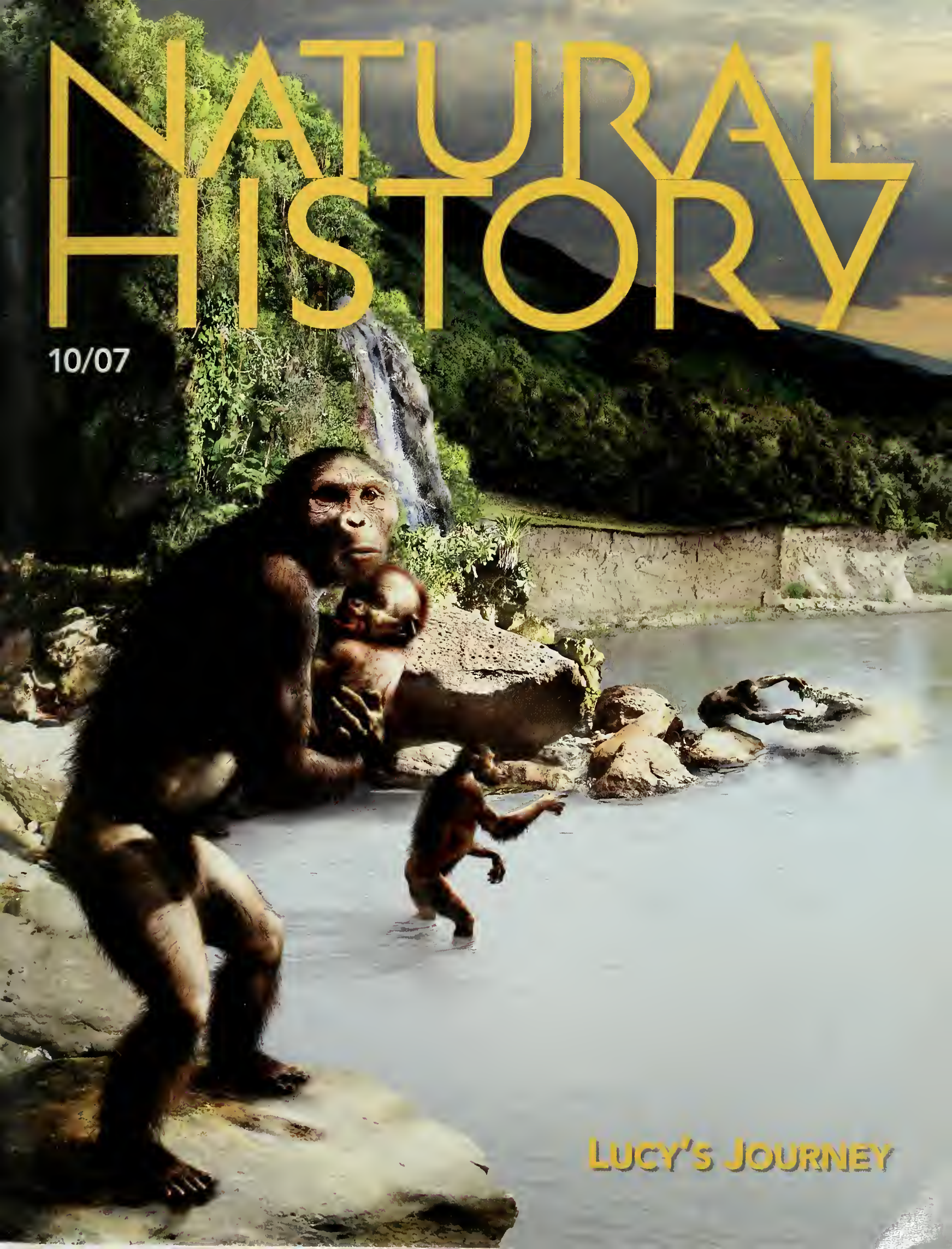
NATURAL HISTORY

10/07



LUCY'S JOURNEY

NATURAL HISTORY

OCTOBER 2007 VOLUME 116 NUMBER 8

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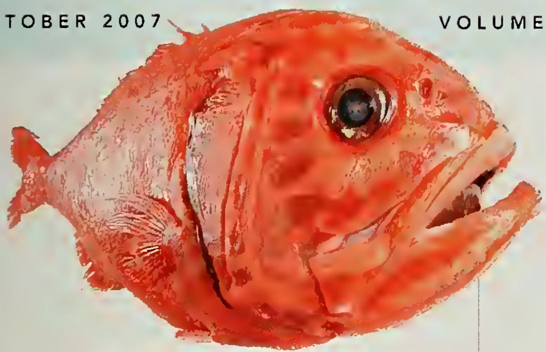

FEATURES

ON THE COVER: Reconstruction of *Australopithecus garhi*, a close relative of *A. afarensis* (Lucy), based on a 2.5-million-year-old Ethiopian fossil. The image is a detail from a digital mural by Viktor Deak, commissioned for "Lucy's Legacy: The Hidden Treasures of Ethiopia," an exhibition now running at the Houston Museum of National Science through April 20, 2008.

DEPARTMENTS

26

12

PICTURE CREDITS: Page 8

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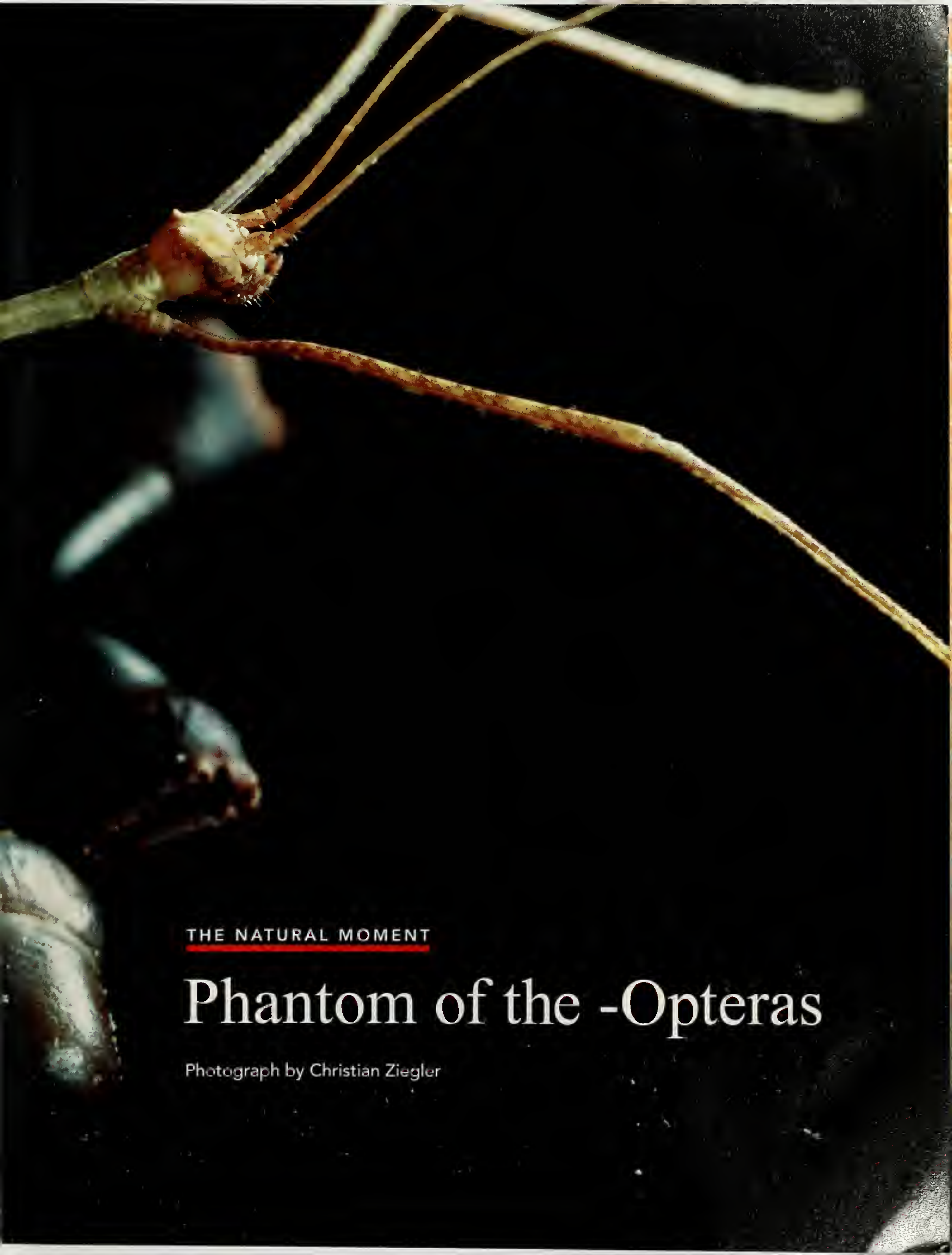

THE NATURAL MOMENT

Phantom of the -Opteras

Photograph by Christian Ziegler

THE NATURAL MOMENT

See preceding two pages

Walking sticks are creeping up on the 250th anniversary of their scientific debut: The Swedish taxonomist Carl Linnaeus first chronicled three species in 1758, calling them the phasmas, or ghosts, of the insect world. The moniker stuck, though it morphed to "phasmids," and it speaks aptly of the creatures' knack for appearing and disappearing among the twigs they mimic. Since Linnaeus, more than 2,800 species of the spindly apparitions have been sifted like needles from arboreal haystacks, and identified.

The egg capsules of the insects have been crucial to their classification. Females, which often become pregnant without males by way of parthenogenesis, deposit eggs on a weekly, if not daily, basis—depending on the species. Some eggs are glued to leaves, others buried or simply dropped on the soil; some hatch in a month, others take a year or more; some are the size of pinheads, others of pine-nut proportion. Certain eggs look so much like seeds that they get protection from ants that tote them back to their nests.

Photographer Christian Ziegler gathered the egg capsules pictured here on a moist forest floor in Panama. The newborn he caught emerging from one of the egg capsules slid out fluidly, long legs last. After five or six molts the nymph will grow to full maturity. Each molt will also give it a chance to regenerate any lost limbs—and refine the art of self-masking.

—*Erin Espelie*

UP FRONT

Shallow-Water Thinking

"Go and look in the fish markets," Richard L. Haedrich tells me, "and you'll see all kinds of fish spread out there. But you won't know where any of it really comes from. They give you the country of origin, but they don't tell you that the Chilean sea bass you're about to buy is a deep-sea fish that lives for a very long time. It's quite tasty, I've been told, but I would never eat Chilean sea bass—and I would probably never eat orange roughy for the same reason."

Haedrich, a biological oceanographer and ichthyologist who is an emeritus professor at Memorial University in St. John's, Newfoundland, has devoted most of his professional life to studying deep-ocean ecosystems. The problem with taking fish to market from the deep sea, as he notes in his article, "Deep Trouble" (page 28), is the slow pace of life there. No sunlight can penetrate to the waters along the continental slopes, at least a hundred fathoms below the surface, where deep-sea trawlers drag their fifteen-ton rigs. Fishes that survive in that gloom rely on a rain of organic matter from the surface layers of ocean. They adapt, Haedrich explains, by "slowing down, living longer, maybe taking longer to mature."

In consequence, he points out, "turnover times for any sustainable fishery in the deep sea are much longer" than they are for the shallow-water fishes that have been the customary targets of the world's commercial fishermen. "That is a fact well-known to deep-sea biologists and deep-sea oceanographers, but it seems that shallow-water thinking has been used" to gauge what can be taken from the deep sea. The result is that "a lot of deep-sea fishing operations have been more like mining operations," Haedrich says. "You clear out one area, go to another area, clear it out, and so keep moving on."

What is to be done? "I think one of the things that consumers ought to do is ask fishmongers where their fish come from, and whether they are taken in a sustainable way," Haedrich suggests. "Only then can the kind of lifestyle practiced by fishermen, and the kind of valuable food they provide, continue for generations to come." To hear the full audio recording of my interview with Richard Haedrich, go to our Web site (www.naturalhistorymag.com); you'll find the audio link on our home page.

• • •

The image on our cover this month was made by Victor Deak, one of the most accomplished paleoartists of our generation. Deak's work last appeared on the cover of *Natural History* in February 2007; this month's cover is a detail from a mural commissioned by the Houston Museum of Natural Science for a special exhibition on Ethiopian archaeology, art, and history, running now through April 20, 2008. The centerpiece of the exhibition is a 3.18-million-year-old fossilized skeleton of a female member of the species *Australopithecus afarensis,* which its discoverers named Lucy. In "Lucy Goes Walkabout" (page 26), Ian Tattersall, a curator in the division of anthropology at the American Museum of Natural History in New York City, describes Lucy, her significance to the understanding of early humans, and what is so intriguing about her current travels abroad to Houston.

—Peter Brown

CONTRIBUTORS

A tropical ecologist by training, **CHRISTIAN ZIEGLER** ("The Natural Moment," page 2) specializes in nature and science photojournalism. He serves as an associate for communication with the Smithsonian Tropical Research Institute in Panama, where he made the images for the book *A Magic Web* (Oxford University Press, 2002). His depictions of forest ecology were also featured in a traveling exhibition produced by the Smithsonian Institution and in an exhibit produced by *GEO* magazine. His photographs have won several international prizes in the *BBC Wildlife* Photographer of the Year and European Wildlife Photographer of the Year competitions. In 2005 Ziegler helped found the International League of Conservation photographers. This year he is collecting images for a new book and museum project, which will take him to the Americas and Asia. See www.naturphoto.de for more information.

RICHARD L. HAEDRICH ("Deep Trouble," page 28) is a biological oceanographer and ichthyologist who specializes in the ways deep-sea fishes relate to their environment. In spite of having what he calls "a strong distaste for getting wet," Haedrich has been chief scientist on numerous research cruises, initially based out of Woods Hole, Massachusetts, and later out of the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. He is an emeritus professor at Memorial University in St. John's, Newfoundland, where he has taught fisheries biology and oceanic biogeography since 1979 and played a lead role in directing oceanic research. His most recent work has focused on changes in the fishery ecosystem of Newfoundland before, during, and after the cod collapse of 1992. He is coauthor, with Nigel Merrett, of *Deep-sea Demersal Fish and Fisheries* (Chapman & Hall, 1997); and from 1999 until 2004 he was co-chair of the ocean fish subdivision of Canada's Endangered Species Committee. He lives in downtown St. John's with his wife, Susan; when not at sea, he enjoys cycling and playing trombone in the easternmost jazz band in North America.

Pollard

Jackson

Based in Christchurch, New Zealand, coauthors **SIMON D. POLLARD** and **ROBERT R. JACKSON** ("Vampire Slayers of Lake Victoria," page 34) are spider biologists who have worked together for almost thirty years. They met at the University of Canterbury, when Jackson was a junior member of the faculty and Pollard was still an undergraduate. Now a full professor, Jackson has spent his career working with jumping spiders in order to understand the evolution of complex behavior in animals with tiny nervous systems. Pollard is now the curator of invertebrate zoology at the Canterbury Museum, as well as adjunct associate professor at the university. In addition to working with Jackson in Kenya, Pollard has been investigating the life of a species of crab spider that lives in the liquid reservoirs of pitcher plants in Asia.

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Cut-rate Proteins

Olivia Judson's excellent article on the cell's use of relatively "cheap" amino acids ["A Terrible Scrooge," 5/07] made me wonder whether the principle could also apply to the so-called essential amino acids—the ones that people cannot synthesize and therefore have to consume. I always thought of our limited ability to synthesize as a shortcoming of our physiology. Now I wonder whether it is also part of the economic scheme: might it be cheaper to go to the grocery store for those molecules than to synthesize them?
Gabor Markus
Buffalo, New York

OLIVIA JUDSON REPLIES: Diet surely shapes the amino-acid composition of proteins—organisms that find it hard to obtain nitrogen, for instance, are less likely to use nitrogen-rich amino acids. But no one has determined whether the effect Mr. Markus suggests is operating. Intriguingly, however, the "essential" amino acids are abundantly available—not only in hunter-gatherer diets, but also in all human diets except the ones of specialized vegetarians.

Save the Vaquita!

I cried when I read "How Now, Little Cow" [7–8/07], Robert L. Pitman and Lorenzo Rojas-Bracho's article about the vaquita. I know people need to make a living, but it's not fair to do it at the expense of another species. The price tag the authors mention, $25 million to eliminate the threat of bycatch, is a drop in the bucket to many entities and individuals.
Ken Cobleigh
Renton, Washington

Name That Plant

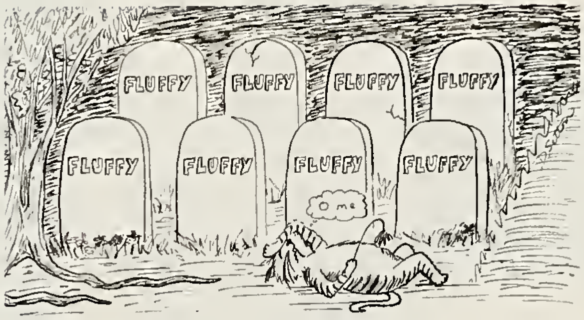
The plant identified as *Gloxinia macrophylla* on page 26 of Wm. Wayt Thomas's article, "Survival of the Rarest" [6/07] should be called *Sinningia macrophylla.* The current name can be found in the *World Checklist of Gesneriaceae.* The plant is cultivated by members of the Gesneriad society.
Dee Stewart
Stow, Massachusetts

WM. WAYT THOMAS REPLIES: I knew that the plant belonged to the genus *Sinningia*, but the name *Sinningia macrophylla* is not listed in the standard reference, the *International Plant Names Index.* I believed that no one had made that nomenclatural combination. For simplicity, then, I said that the plant was originally described as *Gloxinia macrophylla.*

Ask the Experts

I hope you can answer a question I have had for many years. One October years ago (maybe between 1943 and 1945), in northwestern Wyoming at about 7,500 feet elevation, we were bringing horses home from a cattle drive when, between 8 and 10:30 p.m., we were blessed with a meteoric shower of exceptional quality. In these few hours I saw roughly half the "stars" I have seen in all my life. Quite a number of them whistled, hissed, and so on when (I assume) they hit the atmosphere. We had quite an argument about that because I had read that meteors would be about thirty miles above us, but we heard them instantly—as if they were a quarter mile away. How is that possible?

Jack Lozier
Quesnel, British Columbia



Fluffy broods over his reckless ways.

Joe Rao Replies: From Jack Lozier's description, the meteor display was the Giacobinid meteor storm, which took place on the evening of October 9, 1946. Comet Giacobini-Zinner had crossed Earth's orbit fifteen days earlier, and bits of dusty debris from its wake pelted our atmosphere at roughly twenty miles a second, creating the "shooting stars." The astronomer Colin Keay suggests that the simultaneous meteor sounds Mr. Lozier describes arise by electrophonic transduction: the wake of the meteor traps its own magnetic field, generating long radio waves. When the radio waves interact with ground-level objects such as trees, they create audio waves: sound. The same principle may explain reports of auroral sounds, the unease of animals before earthquakes, and sounds heard before lightning strikes nearby.

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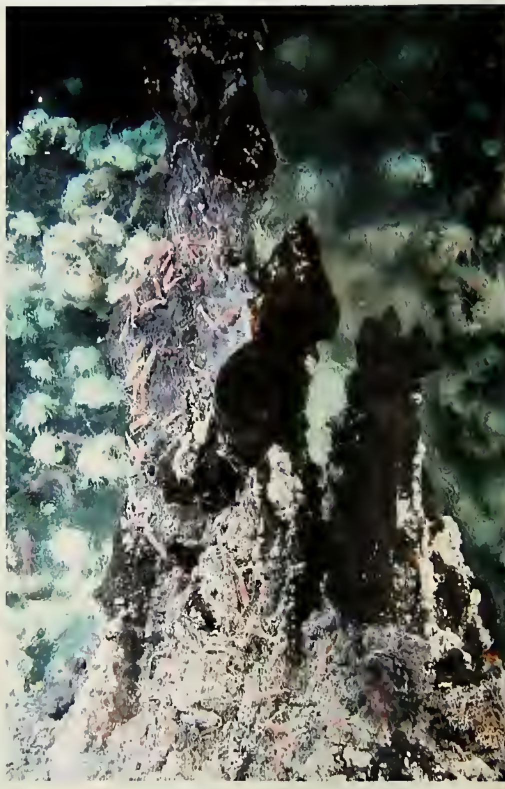
They Came from the Deep



Crabs (Shinkaia crosnieri) *crowd a deep-sea hydrothermal vent, where bacteria related to human pathogens were recently discovered.*

What does a deep-sea thermal vent have in common with the inside of your gut—apart from a tendency to rumble and grumble? It turns out the two places are home to bacteria with a surprising evolutionary connection.

A team led by Satoshi Nakagawa of the Japan Agency for Marine-Earth Science and Technology isolated two previously unknown bacterial species from vents near Japan. The team then compared the new species' genomes to the genomes of two common gut pathogens, *Helicobacter*, which causes ulcers, and *Campylobacter*, which causes diarrhea. The comparison showed that despite eons of evolutionary divergence, the deep-sea species and the pathogens share genes that enable them to colonize animal hosts.

The products of the genes in question enable bacteria to evade host immune systems and stick to host tissues. The pathogens put the genes to work when they infect people or other animals. But the deep-sea bacteria aren't pathogenic. Instead they probably live on the surfaces of shrimp and worms and in snails' gills, and make their living converting chemicals from the vents into energy; their animal hosts house them in return for food. Nakagawa thinks the shared genes evolved in the deep sea to enable symbiosis with animals. Eventually, toxin-secreting pathogens evolved from deep-sea bacteria and repurposed the genes for the more nefarious goal of mounting infections. *(PNAS)*

—*Rebecca Kessler*

Wood ant clutches conifer resin, a natural disinfectant.

Collective Medicine

Wood ants are industrious food gatherers, but why do they bother lugging home inedible gobs of solid conifer resin? The answer, according to a new study, is that the resin disinfects the nest and helps keep the ants free from disease.

Michel Chapuisat and Philippe Christe of the University of Lausanne in Switzerland and two colleagues collected adults and larvae of the wood ant *Formica paralugubris* in the Swiss Jura Mountains. The team placed the ants in experimental containers and exposed them to a bacterium and a fungus that killed most of them within a few weeks. But small pieces of resin added to half the containers greatly improved survival rates for larvae exposed to both the fungus and the bacterium, and for adults exposed to the bacterium.

The resin seems to have antibiotic properties. The investigators think it might release volatile compounds that inhibit the growth of microorganisms in the nest. It's also possible that the ants coat themselves with antibiotics when they touch resin gobs. A few other animals, such as starlings, line their nests with fresh leaves thought to hinder blood-sucking mites and fleas. Chapuisat and Christe's ant study, however, is the first to prove that enlisting plant material to combat pathogens improves survival in a nonhuman animal. *(Proceedings of the Royal Society B)*

—*Stéphan Reebs*

Australia's Rip Van Winkle

If hibernating were an Olympic sport, pygmy possums would be gold medalists. One of the mini-marsupials dozed for a record 367 days, according to Fritz Geiser of the University of New England in Australia. The key to soporific success lies in the pygmy possums' weight-gaining prowess: they can quickly balloon from 0.7 ounce to a supersize 1.9 ounces when food is plentiful. Those enormous fat reserves fuel the big sleep.

Geiser observed a small colony of captive pygmy possums after first letting them fatten up on high-energy food, then cutting off the feast and mimicking the winter light and temperature of their native habitat in southeastern Australia's forests and heaths. The chilly darkness and lack of food triggered hibernation: the animals spent increasingly lengthy periods in a state of torpor, punctuated by brief bouts of activity. The snoozing pygmy possums slashed their energy expenditure to less than 3 percent of that predicted for active animals.

Most hibernators live in northern climates where food and weather are predictably seasonal. Pygmy possums, by contrast, are among just a handful of hibernators from places where the weather can turn nasty or food stocks can crash at any time of year. In such unpredictable climes, it pays to be able to fatten quickly in the good times and turn down the thermostat as needed for extended periods to ride out the bad. *(Naturwissenschaften)*

—*Nick Atkinson*

Fur balls: two pygmy possums, one lean and active, on top, the other, fattened for hibernation

The Kindness of Strangers

"One good turn deserves another." Most people take that aphorism to heart—so much so, studies show, that after receiving help, we are more willing than before to help someone else, even a stranger. It might be tempting to think such virtue is unique to our species, but it turns out that the lowly rat is just as noble.

To find out if grateful rats would lend a paw to perfect strangers, Claudia Rutte of the University of Lausanne and Michael Taborsky of the University of Bern, both in Switzerland, trained rats to pull a lever that introduced food to a rat in a neighboring cage. On five consecutive days, trained test rats were caged either next to other helpful, trained rats or next to unhelpful, untrained rats. On the sixth day, Rutte and Taborsky discovered, test rats that had been paired with helpful neighbors were, on average, 21 percent more likely to pull a lever for a new neighbor they had never encountered than were test rats paired with unhelpful neighbors.

What's more, the rats could distinguish between strangers and former benefactors. In another experiment, test rats that encountered a rat that had given them food earlier were—not 21 percent—but 51 percent more likely to return the favor. Notably, Rutte and Taborsky studied only female rats. No word on whether males would be equally obliging. *(PLoS Biology)* —*S.R.*

Sea rocket knows who's family.

Who's Your Mommy?

Animals aren't the only life-forms that can recognize their family members. Plants can too, it seems.

The sea rocket, *Cakile edentula*, is a member of the mustard family that grows on sandy beaches. Susan A. Dudley of McMaster University in Ontario and her student Amanda L. File measured the growth of sea rockets they had planted in groups of four. Sea rockets in groups of unrelated plants grew many fine roots, the better to compete with one another in the quest for water and nutrients. But when the plants in a pot were siblings that shared the same mother, they restricted their fine-root growth by about 13 percent. After all, there's no point devoting resources to competing with one's siblings when their reproductive success perpetuates one's own genes.

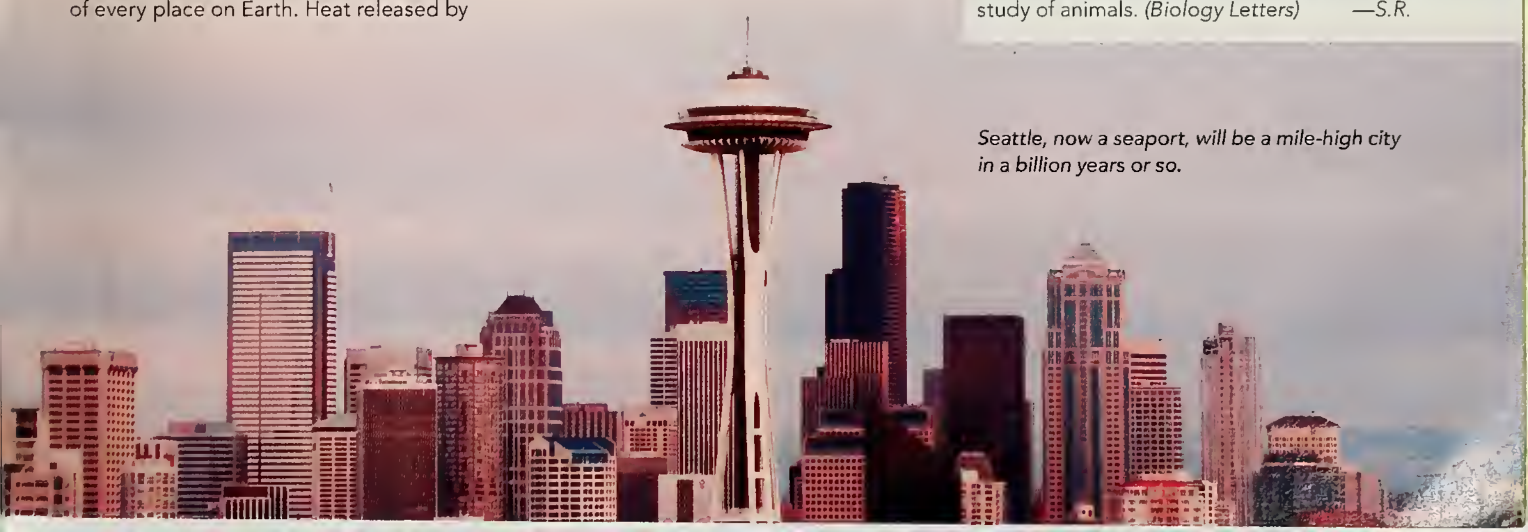
Dudley and File suspect that many plants can detect and recognize their kin. How plants do that remains a mystery, though cueing in to chemicals seeping from other plants' roots is one obvious possibility. Whatever the mechanism, Dudley and File have thrown open the door of plant research to altruism, cooperation, and other social evolutionary concepts once reserved for the study of animals. *(Biology Letters)* —*S.R.*

That Sinking Feeling

New York City sinks 1,400 feet beneath the Atlantic; only the tip of the television tower atop the Empire State Building pokes above the waves. No, it's not a scene from the latest doomsday flick, it's what would happen if the rock underlying the city cooled to the temperature of the rock under northern Canada. And according to two geophysicists at the University of Utah, that's exactly what's in store. The only dry landmasses left from "our" North America will be the Rockies, the Sierra Nevada, and the Pacific Northwest. But don't worry: the cooling of Earth's mantle will take at least a billion years.

Derrick Hasterok and his graduate adviser, David S. Chapman, make their arresting prediction on the basis of a model they developed to illustrate how crust and mantle temperatures help determine the elevation of every place on Earth. Heat released by the mantle makes the overlying crust more buoyant, raising it. But two other important factors—the composition and thickness of the crustal rock—have made it hard to quantify the role of heat alone. Hasterok and Chapman's model solves that problem for the first time by eliminating those factors mathematically.

Not every landmass will sink once the crust cools, they predict. Seattle, for instance, will no longer be a seaport, but a mile-high retreat. It is now insulated from mantle heat by a cold plate of rock that is slowly falling into the mantle. Once the plate completes its descent, the crust above it will warm—and rise—substantially. *(Journal of Geophysical Research–Solid Earth)* —*Harvey Leifert*



Seattle, now a seaport, will be a mile-high city in a billion years or so.

A Hot New Trend

The European heat wave of August 2003 killed some 35,000 people; temperatures in many places topped ninety-five degrees for as long as ten days in a row. A new study shows that the lethal hot spell was part of a century-long trend toward higher summer temperatures and longer heat waves in Europe—and that earlier studies underestimated just how unusually severe recent heat waves have been.

Paul M. Della-Marta of the University of Bern in Switzerland and his colleagues analyzed weather data recorded for more than a century throughout Western Europe. The team discovered that the number of hot summer days—those among the warmest 5 percent ever recorded for their time of year—tripled from 1880 to the present. Meanwhile, the average length of heat waves doubled, to three days, and average summer temperatures rose by nearly three Fahrenheit degrees.

A hundred years ago, weather stations recorded higher temperatures than a modern installation would have, because they didn't properly shield their instruments from reflected light and heat. Della-Marta's team made the most accurate statistical correction of that bias to date, revealing that the change in length of today's heat waves had been underestimated by 30 percent. The trend toward longer, hotter heat waves will likely continue as the globe warms. *(Journal of Geophysical Research–Atmospheres)* —*S.R.*

Out of Sync

Bumblebee pollinates a larkspur flower.

Flowering plants provide food to their animal visitors in exchange for pollination, so both groups are in big trouble if their schedules fail to mesh. Will global warming disrupt their timing and lead to a wave of extinctions? Until recently, a lack of data made it hard for biologists to estimate how large the potential effects might be.

So Jane Memmott of the University of Bristol in England and three colleagues dug into a 1929 tome, *Flowers and Insects*. The book had been largely inaccessible to modern ecologists until Memmott's team digitized it, page by page. Its author, Charles Robertson, catalogued nearly 15,000 associations between 429 plant species and their 1,420 pollinators, a trove of data he gathered in more than thirty years spent watching flowers in Illinois.

On the basis of timing shifts caused by global warming that have already been observed in several plants and pollinators, Memmot and her colleagues figured that by the end of this century the annual activities of plants and pollinators will advance by one to three weeks, depending on the species. The team then modeled how those forecasted shifts would affect the extensive network described by Robertson. They estimate that between one sixth and one half of all pollinator species in northern temperate climates will face disruptions in their food supply lasting between a week and a month. And even a week is long enough for most insects to starve. Of course, the associations could evolve to become more resilient—but confirming that will require watching a lot more flowers. *(Ecology Letters)*

—*Brendan Borrell*

Snow Gray

A billion people living in the dry regions of our planet owe their summer supply of freshwater to snowmelt from nearby mountains. To them, climate change will not be kind. In the future, alpine snow won't last as long as it does now—and not just because of rising temperatures. More frequent dust storms will sprinkle dirt onto the snow, darkening it and so increasing its absorption of the Sun's heat. The snow may melt so fast that water supplies could dry up by summer.

That's the warning sounded by Thomas H. Painter of the University of Utah and several colleagues. Working at a site in the San Juan Mountains of southwestern Colorado, the team documented as many as eight dust storms each year from 2003 through 2006. The windborne dust came from deserts at least a hundred miles away, in Arizona and New Mexico. The team calculated that in 2005 and 2006, the darkened snow cover at their site disappeared between eighteen and thirty-five days earlier in the spring than it would have without a covering of dust.

Farming, grazing, mining, and recreation have long disturbed soil the world over, contributing to dust storms; more frequent and intense droughts projected for the southwestern United States and elsewhere as temperatures rise will only add to the problem. *(Geophysical Research Letters)* —*S.R.*

Dust storm whips sand dunes in Colorado.

THE GREAT OUTDOORS

ARIZONA

Called "the white dove of the desert," San Xavier del Bac is one of the finest examples of mission architecture in the United States

In Arizona, timeless discoveries and off-the-beaten path explorations await around every corner, from Native American sites to Spanish colonial missions.

MISSION SAN XAVIER DEL BAC, IN THE SANTA CRUZ Valley nine miles south of Tucson, rises brilliantly white from the desert floor of dusty green mesquite and sage. A gem of Spanish colonial architecture—perhaps the finest example of mission architecture in the country—it was founded by the celebrated Jesuit missionary and explorer Father Eusebio Francisco Kino, who first visited Bac in 1692. In 1700, Father Kino laid the foundations of the first church and named it San Xavier; the present church was finished in 1797. With its imposing dome and lofty towers, rounded parapets and graceful spires, the mission is a graceful blend of Moorish, Byzantine and late Mexican Renaissance architecture. Inside, the church is made up of a series of domes and arches that create enclaves covered with colorful paintings.

Two archaeological parks preserve the state's Native American heritage. **Casa Malpais**, or "House of the Badlands," is surrounded by unusual beauty on a rim of volcanic rock overlooking the Little Colorado River's Round Valley. Perched at an elevation of 7,000 feet, the archaeological park offers breathtaking views of the White Mountains. Its pottery and architecture are similar to that of the ancient cultures of the

Four Corners area. The Hopi and Zuni people claim an affinity to the site, and therefore some parts of it, considered sacred, are closed to tours. Casa Malpais may have been a ceremonial center used by people from surrounding pueblos as well as its own inhabitants for religious ceremonies. It may have also been used as a regional marketplace. It boasts a large great kiva—carved from volcanic rock—catacomb burials, three stairways, an intermittent wall that surrounds the site, an astronomical observatory, numerous solar petroglyph markers, and astronomically aligned shrines. The site was occupied for about 200 years, then abandoned some 600 years ago.

At **Besh-Ba-Gowah Archaeological Park** in Globe, you may walk through a 700-year-old Salado Culture pueblo, climb ladders to second-story rooms, and view the typical furnishings of the era. Considered one of the most significant finds of Southwest archaeology, Besh-Ba-Gowah has one of the largest single-site archaeological collections in the Southwest. It is one of the most complex of the Salado communities. and was once a ceremonial, redistribution, and food storage complex. Artifacts of this culture are also displayed in the Besh-Ba-Gowah Museum.

Anita Avalos

South of Globe, the 700-year-old Salado culture pueblo known as Besh-Ba-Gowah is one of the most important finds in Southwest archaeology

For your free Arizona travel packet, visit arizona**guide**.com or call 1-866-488-3760 toll-free.

CUSTER COUNTRY, MONTANA

Wrap yourself in the sky—experience the character of history, the spirit of the old west, the art and culture of Southeastern Montana.

CUSTER COUNTRY, IN SOUTHEASTERN Montana, is clean air, endless blue skies, and open hilly country. Our changing landscape is a kaleidoscope of badlands, flatlands, and highlands. The badlands are a dramatic progression of unusual sandstone formations reminiscent of the old west and a backdrop for photographers, bird and wildlife observers and those who just want to breathe deeply and slip through time. The flatlands are vast prairies of grasses and agricultural crops that we share with antelope, deer, and elk; and the highlands of Custer Country include the Bull Mountains and the Pryors—home for Montana's rich wildlife, vegetation, and changing scenery. The blue ribbon Big Horn River and Big Horn Canyon Reservoir attract fishermen from across the country and many foreign countries who know it for its abundance of trophy fish. The Yellowstone River is one of only a few places in the world where the prehistoric paddlefish can be found, and the Tongue River Reservoir yields pike, trout, bass, and many species of pan fish. Ride through Custer Country on the Dinosaur Trail, any of the scenic loops described on our website, or on Interstates 90 and 94, then stop when you feel like it in any of our towns along the road for an infusion of art, culture, and history—and for a great steak! Custer Country fills your soul and leaves memories that last forever. **Order a free Custer Country Travel Guide at 1-800-346-1876 ext. 1507.**

Above left: Makoshika State Park at Glendive; left: Tipis at Little Bighorn Battlefield National Monument

DORCHESTER COUNTY

MUCH OF DORCHESTER COUNTY, in the heart of the Chesapeake Bay, has been declared a state heritage area because its unspoiled countryside preserves the traditions of life along the Chesapeake. Boastng 1,700 miles of shoreline, Dorchester is a haven for boaters and sailors and a great spot for crabbing and fishing. History buffs will enjoy a stroll through the tree-lined streets of downtown Cambridge, lined with rows of Federal and Queen Anne's houses. Dorchester was also the home of Annie Oakley, whose house was in Cambridge, and Harriet Tubman, memorialized in a garden in the town.

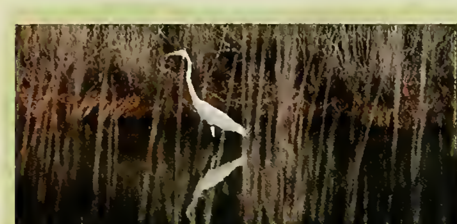
Twelve miles south of Cambridge, visit Blackwater National Refuge, whose 27,000-plus acres of woodland, tidal marsh, freshwater ponds, and managed cropland comprise one of the chief wintering areas for migrating ducks and Canada geese using the Atlantic Flyway. In addition to two species listed as threatened or endangered—the bald eagle and the Delmarva fox squirrel, which are seen regularly at the refuge—the refuge has a diverse population of birds including ospreys and great blue herons, mammals, reptiles, and amphibians. One of the best ways to see the refuge is to kayak or canoe through its three paddling trails; pick up a waterproof map at the visitors' center. Alternatively, bring or rent a bike and cycle along the more than fifty miles of country roads in and around Blackwater, including three cycling loops that follow flat, low-traffic roads.

Loy's Station, in Frederick County, is one of eight covered bridges remaining in Maryland

Frederick County is the perfect place to explore our Civil War heritage.

FREDERICK COUNTY

HISTORIC FREDERICK COUNTY IS LESS THAN ONE HOUR FROM Washington, D.C., Baltimore, and nearby Gettysburg, Antietam, and Harpers Ferry. Known for its historic sites and Civil War heritage, the county was the location of the Battle of Monocacy in 1864, and its towns were occupied by troops who fought at Antietam and Gettysburg. Two Maryland Civil War Trail driving tours (download at civilwartraveler.com/Maryland/index.html) cross the county, enabling you to follow the troops' steps. As a result of these battles, Frederick became a major Civil War hospital center; learn more about this part of the county's history at the National Museum of Civil War Medicine. Visit Monacacy National Battlefield's brand-new visitor center, with state-of-the-art exhibits that broaden the context of this one-day battle into the entire Civil War. If you prefer the great outdoors, check out one of Frederick County's ninety parks, or hike along two well-known trails that pass through the county: the Appalachian Trail, which crosses through Frederick's eastern part (enter at Gathland State Park), and the C&O Canal National Historic Park trail, which takes you along the path of the early nineteenth-century canal. Catoctin Mountain Park, part of the Blue Ridge Mountains, offers fly-fishing as well as twenty-five miles of scenic trails, and you may stay at a WPA built cabin or national historic campsite. In nearby Thurmont, hike to the 78-foot cascading waterfall at Cunningham Falls State Park.



In Kent County, you'll find a treasured national wildlife refuge situated along the Atlantic Flyway

KENT COUNTY

A PENINSULA ON THE EASTERN Shore, Kent County is where fresh and salt water meet, and is a haven for fishing and boating, cycling, birding, and exploring nature.The tidewater tributaries of the Chesapeake course through Kent's unspoiled farmlands, and the waterfront towns, once great shipbuilding and fishing communities, preserve the feel of an earlier, more serene way of life. All throughout the county's tidal shores, you'll see a plethora of aquatic birds including ducks, geese, kingfishers, herons, ospreys, and bald eagles. The estuaries also offer ideal spawning conditions for many fish species, including alewife, shad, blue fish, perch, oysters, the blue crab, and striped bass, known locally as rockfish. You'll find much of the habitat characteristic of the Chesapeake region, from pine forests to meadows to tidal wetlands, on the Eastern Neck National Wildlife Refuge. This island features an observation platform above shoal waters teeming with ducks, geese, tundra swans, and other migrating waterfowl. You'll also see ospreys, deer, and red foxes.

WORCESTER COUNTY

MARYLAND'S ONLY SEASIDE COUNTY, located on its Eastern Shore, Worcester is known for the sandy resort of Ocean City and the wild ponies of Assateague. The county claims to have the best birding in the state, with more than 350 recorded species, from pelicans to peewees, kingbirds and cuckoos, and herons, harriers, and eagles. Worcester owes much of this abundance to a diversity of habitats—including barrier island, a cypress swamp, old forests, and tidal wetlands—and all are easily accessible. With its coastal habitats and temperate climate, the county is the northernmost breeding range of several southern species including the brown pelican; it's also the southernmost winter location of sightings of northern species such as purple sandpipers and great cormorants. Don't leave Worcester without a visit to the famous herd of ponies at the Assateague Island State Park and National Seashore. Hike the three nature trails: Life of the Dunes Trail, Life of the Marsh Trail, and Life of the Forest Trail (the last two are handicap accessible). Bike along the island's designated bike trail or canoe the back waters of Sinepuxent Bay. You might stay in nearby Ocean City (sample the state's best French fries), at a bed-and-breakfast in the Victorian-era town of Berlin, or make your base in pretty and historic Snow Hill, near the Pocomoke River. As if that weren't enough, Worcester also has more than a dozen championship golf courses.

Tim Tadder

Worcester boasts some of Maryland's best birding, a herd of wild ponies along the Assateague shore, and more than a dozen championship golf courses

Fellow Traveler

Fifty years ago this month, the U.S.S.R. launched Sputnik 1, *the world's first Earth-orbiting artificial satellite. Shocked into action, the U.S. ramped up its space program—and its science education.*

By Neil deGrasse Tyson

Sputnik 1, *above right, the first artificial satellite, 1957; Yuri Gagarin, below, the first person in space, 1961*

One floodlit midnight in early October 1957, beside the river Syr Darya in the Republic of Kazakhstan—while office workers in New York were taking their afternoon break—Soviet rocket scientists were launching a two-foot-wide, polished aluminum sphere into Earth orbit. By the time New Yorkers sat down to dinner, the sphere had completed its second full orbit, and the Soviets had informed Washington of their triumph: *Sputnik 1,* humanity's first artificial satellite, was tracing an ellipse around Earth every ninety-six minutes, reaching a peak altitude of nearly 600 miles.

The next morning, October 5, a report of the satellite's ascent appeared in *Pravda,* the ruling Communist Party's official newspaper. ("Sputnik," by the way, simply means "satellite" or, more generally, "fellow traveler.") Following a few paragraphs of straight facts, *Pravda* adopts a celebratory tone and ends on a note of undiluted propaganda:

> The successful launching of the first man-made earth satellite makes a most important contribution to the treasure-house of world science and culture. . . . Artificial earth satellites will pave the way to interplanetary travel and apparently our contemporaries will witness how the freed and conscientious labor of the people of the new socialist society makes the most daring dreams of mankind a reality.

The space race between Uncle Sam and the Reds had begun. Round one had ended in a knockout. Ham radio operators could track the satellite's persistent beeps at 20.005 megacycles and vouch for its existence. Birdwatchers and stargazers alike could see the shiny little ball with their binoculars.

And that was only the beginning: the Soviet Union won not only round one but nearly all the other rounds as well. Yes, in 1969 America put the first man on the Moon. But let's curb our enthusiasm and look at the Soviet Union's achievement during the first three decades of the Space Age.

Besides launching the first artificial satellite, the Soviets sent the first animal into orbit (Laika, a stray dog), the first human being (Yuri Gagarin, a military pilot), the first woman (Valentina Tereshkova, a parachutist), and the first black person (Arnaldo Tamayo-Méndez, a Cuban military pilot). The Soviets sent the first multiperson crew and the first international crew into orbit. They made the first space walk, launched the first space station, and were the first to put a manned space station into long-term orbit.

They were also the first to orbit the Moon, the first to land an unmanned capsule on the Moon, the first to photograph earthrise from the Moon, the first to photograph the far side of the Moon, the first to put a rover on the Moon, and the first to put a satellite in orbit around the Moon. They were the first to land on Mars and the first to land on Venus. And whereas *Sputnik 1* weighed 184 pounds and *Sputnik 2* (launched a month later) weighed 1,120 pounds, the first satellite America had planned to send aloft weighed slightly more than three pounds. Most ignominious of all, when the United States tried its first actual launch after *Sputnik*—in early December 1957—the rocket burst into flames at the (suborbital) altitude of three feet.

In July 1955, from a podium at the White House, President Eisenhower's press secretary had announced America's intention to send "small" satellites into orbit during the International Geophysical Year (July 1957 through December 1958). A few days later a similar announcement came from the chairman of the Soviet space commission, who maintained that the first satellites shouldn't have to be


Laika, first animal in space, 1957

Alexei Leonov, first space walker, 1965

all that small and that the U.S.S.R. would send up a few of its own in the "near future."

And so it did.

In January 1957, the Soviet missile maven and ultra-persuasive space advocate Sergei Korolev (never referred to in the Soviet press by name) warned his government that America had declared its rockets to be capable of flying "higher and farther than all the rockets in the world," and that "the U.S.A. is preparing in the nearest months a new attempt to launch an artificial Earth satellite and is willing to pay any price to achieve this priority." His warning worked. In the spring of 1957, the Soviets began testing precursors to orbiting satellites: intercontinental ballistic missiles that could loft a 200-pound payload.

On August 21, their fourth try, they succeeded. Missile and payload made it all the way from Kazakhstan to Kamchatka—some 4,000 miles. TASS, the official Soviet news agency, uncharacteristically announced the event to the world:

> A few days ago a super-long-range, intercontinental multistage ballistic missile was launched. . . . The flight of the missile took place at a very great, hitherto unattained, altitude. Covering an enormous distance in a short time, the missile hit the assigned region. The results obtained show that there is the possibility of launching missiles into any region of the terrestrial globe.

Strong words. Strong motives. Enough to spook any adversary into action.

Meanwhile, in mid-July the British weekly *New Scientist* had told readers about the Soviet Union's growing primacy in the space race and described the orbit of an impending Soviet satellite. But America took little notice.

In mid-September Korolev told an assembly of scientists about the imminent launches of both Soviet and American "artificial satellites of the Earth with scientific goals." Still America took little notice.

Then came October 4.

Sputnik 1 kicked many heads out of the sand. Some people in power went, well, ballistic. Lyndon B. Johnson, at the time the Senate majority leader, warned, "Soon [the Soviets] will be dropping bombs on us from space like kids dropping rocks onto cars from freeway overpasses." Others were anxious to downplay both the geopolitical implications of the satellite and the Soviet Union's capabilities. Secretary of State John Foster Dulles wrote that the importance of *Sputnik 1* "should not be exaggerated" and rationalized America's nonperformance thus: "Despotic societies which can command the activities and resources of all their people can often produce spectacular accomplishments. These, however, do not prove that freedom is not the best way."

On October 5, under a page-one banner headline (and alongside coverage of a flu epidemic in New York City and the showdown in Little Rock with the segregationist Arkansas governor, Orval Faubus), *The New York Times* ran an article that included the following reassurances:

> Military experts have said that the satellites would have no practicable military application in the foreseeable future. . . . Their real significance would be in providing scientists with important new information concerning the nature of the sun, cosmic radiation, solar radio interference and static-producing phenomena.

What? No military applications? Satellites were simply about monitoring the Sun? Behind-the-scenes strategists thought otherwise. According to the summary of an October 10 meeting between President Eisenhower and his National Security Council, the U.S. had "always been aware of the cold war implications of the launching of the first earth satellite." Even America's best allies "require assurance that we have not been surpassed scientifically and militarily by the U.S.S.R."

Eisenhower didn't have to worry about ordinary Americans, though. Most remained unperturbed. Or maybe the spin campaign worked its magic. In any case, plenty of ham radio operators ignored the beeps, plenty of newspapers ran their satellite articles on page three or five, and a Gallup poll found that 60 percent of people questioned in Washington and Chicago expected that the U.S. would make the next big splash in space.

America's cold warriors, now fully awake to the military potential of space, understood that U.S. postwar prestige and power had been challenged. Within a year, money to help restore them would be pumped into science education, the education of college teachers, and research useful to the military.

Back in 1947, the President's Commission on Higher Education had proposed as a goal that a third of America's youth should graduate from a four-year college. The National Defense Educa-

Valentina Tereshkova, first woman in space, 1963

tion Act of 1958 was a key, if modest, push in that direction. It provided low-interest student loans for undergraduates as well as three-year National Defense Fellowships for several thousand graduate students. Funding for the National Science Foundation tripled right after *Sputnik;* by 1968 it was a dozen times the pre-*Sputnik* appropriation. The National Aeronautics and Space Act of 1958 hatched a new, full-service civilian agency called the National Aeronautics and Space Administration—NASA. The Defense Advanced Research Projects Agency, or DARPA, was born the same year (and so was I).

All those initiatives and agencies funneled the best American students into science, math, and engineering. The government got a lot of bang for its buck; graduate students in those fields, come wartime, got draft deferments; and the concept of federal funding for education got validated.

But some kind of satellite, built by any means necessary, had to be launched a.s.a.p. Luckily, during the closing weeks and immediate aftermath of the Second World War, the U.S. had acquired a worthy challenger to Sergei Korolev: the German engineer and physicist Wernher von Braun, former leader of the team that had developed the terrifying V-2 ballistic missile for the Nazis. We also acquired more than a hundred members of his team.

Instead of being put on trial at Nuremburg for war crimes, von Braun became America's savior, the progenitor and public face of the U.S. space program. His first high-profile task was to provide the first rocket for the first successful launch of America's first satellite. On January 31, 1958—less than

Salyut 1, *first space station, 1971*

four months after *Sputnik 1*'s round-the-world tour—he and his rocketeers got the thirty-pound *Explorer 1,* plus

Continued on page 44

Lucy Goes Walkabout

The travels of a celebrated fossil highlight the vitality of Ethiopian paleoanthropology.

By Ian Tattersall

The world's most famous hominid fossil has taken up temporary residence (until next April 20) at the Houston Museum of Natural Science, as the star attraction of the exhibition "Lucy's Legacy: The Hidden Treasures of Ethiopia." An early hominid and a distant cousin of modern humanity, Lucy died some 3.18 million years ago in what is now the rugged Afar region of northern Ethiopia. At the time of her discovery three decades ago, Lucy was the most complete skeleton known of any hominid predating the Neanderthals—mere parvenus, by comparison. And even though other fossils have since made the headlines, Lucy's name still retains its magic, and her diminutive skeleton (she would have stood a little more than three feet tall) is an instantly recognizable symbol of our deep biological roots.

Lucy's sojourn in Houston is not her first visit to the United States. Following her unearthing by the paleoanthropologist Donald C. Johanson and his colleagues in 1974, Lucy spent the next five years on loan to the Cleveland Museum of Natural History, then Johanson's home institution. There the requisite scientific descriptions were prepared, and molds made so that casts could be distributed for study and exhibition. Since 1980, however, Lucy has resided in Addis Ababa, in a vault at the National Museum of Ethiopia, only seeing the light of day for the benefit of visiting scientists and the occasional dignitary.

Dinosaur bones and many other fossils routinely hit the road, but fossils of extinct hominids tend to be treated as sacrosanct, never allowed to leave their home institutions, let alone their countries of origin. That is regrettable, in part because such fossils are the patrimony of all humankind. Furthermore, paleontology is quintessentially a comparative business: no fossil can be satisfactorily understood in isolation from the wider record.

In 1984, for example, the American Museum of Natural History in New York City held a one-time exhibition called "Ancestors: Four Million Years of Humanity," which brought together fifty specimens from around the globe. Before the exhibition opened, several dozen scientists participated in three days of detailed comparative examinations and a two-day symposium. The experience was a revelation to scholars: for the only time in their lives, they could see these central objects of their study side-by-side. The proceedings led to a volume of scholarly papers, whose conclusions are still being cited.

Skull of "Lucy's Baby," a three-year-old Australopithecus afarensis, was discovered in 1999 by an Ethiopian paleoanthropolgist.

Still, somebody has to take responsibility for caring for the irreplaceable vestiges of our vanished past. As chance would have it, the first 5 million years or so of hominid history unfolded uniquely in Africa, and the nations where the fossil evidence is found can take special pride in preserving them on their home soil. But few governments on that continent have the luxury of munificently supporting such abstract concerns as paleontology. If the wider world wants to know the details of early human history, it must commit the necessary resources.

Early major paleoanthropological explorations in Ethiopia followed the pattern typical throughout Africa: outsiders funded and directed the work. But the initial impetus for it was national rivalry. The biographer Virginia Morrell records that in 1965, the Kenyan paleontologist Louis Leakey ran into Ethiopia's Emperor Haile Selassie at a diplomatic event in Nairobi. In the course of their conversation Haile Selassie reportedly asked, "Dr. Leakey, why has my country got no fossils like you find in Tanzania and Kenya?" Leakey replied that the fossils were surely there; all that was lacking was the Ethiopian government's permission to go and look for them. Predictably enough, an official invitation was soon forthcoming to organize an international fossil-hunting expedition in southern Ethiopia.

From that flowed the investigations in the Afar region of the north, where Lucy, along with many other fossils of her bipedal species, *Australopithecus* *afarensis*, was unearthed. Today the arid badlands of the region are among the most hostile environments on earth. But three or four million years ago the area offered a mosaic of environments that ranged from forest to woodlands to savanna. The place was an ideal locale in which primates whose ancestral forest habitats were being fragmented by climatic drying could experiment with new lifeways that substantially increased their time on the ground [*see illustration on cover of this issue*].

The fossils of *A. afarensis* and potential future finds were destined from the start for the National Museum of Ethiopia, transforming the institution into a magnet for investigators worldwide and a center for training home-grown paleontologists. In the 1970s local people were employed as collectors and guards, but there were no Ethiopian paleontologists. Today that is no longer the case.

There's no more striking exemplar of the transformation than Zeresenay "Zeray" Alemseged, the Ethiopian paleontologist who last year announced the discovery of a skeleton of a three-year-old *A. afarensis* at Dikika, a site not far from where Lucy was found. Now an investigator at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, Alemseged trained in his home country and in France, and earned a postdoctoral fellowship at the Institute of Human Origins, Johanson's center at Arizona State University in Tucson.

Even more complete than Lucy herself, the 3.3-million-year-old Dikika fossil was inevitably dubbed Lucy's Baby (though it lived and died long before Lucy was born). It is exquisitely preserved; the hitch is that the matrix enclosing the fossil is rock-hard, fiendishly difficult to remove without damaging the bones. But Alemseged's painstaking partial removal of the matrix has already confirmed that the species walked upright while on the ground, yet retained characteristics, particularly of the upper body, that would have helped it move around in trees.

The preliminary observations raise once again the question of why hominids became bipedal in the first place. Some have argued that the main advantage of terrestrial walking is that it frees the hands, enabling hominids to carry and manipulate objects. Others have calculated that walking is energetically more efficient. A third group has pointed out that you can spot potential predators from farther away. And it has been engagingly argued that an upright stance helps minimize the impact of the Sun's heat when away from the shelter of trees.

The key is that once a creature is standing upright, it would enjoy all those potential advantages (as well as suffer various disadvantages). And I find it hard to imagine that an arboreal quadruped would ever adopt such an unac-

Continued on page 43

Deep Trouble

Fishermen have been casting their nets into the deep sea after exhausting shallow-water stocks. But adaptations to deepwater living make the fishes there particularly vulnerable to overfishing—and many are now endangered.

By Richard L. Haedrich

The deck was covered with fish. I'd never seen anything like it. There were long, slender eels, black sharks, pale rays, silvery grenadiers with long, pointy tails, and great black things with huge, dark eyes. We'd needed the biggest winch on our research vessel to haul them up from the bottom of the North Atlantic, some 5,000 feet below the surface and a hundred miles east of New York City. My colleagues and I waded into the catch and began sorting the various species into piles, marveling at their extraordinary forms.

I was a young fish biologist at the time, part of a team studying the distribution of fishes elsewhere in the deep sea: not at the bottom but in the midwaters, a part of the water column above the seafloor. We regularly trawled the midwaters at various depths down to 3,500 feet. After towing a net for as long as three hours, we'd come up with a sample at times no bigger than a teacupful—or, if we were lucky, a small bucketful—of sardine-size creatures. But a break in that routine had given me a chance to see what lives even deeper, and so we broke out the bottom-trawl net. Even as the ship's crane swung the bag, or "cod end" of the net, aboard, I could see that bottom samples were entirely different. The net was bulging, and when the knot cinching it shut was undone, a great swirl of mud and sea creatures had spilled onto the deck.

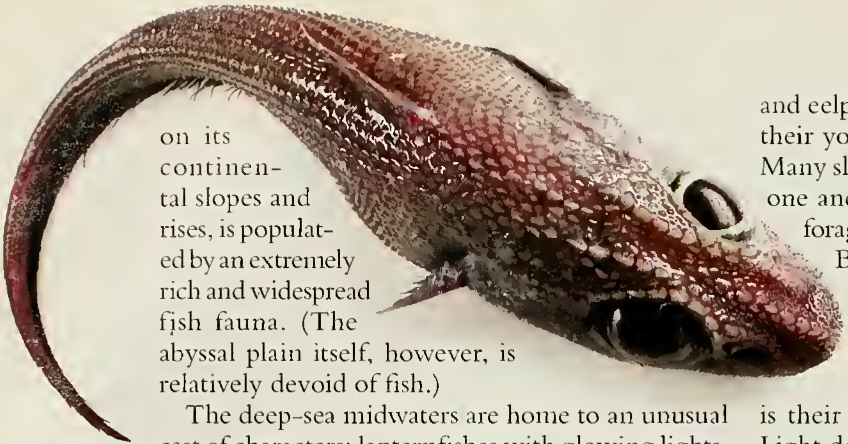
And the fishes! Not a cup or a bucket of small fry, but more like half a ton of strange and wonderfully big fishes. I was hooked. That first bottom trawl, forty years ago, launched a lifelong career in research and teaching about the fishes that live at the bottom of the ocean.

My colleagues and I have learned that those bottom-dwelling animals typically grow slowly, delay reproduction, and live long lives—adaptations to making a go of it in the cold, dark, nutrient-poor waters of the deep-sea floor. But those same attributes make the fishes particularly vulnerable to a new stress: deep-sea fishing. As populations of shallow-water fishes have crashed, the global demand for seafood has led to rapid overfishing of the bottom, along with the habitat destruction that bottom-trawling wreaks. We estimate that more than 20 percent of the northwest Atlantic's deep-sea fish species have declined so seriously that they should be considered for threatened or endangered status. And the same thing is happening the world over: deep-sea fishes everywhere—from Greenland halibut near the Arctic Circle to Chilean sea bass off Antarctica—are being hunted to the verge of extinction. If I were to return to that spot in the North Atlantic where I made my first bottom trawl, the deck would no longer be covered with fishes. I'd be lucky to catch a bucketful.

The deep sea does not begin at the beach; it encompasses the waters from surface to seafloor that lie beyond the continental shelf. Shallow coastal waters overlie the shelf, which can extend a hundred miles or so from shore. There, at the true edge of the continent, where the water is about 600 feet deep, the topography steepens. The seafloor plunges some 6,000 feet down the continental slope, then declines more gently down the continental rise and onto the abyssal plain. The average depth of the plain is 13,000 feet, but it is interrupted by trenches as deep as 30,000 feet, or by mountainous ridges and volcanic seamounts, some of which reach the surface to form island chains, such as Hawai'i [*see inset of illustration on page 31*].

Early ocean explorers thought conditions in the deep sea were too harsh to support life. In fact, though, the deep sea, both in its midwaters and

Roundnose grenadiers pour from a net aboard a bottom trawler 400 miles off Ireland (facing page). Grenadiers, like most deep-sea fishes, mature slowly and live long. Overfished populations can thus take decades or even centuries to replenish themselves. Orange roughy, top right, which may live to be 150, and Chilean sea bass, above, which can live to at least 70 and possibly much longer, have been severely depleted in recent decades. (Fishes are not shown to scale.)



on its continental slopes and rises, is populated by an extremely rich and widespread fish fauna. (The abyssal plain itself, however, is relatively devoid of fish.)

The deep-sea midwaters are home to an unusual cast of characters: lanternfishes with glowing lights, silver hatchetfishes with telescopic eyes, and viperfishes with tremendous fangs, among many others. But midwater fishes are sea monsters in appearance only: most are no longer than a foot. Because of their diminutive size and relatively low density, no extensive deep-sea midwater fishery has yet developed.

The continental slopes are another story. At depths between 600 and 6,000 feet, the slopes are where the fishing happens. Animals living there are bigger and more abundant than in the midwaters of equal depth, largely because the bottom provides both structure and a collection place for food particles falling from the productive surface waters.

Yet despite the increasingly heavy commercial fishing there, much remains unknown about continental slopes. Worldwide, just a fraction of 1 percent of their total area has been explored, and investigators have only recently begun to appreciate the complexity of slope habitats. In part, that's because most of the slopes appear to be featureless expanses of dull mud. Only a few areas, such as the hot vents of tectonically active ridges and trenches, were acknowledged as dynamic and structured ecosystems. But it turns out that even the mud is home to thriving populations of crustaceans, sea stars, urchins, worms, and myriad other creatures. Recently, even deep-sea coral beds have been discovered to be widespread on the world's continental slopes [*see photographs on pages 32 and 33*]. They play host to a highly diverse and little-known fauna, and it is likely that their tangled structure provides protective cover to juvenile fishes.

The fishes of the continental slope display numerous adaptations to deepwater living, which include cold tolerance; longevity; and enhanced vision, hearing, and sound production for making their way in darkness. Certain species, such as deepwater rays, rockfishes, and eelpouts, bear live young or build nests to give their young a head start in a tough environment. Many slope dwellers are relatively large—between one and three feet long—which enables them to forage over broad areas. Many also live in schools. Both their size and schooling behavior have made certain species attractive targets of fisheries—which has in turn brought about the fishes' undoing.

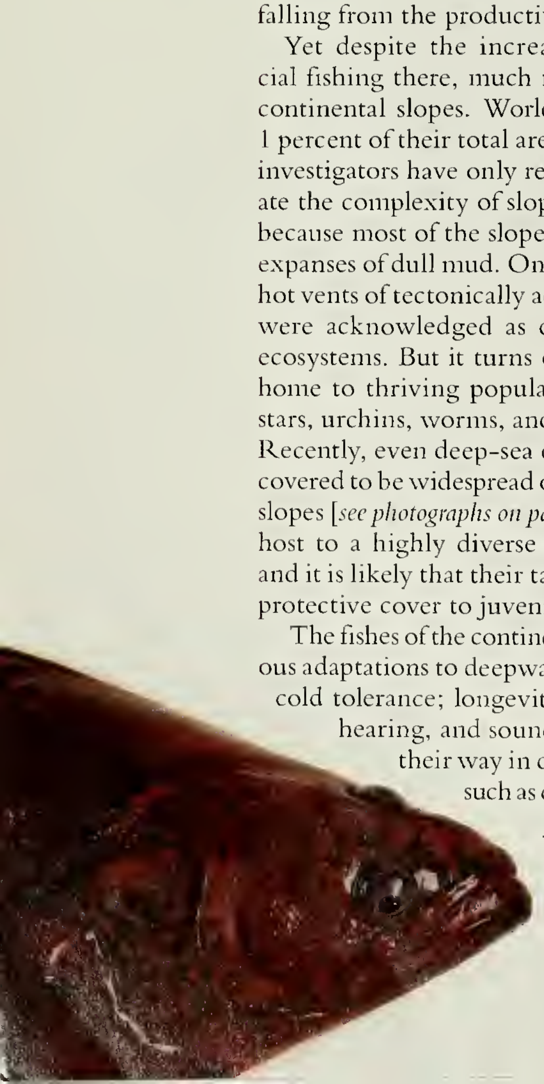
The main reason for their vulnerability is their slow growth rate, a fact of life at depth. Light does not penetrate to the continental slope, so no photosynthesis takes place there, and there is no in situ food production. Virtually all the energy for the slope's food chain must be imported. Most comes in as debris raining from above—from dead phytoplankton to dead whales. Even so, there isn't much. Throughout the deep sea the available food declines quickly with depth, increasing somewhat on the seafloor itself.

As a result, the abundance, biomass, and metabolic rates of organisms also decline. With a low metabolic rate, a fish takes longer to grow to maturity: a cod on the shallow continental shelf matures in four to seven years, whereas a grenadier on the continental slope may take eighteen years. By the time many deepwater fishes are big enough to be worth catching, they are older than your grandmother: the fillet of orange roughy you order at a restaurant could easily come from a fish born before the invention of the automobile.

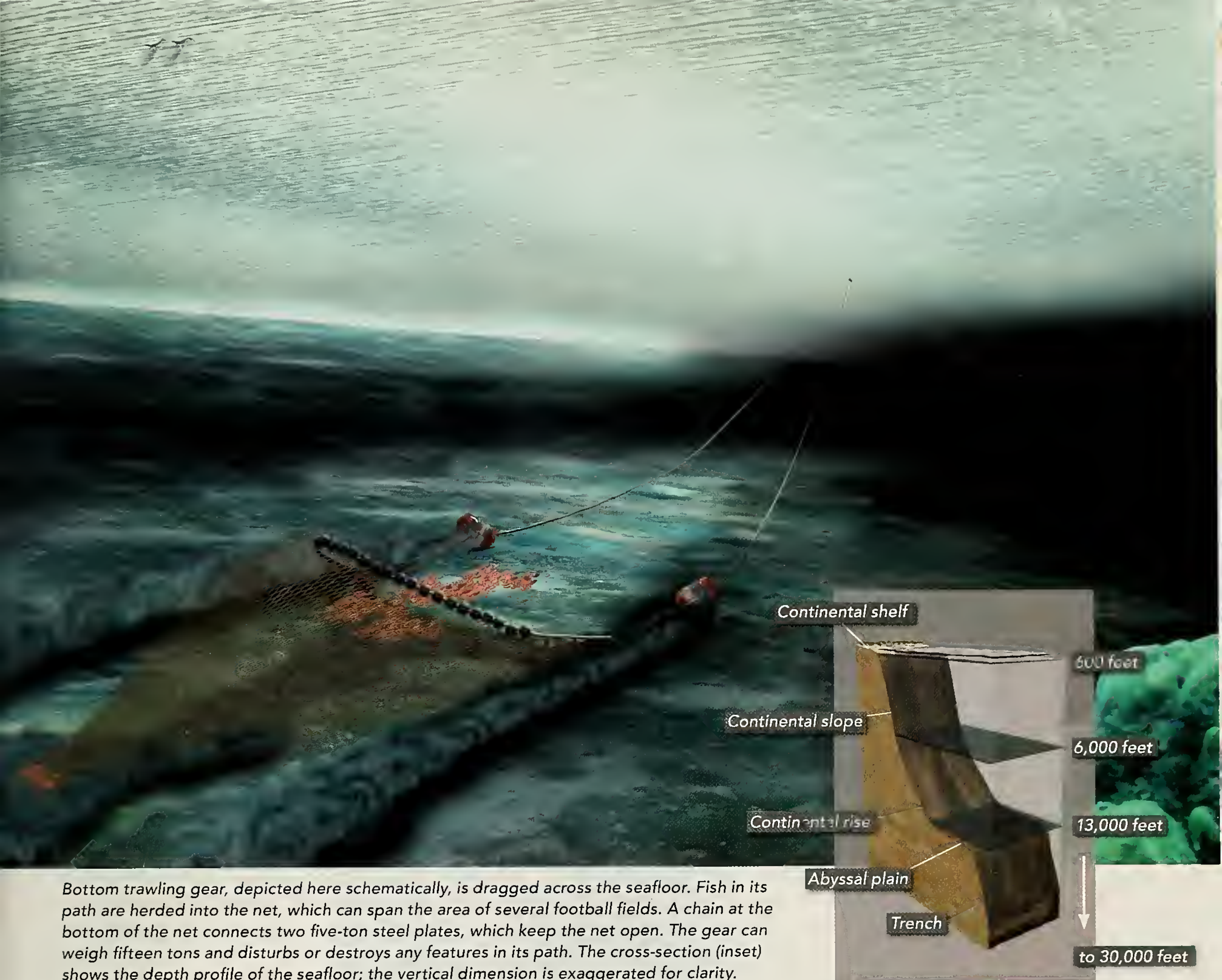
Thus populations turn over quite slowly. A fishery naturally targets the largest individuals, and so can quickly wipe out most of a population's mature, reproductive fish, which can take decades to replenish. Add to that the possibility that some slope fishes might only spawn once at the end of their long lives, and you have a recipe for extinction.

Except for a few special cases, deep-sea fisheries are all of recent vintage. In the early 1970s Soviet fishermen became the first to systematically locate and exploit continental-slope fishes. But despite glowing accounts of the tastiness of the fishes—blue hake, deepwater sharks, grenadiers, and slickheads, among others—a strong international market never developed. The fishery instead supplied immense quantities of low-quality product to the former Eastern Bloc, where cheap protein was in demand. State-sponsored fleets from the Soviet Union—and later, from its former republics—aggressively fished the northwest Atlantic and various other regions into the 1990s; some are still active today.

Worldwide, the expansion to the deep sea stems directly from the severe depletion of shallow-water



Two aggressively exploited deep-sea fishes: roughhead grenadier, top, and Greenland halibut, left. (Fishes are not shown to scale.)



Bottom trawling gear, depicted here schematically, is dragged across the seafloor. Fish in its path are herded into the net, which can span the area of several football fields. A chain at the bottom of the net connects two five-ton steel plates, which keep the net open. The gear can weigh fifteen tons and disturbs or destroys any features in its path. The cross-section (inset) shows the depth profile of the seafloor; the vertical dimension is exaggerated for clarity.

fisheries. In the northwest Atlantic, for instance, the collapse of cod in the early 1990s became one of the most dramatic fish-stock crashes of all time. But the industry found a substitute in the deepwater Greenland halibut. Predictably, that species is now in trouble throughout the Atlantic. Elsewhere, deep-sea fisheries have developed for numerous species, including icefish in the waters off Antarctica, Patagonian toothfish off Argentina and Chile, hoki off Australia and New Zealand, black oreos off New Zealand, thornyheads near Pacific seamounts, and giant rattails in the northwest Pacific.

The deep-sea orange-roughy fishery near Australia is a prime example. It was developed to satisfy the middle-American market for a bland, white fish. Even the name was picked through careful supermarket research (its original moniker, the slimehead, sounded far less appealing). And when that fishery began its inevitable decline, the industry moved on to another deep-sea species, the Patagonian toothfish. It was renamed the Chilean sea bass, even though it is neither a bass nor exclusively Chilean. It, too, has now suffered sharp declines.

The bottom-trawling gear for deepwater fishing is basically the same as the gear deployed in shallow waters, but on an enormous scale. Factory ships longer than 300 feet can hold 1,000 tons of fish and stay at sea for 300 days a year. Massive winches and cables are needed to reach the slope bottom, ten times deeper than the continental shelf. The net itself is woven from heavy polypropylene line and can span the area of several football fields [*see illustration above*]. A pair of steel plates called doors, weighing as much as five tons each and connected to the net with heavy cables, spread the net open under water. The doors and cables scrape along the ocean floor and herd fish into the net—as much as twenty tons in each haul. The entire rig can weigh fifteen tons, and is dragged across the bottom for several hours at a clip of four miles an hour or more. Little more than finely ground rubble remains on the seafloor in its wake.

In theory, a fishery should be managed sustainably, taking no more each year than what reproduction replaces. Thus the size of the take is determined by numerical models that can estimate future populations. Accurate estimates depend on accurate information about a species' age at maturity and its growth rate. Those numbers depend, in turn, on survey data on abundance and body size—a proxy for age.

Yet none of those data existed reliably for deep-sea fishes as their fisheries developed. Managers set catch quotas essentially by guesswork, relying on their knowledge of shallow-water species. They took no account of the far slower turnover rates in a typical population of deep-sea fishes. And even when fisheries could not catch enough fish to meet their quotas, as was the case with the roundnose grenadier for more than twenty years, the quotas were not decreased.

Unfortunately, circumstances today have not much changed. Most deep-sea fisheries, as in decades past, are little more than mining operations that run until they exhaust their target populations and collapse. Then they move on to another species.

In 1987 my students and I began to study the ecology of fisheries. As continental-shelf stocks declined and fisheries moved into deeper water, we followed them out to sea. In 2002 we turned our attention seriously to understanding how fishing had affected deep-sea fishes. We began by examining the roundnose grenadier and the roughhead grenadier, or onion-eye, using scientific survey data assembled annually by the Canadian government. Soviet trawlers and others had been fishing the two species off Canada since 1970, but catches had plummeted in recent years. Sure enough, we discovered that their populations had declined by as much as 99 percent since 1978, precipitously enough to qualify them for endangered status.

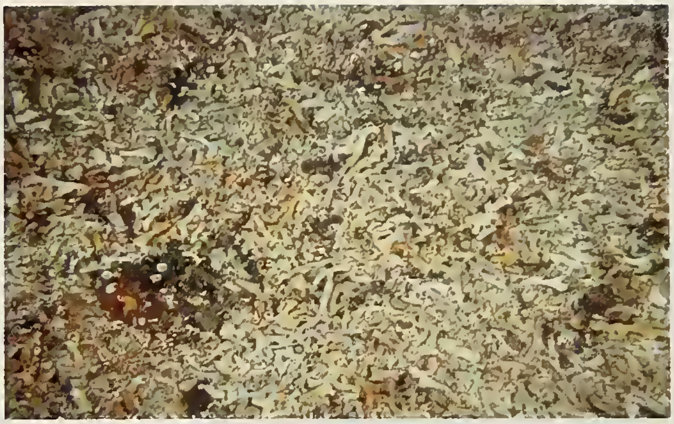
Decline rates are one thing, but the big question both ecologists and fishery managers ask is, how long will species take to recover from exploitation? There is a widespread assumption that fish populations can still recover even after they have declined by 95 percent or more. But that rests on hope as much as on any solid evidence. And even taking an optimistic view, most species—even fast-growing continental-shelf species—will probably need decades, not years, to make a full recovery.

For the roundnose and roughhead grenadiers, even the minimal information required to make predictions about recovery times was not gathered until two decades after the fishery began. By that time, the fishery had collapsed, and populations of both species could qualify for endangered status. My colleagues and I calculated the grenadiers' recovery times on the basis of those data; they range from decades to more than a century, assuming no more fishing—not a surprising result, given those fishes' slow growth, delayed maturity, and long lives.

Large piece of deep-sea coral, unintentionally caught in the net of a bottom trawler, gets tossed back into the sea by a crew member. Deep-sea coral can take centuries to reach the size of the piece shown here, so destroying it could lead to the permanent destruction of any habitat that depends on it.

We have now extended our research on grenadiers to forty species of continental-slope fishes in the northwest Atlantic. (There are about sixty species in all, but we are limited to those for which there are enough data to determine changes in abundance.) It is worth noting that ours is the world's first ecosystem-wide assessment of the effects of fishing in the deep sea—the subject is so little researched. Eight of the forty species, we discovered, have declined so precipitously that they could be considered threatened or endangered. Another ten species have also declined, though not as much.

When we began the research, we had expected to find that large, free-swimming fishes, which are most susceptible to capture by bottom trawls, had suffered the most marked declines. But that was not the case. Rather, the declines were greatest among small species, including the Arctic eelpout, Scotian snailfish, and wolf eelpout. Those species live right on the bottom, often hiding among rocks. We suspect that habitat destruction by trawling, not entrapment in nets, played the leading role in their decline. And though that decline is worrisome enough in its own right, it may portend habitat



Living deepwater coral, above left, makes a sharp contrast with a similar area subjected to bottom trawling, above right. Recent surveys have shown that deepwater corals are widespread on the world's continental slopes. They form complex habitats, which are home to many animals, and they may serve as nurseries for deep-sea fishes.

destruction on a scale that could have repercussions throughout the ecosystem.

The fragile deepwater corals that create desirable habitat for many fish species are no match for the heavy trawls, either [*see photographs above*]. Recent studies have shown that the corals grow extremely slowly: a coral growing on the bow of the *Titanic*, photographed not long ago by a Russian submersible, is hardly two inches tall. Severely damaged deep-sea coral banks will probably take millennia to recover fully. So, in addition to the direct effect of the nets on fish populations, their unintended effect on habitats is so completely and enduringly destructive that the populations may never recover. The species are simply unlikely to survive long enough for their habitats to reestablish themselves.

Fortunately, governments are taking note of the scientific findings—both my own and those of others. Last year a resolution to ban trawling in international waters was debated in the UN General Assembly. It failed, but just barely: UN resolutions require unanimity, and a handful of nations—Iceland the most prominent among them—did not agree with the rest of the world.

Still, many countries are taking unilateral action to limit deep-sea trawling within their own exclusive economic zones (EEZs), the 200-mile-wide strip of ocean that lies just off a nation's shores. Virtually the entire Mediterranean Sea is now protected; Australia, the Azores, New Zealand, and the United States have set aside large regions where such fishing is off limits, as it is in the waters off Antarctica. Trawling bans are now in place over more than 4 million square miles.

That, of course, is a small fraction of the entire world ocean—the Pacific alone is 65 million square miles—and even then the protected regions are hard to patrol. Enforcement is all but impossible in remote areas such as Antarctica. And illegal trawling is not the only threat: poaching, misreporting of catch and bycatch, and various other destructive practices are all too common. The prospects for conservation seem dim. Indeed, fishermen are already turning away from depleted deepwater fish stocks and casting their nets and traps further down the food chain. Deepwater shrimp and crabs have become the latest targets, a familiar story with a predictable end.

Fishing-industry representatives who resist efforts to regulate deep-sea fisheries argue that too little is known to make rational decisions. Declining fish populations, they maintain, probably just reflect natural cycles. But marine biologists nowadays know more than enough about deep-sea ecology and the biology of deepwater fishes to recommend good choices.

Fisheries must balance human needs with the imperatives of the ocean. For the deep sea, in particular, short-term economics must come into alignment with long-term biology—surely a predicament whose resolution is not beyond human ingenuity. We must all learn to live with fishing practices adapted to the laws of nature in the deep sea, just as the fish living there have adapted. Evolution sets the pace of life in accord with physical conditions, and in the deep sea that pace is slow. The pace of our fishing there would do well to match it. □

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Male jumping spider of the species Evarcha culicivora can be distinguished by its bright red face; the female's colors are duller (see photograph on page 37). The species' favorite prey is a female mosquito engorged with her recent blood meals.

Vampire Slayers of Lake Victoria

African spiders get the jump on blood-filled mosquitoes.

By Simon D. Pollard and Robert R. Jackson

The diet of the East African spider *Evarcha culicivora* reminds us of a line from the 1931 film *Dracula*. Soon after Renfield, a visitor from England, arrives at Count Dracula's castle, he struggles to get through an unnaturally large spiderweb that spans a staircase. "The spider spinning his web for the unwary fly," observes the count, ominously. "The blood is the life, Mr. Renfield."

The lifeblood for *E. culicivora* also comes from unwary flies, but it is not the pale blood of the flies that the spider is after. Often enough it is what Dracula was alluding to—human blood. For our spiders suck blood from engorged female mosquitoes, flies that are the miniature vampires of the real world. Some mosquitoes harbor human blood, whereas others may be carrying the blood of other mammals, birds, frogs, lizards, and occasionally even fish.

E. culicivora is a jumping spider, one of 5,000 species belonging to the family Salticidae. The adult is no bigger than about a third of an inch long. Jumping spiders have excellent eyesight, which they use to good effect when hunting, but *E. culicivora* is the only jumping spider—in fact, the only predator of any kind—known to seek out blood-carrying female mosquitoes as prey. When quiescent, it hides in the grass or in other vegetation close to the ground. When it feeds, though, the spider patrols more exposed areas where mosquitoes are apt to land: typically, the bases of tree trunks and the outer and interior walls of buildings.

The species is native to the region of Kenya and Uganda near Lake Victoria, Africa's largest lake. (The lake is also the second-largest freshwater lake in the world, after Lake Superior if you rank by area, or after Lake Baikal, if you rank by volume.) Lake Victoria brews two kinds of storm clouds: the inanimate ones that form high above the water and shed rain, and the astounding living ones—dark clouds as thick as a hundred feet that roll across both water and surrounding terrain—made up mostly of midges. Mosquitoes are only a minority presence in those teeming swarms of "lake flies."

The midges belong mainly to two families, the Chaoboridae, or phantom midges, and the Chironomidae, or nonbiting midges, neither of whose members feed on blood. So they will not satisfy the spider's appetite for blood. Nor will just any mosquito suffice. Male mosquitoes, which subsist entirely on nectar and other sources of sugar, are bloodless. And the females are less appealing, too, if they have failed to find a blood meal. Yet *E. culicivora* is a consummate expert at finding the needle (a blood-engorged mosquito) in a haystack of insects that descend to buildings and tree trunks from the cloud of lake flies. How, we wondered, can the little spider do it?

To explore that and related questions, we established a spider-rearing facility and an experimental laboratory at the Thomas Odhiambo Campus of the International Centre for Insect Physiology and Ecology. The campus is situated in western Kenya in Mbita Point, a village of about 8,000 people on the shore of Lake Victoria. There, and in the Spider Quarantine Laboratory at the University of Canterbury in Christchurch, New Zealand, we have worked with a sizable research team attracted to the bloodlust of *E. culicivora*.

With Godfrey Sune in Kenya and Ximena Nelson in New Zealand, we designed experiments that could clarify how the spiders find suitable prey. In one set of experiments, the spiders had to choose by sight between blood-engorged female mosquitoes and bloodless prey such as lake flies, male mosquitoes, and female mosquitoes that had not had a blood meal. Instead of real prey, we made lures from dead insects, which were washed in alcohol and dried to remove any chemical cues. Then we mounted them in lifelike postures and coated them with a plastic aerosol spray to keep them stationary and intact. Each predator could view the lures lined up around the outside of its cage, a display not unlike the plastic-coated models of food items from the menu at a Japanese restaurant.

A human diner chooses by pointing. Each of our spiders had to indicate its choice by moving into one of a series of glass tubes that led from the spider's cage toward the various offerings. By sight alone, the spider usually chose the lure that represented a blood meal.

Jumping spiders have eight eyes: two large ones (by spider standards), which face forward and can determine the prey's size, shape, and color, and six smaller eyes along its sides that are excellent movement detectors. Amazingly, jumping spiders often make discriminations that rival human eyesight. The trade-off seems to come in processing speed. People decide what they're looking at in a glance, whereas a jumping spider may have to build up a picture by slowly searching the image for specific details.

We also showed that *E. culicivora* smells blood. In similar choice tests with hidden prey as lures, we found that our spiders moved toward air blowing across blood-carrying mosquitoes more often than toward air blowing across other targets.

We hypothesize that sight and smell work together as the spider looks for blood meals among the teeming masses of bloodless insects of similar size. Perhaps odor enables the spider to speed up its decision-making, if, say, the smell of a blood-carrying female mosquito primes it to detect that prey. Imagine being told you're going to see a painting if you look in a certain direction with binoculars. If you then see a certain characteristic smile, you'll probably guess, correctly, that you're seeing the *Mona Lisa*. Something similar could happen when the spider smells blood: seeing the shape of a distended abdomen (where a mosquito stores her blood meal) may be all the additional information the spider needs to know it has found what it is looking for.

We have been testing our hypothesis by adopting the laboratory methods of Dr. Frankenstein. Initially we created static monsters out of body parts from different mosquitoes, to learn what our spiders found most inviting. By attaching male mosquito antennae to a female body, for instance, we could test whether the spiders were attending to that particular feature. More recently we reanimated

Swarm of "lake flies," similar to those of Lake Victoria, rises like smoke over East Africa's Lake Malawi.

Juvenile jumping spider, above right, gets a blood meal by attaching its fangs to the thorax of a mosquito (partly obscured by the spider's body in the photograph), then drawing blood from the prey insect's abdomen. The spider's suction has already drawn blood through the spider's forebody (the cephalothorax) and its narrow "waist" into its own abdomen. The photomicrograph is magnified 13x.

our monsters by creating virtual mosquitoes, projected onto miniature movie screens for the spiders to watch. We digitally add and rearrange various body parts to see how the differences affect the spiders' responses. For example, a red undistended abdomen turns out to be more attractive than a distended but colorless one. The experiments suggest that *E. culicivora,* once primed by the odor of a blood-fed mosquito, just needs to see a distended, reddish abdomen to decide it has seen its favorite prey. The abdomen might be, for *E. culicivora,* the equivalent of the *Mona Lisa*'s smile.

Drinking vertebrate blood taken from a mosquito may be an unusual way for a spider to get a meal, but all spiders are fluid feeders. The typical spider routine is to immobilize an insect with venom injected from a pair of sharp fangs; the spider then secretes digestive fluids from its mouth into the prey's body. Inside the prey, the digestive fluids liquefy the internal tissues, which the spider then sucks out. An adult *E. culicivora* takes about an hour and a half to feed on a sugar-fed mosquito, but only about an hour to feed on a blood-fed one. Thus, by dining on a blood-fed mosquito, the spider enjoys the benefits of fast food. The mosquito's body is something like a paper wrapper around a hamburger: open it, and there's the meal, ready to eat.

The packaging for the blood is actually a bit more complicated than that. When a mosquito takes in a blood meal, its liquid bonanza is stored within a double container: the gut inside its abdomen. For an adult *E. culicivora* that presents hardly any barrier at all. Often at least twice the size of a mosquito, the adult spider rips into its prey, quickly crushing and rupturing the mosquito's fragile outer cuticle, as well as the gut membrane holding the blood. After mixing the blood with its digestive fluids, the spider sucks out the liquid and retires to digest its meal. The mauled corpse suggests an attack by a werewolf rather than by a suave Count Dracula.

Juvenile spiders, however, have a harder time extracting blood from the mosquito gut. A little juvenile attacks by sinking its fangs into the mosquito's thorax until the mosquito is subdued. Lacking large enough weaponry to tear into the body, the juvenile spider then places its mouth over the fang holes and cranks up its powerful stomach and pharyngeal muscles into sucking action. That draws fluid—though not yet blood—from the prey's thorax towards the spider's mouth and into its own digestive tract. The suction eventually ruptures the gut membrane encapsulating the blood. To an observer through a microscope, the scene inside the prey's body soon resembles a lazy, meandering river of blood and other nutrients moving toward the spider's mouth.

The small spider generates enough suction to draw fluids from as far away as the tip of the mosquito's abdomen. The body of the mosquito remains intact, but it collapses inwards from the suction, much as a soft cardboard carton of juice does when a person sucks out the contents with a straw. Eventually, however, the back pressure inside the corpse becomes too strong to suck against, and the juvenile spider relaxes its sucking muscles. Inside the mosquito, the lazy-river scene abruptly reverses into cascades, rapids, and turbulence, as most of the extracted fluid rushes back from the spider. This cycle of sucking and regurgitation repeats many times, as the mosquito's body is turned into an extension of the spider's own digestive tract.

The entire scene is often one of grotesque, comic images, as air and fluids rush in and out of the mosquito's body. For a moment the mosquito may inflate, its proboscis suddenly extending like a party noisemaker. The spider's digestive juices may also flake off the dark pigment covering the mosquito's compound eyes. The eyes, when emptied, become transparent, their little facets resembling cut crystal. Then when the fluid rushes back in, each eye looks like an empty punch bowl being filled with pink lemonade.

For the juvenile *E. culicivora,* all that is just part of the business of feeding. One might wonder why the spider doesn't move its mouth to the mosquito's abdomen, and shorten the distance over which blood has to be sucked. But apparently the repeated cycles of suction and regurgitation are effective in circulating digestive fluid throughout the mosquito's body. And there seems to be a good reason for feeding from the thorax: compared with the mosquito's abdomen, the thorax is a capsule with a rigid surface, providing a stable platform from which the liquid contents of the mosquito's abdomen can be efficiently pumped. In the end, the juvenile predator leaves behind a remarkably intact mosquito carcass.

Mosquitoes are good for delivering blood to *E. culicivora,* but of course they're bad for people. Many diseases are spread by mosquitoes, the most notorious being malaria, a disease caused by *Plasmodium,* a single-cell parasite. Human malaria depends on mosquitoes of the genus *Anopheles.* In Africa, one species in particular, *Anopheles gambiae,* is the malaria parasite's ultimate taxi for moving from person to person. For a mosquito, *A. gambiae* has an exceptionally long life span, and it takes its blood meals almost exclusively from people.

Finding a spider that singles out mosquitoes is welcome news in Africa, but wouldn't it be even better to find a spider that singles out *Anopheles*? Surely, though, that's asking too much. Or is it?

Adults and large juveniles of *E. culicivora* feed on a wide variety of mosquito species when they are hungry. But when they are well fed, they prefer *Anopheles.* In fact, the smallest of the juveniles—tiny ones in their first instar, or first stage of development, whose bodies are only four one-hundredths of an inch long—actually appear to single out *Anopheles.*

The reason is likely that the mosquito's habits make it relatively easy prey for such a small spider. *Anopheles* mosquitoes have a distinctive way of resting, with the abdomen tilted up. That characteristic posture is what the first-instar *E. culicivora* has evolved to exploit. On seeing a blood-filled *Anopheles* female, the small juvenile spider plots a path that will bring it around behind the mosquito and under its raised abdomen. From underneath, it jumps upward and brings down the mosquito.

Many people have trouble finding a mosquito in a crowd of lake flies, and even more trouble sorting out which mosquito is an *Anopheles.* Yet a first-instar *E. culicivora* can make those fine-grained discriminations with apparent ease. Perhaps deliberately breeding small armies of those young spiders could become a new secret weapon against the ancient scourge of malaria. □

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Adult female *E. culicivora* dines on a female mosquito of the species *Anopheles gambiae,* the primary transmitter of the parasite that causes malaria in people.

THIS LAND

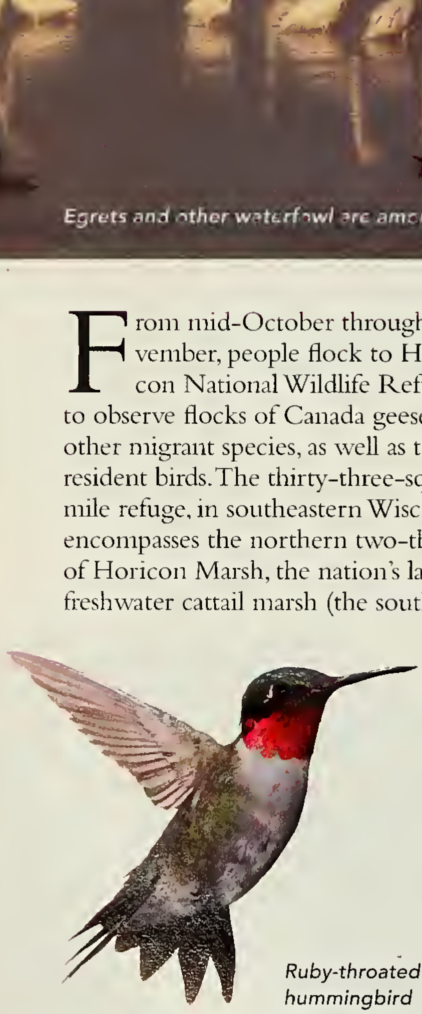
What's Good for the Goose

A Wisconsin marsh offers a welcome rest stop to migrating birds.

By Robert H. Mohlenbrock

Egrets and other waterfowl are among the more than 200 bird species recorded at Horicon Marsh.

From mid-October through November, people flock to Horicon National Wildlife Refuge to observe flocks of Canada geese and other migrant species, as well as the resident birds. The thirty-three-square-mile refuge, in southeastern Wisconsin, encompasses the northern two-thirds of Horicon Marsh, the nation's largest freshwater cattail marsh (the southern third is managed as a state wildlife area). The marsh is a favored stopover for a population of about a million Canada geese that nest near the southern edge of Hudson Bay in summer and fly south to wintering grounds in southern Illinois and nearby parts of the Mississippi valley.



Ruby-throated hummingbird

The flight from Hudson Bay to Horicon Marsh is 850 miles. With a strong tailwind, the geese can average seventy miles an hour, so they can make the trip in as little as twelve hours. The first contingents arrive in mid-September; others make the journey in October or November. At the peak of the migration 200,000 or more Canada geese may be visiting the marsh at one time, "recharging their batteries." They feed almost exclusively on vegetation, not only marsh plants but also waste corn and other resources in the surrounding farmland.

Horicon Marsh owes its existence to glaciers that, during the most recent ice age, scoured a fourteen-mile-long depression into a layer of bedrock made up of relatively soft shale. When the ice began to recede, about 12,000 years ago, a lake of meltwater filled the depression, held in by a glacial deposit of earth and stones called a recessional moraine. Over time, what is now the Rock River flowed over that natural dam and so eroded it, draining the lake and leaving a vast wetland.

In prehistoric times, a succession of Native American peoples derived resources from the marsh. When European American pioneers arrived in the early nineteenth century, they encountered local settlements of Potawatomi and Ho-Chunk (Winnebago) Indians. In 1846 the European American settlers at the south end of the marsh built a dam on the Rock

HABITATS

Marsh Aquatic plants scattered across the marsh include cattails, cursed crowfoot, hard-stem bulrush, marsh spikerush, marsh yellow cress, river bulrush, soft-stem bulrush, and water smartweed. Several species of duckweeds float on the water; naiads and pondweeds, rooted in the marsh bed or drifting in the water, rise to just below the surface.

Streamside Trees along the streams include black willow, box elder, eastern cottonwood, and silver maple. Among the shrubs are common elderberry, gray dogwood, ninebark, pussy willow, and red-osier dogwood. Cleavers, cow parsnip, hairy hedge nettle, late goldenrod, meadow rue, panicled aster, spotted touch-me-not, and wood nettle are common wildflowers.

Moist woods American elm, box elder, and red ash are the dominant native trees,

VISITOR INFORMATION
Horicon National Wildlife Refuge
W4279 Headquarters Road
Mayville, WI 53050
920-387-2658
www.fws.gov/midwest/horicon

River, which temporarily changed the marsh back into a huge lake. But in 1869 the dam was removed, and the lake began to revert to marsh. The state wildlife area was established in 1927, and the rest of the marsh was purchased in 1941 to create the national wildlife refuge.

On the east side of the marsh, most conspicuously about a mile and a half north of the refuge visitor center, the adjoining land is elevated as a terrace, known locally as the Ledge. The Ledge owes its contour to an underlying formation of hard dolomite rock, which geologically is part of the Niagara Escarpment. The erosion-resistant rock follows a huge arc all the way from Horicon Marsh 500 miles eastward to Niagara Falls, which cascades over it. Along much of its route, the formation is either under water (at lakes Michigan, Huron, and Erie) or beneath the surface land. Here and there, however, the dolomite is exposed, most notably at Niagara Falls, which is receding upstream as the water wears the escarpment away.

Although most of the refuge is marshland, it also includes prairies, streambank plant communities, and woodland areas. At the north end of the refuge, originating at the Marsh Haven Nature Center, the 0.4-mile Egret Trail provides a good cross-section of the marsh from a floating boardwalk before leading into a moist forest. Hikers can sample drier woods in upland areas along the half-mile-long Red Fox Trail.

The spectacular fall goose migration makes October and November the most popular months for visiting the refuge. Flocks also stop here on their way north, from late February until the end of April, but the spectacle is more modest. At that time of year food is relatively scarce, and the geese, which must quickly gain weight for the spring migration, spread out over a larger territory to feed.

In April and May, however, the marsh is alive with ducks and songbirds. And during the summer the refuge harbors large numbers of redhead ducks, yellow-headed blackbirds, and American coots. Altogether, at least 227 kinds of birds can be seen here, including bald eagles, egrets, hummingbirds, ospreys, peregrine falcons, sandhill cranes, and trumpeter swans.

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Canada geese at Horicon Marsh, a favored stopover during their fall migration

accompanied by common buckthorn, an invasive species from Europe. Common chokecherry and nannyberry are the most abundant smaller trees. The canopy provides shade for wildflowers including spring favorites such as large white trillium, purple wake robin, both true and false Solomon's-seal, Virginia waterleaf, wild geranium, and species of yellow, white, and blue violets. Late goldenrod and panicled aster bloom in the autumn.

Upland woods Bitternut hickory, bur oak, red oak, shagbark hickory, slippery elm, and wild black cherry are the most prominent trees. Shrubs and small trees include black raspberry, cock-spur thorn, prickly ash, prickly gooseberry, round-leaved dogwood, and wild black currant. Most of the wildflowers bloom during summer and autumn, including asters, Canada black snakeroot, goldenrods, tall agrimony, and white avens.

By Laurence A. Marschall

The Most Important Fish in the Sea: Menhaden and America
by H. Bruce Franklin,
Island Press; $25.00

To my knowledge, I have never eaten a menhaden, though it is the most common fish native to the East Coast of North America. Nor is there a trace of menhaden in those fish-oil pills I down every morning (according to the label, they contain only anchovies, sardines, and soybeans). In fact, according to H. Bruce Franklin, a cultural historian at Rutgers University–Newark, menhaden rarely make it directly to anyone's table: their bodies are riddled with bones, their flesh is saturated with a disagreeable-tasting oil, and, even to hard-nosed fishermen, they smell awful. Yet, paradoxically, they are one of the most heavily harvested and critically important of all marine species.

As Franklin tells it, the commercial exploitation of menhaden began with the *Mayflower* landing in 1620. The Wampanoag Indians taught Puritan settlers that planting the seemingly useless fish along with seed corn would substantially increase the harvest. Organic fertilizer became increasingly essential as overfarming depleted New England soil, and within a century, farmers living near the coast were dumping menhaden by the thousands on each acre of their fields. Otherwise inedible, the menhaden had become an integral part of the American food chain.

By the middle of the 1800s, commercial menhaden fishing had become a growth industry. From Maine to North Carolina, huge rendering plants sprang up along the shore, grinding millions of bony carcasses into meal to spread across the wheat fields of an expanding nation. In the second half of the nineteenth century, menhaden factory ships began to take to the seas, scooping up vast schools of fish in mile-long nets. Menhaden ships could fill to capacity in a matter of days, reaping enormous profits for their owners.

Needless to say, the seemingly inexhaustible bounty did not last. It was about 1880 when the fishermen of Maine first began to notice the absence of menhaden, and the decline continues to this day. It was not immediately evident, however, that the species was in trouble. Improved harvesting methods, including the use of sonar, kept increasing the size of the menhaden catch. By the mid-1980s, 2.7 billion pounds of menhaden were caught each year, more than the combined catch of all other species of fish in the U.S. in both weight and numbers.

Today, of the fifteen states along the Atlantic coast, only Virginia and North Carolina permit industrial menhaden fishing. The industry has shrunk to one major company, Omega Protein, which maintains fleets in the Chesapeake Bay and the Gulf of Mexico. Its products are no longer major sources of raw materials for farming and manufacturing, but have dwindled to omega-3 supplements and feed for factory-farmed salmon.

Yet even one such company is too many, Franklin argues. As filter feeders that eat enormous amounts of microscopic plant life, menhaden underpin the food chain, preventing algal blooms in bays and harbors and providing food for the bluefish, stripers, and other edible fishes that grace the table. Their absence is sorely felt wherever industrial interests have harvested them.

Franklin's book is thus not merely an elegant and erudite study of a moribund industry, but an impassioned plea to return our ailing East Coast waters to a state of healthy equilibrium.

Glorified Dinosaurs: The Origin and Early Evolution of Birds
by Luis M. Chiappe,
Wiley-Liss; $69.95

In 1861, two years after the publication of Darwin's *Origin of Species*, a Bavarian quarry worker unearthed a nearly complete impression of a crow-size, winged reptile with feathers, sandwiched inside a 150-million-year-old slab of limestone. Named *Archaeopteryx lithographica* by the German paleontologist Hermann von Meyer, the striking fossil deepened an existing suspicion that dinosaurs akin to *T. rex* were the ancestors of modern birds.

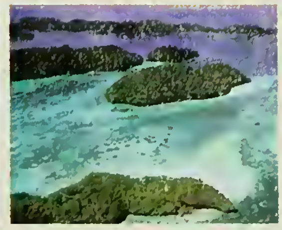
Yet the kinship of *Archaeopteryx* to penguins, chickens, and the other 10,000 living avian species remained uncertain, primarily because the fossil record was slow to reveal further birdlike specimens. In succeeding years, facing the absence of evidence, paleontologists began to waver. Birds, perhaps, descended from an earlier, less specialized ancestor. Throughout much of the twentieth century, cautious paleontologists regarded the similarities between *Archaeopteryx* and avians as examples of convergent evolution, the independent development of similar structures in divergent species. That's the story of bird evolution I learned in school.

But in the past fifteen years discoveries of many fossils of feathered and winged dinosaur species, primarily from Asia, have made it clear that first impressions were correct. The family tree of birds has by now been so thoroughly sketched in, all the way back to *Archaeopteryx,* that to Luis M. Chiappe, director of the Dinosaur Institute at the Natural History Museum of Los Angeles County and a specialist in avian paleontology, birds are not only descendants of dinosaurs, they are dinosaurs. In this handsome book, whose brilliant illustrations and magisterial breadth beg comparison with Bert Hölldobler and Edward O. Wilson's classic monograph, *The Ants,* Chiappe lays out the evidence and presents the case with a flourish.

Among the most impressive specimens he showcases is *Microraptor gui,* a broad-winged dinosaur about the size of a pheasant, whose fossilized remains were discovered in northeastern China in 2003. Like *Archaeopteryx,* it sported a long, plumed tail, and its wing feathers resembled the ones of modern birds, both in size and distribution. Possibly *Microraptor* could fly, but paleontologists remain puzzled by

Archaeopteryx lithographica





a long row of feathers that stuck outward from its lower legs: in Chiappe's words, "a sort of avian version of the heel-winged Mercury of the Roman pantheon." Leg feathers might have added some lift if they could be held horizontally, but the anatomical evidence suggests that *M. gui* could not rotate its hind limbs that way.

The case of *Microraptor* highlights the difficulties paleontologists face in recreating the prehistory of birds. Color photographs throughout the book clearly convey the detail of skeletons and the astonishing filigree the plumage has etched into rock. But the artful visualizations of "living" creatures that accompany the photographs are at best educated guesses. The specifics of how early birds learned to fly (and how some later lost the knack), how they reared their young, how they hunted, and how long they lived, remain elusive.

And what is one to make of *Mononykus*, a species of graceful feathered creature discovered in the Gobi desert in the 1990s? Undoubtedly, it is part of the bird clan, but its stubby arms, each with a single claw, were plainly useless for flight. Did it perhaps burrow in the ground, rooting for grubs like an avian anteater? The question is just one of the many mysteries and delights of a book that dinosaur lovers and bird fanciers alike will want to make part of their permanent collections.

Riddled With Life:
Friendly Worms, Ladybug Sex, and the Parasites that Make Us Who We Are
by Marlene Zuk,
Harcourt, Inc.; $25.00

Think of this book," its author writes, "as a disease appreciation course." Don't get her wrong, though: Marlene Zuk, an evolutionary biologist at the University of California, Riverside, is not suggesting that people learn to love tapeworms, papilloma viruses, or plague bacilli. Nor is she preaching that suffering from the depredations of such beasties is, somehow, a good thing for body or spirit—at least, not always. Rather, she understands that invasive creatures are, like thunderstorms, earthquakes, and gravity, irreducible parts of the human environment. Living the good life, to Zuk, means reaching a kind of détente with the creatures that live around and in us.

That point of view may seem strange to those of us who live in cities where water is filtered and chlorinated, vaccination is nearly universal, and antibiotics are as common as table salt. But reflect on the cultural response in parts of Africa to the worms that cause schistosomiasis: the parasites are so much a part of everyday life that blood in a boy's urine is viewed as a sign of maturity, akin to menstruation. It's not that Zuk is advising third-world countries to shut up and learn to live with what they've got. Her insight into disease is that, though some invasive microorganisms should be controlled, others can be endured, and still others may actually be helpful.

The helpful ones, in fact, may form the majority. It's common knowledge that microorganisms thrive in the digestive tract, helping digest essential nutrients. But did you know that biologists estimate that microbial cells outnumber human cells in a person's body by ten to one? The body, like the democracy of ancient Athens, is an elite community of cells bearing human DNA, but supported by a vast un-derclass of foreign laborers. Eliminate that work force, and we're in trouble.

There are disturbing signs that the modern mania for antisepsis is already causing trouble. The appearance of antibiotic-resistant strains of bacteria is just one of those signs—a response to the man-made evolutionary pressure introduced by the overuse of wonder drugs such as penicillin. Epidemiologists have also noted a correlation between improvements in sanitation and the frequency of immune disorders such as asthma and Crohn's disease, an inflammatory disorder of the digestive system. Zuk even cites some intriguing studies in which people were deliberately infested with a parasite to treat disease. For example, live eggs of the pig whipworm seem to send Crohn's disease into remission with no adverse side effects.

Zuk's book is not primarily about worms and germs, though. Those tiny stowaways are only examples of her greater theme: how parasitic species coevolve with their larger hosts. Viewed through the lens of Darwinian selection, parasites have influenced everything from dogs' penchant for rolling in garbage to the overwhelming preference of organisms for sexual rather than asexual reproduction. As the title suggests, we all may be riddled with life-forms that do not share our genes, but without them we would not be fully human.

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

Continued from page 27

customed and difficult stance on the ground simply for any of the commonly cited reasons. Only an arboreal ancestor that was already comfortable holding its body upright when moving around in the trees would have done so. When Alemseged finally liberates the Dikika child, perhaps its comparison with Lucy, an adult form, will provide new insight into the species' accommodations to life both in the trees and on the ground.

Meanwhile, Lucy's appearance in Houston is a landmark occasion, and she may well continue traveling to a series of international venues for five years or more. Most paleoanthropologists will be uneasy until she is safely "home." But as a roving ambassador, she not only reminds us of our remote human past, but also heralds dynamic new dimensions of Ethiopian achievement.

IAN TATTERSALL is a curator in the division of anthropology at the American Museum of Natural History in New York City.

nature.net

Beep Beep

By Robert Anderson

Born in 1960, I have no memories of the heady years when our species first vaulted to a higher plane, Earth orbit—though I did witness the end of the space race, when astronauts landed on the Moon. What was it like, half a century ago, to tune a ham radio to *Sputnik 1*'s ominous beeping as the satellite sailed overhead? Still, I can get a taste of it: the evocative sounds are accessible on the Internet. And movies such as *October Sky* (1999) give me a sense of how the first artificial satellite drew young Americans into rocket science. Please visit the magazine online (www.naturalhistorymag.com), where I review Web sites devoted to *Sputnik*'s cultural and scientific impact.

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

Continued from page 25

its eighteen pounds of scientific instrumentation, into orbit.

If you want to reach orbital speeds (about 18,000 miles an hour), you'd better not burden your rocket with dead weight on the way up. Rocket motors are heavy, fuel tanks are heavy, fuel itself is heavy, and every kilogram of unnecessary mass schlepped into space wastes thousands of kilograms of fuel. The solution to dead weight is the multistage rocket. Use up the fuel in the first-stage fuel tank; throw it away. Use up the fuel in the next stage; throw that away too.

The rocket that launched *Explorer 1*—the Jupiter-C—was multistage. At takeoff, the loaded Jupiter-C weighed 64,000 pounds. The final stage weighed eighty.

Like the R-7 rocket that launched *Sputnik 1*, the Jupiter-C was a modified weapon. The science was a secondary, even tertiary, outgrowth of military R&D. Cold warriors wanted bigger and more lethal ballistic missiles, with nuclear warheads crammed into the nose cones.

High ground is the military's best friend, and what ground could be higher than a satellite orbiting no more than forty-five minutes away from a possible target? Thanks to *Sputnik 1* and its successors, the U.S.S.R. held that high ground until 1969, when, courtesy of von Braun and his colleagues, America's Saturn V rocket took the *Apollo 11* astronauts to the Moon.

Today, whether Americans know it or not, a new space race is under way. This time, America faces not only Russia but also China, the European Union, and India. Maybe this time the race will be one between fellow travelers rather than potential adversaries—more about fostering innovations in science and technology than about struggling to rule the high ground.

Astrophysicist Neil deGrasse Tyson *is the Frederick P. Rose Director of New York City's Hayden Planetarium at the American Museum of Natural History.*

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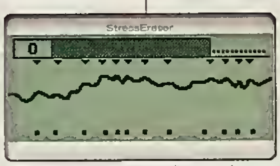

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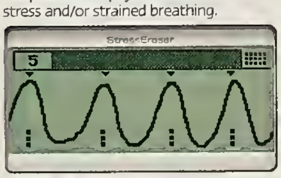

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John and AMANDA

A scientific legacy stretches from the core of the Sun to deep beneath Antarctic ice.

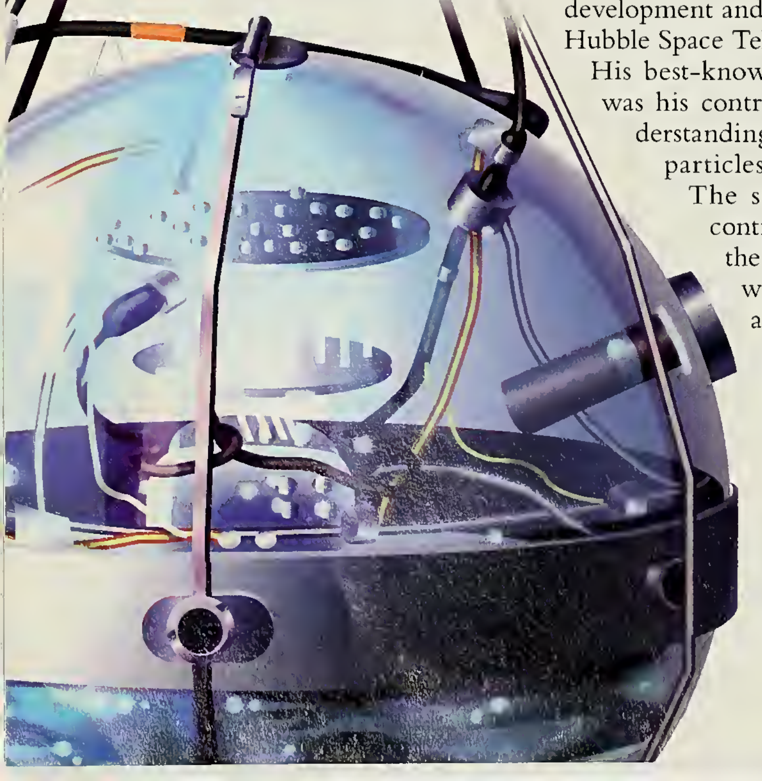
By Charles Liu

Just about everyone in the field of astronomy today has a story or two about John Norris Bahcall. Not all that long ago, at a small scientific conference, a fellow graduate student and I were chatting, when my friend suddenly gestured toward a tall, thin, bespectacled man who'd just come into view. "Is that John Bahcall?" he asked me. I told him it was. "Wow," he replied. "John Bahcall. He's got to be the most intimidating man in all of astronomy!" Considering that this friend is now himself one of the most accomplished—one might even say "intimidating"—astronomers of my generation, that was a weighty assessment indeed.

If there was anything intimidating about John Bahcall, though, it was the list of his achievements in astrophysics, not his demeanor. Although I only interacted with him on a few occasions—conferences, colloquia, and the like—it was apparent to me that this quiet, intensely thoughtful man was a warm, kind soul who was deeply loved by his family and friends. When he died in August 2005 of a rare blood disorder, the entire astronomical community mourned his passing.

Bahcall's legacy extends into pretty much every corner of the study of the universe. Here's just a sampling of subjects to which he made major contributions: the standard model of the Milky Way galaxy; the standard model for the interior of the Sun; models of the distribution and behavior of dark matter; the characterization of galaxies that host quasars; the interpretation of absorption lines in the spectra of quasar light; the understanding of supermassive black holes; and the development and deployment of the Hubble Space Telescope.

His best-known work, however, was his contribution to the understanding of the elementary particles called neutrinos. The study of neutrinos continues today around the world—even all the way "down under," in an intriguing project to which Bahcall contributed toward the end of his career. The project is known by its acronym, AMANDA, the Antarctic Muon and Neutrino Detector Array, and it lies, for the most part, buried a mile down inside the ice at the South Pole.



Neutrino means "little neutral one" in Italian, the native language of the physicist Enrico Fermi, who coined the name in 1933. Three years earlier, the Austrian physicist Wolfgang Pauli had predicted the existence of the particle, to explain the puzzling observation that bits of energy seemed to be consistently missing from certain nuclear reactions. No one confirmed the existence of neutrinos, though, until 1956. The reason they went missing for so long is that they penetrate matter so effortlessly that they rarely leave a trace of their passage.

How penetrating are they? Here's an instructive example. Most physicists are accustomed to thinking of gamma rays as powerful, highly penetrating radiation. Yet the gamma rays generated at the core of the Sun are so thoroughly blocked and scattered by the surrounding dense solar plasma that they routinely take more than 100,000 years to bounce their way to the surface and out into space. By contrast, neutrinos generated at the same place, by the same nuclear reactions, flash through the overlying Sun-stuff in less than three seconds!

About half a century ago, astrophysicists—Bahcall among them—realized that neutrinos could be a key to learning just what is going on at the center of the Sun. Almost everything known about the universe comes from the study of light. So it is with sunlight, which takes only about eight minutes to reach us from the Sun's surface. Yet that light is actually quite ancient, the cumulative outcome of nuclear reactions that extend back long before early humans began painting on cave walls. Neutrinos, however, reach us fresh from the Sun's nuclear oven. Hence, Bahcall and his colleagues reasoned,

Globular modules that contain detectors for catching the rare signal of a passing neutrino are strung together vertically and buried deep within the ice at the South Pole. The artist's rendering across these two pages depicts some of the 680 modules in the current array.

neutrinos could reveal what's going on inside the Sun right now.

In 1964 Bahcall and the late physical chemist Raymond Davis Jr. proposed that a radically new kind of astronomical instrument could be built to study the Sun. Bahcall calculated that some 300 billion solar neutrinos should be passing through every square inch of Earth's surface each second. With that many incoming neutrinos, and enough matter to act as atomic targets, the neutrinos could be monitored despite the extreme rarity of their interactions.

Davis, for his part, described how to monitor the neutrinos: some of them could be detected as they streamed into a big tank filled with thousands of gallons of pure liquid, placed deep underground to shelter it from other forms of radiation. That idea led directly to the Homestake Gold Mine experiment in South Dakota—the world's first solar neutrino telescope. In the decades that followed, Bahcall, Davis, the Japanese physicist Masatoshi Koshiba, and many other investigators pursued the ghostly particles with a variety of such neutrino telescopes, but all based on Bahcall's and Davis's original ideas.

Serendipitously, in 1987, neutrinos reached Earth from an exploding star 170,000 light-years away. Worldwide, such neutrino telescopes collected only a few dozen neutrinos from Supernova 1987A, but that was enough to whet observers' appetites. We astronomers dreamt of creating neutrino telescopes that could detect neutrinos from other distant events and objects: quasars, supernovas, colliding black holes, and more.

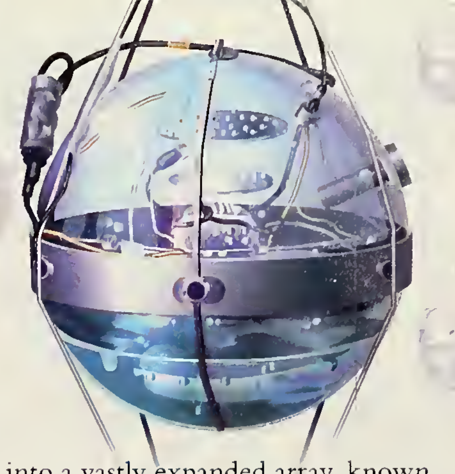
Bahcall was as interested in those distant, typically extragalactic neutrinos as he was in the solar ones. Working with Eli Waxman, who at the time was one of his colleagues at the Institute for Advanced Study in Princeton, Bahcall calculated how many neutrinos should reach Earth from such faraway sources, and what kinds they would be. About that same time, he got involved with AMANDA.

As hard as it is for people to live and work at the South Pole, it's probably the best place on Earth to do neutrino astronomy. When neutrinos do have one of their rare interactions with matter, the interaction gives rise to a brief, weak flash of light called Cerenkov radiation. Under the right conditions, ice is transparent to Cerenkov light; so if such flashes are generated within ice, they can be detected. And one thing abundant at the South Pole is ice.

AMANDA is an array of light detectors buried in holes in the ice a few feet wide and more than a mile deep. Each hole is bored with high-powered drills that cut with superheated water instead of diamond bits. Before the water refreezes, long chains of basketball-size glass globes are lowered into the lower half of the holes [*see illustrations on these two pages*]. Inside each globe is a sensitive light detector, which monitors the ice in all directions. Operational for about a decade now, the array has been has been continually upgraded and expanded. The current configuration, called AMANDA-II, includes nineteen detector chains strung with a total of 680 globular modules.

The most recent studies have included a search for neutrinos from gamma-ray bursts, among the most powerful sources of energy in the universe. Those distant cosmic events release more energy in a few seconds than our Sun will generate in its entire 10-billion-year lifetime. The detection of neutrinos would provide clues to the still-mysterious process that generates the bursts.

The news so far is . . . no news. In a recent paper, AMANDA investigators reported no evidence of neutrinos from gamma-ray bursts. But the good news is, they didn't expect any. According to the Waxman-Bahcall predictions, AMANDA-II is not likely to see anything from gamma-ray bursts unless it can be made at least ten times more sensitive to neutrinos. And that's precisely what the South Pole experimenters are working to do. AMANDA-II is being incorporated



into a vastly expanded array, known as IceCube, which will have more than 4,000 detector modules spread through more than a cubic kilometer of ice. If the enlarged array detects neutrinos emitted from gamma-ray bursts, the achievement will become yet another parcel of John Bahcall's scientific legacy.

That reminds me of another incident from my grad school days. A number of us students were having lunch at an observatory cafeteria, discussing the giants of astronomy and astrophysics: Galileo, Newton, Hubble, and others. Who among our professors and mentors, we wondered, might be remembered in history alongside those immortal names? Even as we agreed that only time would tell, one of my classmates—she's now one of the world's leading astronomers—said, "Maybe John Bahcall?" His was the only name anyone mentioned.

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

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THE SKY IN OCTOBER

By Joe Rao

Mercury begins October just past its greatest elongation, twenty-six degrees east of the Sun. But as seen from latitude forty degrees north, the planet, shining at magnitude zero, sets only three-quarters of an hour after sundown. In the continental United States, Mercury is probably visible to the unaided eye only from the Gulf Coast states and the Southwest. It reaches inferior conjunction (between the Sun and Earth) on the 23rd, but just a week later, assiduous observers who scan the eastern horizon with binoculars about forty-five minutes before sunrise might catch their first morning glimpse of the planet. That same morning, the first-magnitude star Spica lies about three degrees to the lower right of Mercury. You can locate Spica by extending the curve of the Big Dipper's handle about thirty degrees across the sky to the bright star Arcturus, then continuing another thirty-five degrees.

Venus arrives at the pinnacle of its current morning apparition. All month it rises at or shortly before 3:30 A.M. local daylight time, its earliest rising time this year and next. That's a full two hours before the first sign of dawn as October begins, and two and a half hours by month's end. During the first half of the month, an ever-changing celestial array greets early risers, as Venus, Saturn, a lovely crescent Moon, and the first-magnitude star Regulus square-dance across the eastern horizon. On the morning of the 7th Venus, Saturn, and Regulus form a large triangle around the Moon. On the 8th and 9th Venus appears to pass south of Regulus. Finally, on the 14th Venus passes south of Saturn. Venus reaches its greatest elongation, forty-six degrees west of the Sun, on the 28th. At the start of the month a telescope or a steadily held pair of binoculars reveals Venus as a wide crescent. But as the planet pulls ahead of Earth and speeds away in its orbit, Venus shrinks in diameter even as it grows fuller in phase. Its dichotomy, or half-full phase, probably won't appear in telescopes until around the 3rd, nearly a week after one would expect it, at elongation. That mysterious lag is known as Schroter's effect.

Mars spends the month in the constellation Gemini, the twins—more precisely, within the feet and legs of the younger twin, Castor (according to old allegorical drawings of that constellation). The Red Planet rises well north of east around 11 P.M. local daylight time on the 1st, and closer to 9:30 P.M. by month's end. You'll find Mars poised near the meridian before the break of dawn.

Jupiter, at magnitude –2.0, is in the southwestern sky at dusk. It sets around 10 P.M. local daylight time on the 1st and almost two hours earlier by Halloween. As dusk fades, watch as the ruddy star Antares comes into view, twinkling and blinking between six and ten degrees below the King of Planets.

Saturn, shining with a mellow yellow light at magnitude +0.8 in the constellation Leo, the lion, rises around 4 A.M. local daylight time on the 1st and around 2:15 A.M. LDT by month's end. The ring system is gradually closing as seen from our earthly perspective, diminishing its inclination from 8.8 degrees to 7.4 degrees in the course of the month.

The Moon arrives at last quarter on the 3rd at 6:06 A.M. and wanes to new on the 11th at 1:01 A.M. It waxes to first quarter on the 19th at 4:33 A.M. and to full—the "Hunter's Moon of October" on the 26th at 12:52 A.M. Roughly seven hours later, at 8:00 A.M., the Moon reaches perigee, its closest orbital approach to the Earth, 221,676 miles away. As a consequence, the tides are far higher than normal during the following few days.

Unless otherwise noted, all times are eastern daylight time.

EXPLORER GUIDE

It's Not Easy Being Clean

R.MICKENS/AMNH

Mike Smith gives an African elephant a gentle dusting.

Live African elephants often shower themselves with dust to protect their skin from insects and the searing heat. While these are not such a problem inside the Museum, the African elephants in the Akeley Hall of African Mammals nonetheless collect their share of dust. And so, for that matter, do the birds, dinosaurs, mammals, fish, and other creatures in the Museum that are exhibited in the open without a protective covering of glass.

Regarding the African elephants, "a little bit of dust looks natural," says Stephen C. Quinn, Senior Project Manager in the Department of Exhibition. "But there's a difference between a suggestion of the dust raised on the African plains or the patina of antiquity versus real neglect." Dust left unattended, Quinn explained, eventually forms dust bunnies that, especially in a nature exhibition, are "very unnatural."

So in what has become an annual ritual, recent visitors to the Akeley Hall were treated to the sight of a huge mechanical lift flanking the eight African elephants posed in a perpetual march down the center of the Hall. For two days, Mike Peter Smith, Exhibition Maintenance Supervisor, methodically made his way around the herd, the lift giving him the height he needed to get to hard-to-reach places—like, behind those large ears. Using a special vacuum on which the suction can be finely tuned, Smith removed a year's worth of dust from the massive heads, backs, flanks, trunks, and tusks of each elephant, often gently brushing it toward the nozzle of the vacuum rather than subjecting the skin's surface to direct contact. Once these higher tasks were completed, he finished cleaning the legs, feet, and underside from the ground.

This is a job Smith will repeat again and again, moving around the Museum with the lift, vacuum, and brush, and sometimes a feather duster, to clean all specimens not in cases, a small percentage of the 300,000 items on display at any given time out of the 30 million or so in the Museum's collections. In addition to the African herd, Smith's charges include a pair of Asian elephants in the Hall of Asian Mammals; the soaring dinosaur casts that include the world's highest freestanding mount of a dinosaur, the *Barosaurus* poised to protect her young from the jaws of an *Allosaurus*, in the Theodore Roosevelt Rotunda; and the many denizens of the fossil halls on the fourth floor. These last get a once-over every six months, and the decks beneath as often as every three weeks, less for dust than for debris, such as lollipops, batteries, even toy dinosaurs.

Similarly, Smith is also responsible for cleaning the creatures in the Dzanga-Sangha Rain Forest, the walk-in diorama at the heart of the Hall of Biodiversity. And sadly, here too, like human pollution in the real world, Smith too often finds discarded water bottles, paper, and other man-made messes.

The fish casts, birds, and sea creatures outside and inside the Milstein Hall of Ocean Life are also regularly dusted in-house, with one large exception: the blue whale. Cleaning the 94-foot-long, 21,000-pound model hanging from the ceiling—as well as the planets hanging in the Rose Center for Earth and Space—requires a private contractor and scaffolding. Although the last time it was cleaned, Smith says, "I had to put a chin strap under the whale's chin. She kind of wobbles."

The Butterfly Effect

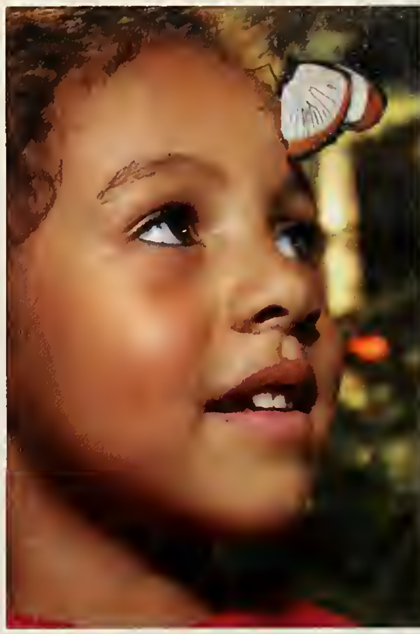
Live butterflies return on Saturday, October 6, and with them comes one of the most crowd-pleasing experiences the Museum offers—the possibility of an up-close encounter with one of the 500 free-flying creatures at the heart of this popular exhibition.

Now in its tenth year, The Butterfly Conservatory: Tropical Butterflies Alive in Winter turns the Whitney Memorial Hall of Oceanic Birds, on the second floor off the Theodore Roosevelt Rotunda, into a 1,200-square-foot, temperature-controlled habitat for monarchs, zebra longwings, orange-barred sulphurs, and other species from Florida, Costa Rica, Kenya, Thailand, Malaysia, Australia, and Ecuador. Here you will find a curious blend of activity and stillness, as the butterflies and moths flit around and children and adults stand motionless amid the lush vegetation in hopes of being mistaken for a fruit tree, a palm frond, or other appealing perch. Invariably, hushed exclamations and giggles erupt as one or another of the creatures alights on an adult's head or a child's outstretched hand, to the surprise and delight of anyone close by.

Are there some species more likely to fraternize than others? Yes. Among the more gregarious are the paper kite, which might land on your head; the owl butterfly, which tends to mistake people for tree trunks; and the Julia butterfly, which is drawn to the backs of people's hands when they sweat, a not uncommon occurrence given the vivarium's steady 80 degrees Fahrenheit and 75 percent humidity.

So come enjoy this rare and wonderful taste of the tropics, and don't be surprised if you are taken for a ride!

The Butterfly Conservatory: Tropical Butterflies Alive in Winter opens October 6. Visit www.amnh.org for more information and to purchase tickets.



D. FINNIN/AMNH

A visit from a red-spotted diadem is enough to leave a child breathless.

Science and Society: Words and Music

Much of the Museum's work revolves around where we've come from and where we are headed. But two lectures by prominent researchers making science accessible and engaging to the public will address another key concern: what makes us tick now. The first talk, by psychologist Steven Pinker, involves the role of language in thought and emotion; the second, by neurologist Oliver Sacks, considers the ways in which music moves us.

The lectures are the second and third in a compelling new series called Science and Society, which brings to the institution and the public environmentalists, scientists, activists, and others whose work has a bearing on our everyday lives. The first lecture in the series featured Nobel Peace Prize laureate and Kenyan political figure Wangari Maathai, a groundbreaking environmentalist and author of the memoir *Unbowed*.

NANCY CRAMPTON (LEFT) REBECCA GOLDSTEIN (RIGHT)

Oliver Sacks (left) and Steven Pinker (right)

On Thursday, October 4, Pinker, Johnstone Professor of Psychology at Harvard University, will discuss how language structures our thoughts, emotions, and relationships, ideas laid out in his latest book, *The Stuff of Thought: Language as a Window into Human Nature*. He will consider why we frame abstract ideas in concrete metaphors, why we veil bribes, threats, or sexual overtures in euphemism and innuendo, and even why some of us swear or get upset when other people swear.

Later in the month, on Thursday, October 25, Sacks will discuss his new book, *Musicophilia: Tales of Music and the Brain*, in which he recounts the experiences of patients, musicians, composers, and lay people in his exploration of the complexities of the human response to music and its power to affect us physically and emotionally.

Book signings will follow each lecture.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY

www.amnh.org

EXHIBITIONS

Mythic Creatures: Dragons, Unicorns, and Mermaids
Through January 6, 2008
Mythic Creatures traces the origins of legendary beings of land, sea, and air. Cultural artifacts bring to light surprising similarities—and differences—in the ways peoples around the world have depicted these beings, and fossil specimens suggest a physical basis for the many forms they have taken.

Mythic Creatures: Dragons, Unicorns, and Mermaids is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with The Field Museum, Chicago; Canadian Museum of Civilization, Gatineau; Australian National Maritime Museum, Sydney; and Fernbank Museum of Natural History, Atlanta. *Mythic Creatures* is proudly supported by MetLife Foundation.

D FINNIN/AMNH

This extinct primate, *Gigantopithecus blacki*, may have inspired the myth of ape-men like the Yeti.

Undersea Oasis: Coral Reef Communities
Through January 13, 2008
Brilliant color photographs capture the dazzling invertebrate life that flourishes on coral reefs.

Beyond
Through April 6, 2008
Exquisite images from unmanned space probes take visitors on a journey through the alien and varied terrain of our planetary neighbors.

The presentation of both *Undersea Oasis* and *Beyond* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Unknown Audubons: Mammals of North America
Through January 6, 2008
The stately Audubon Gallery showcases gorgeously detailed depictions of North American mammals by John James Audubon, best known for his bird paintings.

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

Exoplanets and the Search for Life
Through March 2008
Two striking astronomical instruments demonstrate the need for extremely specialized tools in the search for planets around stars other than our own Sun.

This exhibit, part of the education and public outreach efforts of NASA's Navigator Program, was made possible through a grant from NASA's Michelson Science Center at the California Institute of Technology.

LECTURES

The Unnatural History of the Sea
Tuesday, 10/2, 7:00 p.m.
Author Callum Roberts explores the history of commercial fishing and the depletion of marine life. He also suggests ways to restore the prosperity of the seas.

The Immortalists
Thursday, 10/11, 7:00 p.m.
Writer and reporter David M. Friedman tells the story of aviator Charles Lindbergh and Nobel Prize–winning surgeon Alexis Carrel and their successful quest to build a machine to keep organs alive outside the body.

Leviathan: The History of Whaling in America
Tuesday, 10/30, 7:00 p.m.
Marine writer Eric Jay Dolin chronicles the social and economic history of the whaling industry in America, as well as the natural history of whales themselves.

SCIENCE AND SOCIETY
An Evening with Steven Pinker
Thursday, 10/4, 6:30 p.m.
See previous page.

An Evening with Oliver Sacks
Thursday, 10/25, 7:00 p.m.
See previous page.

WORKSHOPS

Understanding Our DNA
Three Tuesdays, 10/9–23, 6:30 p.m.
Participants in this hands-on workshop will make their own DNA "fingerprints" and explore their implications.

Illuminated Manuscripts
Sunday, 10/14, 11:30 a.m.–1:00 p.m. (Ages 5–7, each child with one adult) and 2:00–3:30 p.m. (Ages 8–10)
Thursday, 10/18, 6:30–8:30 p.m. (Adults)
Grinding natural pigments and using real 22-karat gold leaf, participants will create their own medieval-style painting.

FAMILY AND CHILDREN'S PROGRAMS

Field Trip to the Moon
Every Wednesday, 10:30 a.m.
Guided by a live presenter, this new program flies visitors to the Moon in the Hayden Planetarium.

Wild, Wild World: Bats
Saturday, 10/27, 12:00 noon–1:00 p.m. and 2:00–3:00 p.m.
Not only are bats not to be feared, they need our protection. Find out more in this live-animal presentation.

Dr. Nebula's Laboratory: Mythic Stories and Tales
Sunday, 10/21 2:00–3:00 p.m.
(Families with children ages 4 and up)
Help Scooter, Dr. Nebula's apprentice, tell stories of magical creatures from the ancient past.

ROSE CENTER FOR EARTH AND SPACE
Sets at 6:00 and 7:30 p.m.
Friday, 10/5
Ray Mantilla and the Good Vibration Band

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

Astrofavorites: The Earth and Space Collection
Three Thursdays, 10/4–18, 4:00–5:30 p.m. (Ages 4–6, each child with one adult)
Our most popular children's workshops are now available as a discounted series.

NASA, THE HUBBLE HERITAGE TEAM, AND A. RIESS

Galaxy NGC 3370

Twinkling Stars: Mythic Creatures in the Sky
Two Tuesdays, 10/9 and 16, 4:30–5:30 p.m. (Ages 4–6, each child with one adult)
This introduction to the night sky is for budding astronomers.

Visit the Space Station
Sunday, 10/28, 11:00–12:30 p.m. (Ages 4–5, each child with one adult) and 1:30–3:00 p.m. (Ages 6–7, each child with one adult)
Kids can "experience" life in space in this workshop.

Robots in Space II (Intermediate)
Three Wednesdays, 10/10–24, 4:00–5:30 p.m. (Ages 8–10)
Young robotics enthusiasts can design robotic explorers.

HAYDEN PLANETARIUM PROGRAMS

Dark Energy
Monday, 10/15, 7:30 p.m.
With Adam Riess of Johns Hopkins University.

TUESDAYS IN THE DOME
Virtual Universe
Solar System Armada
Tuesday, 10/2, 6:30–7:30 p.m.

Celestial Highlights
Those Blinking Autumn Stars
Tuesday, 10/30, 6:30–7:30 p.m.
Public programs are made possible, in part, by the Rita and Frits Markus Fund for Public Understanding of Science.

INFORMATION

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

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., and Saturday, 9:00 a.m.–4:00 p.m., or visit www.amnh.org. A service charge may apply. All programs are subject to change.

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

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions
Journey into deep space to explore the hypersonic impacts that drive the formation of our universe. Narrated by Robert Redford.

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

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

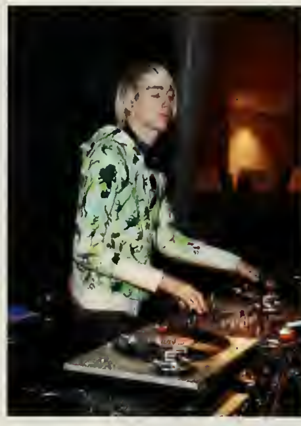
Presented in association with MTV2 and in collaboration with renowned artist Moby.

IMAX MOVIES

Dinosaurs Alive!
On location with AMNH scientists past and present, this stunning new large-format film uses scientifically accurate, computer-generated images to bring to life these intriguing animals, from the earliest dinosaurs of the Triassic Period to the creatures of the Cretaceous.

LATE NIGHT DANCE PARTY

One Step Beyond
Friday, 10/19, 9:00 p.m.–1:00 a.m.
This monthly party in the Rose Center features the biggest names in techno, electronica, and jazz. Food and drink fuel the festivities.

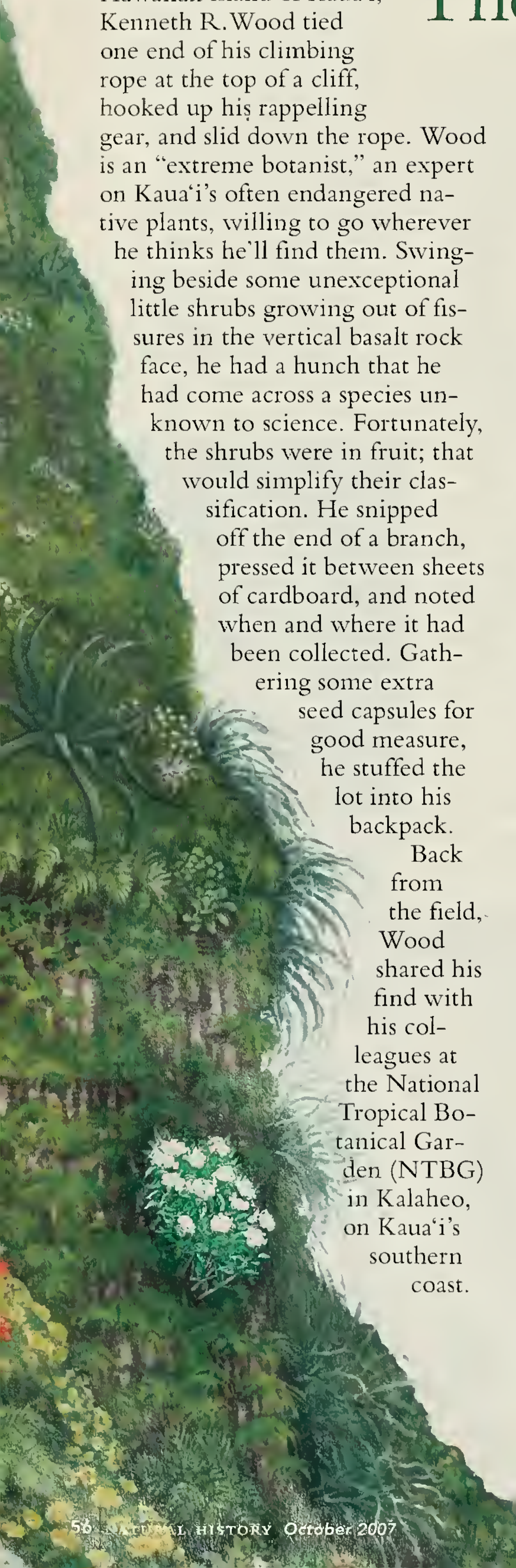


R. MICKENS/AMNH

One Step Beyond brings the party to the Rose Center.

Where Have All The Flowers Gone?

By Peter Brown



High on Mount Haupu, in a rugged part of the Hawaiian island of Kaua'i, Kenneth R. Wood tied one end of his climbing rope at the top of a cliff, hooked up his rappelling gear, and slid down the rope. Wood is an "extreme botanist," an expert on Kaua'i's often endangered native plants, willing to go wherever he thinks he'll find them. Swinging beside some unexceptional little shrubs growing out of fissures in the vertical basalt rock face, he had a hunch that he had come across a species unknown to science. Fortunately, the shrubs were in fruit; that would simplify their classification. He snipped off the end of a branch, pressed it between sheets of cardboard, and noted when and where it had been collected. Gathering some extra seed capsules for good measure, he stuffed the lot into his backpack.

Back from the field, Wood shared his find with his colleagues at the National Tropical Botanical Garden (NTBG) in Kalaheo, on Kaua'i's southern coast.

Sure enough, the plant was new to science—a species of star violet that taxonomists will soon designate *Kadua haupuensis,* in the coffee family. The green thumbs in the NTBG "intensive care unit" coaxed the seeds into sprouting and distributed some of the young plants to other gardens around the island.

A year went by before Wood returned to the cliff to collect more seeds and reassure himself that his small, wild patch of *K. haupuensis* was still growing safely. But when he rappelled to the site, the plants had vanished. Browsing goats, a non-native species, had probably eliminated what nature had taken hundreds of thousands of years to develop. Only Wood's serendipitous encounter, and his dedication to his role as a modern-day Noah, had saved *K. haupuensis* from extinction.

Why should anyone care? Surely one rare plant, gone from the face of the earth, can't be one of humanity's great concerns. Isn't scurrying around collecting samples of species for a botanical "ark" a quixotic enterprise? It's a fair question. Maybe the Hawaiian experience is the best way to answer it.

When seafaring Polynesians first landed on the islands between 1,000 and 2,000 years ago, they brought along small pigs and Polynesian rats in their dugout canoes: food in a pinch. Much later, in the late eighteenth century, the first Europeans on the islands introduced goats and a bigger breed of pig, and black rats and Norway rats came along for the ride. The goats thrived in the wild, where they destroyed cliffside native plants and set off rock slides. The European pigs interbred with their smaller Polynesian cousins to create a rugged, intelligent, and ecologically destructive feral pig. And the three species of rats not only ate seeds of native plants, but also raided birds' nests for their eggs. Afflicted as well by introduced avian malaria, the forest bird populations crashed. Plants dependent on forest birds for pollination were rapidly deprived of their services. In short order, a few invasive species had stumbled upon choke points of the entire ecosystem. Botanists at NTBG are rushing to save what's left of the native plants, but roughly a hundred Hawaiian taxa have already gone extinct.

Where are the choke points of other ecosystems? Can introducing a few species elsewhere cause the rest of the edifice to collapse? No one really knows. Nature can be highly resilient, but the Hawaiian experience shows that innocent mistakes can also lead to devastating changes on timescales measured not in millennia, but in years or months.

"Sometimes you'll go out to an area and go all the way down a rope, and there's no plant," says Steven P. Perlman, another extreme botanist with NTBG. "Everything is dead. And at that point, you hit this low. I've even said I think we need hospice training, because we're dealing with terminal patients, and they die on you. If you see them for ten or twenty years, they're your friends, and you know what they look like. Then you come back and they're dead and dried up. I've gone back and actually witnessed extinction at least a dozen times. And then I think, yeah, I'm not coming here again. I'll go out and get drunk or something, because I've just lost a friend."

PETER BROWN is Editor-in-Chief of Natural History.