your first stop in San José should be the offices of the Costa Rican Institute of Tourism. The ICT can help point you in the right direction and provide you with a map of the city to help you get your bearings.

After taking advantage of San José's lovely parks, cathedrals, and museums, you can take a day trip or several overnight trips to Costa Rica's Central

Valley. The Reserva Forestal Cordillera Volcánica Central is made up of close to 165,000 acres of protected land, including three national parks and a variety of private and national forestry reserves. Here you can easily explore the Volcano Route between four of the area's volcanoes – Irazú, Turrialba, Barva, and Poás.

One of Costa Rica's newest ecotourism destinations is located only an hour out of San José, near Poás Volcano National Park. La Paz Waterfall Gardens offers visitors the choice of four hiking trails that wind around five waterfalls and through a tropical forest.

Before heading down to the falls, the trail first leads into a huge butterfly observatory. The enclosed structure allows butterflies to soar freely while visitors walk around the natural habitat. The next stop on the trail is a lovely hummingbird garden that 16 different species of hummingbirds call home. After exploring the Central Valley, you can find plenty of restaurants in San José to help extend the pleasures of the day. Nearly every cuisine in the world is represented, and each one will include typical "Tico" warmth and hospitality.




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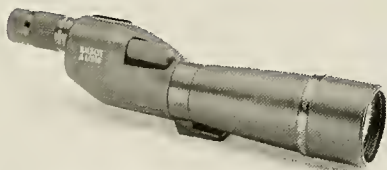
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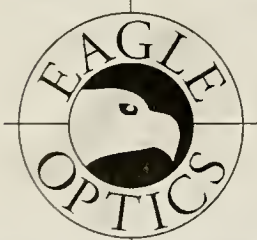


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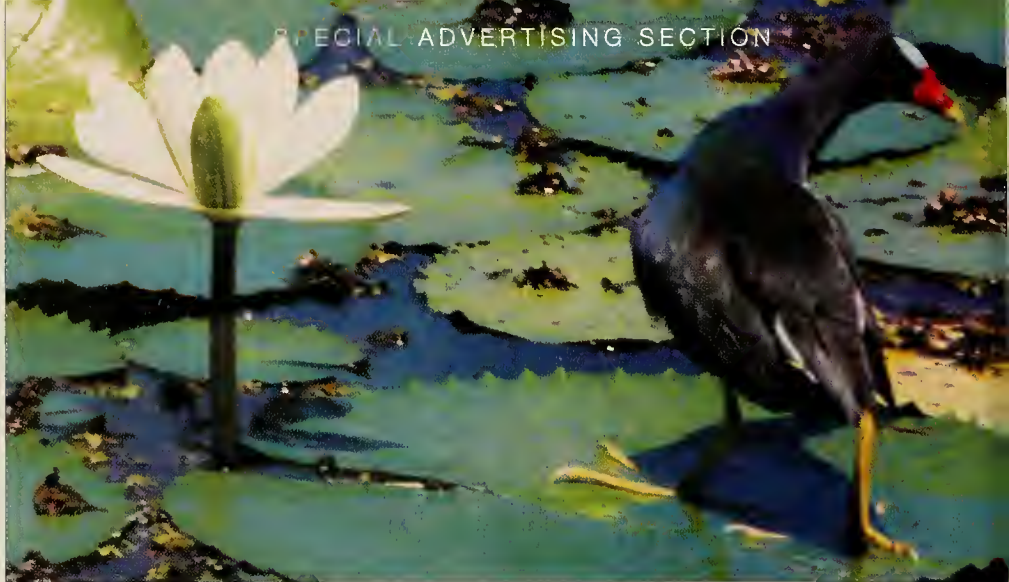
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Eagle Optics, the leader in supplying optic equipment to bird watchers, amateur astronomers, and outdoor enthusiasts, supports a number of nature festivals around the country, and this fall is no exception. On

October 4-7, Eagle Optics is a proud sponsor of the Florida Birding Festival and Nature Expo at the Harborview Center in Clearwater, Florida.

The Expo will offer field trips, exhibitions, demonstrations, and lectures. Take an expedition through Pinellas County's newest park, Wall Springs. And an evening walk on the beach under the stars will be a remarkable nature experience as guests learn about tidal influences and discover the birds, crustaceans, and other creatures that make the beach home. An impressive lineup of keynote speakers includes Dr. Jerry Jackson, who will present "John James Audubon - His Art and Science;" Arthur Morris, who will teach the "Art of Bird Photography;" and Paul Konrad, who will host "Favorite Birding Hotspots."

In addition to promoting the natural beauty of Florida, the festival's goal is to expand conservation and environmental management efforts throughout the Tampa Bay area. To support this effort, proceeds from the festival will benefit the Pinellas County Environmental Foundation (PCEF).

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One of your stops on the Alabama Coast should be the Bird Banding Station at Fort Morgan State Park. This fall's bird banding will take place from October 6th through the 18th. The Hummingbird Study Group captures and bands hummingbirds and other Neotropical migrants at this historic location, which is the last departure point for thousands of migrating birds before they journey across the Gulf of Mexico. Banding sessions at the Fort Morgan Bird Banding Station are open to the general public. There is an admission fee to get into the fort, but the banding sessions are free.

Before you head down south, call the Alabama Gulf Coast Convention & Visitors Bureau for a copy of the Alabama Coastal Birding Trail brochure, a 51-page booklet, complete with maps and full-color photographs, that introduces visitors to the trail. The brochure gives directions to the area's most-frequented birding spots and lists the indigenous Alabama birds and migratory Neotropical songbirds that might be observed in the different habitats around the Gulf Coast.



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This year, Swift introduced the Swift 829 Warbler, a newly designed waterproof binocular that weighs only 20 ounces. Specifically designed with a bird watcher in mind, this binocular has a textured

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Norwegian Coastal Voyage

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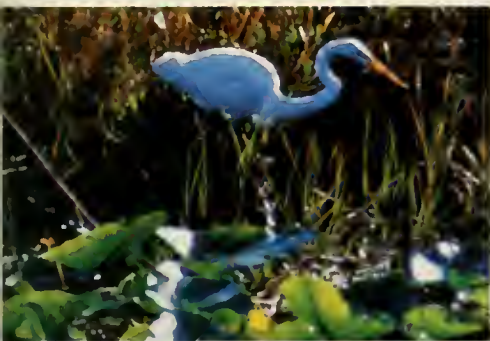
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# Maryland *birding*



In the fall, sparrows, warblers, and yellow throats all stop in Maryland on their annual migration south. Visit Charles County to take advantage of a dense population of nesting bald eagles, acres of beautiful forestland, and 150 miles of spectacular shoreline. The county is bordered on the east and south by the Potomac River, on the west by the Wicomico River, and

on the north by the Mattawoman Creek. The habitat includes many large and small lakes, ponds, and extensive wetlands.

Chicamuxen Wildlife Management Area abounds with a wide variety of waterfowl species. Check your field guide to identify gadwalls, widgeons, wood ducks, hooded mergansers, ringnecks, and maybe a scalup or a canvasback. Also, adult and immature bald eagles can be seen almost daily hunting the marshes and upland areas.

Birding in Worcester County offers a remarkable unspoiled wilderness that attracts, sustains, and protects much natural life. Within a radius of just a few miles exist the unique—yet easily accessible—worlds of a barrier island, a cypress swamp, centuries-old forest, tidal wetlands, and secluded fields. Stop along the coast in Assateague and view innumerable migratory species, including peregrine falcons, merlins, and enormous flocks of tree swallows continuing their flight south.

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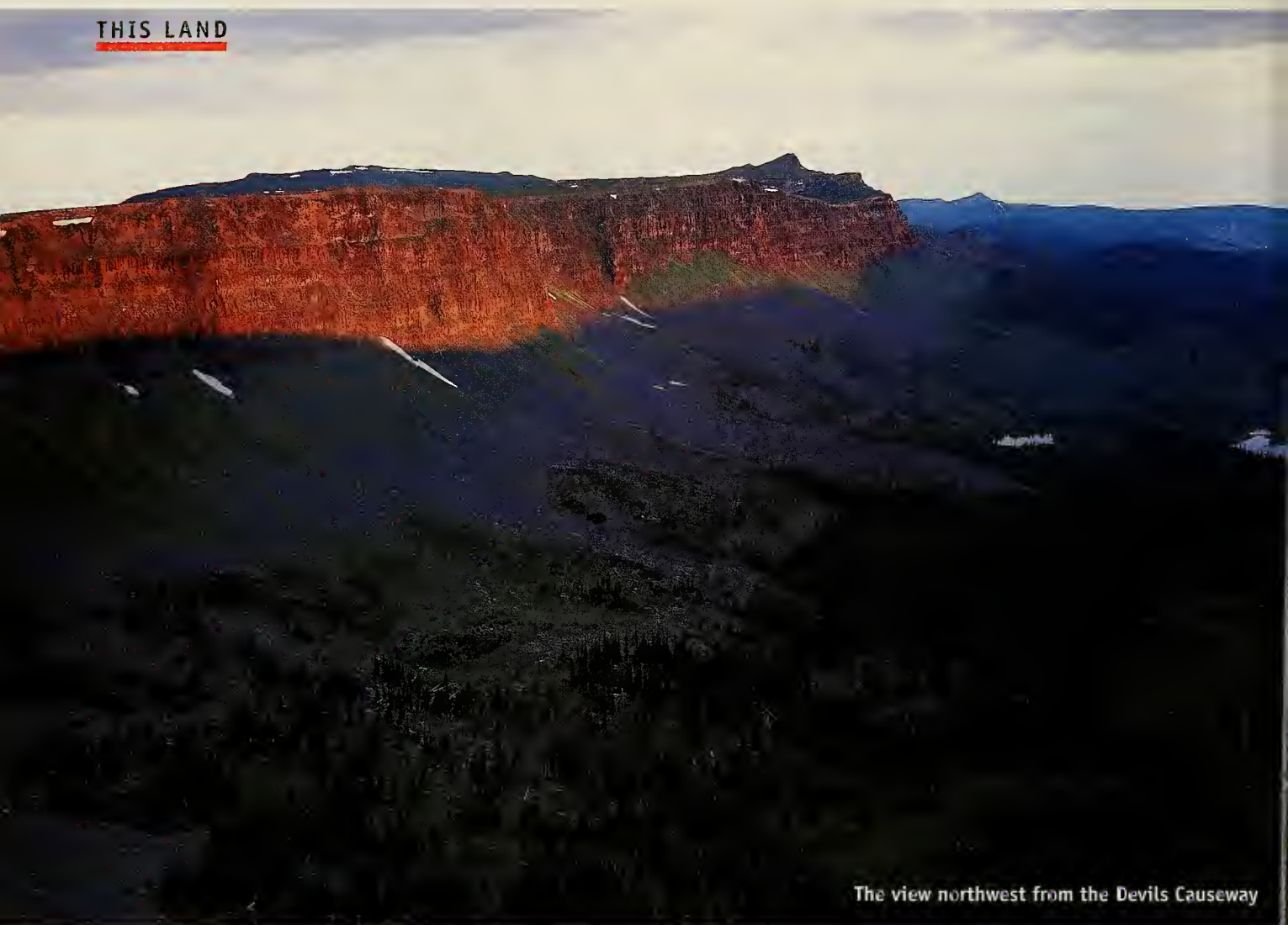
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## THIS LAND



The view northwest from the Devils Causeway

# Colorado's Flat Tops

Lava, glaciers, wind, and water have left a legacy of eye-catching mountains.

By Robert H. Mohlenbrock

**I**n northwestern Colorado, within the great Rocky Mountain range, is a mass of blunt-topped mountains known as the Flat Tops. Rising roughly 9,000 to 12,000 feet above sea level, they have been carved out at the eastern edge of a large plateau by the action of wind, water, and Ice Age glaciers. The patterns of erosion are striking, in part because underlying layers of sedimentary rocks

(sandstone, limestone, shale) are capped by a harder layer of basalt, a volcanic rock. Some of the mountains have amphitheater-like shapes that almost appear to be the work of giants.

Flowing westward across the plateau from the Flat Tops is the White River, a tributary of the Colorado. It passes through rolling grasslands and, in less arid areas (generally on north- or east-facing

slopes and along streams), through stands of forest. Above the timberline, which lies at about 10,200 feet, the habitat is alpine tundra. From there down to about 8,100 feet is a subalpine forest with subalpine fir, mountain ash, and other species. Below this level grows montane forest, where the subalpine fir and mountain ash are virtually absent. A spruce bark beetle epidemic in the middle of the



twentieth century left behind many standing dead trees in the Flat Tops area, so it is often referred to as the Ghost Forest.

The Flat Tops fall within the Routt and the White River National Forests, where a nearly 370-square-mile section has been designated the Flat Tops Wilderness Area. This rugged zone is off-limits to motorized vehicles and equipment, but a scenic, mostly gravel highway meanders across the plateau for eighty-two miles, connecting Yampa and Phippsburg in the east to Meeker in the west. Taken westward, the highway first climbs to Dunckley Pass and, after following a roller-coaster course, tops out at 10,343 feet at Ripple Creek Pass. It then descends toward the North Fork of the White River. The main road continues downriver, but a turnoff can be followed upriver for about eight miles to Trappers Lake, near which are a campground and the Trappers Lake Lodge and Resort.

Trappers Lake, which lies within the wilderness area, was the first U.S. National Forest property to be treated as a wilderness—long before Congress passed the Wilderness Act of 1964. In 1919 the U.S. Forest Service hired a young landscape architect, Arthur H. Carhart, and told him to do a survey for a road around the lake and several homesites on the lakeshore. Carhart completed the task but urged his supervisor, Carl Stahl, to save the lake for wilderness recreation. Stahl backed the recommendation, and in 1920 Trappers Lake was declared an area to be kept free of roads and development. Carhart's vision remains a landmark in the history of wilderness preservation: "There is a limit to the number of lands of shoreline on the lakes; there is a limit to the number of lakes in existence; there is a limit to the mountainous areas of the world," he wrote in a memorandum. "There are portions of natural scenic beauty

which are God-made, and . . . which of a right should be the property of all people."

Trappers Lake is nearly a mile and a half long and a little more than half a mile across at its widest point. Providing a formidable background on its northeast side is the so-called Chinese Wall, a sheer face that rises 1,650 feet. This basalt formation extends for nearly five miles in an irregular semicircle. Because of its sheerness and direct exposure to the afternoon sun, the side facing the lake is bare of vegetation except for some rock-hugging lichens.

The view of the Chinese Wall from below is rewarding enough, but adventuresome hikers can take various trails that provide a close-up experience. (Horses may also be hired at the lodge.) My wife, Beverly, and I took the Stillwater Trail, which heads east from Trappers Lake, passes Little Trappers Lake, and, after a sharp bend, comes face-to-face with the wall. At this point the trail climbs over the formation's south end, going from 10,000 feet to 11,000 feet in little more than a mile. After another mile, we turned onto the Chinese Wall Trail, which winds northward near the top of the mountain.

Two miles along this route, we came to a branch trail leading east to the Devils Causeway. This, we soon discovered, is a craggy ridge only four feet wide, with precipitous 1,500-foot drop-offs on both sides. The passage looked far too scary, so we retraced our steps and continued north. After a gentle descent, we reached the Lost Lakes Trail and headed back south to complete our round trip.

CARR CLUTTON; MINDEN PICTURES



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**Top:** The Chinese Wall viewed from Trappers Lake. **Above:** An aerial view shows the wall as a dark, shadowy edge beginning at bottom left.

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





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DENNIS FLAHERTY



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## HABITATS

**Grassy meadows** often appear on flat terrain and on west- or south-facing slopes. Slender wheatgrass, nodding brome, fringed brome, oat grass, red fescue, June grass, and mountain muhly are the most abundant species in dry areas. Most of these flower beginning in July and continuing on into autumn. Where a more moist habitat is created by seeps, the grasses include redbud and meadow foxtail. Above 10,000 feet, Thurber's fescue and alpine timothy are common.

Roads that penetrate the Flat Tops have disturbed the native vegetation, permitting the invasion of European species such as orchard grass and timothy, along with opportunistic wildflowers such as milfoil (yarrow), oxeye daisy, fleabane, Indian paintbrush, and thistles.

**Alpine tundra** vegetation consists of dwarf willow trees about one foot tall, an abundance of sedges, and various deep-rooted, mat-forming wildflowers. Among these are nailwort, slender mountain sandwort, rock jasmine, and alpine primrose.

**Subalpine forest** has subalpine fir, Engelmann spruce, lodgepole pine, and mountain ash. Myrtle-leaved blueberry is the most abundant shrub, while a species of wild rose (*Rosa*

*woodsii*) and Colorado currant are also common. Wildflowers include larkspurs, Colorado blue columbine (the state flower), several species of beard-tongue (*Penstemon*), sweet cicely, Jacob's-ladder, and several kinds of *Arnica*—whose flower heads resemble those of daisies, except that they are entirely yellow or orange.

**Montane forest** has lodgepole pine and Engelmann spruce, with Douglas fir often found on north slopes and ponderosa pine on south slopes. Other trees include aspen and Rocky Mountain maple. The mixture of shrubs and wildflowers is similar to that in the subalpine zone, but wax currant grows here instead of Colorado currant.

**Wetland** habitat appears along the streams and around the ponds and lakes that dot the plateau. These areas are often lined with Geyer's willow, Wolf's willow, and narrowleaf cottonwood. Red elderberry, snowberry, and a species of prickly currant are common in the shrub zone. Among the wildflowers are a wild geranium, an aster (*Aster porteri*) with smooth stems and leaves, leafy arnica, yellow monkey flower, meadow rue, and bluebells. The scouring rush, a spore-bearing plant with jointed, leafless stems, is also common.



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CONSUELO DE MORAES AND ANDRÉ SOUZA

**STAY AWAY FROM TOBACCO** Scientists have long known that plants can send a strong message to hungry insects by releasing volatile, sniffable chemicals. Now a team of entomologists led by Consuelo De Moraes, of the USDA-ARS Center for Medical, Agricultural, and Veterinary Entomology in Gainesville, Florida, has found that not only does at least one plant—*Nicotiana tabacum*, the most common species of tobacco—emit volatile chemicals by day, it emits a different blend of chemicals by night. And this cyclical chemical production is closely linked to the life cycle of the plant's main nonhuman consumer, the tobacco budworm (*Heliothis virescens*), whose adult stage is a nocturnal moth.

The newly discovered nighttime blend of volatile compounds released by *N. tabacum* can be detected by receptors on the moth's antennae; the female moth interprets the compounds as a warning that the plant is saturated with competitive insect larvae or that it is of low nutritional value. Either way, she tends to get the message and go elsewhere to lay her eggs.

If, however, a moth manages to lay eggs on *N. tabacum*'s leaves, and caterpillars emerging from those eggs feast on the leaves in the light of day, the caterpillars' saliva is drawn into the plant's vasculature. There it stimulates the production of daytime-only compounds. These attract the tobacco budworm's natural predators, which follow the wafting chemicals to the infected plant and dine on the caterpillars. The researchers are now exploring whether the moths are "making sophisticated choices

based on the likely presence of particular larval competitors and perhaps even of particular predators and parasitoids." ("Caterpillar-Induced Nocturnal Plant Volatiles Repel Conspecific Females" and "Night Moves of Pregnant Moths," *Nature* 410, 2001)—Heather Van Doren

**SHARK TALES** Surprisingly little has been known about how the great white shark (*Carcharodon carcharias*) goes about its daily business. But new genetic research shows that in some ways, the great white behaves more like a marine mammal than like other fish.

Zoologist Amanda T. Pardini, of the University of Aberdeen in Scotland, and colleagues examined mitochondrial DNA (which is inherited only from the mother), as well as DNA inherited from both parents, in great whites in South African, New Zealand, and Australian waters.



MIKE PARRY; KINDEN PICTURES

Analysis of the mitochondrial DNA showed that the sharks from Australia and New Zealand constitute a single population, genetically different from the South African sharks. But when the researchers tested the bi-parentally inherited DNA, they found *no* significant genetic differences between the two groups. These apparently contradictory results suggest that female great whites seldom stray from their native territories and so never have an opportunity to pass on their mitochondrial DNA to other populations, whereas males go much farther afield and contribute genes to different populations, negating local differences that arise in the bi-parentally inherited genome. A

disparity between the home ranges of males and females is also commonly found in marine mammals such as whales and dolphins. ("Sex-Biased Dispersal of Great White Sharks," *Nature* 412, 2001)—Kirsten L. Weir

**EXPANSIVE INSECTS** Climate warming has increased the amount of suitable breeding ground available to a few fortunate insects whose need for warmth used to confine them to scattered tepid areas. According to C. D. Thomas, of the University of Leeds, and colleagues, the silver-spotted skipper (*Hesperia comma*), a butterfly previously restricted to south- and southwest-facing chalk grassland fragments in southeastern England, now roams a wider territory, encompassing east-, west-, and north-facing hillsides as well. Since 1982, the area hospitable to the butterfly has doubled, the distances between the separate patches of hospitable land have decreased, and *H. comma* populations have begun to generate emigrants. As a result, the butterfly's geographic range has tripled.

Another butterfly that has expanded its horizons is the brown argus (*Aricia agrestis*) in central England. Historically, in the southern parts of its range, its host plants were primarily *Geranium* species. In the northern, cooler parts, it favored *Helianthemum chamaecistus*, a plant that grows on sheltered or south-facing hillsides, which are likely to be warmer than most *Geranium* habitats. During the past twenty years, however, the brown argus has been spreading its wings—mostly northward into *Geranium*-rich areas. Why is the butterfly lighting on northern geraniums that previously it did not bother with? Answer: climate. In the 1980s and 1990s, the northern *Geranium* habitats warmed. Not only has the brown argus moved into those habitats, it's been using them as stepping-stones to populations of *H. chamaecistus* that used to be too far apart.

The researchers also found that two species of bush crickets have prospered. Formerly restricted to southern coastal areas of England, the long-winged cone-head (*Conocephalus discolor*) and the flying form of Roesel's bush cricket (*Metrioptera roeselii*) have begun to spread northward and inland. ("Ecological and Evolutionary Processes at Expanding Range Margins," *Nature* 411, 2001)—Kate Hamill



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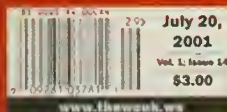


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# ENGINEERING THE APPLE

*By Sue Hubbell*

Adapted from *Shrinking the Cat: Genetic Engineering Before We Knew About Genes*, by Sue Hubbell. Copyright © 2001 by Sue Hubbell. Published by Houghton Mifflin and reprinted by permission.







Braeburn apple, Wenatchee, Washington

JOHN MARSHALL



## Eating apples were first harvested millennia ago in central Asia. Humans have been tinkering with the fruit ever since.

**A Roman mosaic, below, shows farmers grafting apple trees. Opposite page: The harvest at an organic orchard in Washington State.**

**O**ne autumn morning not long ago, I was walking down a row of espaliered apple trees near Geneva, New York. I was visiting the biggest living library of apple trees anywhere in the world—the Plant Genetic Resources Unit of the U.S. Department of Agriculture (USDA), based at Cornell University. The day was cold and the sky leaden, promising an early snow, but maples in full autumn color ringed the field and echoed the cheerful reds, russets, and yellows of the apples. Some of the apple trees had drooping limbs; some grew straight and stiff. The shape of the leaves and the color of the bark varied, as did the fruit—some in clusters, some dangling independently. Some apples were huge, others not even bite-sized. The names of some apples were

unfamiliar to me, yet they tasted so good that I wondered why they weren't in markets. Others were so sour or bad-tasting that I quickly understood what apple growers mean by the word "spitters." The trees—and the look and taste of the fruit they bore—were so dissimilar that it was hard to believe the entire group was botanically related. But my guide for the morning, Philip Forsline, curator of apples and sour cherries for the USDA, told me that even bad-tasting ones could be of interest because of their manner of growth, time of bearing, hardiness, or resistance to disease and pests.

Commercial apples are a serious business in the United States, the world's second-largest apple-producing country (after China). Putting in a commercial orchard or replanting an old one with a new variety takes money, time, and labor. Years pass before new trees bear enough fruit to pay back the orchardist for the investment, so apple developers need to be sure of the qualities being packed into a new variety before they promote it. And this is where apples present a real challenge. Nearly every apple tree grown from a seed is a new variety, whose fruit may not be at all like that of the mother tree. Such unpredictability is a serious problem for orchardists. Their most common solution—invented long before there was a sheep named Dolly—has been a type of cloning known as grafting, an ingenious way that humankind discovered to make an end run around the intricacies of apple genetics. Orchardists take a shoot (called a scion) from a tree that bears good eating apples and bind the shoot to the trunk of a tree that doesn't produce good apples but has other desirable properties, such as vigor, resistance to disease, or the ability to stay a manageable size. The grafted shoot will grow up to produce the same good apples as the tree it was taken from. It is a clone of that tree, growing on another root system.

A hands-on solution to a practical problem, grafting offers little insight into apple genetics, which are so complex that bewildered botanists used to think that apples did not obey Mendel's laws. It is true that the progeny grown from the











FRONTISPIECE FOR JOHN MILTON'S COMUS. ILLUSTRATION BY ARTHUR RACKHAM. MARY EVANS PICTURE LIBRARY



seeds of an apple tree do not sort themselves out into the neat, predictable pattern that Gregor Mendel first laid out in the 1860s with his pea plants. But we now know that Mendel was lucky. The pea plant traits he studied (flower color, for instance) are controlled by single genes (or “factors” of inheritance, as he called them). More often, though, a single trait is affected by more than one gene. In addition, certain genes are expressed only

## **Apple growers have benefited from the fruit’s easygoing acceptance of extra chromosomes.**

when environmental conditions activate them (such as the darkening of Siamese kittens’ paws due to the lower temperature of their extremities). And that’s just for starters.

Like cats and people, most apple trees are diploid—that is, their genes occur on pairs of chromosomes. Typically, apples have seventeen pairs of chromosomes, for a total of thirty-four. But some varieties are haploid, with seventeen *single* chromosomes. Others, especially among crab apples, are polyploid, which means that their chromosomes are not paired but tripled, quadrupled, quintupled, or even wadded up into bundles of six. In fact, some apples have as many as eighty-five chromosomes. And each of the genes on each of the chromosomes can have different alleles (alternative forms). A single seed may thus contain a lot of genetic variation that has accumulated down through the ancestral lines.

Orchardists have unquestionably benefited from the apple’s easygoing acceptance of extra chromosomes. Many familiar varieties of apples are polyploid: Stayman, Jonagold, Baldwin, and the beloved old pie apple Rhode Island Greening. The Jonagold is a modern, contrived cross between Jonathan and Golden Delicious parents. But the Stayman sprang up all on its own, from a Winesap seedling in Kansas; the Baldwin and Rhode Island Greening, too, were spontaneous polyploids.

The desire for a predictable product, however, has led most growers to focus on a very limited portion of the apple’s tremendous genetic diversity. In fact, the vast majority of contemporary apples are the progeny of just a few varieties—a dozen at best. As a result, today’s available genetic base is meager compared with that in the nineteenth century,

when an estimated 7,000 or more kinds of apples were cultivated. In addition, many of the varieties commercially grown today “present well” (that is, have a uniform, unblemished appearance), but they no longer have much flavor. This is why many horticulturists have recently been devoting themselves to tracking down old varieties on abandoned farms and in old cow pastures. And it is why, since 1989, the USDA has been sending scientists on collecting expeditions to the presumed birthplace of eating apples: the high-altitude forests of Kazakhstan, in central Asia.

The apple brought back to the Cornell facility from Kazakhstan is *Malus sieversii*, a tree with no common name. Many researchers, including Philip Forsline, believe that *M. sieversii* is the principal ancestor of all the varieties of apples we buy at the supermarket, which are collectively known as *M. x domestica*. The *M. sieversii* seeds gathered during the first expedition to this species’ homeland—in the region of the Kazakhstani industrial town of Almaty (formerly Alma-Ata, “father of apples”)—have produced trees that are now mature enough to bear apples. Trees at the facility are grown in tight, close rows, which keeps them more compact and uniform than they would be in their native forests. Nevertheless, even to an untrained eye the individ-

**Legendary apples, opposite page: The Hesperides guard a tree bearing the golden apples given to Hera as a wedding present. Below: *Temptation of Eve*, by the sculptor Gislebertus, ca. 1130.**



ual trees show obvious differences. The leaves are of various shapes and hues; the trees branch and twig in different ways. Some send up many stems, giving the trees a shrubby appearance.

Also in the USDA collection are younger *M. sieversii* trees, grown from seeds gathered more recently and a long way from Almaty, in places that have never been farmed. Too young to bear fruit, these trees are still thorny, betraying their relationship to roses. (Roses and apples belong to the large family Rosaceae, which also includes strawberries,



Ready for the harvest: Three-year-old Gala apple trees in a commercial orchard, right. Below: Grafting involves inserting and sealing "scion wood" into slits in a tree's trunk.



JOHN MARSHALL



JOHN MARSHALL

pears, and the stone fruits, such as plums, cherries, and apricots.) Some of the new seedlings are already showing resistance to various pests and diseases. According to Forsline, "The interesting thing is that since the trees in the apple forests grow up from seeds, each is different from its neighbor. You can see a healthy tree growing right next to a diseased one. Resistance is genetic. We think it would be good if we can incorporate resistance into commercial varieties of apples."

Apples of the species *M. sieversii* were first described in modern times by P. S. Pallas, a German naturalist who in 1786 saw them growing in the Caucasus, where, he noted, apple trees competed for dominance with oaks. In 1911 Frank Meyer, an American who traveled the world looking for unusual plants, took note of the apple forests in the Tien Shan ("mountains of heaven"), a range straddling the border where China meets Kazakhstan and Kyrgyzstan. Meyer had crossed into those mountains from China in early spring and had spent the

next few months exploring the range, struck by the unusual forests of apples he found, sometimes at altitudes of 10,000 feet. No one followed up on his discovery until the 1920s, when Russian agronomists started investigating the area.

People who think the apple originated in Kazakhstan theorize that *M. sieversii* probably hybridized rapidly with crab apples native to central Asia. According to some botanists, it is those hybrids, not pure *M. sieversii*, that became the ancestors of what we now think of as proper eating apples. But others disagree, seeing the wide distribution of crab apples—which are native not only to Asia but to northern latitudes around the world—as evidence for apples having had other places of origin. Through genetic change, crab apples might, on their own, have come to produce apples that were sweeter and bigger—the ancestors of domestic apples.

The question of whether apples began in one place or several may now have been settled by Barrie Juniper and other scientists at the University of Oxford, who have been analyzing the chloroplast and nuclear-DNA sequences of cultivated apples in order to untangle their origins. Their work to date has uncovered no evidence that *M. sieversii* hybridized as it moved westward—supporting the claim that the wild apple forests of Kazakhstan did indeed give rise to the sweet eating apple.

**Grafting was humankind's way of making an end run around the complexities of apple genetics.**

Wherever apples originated, by the middle of the third millennium B.C., tasty eating apples were being cultivated far to the west of the Tien Shan range, even as far as Persia. By the first millennium B.C., apples had become a standard part of the diet of the well-to-do in the Mediterranean world. The Romans spread the knowledge of apples and their cultivation throughout the territories they conquered. By medieval times, orchardists in Europe had become so skilled that the privileged classes could offer apples to their guests every month of the year by growing some varieties that ripened early and others that were "good keepers," retaining their freshness through the winter. To own an apple orchard was as much a source of pride as having a good wine cellar is today.





Yet apples were not universally admired during the Middle Ages, especially among the less privileged. Popular wisdom had it that apples caused “bad stomachs” and fever, as well as “ill humors.” This belief may well have been reinforced by the apple’s association with the Fall in various translations of the Bible, including the King James Version (though in the oldest Hebrew and Greek texts, the Tree of Knowledge bears merely a generalized “fruit”).

For several hundred years, apples were treated with some suspicion, but by the seventeenth century the fruit was back in favor, and many varieties were being grown and grafted throughout Europe. Settlers in the New World, finding the place lacking in sweet apples, were quick to import them from Europe. New Englanders grew apples not so much for eating as for animal feed and cider making. (At the time, access to potable water was not a simple matter of turning on the tap, and the newcomers needed to produce a beverage that would satisfy thirst without making them ill. Cider, fresh or hard, was such a drink.) For these purposes, good eating apples were not necessary. In addition, the first settlers—often urban dwellers unskilled in rural crafts—may simply have been ignorant of grafting.



**Above:** Apple specialist Philip Forsline in a Kazakhstani forest of *Malus sieversii*. **Map:** The town of Almaty is known as the “father of apples.”

For whatever reasons, most apple trees in America grew for a couple of centuries without benefit of grafts. And without grafting to produce only selected strains, the rich genetic heritage locked up inside the wild apple trees was allowed expression—serving as what one collector of wild apple seedlings called “the biggest genetic experiment the planet has ever seen.” This genetic experiment was taken westward by John Chapman, better known to generations of Americans as Johnny Appleseed, who traveled more than 100,000 miles across the Midwest, handing out and planting apple seeds along the way. Since he was a follower of Emanuel Swedenborg, an eighteenth-century Swedish scientist and religious thinker who con-



Isaac Newton's tree-shaded worktable, below. Did a falling apple inspire his concept of gravity? Opposite page: Fluctuating summer weather resulted in three stages of bloom at one time for a Braeburn apple.



ERICH LESSING/ART RESOURCE

demned tampering with the will of nature, Chapman eschewed grafting.

By the time of Johnny Appleseed's death in 1845, however, grafting was becoming the preferred method of propagation for serious commercial orchardists in the United States, as had long been the case in Europe. Greater control over apple production led to a growing emphasis on the appearance, shipping, and keeping qualities of apples rather than on their flavor. And by limiting the genetic base of the apples they grew, orchardists increasingly found the fruit susceptible to scab, mildew, brown rot, and a host of other diseases—not to mention codling moths, aphids, and spider mites, three of the hundreds of insects and mites that plague the modern grower. Nowadays those diseases and pests are fought with a whole witches' brew of chemical sprays, dusts, and powders—which gets us back to the USDA's interest in the apples from Kazakhstan, many of which show innate resistance to bugs and blights.

When resistance comes from several genes—that is, when it is polygenic—it is longer lasting, but such resistance is harder to achieve in crossbreeding. Single-gene crossbreeding for resistance can be done by first making the original cross and then backcrossing to eliminate traits such as small size and sour taste that may have come along with the desired gene. But when the trait is polygenic, it may take five or six backcrosses to eliminate the unwanted genes that have hitchhiked along with those helping to confer resistance. One apple tree generation is about four years (that's how long it takes, on average, before a tree bears fruit), so the development of polygenic resistance would take something like twenty years, as well as a plot of land big

enough to grow and try out many crossbred trees.

This explains why many apple breeders are interested in genetic engineering—in the new sense of what is called transformation. If the genes responsible for a certain trait can be identified and di-

rectly transferred, the process of transformation is quick, efficient, and in some ways easier than crossbreeding, because it eliminates the need for backcrossing. Resistance can even be transferred from animal species. The cecropia moth, for example, produces a peptide that attacks many kinds of bacteria. When the moth gene responsible for producing that protein was added to the DNA of apples used for rootstocks, the apples grafted onto them

## *Apples from Kazakhstan don't need a whole witches' brew of chemical sprays, dusts, and powders to fight off bugs and blights.*

became resistant to fire blight, a devastating bacterial disease that turns apples, pears, and other plants black. And at least for Gala and McIntosh apples, the same cecropia moth gene seems to help confer scab resistance, too.

Whatever the promise (or, in the opinion of some, the threat) of genetic engineering, everyone agrees that preserving the natural diversity of apple trees should be a high priority. And on this score, there is cause for alarm: the apple forests of Kazakhstan are in danger of disappearing. "During the Soviet period," says Forsline, "the area was held as national parkland, but with the breakup of the Soviet Union, the mountains are no longer protected. Wealthy people are having many remote areas bulldozed and cleared in order to build vacation homes. The apple forests are disappearing, and the groves nearest to Almaty are 90 percent gone."

At the end of my tour through the Geneva orchards, I asked Forsline which apples would continue to grow if humans disappeared from the planet. He reflected for a moment and said, "Well, the eating apples that we've grown on this continent would soon be gone. Those need our care, and besides, they aren't native here. I don't think any of them would survive here." He paused, then added, "But apples would still grow in central Asia, and they'd be better."

In what way? I asked.

"The places where they grow now would no longer be threatened by development, and they would continue to evolve, growing hardier, more resistant to disease and pests, and better fitted to their particular surroundings." □







# Sea Hunters of Lamalera



*In an Indonesian coastal village, boatbuilders and whalers follow ancient rules.*

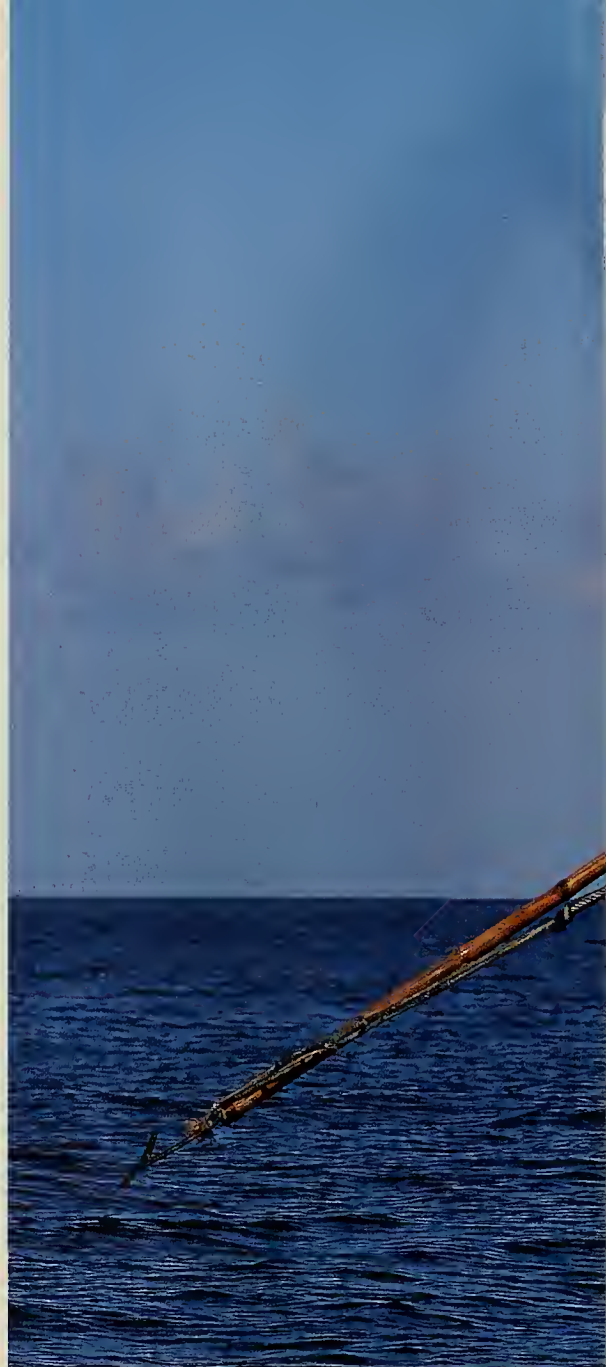
*Story and photographs by Fred Bruemmer*

**Above:** In a painting on the prow of a Lamaleran boat, the snake symbolizes the tidal wave that destroyed the villagers' ancestral home. **From his narrow platform on the bow, top right, a harpooner is ready to strike.** **Below right:** Boats leave Lamalera at dawn with their palm-leaf sails unfurled.

Their boats are sacred and, they believe, immortal. Their prey is gigantic and dangerous. They are the sea hunters of Lamalera, an isolated village on the tiny Indonesian island of Lembata, 1,200 miles due east of Jakarta.

To the 150 or so hunters and the rest of the village's 2,000 people, each of the fifteen boats that operate out of Lamalera (formerly known as Lomblen) is a living being that links them to their ancestors and their ancestral home. That home, as legend has it, was to the north, on an island destroyed centuries ago by a tidal wave. After a long journey, two boatloads of survivors landed on the harsh, volcanic coast of Lembata, where they built a village above a crescent beach facing the turbulent but rich Sawu Sea. One of the two boats that brought their ancestors to Lamalera was, say the villagers, the *Kebako Pukā*.

In Lamalera I often traveled in a boat also called the *Kebako Pukā*, which, according to its crew, was identical in every detail to the original (the model for subsequent boats). When a boat dies—in a storm, of old age, smashed by a furious whale—the villagers mourn for two months while a replacement is built. It takes eighteen trees to build one. Root ends are used to make the stern, so that their life force will flow toward the head of the boat.



Planks are carefully adzed—never bent—to the correct curve. The planks are caulked with palm-fiber oakum. Hand-carved wooden pegs—never nails, screws, or anything else metal—are driven in with stone hammers. Carved crosspieces are lashed to the frame with rattan. Finally a sacred symbol is painted on the prow; a common one is eyes that search unceasingly for prey. On the prow of the *Kebako Pukā* a snake coils around a mountain, symbolizing the tidal wave that destroyed the Lamalerans' ancestral home.

The boats are made by *ata molā*, highly skilled craftsmen from the village's nineteen boatbuilding clans. Robert Barnes, professor of social anthropol-





ogy at the University of Oxford and an expert on Lamalera's history and customs, has noted that the term *ata molā* is also used to refer to a priest.

The finished boat is heavy and sturdy. Thirty feet long, six feet wide in the beam, tapered at both bow and stern, it has a false keel of softwood that can easily be replaced if damaged in rough landings, a frequent occurrence. Its huge rectangular sail is woven from the leaves of gebang palm and suspended from a twenty-five-foot-high bipod bamboo mast. Two outriggers give the vessel great stability. Beyond the bow juts a narrow, five-foot-long, bamboo-and-plank platform. This is the precarious place from which the boat's single har-





pooner will launch his *kāfēs*, harpoons at the tip of ten-foot poles.

In Lamalera, animistic beliefs in the sanctity and spirituality of hunted animals exist in syncretic harmony with devout Catholicism. (Jesuit missionaries began visiting the village in the 1800s, and a permanent Catholic mission was established there in 1913.) Custom and conduct are governed by an ancient oral code. With little agriculture—villagers grow some corn and manioc—and no other industry, it is hardly surprising



Oil (for cooking and for lighting) is rendered from whale blubber, above. Right: Villagers drag a pilot whale to shore.



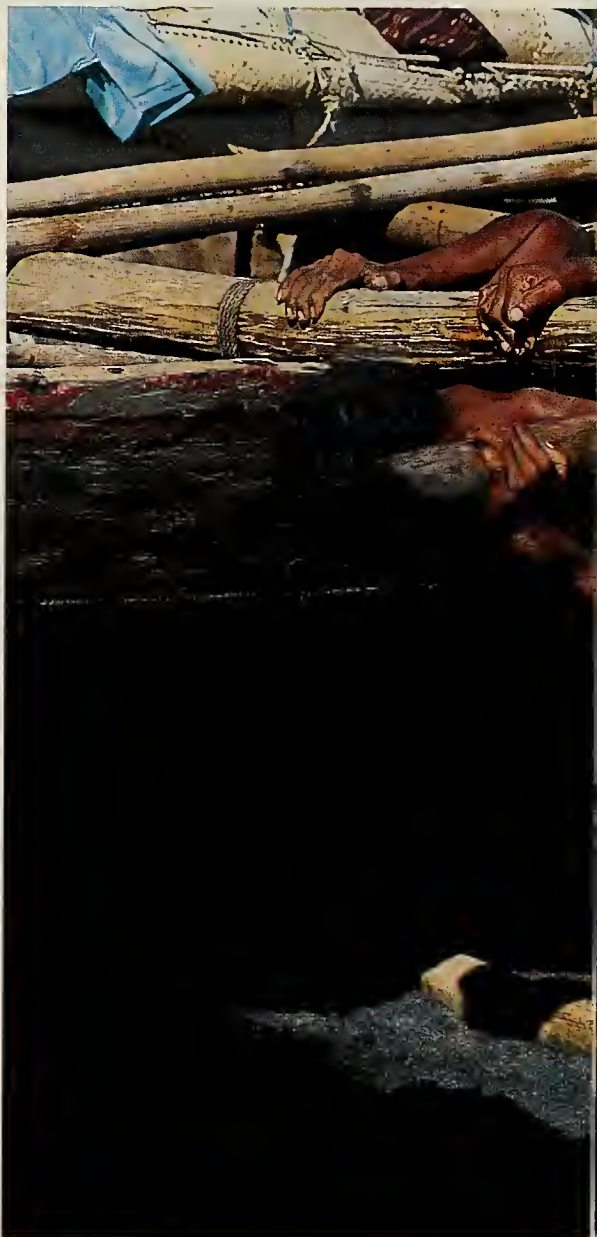
that the hunt is the center of life. Each May, after the priest has blessed the fleet and prayers have been offered to Kotekema, the spirit of the sperm whale, the hunting season begins. It will last until October.

Lamaleras hunt several species of whales, the most feared, most respected, most sought after of which is the sperm whale. The annual catches peaked at fifty-six in 1969. But then, say the villagers, they sold one of the sacred sperm whale skulls lining the beach to tourists from a passing ship. This offended the whale's spirit, and for years afterward, no more than ten sperm whales a year were harvested. Catches have increased since 1990, however.

Today the sea hunters take mostly young male sperm whales, twenty to forty feet long, which eat the abundant Sawu Sea squid. Crews are leery of the full-grown sperm whale bull (up to sixty feet in length), a rarer sight. In 1994 two Lamalera boats

sank after being struck by a whale that had towed them for miles, almost to the island of Timor. A third boat picked up the crews and drifted for days until it was rescued by a passing ship.

Rejecting spinner dolphins (too fast) and baleen whales (taboo), Lamaleras hunt several species of sharks, including the great white but most often the large and lethargic whale shark (known to them as the stupid fish). They also go after sunfish, marlin, and dorado, as well as manta rays (the largest of all the rays, these can weigh up to one and a half tons). The hunt is hard work. The crews are out all day beneath the burning sun—and often return with nothing to show for their day at sea. They rarely eat or drink on board, so I learned to fill myself with





liquids, camel-like, before going out with them.

Weather permitting, the fleet sails at dawn every day except Sunday. On a slipway of hardwood logs, the heavy boat is slid from its palm-leaf-thatched shelter at the back of the beach down to the lethal-looking, pounding surf where the crew calmly waits for the highest wave. With one mighty shove from them, the boat rides out. The men quickly slide aboard, otter-smooth. They pole out beyond the breakers, settle on the thwarts, then row with all

*The boats have false softwood keels that can easily be replaced if damaged in rough landings.*

their strength to an ancient rhythmic chant, "Hilabé, hilabé, héla, héla/hilabé, héla, héla. . . ." Farther out, the chant changes into a song that translates as "We are the men from Lamalera/We are the hunters of the whale."

Suddenly, a few miles from shore, they stop while the harpooner sharpens his *kāfés*. The men remove their hats and pray, first a paternoster in Lamaholot (the language of Lamalera, Lamaholot is one of many languages of eastern Indonesia), then a final plea: "Lord bless our hunt and let us return alive." With this ritual, the hunt becomes holy. The mast is raised, the great golden sail is unfurled, and the boat sails farther out into the Sawu Sea—often up to eight miles. There the



The heavy boats are thirty feet long and six feet wide. It takes many hands to haul a boat from the sea.





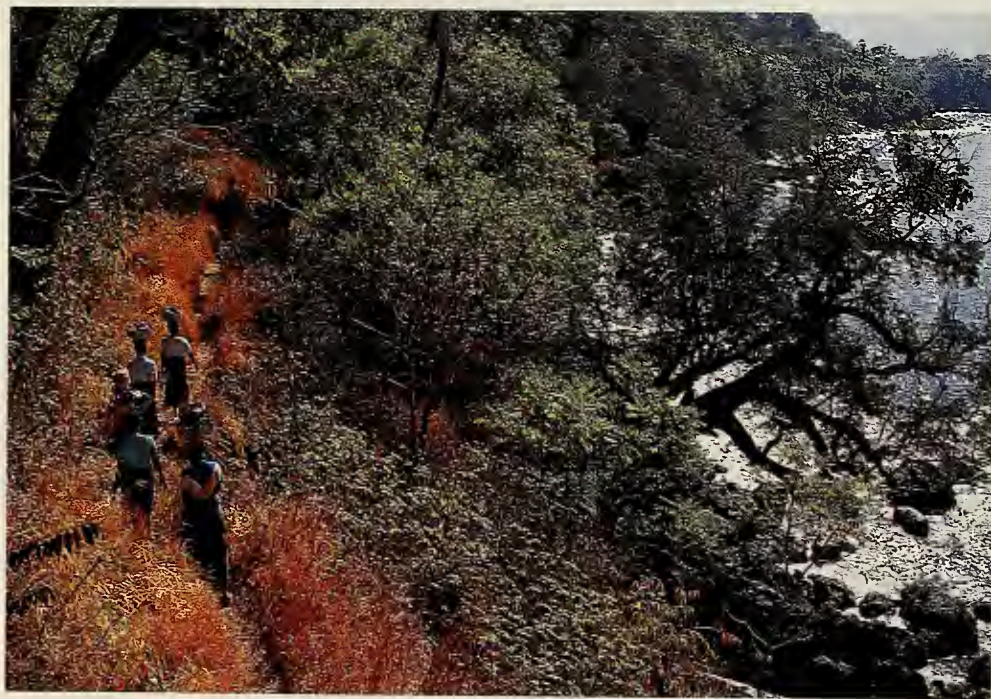
weather. Finally he tenses and, in a great leap, flings himself on the prey and drives in the harpoon. Yes, the harpooner always jumps onto the back of the whale, shark, or ray—such leaping greatly increases his accuracy and killing power. Although pulled

*Looking for a quick kill, they dived beneath the massive manta ray and stabbed it.*

along by the frantic animal, he swiftly grabs an outrigger and slides smoothly back on board.

I watched once as a wounded manta ray dived rapidly, the wrist-thick palm-fiber rope attached to the harpoon pole flying overboard in spinning coils, lethal to anyone who might get caught in them. At last the rope went slack, and as the men

strained to haul up the struggling fish that must literally have weighed a ton, they sang a loud song that they believe is heard by a ray's spirit. "We do not hunt for fun," they sang. "We desperately need your meat to live, to feed our hungry children." Part incantation, part plea, such a song must appease the ray's spirit before the fish can be killed. When the ray was near the surface, several men jumped overboard. Looking for a quick kill—a ray's thrashing wings can span twenty-five feet and break both men and boat—they dived beneath the massive fish and stabbed it with long-bladed, bamboo-handled knives. The fish was cut into chunks at sea; the rest of the butchering



**Lamalera women, above, carry meat and fat to a market five miles away. They barter for fruit, vegetables, rice, and maize with women from mountain villages, top.**

crew tacks and jibes, ever alert for the telltale spout of a distant whale, the curled tip of a manta ray's wing, the sheen of a shark near the surface.

Out there, with nothing to distract from the lazy roll of oily swells, the boat's dull creaking, the faint flapping of the sail, the burning sun, I learned what Samuel Taylor Coleridge meant by "As idle as a painted ship/Upon a painted ocean." Then, at a sudden cry, the crew swings into action, rowing and paddling to the rapid cadence of time-honored chants. On his perch the harpooner is at ease, even when the boat pitches, slews, and yaws in stormy

would be done on dry land. When a whale or shark is caught, it's lashed alongside the boat and hauled slowly to shore.

In Lamalera, life is lived on the seashore. Children play in the surf; old men sit in the shade, smoking thin cigarettes rolled with strips of lontar palm leaf, talking about long-ago hunts, weaving new sails, or braiding new ropes. But the instant a boat rides in on a soaring swell, all the males, from tots to aged men, rush to help haul the boat up onto the beach. Then the kill is cut up and divided among members of the boat clan, as well as the sail-



makers and boatbuilders. Shares are determined by custom, with the biggest portion going to the harpooner. His share is called *lei nakē*, “the wages of his feet,” in tribute to his balance on the narrow platform; he in turn is obliged to present his share to the oldest male in his direct paternal line.

The meat and fat are sun-dried on racks, and every part of the animal is used. It is considered sinful—and an offense to the dead animal’s spirit—to waste anything. About half the bounty is kept in the village. The rest is traded: Lamalera, an almost moneyless society, depends primarily on barter.

Every Saturday at dawn, the women and girls walk five miles to a market at Wulan Doni, where they trade with women from many mountain villages. Carrying heavy basins of meat and fat on their heads, they proceed straight-backed along a path used by untold generations. At the market, women from the mountain villages spread agricultural produce under the trees. The women of Lamalera sit apart. Once they and the others have paid a tiny tribute to a few families that keep the market area clean, a whistle shrills and the bartering begins. There is little or no haggling, because every item has a traditional value: a piece of dried whale meat two fingers wide and a hand-length long, for example, is worth twelve bananas. In the afternoon, the Lamalerans set off for home with basins of maize, rice, yams, bananas, cassava, and other fruits and vegetables.

In 1973, in an effort to modernize the sea hunt, the UN’s Food and Agriculture Organization (FAO) sent a whaling ship, along with a Norwegian master whaler, to Lamalera. The experiment lasted three years, and it nearly wrecked the barter-based economy and harmony of the village. The FAO’s final report concluded that the hunters “have evolved a method of whaling

which suits their natural resources, cultural tenets and style.” Many Lamalerans have left in search of a different life, of course. Several are Catholic priests, some ordained in Rome and Berlin; other emigrants include a professor of linguistics, a general in the Indonesian army, the captain of a luxury liner, civil servants, and businessmen working throughout Indonesia. But in Lamalera the boats still sail at dawn, the golden sails unfurl, and sunburned men invoke the blessings of God and the ancient spirits so that their hunt may be successful and they may make it home alive. □

After a whale is butchered at the water’s edge, women carry basins of meat and fat to be dried on racks farther up the beach.





**A** century and a half ago, the world's mountainous regions were somewhat colder than they are today. We know this because historical records—writings, paintings, early photographs—show that glaciers were larger then. In the Swiss Alps, the area for which the most detailed documentation is available, glaciers expanded during the Little Ice Age, a cold episode that ran from about 1300 to 1860. (This ice age is called “little” because, even at its worst, the cooling required to produce it was

only one-tenth the cooling that induced the “big” ice age that peaked 20,000 years ago.)

Though records for glaciers in other parts of the world are less detailed, we know that in the high peaks of the tropical Andes, in the temperate-zone Andes of Chile and Argentina, and in the Southern Alps of New Zealand's South Island, glaciers were substantially larger in 1850 than they are now. So we suspect that the Little Ice Age cooled not just Europe but the world.

The Little Ice Age ended abruptly. Starting in

*By Wallace S.  
Broecker*



# Glaciers

The Perito Moreno  
Glacier advances  
into a lake in  
southern  
Argentina.



1860, the world's glaciers began a retreat that has continued right up to the present. Without a doubt, therefore, planet Earth has gotten warmer over the past century and a half. But humanity's exact contribution to the warming is still under debate. Along with most atmospheric scientists, I take very seriously the results of computer simulations showing that human-produced forces are very likely driving the rise in temperature that we have seen over the past quarter century. Yet roughly half the overall warming since 1860 occurred before

carbon dioxide (CO<sub>2</sub>) emissions from human activities had reached significant levels. Some take this as evidence that most of the current upswing in temperature is merely a continuation of the natural events that brought the Little Ice Age to a close.

To truly understand the scenario of global warming, we need to know how much Earth's temperatures would have fluctuated in the absence of the Industrial Revolution and whether we are now exacerbating or counteracting these fluctuations. And we can know these things only if it can



# *That Speak in Tongues* *and other tales of global warming*





PRIVATE COLLECTION, ZÜRICH



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The lower Grindelwald Glacier in Switzerland once reached down into a populated and accessible valley, making it a popular tourist attraction. The many artists' representations of the glacier enable present-day climatologists to reconstruct its variation over time. Four such depictions, left to right, showing the glacier in 1748–49, 1774–76, 1794, and 1826, are by Emanuel Handemann, Caspar Wolf, Joseph Anton Koch, and Samuel Birman, respectively.

be shown that Earth has had predictable temperature cycles during the past several thousand years. Many scientists doubt that such large-scale regularities exist, but assuming for the moment that they do, how would we detect them? Even year-to-year changes in average global temperature are difficult to chart, despite the help we get from the worldwide network of thermometers and from the scores of satellites orbiting high above Earth. Getting a sense of relevant natural fluctuations is especially difficult because during the period that geologists call the Holocene Epoch (the 11,000 years since the end of the last ice age), Earth's temperatures have been remarkably stable. Unlike the previous 100,000 years, when the climate underwent numerous large jumps and drifts, measured in many degrees Fahrenheit, the changes during the entire Holocene have been only 1° or 2° F—too small to ascertain with the natural climate indicators we have been using until now (such as tree rings and fossil pollen), whose accuracy is no better than 2° F.

This is why climatologists have turned to mountain glaciers. The record created by these glaciers is an excellent proxy for climate, standing in for hundreds of years of thermometer readings. Not only does this proxy tell us about past temperatures, its margin of error is less than 0.4° F.

Everywhere on Earth, the higher you climb, the colder it gets. The reason is that as air rises, it expands and therefore cools. On average, air temperature changes at a rate of 1° F for every 300 feet of elevation. At some point on the way up, air temperature reaches the freezing point. Glaciers can't form or endure, of course, unless the air temperature remains low, and how far down a mountain they reach depends on what glaciologists call the equilibrium snowline—the boundary between an upper zone where accumulation of snow outpaces melting and a lower zone where the reverse is true. This

boundary corresponds fairly closely to the altitude at which air temperature reaches the freezing point. In the Alps, large glaciers have tongues of ice streaming down past the equilibrium snowline and on into valleys in the lower zone. The melting in such tongues below the snowline is balanced by the downward flow of ice from above the snowline. When the air temperature shifts, such tongues can shrink or enlarge dramatically. For example, since 1860 the Rhône Glacier, in the Alps of southwestern Switzerland, has retreated about three miles in response to a rise in the equilibrium snowline of

### ***Records of glacial advances and retreats provide an accurate gauge of temperature changes.***

about 300 feet. This rise corresponds to an atmospheric warming of slightly more than 1° F.

Such astounding sensitivity suggests that a record of glacial advances and retreats during the Holocene Epoch would yield the information we seek about recent climate cycles. But this is easier said than done. The problem is that glaciers act like giant erasers. Each advance eradicats almost all traces of what's come before. At their greatest size during the Little Ice Age, Europe's glaciers covered an area at least as large as was covered in any previous Holocene advance, so the record of earlier Holocene advances is mostly obscured.

We do, however, have evidence that well before the Little Ice Age—several times during the past 11,000 years, in fact—Alpine glaciers pushed out to roughly the same position they occupied in 1850. One such indication is the size of the moraines—the looping walls of debris that mark the edge of each major Alpine ice tongue. These piles of rocky rubble are huge, some standing 300 feet above the valley





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H. J. ZUMBUENL

floor. It is difficult to imagine that they could have been formed during a single forward push of ice; instead they appear to be the result of a great many such pushes in the course of thousands of years. Within these huge debris piles are layers representing ancient soils, indicating that many earlier advances occurred. But carbon 14 dates derived from soil materials are often misleading and so cannot be relied on to provide the precise chronology we seek.

During the last decade, however, a major breakthrough occurred, owing to the appearance of a new climate proxy: wood and peat that have been washing out from beneath the retreating Alpine glaciers. For this kind of material, carbon dating is quite reliable and allows us to determine precisely the warm periods when trees and other plants were able to grow in places that are now covered by glaciers.

In September 2000, I had the opportunity to witness a harvest of this ancient wood and peat when Christian Schluechter, a University of Bern geologist who pioneered such studies, led a small group of interested scientists to the terminus of the Unteraare Glacier in the northern Swiss Alps. He explained to us that once each year, toward the end of summer, the meltwater that has accumulated beneath the ice suddenly breaks out of its confinement and sweeps over an apron of large cobbles lying at the foot of the glacier. To our amazement, we saw pieces of wood and peat wedged here and there among the cobbles. During the single hour our helicopter taxi service allotted us for exploring the apron, our group found fifty separate pieces. Many of them showed evidence of compression, shearing, and twisting caused by the weight and motion of the overlying ice.

Our finds were not the first "warm artifacts" to be harvested from the forelands of retreating Swiss glaciers. Schluechter and his colleagues had been

collecting wood and peat fragments for several years and have obtained carbon dates for nearly a hundred of them. Some of the wood dates all the way back to the earliest Holocene. Even more important, rather than being spread evenly through time, the dates for these pieces of wood and peat fall into distinct groups, with each group presumably representing a warm episode when Alpine glaciers were even smaller than they are today.

Geologists are now investigating whether these groupings correspond to another new source of evidence of cyclic patterns in Earth's recent history. This evidence comes from studies of sediment in the deep waters of the North Atlantic. The rock fragments in these sediments are much too large to have been transported there by ocean currents; they could have reached their present location only by having been frozen into large icebergs that floated long distances from their point of origin before melting. During the past decade, Gerard Bond, my colleague at Columbia University's Lamont-Doherty Earth Observatory, has studied the makeup of such ice-rafted debris. Noticing that some of the sediment grains were stained with iron oxide, he reasoned that they must have come from locales where glaciers had overrun outcrops of red sandstone. Bond concluded that a detailed analysis of deep sediment cores would reveal changes in the mix of sediment sources over time. This proved to be an excellent strategy, for Bond found something so unexpected that it stunned all of us who study climate history. The proportion of these red-stained grains fluctuated back and forth over time from lows of 5 percent to highs of about 17 percent, and

**Photographs of the lower Grindelwald Glacier taken in 1858 and 1974 demonstrate how much it has shrunk since the end of the Little Ice Age, a relatively cool period that lasted from about 1300 to 1860.**

ILLUSTRATIONS FROM PLATE 3.8, COPYRIGHT © 1999 BY HEINZ J. ZUMBUENL, INSTITUTE OF GEOGRAPHY, UNIVERSITY OF BERNE, FROM "HOLOCENE GLACIAL FLUCTUATIONS," BY H. HOLZHAUSER AND H. J. ZUMBUENL, IN *HYDROLOGICAL ATLAS OF SWITZERLAND* (BERNE: FEDERAL OFFICE OF TOPOGRAPHY/FEDERAL OFFICE FOR WATER AND GEOLOGY, 1999)



**The present-day pattern of ocean circulation appears to be driven by the sinking of dense, cold water in the North Atlantic. This draws a flow of warm surface water (the Gulf Stream) far to the north. Disruption of this pattern in the past led to the cooling of lands bordering the North Atlantic, such as Greenland, Iceland, and northern Europe.**

these fluctuations had a pattern: a nearly regular, 1,500-year cycle. Even more amazing, he found that the cycles ran virtually unchanged, in both amplitude and duration, through both ice-age and non-ice-age periods during the last 100,000 years.

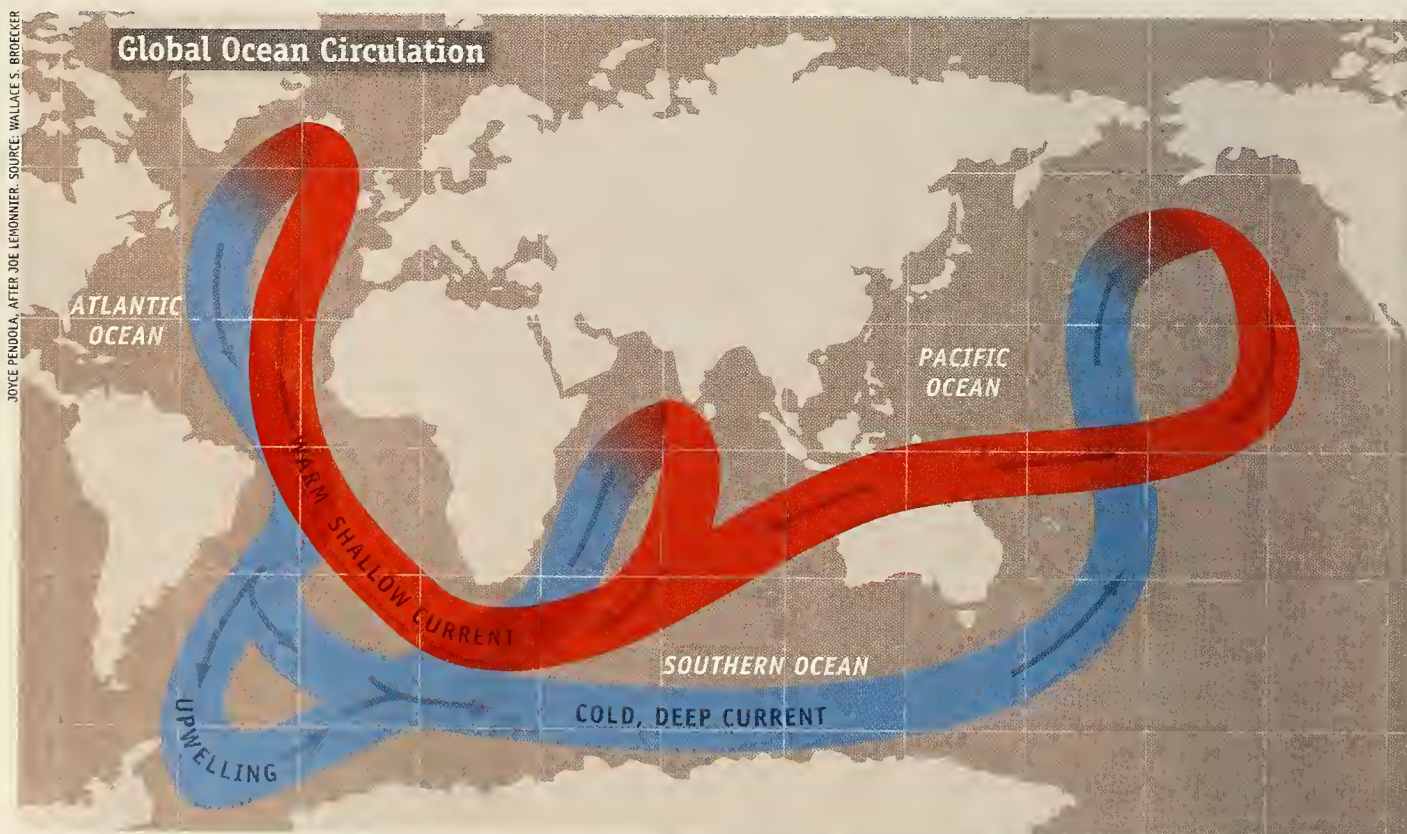
Bond puzzled over what might be pacing this cycle. As a geologist, he knew that the sources of the red-stained grains were generally closer to the North Pole than were the places yielding a high proportion of “clean” grains. At certain times, apparently, more icebergs from the far north were making their way well to the south before finally melting and shedding their sediment. Bond hypothesized that the alternating cycles might be evidence of changes in ocean-water circulation.

Ocean waters are constantly on the move, and water temperature is both a cause and an effect. As water cools, it gets denser and sinks to the bottom. In one part of what I like to call the “bipolar seesaw,” the bottom layer of the world’s oceans comes from cold, dense water sinking in the far North Atlantic (see diagram, below). This causes the warm surface waters of the Gulf Stream to be pulled northward, as they are today. Bond realized that during this part of the ocean cycle, a large proportion of the icebergs that bear red grains would melt while still fairly far north. But sometimes the ocean

reorganizes itself, and the Southern Hemisphere holds sway in driving ocean circulation. At such times, surface waters in the North Atlantic would generally be colder, permitting icebergs bearing red-stained grains to travel farther south before melting and depositing their sediment.

The onset of the Little Ice Age in about 1300, which followed the so-called Medieval Warm Period of the eighth through tenth centuries, may represent the most recent time that such a switchover occurred. The contrast in the North Atlantic is apparent if we consider that in the tenth century, Erik the Red and his band of Vikings colonized the lands surrounding the fjords in southwestern Greenland. Not only did the Vikings navigate their wooden vessels back and forth between Scandinavia and Greenland without being thwarted by sea ice, but they were also able to grow enough grass to support sizable flocks of sheep. As time went on, however, conditions deteriorated. The last recorded communication from the colonists occurred in the early fourteenth century—just at the onset of the Little Ice Age in the Alps—and eventually the colony died out (see “The Vikings’ Silent Saga,” *Natural History*, November 2000).

Further evidence of the impact of the Little Ice Age comes from records kept by Icelanders, whose





writings indicate that between 1650 and 1850, their island was icebound for several months each year—a great hardship, since fishing was a main source of sustenance. They reported with pleasure that the ice began to wane in 1880, permitting them to extend the fishing season. Readings from their thermometers (which they began to use in about 1870) also suggest that the mean annual temperature was rising.

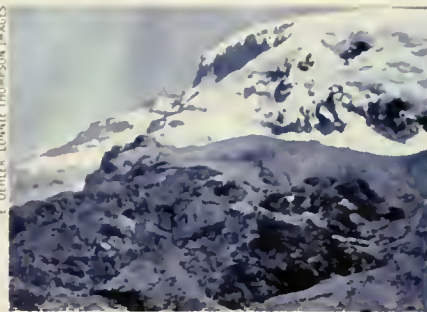
Could it be that these ocean oscillations, because of their effect on air temperature, also explain the snowline fluctuations seen in the Swiss Alps? So far, none of the wood or peat fragments sluiced from beneath the ice have yielded carbon 14 dates from the eighth through the thirteenth centuries, which would correspond to the Medieval Warm Period and the interval leading up to the Little Ice Age. But another source of evidence demonstrates that Alpine glaciers were smaller during this time. Medieval farmers living below the huge Aletsch Glacier, in what is now south-central Switzerland, constructed a crude aqueduct of hollowed-out

## ***A 1,500-year cycle in ocean temperature affects how far south North Atlantic icebergs can travel.***

larch tree trunks to carry water from a small mountain lake down to a village. We know from written records that parts of this aqueduct had to be rebuilt after being overrun by the 1350 advance of the Aletsch Glacier.

If future dating of wood and peat expelled from beneath retreating glaciers in the Alps and other mountainous regions worldwide supports Bond's 1,500-year cycles, and if the Medieval Warm Period/Little Ice Age oscillation can be shown to be part of the most recent of these cycles, we will have taken an important step toward establishing a major natural rhythm in Holocene Epoch temperatures. This rhythm could then be extrapolated into the future. Because the midpoint of the Medieval Warm Period was about A.D. 850, an extension of Bond's cycles would place the midpoint of the next warm interval in the twenty-fourth century.

While offering a useful basic framework, this pattern alone does not account for all aspects of past fluctuations and thus is not a sufficient predictor for the future. For example, we usually think of cycles as having a regular, bell-like shape. But during the millennia corresponding to the last ice age, Bond's 1,500-year cycles were closer to rectilinear, indicat-

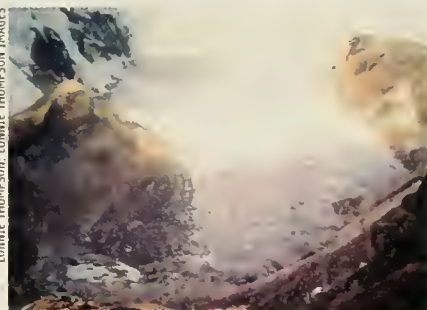


ing sudden starts and stops. As is clearly recorded within the deep layers of Greenland's ice, the transitions often took just a few decades. This abruptness was especially pronounced as the climate warmed. Has this also been the case during our own epoch, the Holocene? If the Holocene's "Bondian" cycles, too, have been rectilinear, one would expect the post-Little Ice Age warming to have been completed within a few decades. One would also expect that in the absence of the Industrial Revolution, global temperature would have stabilized for a warm plateau of several hundred years. But in fact, global temperatures in the decades immediately after the Little Ice Age did not simply jump to a new plateau.

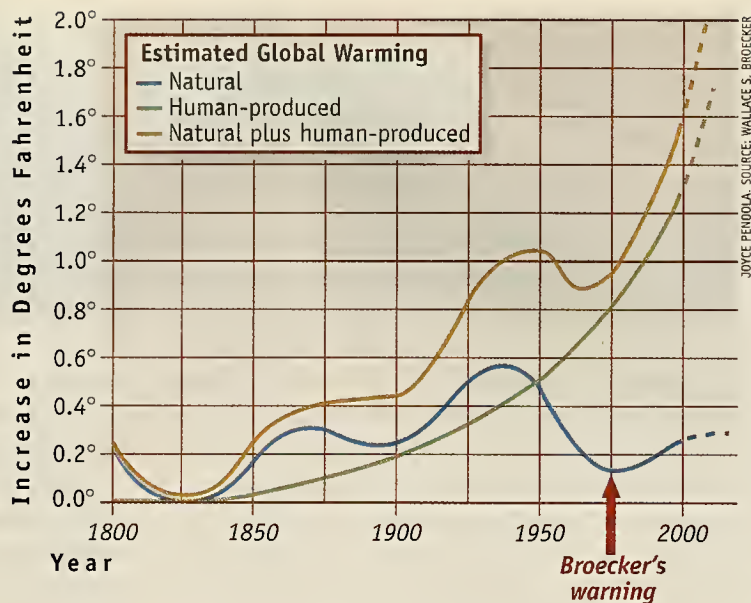
Also, studies of Alpine glaciers show that the Little Ice Age had three cold peaks, in about 1350, 1650, and 1850. Do we have any clues about the causes of these additional, smaller fluctuations? I pondered this problem in the early 1970s. At the time, Holocene climate records were few and far between. In fact, only one—a 70,000-year record obtained from a one-mile-long, four-inch-diameter ice core drilled in northern Greenland—had enough length and detail to provide any clues. Danish paleoclimatologist Willy Dansgaard and his colleagues had managed to obtain paleotemperature results from samples of this core and had concluded that much of the variation in climate could be accounted for by a combination of 80-year and 180-year cycles, which they thought reflected periodic fluctuations in the Sun's energy output. When I merged Dansgaard's pattern with that of the warm-

**Tanzania's Kilimanjaro has lost more than four-fifths of its summit ice in the past century. Above left, the peak in 1912; at right, in 2000.**

**Qori Kalis Glacier in the Andes of southern Peru: Photographs taken in 1978, below left, and 2000 provide more evidence that global warming is a worldwide phenomenon.**







**Above:** Though the cumulative global warming since 1800 amounts to less than 2° F, it is expected to increase, owing mainly to the contribution of human-produced climate effects. In 1975 the author warned that an upturn in the natural cycle would reinforce these human-produced effects. **Right:** Wood washed from beneath Switzerland's Unteraare Glacier.

ing expected from the steady increase in man-made greenhouse gases, I obtained a composite that matched the major features of the actual global thermometric record—namely, a warming phase extending from 1860 to the time of World War II and followed by a thirty-year pause (see graph, above). I predicted that when, in the near future, Dansgaard's natural cycle turned from a cooling into a warming phase, the natural and the man-made factors would join forces and produce a prominent renewal of the warming trend. My warning was published in the journal *Science* in 1975. In 1976 the thirty-year plateau came to an end, and the warming that then began has continued right up to the present.

My prediction was correct, but was it soundly based? Ten new ice-core records—from Greenland, from Antarctica, and from high-mountain sites elsewhere on the planet—are now available. None show Dansgaard's combined 80-year and 180-year cycles. I thus have been inclined to write off the success of my prediction as just a happy accident. Still, the changes we are attempting to document have a magnitude of only a few tenths of a degree,



and perhaps in most records they are masked by regional climate change.

What drives Bond's 1,500-year cycle? High on the list of possibilities must be the Sun. But sufficiently accurate, satellite-based measurements of solar activity cover only the past twenty years—not long enough to warrant our drawing firm conclusions. We do, however, have a longer-term record of the number of dark spots resulting from magnetic storms on the Sun's surface. These spots usually wax and wane in an eleven-year cycle. During an interval known as the Maunder Minimum (A.D. 1650–1710), however, no sunspots were observed. Minze Stuiver, an isotope geologist at the University of Washington, has shown that more carbon 14 atoms were created in our atmosphere during the Maunder Minimum than either before or after it. The reason, Stuiver postulated, is that the electrically charged particles streaming out of sunspots generate a magnetic field that deflects incoming cosmic rays from our solar system. During periods of low sunspot activity, such as the Maunder Minimum, however, the magnetic shield is turned off and more cosmic rays bombard Earth's atmosphere, manufacturing extra carbon 14 atoms. Having demonstrated the link between sunspots and carbon 14 production, Stuiver was then able to use carbon 14 measurements on tree-ring-dated wood to deduce sunspot minimums prior to the invention of the telescope. His data indicate that these occurred at roughly two-century intervals and might be the cause of Dansgaard's 180-year cycle. Stuiver's record contains no hint of Dansgaard's 80-year cycle or of Bond's 1,500-year cycle, however.

If not the Sun, then what might be the driver of Bond's cycle? For me, the top candidate remains the ocean's bipolar seesaw. In the global ocean circulation pattern we are accustomed to seeing, sinking cold surface water in the North Atlantic is replaced by warm Gulf Stream waters, which are drawn northward. What may underlie this pattern is actually salt, since an extra gram of salt per liter makes seawater denser by an amount equivalent to a cooling of 8° F. The North Atlantic is unusually salty, because the location of mountains and the direction of prevailing winds lead to the export of water vapor from the Atlantic to the Pacific Ocean. The salt left behind makes that surface water not only saltier but denser, and the water sinks in the familiar pattern.

Meanwhile, acting like a giant conveyor belt, the normal circulation of the world's oceans transports excess salt out of the Atlantic Ocean. This



process may not occur at a steady rate. Rather, it may oscillate, leading to Bond's 1,500-year cycle. As I see it, at times the conveyor mechanism carries salt away faster than it is being replaced. This may lower the water density in the North Atlantic enough to make the conveyor shut down. At this point, the warm Gulf Stream weakens, and the circulation pattern reorganizes itself under the domination of the Southern (Antarctic) Ocean. With the new regime, salt ceases its rapid departure from the North Atlantic, and salt levels there begin to rise again. When the northern waters are again dense enough to rejuvenate deep-water formation in the North Atlantic, the cycle is complete.

The details of this mechanism are still not clear, but what *is* clear is why such a cycle might lead to warmings and coolings of the lands surrounding the

### ***Are underlying natural cycles retarding or reinforcing human-induced global warming?***

North Atlantic. When the north rules, an enormous amount of heat—as much as would be generated by a million large power plants—is carried north of the Strait of Gibraltar by the Gulf Stream. This heat is released into the atmosphere in winter and is carried to northern Europe by the prevailing westerly winds. When the south rules instead, this source of heat is lost and the Alps cool.

But how does any of this explain the cooling in the Southern Hemisphere—the Little Ice Age in New Zealand's Southern Alps and in South America's Andes? Instead of being limited to the land area adjacent to the North Atlantic, this cold episode appears to have affected much of the planet. There must have been some link between patterns of ocean circulation and conditions in the atmosphere that affected both hemispheres. Although the nature of this link has not been discovered, it probably involves Earth's "tropical heat engine"—the way air rising from the equator fuels the atmosphere with heat and water vapor.

So where do we stand? For a start, certain regular fluctuations in the Holocene climate seem to occur, but scientists are still left with many uncertainties about them. This prevents us from making a meaningful prediction concerning how the climate would have changed in the absence of the Industrial Revolution. We cannot prove the existence of either the 1,500-year cycle—which the available

Greenland ice cores fail to record—or the combined 80- and 180-year cycles. However, we can state with some confidence that natural Holocene temperature fluctuations have been on the same scale as the human-caused effects estimated to result from greenhouse gases. Hence, we cannot assume that in the absence of human intervention, Earth's temperatures would have remained stable.

Unfortunately, we cannot even say whether natural changes are at this point retarding or reinforcing human-induced greenhouse warming. The situation will be much clearer two decades from now,

**Rock debris surrounds a lake below Hooker Glacier, in New Zealand's Southern Alps. The debris is a residue of the glacier's advances during the Little Ice Age.**

GEORGE H. DENTON, UNIVERSITY OF MAINE





however, as computer simulations predict an additional 1.5° F warming by the year 2020. If such an increase in global temperatures occurs, there will not be any doubt: natural causes alone would not have been sufficient to account for it.

Does this mean we can all sit back, do nothing, and wait for the results to roll in? Certainly not. In twenty years, we may well conclude that we must stem the rise of CO<sub>2</sub>, and if so, we've got a lot of preparation to do. Very likely, fossil fuels will remain our primary source of energy. With more people and a higher standard of living in the less developed countries—and with even a sustained per capita level of demand in the United States—energy use will at least double by the year 2050. We must learn how to remove CO<sub>2</sub> from power-plant exhausts and

***We may have to remove CO<sub>2</sub> from power-plant exhausts and even from the atmosphere itself.***

probably from the atmosphere itself. (Estimates of the cost of CO<sub>2</sub> removal suggest that it would add a few cents per kilowatt-hour to the cost of electricity or about forty cents per gallon to the cost of gasoline.) Plus, of course, the CO<sub>2</sub> we remove must be put somewhere: stored in the deep ocean or in deep saline aquifers or, if we want to be sure it never comes back to haunt us, converted into magnesite (MgCO<sub>3</sub>), a geologically inert mineral. More difficult than the technical aspects are the political ones. Ready or not, we will have to face them all.

To strengthen their case, corporate spokespersons, avid consumers, and plenty of other people and institutions inclined to dismiss the ongoing rise in atmospheric CO<sub>2</sub> as inconsequential may be happy to latch on to the paleoclimatic reconstruction presented here. This would be unfortunate. Unless all the work done on climate simulations and fossil-fuel-use projections is seriously flawed, one thing is certain: our planet will indeed experience a major human-induced warming during this century.

We have learned that Holocene temperatures have undergone natural fluctuations, but the causes of these changes are so subtle that we have yet to figure them out. Apparently, our climate system responds to even tiny nudges. This being the case, the potential effects of human activities should not be underestimated. If we continue along a business-as-usual energy course, we'll be giving the climate a large shove. □

**Fragments from Alaska's Columbia Glacier, a thirty-five-mile-long stream of ice that sheds icebergs into Prince William Sound**

CARR CLIFTON; MINDEN PICTURES











**A small European legless lizard called the slow worm, above, rests on a rock beside its rusty tin shelter.**

**L**izards have legs; snakes don't. This generalization, which many of us learned in grade school, may be useful as a rule of thumb but is surprisingly inaccurate. Some snakes, such as pythons, retain tiny leg bones, which may be visible as minuscule claws at the base of the tail. Perhaps more surprisingly, dozens of lizard lineages have lost their limbs over evolutionary time and are now, at least superficially, indistinguishable from snakes. (Snakes are actually just a highly modified group of lizards, but one characteristic that sets snakes apart is a flexible skull, allowing them to

swallow prey larger than their heads.) Limbed and limbless species of lizards may even be found within the same genus. Because these dramatic changes have occurred repeatedly, they provide a wonderful natural experiment that can help us understand how major transformations in body form happen.

With collaborators Jamie Slingluff and Tod Reeder, I have begun to study these transformations from lizardlike to snakelike form. By combining detailed body and limb measurements, evolutionary trees derived from DNA data, and statistical analyses, we have found that this transition involves three



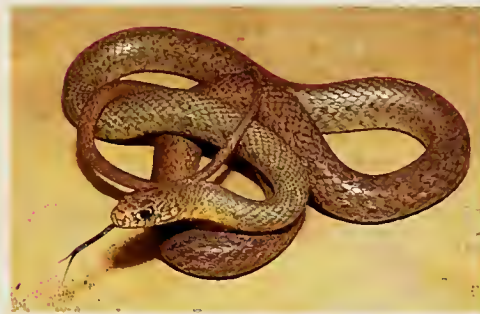
# Shape Shifters

*Time after time, lizards have dropped their legs in favor of a snakelike body form.*

By John J. Wiens



MALL BENWIG; OXFORD SCIENTIFIC FILMS



SUZANNE COLLINS; PHOTO RESEARCHERS, INC



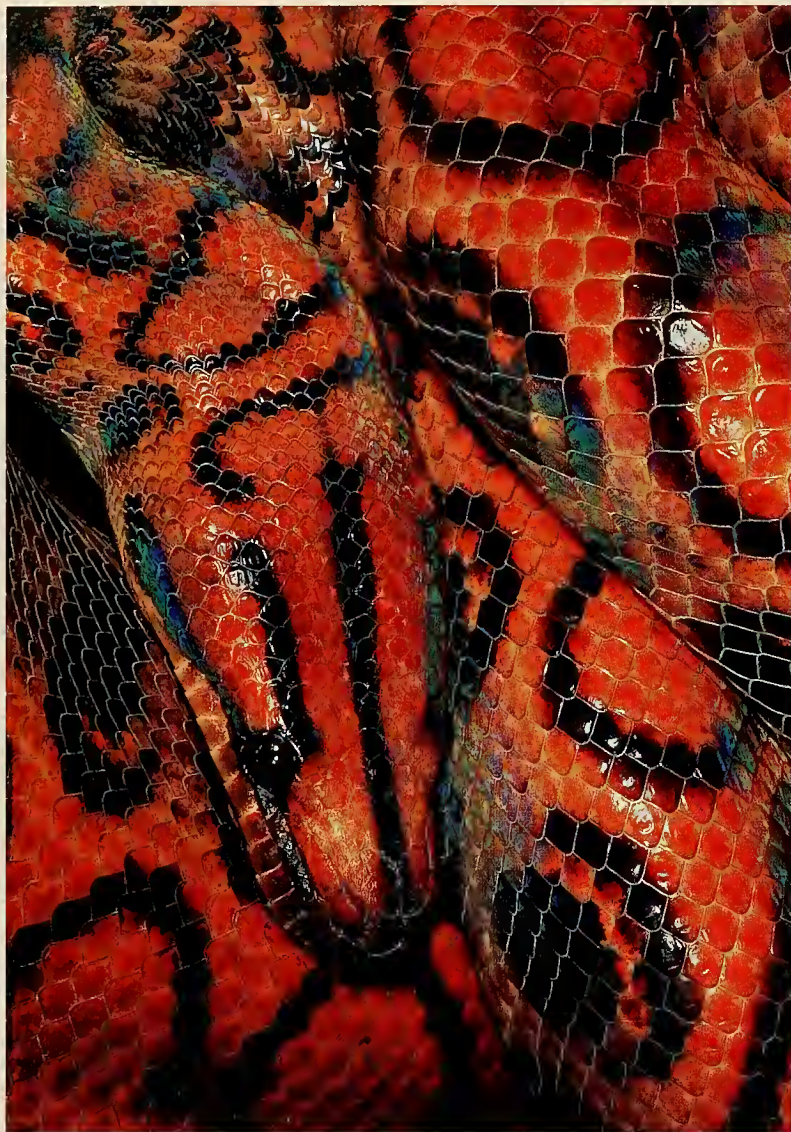
KEN GRIFFITHS; ANI PHOTO LIBRARY

**Top:** The Eastern racer, a typical snake, is strikingly similar in appearance to a legless pygopodid lizard from Australia, bottom.

tightly correlated evolutionary changes: increase in total length, reduction in limb size, and loss of fingers and toes.

We have also found that despite the overall similarity of snakelike lizards, two distinct types—burrowers and “grass swimmers”—have evolved over and over again. Burrowers tend to be small and to have relatively short tails and long trunks. (The trunk is the body length minus head and tail.) By contrast, grass swimmers live above ground, often in dense grass, and have longer tails and shorter trunks than burrowers do. They may





GREGORY G. DIMILIJAN; PHOTO RESEARCHERS, INC.

While most snakes (such as the rainbow boa, above) have short tails and live above ground, snakelike lizards are generally either long-tailed surface dwellers or short-tailed burrowers. Because the most primitive lineages of snakes are burrowers, short tails in surface-dwelling snakes may be an evolutionary leftover from an underground ancestry.

also be considerably larger: some are big enough to eat mice.

The reasons for this dichotomy in body form and habitat are not yet clear, but we have some ideas. Surface-dwelling lizards are exposed to many predators, such as hawks and skunks. The tail, which lacks vital organs for most of its length, is less critical to survival than are other parts of the body, and many long-tailed surface-dwelling lizards, whether limbed or limbless, have tails that break easily when grabbed by an attacker. (Fortunately for the lizards, their tails regenerate.) Indeed, the unusual fragility of the elongate tail in the snakelike

Long-tailed surface dwellers, glass lizards have fragile tails that can break off if grabbed by a predator. A broken tail grows back, though typically in a different color and shorter than the original.



genus *Ophisaurus* is reflected in its common name: glass lizard. Burrowers, which spend most of their time hidden from predators, have short tails that are rarely modified for breaking.

The small body size of many burrowers may also help explain their short tails. Trunk space is at a premium in small lizards, because having a tiny





JAMES R. ROBINSON, ANIMALS ANIMALS



JAMES R. ROBINSON, ANIMALS ANIMALS

California legless lizards—short-tailed burrowers—are found on beaches and in other sandy habitats.



JACK BIERMID, BRUCE COLEMAN, INC

body cavity can reduce the size and/or the number of young (a potential evolutionary handicap). Increasing the length of the trunk at the expense of the tail may allow small burrowers to maintain enough room for developing eggs or embryos (most of these lizards lay eggs, but some give birth to live young).

The glass lizard above is a grass swimmer whose tail makes up more than two-thirds of its total length. In burrowers (such as the California legless lizard, top right), the tail may be only one-third of the total length.

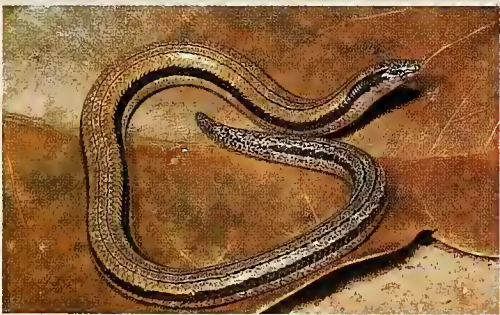




ROBERT W.G. JENKINS; ANT PHOTO LIBRARY



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ROBERT VALENTIC; NATURE FOCUS

Some groups of lizards have members representing nearly every stage in the transition from lizardlike to snakelike body form. In the Australian skink genus *Lerista*, for example, are species with four limbs, top, two limbs, middle, and no limbs, bottom.

We will continue to explore this puzzling dichotomy among snakelike lizards, as well as the more fundamental question of why lizards have repeatedly evolved to become snakelike in the first place. One hypothesis is that reduced limbs and elongate bodies may streamline lizards, helping them move more easily in underground tunnels and through dense grass. To test this hypothesis, our plans include the staging of a “Lizard Olympics”—taking individuals from species representing various points in the transition from lizardlike to snakelike body form and comparing their athletic abilities as they move in different habitats. □



TOM MCHUGH; PHOTO RESEARCHERS, INC.

In most lizard lineages that have become snakelike, the front limbs were lost first. The Mexican worm lizard, an exception to this trend, has reduced its rear limbs but has retained well-developed front legs, which it uses for burrowing.



MICHAEL FODDEN; OXFORD SCIENTIFIC FILMS

The galliwasp, in the family Anguillidae, represents the ancestral four-legged form from which both snakelike, burrowing anguillids (e.g., the California legless lizard) and grass swimmers (e.g., the glass lizard) evolved.

Why so many lizards (including the hooded scaly foot, opposite) evolved a snakelike form is a question that remains unanswered.

One hypothesis is that since legs hinder movement in dense grass and in tunnels—two common habitats of snakelike lizards—natural selection may favor their loss.







## REVIEW

Before Marxism lost its footing, its pamphlets discussed “post-capitalist” society as if the demise of free enterprise were just around the corner. I am always wary of in-your-face declarations of victory—titles like “The Triumph of X or Y,” for instance—since they tend to be either unnecessary or premature. Several books on evolution and sociobiology carry such titles, and now here comes *Evolution: The Triumph of an Idea*, the companion book to a PBS television series. Having watched the full eight hours of the *Evolution* video, I understand why this book title was selected, but, just as the series does, I will postpone discussing this issue until the end.

Why has no one until now had the brilliant idea of putting together a series explicitly about evolution? It is such a delightful story to tell: how Darwin began developing his theory during his travels on the HMS *Beagle*; how, with his habitual intellectual honesty, he gave full attention to every possible objection; Darwin’s receipt of Alfred Russel Wallace’s manuscript, which led to a hasty session at the Linnean Society to declare the idea of evolution by natural selection; the resistance from paleontologist Richard Owen, English cleric Samuel Wilberforce, and others; the ultimately wide acceptance of the theory; and how the *Origin of Species* inspired generations of scientists to look at the world in an entirely new light (as all good theories do), which confirmed at every turn the soundness of its assumptions.

The television series opens with lots of acting: a youthful Charles Darwin debating new ideas with his drunkard brother, Erasmus (named after their grandfather, who a century earlier had proposed that “Organic Life beneath the shoreless waves, / Was born and nurs’d in Ocean’s pearly caves”). Then we see Darwin lighting up with recog-



Volcanoes and marine iguanas of the Galápagos inspired Charles Darwin to imagine a younger world.

# Sing the Song of Evolution

Finally, television takes a comprehensive look at Darwin and his ideas.

Frans B. M. de Waal

niton and understanding as he reads British economist Thomas Malthus’s work on the social struggle for resources. Another scene shows Darwin, with his favorite daughter, Annie, by his side, staring through a microscope at a barnacle as she playfully pronounces the animal’s name as “Barney Ickle.” Annie’s death from scarlet fever, at the age of ten, is also depicted, with her father angrily and symbolically turning away from the church at her funeral. Her death, Darwin wrote, had robbed him of “the solace of our old age.”

A range of topics in modern evolutionary biology are covered next. We see how random selection can transform evolution into an enemy—for example, when it turns viruses into lethal pathogens (here we see harrowing images of AIDS patients and of prisoners in Russia infected with multidrug-resistant tuberculosis). We also consider

selection as the “friend” that shaped the evolution of the eye. This model organ is full of clues to random selection. The series does an excellent job of getting across that evolution has to deal with existing material, not only for the eye but also for quadrupedal locomotion and the genetics of fruit flies. The message is that the natural world is full of reused baggage. Truly “intelligent” design from scratch could have produced a much more effective eye—without a blind spot, say—but evolution has to work with the old to make the new. “Tinkering” is therefore a word frequently used by the eminent scientists interviewed in *Evolution*.

Evolution is as much about destruction as it is about creation. Thus, one episode in the series covers mass extinctions and the need to preserve biodiversity, while another looks at sexual reproduction, without which viruses



would freely attack species that are “sitting ducks” because of their lack of genetic diversity. I found these episodes most satisfying because they combine new thinking in evolutionary biology with the work of scientists who are collecting the corroborating evidence, such as in the testing of the Red Queen hypothesis (named for Lewis Carroll’s character, who said to Alice, “Now, here, you see, it takes all the running you can do, to keep in the same place”—that is, a host population continually evolves to stay one step ahead of its parasites and pathogens).

The task of choosing which topics to include must have been almost impossible, given the project’s scope. Evolution is such a dominant concept that it has become synonymous with the life sciences in general. Yet I do wonder why barely any attention is paid to certain controversies (such as sociobiology and punctuated equilibrium) and to some of the most exciting theoretical extensions (kin selection theory, for example, or the handicap principle), while much time is devoted to highly speculative ideas (the connection between our gossiping and other primates’ grooming, human brain size as a product of males trying to impress females, cultural change mimicking genetic evolution). The narrative doesn’t give viewers many clues to distinguish the tried-and-true from the half-baked. The readable companion book, expertly written by science writer Carl Zimmer, generally does a better job of sorting out what is serious science and what, at this point, is an idea whose triumph remains up in the air.

This brings me back to the word “triumph” in the book’s title, which betrays a preoccupation with the adversaries of evolution. By paying less attention to the peculiarly North American tension between Biblical literalism

and the life sciences, the series could have truly celebrated a magnificent idea that has won over essentially everyone in the world willing to listen to scientific arguments (including the pope). Science is a brutal process of holding ideas up against the light of data, and if one does so—as this series does with the theory of evolution—there is absolutely no reason to sound defensive about it. With overwhelming substantiation, theory has become fact. Facts don’t “triumph”; they simply *are*.

In the last segment, we catch a glimpse of ongoing attempts at indoctrination by those who believe otherwise, such as a guy with hat and guitar jovially conducting a sing-along with a Christian audience, including many children: “I don’t believe in evolution, I know creation is true/I believe that God above created me and you.” Sing such lines a hundred times when you are young and, yes, you will be thrown into turmoil when first exposed to modern science. The struggle of some college students with issues that pit religion against the theory of evolution is painful to watch, because the conflict is wholly unnecessary. Evolution deals with how life arose; religion with how it is to be lived.

If *Time* can put a chimpanzee’s face on its cover with the title “How Apes Became Human” (July 23, 2001), the idea of evolution has evidently become mainstream. It is time to treat it as such. This series presents its fascinating story in a lively yet responsible manner, bound to delight and inform.

*Frans B. M. de Waal is C. H. Candler Professor of Primate Behavior and Director of Living Links at Emory University in Atlanta. His latest book is The Ape and the Sushi Master: Cultural Reflections of a Primatologist (Basic Books, 2001).*

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## Follow a Fossil

By Robert Anderson

My five-year-old has informed me that he is, without question, going to be a paleontologist when he grows up. Not wanting to discourage him, I took him to see the Rancho La Brea Tar Pits in Los Angeles, where fossil collectors laboring away in Pit 91 were unavoidably smeared with black goopy tar and the air reeked of hydrocarbons. It was worse than a refinery. Although unperturbed by the working conditions, my son was disappointed to learn that the tar-pit remains represented a very recent slice of geologic time (as you will see if you visit [www.tarpits.org](http://www.tarpits.org)) and held no chance of yielding dinosaurs.

I found a great Web site for him that reinforces the stark reality of paleontology: that while being a lot of fun, it is also very hard work. The Denver Museum of Nature and Science’s “Follow a Fossil” ([www.dmnh.org/denverbasin2/fossil](http://www.dmnh.org/denverbasin2/fossil)) describes prospecting for fossilized ancient life-forms and the labor involved in transferring them from field site to museum.

In the section on vertebrates, we track the path of a rather obscure Cretaceous turtle (they can’t all be *T. rex*) from where it was dug up in North Dakota through its “jacketing,” cleaning, casting, storage, and identification. Another section explores invertebrates—specifically, ammonites found in Colorado that are the size of man-hole covers.

Will my son, still fixated on dinosaurs, become motivated to rough it in the field? I have yet to tell him about the job I once had sorting fossil plankton skeletons the size of sugar grains. I don’t want to burst his bubble.

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



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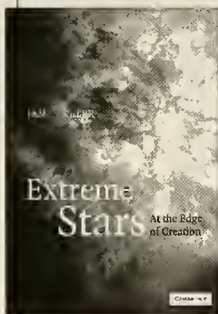
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## BOOKSHELF

### The Triumph of Sociobiology, by John Alcock (Oxford University Press, 2001; \$27.50)

In 1975, ant expert E. O. Wilson published *Sociobiology: The New Synthesis*, a systematic study of the biological basis of all social behavior. Alcock, a biologist, looks at the ongoing debate sparked by Wilson's ideas and shows that they make sense in light of evolutionary theory.

### Rock of Ages, Sands of Time, paintings by Barbara Page, text by Warren Allmon (University of Chicago Press, 2001; \$45)

Page depicts a sampling of the earth's organisms at million-year intervals to represent evolutionary history from "the origin of macroscopic life on this planet [to] the recent conclusion of a millennium." Succinct essays by Allmon introduce readers to each geological period. Page's 544 contiguous panels will be installed in the new Museum of the Earth in Ithaca, New York, in 2002.

### Wildlife Wars: My Fight to Save Africa's Natural Treasures, by Richard Leakey and Virginia Morell (St. Martin's Press, 2001; \$25.95)

The views and voice of Leakey—physical paleoanthropologist, director of the Kenya Wildlife Service (1989–94), and advocate of African wildlife conservation—are captured here by Morell, a journalist who has relied on Leakey's notes and diaries and on her many discussions with him.

### The Tangled Field: Barbara McClintock's Search for the Patterns of Genetic Control, by Nathaniel C. Comfort (Harvard University Press, 2001; \$37.50)

This readable biography of one of the twentieth century's most important geneticists interweaves fact and insight about McClintock as both person and

scientist. Her discovery of mobile genetic elements in corn and her efforts to resolve fundamental problems in biology (development, heredity, and evolution) make her, in Comfort's view, a rare visionary.

### Uncle Tungsten, by Oliver Sacks (Knopf, 2001; \$25)

"Many of my childhood memories are of metals: these seemed to exert a power on me from the start," neurologist Sacks writes at the beginning of his vivid memoir about growing up in wartime England and discovering the life of the mind.

## PHOTOGRAPHY



### Sacred Places, by Kenro Izu (Arena Editions, 2001; \$65)

### The World According to Pimm: A Scientist Audits the Earth, by Stuart Pimm (McGraw-Hill, 2001; \$24.95)

In a book packed with sobering information, conservation biologist Pimm considers our global use and misuse of water and land and the wildly acceler-



ating rate of species extinction, yet he remains confident that good stewardship will save the planet.

**The Northern Lights: The True Story of the Man Who Unlocked the Secrets of the Aurora Borealis**, by *Lucy Jago* (Knopf, 2001; \$24)

Explaining these colored arches, bands, and curtains in the night sky became the lifework of Norwegian scientist Kristian Birkeland, whose theories about the northern lights, electromagnetism, comets, and the sun were accepted by the scientific community only after his death in 1917.

**Rowing to Latitude: Journeys Along the Arctic's Edge**, by *Jill Fredston* (North Point Press, 2001; \$24)

Be it storm, bear, or iceberg, nothing is predictable in Fredston's account of summering in the Arctic with her husband in a pair of oceangoing sculls (both work as avalanche experts in Alaska during the winter). One unusual discovery in Norway's Svalbard Islands was a bowhead whale hanging fifty feet above the water, its belly still embedded in the melting glacier that had encased it during the Little Ice Age (1300–1860).

**Women of Discovery: A Celebration of Intrepid Women Who Explored the World**, by *Milbry Polk and Mary Tiegreen* (Clarkson Potter, 2001; \$40)

Here, packed with illustrations and photographs, are the stories of eighty-four visionaries, adventurers, artists, and scientists—from Chinese poet Lady Wen-chi, kidnapped by Mongol warriors circa A.D. 190, to U.S. geologist Louise Hose, a dedicated caver who has recently uncovered new life-forms in the sulfurous passageways of Mexico's Cueva de Villa Luz.

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

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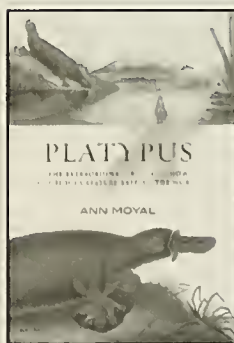
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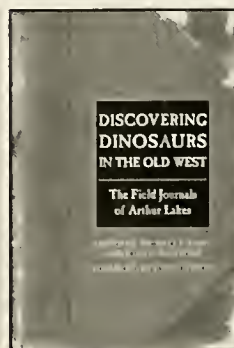
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## CELESTIAL EVENTS

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# Seeing Doubles

Observe the stars one,  
by one, two by two,  
four by four . . .

By Richard Panek



At some time or other, you've probably found yourself staring up at the stars and marveling, "Look at all those points of light!" Maybe for emphasis you added an adjective: "Look at all those *individual* points of light!" If so, you were wrong.

Contrary to appearances, if not common sense, the majority of "stars" are not individual points. They're systems of multiple stars so far from

Earth that to the naked eye, each system appears to be a single entity. The illusion is especially convincing because it reinforces an insidious prejudice, one so fundamental to the way we think about the universe that we might easily overlook it. In fact, for thousands of years, we did. Because we see a singleton, the Sun, in our daytime sky, we assume that the stars in our nighttime sky must be the same.

But the Sun is actually an exception. When British astronomer William Herschel undertook, in the late eighteenth century, the first comprehensive telescopic survey of stars, he started finding doubles everywhere. At first he figured that such pairs consisted of two stars vastly distant from each other but coincidentally lying along a single line of sight—a visual phenomenon we now call optical doubles. And some were. But over time, he observed that most were two stars interacting through their mutual gravitational attraction—*physical* doubles. Not only did this surprise Herschel, but it provided stunning support for the idea that Newton's theory of gravitation applied beyond our solar system—that it just might be universal, after all.

One especially prominent example—the second point of light from the end of the handle in the Big Dipper—provides a sort of history of our evolving understanding of double stars. This "star" is actually two stars, an optical double consisting of Mizar (the brighter star) and Alcor.

(The pair are circled by the red "o" in the photograph at left.)

From the earliest days of sky watching, the ability to perceive this optical double served as a test of eyesight among Arabs and Native Americans. But Mizar itself is not an individual star. Most standard sources credit Italian astronomer Giovanni Battista Riccioli with being, in 1650, the first to resolve Mizar (through a telescope) into Mizar A and Mizar B,



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though recent research indicates that the honor might belong to Benedetto Castelli and date back to 1617—less than a decade after the invention of the telescope. Either way, to Mizar goes the distinction of being the first telescopic binary.

Then in 1889, Harvard astronomer Edward C. Pickering examined the lines in the stars' spectra and found that one of the two, Mizar A, was itself a binary, thereby bestowing on it the distinction of being the first spectroscopic binary. Later analysis revealed the same to be true of Mizar B. A spectroscopic binary, by definition,

*From the earliest days of sky watching, the ability to perceive this optical double served as a test of eyesight among Arabs and Native Americans.*

should frustrate even the most powerful telescope, but in 1996 the Navy Prototype Optical Interferometer focused on the Mizar A binary—which, for the record, comprises Mizar Aa and Mizar Ab—and produced what was at the time the highest-resolution image in the history of optical astronomy.

As should be apparent by now, the designation “binary” or “double” hardly does justice to the complexity of Mizar's system of stars. In such cases, astronomers instead use the term “multiple star system,” though if they need to be specific they can invoke “triple,” “quadruple,” and so on.

In all its manifestations, however, Mizar lacks one important distinction that astronomers make when it comes to star systems: it is not an “eclipsing binary.” This term refers to a pair of stars, one of which has an orbit that takes it on a path directly between the other star and Earth, producing a visible variation in the overall brightness of the pair. In 1669, Italian astronomer Geminiano Montanari discovered just such a peculiar and periodic variation in the star Algol

(not to be confused with Mizar's companion, Alcor), in the constellation Perseus, and today eclipsing binaries are sometimes called Algol-type variable stars.

This month the Big Dipper is low on the northern horizon in the first hours after nightfall. If the sky is calm and clear and your eyesight is good, you should be able to see both Mizar and Alcor on your own, though you'll definitely need the help of a telescope or binoculars to distinguish Mizar A from Mizar B. Meanwhile, the eclipsing binary Algol will be rising in the northeast at nightfall and

reaching its zenith at about 3:00 A.M. Its companion, however, will be evident only through a sudden dip in brightness for several hours every 2.87 days, when Algol drops from magnitude +2.1 to +3.4. (The specific times during October—or any other month—when Algol experiences this variation can be found on *Sky and Telescope's* Web site at [www.skypub.com/sights/variables/algol.html](http://www.skypub.com/sights/variables/algol.html).)

And let's not lose sight of Mizar's optical neighbor, Alcor. Yes, it's a binary, too, but of the spectroscopic type, which means that you won't be able to distinguish its two component stars even with the help of a telescope. Nonetheless, it's worth at least a token glance, if only in honor of its ancient Arabic name, Suha, whose English translation could apply equally well to so many of those other seemingly individual points of light up there: “the overlooked one.”

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



**Mercury** reaches inferior conjunction (between Earth and the Sun) on October 14, but in the following two weeks it zooms up and away from the eastern horizon to put on its best morning show of the year. Beginning on the 20th, the planet emerges from the bright morning twilight  $9^\circ$  below and to the left of Venus. Each morning thereafter, Mercury moves a couple of degrees closer to Venus, brightening noticeably. Between October 28 and November 7, Mercury and Venus are less than  $1^\circ$  apart, and both are plainly visible. Mercury is at its greatest western elongation on October 29, reaching an unusually bright magnitude of  $-0.5$ ; situated  $19^\circ$  above the eastern horizon at sunrise, it lies just  $0.6^\circ$  to the left of Venus.

**Venus** begins the month by rising, lustrous, in the east-southeast about one and a half to two hours before sunrise. It then sinks a little with each passing week. On the morning of the 15th, the planet rests just above and to the right of the Moon. In the final days of October, binocular users may spy the first-magnitude star Spica emerging from the dawn glow well below Venus and its closest dancing partner of the month, Mercury.

**Mars** moves out of Sagittarius and into Capricornus late in the month. At dusk, the planet is visible low in the south-southwest, setting more than four hours later. Mars starts October at magnitude  $-0.4$  (a bit brighter than the similarly-hued star Arcturus), but by the end of the month, as Mars continues to recede from Earth, it slips to magnitude  $+0.1$ . Back in June, Mars came within 41.8 million miles of Earth; by October 31, it's 99.3 million miles away.

**Jupiter** rises at about midnight local daylight time at the beginning of

October. Two hours later, it is the brightest starlike object in the sky, visible at about  $20^\circ$  above the eastern horizon. By the 31st, it rises close to 9:00 P.M. local standard time. Jupiter currently resides in the feet of Gemini, not far from the upraised club of Orion. In midnorthern latitudes, observers can see Jupiter shining regally near the zenith toward dawn, the highest position the planet has reached since 1990. The Moon passes near Jupiter late on the night of October 9–10.

**Saturn**, in Taurus, rises in the east-northeast a little more than three hours after sunset on October 1 and about two hours after sunset on the 31st. It can be found about  $6^\circ$  northeast of the first-magnitude star Aldebaran all month. By dawn, Saturn is high in the west-southwestern sky. No one with a telescope should resist the temptation to turn it on glimmering Saturn. You should readily be able to see the planet's rings in all their icy elegance and perhaps a few of Saturn's larger moons as well. A gibbous Moon hovers near Saturn and Aldebaran late on the night of October 6–7.

**The Moon** is full—a harvest moon—on October 2 at 9:49 A.M. Last quarter Moon falls on the 10th at 12:20 A.M. The Moon is new on October 16 at 3:23 P.M., and first quarter comes on October 23 at 10:58 P.M.

**Eastern Standard Time** goes into effect for the United States (except for Arizona, Hawaii, and Indiana) on October 28, the last Sunday in the month. Officially, on this date the hour from 1:00 to 2:00 A.M. is repeated, so turn your clocks back one hour anytime thereafter.

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

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## BIOMECHANICS



# A Fish Story

The spiny puffer's means of defense is hard to swallow.

Story by Adam Summers ~

Illustrations by Sally J. Bensusen

**W**hen alarmed, some toads and snakes puff themselves up impressively. Hedgehogs, porcupines, and some Old World salamanders sport protective spines. But only the spiny puffer (*Diodon holocanthus*) combines inflation and pointy spikes in one spectacular defense mechanism.

Also called balloonfish, spiny puffers belong to the Tetraodontiformes, an order of fishes known for their strange structures and odd behaviors. The boxfish, for example, is an aquatic tank with two bony skeletons, one on the inside to support its innards and one on the outside to deter predators. And the massive, tailless ocean sunfish, another relative, is essentially a huge disk—consisting of head and torso—pushed along by a couple of fins.

Compared with creatures like

these, the spiny puffer seems relatively normal when relaxed. But when threatened, the puffer undergoes a remarkable transformation, its body swelling until the fish is three times its usual size and has become a rigid, near-perfect sphere covered in spiky armor—not a good design for swimming but decidedly discouraging to attackers.

Beth Brainerd, of the University of Massachusetts, studies the biomechanical tricks the puffer uses to accomplish its swell feat. A more accurate name for this fish would be “pumper,” because it inflates not by puffing itself up but by pumping water into its stomach (which has ceded its digestive function entirely to the intestine). The stomach expands to nearly a hundred times its original volume, an astonishing increase made possible by the stomach’s being pleated, like a skirt. An amazing amount of material can be hidden away in pleats. Consider that a typical Scottish kilt is made from eight yards of tartan fabric, whereas the typical Scotsman is only about a yard around. And the pleats of a puffer’s stomach are more extensive than those of a kilt: inside the largest pleats (each of which is about three millimeters wide) are smaller folds, with yet smaller folds inside each one, and so on, down to pleats so tiny that they can be seen only through a microscope.

As the puffer fills with water, the fish’s spine, already slightly curved,

bends into an upside-down U shape, and the liver, intestines, and other internal organs become squeezed between the fish’s backbone and its rapidly expanding stomach.

Meanwhile, the fish’s skin is pushed out, obscuring most of the puffer’s features. Only the mouth—a cartoonish orifice containing heavy, crushing plates capable of pinching a human finger to the bone—remains unaffected.

The skin of a fully inflated puffer is stretched to one and a half times its resting length. But while the skin’s elasticity accounts for the change in the volume of the fish, stiffness and strength are required to turn the creature into a rigid ball. For this the puffer again turns to pleats. Brainerd discovered that the spiny puffer’s skin consists of two layers—a thin, elastic outer layer and a fibrous inner layer. This inner layer of skin is pleated and, when extended, quite stiff. So why bother with the outer elastic layer? To answer that, one need only picture a deflated, pleated puffer—it would be a rumpled, hydrodynamically impaired laughingstock.

The skin also helps deploy the puffer’s armor. The scales of this fish have been modified into slender spikes, each on a tripod-shaped, bony base embedded in the skin. Normally the tripod lies on its side, with the spike flat against the skin, pointing backward. But when the fish puffs up, the stretched skin pulls two of the

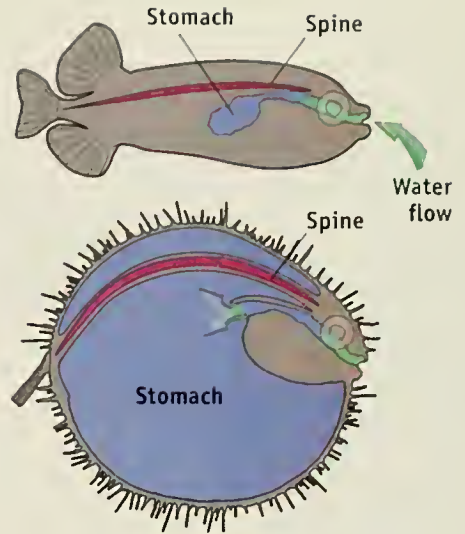


tripod's legs backward and one leg forward, snapping the spike upright. The three legs provide a secure base that blunts the force of anything pushing against the spike's sharp tip.

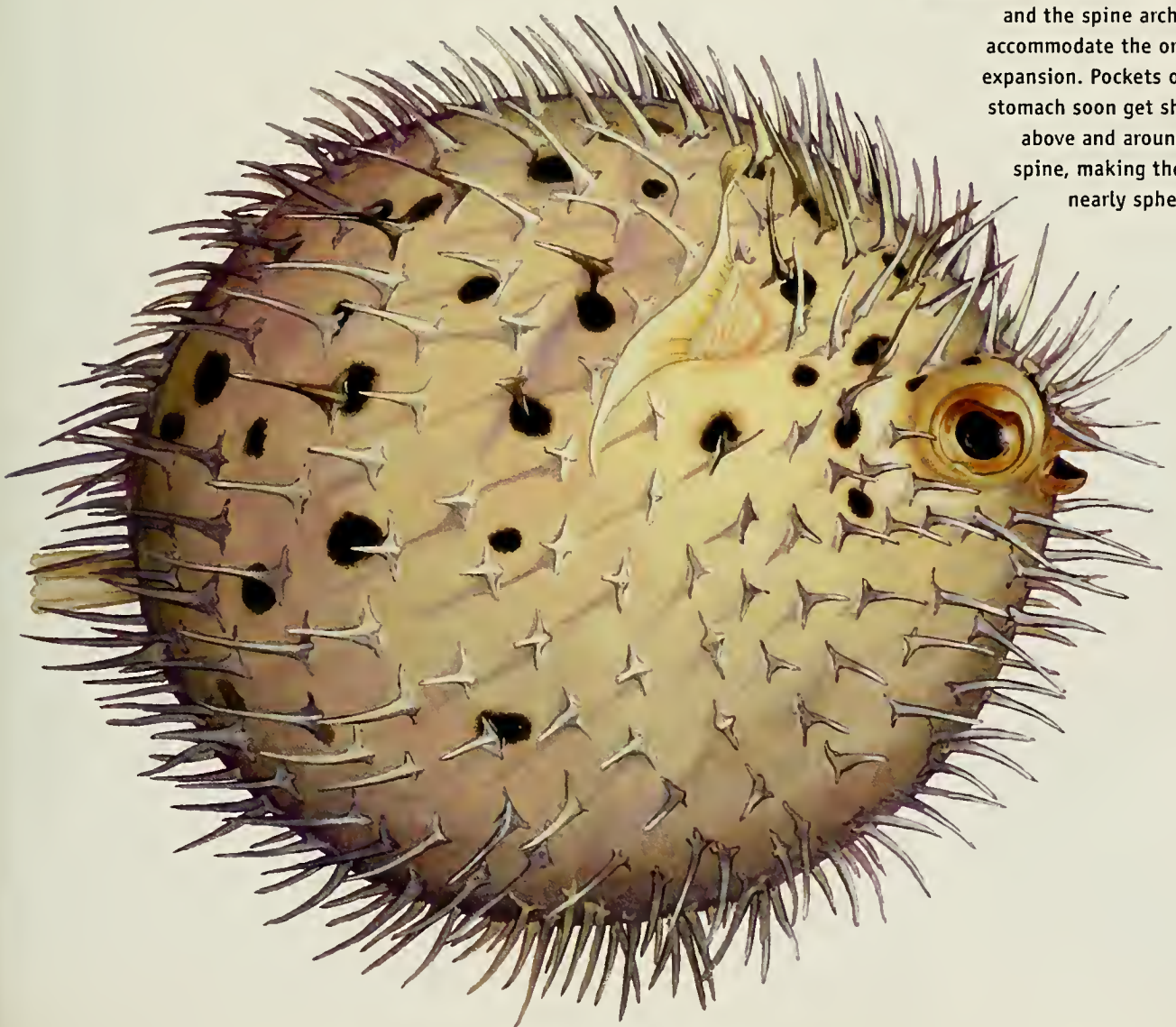
Peter Wainwright, an evolutionary physiologist at the University of California, Davis, has found clues to the origins of puffing in the triggerfish *Balistes capriscus*, a close relative of the spiny puffer. Triggerfishes feed on unusually well defended prey: spiny sea urchins. The fish's usual modus operandi is to shoot jets of water at the urchin's side until it rolls over, exposing its unprotected "belly" (actually its mouth, with which it grazes on the

seafloor). The triggerfish uses the same muscles to blow water out of the stomach that the spiny puffer uses to pump water into it. Both fish first expand their mouths to draw in water, but the puffer then pumps the water into its stomach, while the triggerfish opens its mouth and pumps the water back out. Natural selection may have taken advantage of a pumping mechanism that had evolved for disabling prey—turning it inward and transforming it into a mechanism for self-inflation.

*Adam Summers is an assistant professor of ecology and evolutionary biology at the University of California, Irvine.*



As a spiny puffer pumps water into its stomach, the stomach inflates and the spine arches to accommodate the organ's expansion. Pockets of the stomach soon get shoved above and around the spine, making the fish nearly spherical.







THE NATURAL MOMENT





# Bat Boy

Photograph by Theo Allofs

The world's 925 or so species of bats fall into two suborders. In the Americas, we are most familiar with the larger group, whose members are small and employ echolocation to catch flying insects. The other suborder comprises the largest-bodied flying mammals, including flying foxes. All strictly plant eaters, the sixty kinds of flying foxes are found mainly in India, mainland Southeast Asia, the islands of Indonesia, and Australia. Instead of using sonar when foraging at night, they rely on their excellent vision to find fruits and blossoms. In Australia, hundreds of thousands of flying foxes, often members of several species, congregate daily at arboreal "bat camps." After hanging upside down all day—squatting, grooming, and nursing their young—they take wing at night to seek food.

This male little red flying fox ("little" is part of its common name) is grooming its wings while hanging among hundreds of other bats in a

eucalyptus tree near Brisbane, on Australia's east coast. Formerly dependent on the once-widespread eucalyptus forests, flying foxes now settle near farms and urban areas, where they incur the wrath and vengeance of farmers and homeowners by eating fruit from gardens and orchards.

As the only mammals capable of sustained flight, bats rely on their semitransparent wings, composed of two layers of hairless skin stretched between the bones of their elongated forelimbs and those of their short hind limbs. Licking the wings is part of a daily routine. While grooming, the male flying fox keeps his genitals exposed, indicating to nearby females that he is receptive to mating. When his wings are spotless, he will coat them with an oily substance (produced by glands in his nose) that helps keep the membranes flexible and waterproof.—*Richard Milner*



## ENDPAPER

# “Suddenly you know the answer.”

By Nathaniel C. Comfort

Barbara McClintock, the great geneticist of maize, was so smart she could seem mystical. But her power to solve complex genetic problems was not supernatural, only a matter of speed. In a process she called integration, McClintock got “signals” from her subconscious: “I cannot tell you necessarily where they come from, but the whole thing is solved suddenly.”

This sort of experience seems to be reported most often by mathematicians and physicists. The most famous integrator of all was Albert Einstein. He worked on problems, he once said, by playing with “certain signs and more or less clear images which can be voluntarily reproduced and combined.” Some elements were “of visual and some of muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary stage.” Einstein said he reached his theory of relativity by imagining he was riding a light wave, and then looking around and describing what he saw.

For McClintock, the solution came too fast for pictures: “It’s faster than I can recognize. Suddenly everything seems clear. Then you are able to put it in steps, 1, 2, 3, 4, and tell somebody about it and it seems perfectly logical. But that’s not how it’s arrived at; it’s arrived at in some complex way that I have no way of stating. Suddenly you know the answer.” When McClintock could not solve a problem, she said it was because she had not “oriented” herself properly to see the relationships among the pieces of her puzzle. Once oriented, she maintained, “I could integrate whatever I saw immediately.”

Srinivasa Ramanujan, the self-taught Indian number theorist discovered by English mathematician G. H. Hardy, produced fantastic conjectures. Hardy then worked with him to



Barbara McClintock

derive formal proofs. Ramanujan was said to be “personal friends” with every positive integer, producing spontaneous observations—for example, that 1,729 is the smallest number expressible as the sum of two cubes in two different ways. Of John Nash, the creator of game theory, Sylvia Nasar (his biographer) observed, “Not very long after he started thinking about a problem, he would have just a very clear vision of where the solution lay. And he wouldn’t know how to get to it and it might take a year or two to get there, but he had this vision.” Physicist Richard Feynman integrated, too. His colleague Murray Gell-Mann once described the Feynman problem-solving method this way: “You write down the problem. You think very hard. Then you write down the answer.”

McClintock described integration as a form of computation, a rational, rapid process of working out connections and logical steps. Her ability appeared especially remarkable when she used it to solve problems that other scientists had been puzzling over for months. As a young scientist at Cornell University, she was part of an extraordinary group of corn geneticists. In about 1930, Charles Burnham, another member of the group, was studying a trait with a bizarre pattern of inheritance. McClintock got hooked on the puzzle. Quite “disturbed” by the problem one day, she said, “I left the field, which was down in a hollow, and I walked up to my laboratory and I sat in my laboratory for about thirty minutes. Just sat there thinking about it, and I suddenly jumped up and ran down to the field. I was at the top of the field and everybody was down at the bottom, and I was saying, ‘Eureka, eureka, eureka, I have it!’” The pattern, she realized, could result from the presence of an extra chromosome. When she joined the others, Marcus Rhoades, another colleague, said to her, “Prove it.” Only then did she sit down with a brown paper bag and a pencil and sketch out her solution. She was right.

Integration for McClintock was an internal process of self-control and awareness. In explaining how one got into the integrating frame of mind, she could only repeat, “You do something with yourself. You do something with yourself.”

*Nathaniel C. Comfort is deputy director of the Center for History of Recent Science, in the Department of History at George Washington University.*



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


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