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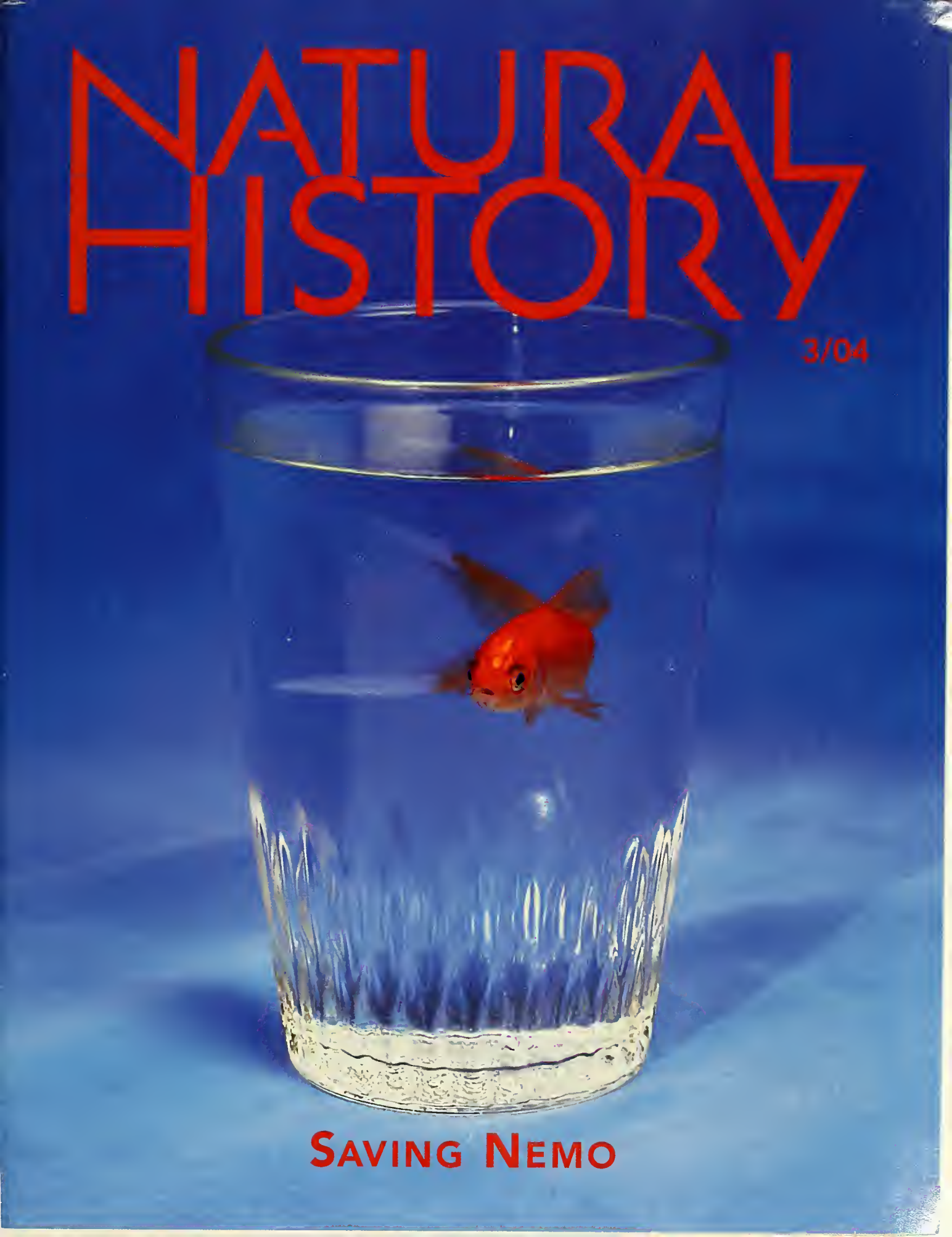

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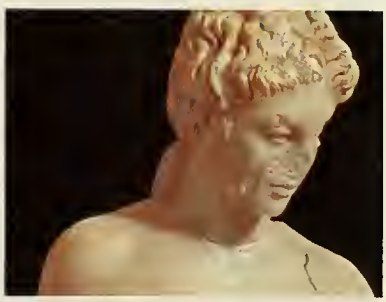

COVER STORY

ON THE COVER: *A Fish Named Rhonda*
Photograph by Jacquelyn C. Black

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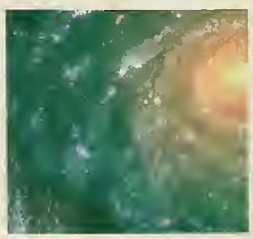

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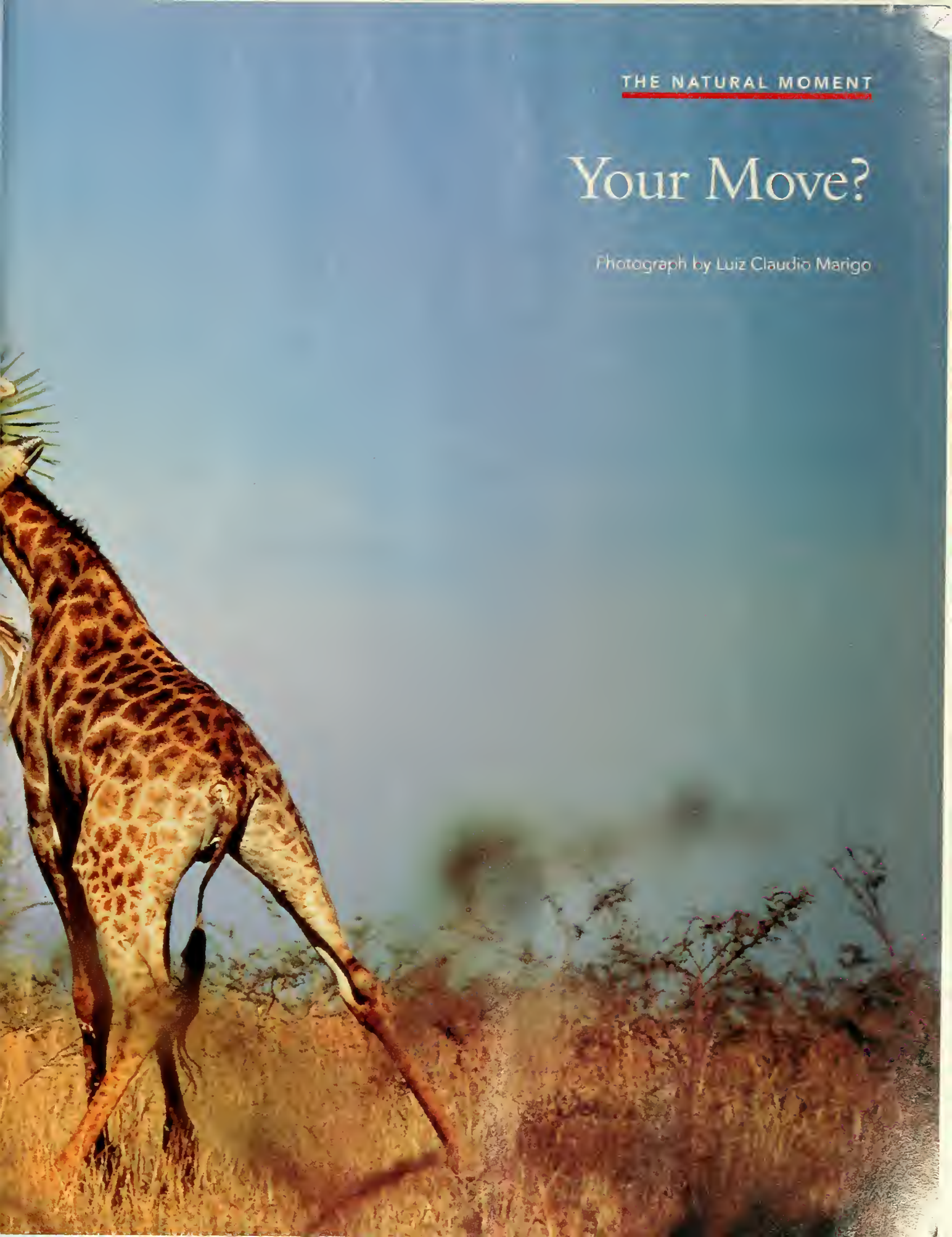
Your Move?

Photograph by Luiz Claudio Marigo



◄ *See preceding pages*

If Rudyard Kipling had written a Just So Story titled, "How the Giraffe Got His Neck," Kipling might have begun his fable with sparring males not unlike the two pictured here. Male giraffes often vie for dominance by intertwining, twisting, and slapping their necks together, a practice aptly called "necking." They also throw the occasional high kick and head butt, in attempts to knock their opponents off guard. A fable based on such behavior might even have some truth to it: a few biologists have suggested that giraffe necks grew longer because females saw them as a sign of male vigor.

Kipling may have short-changed *Giraffa camelopardalis,* but evolutionary biologists have not. Darwin mentions the giraffe in *Origin of Species,* under the heading "Organs of little apparent importance." There he hails the animal's tail as a well-designed tool for fly swatting—indispensable for dealing with Africa's abundance of insects. And in hopes of finding clues about how terrestrial dinosaurs functioned, anatomists have been keen to learn how giraffes regulate blood flow to their brain and kidneys.

Photographer Luiz Claudio Marigo found the young giraffes pictured here in Hluhluwe-Umfolozi Park, near the South African town of Mtubatuba. After nearly an hour of exchanging routine blows, one giraffe slung his head to the ground and *lifted* his rival's leg into a pose that looks more like a limber hind-kick than a trip-up. Once in this position, though, both giraffes froze—stymied about what to do next. —*Erin Espelie*

Fact-Checking

A couple of months ago I took a turn as a panelist on a TV talk show, looking back at some of the top science stories that broke in 2003. My fellow panelists were all seasoned science journalists, terrifically bright and well informed. If you watched the show, you'd come away with a pretty fair idea of what the stories we covered were all about.

What I found fascinating, though, was the way the show was put together. There's a term of art for it: "live to tape." It means just what it says—whatever happens "live," in front of the camera, is recorded for later broadcast. Actually, we did rehearse a few sections—the opening, the closing—but mostly we just winged it. At one point I had to explain "serotonin reuptake inhibitors" ("Let's see, does that mean there's more neurotransmitter in the neuron? Less?"). The moderator helped. But did we get it right? No one was around to check. The producers had neither the time nor the money to edit. The audience got it pretty much the way we said it the first time.

I'm probably being naive, but to a print guy like me, that's absolutely frightening. In the magazine world, we live and die by our fact-checkers. That term is transparent as well: they keep the rest of us honest. They know where to find reliable information. They have a nose for hype and bull. Every line in every story in this magazine gets a fact-checker's scrutiny.

Of course, we still make mistakes. You'll find an especially embarrassing one in our February 2004 issue (see "Letters: Amendment," page 11). We reported in June—on the basis of the most reliable estimates we could find—that 170,000 objects were missing from the Iraq National Museum in Baghdad. That turned out to be hooey. The true number, as Zainab Bahrani carefully explains in this issue ("Lawless in Mesopotamia," page 44), is closer to 15,000. The signal-to-noise ratio, as my friend Dennis Flanagan puts it, is never infinite. But careful fact-checking makes the fidelity pretty high.

I don't mean to say that the difference between care and carelessness is a matter of the media themselves. It's not print vs. video vs. blog. Rather, it's the rhythm of the thing. All news, all the time, breeds rush, confusion, trivialization, addiction to the moment. There is, in contrast, a discipline to a print magazine, just as there is in science: a set of accepted procedures, canons of evidence, rules of inference, a body of common knowledge. Journalism is—or should be—much like science itself. Both seek the facts, and the understanding of the facts that comes with balance and impartiality. Both are—or should be—self-correcting. As Neil deGrasse Tyson notes in his column, "Nebulous Categories" (page 24), astronomers once thought all nebulae were part of our galaxy; now they agree many nebulae are *other* galaxies.

Isn't all this commonplace? But think: Are the facts important in voting for president? In deciding to go to war? In thinking about national priorities as reflected in the budget? If those of us in "the media" abandon professional self-respect and join the blatherers who say whatever comes into their heads, why wouldn't we deserve the cynicism of those who think we just do it for the money? —PETER BROWN

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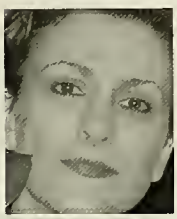
Approached by the Italian Olympic tae kwon do team for the right to use his image of sparring giraffes ("The Natural Moment," page 4) as a uniform logo, LUIZ CLAUDIO MARIGO declined. A native of Brazil, the photographer has exhibited in one-man and group shows in both South America and Europe, and contributed to a number of scientific and wildlife publications.

After her first encounters with the magnificent ruins of such cities as Babylon and Hatra, says ZAINAB BAHRANI ("Lawless in Mesopotamia," page 44), she became fascinated with ancient Mesopotamia. The Iraq National Museum, in her native city of Baghdad, was a favorite haunt of her early youth. When news of the museum's looting first emerged, in April 2003, she was determined to return and help with the rescue effort. Educated in Europe and the United States, Bahrani is now the Edith Porada Associate Professor of Ancient Near East Art History and Archaeology at Columbia University. She is the author of *Women of Babylon: Gender and Representation in Mesopotamia* (Routledge, 2001) and *The Graven Image: Representation in Babylonia and Assyria* (University of Pennsylvania Press, 2003).

MELANIE L.J. STIASSNY ("Saving Nemo," page 50) has spent the past twenty-five years studying the evolution and behavior of tropical fishes and looking for ways to safeguard them and their habitats. She is the Axelrod Research Curator in the American Museum of Natural History's Department of Ichthyology, an adjunct professor at Columbia University, and served as the head curator for AMNH's renovated Hall of Ocean Life. High on her recommended reading list, she says, is *One Fish, Two Fish, Crawfish, Bluefish: The Smithsonian Sustainable Seafood Cookbook,* by Carole C. Baldwin and Julie H. Mounts (Smithsonian Institution Press, 2003), followed by *Song for the Blue Ocean,* by Carl Safina (Henry Holt and Co., 1998).



When the American Geophysical Union devoted several sessions of a meeting last year to exploring the nature of the center of the earth, ROBERT ZIMMERMAN ("Deep Impressions," page 56) was eager to attend. "I love science and the search for knowledge. I also enjoy caving and the exploration of the unknown. This topic seemed to combine all these interests." A freelance science writer based in Beltsville, Maryland, Zimmerman is the author, most recently, of *Leaving Earth: Space Stations, Rival Superpowers, and the Quest for Interplanetary Travel* (Joseph Henry Press, 2003), which describes how cultural changes in both the United States and Russia in the past few decades have affected their national space programs.

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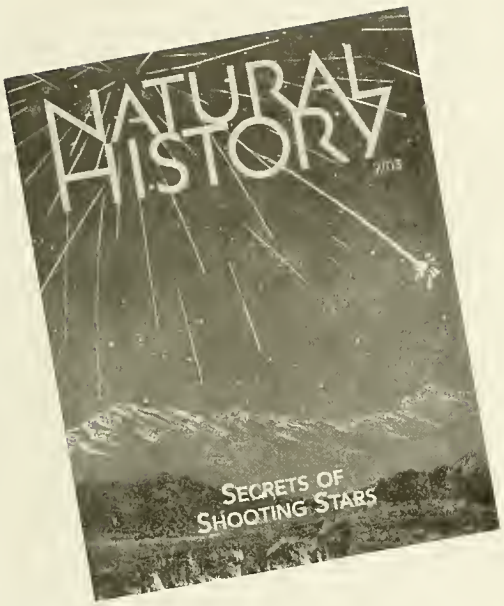

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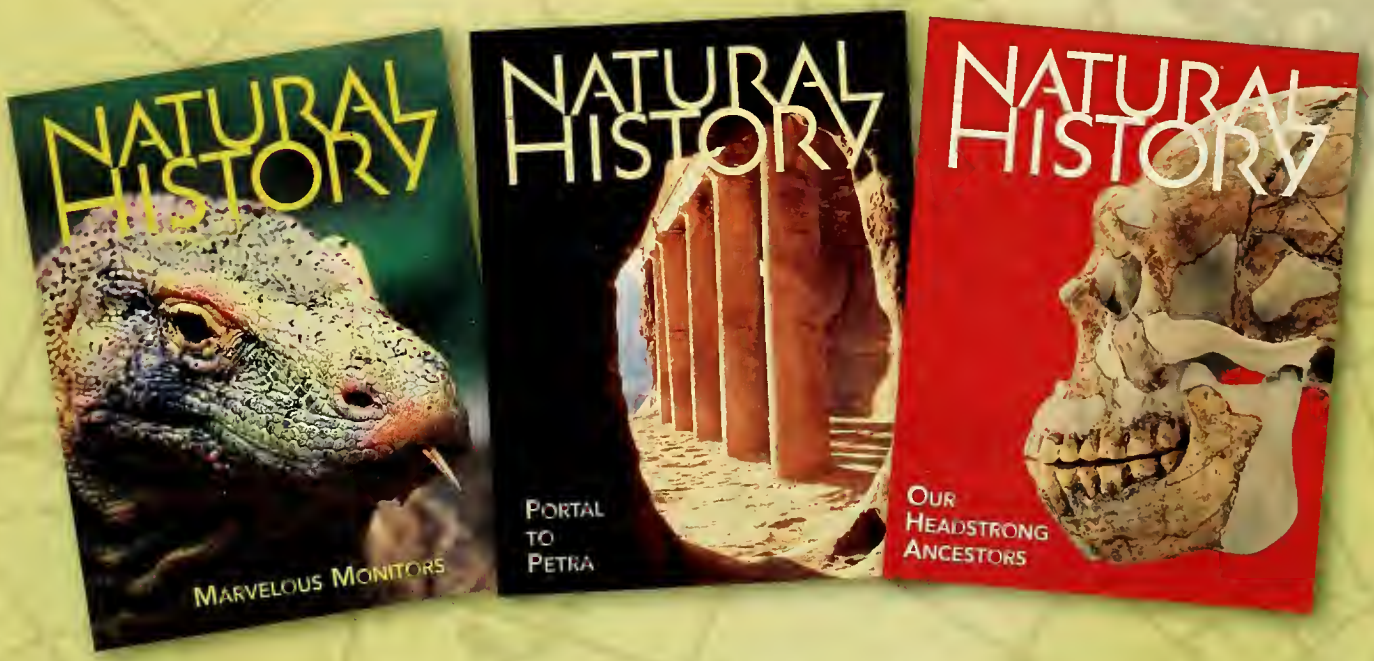

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Whale Watch

Like the whales in the Antarctic ["Good Whale Hunting," by Robert L. Pitman, 12/03-1/04], orcas in the Pacific Northwest also seem to occur as distinct populations: "resident" and "transient." The former subsists on fish, primarily salmon, whereas the latter preys primarily on seals. Could these two be different species as well?
Ken Sweetman
Bend, Oregon

ROBERT L. PITMAN REPLIES: Whale scientists differ on how many species of killer whale inhabit the Pacific Northwest. The evidence is clear from genetic studies and years of systematic field observations that residents and transients do not interbreed, and haven't for a very long time, even though they often occur in the same areas. Many would thus infer that reproductive barriers are already in place, and that the two forms are best regarded as separate species. How the populations are described matters because it can influence the level of protection the animals get under the law.

Monitor Arithmetic

In "The Lizard Kings" [11/03], Samuel S. Sweet and Eric R. Pianka leave us hanging when they write that white-throated monitors "can count up to six." How do we know? And why only to six?
Jeff Orleans
Princeton, New Jersey

SAMUEL S. SWEET AND ERIC R. PIANKA REPLY: We based our statement about monitor counting on recent experiments on captive white-throated monitors *(Varanus albigularis)* by John Phillips, an investigator at the San Diego Zoo. A lizard was fed snails in groups of four. Each snail was placed in a separate compartment connected to three others within a chamber, and the compartments were opened one at a time to allow the monitor to eat the four snails. On finishing the fourth snail, the lizard was allowed into another chamber containing four more snails.

After such conditioning, one snail was removed from some snail quartets. The lizard reacted by searching extensively for the missing fourth snail, even when it was free to move on to the next group. Similar experiments with varying numbers of snails in the groups showed that the monitors can count up to six. With groups larger than six, however, the monitors seemed to stop counting: they merely classified them as "lots," eating them all before moving on to the next chamber. Such an ability to count probably evolved as a consequence of raiding nests of reptiles, birds, and mammals, because the average clutch or litter size is about six.

"Do I want the part? That depends. . . . Am I a majestic relative of the horse or a lion's lunch?"

Throw Backs

In his review of two books about the evolution of bipedalism ["Stand and Deliver," 11/03], Ian Tattersall does not say whether either book addressed this question: How could small, ape-brained hominids have survived leaving the safety of the trees and going bipedal? Here's a theory to add to the others.

Chimpanzees are known to toss branches at predators to try to scare them off. It's not a stretch to imagine that human ancestors adopted the same tactic. As woodland gave way to grassland, objects readily available on the ground, such as sticks, clumps of sod, and stones, would also have been more effective throwing weapons than branches snapped off trees. The ability to aim projectiles is one advantage our ancestors might have enjoyed. And have you ever noticed that baseball pitchers (or javelin and discus throwers) have strong, well-developed legs? They provide a firm launching pad.

So bipedalism may have first rapidly developed not to run fast, or to free the arms for carrying, but to throw objects with force. One rock could startle a beast, and a shower of them, launched by a hominid group, would certainly send it fleeing.
Stephen T. Palmer
Plainfield, New Jersey

IAN TATTERSALL REPLIES: Stephen T. Palmer is not the first to suggest that these small-bodied and otherwise relatively defenseless primates might have discouraged potential predators by throwing objects at them. Such activities might have predisposed them to the hand-eye coordination that later hominids exploited in making the first stone tools. Unfortunately, it's hard to see how one could positively demonstrate which of its potential advantages was the crucial determinant of the success of bipedalism.

The View from Mars

Has anyone ever determined how bright Earth would appear to an observer on Mars, as a morning or evening "star"? Would the Earth appear brighter from Mars than Venus does from Earth?
Fred W. Chesson
Waterbury, Connecticut

JOE RAO REPLIES: The Earth as seen from Mars would closely mimic how we on Earth see the planet Venus, as Fred Chesson suggests. Since Earth is closer in to the Sun than Mars is, Earth would be a brilliant "star" that would appear to follow the Sun down the sky after local sundown or

to lead the Sun above the horizon before local sunrise. In addition, Earth would show phases, just as Venus does as seen from Earth.

This month the Earth rises in the martian morning sky, ahead of the Sun. We would appear as a brilliant bluish-white star of magnitude –2.3, apparently hovering not too far from Venus. An observer on Mars would also be able to see our Moon, if not with the unaided eye, then with slight magnification. On May 8, 2003, the *Mars Global Surveyor* made the first image of the Earth-Moon system as seen from Mars; the result is fuzzy and somewhat humbling (see www.jpl.nasa.gov/releases/2003/75.cfm).

Dubious Species?

In "Evolutionary Anthems" ["Biomechanics," 10/03], Adam Summers reports the work of Jeffrey Podos and his colleagues, which suggests that the songs of Darwin's finches might be responsible for the group's rapid speciation. He counts fourteen species, but by my count that is at least one too high. Two of the putative species, the mangrove and the ground finch, interbreed and produce fertile offspring. By Ernst Mayr's definition, that makes them one species.

Dubious species pervade the world of taxonomy. In particular, songs no more determine finch species than they do human ones. Women who sing in church choirs and men who rap are not members of different species. They might not even ordinarily mate, but they can, so they belong to one species.

Frank Weigert
Wilmington, Delaware

ADAM SUMMERS REPLIES: I would agree with Frank Weigert that where interbreeding occurs, the existence of separate biological species is called into question. In the case of incipient speciation, however, I think it is more interesting to understand the trajectory of the evolutionarily salient units rather than the progress of the biotic isolating mechanisms. Regardless of species, or subspecies, count, I find it fascinating that the song that enables members of a population to recognize one another is ultimately affected by diet. The song can therefore serve as an honest signal, passed along prior to mating, about functional capacities such as the ability to process certain foods.

AMENDMENT: Many readers noticed the continental mix-up, due to an editing error, in Adam Summers's column "Like Water Off a Beetle's Back" (February 2004). The southern tip of Africa is the Cape of Good Hope, not Cape Horn.

Natural History*'s e-mail address is* nhmag@naturalhistorymag.com

Running the Numbers

It's well known among primatologists that the number of males within a group of, say, baboons, chimpanzees, or lemurs is related to the number of females. Patrik Lindenfors, a zoologist at the University of Virginia in Charlottesville, and two colleagues have now identified which sex appears to be in charge of regulating those numbers.

Gathering of the gals

The biologists reanalyzed previously recorded data for a variety of primate species and discovered that females are the vanguard of the revolution: changes in the number of males lag behind changes in the number of females. Female numbers apparently respond directly to such evolutionary pressures as predation, climate, and the availability of food. The females tailor their social relationships accordingly, and the males—if they hope to mate with anybody—must then adjust to the new size of the sisterhood. ("Females drive primate social evolution," *Proceedings of the Royal Society of London* B (Suppl.) 271:S101–S103, February 7, 2004)

—*Caitlin E. Cox*

Sunburn

People generally think of fossil fuels as energy sources, but of course they're also storehouses for some of the prehistoric solar energy it took to grow the plants that eventually gave rise to the fuels. Jeffrey S. Dukes, an ecologist at the University of Massachusetts in Boston, recently calculated how much solar energy went into the process over millions of years, and how little carbon from the original plant material got passed along.

Dukes found that the fossil fuels burned in one year—1997—were derived from more than 400 years' worth of photosynthetically captured energy. And, he says, a gallon of gasoline represents the remains of nearly 200,000 pounds of ancient plant material. ("Burning buried sunshine: Human consumption of ancient solar energy," *Climatic Change* 61:31–44, November 2003) —*C.E.C.*

Hobson's Choice

Conservation usually involves compromises, and not always between nature and people. A case in point is *Urocyon littoralis*, an endangered fox species that lives on the Channel Islands off the coast of southern California. About ten years ago, golden eagles moved in. They fed mostly on feral pigs, but soon started taking many of the unwary, cat-size foxes as well. Now the fox populations are crashing.

But here's the rub: the feral pigs are slated for eradication by the National Park Service. Simulations by Franck Courchamp of the University of Paris-South in Orsay, France, and his colleagues show that the loss of the feral pigs could cause hungry eagles to put even more strain on the few remaining foxes. Hence, to protect an endangered fox species, the golden eagles—a protected, though not endangered, species—are being translocated and, in some cases, killed. ("Removing protected populations to save endangered species," *Science* 302: 1532, November 28, 2003)

Island gray fox, a rare California native

—*Stéphan Reebs*

Clear and Present Danger

When insects munch on plants, some of the munchees call 9-1-1. The way the plants do that is to make chemicals that waft through the air, beckoning to predators. And when the predators arrive on the scene, they grab the plant-eaters for their own dinner. Now Stefano Colazza, an entomologist at the University of Palermo in Italy, and his colleagues have shown that some bean plants don't wait for the munchers to start munching.

Plant-eating insects often start life as eggs deposited on leaves. In the bean plants Colazza studied, just a few leaves covered with a herbivore's eggs cause the entire plant to produce chemical attractants; those signals lure insects that then lay their own eggs inside the eggs of the herbivore. Some trees are known to take similar preventive measures, but they react to damage inflicted to their leaves during egg laying—not, as the bean plants do, to the eggs themselves. ("Insect oviposition induces volatile emission in herbaceous plants that attracts egg parasitoids," *Journal of Experimental Biology* 207:47–53, January 1, 2004) —*S.R.*

How Flies Show Off

Erebomyia exalloptera, a newly discovered species that lives in Arizona, is not your run-of-the-mill fly. It has a thin body and long legs, and one wing of the male fly has a concave edge, making it 6 percent smaller than the other. Two entomologists now suggest the lopsidedness might be traced to female predilections.

Justin B. Runyon of Pennsylvania State University in University Park and Richard L. Hurley of Montana State University in Bozeman report that during courtship, a male in the wild first hovers near a female, then lands behind her and fans his wings.

Females, whose own wings, sensibly enough, are symmetrical, may find lopsided flying in males a sexy bit of derring-do. After all, if—as Runyon and Hurley assume—such flying is difficult, the males may be signaling that their superior genes enable them to live and prosper despite the handicap. ("A new genus of long-legged flies displaying remarkable wing directional asymmetry," *Proceedings of the Royal Society of London* B (Suppl.) 271:S114–16, February 7, 2004) —*S.R.*

Five Easy Pieces

For decades, physicists have been seeking exotic particles, fundamentally different from the particles that make up "ordinary" quark matter. Until last spring, all known assemblages of quarks occurred in twos and threes: the baryons (among them the familiar proton and neutron), made of three quarks; and the mesons (less familiar beasts such as the pion and the rho meson), made of one quark and one antiquark. But in March 2003 a team of physicists announced a new particle species in which five quarks join forces: the pentaquark. Other investigators soon confirmed the discovery. Now, proving the pentaquark was no fluke, another team of physicists, known as the NA49 Collaboration—working at CERN, the European Organization for Nuclear Research near Geneva, Switzerland—has found several new kinds of pentaquarks.

Quarks come in oddly named "flavors," and all the new species include two strange, one anti-up, and either an up or a down quark among the five (the pentaquarks discovered last spring all had two ups, two downs, and one anti-strange). These findings elucidate the deep structure of matter.

Coincidentally, the discoveries of the new affinities quarks have for one another come as physicists at the Brookhaven National Laboratory in Upton, New York, seem close to announcing the ultimate quark "soup"—a so-called quark-gluon plasma—which reproduces, on a small scale, the physical state of cosmic matter during the earliest moments of the big bang. (www.arXiv.org/abs/hep-ph/0401034; www.arXiv.org/abs/hep-ex/0310014)

—*Joomi Kim*

Cryptic Creatures

Only three of these pictures are close-ups of the same animal. Which one doesn't belong?

(Answer on page 71)

Smoke Signals

According to one account, what finally led to the demise of dinosaurs were global wildfires, triggered by the huge heat blast of a six-mile-wide meteorite that struck Earth near the Yucatán Peninsula 65 million years ago. In that scenario, the fires simply barbecued the hapless dinos, and much else besides. Indeed, 65-million-year-old sediment layers from many sites across the planet include an unusual amount of soot.

Claire M. Belcher, a geologist at the Royal Holloway University of London, and her colleagues, however, raise doubts about the global inferno. The huge fires, they assert, should also have left plenty of charcoal in the sediments. But the amount of charred material they found in the relevant layers of sedimentary rocks from five North American sites, in areas known not to have been covered by water at the time, was so small that it falls far short of what episodic local fires would have left.

Belcher's team proposes instead that the worldwide soot might have been dropped by strong winds whipped up by a large fire that burned in a limited area. Alternatively, the soot might have come from the vaporization of oil deposits at the site of the meteorite impact. Either way, *T. rex* and its compadres could have been done in by airborne particles that blocked the Sun's essential light and heat—but not been cooked alive. ("Fireball passes and nothing burns—The role of thermal radiation in the Cretaceous-Tertiary event: Evidence from the charcoal record of North America," *Geology* 31:1061–64, December 2003) —*S.R.*

("Samplings" continues on page 23)

New Brunswick

Today I left my footprints on the ocean floor... Tomorrow I'll open the door to a world of natural wonder next door in New Brunswick, Canada!

You're welcome here...beneath the towering flowerpot rocks, carved by the world's highest tides. In the wake of awesome Natural Wonder, you'll find New Brunswick's Bay of Fundy, **One of the Marine Wonders of the World**. A place where you can **walk on the ocean floor** and only hours later, kayak above the very same spot. Incredible Natural Wonders... it's just another day on New Brunswick's Bay of Fundy!

Over 300 bird species cross New Brunswick's skies. Visit the Bay of Fundy's Grand Manan Archipelago (one of Thayer's Top 100 Birding Hot Spots) or Miscou Island's spectacular coast. **Some of the best whale-watching** on Canada's East Coast happens right here in the nutrient-rich waters of the Bay of Fundy! You can see so many different species... Minkes, Finbacks, Humpbacks, Blues, even the very rare Right whale and more!

"We'll let endless rivers be our roads and let wonder flow from the soul."

The St. John River reaches from the Bay of Fundy up beyond the **breathtaking Grand Falls Gorge** and into the heart of the province. The **legendary Miramichi** calls fly fishers from around the world to its salmon-fishing paradise. And the beautiful St. Croix, Kedgwick and Restigouche rivers let you canoe for endless days along spectacular, unspoiled wilderness. That's just the start of river life as lived in New Brunswick!

"An afternoon so pleasantly lost amid the dunes finding yourself among a sifting sandy treasure."

Visit the preserved beauty of the Irving Eco-Centre, La Dune de Bouctouche. Here the boardwalk brings you close to the botany and biology of **one of the last sand dunes** on the northeastern coast of the continent. Rare plants can bloom. Even more rare birds can nest in the security of this eco-treasure.

you'll be awed by its **untouched vastness**. Canoe the lakes and rivers that the mountains frame. Hike endless trails that take you to lookouts and views that are something more than breathtaking...they are inspiring.

"It's all waiting... next door, in New Brunswick, Canada"

From the phenomenal Fundy Tides to the vastness of nature that reaches into your soul... you've been awestruck by these amazing Natural Wonders but there's so much more to experience and explore throughout New Brunswick!

Take a province-wide tour of our **incredible attractions...** see the longest covered bridge in the world, enjoy the dinner theatre at the Village Historique Acadien and more! Visit our Hometowns and spin a yarn with local storytellers, shop for unique local crafts like pottery or discover the therapeutic nature of handmade soap!

Freshly caught lobster, king-size Atlantic salmon and more... all cooked in unique local **seafood** recipes or just the way you like it! And after a wonder-filled day is through, relax at a **spa** or spend a night tucked away at a luxurious downtown hotel, château, a **seaside resort**, or near the fireplace of the cosiest B&Bs! There are not many places where you can find world-class cities with so much to offer, so close to incredible Natural Wonders!

Opposite page: top: The Hopewell Rocks, Hopewell Cape; left: Atlantic Puffin; this page: above: Mt. Carlton; below left: Grand Falls Gorge, Grand Falls/Grand-Sault; below right: Ecological Park of the Acadian Peninsula. Laméque.

"Inspiration will come... with the wisdom of stones that were here when the stars were born."

Rising majestically along the west side of the province toward Chaleur Bay, the Appalachians are a mantle of wondrous natural beauty. These are **some of the oldest mountains** on the planet and are spectacular to tour year-round!

In exploring New Brunswick's Appalachian Range,

It's a world of Natural Wonder... it's all here, next door... in New Brunswick, Canada!
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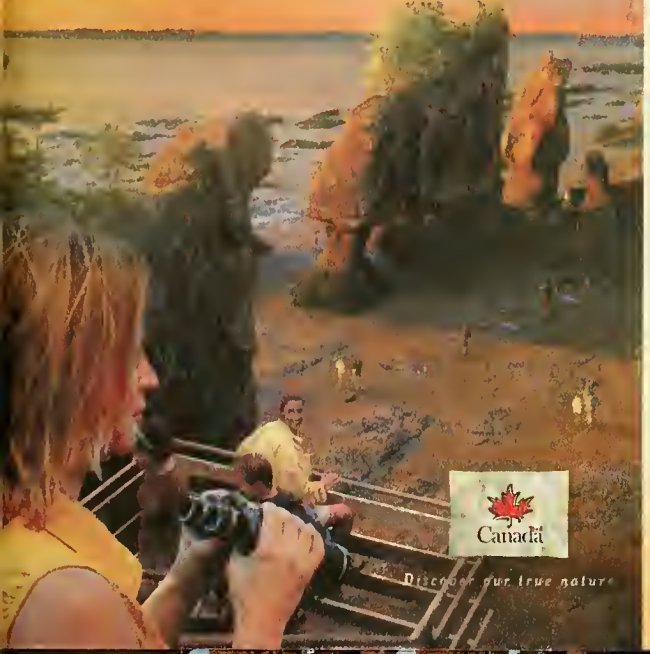
Grande-Anse

The French Flavour of Our Acadian Culture!

City of Edmundston

Restaurants, Bistros and the Best in Nightlife!

Today I left my *footprints* on the ocean floor...



Tomorrow, I'll open the door to a world of Natural Wonder!

From the world's highest tides to whales, wildlife, endless beaches, dunes, and some of the oldest mountains on the planet... there's a world of wonder waiting for you next door in New Brunswick, Canada! **Fill in and mail this reply card to receive your FREE Vacation Planning Kit!**

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Address: _____

_____ **Apt#:** _____

City: _____

State: _____ **Zip Code:** _____

Telephone: (____) _____

E-mail: _____

❑ Yes, you may contact me in the future about travel to New Brunswick, Canada.

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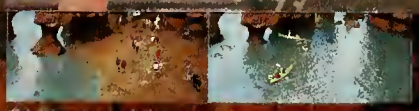
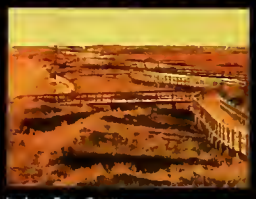
Grand Falls Gorge, Grand Falls/Grand-Sault



Tide times vary daily. The Hopewell Rocks, Hopewell Cape

In the wake of incredible Natural Wonder, you'll find New Brunswick's **Bay of Fundy, One of the Marine Wonders of the World.** A place where you can walk on the ocean floor and only hours later, kayak above the very same spot. More wonders await you on awesome **rivers that stretch from breathtaking to beautiful.** Spend an afternoon amid **one of the last great sand dunes on the northeastern coast of the continent.** Or find new inspiration atop the Appalachians... **some of the oldest mountains on the planet.** From the unique flavour of Hometowns and cities to a lobster dinner in the intimacy of a seaside inn... it's a world of Natural Wonder... **it's here, next door... in New Brunswick, Canada!**



Irving Eco-Centre, La Dune de Bouctouche

1604 - 2004

In 2004, New Brunswick will celebrate the 400th anniversary of the first French settlement in North America, which occurred on St. Croix Island.

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Bermuda

Bermuda is famous for its pink sand beaches, lush gardens, and perfect weather—but birders in the know actually come to this gorgeous subtropical island for world-class birding. After a morning relaxing on a sun-kissed beach, spend the rest of the day observing the island's colorful combination of native species and migrating visitors.

Be prepared to spot a wide variety of birds—360 species have been recorded in this 21-square-mile paradise. Before you go, print out a Bermuda Birding Life List from www.bermudatourism.com/pdf/birding_list.pdf.

The bright, lemon yellow great kiskadee, found in abundance, was introduced in the 1950s and is both easy to spot and easy to hear. Listen for the loud and distinctive *kis-ka-dee* call that gave this raucous member of the flycatcher family, now a year-round resident, its descriptive name. You'll find the kiskadee everywhere along the island—in trees and shrubs or diving for fish. A trip out to the ocean is more than worthwhile. You will find four species of shearwater: great, Cory's, sooty, and manx. You may also observe jaegers, terns, and petrels as they make their long ocean journey and be rewarded with views of flying fish and the occasional humpback whale.

You'll also find excellent birding at Bermuda's numerous nature reserves and preserved green spaces, which will one day form an "emerald necklace" around the island. Last December the National Trust opened a new walking trail along Warwick Pond, an important sanctuary for resident and migratory waterfowl, with interpretive panels that inform visitors about the significance of the pond and the surrounding wood and farm land. This space, which had been essentially inaccessible to the public, has the largest allspice trees in Bermuda as well as a large number of Bermuda cedars, and the trail is a good looking-out point from which to explore the island's habitat and bird life.

With world-class resorts and charming bed-and-breakfasts with private gardens, sumptuous meals, turquoise waters, excellent snorkeling and scuba diving, and a host of other attractions, it's not surprising that visitors come back to Bermuda year after year!

Clockwise from top left: path to the beach; riding on the dunes; world-class scuba diving; the island's favorite sport, cricket.

West Virginia

Photos: West Virginia Division of Tourism

Top left: Cardinals in snow; above: Blackwater Falls.

In Wild and Wonderful West Virginia, nature is always nearby. With 1.6 million acres of public lands and 316 species of birds, the state is a haven for birds and birders alike. Sprawling Monongahela National Forest, encompassing almost a million acres, is home to 230 species of birds, including warblers, a variety of migratory hawks, and songbirds. Monongahela includes Cranberry Glades, where you'll find Swainson's and hermit thrushes, mourning warbler, northern waterthrush, and swamp sparrow. Watoga State Park, in the southern part of the Monongahela, shelters a variety of wetland birds, including American woodcocks, wood ducks, and waterthrushes. Don't miss the Hanging Rock Raptor Observatory, a monitoring point for hawk, eagle, falcon, and osprey migration. Check out other top birding locations at www.birding.com/wheretobird/WestVirginia.asp.

For a break from birding, visit the 1850s town of Harpers Ferry or the state's capital city, Charleston, famous for its historic houses. If the Great Outdoors is more to your liking, hook some trout in a clear stream, or thrill to some of the best whitewater rafting east of the Colorado. You'll find it all in West Virginia.

Take in the view from our mountains and gain a whole new perspective.
Watch history and nature come alive in West Virginia, Wild and Wonderful.

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Newfoundland & Labrador

Millions of birds. No zoom lens required.

Gannets, murres, kittiwakes. Storm-petrels, ospreys, gulls. Razorbills, ravens and "foxy toms." More than 350 species of birds. Newfoundland and Labrador is the seabird capital of North America. Quite likely the best place in the world to view them up close in their natural habitat. Very close. More than 95 percent of all seabirds that congregate here gather in approachable protected reserves — some 9.5 million pairs. Nowhere else are the cacophonous sounds and colorful personalities of these marine creatures so accessible.

At Witless Bay Ecological Reserve — a short drive from St. John's — board a boat, don your hat, and look up. Our provincial bird, the puffin, nests here in staggering numbers. Newfoundland and Labrador is the true home of the Atlantic puffin; over 90 percent of the continent's entire population lives here. These stout, wobbly little "sea parrots" are amazing swimmers and fishers. Knowledgeable boat-tour operators can point out where the puffins burrow into the soft earth, creating thousands of nesting holes.

Go inland to see falcons and hawks, boreal owls, and the place where the eagle has landed. The province is home to one of the largest American bald eagle populations in North America.

Cape St. Mary's Ecological Reserve, an award winning destination, is the most accessible seabird colony in the western hemisphere. Here the gannet population is so tightly clustered you wonder if they'll land on each other. But they're too graceful for that. Hoping to see a Leach's storm-petrel?

Birds by the millions, and so close. Rare and common, with flights arriving daily. A place truly for the birds.

Top left: A flying blizzard descends on these cliffs every year; top right: Newfoundland and Labrador have some of the world's most accessible seabird sanctuaries; below left: The grace of the gannet in flight; below right: The Atlantic puffin, more adept in water than in flight.

The most easterly point in North America, Cape Spear National Historic Site.

At the edge of the western world, there's a place where the day dawns first.

Of all the sunrises in North America, this is the first. The yawn and stretch of a new day. Here, you can see the oldest lighthouse in Newfoundland and Labrador live life on the edge, as it has for 160 years. In the far east of the western world.

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Little St. Simons Island

Photos: Keith Whittington

Above: fallow deer; right: the Lodge; bottom right: canoeing on a creek.

Virtually untouched for centuries, Little St. Simons is a private 10,000-acre barrier island along the Georgia coast. Pristine beaches, maritime forests, shimmering marshes, and tidal creeks await your exploration.

Accessible only by boat, the island provides a natural habitat for a diverse community of wildlife including alligators, fallow deer, dolphins, river otters, and armadillos. Located along the Atlantic Flyway, Little St. Simons is one of the best locations for birding on the Georgia coast, with over 280 species of birds. Shorebirds are especially abundant, drawn by large areas of intertidal flats and sandbars. The island also attracts a variety of wading birds such as herons and egrets and many songbirds. The prime seasons for migratory species are mid-April through early May and mid-September through mid-October.

Make your reservation now for the Spring Birding Week (April 10–17, 2004) and witness the migration of hundreds of species. Naturalists' guided tours and evening presentations will be offered.

The Lodge on Little St. Simons Island accommodates just 30 guests, who will be treated to three bountiful meals each day. Fifteen guestrooms are arranged in five charming cottages dating back to 1917.

George Gardner

 (Continued from page 13)

Going to Great Lengths

Here's one for the *Guinness Book of World Records*, in the yet-to-be-created category of "longest body-part extension": small clams that stretch their single foot out to thirty times the length of their shell.

Some species of clams in the family Thyasiridae live symbiotically with sulfur-loving bacteria: the bacteria, which live on the clams' gills, get sulfide from the clams, and the clams, in turn, feed on the bacteria. But because the clams need oxygen, they can't survive deep in the sediment, where the sulfide is most abundant. Instead, they live near the surface of the sediment and extend their foot down to "mine" the sulfide below.

Suzanne C. Dufour and Horst Felbeck, both of the Scripps Institution of Oceanography in La Jolla, California, raised both symbiotic and nonsymbiotic species of thyasirids in thin aquariums, so that they could make two-dimensional X rays of the burrows dug by the clams. The symbiotic species dug downward; the nonsymbiotic species did not. And when the investigators cut back on the sulfide, the symbiotic clams dug extra deep. One tunnel was five and a half inches long, made by a clam whose shell measured less than two-tenths of an inch—a new record, relative to body size. ("Sulphide mining by the superextensile foot of symbiotic thyasirid bivalves," *Nature* 426:65–67, November 6, 2003) —*S.R.*

French School, 300th Century B.C.

About 140 miles southwest of what is now the city of Paris—and more than 32,000 years before Picasso noticed the resemblance between an upside-down bicycle seat and the head of a bull—an observant Neanderthal passing time in a cave beside the Loire River noticed some similarities between a certain chunk of flint and the face of a mammal. But this Paleolithic Picasso, endowed with a seemingly modern sensibility, didn't leave it at that: the incipient sculptor turned it into something more complex.

Face in the flint?

Jean-Claude Marquet, an archaeologist and the curator of the Museum of Prehistory of Grand-Pressigny in Saint-Avertin, France, discovered the palm-size object, side by side with Mousterian tools, in an obviously undisturbed layer of coarse sand about eight feet underground. He and his colleague Michel Lorblanchet of the National Center of Scientific Research in Saint-Sozy, France, have found strong evidence that the flint was substantially altered by hominid hands.

Flakes were intentionally chipped off around the periphery. A bone splinter was pushed into a naturally occurring "tube" that runs behind, and perpendicular to, a rocky bridge shaped something like a nose. And two little flint pegs were jammed between the bone and the large chunk of flint, causing the bone to remain solidly in place—and thus to resemble two eyelids in eye sockets beneath the double arch of a brow ridge. The archaeologists contend that the object ranks among the half-dozen earliest manifestations of the impulse to make art. ("A Neanderthal face? The proto-figurine from La Roche-Cotard, Langeais (Indre-et-Loire, France)," *Antiquity* 77:661–70, December 2003)

—*Avis Lang*

Green Means Go

If moviemakers ever need a new insect to star as, say, a living traffic light in a sequel to *Antz* or *A Bug's Life*, they could do worse than to cast the Jamaican click beetle. Unique among bioluminescent animals, *Pyrophorus plagiophthalamus* emits light of different colors from different organs: a pair on its back (yellow-green to green light) and a loner on its belly (yellow-green to orange).

Uwe Stolz, a biologist formerly at the University of Notre Dame in Indiana, and his colleagues have established which gene the click beetle's belly organ activates to make luciferase, the enzyme involved in biological light emission. They've also found that evolutionary changes in key amino acids in the luciferase have translated into a shift toward orange. What's driving the changes? Sexual selection, perhaps.

Click beetle signaling her receptivity

Flying overhead during mating season, the males switch on their belly lights; down in the brush, females that find the lights attractive respond with their back lights. These days, guys that flash orange may be getting the green light more often than those that flash old-fashioned yellow-green. ("Darwinian natural selection for orange bioluminescent color in a Jamaican click beetle," *Proceedings of the National Academy of Sciences* 100:14955–59, December 9, 2003) —*S.R.*

Nebulous Categories

The many species of galaxies turn out to be close kin.

By Neil deGrasse Tyson

Spiral galaxy NGC 1232

Two and a half centuries ago, before the English astronomer Sir William Herschel built the world's first seriously large telescope, the known universe was little more than the stars, the planets, the Sun and Moon, and the Galaxy, forming a milky band across the night sky. Indeed, the word "galaxy" derives from the Greek *galaktos*, or milk. The sky also held the nebulae—fuzzy, indeterminate objects such as the Andromeda nebula, which lives among the stars of the constellation Andromeda.

Herschel's telescope was forty-eight inches across, an unprecedented size in 1789, the year it was built. It was an ungainly instrument, but when he aimed it at the heavens, Herschel could readily see the countless stars that make up the Milky Way. Using his forty-eight-incher as well as a smaller, more nimble telescope, Herschel and his sister Caroline compiled the first extensive "deep sky" catalog of northern nebulae. Sir John—Herschel's son—continued the family tradition, adding to his father and aunt's list of northern objects and, during an extended stay at the Cape of Good Hope at the southern tip of Africa, cataloging some 1,700 fuzzy objects visible from the Southern Hemisphere. In 1864 Sir John produced a synthesis of the more than 5,000 known deep-sky objects: *A General Catalogue of Nebulae and Clusters of Stars*.

In spite of that large body of data, nobody at the time knew the true identity of the nebulae, their distances from Earth, or the differences among them. Nevertheless, the massive 1864 catalog made it possible to classify the nebulae morphologically—that is, according to shape. In the "we call 'em as we see 'em" tradition of both umpires and astronomers, the spiral-shaped nebulae were called spiral nebulae, those with a vaguely elliptical shape were called elliptical nebulae, and the various irregularly shaped nebulae—neither spiral nor elliptical—were called irregular nebulae. Finally, nebulae that looked small and round, like a telescope's view of the planets, were called planetary nebulae, thus permanently confusing newcomers to the subject.

For most of its history, astronomy has remained plainspoken and has employed descriptive methods of inquiry that greatly resembled the ones used in botany. From the ever-lengthening compendiums of stars and fuzzy things, astronomers searched for patterns and sorted objects accordingly. It's a sensible approach: most people, beginning in childhood, arrange things according to appearance and shape without even being told to do so. But it can carry you only so far. The Herschels always assumed, because many of their fuzzy objects span a patch of about the same size on the night sky, that all the nebulae lay at about the same distance from Earth. So to them it was simply good, even-handed science to subject all the nebulae to the same rules of sorting.

Trouble is, the assumption that all nebulae lay at similar distances turned out to be badly mistaken. Nature can be elusive, even devious. Some of the nebulae classified by the Herschels are no farther away than the stars, and so they are relatively small (if a trillion miles across can be called "relatively small"). Others turn out to be much more distant, and so, to appear the same size on the sky, they've got to be much larger than the fuzzy objects nearby.

The take-home lesson is that at some point you've got to stop fixating on what something looks like and start asking what it is. Fortunately, by the late nineteenth century, advances in science and technology had empowered astronomers to do just that: to move beyond merely classifying the contents of the universe. That shift led to the birth of astrophysics.

Just about the time Sir John Herschel published his vast catalog, a new scientific instrument, the spectroscope, joined the search for nebulae. The sole job of a spectroscope is to break light into a rainbow of its component colors. The fine details in that color spectrum hold information about not only the chemical composition of the light source but also, because of a phenom-

We found our best watch in a history book

In 1922, a small watchmaker in Switzerland patented the first automatic watch to display the day, month and date. Only 7 of these magnificent timepieces were ever made and this watch was almost lost to history. Today, they are so rare that one original chronograph watch would probably fetch more than $300,000 at auction.

These watches were among the most stylish of the roaring 20's. And yet no one has attempted to remake this 1922 classic until now. The Stauer watch design that you see here has been painstakingly recreated from the original functions to please even the most discerning owner. The owner of this classic chronograph watch is sure to look distinguished and set apart from the crowd. From the sweeping second hand to the Roman numerals on the unique ivory-colored face, every detail has been carefully reproduced. This Stauer reissue is a limited series, allowing you to wear a watch far more exclusive than many Rolex, Movado, TAG Heuer or Breitling watches.

The watch has a 21-jewel mechanical movement, the kind desired by fine watch collectors. We have updated this movement with kinetic power thus the watch never needs to be manually wound. The watch comes in a beautiful case and comes with both interchangeable black and brown leather bands.

This is a chance to claim a piece of watchmaking history in an elegant design that is still priced to wear every day. This offer is being made directly to you so you can add this watch to your collection at a very affordable price. The watch comes with a 30-day no questions asked money-back guarantee. If you're not completely satisfied, simply return it for a full refund of the purchase price.

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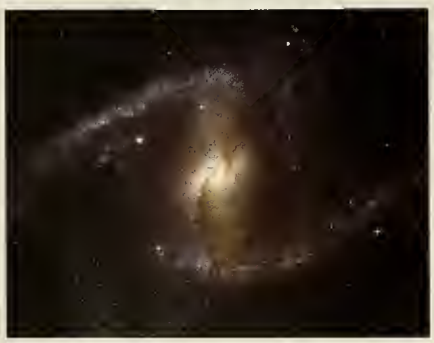
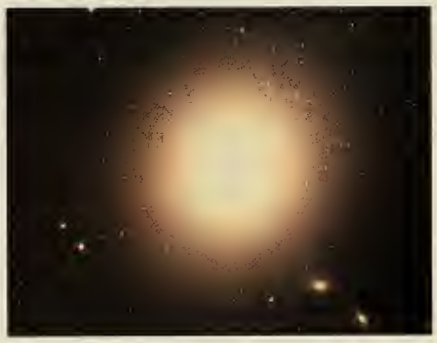
enon called the Doppler effect, the motion of the light source toward or away from Earth.

Spectroscopy showed that nearly all the spiral nebulae, a shape that happens to predominate outside the swath of the Milky Way, are moving away from Earth, and at very high speeds. In contrast, it showed that all planetary and most irregular nebulae are traveling at very low speeds—some toward us and some away from us. Had some catastrophic explosion taken place in the center of the Milky Way, kicking out only the spiral nebulae? If so, why weren't any of them falling back? The conundrum persisted, even though advances in photography brought forth faster emulsions, enabling astronomers to measure the spectra of ever dimmer nebulae.

By the 1920s, however, another key instrument had appeared on the scene: the formidable 100-inch Hooker Telescope at the Mount Wilson Observatory near Los Angeles. In 1923 the



Barred spiral galaxy NGC 1365



Elliptical galaxy M87

American astronomer Edwin P. Hubble, using this telescope—the largest in the world at that time—discovered a special breed of star, a Cepheid variable, in the Andromeda nebula. Variable stars of any species vary in brightness according to well-known patterns; the Cepheid variables are extremely luminous and therefore visible over vast distances. Hubble knew the distances to a few of them within the Milky Way, yet to his astonishment, the Cepheid he saw in Andromeda was much dimmer than any of them.

The most likely explanation for the dimness was that the new Cepheid, and thus the nebula in which it lived, was much farther away than the Cepheids in the Milky Way. Hubble realized that the Andromeda nebula was so far away it could not possibly lie among the stars in the Milky Way—and could not have been kicked out, along with all its spiral sisters, during a catastrophic milk-spill.

The implications were breathtaking. Hubble's discovery showed that spiral nebulae are entire systems of stars in their own right, as huge and as packed with stars as our own Milky Way. In the words of the nineteenth-century German naturalist Alexander von Humboldt, countless "island universes" lie beyond our own galaxy. The Andromeda nebula was, in fact, the Andromeda galaxy.

By 1936, enough "island universes" had been identified and photographed through the Hooker and other big telescopes that Hubble, too, decided to try his hand at morphology. In his book *Realm of the Nebulae,* he based his classifications on the untested assumption that variations from one shape to another signify evolutionary steps from birth to death. The book includes a now-famous diagram shaped like a tuning fork, whose handle represents the so-called elliptical galaxies; rounded ellipticals are at the end of the handle, and more flattened ellipticals toward the two tines. Along one tine are ordinary spiral galaxies; those nearest the handle have very tightly wound arms, and those toward the end are increasingly open. Along the other tine are spiral galaxies whose central region displays a straight "bar" but that are otherwise similar to ordinary spirals.

Hubble imagined that galaxies start life as round ellipticals and become flatter and flatter as they continue to take shape, ultimately acquiring a spiral structure that slowly unfurls with the passage of time. Brilliant. Beautiful. Even elegant. But just plain wrong. Not only were entire classes of irregular galaxies omitted from this scheme, but astrophysicists would later learn that the oldest stars in every galaxy are about the same age, implying that all the galaxies were born during a single era in the history of the universe.

Come the 1960s, an American astronomer named Halton C. Arp became the champion of galaxies that did not fit the simple Hubble classification scheme. In the spirit of "Give me your tired, your poor, your huddled masses," Arp photographed 338 disturbed-looking systems through the 200-inch Hale Telescope at the Palomar Observatory near San Diego, California. The resulting *Atlas of Peculiar Galaxies,* published in 1966, became a treasure chest of research opportunities on what can go wrong in the universe.

It turns out that many embarrassingly irregular galaxies in Arp's atlas are the merged remnants of two once-separate galaxies that have collided [*see photograph on opposite page*]. And so most of those "peculiar" galaxies are not different kinds of galaxies at all—any more than a wrecked Lexus is a new kind of car.

To track how a galaxy collision unfolds, you need a lot more than pencil and paper, because every star in both galaxies has its own gravity, which simultaneously affects all the other stars in the two systems. What you need, in short, is a computer. Galaxy collisions are stately dramas, taking hundreds of millions of years from beginning to end. Using a computer simulation you can start, and then pause, a collision after 10 million years, 50 million years, 100 million years. At each point, things look different. And when you step into Arp's

atlas—batta-bing!—here's an early stage of a collision and there's a late stage, here's a glancing blow and there's a head-on collision.

Although the first computer simulations were done in the early 1960s—and although there was a surpassingly clever attempt by the Swedish astronomer Erik Holmberg in 1941 to recreate a galaxy collision on a tabletop, with light as an analogue to gravity—it wasn't until 1972 that Alar and Juri Toomre, brothers who both teach at the Massachusetts Institute of Technology, generated the first compelling portrait of a "deliberately simple-minded" collision between two spiral galaxies. The Toomres' model revealed that tidal forces are what actually rip up the galaxies. As one galaxy nears the other, the gravity gets rapidly stronger at the leading edges of the collision, stretching and warping both galaxies as they pass through each other. Those distortions account for most of what's peculiar in Arp's atlas of peculiar galaxies.

How else can computer simulations help? Hubble's tuning fork distinguishes "normal" spiral galaxies from spirals that show a bar across the center. Simulations show that the bar could be transitory, not the distinguishing feature of a different species: contemporary observers of barred spirals might just be catching such galaxies in a phase that will disappear in 100 million years or so. But since we can't hang around long enough to watch the bar disappear in real life, we have to watch it come and go on a computer, where a billion years can unfold in a matter of minutes.

Astronomers in the 1960s and 1970s also began to use telescopes equipped with detectors that were sensitive to invisible bands of light, such as radio waves and X rays. The portrait of a galaxy could thus include information about its appearance in these other bands of the electromagnetic spectrum. Combining the new spectral bands with even better photographic emulsions revealed a zoo of new galaxy species in the depths of space. Most remarkable among them were objects that, in photographs, look like simple stars, but give off radio waves of extraordinary intensities. The working description for those objects was "quasistellar radio source," which quickly became "quasar" for short. Even more remarkable than their

Antennae galaxies colliding

radio emissions were their distances—as a class, they're the most distant objects in the universe. For quasars to be that small and that visible, yet that far away, meant they had to be an entirely new kind of object. How small? No bigger than the solar system. How luminous? Even the dim ones outshine most galaxies.

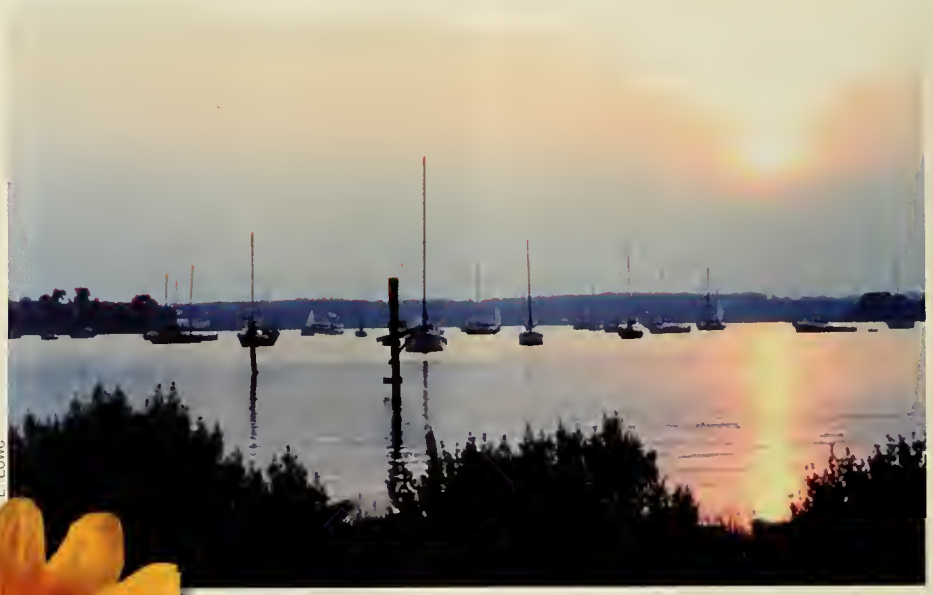
By the early 1970s astrophysicists had converged on an answer to the mystery of quasars: a supermassive black hole lurks at the heart of each one, gravitationally devouring everything in its grasp. Even though the big black holes measure as little as ten light-hours across, they are millions of times the mass of the Sun and wreak havoc on their immediate environment. Gas clouds that funnel into the maw of the black hole typically slam into the swirling gas clouds just ahead of them. These stretched and shredded clouds form a rotating "accretion disk" that slowly feeds the hole at its center. The disk is an engine that spews forth titanic jets, or streams, of matter and energy that punch their way through the cyclone of incoming matter, escaping above and below the disk itself.

The black hole model accounted for how small and bright the quasar is, but

(Continued on page 37)

MARYLAND

From the Appalachian Mountains to the Chesapeake Bay, from the Potomac and Patuxent Rivers to the Atlantic Ocean, the beautiful state of Maryland boasts a vast assortment of outdoor activities, unique attractions, and historical landmarks. In addition to its most famous cities, Baltimore and Annapolis, Maryland offers a wealth of diversity in its geography and attractions. You can take a driving tour along Maryland's Civil War trails—there are more than sixty Civil War sites here—a sailing trip to view Chesapeake Bay lighthouses, an outing to a local pasture where some of the state's famed thoroughbreds graze, or tour the world's oldest continuously operating airport, the College Park Aviation Museum.



E. Lowe

Above: Life on the water in southern Maryland; left: Black-eyed Susan, the State Flower of Maryland; below: Baltimore Oriole, the State Bird of Maryland

If you are interested in the Great Outdoors, start your Maryland exploration in the Western Region, where you'll find rugged mountains, crashing waterfalls, and a piece of the Appalachian Trail. This is also Deep Creek Lake country, home to the largest lake in Maryland, famous for its boating and fishing. In the Capital Region, adjacent to Washington, D.C., you can experience three centuries of Maryland history and American life, from the earliest colonists to the pioneers in space flight. Here, you can visit the homes of Francis Scott Key or Elizabeth Ann Seton, the first American saint, then learn about space travel at NASA Goddard Space Flight Center.

Maryland's Southern Region boasts historical sites dating back to prehistoric times. Here along the Atlantic Coastal Plain—where many people still farm, or fish from the waters of the Chesapeake Bay and the Potomac and Patuxent—you can learn about the life of Native Americans before European contact. The Central Region offers vineyards, immaculate public gardens, and Baltimore's Inner Harbor.

Kevin Karlson

What's new in Baltimore, Maryland's largest city? Visit the brand-new Frederick Douglass-Isaac Myers Maritime Park (1414 Thames Street), one of the city's most historic waterfront properties and a national cultural center dedicated to African-American maritime history. The facility's centerpiece is a working shipyard, reminiscent of the first black-owned marine railway and shipyard in the country. The site honors Isaac Myers, the shipyard's owner, as well as Frederick Douglass, an escaped slave who worked as an abolitionist.

Don't leave Maryland without a stay in the beautiful Eastern Shore, with its abundance of creek to bay fishing, quiet country roads, and beaches. This is the best place to enjoy a succulent, super-fresh dinner of Maryland's famous crabs, to explore a fragile Chesapeake marsh, or simply to sit back and enjoy the scenery.

Even The Fun Is Authentic.

A perfect day for sailing the Chesapeake.

We feasted our eyes on the sea life at the National Aquarium in Baltimore

Good thing we brought the roof rack!

And feasted on seafood at a bayside restaurant.

We followed a day of antiquing with a night on the town in historic Annapolis.

The lighthouse keeper spun us a yarn...

...while the kids got acquainted with his black lab, "Scout."

Robert L. Ehrlich, Jr., Governor
Michael S. Steele, Lt. Governor

Maryland
Welcome

Visit www.MDwelcome.org
or Call 1-800-984-9502

For a free vacation guide and travel card, good for tons of hot deals.

ANNAPOLIS/ANNE ARUNDEL COUNTY

Anne Arundel County, Maryland, is home to so many of the Mid-Atlantic region's most visited attractions. Historic Annapolis, Maryland's capital, charms visitors with its maritime heritage, African-American heritage, and charming historic homes. Travel south of Annapolis to Historic London Town & Gardens and see public archaeological digs and a natural shade garden that includes an artful combination of native and exotic plants. Continue your tour of south Anne Arundel County with the new audio travelogue, *Roots & Tides, a Journey Through Southern Anne Arundel County*. The CD and accompanying map take listeners past old tobacco farms and 18th-century mansions though the picturesque watermen's villages of Deale, Shady Side, and Galesville. Historians, archaeologists, musicians, and local residents tell the story of this unique slice of the Chesapeake Bay shoreline.

City Dock and State House

For more information or to request a free visitors' guide to Anne Arundel County, call 410-280-0445, ext. 10, or visit www.visitannapolis.org.

CALVERT COUNTY

Top: Barns; bottom: Cove Point Lighthouse

Calvert County, a short drive from Washington, D.C., is a place where time really does move a little more slowly. See the majestic Calvert Cliffs with their treasure of prehistoric fossils. Experience Battle Creek Cypress Swamp Sanctuary, America's northernmost stand of bald cypress trees. Explore the heritage and agricultural history of Southern Maryland at Jefferson Patterson Park and Museum. Cruise around Solomons Harbor on a sightseeing boat or visit the Calvert Marine Museum. Climb up the stairway to the Drum Point Lighthouse or take a shuttle to see the Cove Point Lighthouse. Calvert is Maryland's sportfishing capital, with the largest fleet of charter boats in the state.

Enjoy the Chesapeake Bay lifestyle and discover a place where there are still places to discover.

CHARLES COUNTY

Less than an hour from Washington, D.C., Charles County is a haven for nature lovers and history buffs on southern Maryland's coastal plain. Enjoy first-class fishing, 150 miles of spectacular shoreline, beautiful forests, lakes, ponds, and extensive wetlands.

DORCHESTER COUNTY

The county's abundant undeveloped areas support a dense population of bald eagles and 321 other bird species. Every spring for the past fifty years, nearly 1,500 great blue herons nest in the treetops of Nanjemoy Creek Great Blue Heron Sanctuary. This creek, popular with fishermen, also is a good spot to sight ospreys and bald eagles. Birds are also seen at Chicamuxen Wildlife Management Area and Cobb Island, a popular spot for fishing and boating.

History buffs won't want to miss a tour of the Dr. Samuel A. Mudd House, the early Victorian frame farmhouse that was home to the country doctor who set the leg of John Wilkes Booth, President Lincoln's assassin, unwittingly aiding in his escape.

Dorchester County is centrally located on Maryland's Eastern Shore in the Heart of Chesapeake Country. With 1,700 miles of shoreline, Dorchester offers unsurpassed natural resources as well as a distinctive heritage and warm hospitality. The county inspired James Michener's epic novel *Chesapeake* and is the birthplace of Harriet Tubman. It is home to the only fully operational wooden barrel manufacturer and English post-style windmill in Maryland, plus world-renowned Blackwater National Wildlife Refuge.

Left and above: Chesapeake country views

Imagine yourself paddling, cycling, fishing, or boating along our waterways . . . watching as watermen harvest their day's catch . . . sailing on a skipjack, or strolling historic towns. When you're done, retreat to a quiet inn or pamper yourself in the luxurious resort accommodations. In Dorchester County, the seafood dining is always casual and fresh.

Tourism Council of Frederick Co.

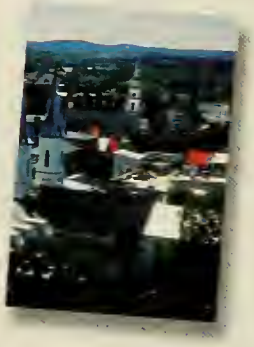
Clockwise from top: Monocacy National Battlefield; Rose Hill Manor; Frederick's clustered spires

FREDERICK COUNTY

Discover the many attractions and historical sites of Frederick County, less than an hour away from Washington, D.C. Amid vineyards, covered bridges, and old railroads, Frederick boasts a strong Civil War heritage. The county is home to Antietam National Battlefield, one of the best preserved battle sites in the country, where the bloodiest one-day battle in U.S. history took place. Other sites include the Monocacy National Battlefield, where a battle held on July 9, 1864, resulted in delaying Jubal Early's raid on Washington, and South Mountain Battlefield State Park (includes Gathland State Park and Washington Monument State Park, where you can hike on the Appalachian Trail). Also visit the National Shrine of Saint Elizabeth Ann Seton, which honors the first American-born canonized saint.

GARRETT COUNTY

Long awaited and anxiously greeted, the warmer days of spring coax pale green buds from bare branches. Young creatures venture into the sunshine to explore a new world transforming from grays to greens and golds. The Deep Creek Lake area, with its promise of renewal, is the perfect place to experience this season. It will awaken your senses to the colors, the sounds, and the scents of the natural world.



This would be the time to have a camera ready to capture the sights and the memories of spring-time in the mountains. To find the

elkridgenatureworks.com

Top: Garrett County wildflower; bottom: Nature hike

MONTGOMERY COUNTY

Bordering Washington, D.C., Montgomery County is a great place to stay when you want to explore the nation's capital but also benefit from the county's very special attractions. Choose from any number of museums, public galleries, theaters, historic sites, and parks. Visit the Clara Barton National Historic Site in Glen Echo (301-492-6245; open daily, 10 A.M. – 5 P.M., shown by guided tour only), which commemorates the life of Clara Barton, founder of the American Red Cross. The home, built in 1891, served as the headquarters and warehouse for the organization. Special events, such as plays and open houses, appropriate for all ages and free, are offered throughout the year.

Clara Barton

Nearby the Barton house is the historic Chesapeake & Ohio Canal, which operated from 1828 to 1924 and follows the route of the Potomac River for 184.5 miles, from Washington, D.C., to Cumberland, Maryland. Along this route, you'll find hundreds of original structures, including locks, lock houses, and aqueducts, dating from the canal's heyday. Bike or hike along the nearly level, continuous trail through the spectacular scenery of the Potomac River Valley.

best places to hear bird song, to glimpse woodland critters, to see early wildflowers, or just get out and stretch those muscles, there are guides, tours, and rental equipment available.

Explore the biological riches of Maryland's mountain wild lands and forests on a guided hike or comfortable walk with Elk Ridge Nature Works. Take a bike tour or flatwater kayak trip with High Mountain Sports. Camp Earth offers to connect you with nature on a custom ecology tour, which may be on land or water. If you prefer exploring mountain trails by horseback, visit one of our local stables or discover a wide range of outdoor spring programs, such as wildflower walks, medicinal plant walks, and birding.

elkridgenatureworks.com

QUEEN ANNE'S COUNTY


Sudlersville Train Station Museum

In lovely Queen Anne's County, on the scenic Eastern Shore of the Chesapeake Bay, enjoy a succulent crab or oyster dinner beside a bustling marina, fish and crab on the Bay, bicycle through historic and picturesque small towns, and hike through marshes.

Start your journey at the Chesapeake Exploration Center on beautiful Kent Narrows. The center is home to "Our Chesapeake Legacy," a hands-on, interactive exhibit providing an overview of the Chesapeake Bay region's heritage, resources, and culture. The exhibit covers the Bay's early history, and explores the importance of the key industries of agriculture and commercial fishing.

Kent Island, just across the Chesapeake Bay Bridge, is the oldest settlement in Maryland. In Stevensville, the largest town, visit the restored Stevensville Train Depot and Christ Church, home to Maryland's oldest congregation, founded in 1631. Matapeake State Park, on the island's western shore, offers views of the Bay Bridge, boat ramps, and a 900-foot-long fishing pier. Terrapin Beach Nature Park includes a one-mile nature trail, pond, two observation blinds, and a boardwalk to the Chesapeake Bay.

ST. MARY'S COUNTY

The expansive Chesapeake Bay and two mighty rivers, the Patuxent and the Potomac, cradle the peninsula of St. Mary's, shaping both its geography and its way of life. Cruise open water on an authentic skipjack, and explore tidal inlets by canoe or kayak. Climb to the top of the only remaining lighthouse on the Potomac. Here, where Maryland began, historic sites abound.

Visit St. Clement's Island, where English colonists landed in 1634, or Historic St. Mary's City, the state's first colonial capital and its

Left: Navigating with a sextant; above: Piney Point Lighthouse

premier outdoor living history museum and archeological park. Enjoy the seasonal harvest of crabs and oysters—available for sampling at waterside eateries and the many heritage festivals held throughout the year.

TALBOT COUNTY

Shannon Potter

Grapevines in Talbot County

In Talbot County, explore the unspoiled beauty and historic lore of Maryland's Eastern Shore. Talbot's charming and historic small towns include the waterfront village of St. Michaels, Easton, Oxford, Tilghman Island, and Wye Mills.

This spring the county is sponsoring a spectacular long weekend (April 29 through May 2) dedicated to three of life's best subjects: great food, fine wine, and Maryland's Eastern Shore. Top chefs from all over the country, joined by renowned sommeliers, will gather here to prepare meals "as breathtaking as the Chesapeake sunsets." The host chefs and vintners will dazzle festival-goers with their delectable treats, cooking demonstrations, wine seminars, and educational discussions. While you're visiting, stay at a luxurious country inn or resort, and allow some time for a host of appealing attractions: swing away at the Harbourtowne Golf Resort, browse through antiques shops and art galleries, climb aboard a skipjack sailboat or bugeye, or take an ecotour of restored Poplar Island.

WORCESTER COUNTY

Located on Maryland's Eastern Shore, Worcester is known as the "seaside county," where you'll find the year-round beach resort Ocean City and the famous wild ponies of Assateague Island State Park.

Tim Tadder Photography

Assateague Island pony

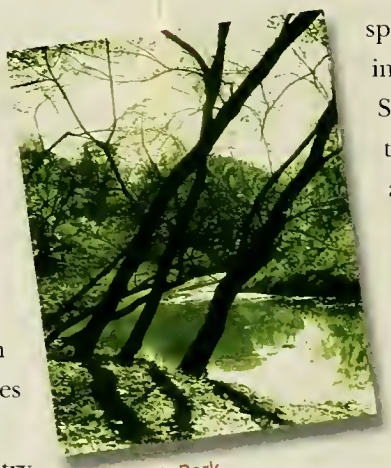
With a range of habitats—barrier islands, coastal bays, tidal wetlands, cypress swamps, fields and forests—it's not surprising that Worcester has more recorded bird sightings than any county in Maryland. This spring, celebrate the migration of hundreds of warblers, shorebirds, and waterfowl as well as many nesting birds and raptors during the Delmarva Birding Weekend (April 24–25), which combines boat trips, canoe and kayak treks, and other expeditions. Read about this weekend and the county's spectacular birding at visitworcester.org.

Nassawango Iron Furnace

Worcester is known for its more than a dozen championship golf courses and 100 miles of marked bicycle trails on flat country roads. Accommodations range from casual bed-and-breakfasts to charming inns on the National Register of Historic Places.

JOHNS HOPKINS UNIVERSITY PRESS

Founded in 1878 in Baltimore, Maryland, Johns Hopkins is the oldest university press in continuous operation in North America and a great source of publications of special interest to naturalists. For example, *Rock Creek Park*, by Gail Spilsbury, celebrates Rock Creek Park, a resplendent wilderness retreat in Washington, D.C., conceived in 1902. Beautifully illustrated with fifty paintings and archival and contemporary photographs, the book tells the riveting story of this unique park's formation and preservation, focusing on how Frederick Law Olmsted Jr. and other visionaries laid down precedents for its preservation. Located in the middle of our nation's capital, Rock Creek Park has managed to remain true to its original vision, the "permanent preservation of its wonderful beauty, and the making of that beauty accessible to the people without spoiling the scenery in the process." Spilbury recounts the park's history and explores how its philosophy of landscape deeply influenced its remarkable degree of historic integrity over the past century. The book pays tribute to the Olmsted family for their contribution to urban and park planning throughout the United States.



Rock Creek Park

 (Continued from page 27)

said nothing of the black hole's source of food. Not until the 1980s would astrophysicists begin to understand the quasar's environment, because trying to take a photograph of it was like taking a head-on shot of a Hollywood floodlight in hopes of catching the image of a firefly flitting past. But eventually, having developed techniques to mask the light, astrophysicists were able to detect fuzz surrounding some of the dimmer quasars. As detection tactics and technologies improved further, every quasar revealed fuzz; some even revealed a spiral structure. Quasars, it turned out, were not a new kind of object but rather a new kind of galactic nucleus.

Irregular dwarf galaxy NGC 4449

In the early 1990s, one of the costliest astronomical instruments ever built was launched into space: the Hubble Space Telescope. From its vantage point above Earth's obscuring atmosphere, Hubble could peer into uncharted regions of ordinary galaxies, including their centers. Gazing into those centers, it found that the stars there were moving inexcusably fast, given the inferred gravity of other stars in the vicinity. Hmmm, strong gravity, small area . . . must be a black hole.

The growing roster of ordinary galaxies known to have a black hole at their center began to raise eyebrows among investigators: A supermassive black hole that's not a quasar? A quasar that's surrounded by a galaxy? One couldn't help but rethink the picture of how things work.

Some galaxies start life as quasars. To be a quasar—which is really just the blazing visible core of an otherwise run-of-the-mill galaxy—the system has to have not only a massive, hungry black hole but also an ample supply of infalling gas. Once the supermassive black hole has gulped down all the available food, the quasar simply shuts off. You've then got a docile galaxy with a dormant black hole snoozing at the center.

Sometimes the streams of material falling into a galaxy's central black hole flow slowly and steadily, at other times episodically. Such systems populate the menagerie of galaxies whose nuclei are active but not ferocious. Over the years, names for the various kinds began to proliferate: there were LINERs (low-ionization nuclear emission-line regions), divided into a minimum of two subclasses, LINER 1 and LINER 2; Seyfert galaxies, divided into Seyfert 1's and Seyfert 2's; N galaxies; blazars. Because all these galaxies, quasars included, have active galactic nuclei, they're called AGNs.

Astrophysicists did not lock in on the true identity of AGNs until they classified the galaxies by their spectra across the full breadth of their electromagnetic emissions. But once they did—in the mid- to late 1990s—they were able to perfect the black hole model and characterize nearly all the beasts in the AGN zoo by measuring only a few variables: the mass of the galaxy's black hole, the rate at which it's being fed, and the angle at which we view the accretion disk and its jets. Small variations in those quantities accounted for nearly all the galactic diversity, leading to a de-speciation and a deeper understanding of the formation and evolution of galaxies.

The fact that so much can be accounted for—differences in shape, size, luminosity, and color—by so few variables is an unheralded triumph of late-twentieth-century astrophysics. Because it took a lot of investigators and a lot of years and a lot of telescope time, it's not the sort of thing that gets announced on the evening news—but it's a triumph nonetheless.

What, then, can one say about the morphological method that governed so much research into the life and times of galaxies? To dismiss the method would be foolish. You've got to know what two objects have in common to appreciate how they differ. And you've got to know how two objects differ before you can appreciate what they have in common. Either way, you need some method of organizing whatever information is available.

The problem with relying on morphology is that you can describe something forever. But to understand it you have to go beyond its mere appearance. Observation and description aren't enough; you need analysis. And there is often a universe of difference between the way things look, and the way things are.

Astrophysicist Neil deGrasse Tyson is the Frederick P. Rose Director of the Hayden Planetarium in New York City.

Pele, the fire goddess of Hawai'i, with Kamapua'a, the Polynesian pig god. Woodcut by Dietrich Varez

Patching Up Paradise

Hawai'i's rarest bird is no match for feral pigs. The best hope may be to capture the birds and fence the pigs.

By Mary K. Miller

On a mission to save one of the world's rarest bird species, the team was about ready to throw in the towel. Deep in the rainforests of eastern Maui, 5,000 feet above sea level on the windward slopes of the dormant volcano Haleakala, they had spent forty days erecting mist nets in hopes of capturing a po'ouli (poh-oh-U-lee) (*Melamprosops phaeosoma*). One of eighteen endangered or threatened species of endemic Hawaiian forest birds called honeycreepers, the po'ouli was doomed if left to its own devices. Only one male and two females were known to remain in the wild, and though all three lived on the forested slopes of the huge volcano, their home ranges were separate. The birds were unlikely to meet and mate.

So in the early spring of 2002, under the auspices of the Maui Forest Bird Recovery Project, the team of eleven had made their way up through the difficult terrain. The plan was to move a female po'ouli into the male's territory and then let nature take its course. But with the bird's breeding season almost at an end, time was running out. Along on the rescue trek was Betsy Gagne, a biologist for the state of Hawai'i who had a special interest in preserving the species; Gagne had been the first scientist to lay eyes on a po'ouli, on an expedition to the region in 1973. At that time, biologists estimated, between 100 and 200 of the birds lived in Haleakala's rainforests. Now, Gagne was along to save the survivors.

The forest that is home to the three remaining po'ouli is inaccessible except by helicopter or after a long day of rough hiking. It lies in the Hanawi Natural Area Reserve—7,500 acres of tangled forest sliced by deep gulches and drenched each year by more than 300 inches of rain. According to Michael G. Buck, administrator of the Hawai'i Division of Forestry and Wildlife, Hanawi includes the most pristine remaining tropical rainforest in the United States. The reserve is home to a dense community of ferns and other forest plants, including the giant tropical plant known as *'ape 'ape*, whose cupped leaves can span more than four feet across. Among Hanawi's animal residents are four other species of endangered honeycreepers, as well as countless native land snails and insects.

As hard as Hanawi is for people to reach, though, it has, until recently, been quite accessible to another destructive animal. Feral pigs have long wreaked havoc in the Hawaiian islands, and they are particularly damaging to native plants and

Po'ouli, a Hawaiian honeycreeper, may be the rarest bird on Earth. Only three individuals are known; they inhabit the high-elevation rainforest on the slopes of Maui's Haleakala volcano.

birds. The list of their ecological sins is long: pigs rototill soil in search of tasty morsels, dismember tree roots, and rip out ferns and other understory plants. Those plants are both home and sustenance to native insects and snails that make up the bulk of the po'ouli's diet.

Pigs also munch directly on succulent native plants, on snails, and, where there are ground-nesting birds, on the occasional egg. They contaminate streams with their droppings, trample the forest floor, tear up creek beds, and excavate wallows. Pig wallows become breeding grounds for *Culex* mosquitoes, which carry avian malaria and bird pox. Hawaiian native birds have no immunity to mosquito-borne diseases, because mosquitoes themselves are an island import. Such diseases have contributed to the extinction of perhaps dozens of endemic birds. Finally, swine-generated damage to the ecosystem makes it easier for nonnative plants such as strawberry guava and banana poka to take root and crowd out native vegetation.

Given the depredations of the pigs, it is a wonder that the po'ouli has survived this long—or that the bird still has any native forest to inhabit. In fact, though, the pristine state of the forest in the Hanawi Reserve is no accident. The state's Department of Land and Natural Resources has undertaken intensive conservation work to preserve high-elevation ecosystems. Perhaps the most labor-intensive part of the work has been the construction of fences—not to keep some animals in, but to keep others out, particularly the pigs. (Fence construction, of course, is no defense against smaller non-native mammals such as rats, mongooses, and feral cats, which can readily slip through or climb over wire.)

But fence building has become a contentious issue in the islands, involving conservationists, hunters, park personnel, and native Hawaiians, often in unfamiliar roles. The reason is that pigs, besides being environmentally destructive, are also highly prized as game animals. And so the debate has created a peculiar circumstance in which groups that are usually allies, such as the preservers of native fauna and the preservers of cultural values, sometimes end up, both literally and figuratively, on opposite sides of the fence. In a sense, the question boils down to a stark but simple one: Birds or pigs?

Rainforest in the Hanawi Reserve, on the windward slopes of Haleakala, gets more than 300 inches of rain a year.

A stocky, dusky little bird with a black face (in the Hawaiian language *po'ouli* means "black face"), the po'ouli seldom sings or calls, and its furtive habits and cryptic coloration also make it much harder to spot than other Hanawi forest birds. The bird spends much of its time on the ground and in low vegetation hunting for native tree snails. In fact, it is the only member of the honeycreeper family to feed almost exclusively on the snails. Ornithologists place the po'ouli in its own genus and consider its lineage to have been an early branch on the evolutionary family tree of the honeycreepers. That evolutionary singularity makes the rescue of the po'ouli from extinction a crucial priority.

Compared with the po'ouli, pigs reached Hawai'i only yesterday—though in fact the first pigs arrived more than 1,600 years ago with Polynesian seafarers who discovered the islands and settled there. The earliest pigs were tame and relatively small, about forty-five pounds each. Because the Polynesians regarded them as valuable property, the pigs were cared for and kept near villages, and so they didn't pose much of a problem to the island environment. The Polynesians—ancestors of today's native Hawaiians—also brought with them other nonnative species, including dogs, domestic fowl, geckos, Pacific snails, Polynesian rats, and skinks, as well as taro and other edible plants for cultivation.

Before the Polynesians inhabited Hawai'i, the islands were densely forested all the way to the shoreline. Those lowland forests were the preferred habitat of the po'ouli, but as the human population grew, the forests were cleared to make way for settlements and the cultivation of taro. In eastern Maui the po'ouli was forced to retreat into forests at higher elevations. Evolutionary biologists estimate that from the time of the founding Polynesian population, around A.D. 400, until the arrival of the English under Captain James Cook in 1778, half the native bird fauna of Hawai'i disappeared, victims of habitat loss and direct predation by humans.

Still, the higher-elevation forests remained intact until the next wave of settlers arrived, primarily from Europe and the United States. The newcomers brought with them cats, cattle, goats, sheep, and songbirds, but most important, they brought a particularly destructive, large, and wily breed of swine. These pigs, which weighed as much as 450 pounds, quickly began to interbreed with the docile Polynesian variety. The progeny ran wild and moved upland into the still-pristine rainforests.

By the early part of the twentieth century feral pigs had become so numerous on the islands that large-scale, organized hunts were instituted. The largest state- and federal-sponsored hunting effort was on the Big Island of

Hawai'i, where from 1921 until 1946 officials eradicated more than a quarter of a million feral animals, including almost 50,000 pigs. Pig numbers have fallen since those bad old days, thanks, in part, to continued, but smaller-scale, state-sponsored hunting on public lands. The animals remain, however, near the top of the biological enemies list.

But the pigs have their own fan base. Private hunters—some 10,000 of them throughout the state of Hawai'i—constitute a strong and vocal political lobby. That political reality makes the reintroduction of more extensive pig eradication by the state unlikely, and even the construction of pig fences unpopular. The hunters maintain that installing fences within wildlife reserves eliminates prime pig habitat, and they view even the limited killing of pigs by wildlife officials as a waste of good game meat.

Wild pigs in Hawai'i have an active fan base among hunters, but their rooting, foraging, and wallowing leave native forests a muddy mess.

Hunters often ply their craft with dogs, which track and corner sharp-tusked wild boars in the remote backcountry of the islands. (The dogs can suffer the brunt of the pig encounters, and some experienced hunters carry needle and thread to sew up their dogs' injuries on the spot.) And the dogs and hunters do a credible job at keeping the pig population in check. According to Michael Buck, hunters bagged 350 pigs a season, on average, during the past three years in Maui alone, and nearly 2,000 a year in the islands as a whole.

Betsy Gagne, the biologist along on our hunt for the po'ouli, has no quarrel with Buck's statistics, but she finds the hunters' blanket opposition to fencing, well, piggish. She notes that out of 800,000 acres of forest under state control, only 100,000 acres are behind fences or in restricted wildlife reserves such as Hanawi. (Another million acres or so is under private ownership or federal jurisdiction, including military training areas.) The state reserves, she points out, are usually too steep or too remote to be practical for hunting on foot.

To some Hawaiians, though, statistics and practical terrain are just beside the point. Intersecting with the hunters' lobby is the movement to preserve the traditions of the native Hawaiians. Polynesians and their Hawaiian descendants depended on the pig for food, and they also revered the animal in the form of a demigod they called Kamapua'a. Regarded as a trickster, Kamapua'a was also a shaper of the local landscape, who was shaped himself by the character of that land. Like other animal folk figures, the pig god was considered a powerful, if mischievous, local deity. Pigs, then, could be honored, or consumed on special occasions, or both; in any event, some Hawaiians see the pigs' exclusion from any forest areas as an assault on their hunting rights and lifestyle.

The three wily po'ouli eluded capture this past winter.

In 1996 the fencing of 2,000 acres of intact forest within the larger Hanawi reserve was completed. But now, in spite of opposition, the East Maui Watershed Partnership, a coalition of federal and state government and private landowners, is in the process of fencing off 10,000 acres of native forest above 3,500 feet in part of the watershed adjacent to the reserve. The watershed, which covers 100,000 protected acres on the windward, or northeastern, slope of Haleakala, is critical because it supplies more than 60 billion gallons of freshwater a year, an amount that currently meets residential, commercial, and agricultural demands throughout Maui

The goal of fencing is straightforward: to restore or preserve ecosystems of native plants, invertebrates, and birds. But it is expensive: in the steep, forested terrain of Hanawi, fences that deter pigs, deer, and other mammals can cost more than $30,000 a mile to build and maintain. Given that cost, some critics might argue that fencing is a quixotic, impractical attempt to turn back time and restore forests to pre-Polynesian-settlement conditions. So the first question is

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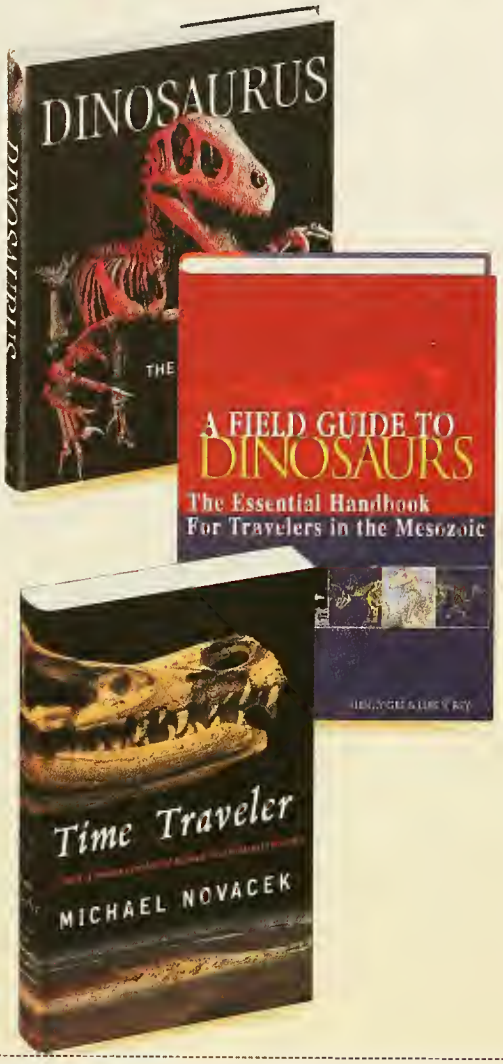

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the empirical one: does it work?

A rigorous test of how effective fencing could be in restoring habitat denuded by pigs, goats, and other exotic species was first conducted back in 1968. Conservationists fenced off about three and a half acres of fern forest near the Thurston Lava Tube in Hawai'i Volcanoes National Park. Then, after the fence was put up, restorers culled feral animals and uprooted exotic vegetation inside the fence. Thirteen years later the plot inside the fence was drifting back toward the flora of old Hawai'i. Native ferns and other plants were outcompeting Hilo grass, strawberry guava, and other exotics. Whether the plot will eventually revert to its pristine pre-settlement state and provide critical habitat for endangered honeycreepers, land snails, and other endemic species remains an open scientific question. And if it does, whether such a seemingly lost habitat is worth the time and expense of restoration is a question no scientist can finally answer.

What science can say is that other studies have confirmed the results of the Thurston experiment. From 1991 until 1998, another controlled study was conducted in Volcanoes National Park. Within the first two years after fences were installed and the pigs removed, the natural plant understory increased by nearly 50 percent. Ferns, a favorite food of pigs, made a resurgence; larger tree ferns and native woody plant species, whose roots are often trampled by pigs, also recovered.

But the story is not a uniformly hopeful one. Sadly, according to Buck, some areas are beyond recovery. Parts of the lowlands and the tourist meccas along the coasts of all the islands cannot be restored. The best strategy, Buck maintains, is to find pristine or lightly disturbed areas, such as Hanawi, and protect them before they are ravaged by pigs and other invasive species.

Even inside the fences, within its pig-free forest refuge, the po'ouli still seemed headed for extinction. Gagne and the team of rescue biologists had endured the slippery mud, treacherous gulches, and seemingly perpetual rain for weeks, but their plan to save the po'ouli was coming to naught.

Finally, in early April of the 2002 expedition, a female po'ouli flew into the fine mesh of a net. After carefully extricating her, the biologists placed her into a specially outfitted carrier. Everyone was relieved when she began munching snails and insects, a good sign that, unlike her captors, she wasn't unduly stressed. That night, the po'ouli was released into the new territory, about a mile and a half away, in the hope that she would go to roost and encounter the male at dawn. The first signs were promising, but by the afternoon of the next day she flew back to her home grounds.

Fence was erected in the Hanawi Natural Area Reserve against the depradations of feral pigs. Pigs were removed from the area to the right of the fence, leaving lush, pristine plant growth.

Not willing to give up easily, biologists from the Maui Forest Bird Recovery Project developed a new plan: to capture the three remaining po'ouli and bring them into a captive breeding program on Maui run by the Zoological Society of San Diego. It's a long shot, but there aren't many other options, and there are precedents. New Zealand's black robin was pulled from the brink of extinction when a single wild pair were bred in captivity. In 1973 the entire known population of Mauritius kestrels had dropped to seven individuals, with only two breeding pairs. During the 1990s, captive breeding and release efforts were successful, and by 2000 at least 650 wild kestrels were flying over Mauritius. And a few islands of optimism remain for the po'ouli. The team has gained experience in handling the bird, and the bird has seemed at ease in captivity. Those factors suggest that the birds can be transferred to a breeding center.

A new series of trips to Hanawi began in the fall of 2003 and will continue until this June. So far, the three birds remain in their separate home ranges and appear robust and frustratingly wily about the mist nests. The current coordinator of the Maui Forest Bird Recovery Project, Kirsty Swinnerton, is a biologist who specializes in endangered species, and who worked on the recovery of the Mauritius kestrel. The male po'ouli, a "tough little bird," according to Swinnerton, has come within twenty feet of the mist nets. But, so far, he has eluded capture.

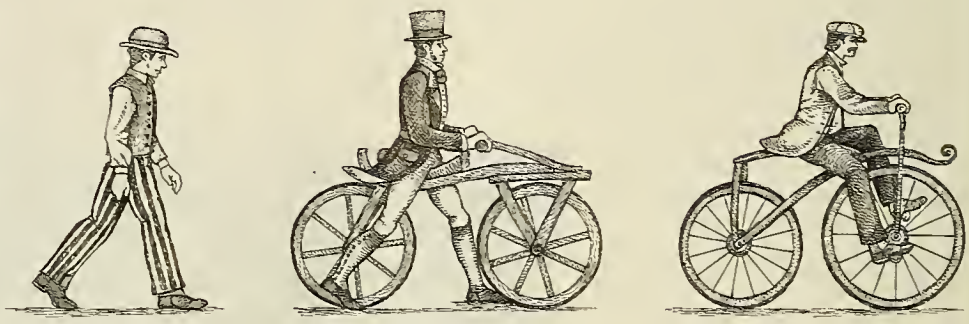
Buck is realistic about the plight of the birds. At least, he notes, the efforts to save them have created a fitting legacy: "the pristine forest that we've protected for at least three other endangered Hawaiian forest birds and for countless other native species of rainforest plants and animals." But the team from the Maui recovery project is holding out for more. Betsy Gagne, recalling her first glimpse of the secretive birds thirty years ago, remains resolute even as she feels they might be slipping away. "They've always been like little ghosts," she says, "absolutely unique and worth the work."

Mary K. Miller, a freelance science writer, is also a science and media producer for the Exploratorium in San Francisco. Her work has taken her from a genetics laboratory on Long Island, New York, to an astronomical observatory at the South Pole.

Meddling with Pedaling

Even as bicycle designs have improved, all bikes have been well matched with the peak power output of the muscles that drive them forward.

By Adam Summers ~ Illustrations by Patricia J. Wynne



I live in the fantasy world of southern California, where an uninterrupted stream of pastel-colored, fat-tired, two-wheeled beach cruisers swan down endless miles of flat pavement next to the Pacific. A few miles away, the steep canyons of the Santa Monica Mountains are a playground for weekend Lance Armstrongs, clad in skintight spandex, pedaling high-tech titanium steeds uphill and down. It's is a far cry from my hometown, New York City, where drab, battered bicycles dodge buses, taxi doors, sewer grates, and potholes. Chained to "No Parking" signs and attacked by parts-hungry vandals, the big-city bikes are sometimes reduced to two wheels and a seat—which inadvertently creates a postmodern version of the most primitive two-wheeler: the hobby horse.

In an age of sleek, high-tech titanium, a study of such a contraption might seem silly. But from the perspective of the biomechanist, a bicycle is comparable to a trot or a gallop of a horse: a solution to the problem of self-propelled locomotion that, even though it enables faster forward motion, does not necessarily use the muscles that power the motion as efficiently as walking does. Muscles, after all, can be "driven in the wrong gear," just as a car can: if they try to contract too slow or too fast, you don't get nearly as much power out of them as you do when they contract at their optimum frequency.

With those ideas in mind, two biomechanists, Alberto Minetti of Manchester Metropolitan University in England and Paola Zamparo of the University of Udine in Italy, and John Pinkerton, an English bicycle historian, have taken a close look at the hobby horse and other machines in bicycle history, and have gained important new insights about how the bicycle evolved. For one thing, they discovered to their surprise that even the very first bikes were able, at the higher speeds of self-powered locomotion they made possible, to take advantage of the peak efficiency of the rider's muscles, just like today's most tricked-out bike. The investigators also found that the evolution of these machines has been largely a matter of reallocating the rider's power output. Instead of wasting output energy in overcoming the rolling resistance of the wheels and in pumping the limbs and moving the body's center of gravity, modern bicycles redirect the rider's energies into overcoming wind resistance. Those changes have led to progressively higher speeds for the same amount of effort.

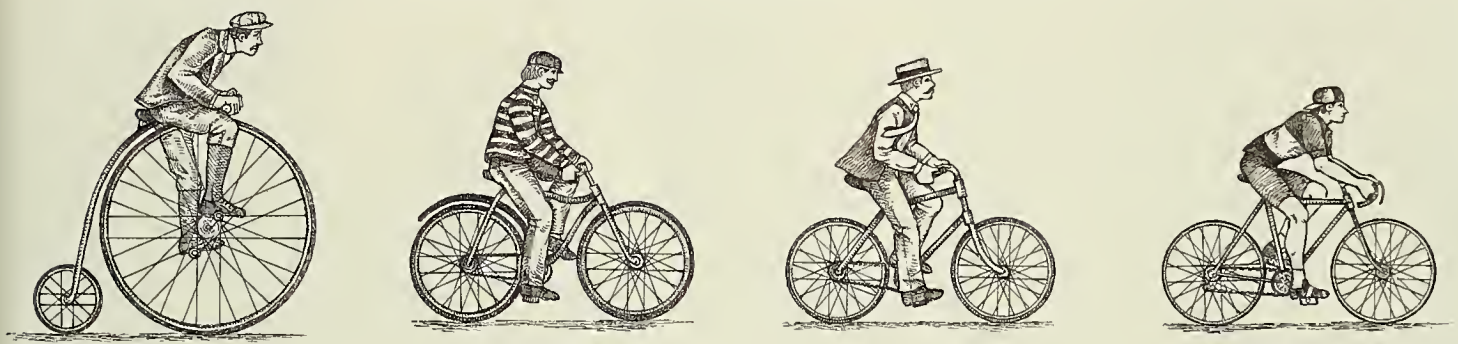
The first bicycle was the hobby horse, which debuted in 1817 as a toy, rather than as transport. The rider sat astride a leather seat and kicked the contraption along. Fred Flintstone would have been right at home. But the machine was a giant step forward in the use of the rider's energy. Its key innovation was to free the legs from their usual job of lifting the body off the ground. The muscles could be devoted exclusively to powering forward motion, and the rider could propel the machine at walking speed using 50 percent less energy per unit of distance traveled.

From such humble beginnings improved machines quickly developed. By 1863, attaching cranks and pedals to the front wheel of the hobby horse had produced the velocipede, commonly known as the boneshaker. This

bicycle had wooden wheels with metal rims, and even on packed-earth pathways it must have lived up to its nickname.

The next major innovation was the high wheeler, designed to increase the distance traveled with each revolution of the pedals. The bicycle combined a large front wheel with a smaller rear one—making it fast but a long way down if the rider fell off.

In 1885 the Rover bicycle incorporated a chain or shaft drive to transmit the pedal power to the rear wheel. The mechanism added weight and complexity, but it enabled the bike to have smaller, identical wheels, as well as pedals that rotated at a different frequency than the driven wheel. By the 1890s air-filled tires were added, and the bicycle attained a recognizably modern form.



Milestones in the evolution of human self-powered locomotion are highlighted from left to right in the drawings. A person walking at four miles per hour expends energy at a rate of about 350 watts (slightly less than half a horsepower). The development of the bicycle during the past 200 years made it possible, with almost every major innovation, to increase the speed on land for the same power input; it stands today at roughly fifteen miles per hour. Only the Rover (third from right) was slower than its quicker, but far more dangerous, predecessor, the high wheeler (center).

Minetti and his colleagues measured the motion and metabolic rates of bike riders as they circled a flat concrete track at a series of constant speeds on each of these antique and modern bicycles. Their unsurprising finding is that the more modern a bike is, the less energy it costs to move bike and rider from place to place. Pedaling a mile on a modern racing bike burns 20 percent of the calories needed to walk the same route and 40 percent of those needed to cover the distance on a Rover bicycle. (Only the Rover was more energetically costly to ride than its predecessor.)

Minetti points out that the work of cycling comes in three parts: air resistance (or drag), rolling resistance, and "internal work." Rolling resistance is simply the resistance of the wheels to rolling and of the rubber tires to being squashed by the weight of the rider. Internal work sums up the energy of the cyclist: the rocking torso, pumping legs, hard breathing, and so forth. In 1899 Charles "Mile a Minute" Murphy discovered that he could bicycle at unheard-of speeds by skipping out on some of this work.

Murphy noted that when practicing his cycling in a garage, with the rear wheel spinning freely, he could easily pedal a safety bicycle fast enough to ride a one-minute mile. Murphy did all the internal work, but suffered none of the drag or rolling resistance. Working with the Long Island Rail Road, he rode his bike behind a train along a three-mile long wooden course laid between the tracks. So shielded, his drag was nearly nothing, and he achieved a speed of 62.28 miles an hour—though he was nearly undone by the rolling friction he had not experienced while pedaling in the garage: he fell behind the train, but caught up just in time to be hoisted aboard before his smooth wooden course gave way to unforgiving railroad ties.

Minetti's most intriguing result is that the peak efficiency of bicycling for the cyclist, the mechanical work output divided by the metabolic cost of biking, has remained relatively constant at about 27 percent since the time of the hobby horse. But even as a person puts the same amount of energy into any of these machines, the newer bicycles are better at stretching the energy out. A brisk walking pace on level ground requires that energy be invested at a rate of about 350 watts, and results in a speed of about four miles an hour. The same power input gets more than six miles an hour out of a boneshaker and twelve miles an hour from both a pneumatic-tired safety bicycle and a common modern bicycle; 350 watts will power a slick racing bike to fifteen miles an hour.

The invention of variable gearing enabled bicyclists and cars alike to change the speed of peak efficiency. In a triumph over internal work and rolling resistance, with a many geared bicycle, the Dutch bicyclist Fred Rompelberg managed to pedal 166.9 miles an hour behind a pace car on Utah's Bonneville Salt Flats. The high wheeler is far from the most dangerous bike around these days.

Adam Summers (asummers@uci.edu) *is an assistant professor of ecology and evolutionary biology at the University of California, Irvine.*

Lawless in Mesopotamia

Lower level of a major storeroom of the Iraq Museum in Baghdad is shown after the looting of April 10–12, 2003. In addition to the 15,000 objects (out of an estimated 17,000 originally stolen objects) that are still missing, many other objects left behind are damaged or destroyed. Proper cataloging of the remains will take at least a decade, and their restoration even longer.

Iraq's antiquities were looted mostly by professional thieves, not by random hooligans. Archaeological sites are still imperiled by looters, as well as by hastily planned reconstruction.

By Zainab Bahrani

Standing in the storerooms of the Iraq National Museum one morning last summer, I found myself surrounded by the appalling chaos left by looters. Everywhere manuscripts were strewn about, mixed with modern catalogue cards and broken bits of 6,000-year-old pottery. Smashed ancient glass lay where looters had dropped objects in their haste. Scanning the scattered shards, as an art historian and specialist in the archaeology of the ancient cultures of the Tigris-Euphrates valleys, I automatically began to identify objects and assign them dates. On the floor in front of me were remains of Mesopotamia, the cradle of civilization: the land where the first cities were built, where writing was invented, and where human beings first conceived of institutionalized government and codes of law. The irony was that I now stood in a land without law, where the want of law had led to the plunder and destruction of so much of humanity's cultural heritage.

I had come to Baghdad in June 2003 to help the Iraq Museum in the wake of the looting. I had learned of the disaster in the early morning hours of April 12, from a good friend and colleague at the University of Oxford, Eleanor Robson. She had broken the news to me gently, as one would report the death of a very close friend. Still, I was devastated. In the lead-up to the war, the two of us had been working together closely to identify endangered sites and monuments; members of the archaeological community had provided a list of vulnerable sites to the U.S. State Department and the Pentagon. Along with other Mesopotamian scholars, we warned that without preventive action during any military incursion, looting at museums and archaeological sites was likely.

It was against that backdrop that we in the international scholarly community greeted the news of April with outrage and disbelief: in spite of all our pleas, from both sides of the Atlantic, orders had not been given to protect the museum.

On April 16, four days after the news of the looting had become public, U.S. troops secured the Iraq Museum, and by April 22 a team headed by Marine Colonel Matthew F. Bogdanos arrived at the museum to investigate. The international community also took initial steps toward a rescue effort immediately after the news of the looting broke: UNESCO called an emergency meeting in Paris, even before the Iraq Museum had been secured. Soon afterward, Neil MacGregor, the director of the British Museum, convened a second emergency meeting in London to develop plans for taking inventories, undertaking the emergency conservation of objects, and providing equipment and supplies to the national department of antiquities. I was called to both meetings to discuss practical plans and strategies.

At the time I tried to be optimistic. Surely, I thought, concrete assistance would soon follow the urgent recommendations that we had drawn up at the London meeting. But we quickly found that many obstacles prevented immediate action in Iraq. Frustrated by the lack of institutional action, I resolved to

travel to Baghdad—on my own, if necessary. As a scholar of Mesopotamian culture and as a native of Iraq, I felt compelled to assist in the rescue of Iraq's cultural heritage.

As it turned out, two colleagues travelled with me, Elizabeth C. Stone of Stony Brook University in New York and Paul E. Zimansky of Boston University. Driving from Amman, Jordan, we carried computers, digital cameras, satellite phones, and office furniture. In Baghdad, each of us became occupied with a different part of the rescue effort. My colleagues worked to install communications systems and lay the groundwork for Iraqi collaboration with colleagues at universities outside Iraq, while I focused on assessing museum losses.

Marble statue of Apollo, originally from Hatra, once stood in the Iraq Museum as a testament to Mesopotamia's participation in Greco-Roman culture. This exquisite, second-century A.D. work was destroyed (see remains at bottom right) by looters who took the head, presumably for sale outside Iraq.

Those losses, as all the world knows, were tremendous. But the original reports—that 170,000 objects had been looted—are now known to have been much too high. In fact, the number was probably closer to 17,000, still an overwhelming disaster for the collection. Forty well-known works were stolen from the galleries, though thirteen of them have since been recovered. The marble staircase leading to the upper galleries was destroyed when looters apparently dragged down a 330-pound copper statue dating to the twenty-fourth century B.C. It was one of the most important objects stolen—it bears a dated royal inscription and is an early example of a sophisticated casting technique, known as the lost-wax process. Many archaeologists had given up on the piece, assuming it had been melted down. But, miraculously, on November 3, military police found it intact, indicating that the looters who took it were well aware of its value.

Walking through the galleries of the museum on my first day there, I was overjoyed to find a number of well-loved objects still safely in place. The largest room, with Assyrian sculpture lining the walls, was in very good condition, and some significant works, such as the Priest King Stele, from 3000 B.C., still undisturbed. But in the dual-level galleries that house objects from the World Heritage site of Hatra, the scene was different. Here, Greek-style sculptures had been decapitated, their heads carried off for sale on the international antiquities market. Among them was a now headless Nike, goddess of victory. On the floor of the upper galleries lay the remains of what had been a marble statue of Apollo, smashed into innumerable fragments. That head was missing, too, and what remained of the body appeared to be beyond repair, much of the stone nearly pulverized by those who attacked it. Nearby were the fragments of a marble Eros and a statue of the Roman emperor Trajan, now both headless.

Nike was

The pattern of destruction made it immediately clear to me that this was not a case of random desecration by an oppressed population taking revenge on a hated regime. Instead, the localized mutilation left no doubt that the looting of the museum involved a faction of professional antiquities thieves who knew exactly what kinds of objects to take, where to find them in the museum, and which ones would fetch the highest prices. It should be noted that as early as 1970 a UNESCO convention made the import, export, and transfer of ownership of cultural property illegal; in the aftermath of April's looting spree, on May 22, 2003, the UN Security Council passed a resolution specifically banning the trade in Iraqi antiquities.

Fortunately, several of the most important objects from the Iraq Museum were recovered, thanks to the efforts of U.S. military investigators, Iraqi police, and international law-enforcement officials. In addition to the copper statue, two pieces dating to about 3200 B.C.

have been recovered: the so-called Uruk vase and the Uruk head, both from Mesopotamia's first major city. The vase is a large stone vessel, decorated with reliefs depicting offerings to Inanna, goddess of fertility, during her ritual marriage to the king; it is one of the earliest works of narrative representation in history. On June 11, three men returned it to the museum in pieces. Because most of the breaks are old and the pieces large, however, the vase can be repaired.

The Uruk head, an alabaster head of a female, was recovered on September 16. About eight inches high, the head was part of a composite statue that had stood in the temple of Inanna in Uruk. The sensitively sculpted face probably represented Inanna herself. In all, more than 2,000 objects taken from the Iraq Museum have now been recovered, but the number still missing is estimated at 15,000.

Ashes of burned books litter the floor of Dar al-Kutub wa-al-Watha'iq (the National Library and State Archives) in Baghdad. Many cultural institutions throughout Iraq, not just the Iraq Museum, were trashed and looted after the fall of Baghdad to coalition forces in April 2003.

What has been almost lost, though, in the press coverage of the Iraq Museum is that other Iraqi cultural institutions were likewise looted. Among them are the Museum of Modern Art, Dar al-Kutub wa-al-Watha'iq (the National Library and State Archives), and Maktabat al-'Awqaf Markaziya ("the Central Religious Endowment Library"), all in Baghdad, and Mosul's museum of antiquities. The extent of the losses to the libraries has not yet been assessed, and valuable manuscripts from them are as likely to appear on the international market as stolen antiquities are.

now headless; the statues of Apollo, Eros, and Trajan were decapitated.

In spite of the losses, the retrieval of lost objects has been heartening, and plans for the renovation of the Iraq Museum complex are under way, largely funded by the U.S. State Department. The Iraqi-Italian Institute of Archaeological Sciences is funding and supervising the construction of a conservation laboratory. Belgium and UNESCO are upgrading one of the storage rooms. Nevertheless, on balance, the serious threats to the cultural heritage of Iraq have not diminished. Now the greatest concerns lie outside the capital, where massive losses and the destruction of archaeological sites continue unchecked.

Part of the problem is that much of Iraq's cultural heritage is still undiscovered, and thus not yet excavated. Many ancient heritage sites are often not clearly visible to the nonspecialist. A construction company tearing into unsurveyed land may even destroy unrecognized ancient cities with their bulldozers. A good example of the potential for damage is the area around the Great Mosque of Samarra. To the untrained eye, there are no historical remains to prevent usage of the area. Yet it is widely known among scholars that the mosque was an integral part of a medieval royal city.

The most sensible thing to do would be to include archaeologists from the Iraqi State Board of Antiquities and Heritage (SBAH), the centralized governmental organization in charge of all antiquities projects and museums in the country, in the planning stages of any construction projects. Those archaeologists have long been responsible for preconstruction archaeological surveys throughout the country, and so they are the most familiar with the ancient Mesopotamian and medieval sites and monuments. Such surveys are standard in countries with a substantial archaeological heritage, such as Greece and Egypt, and they have long been routine in Iraq.

The legal standards that prevail in antiquities-rich countries everywhere hold that if a construction project might damage a site, the project must be relocated. When a project cannot be moved, salvage excavations must be done first. A good precedent in the Arab world was set in the 1960s, during the

construction of the Aswan High Dam and Lake Nasser in Egypt: before the construction, ancient Egyptian temples such as the ones on Philae Island and at Abu Simbel were moved to new sites.

International laws also require that all excavations, whether for salvage or research, be conducted by specialists in the archaeology of the region (in this case, therefore, by Mesopotamian archaeologists), and in accordance with professional archaeological standards. Any excavated objects must be recorded, documented in published materials, and moved to new locations if necessary. The objects legally remain the property of the country in which they are excavated.

The antiquities laws in prewar Iraq were in accord with international standards, and they remain the guiding principles for addressing issues of cultural heritage. Indeed, the Archaeological Institute of America, the largest organization of professional archaeologists in North America, and the international community of Mesopotamian specialists have urged all authorities in power in postwar Iraq to uphold the validity of the prewar antiquities laws. It is only right that the cultural heritage of Iraq be given the same protection as any other country with an archaeological heritage.

Eighth-century B.C. ivory statue of a female nude is one of 2,000 objects now missing from the collection of the Iraq Museum. The statue, about thirteen inches high, highlights the ancient Mesopotamian delight in the sexual aspects of life. It was excavated from the women's quarters of the royal palace in Nimrud, in northern Iraq.

Yet the signs that such standard procedures will be followed in the near term are not good. No professionals who work on the conservation of cultural heritage have yet participated in any conferences on the reconstruction of Iraq. The Rebuilding Iraq Conference, held in Washington in early December of last year, was a case in point. Furthermore, two military-airport construction projects that fall under the Coalition Provisional Authority (CPA), the civilian provisional governing body set up by the U.S. military, have already damaged archaeological sites at the important ancient cities of Ur in the south and Nineveh in the north. Expanding military installations at Babylon, Samarra, and Tell 'Afar, have damaged archaeological remains at those sites as well.

A construction company tearing into unsurveyed land with bulldozers could destroy an unrecognized ancient city.

In addition to the threats posed by reckless and hastily planned reconstruction, the looting of archaeological sites continues across the country. Much of it is fueled by unscrupulous collectors of these artifacts operating in the international antiquities market, which operates primarily in the United States, Western Europe, Israel, and Japan. Looters, apparently working for outside interests, have already irreversibly destroyed several sites: the ancient cities of Isin, Larsa, and Mashkan Shapir, for instance, and perhaps the ancient city of Nippur, in southern Iraq. Parts of the wall of the Assyrian palace at Nimrud, in the north, have been hacked out, as if cut to order for a foreign collector.

In response, the CPA's senior adviser on cultural affairs, Mario Bondioli-Osio, has announced plans to deploy 1,300 antiquities police at archaeological sites in six of the eighteen provinces of Iraq. Because the looters are armed, the police force must also be armed, and mobile.

Protection of antiquities involves more than guarding against looting, however. In July 2003 the CPA decided to exhibit in the Iraq Museum the "Nimrud gold," the contents of the tombs of the queens of Assyria of the ninth and eighth centuries B.C., which have been compared in splendor to the treasures of the tomb of Tutankhamun. With great haste, delicate and fragile ancient gold was installed and exhibited to the press and to various dignitaries. Then, because of the security risks, the exhibition was taken down within a matter of hours and the objects returned to their vaults. The entire affair appears to have been an effort to prove to the world that the museum was up and running again, but in fact it needlessly placed priceless artifacts in jeopardy. The process would not have been permitted under normal museum practices.

Recent reports from Baghdad indicate that the CPA, with the National Geographic Society, is planning a traveling exhibition of the Nimrud gold in the United States. But though such an exhibition could benefit the restoration effort by raising public awareness of the magnificence of Mesopotamian arts and culture, it again raises serious questions about decision-making among those responsible for protecting Iraq's cultural property. Traveling exhibitions require specific kinds of conservation and expertise in handling and packing of objects, and they need to be organized by curators and conservators who are suitably trained. If such standards are not followed, the artifacts could be irreparably damaged. Another concern is that the Nimrud gold, which was excavated just before the first Gulf war, has never appeared in an exhibition open to the Iraqi people. It would seem inconsiderate to allow it to travel to the United States before Iraqis have had the chance to see it.

Will lawfulness ever return to the birthplace of law? According to the terms of international accords, such as the 1949 Geneva Convention and the 1954 Hague Convention, an occupying force is responsible for the protection of cultural property. Ironically, much of the destruction of heritage in Iraq has taken place since the bombing campaign of spring 2003. Nevertheless, it would be ignorant of the ground truth, and a slap in the face at the tremendous recovery efforts, to admit defeat within Iraq in the efforts to preserve and protect the nation's cultural treasures.

The work of the U.S. State Department in the renovation of the Iraq Museum and the adjoining offices of SBAH is an encouraging step toward protecting Iraq's heritage. As of this writing, many international nongovernmental organizations (NGOs) that specialize in cultural heritage have made long-range plans for monument surveys and inventories of sites, as well as for conservation and curatorial assistance. Those moves are much appreciated by archaeologists and Iraqis.

One major obstacle for those outside Iraq who would like to take part in such efforts, of course, is the serious personal security risk of working in Iraq. Largely because of that risk, only a small number of international specialists, out of passionate commitment, have bravely traveled to participate in the rescue effort so far. For their part, Iraqi archaeologists are limited in what they can do by the lack of supplies and lack of access to the sites. They are frustrated, too, by delays in the execution of plans, even as they witness the daily destruction of unsurveyed terrain, of sites that may conceal treasures destined to remain forever lost. The best hope is that the authority for coordinating national and international efforts will be fully restored to the men and women of the Iraqi State Board of Antiquities and Heritage—those who best know how to protect and conserve this great human heritage. □

U.S. tank stands guard at an entrance to the Iraq Museum after the looting of April 2003. The hole in the façade was made on April 11, 2003, by U.S. troops who fired on a sniper hiding in the museum.

Saving Nemo

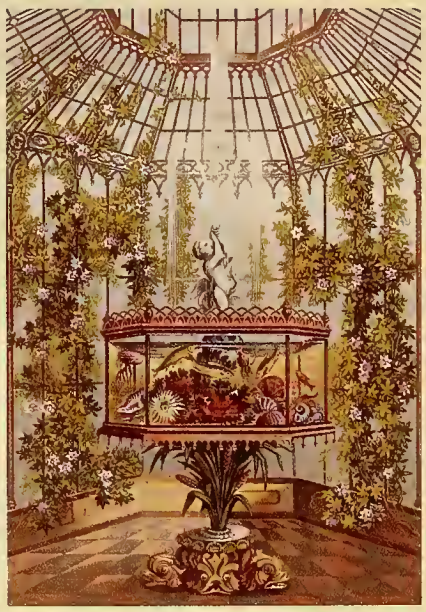
Aquariums, once water-filled cabinets of curiosities, exert potent economic forces that can foster conservation in the wild.

By Melanie L.J. Stiassny

Aquariums have come a long way since the days of Madame Rondelet. Her husband, Guillaume Rondelet, a sixteenth-century French physician and the author of an early illustrated book on marine life, is regarded by many as the father of modern ichthyology. For her part, Mme Rondelet might well deserve to be called the mother of modern fish keeping; as her story has come down to us, she managed to keep a fish alive in a glass of water for three years.

It is unlikely, of course, that hers was the first aquarium. Fishes have been kept and bred for millennia, for food as well as amusement, but the ancient origins of the practice are obscure. Perhaps the Sumerians were the first fish keepers; certainly the manipulations of carp and goldfish by the Chinese, and later by the Japanese, are of ancient lineage. And a Roman notable, Quintus Hortensius, is reported to have wept when his favorite eel died in captivity.

But today's fish tanks were far beyond the reach of Mme Rondelet and her contemporaries—to say nothing of the ancients. For one thing, plate glass was not available until the late seventeenth century. More important, though, was the lack of the most basic understanding of the relations between aquatic plants and animals, the cycling of nutrients, or practically any other detail about the ecology of a healthy aquatic community.

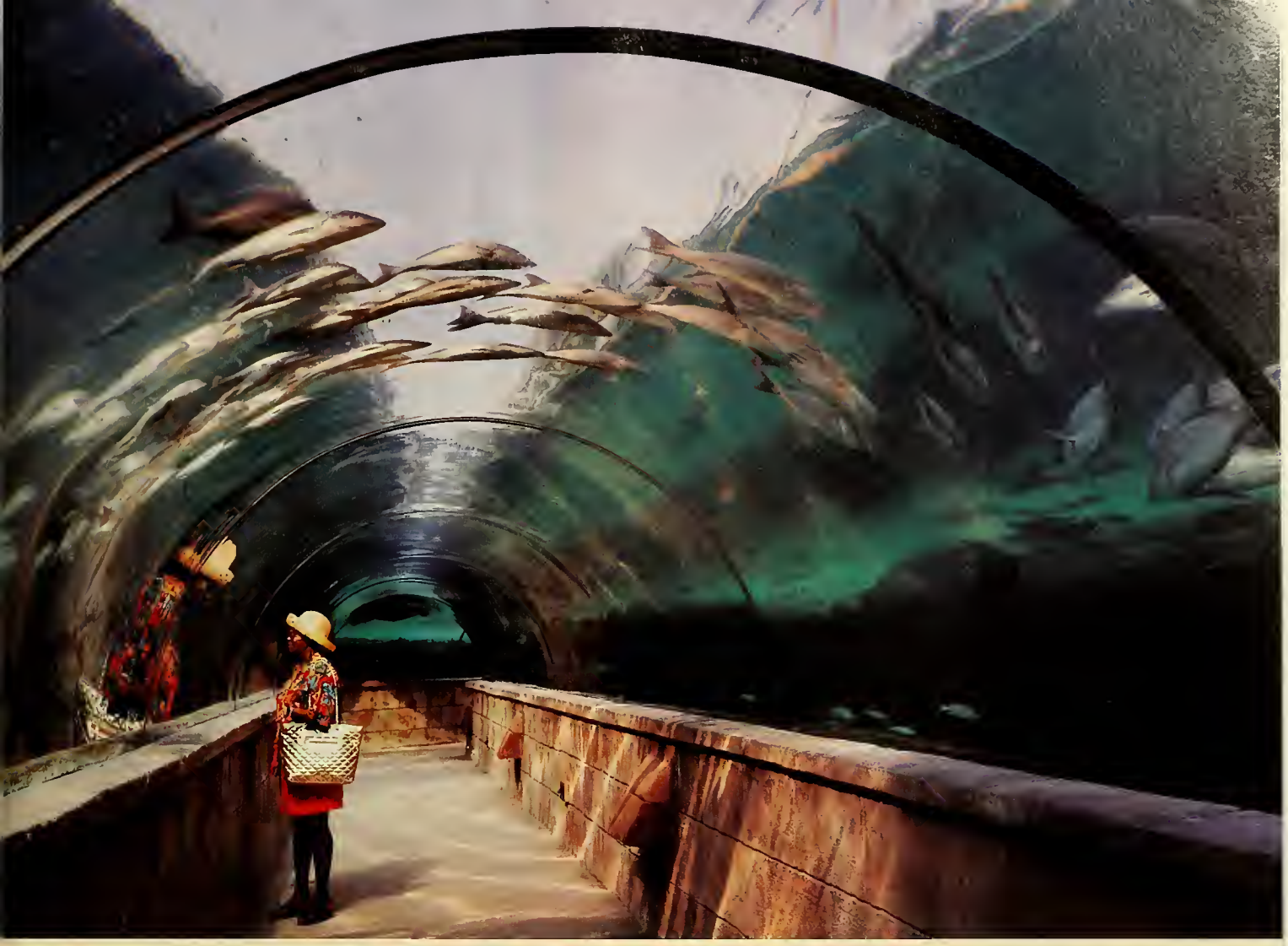


Early aquarium (from an engraving, c. 1875) was not so different from what one might find in an office or a living room today.

In any event, the keeping of fishes as household pets did not become popular until the first half of the eighteenth century, and the first public aquariums appeared in Europe only in the early 1850s. By 1928 some forty-five public or commercial aquariums had been installed worldwide, and today many towns and cities have aquariums that attract hundreds of thousands of visitors a year.

As for the popularity of fishes kept as pets, in the United States they rank behind only cats and dogs. More than 7 million households give fishes a home. For some people the animals are just color-coordinated living furniture. But for others, the family fish tank is a living laboratory that ignites the first spark of scientific curiosity and engenders an enduring love of nature.

But the popularity of fishes cuts two ways. On the one hand, public aquariums and the practice of keeping tanks at home increase people's awareness of aquatic nature. The resultant demand for aquatic organisms to fill the tanks creates livelihoods for animal suppliers, and the proceeds from the trade are particularly welcome in low-income coastal communities in the tropics. On the other hand, the burgeoning demand for live fishes and invertebrates can put heavy pres-



Public aquariums, such as this one at Paradise Island in the Bahamas, are sometimes designed to virtually surround the visitor, in an effort to cultivate a better appreciation for aquatic wildlife and its environment. Developing that public appreciation, fostering other educational activities, and distributing funds to conservation projects in the field are the three chief ways public aquariums can help protect threatened species and ecosystems.

sures on tropical ecosystems. Yet the tension between keeping up with demand and maintaining the ecosystems that supply it need not become a wasting, zero-sum game. If the methods for harvesting animals from tropical ecosystems are managed carefully, suppliers will be able to provide lively displays for fish tanks in the dentist's office, while helping ensure that the source populations continue to thrive in the wild.

On any list of the roles and cultural value of aquariums, entertainment must rank high. In North America alone some 134 million people visit the 200 or so accredited institutions of the American Zoo and Aquarium Association each year: more people than attend all major-league sports venues combined. And beyond pure entertainment, who would dispute the atmosphere of relaxing serenity aquariums have to offer, the opportunity to contemplate the otherworldly grace and beauty of the aquatic realm? Aquariums afford access to worlds that we, as terrestrial creatures, must share, yet rarely glimpse. Moreover most large public aquariums are not only responsive to the entertainment value of healthy animals, but fully committed to educating their visitors about the aquatic environment, its fragility, and the need for its conservation.

Large public aquariums can also play direct roles in conservation, in addition to their educational one. Some have breeding programs for marine mammals, invertebrates, and other species, including a few marine fish species they can raise in captivity. Many channel funds to reserves, parks, and other conservation programs in the field.

Still, probably the most consequential effect of aquariums is via their role as economic engines; that is particularly true for small, privately owned fish tanks in businesses and homes. The annual trade in

live marine animals is estimated to be worth between $200 million and $300 million, and still growing. Such figures translate into large numbers of wild animals taken from the sea, mainly from reefs: some 24 million ornamental fishes, 12 million pieces of coral, and 10 million ornamental invertebrates are sold each year, and many more die along the way.

The trade in freshwater organisms is even larger than the marine trade. But the freshwater trade relies heavily on animals raised in captivity. Freshwater fishes, by their very nature, are already adapted to life in relatively contained habitats. Their eggs tend to be large, well provisioned, and they sometimes even get parental care. Marine species, by contrast, tend to deposit, fertilize, and then abandon their small eggs to their fates. When the eggs hatch, the tiny fry generally have a protracted larval stage, during which they are dispersed over large ocean areas as plankton. Thus the larvae of most marine fish species are smaller, less hardy, and more difficult to feed than their freshwater counterparts.

As a result, freshwater fishes tend to fare much better when raised in tanks than marine species do. As many as 90 percent of the freshwater fishes commonly found in aquariums have never known a river or a lake; most have been reared in large facilities in Singapore or Florida and can no longer even be considered wild animals. Ironically, in fact, many freshwater habitats have become so degraded that some species are more common in dentist's offices than they are in the wild—some species of African lake cichlids fit into this category. A few species of pupfish are actually extinct in nature yet thrive in household aquariums.

The great majority of animals in the marine trade, however, must be systematically hunted and taken from the wild. Of the 1,500 marine fish species that are regularly traded, only about seventy have been successfully bred in captivity. And of those seventy, only a handful are currently raised in quantities viable for commercial use.

Compounding the difficulty of captive breeding is the fact that most marine fishes are taken from coral reefs, themselves among the most endangered of marine habitats. Although reefs account for just one-quarter of 1 percent of the marine environment, they are home to some 4,000 marine fish species, or roughly a third of the total. Reefs also harbor some 800 reef-building coral species, and innumerable other invertebrate species. Yet coral reefs are threatened by a deadly mélange that includes global warming, coastal development and runoff, marine pollution, destructive fishing practices, and overexploitation.

Most marine fish species for both public and private aquariums—such as this diverse school at Paradise Island—must be collected in the wild. Raising them in captivity has proved difficult and often impossible because of the needs of their minuscule larvae.

The nature of the marine fisheries trade presents government regulators and conservation advocates with something of a dilemma. As I noted earlier, the trade is an important industry for residents of coastal communities close to coral reefs, communities that are generally impoverished. Unfortunately, though, many of the collection techniques the industry has historically relied on are destructive and unsustainable, and its husbandry practices are often poor. Moreover, until recently no one could determine an appropriate response to the situation because sound data on the trade and its impacts on reef communities were simply lacking.

At least now the data shortage has been corrected. A new report, *From Ocean to Aquarium: The Global Trade in Marine Ornamental Species*, published in 2003 by the United Nations Environmental Program (UNEP) and its biodiversity and policy implementation arm, the World Conservation Monitoring Center (WCMC), is a thoughtful and

data-rich synthesis of the issues. Much of the data I mention here comes from this report (available online at www.unepwcmc.org/resources/publications/WCMC_Aquarium.pdf).

When I first read the UN report I was struck by a certain pleasant happenstance. Its publication coincided with the nationwide release of the animated feature film *Finding Nemo*. In the story, a father-son fish tale, a young clownfish is kidnapped from the family's anemone home by an oblivious scuba-diving dentist. The story follows the adventures of Nemo's timid dad, Marlin, who sets out to rescue his son from incarceration in the dentist's dismal office in Sydney, Australia. It occurred to me that at the same time Marlin was trying to find Nemo on the silver screen, the new UN report was offering real insights into how the rest of us can save Nemo—or at least his kind.

Worldwide there are twenty-seven species of clownfish in the genus *Amphiprion*, and, according to the report, about fourteen of them are regularly raised in captivity (which makes them a rarity among marine aquarium fishes). Clownfishes, as the movie suggests, have a special symbiotic relation with certain species of sea anemone. Anemones, together with organisms such as corals and jellyfishes, are cnidarians; like their relatives, anemones have tentacles covered with harpoonlike stinging capsules called nematocysts. The stinging cells can cause plenty of damage to the anemones' predators and prey alike, but clownfishes are immune to the stings of their home anemone.

Whatever the source of this immunity, it enables each clownfish to swim freely among its home anemone's tentacles. That provides the fish with a safe haven and a home for life. And in return, the fish helps protect its host anemone from predators. Most clownfishes are hardy and relatively easily kept in a fish tank; as a result clownfishes have become popular pets. Thousands of anemones and more than 145,000 of one particular fish species, the clown anemonefish *(A. ocellaris)* are sent to market each year. Ironically, given the conservation message of *Finding Nemo*—that life in the wild is better than incarceration in a tank—sales of clown anemonefish and similar species rose considerably after the film opened, according to Paul Holthus, president of the Marine Aquarium Council in Alexandria, Virginia.

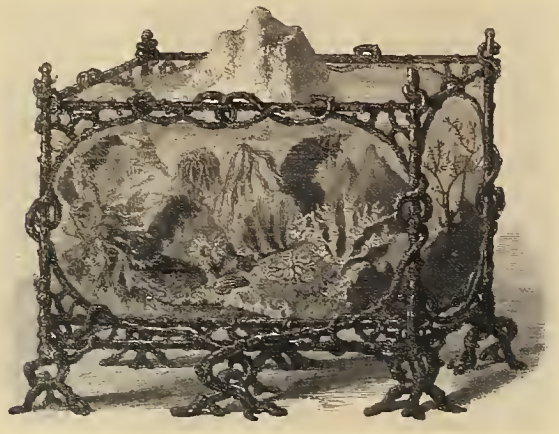
That unintended consequence notwithstanding, there's a great deal to like about *Finding Nemo*—both in its conservation message and in its wonderfully animated and entertaining story. But I can't restrain myself from two ichthyological asides. The first is about the film's anthropomorphic characterizations. In a crucial scene of the movie, Nemo's mother and his unhatched siblings are eaten by a barracuda. Nemo is the lone larva to survive. Nemo's father becomes an overprotective worrywart after the disaster, and both quite evidently miss Nemo's mother very much.

The trouble with all this understandable humanizing of the characters is that in nature, clownfishes are protandrous hermaphrodites. What that means is that they start life as males, but under certain circumstances become females. Typically an adult pair—a female and a male—and between two and four smaller fish live together in a single anemone. The dominant, largest fish is generally a female. She possesses functioning ovaries and degenerate testicular tissue. The next-largest fish has functioning testes as well as some latent ovarian cells. If the dominant female dies, her mate's gonads cease to function as testes and the egg-producing cells become active. Simultaneously, the largest of the non-

breeding individuals becomes the functioning male.

So, had Marlin, Nemo's dad, just hung around for a while, he would have become a she and Nemo would have had his mom back. Then, with time, Nemo himself would have matured into a functional male, and . . . but perhaps that's all a bit too dark for the story line.

My second thought as an ichthyologist is, What species is Nemo? According to the UNEP-WCMC report, *A. ocellaris* is the second most commonly imported marine ornamental fish species worldwide. Its close cousin *A. percula*, however, is the clownfish more commonly imported into the United States. Both species look very much like Nemo—though I'd say *A. ocellaris* is closer to what the artists at Pixar Animation Studios were drawing. The species are almost identical, except for some minor color differences and the fact that *A. ocellaris* usually has eleven spines on its dorsal fin, whereas *A. percula* has ten.



Aquarium, from an engraving, c. 1859

But here's the clincher: The range of *A. ocellaris* extends into the Indian Ocean from the coast of northwestern Australia, whereas *A. percula* is from the western Pacific and occurs on Australia's Great Barrier Reef. But in the story, Nemo's dad Marlin hitches a ride on the East Australian Current to get himself to Sydney. Because the current moves eastward he would pretty much have had to live somewhere in the western Pacific, probably on the northern Great Barrier Reef. That makes Nemo *A. percula*, the orange clownfish, no question. And to think anyone ever told me that my studies of fish taxonomy would never get me anywhere.

In spite of the bleaker aspects of the marine-aquarium trade, there is plenty of reason for optimism. Animals taken from reefs for aquariums are among the reef habitat's most valuable products. A pound of fishes harvested from the reefs of the western Indian Ocean and sold for aquariums earns more than $200 for the local fishermen; the same pound sold for food would yield them less than $3. Similarly, live coral earns some $6,300 per ton for the gatherer, whereas the same ton of coral taken for limestone fill—often extracted with dynamite—sells for around $50. Hence market forces could provide a strong financial incentive for both subsistence harvesters and local authorities to maintain and protect their reefs.

For that to happen, though, both groups must end destructive, unsustainable harvesting methods. For example, methods such as the use of sodium cyanide to "temporarily" poison or stun fishes are still practiced, and must be stopped. And progress is being made. In the Philippines an innovative program run by the Philippine government together with the Honolulu-based International Marinelife Alliance has been retraining fishermen to use nets to harvest fishes instead of cyanide. Education programs in both the media and schools have stressed the value of healthy reefs to residents of coastal communities. Five facilities for detecting cyanide in the harvested fishes were set up, and they, too, have helped lower the fraction of fishes testing positive for cyanide from 80 percent in 1993 to 20 percent in 1998.

Such a program offers hope that harvesting reefs need not obliterate them. To be effective in the long term, however, the programs will demand vigilance and commitment by the governments of the source countries as well as by the governments of the importing countries. Governments and non-governmental organizations can work together to implement export quotas and permits, establish marine reserves, and temporarily close critical areas to help promote sustainable practices.

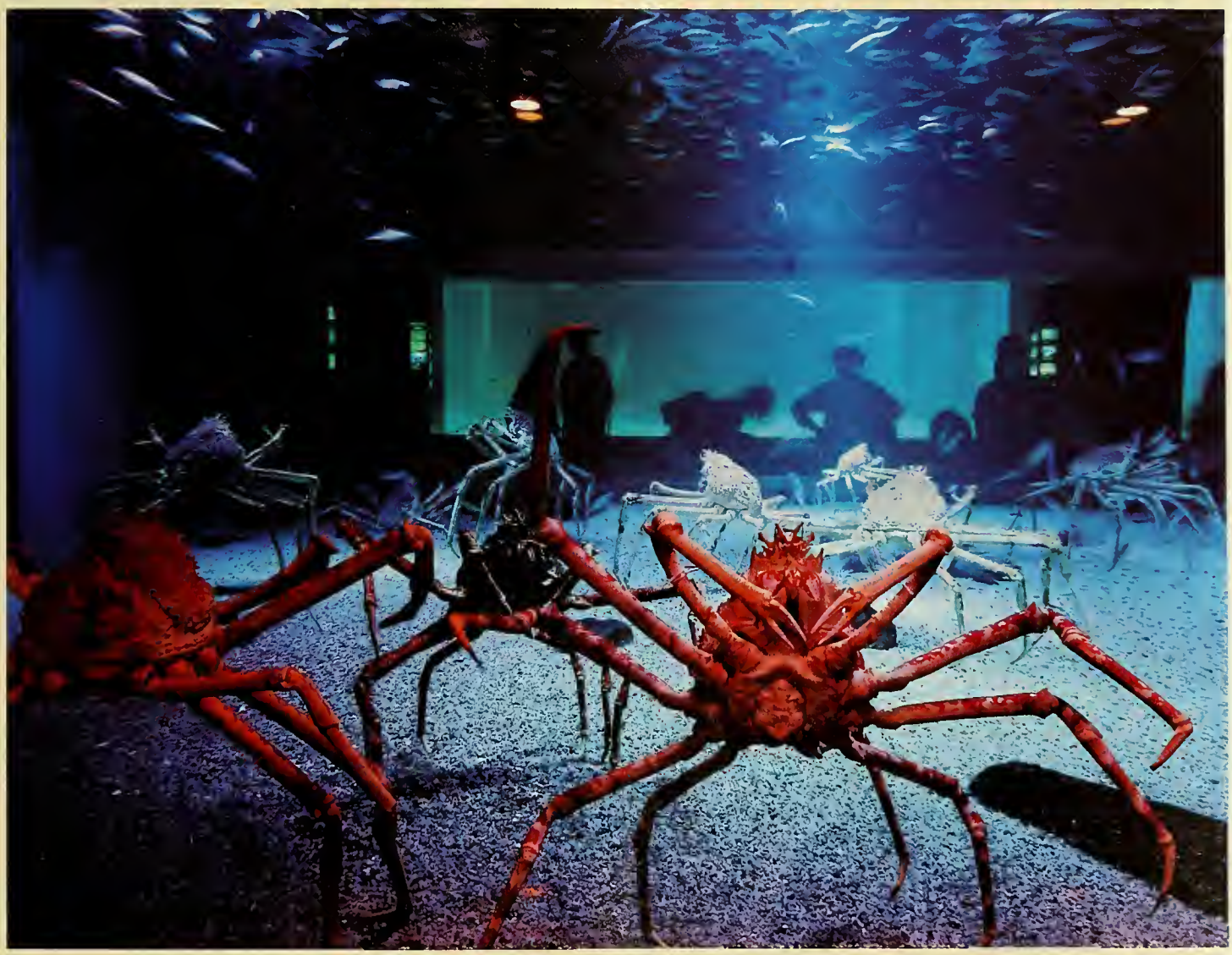
The scientific study of reef organisms and their role in a functioning ecosystem is another obvious course to pursue. Data gathered on the suitability and resilience of various organisms to harvesting, on their life histories, and on their adaptability to life in aquariums will be needed to make sound decisions. More data may also help investigators develop techniques for raising marine animals in captivity, thereby reducing the pressures of harvesting on their counterparts in the wild.

But perhaps the best approach to saving Nemo is the one based on the simple idea that an educated and concerned body of consumers can have a major impact on how the industry supplies the organisms the public demands. Groups concerned with the fate of dolphins, and of tuna, cod, salmon, sturgeon, and other food fishes, have long advocated such a strategy. Similar consumer-based

approaches are being developed to encourage best practices in the harvesting, holding, packaging, and transportation of animals for the aquarium trade. The Marine Aquarium Council (MAC), for instance, seeks to create standards and certify sustainable practices for the trade; the council's strategy is then to stimulate consumer demand for the certified products. A list of the companies now seeking certification, or which already sell MAC-certified marine animals, can be found at www.aquariumcouncil.org

Whenever you or I enter a restaurant or a supermarket, we have innumerable choices about the seafood we buy. In making our choices, we vote with the pocketbook, and that vote carries enormous weight with producers. We have the power essentially to force producers to minimize environmental costs—for unless they do, we will buy elsewhere. If the real cost, for instance, of gorging on "all you can eat" seafood buffets were part of the advertising campaign, I doubt we would find the menu so appetizing.

The same is true when we choose our aquarium pets. Guillaume Rondelet might have had some idea that he was initiating a new science when he wrote his book on marine life. But Mme Rondelet, who would never have guessed that fishes might someday be endangered, could never have known that she might be taking the first step toward saving fishes when she kept one of them in a jar. □



Giant Japanese spider crabs—harvested both for food and as an aquarium attraction—amble on the floor of a display at the Kaiyukan Aquarium in Osaka, Japan. Consumers, whether buying food, filling their own fish tanks, or visiting large aquariums, have the power of the purse strings to insist that the market that provides the animals does not simultaneously destroy them.

The photographs that accompany this article were made by Len Jenshel. They are reproduced from the book *Aquarium*, by Diane Cook and Len Jenshel (Aperture Foundation, Inc., 2003).

Movie poster for Journey to the Center of the Earth, *1959, based on Jules Verne's 1864 classic*

Deep Impressions

The Earth's core may never be sampled directly, but its effects make themselves felt every day.

By Robert Zimmerman

Although it lies less than 2,000 miles directly beneath our feet, the Earth's core is off limits. The deepest any human being has traveled in that direction is 6.78 miles, by diving vessel into the Mariana Trench, in the western Pacific Ocean. The farthest down any drill has bored—on the Kola Peninsula in the Russian Arctic—is 7.62 miles. And the deepest rocks anyone has inspected—regurgitated to the surface through volcanic action—come from at most 400 miles down. And yet, with indirect measurements and laboratory experiments, geophysicists are building up a reasonably detailed picture of Earth's inner composition and structure. As a result, they are beginning to apply that knowledge to explain some peculiarities about the way our planet acts.

Part of the reason, in fact, that geophysicists can say anything at all about the "deep Earth" is that it is by no means totally isolated. Its effects, some subtle, some overt, are felt every day, both on the surface and far above it. Every compass owes its workings to the magnetic field generated in the Earth's core: both human-made compasses, the kind carried along for a walk in the woods, as well as a profusion of natural compasses—literally, magnetic materials in the heads and bodies of many birds and other animal species—that have been recognized as the secret behind those species' navigational virtuosity.

In space, the Earth's magnetosphere, or magnetic field, deflects the streams of charged atomic nuclei and other particles that emanate from the Sun, as well as from deep space. (In *The Core*, one of last year's special-effects blockbuster movies, the Earth's magnetic field dissipates. That's a disaster, according to the movie, because within a few months it exposes all life on the surface to the killing rays from space. Unfortunately for the movie's premise—though fortunately for us—the upper atmosphere is also quite effective at shielding the surface from incoming particles.) The magnetosphere also shapes the solar wind into streams and sheets of colored lights—the auroras—around the Earth's north and south magnetic poles.

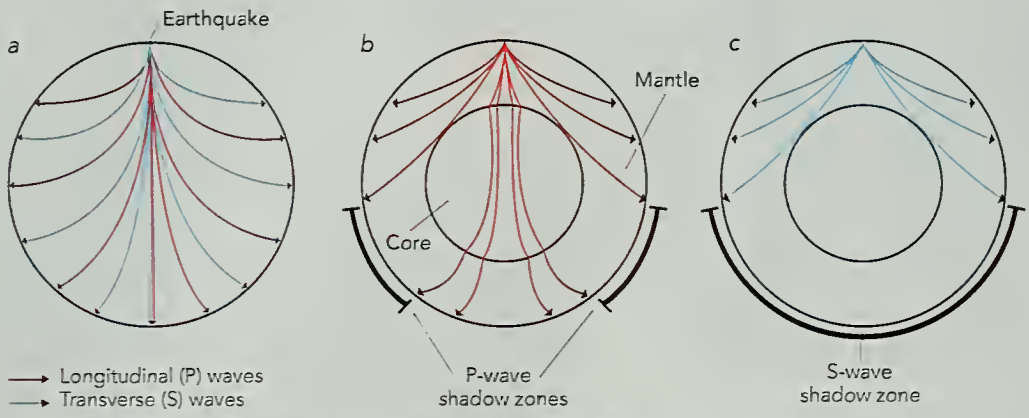
But the most important surface effect of the core is so familiar that it is seldom even recognized for what it is. The weight of objects—the pull of gravity at the surface—on a planet the size of ours would be far less than it is if the density of Earth's innards were roughly the same as the density of most of the rocks at the surface. Part of the reason the density increases toward the center is that the deeper stuff is compacted by the overlying weight. But compaction alone does not account for the degree of surface gravity. In fact, until the turn of the twentieth century, one of the few reasonable conjectures about the Earth's interior was that it had to be made of something different, and certainly something much denser, than most of the kinds of rock accessible at the surface. Some geologists guessed that the innermost region was made up of molten iron, but they couldn't be sure.

All that changed once the first accurate, sensitive seismographs were developed and distributed around the globe. The scientific study of the deep Earth really began only when seismologists recognized that the squiggle patterns registered on their machines by distant earthquakes reflected the inner structure of the Earth, much as an X ray reveals bone and other tissues beneath the skin.

In 1906 the English geologist Richard D. Oldham observed that the waves passing through or near the Earth's center did not travel in the uniform way that would be expected if the interior were made up entirely of just one kind of material. He concluded that inside the planet is a dense iron core about two-fifths the diameter of the Earth. Other workers soon refined Oldham's picture, determining that Earth is

built in layers, somewhat like a coarse onion, with a core about 4,300 miles in diameter.

The seismograms recorded for various earthquakes typically exhibited a pattern: for each shake of the ground at a quake's epicenter, the recording pen would register two small squiggles followed by a large one. The first two squiggles were caused by waves traveling through part of the Earth's dense interior. The last squiggle represented waves reaching the seismograph more or less along the ground. By comparing seismograph recordings at various distances from an earthquake's epicenter, investigators traced the boundary between the Earth's crust and the planet's denser interior.



Seismic waves show that the interior of Earth is differentiated into at least two distinct kinds of material, a core and an overlying mantle. A uniform solid would become increasingly dense toward the center, because of the weight of the overlying material; the density variation would cause seismic waves to curve uniformly (a). But observations of longitudinal waves, or P-waves, show that they leave a characteristic "shadow" on part of the hemisphere opposite their source. The "shadow" is explained by the refraction of the P-waves as they pass through the denser core (b). Transverse waves, or S-waves, are completely blocked by the core (c), which shows that at least the outer core is liquid. Highly refined studies of seismic waves reveal a solid inner core.

The presence of the first two, smaller squiggles was an even more telling clue. The first recorded the arrival of longitudinal, or compression, waves—much like sound waves—which travel as compressions and expansions of the medium between the earthquake and the seismograph. Those waves became known as primary, or P-waves. The second squiggle was caused by transverse waves, side-to-side or up-and-down disturbances comparable to an ocean wave. The transverse waves were called secondary, or S-waves. The discovery that S-waves failed to arrive at some regions on the Earth's surface in the hemisphere opposite an earthquake provided the key piece of evidence of a liquid core. S-waves, unlike P-waves, cannot travel through a liquid [*see illustration above*].

Then, in 1936, the Danish seismologist Inge Lehmann took a closer and more detailed look at the speed of the P-waves that pass through the core. Oldham's iron core, Lehmann realized, is actually made up of a solid inner core about 1,500 miles across, surrounded by an ocean of molten iron 1,400 miles deep. Given the pressure on the iron ocean exerted by the weight of 1,800 miles of overlying rock, the temperature of the iron would have to be much higher than 2,795 degrees Fahrenheit, the melting point of iron at Earth's surface. Investigators also quickly realized that convection currents in this hot iron ocean would generate electric currents. Any electric current generates a magnetic field, so the prime suspect for the source of the Earth's planet-wide magnetic field became the liquid iron core.

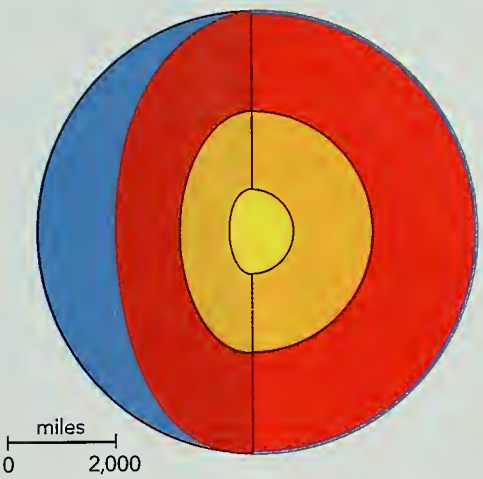
By 1952 the geophysicist Francis Birch was able to synthesize the accumulating information about the dimensions and properties of Earth's inner regions, compare it with the known properties of solid and molten iron, and determine that the core was not as dense as Oldham and Lehmann had originally thought. Birch calculated that about 10 percent of the molten layer must be made up of lighter materials mixed in the iron.

Birch further concluded that the core had once been entirely molten, but that, as the Earth has cooled, the inner core has slowly been condensing out of the liquid as a crystalline solid. As the iron atoms lock themselves into a crystal structure, the unknown lighter materials become increasingly concentrated in the layer of liquid iron closest to the boundary of the crystal. Those lighter materials slowly rise upward through the molten iron, creating convection currents in the outer core. That movement of material, known as compositional convection, is largely responsible for generating Earth's magnetic field.

Much has been subsequently added to Birch's synthesis of what is known about the core. With faster computers and a growing network of more sensitive digital seismographs, earth scientists have been able to supply intriguing new details to the model. A major discovery came in 1986, when a group of investigators at Harvard University ana-

lyzed the travel times of waves traversing the entire width of the Earth, through the inner core. To their surprise, they found that waves traveling parallel to the equator took 2 to 3 percent longer to make the journey than waves going from pole to pole. The data suggested that the iron crystals of the solid inner core are not jumbled randomly, but instead are packed neatly, parallel to the Earth's axis.

Geophysicists have since refined those conclusions. It turns out, for instance, that not all the crystals in the inner core are uniformly arranged. In the Western Hemisphere, the crystals are more closely aligned with one another, thereby speeding seismic waves on their way. In the Eastern Hemisphere, however, the crystals in the top 250 miles of the inner core seem to be randomly oriented, and so they have no "streamlining" effect on the seismic waves traveling through them. Why such an asymmetry should exist is not clear. Kenneth C. Creager, a seismologist at the University of Washington in Seattle, calls it "the $64,000 question."



Onion-like shells of differing materials make up the inside of the Earth. The iron core at the center may once have been entirely molten, but as the planet cools, the molten iron in the outer core (orange), a shell now about 1,400 miles thick, solidifies and condenses onto the solid inner core (yellow), about 1,500 miles in diameter. The movement of lighter impurities forced out of the solidifying iron is largely responsible for generating the electric currents in the liquid outer core that are the basis of the Earth's magnetic field. The core is surrounded by a mantle of dense, mostly solid rock (red), about 1,800 miles thick. The continents and the floors of the oceans are parts of a thin crust (blue), which varies from three to forty-eight miles thick.

Other seismic studies in the 1990s pointed to an even more intriguing—in fact, downright weird—possibility: the solid inner core may be rotating slightly faster than the shell of mantle and crust that surrounds it. In other words, the liquid iron ocean acts as a kind of fluid coupling between the solid core and the solid mantle, actually allowing some slippage. In 1996 Xiaodong Song, now of the University of Illinois at Urbana-Champaign, and Paul G. Richards of the Lamont-Doherty Earth Observatory in Palisades, New York, noticed that the travel times for seismic waves passing through the inner core had been changing slowly in the preceding several decades. Most seismologists think that, at least in recent decades, the slippage has amounted to about a third of a degree per year. But uncertainty persists: Is the mismatch a regular phenomenon, or is it just the "upswing" in a longer-term oscillation? If the latter, there could also be periods when the core rotates a little more slowly than the outer layers of the Earth.

The discovery of the slippage has put a new spin on astronomical data from the past 150 years, which show that the length of the day has slowly fluctuated by as much as six milliseconds. In fact, in the late 1980s Jean-Louis Le Mouël and his colleagues at the Laboratory of Geomagnetism in Paris had extensively examined the connection between the length of the day and the fluid in the outer core. They calculated that the time variations could be explained by variations in the transfer of angular momentum between that fluid and the mantle. The same interaction, they argued, accounted for the slow westward drift that has been observed in certain features of the Earth's magnetic field.

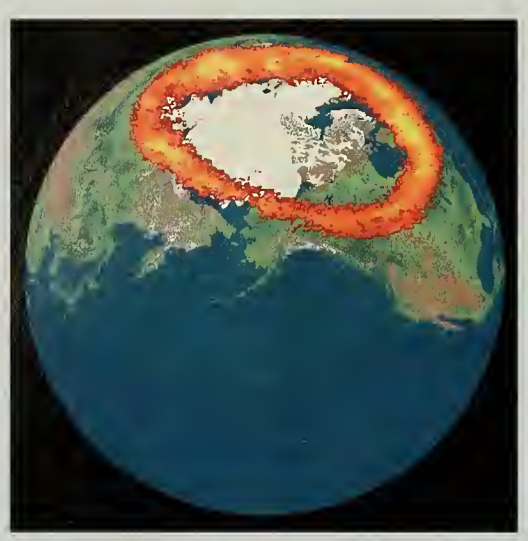
As seismologists deployed increasingly sophisticated seismic equipment to peek into the Earth's innards, other earth scientists began to focus on laboratory techniques for filling in the many gaps in knowledge about how materials behave at the high pressures and temperatures thought to exist in the core. For example, geophysicists since Birch have known that the liquid iron in the outer core is slowly solidifying. Yet the freezing point of iron within the core, where pressures are so extreme, remains a mystery. The best current estimate is about 9,300 degrees F plus or minus 1,300 degrees. But the actual figure could fall far outside that range, depending on the nature of the lighter materials that, as Birch calculated, make up about 10 percent of the molten iron ocean.

Geophysicists have suggested a number of candidates for these impurities, including oxygen, potassium, silicon, sulfur, and even hydrogen. Testing the properties of molten iron combined with various mixes of these elements in the laboratory could help identify the lighter constituents of the core, because their presence substantially changes the properties of the melt. Oxygen, for instance, raises the

freezing point of iron; sulfur lowers it. Different elements require different concentrations to explain the data: a 1 percent mixture of oxygen freezes at 12,000 F, whereas an 8 percent mixture of sulfur freezes at 5,800 degrees F.

In 1958 workers at what was then called the National Bureau of Standards and at the University of Chicago developed the diamond-anvil cell, a tool for re-creating the incredibly high pressures that prevail in the Earth's core. The device is quite simple in design, not unlike a high-tech nutcracker, and generally small enough to fit in a briefcase. Two small but precisely carved gem-quality diamonds are placed in complementary holders so that their smallest flat surfaces face each other. To create a gasket, a disk of steel is placed between them, and the diamonds are pressed together to create an impression on the disk. A hole the thickness of a human hair is then drilled in the center of the impression, a sample of whatever material is to be tested is placed in the hole, and the diamonds are squeezed together. The mechanical advantages built into the tool are so high that, just by turning a screw by hand, the pressure on the sample within the small hole can be cranked up as high as several million atmospheres. And because the diamonds are transparent, they serve as windows both for probing and heating the sample with a laser, and for observing the composition and structure of the sample at such temperatures and pressures.

Although its ease of use makes the diamond-anvil cell an excellent tool, experiments to simultaneously reproduce the highest temperatures and the highest pressures at the Earth's core are exceptionally challenging. For an alternate tool to study those conditions—if only for a very short time—earth scientists can resort to high explosives. In one setup, several hundred-pound disks of explosive material are detonated, driving a steel plate against the sample and sending a pulse of high pressure through the sample. Optical and electronic sensors measure the temperature and other properties of the sample for the few microseconds before it is obliterated.



Shimmering aurora borealis (here shown as an orange and yellow ring from a satellite photograph superposed on an image of the Earth's surface) results when electrically charged particles spewed out by the Sun are intercepted by Earth's magnetic field and, as they are guided downward toward the magnetic pole, collide with the atmosphere. The lines and poles of the magnetic field roughly align with the planet's axis, because they are influenced by the alignment of the iron crystals that make up Earth's solid inner core. The iron crystals are not randomly oriented, because they form under the influence of Earth's spin.

A second rapid-compression technique, developed in the 1970s, is to fire a small projectile at the study sample from a two-stage, sixty-foot cannon called a gas gun. A hunk of plastic and lead, fired down the first stage, a barrel half the length of the gun and six inches in diameter, acts like a piston to compress hydrogen gas against a diaphragm at the end. When the pressure becomes high enough to burst the diaphragm, the gas spews into the second stage, a barrel also thirty feet long but only an inch across. The gas pressure in the second barrel accelerates another composite projectile to velocities exceeding four miles per second. When the projectile hits the target sample, it generates the desired pressures and temperatures.

Such experiments have shown that solid iron can assume one of four crystalline phases, or geometric arrangements of the iron atoms; the phase depends on the temperature and pressure. Most investigators think the "hexagonal close-packed" phase, the most compact of the four, with about twice the density of ordinary solid iron, is the most likely state for iron in the inner core. Several experiments, however, have suggested that a variation of the "body-centered cubic" phase might also be stable in the core. Because the latter crystal is less dense, its presence would affect the density difference between the solid inner core and the liquid outer core, which in turn would affect the theory of how compositional convection generates the Earth's magnetic field.

Another way to study crystalline structure in iron is to substitute other materials—from seawater to zinc—that can form hexagonal close-packed solids. That research suggests that as the liquid iron in the outer core solidifies, hexagonal platelets grow and assemble themselves into stacks like piles of poker chips. The Earth's spin favors the growth of platelet stacks that run parallel to the Earth's axis. At the boundary between the inner

and outer cores, moreover, the crystallizing and liquid iron mingle to form a "mushy" region as much as a couple of miles deep.

The improved data (coarse though it remains) has made it possible for theorists to make the first reasonable conjectures about what is going on inside the Earth, and how those processes affect its surface. For example, the improved seismic data persuaded earth scientists that the topography of the inner surface of the mantle is quite rugged, with peaks and valleys ranging in size from several hundred feet to several miles. Soon after that consensus formed, others suggested a mechanism for the variations in the momentum transfer between the liquid core and the mantle: they could be caused by currents and eddies in the liquid iron ocean as it washes against the upside-down hills of the solid mantle above it.

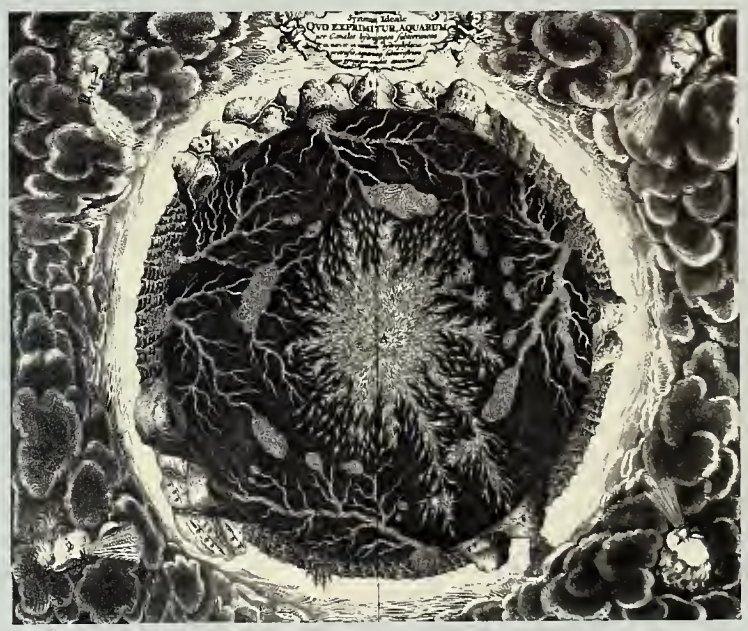
Richard A. Muller, a physicist at the University of California, Berkeley, has sought to link the interaction of the inner core, outer core, and mantle to a range of other phenomena, notably asteroid impacts, mass extinctions, hot spots, and magnetic field reversals. Muller has always been interested in the effects of catastrophes on geologic history. "I sometimes joke my work has been one disaster after another," he says. According to Muller's hypothesis, as the unknown lighter components in the Earth's outer core drift outward, they pile up on the underside of the solid mantle, almost like a strange kind of snow, accumulating on the mantle's topsy-turvy slopes. Eventually, the material overloads itself and tumbles outward, away from the denser iron and toward the lighter mantle in a strange, bottoms-upward avalanche.

Most such landslides are too small to matter. But Muller notes that a large asteroid hitting the Earth at an oblique angle could shake the mantle violently enough to trigger avalanches of vast proportions. During such giant, inverted landslides, the sudden agitation of the liquid outer core could lead to a hiccup in the Earth's magnetic field, a temporary shutdown. When, after a period of several thousand years, the field came back to life, there would be a fifty-fifty chance that its polarity was reversed. The mechanism, Muller argues, would explain the seemingly random and periodic reversals in the Earth's magnetic field, episodes recorded in rocks of known geological age.

Muller further notes that if an avalanche is large enough, it would expose a substantial area of the solid mantle directly to the hot, liquid iron ocean. The mantle would melt, giving rise to a plume, or flow, of magma that would reach all the way to the Earth's surface. So-called flood basalts, the result of massive outpourings of lava, mark certain huge regions of Earth's surface. Muller's theory might account for their origin.

Finally, Muller's theory offers an explanation for the period from 120 million until 85 million years ago when there were no reversals of the Earth's magnetic field. According to Muller, a large asteroid impact could have triggered simultaneous landslides across the entire mantle base, producing a plume that eventually created the Ontong-Java plateau, the largest flood basalt on the Earth's surface. After such a sweeping collapse, no avalanches would take place for many millions of years, until a new layer of unstable material could accumulate on the mantle slopes. That could account for the apparent pause in the reversals of the magnetic field.

Muller's theory presents some tantalizing possibilities, but by its very sweep it also demonstrates how hard it is to keep theories about the deep Earth well grounded. "It is very speculative," remarks Michael



Seventeenth-century conception of Earth's interior portrays underground water sources and a fire-filled center. The drawing is from Mundus Subterraneus *(1664–65), by Athanasius Kircher.*

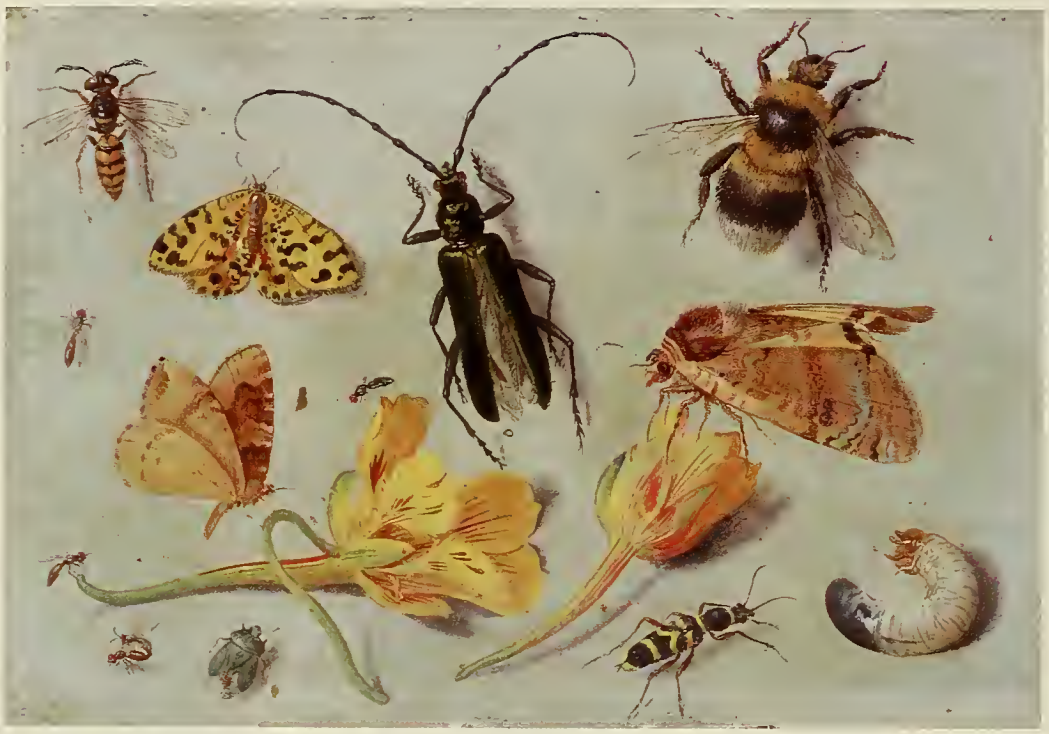
I. Bergman, a geophysicist at Simon's Rock College in Great Barrington, Massachusetts. "Until you do the work to back it up, it is merely an outrageous, if neat, hypothesis." Still, investigators remain remarkably enthusiastic and hopeful about what is, after all, a young and fresh field. "That's what I find exciting," remarks Kenneth Creager: "There are new things to be discovered. It is just a matter of coming up with a clever way to pull new knowledge from the data." □

REVIEW

Better Living through Chemistry

An entomologist recounts a lifetime of adventures exploring the secret defenses of bugs.

By Robert L. Smith



Jan van Kessel, the Elder: Bumble bee, beetle, chrysalis, moth, wasp, and nasturtium; seventeenth century

If you were starting out in science any time after the mid-twentieth century, the typical formula for career success was to identify a narrow research topic and then stick to it for your life's work. In biology your focal point would probably be some problem in a subdiscipline such as anatomy, behavioral science, ecology, embryology, genetics, or physiology. A specialist in animals might spend an entire career studying only reptiles, or birds, or mammals. And a scientist who works with such relatively small groups may come to know them well enough to love them. But in the study of insects, the variety is almost overwhelming; the described species alone represent three-fourths of the planet's fauna. There are scientists who are fond of ants, or butterflies, or dragonflies—or perhaps even a particular family of beetles. But even among scientists who call themselves entomologists, those who develop such a wide acquaintance that it leads to an understanding of, and even fondness for, *all* insects are a rare breed indeed.

For Love of Insects
by Thomas Eisner
Harvard University Press, 2003; $29.95

Thomas Eisner belongs to that rare breed. In his new book, *For Love of Insects,* Eisner describes a lifetime of field observations and laboratory experiments on an amazingly broad sampling of the class Insecta, together with the rest of the terrestrial arthropods. Along the way, he is a font of information about the workings of myriad biological adaptations. Together with the book's exquisite and detailed photographs, provided mainly by the author, his graduate students, and other colleagues, Eisner's text is the research retrospective of a self-described "incorrigible entomophile"—

one of the world's most visible and admired entomologists.

Eisner has won both scholarly and popular acclaim, not by shining a single pinpoint of light deep into the vast unknown world of insect biology, but by puncturing the darkness at a thousand different points. What his work illuminates is an amazingly rich tapestry of biological adaptation among the six- (or eight- or "thousand-") legged creatures. Edward O. Wilson of Harvard University, another legendary entomologist, has described Eisner in similar terms, as a kind of scientific pointillist: stepping back from Eisner's work, its accretion of very small dots and diminutive brush strokes reveal an overarching, coherent picture of a broad slice of nature.

As its title suggests, *For Love of Insects* is mainly about insects and science. But it is also a collection of engaging research stories, artfully told with humor and suspense by a fascinating guy. Eisner's talents, energy, and curiosity have led both to wonderful science and a glorious life. The reader does learn something about that life in the book, but only where it serves Eisner's narrative. So before I say more about the book itself, let me fill in a few biographical details.

Eisner was born in Berlin in 1929. His parents moved the family to Spain just before Germany's slide into the abyss, but the ferment of the Spanish revolution, and the imposition of another version of fascism, uprooted the family again. They moved briefly to Paris, then wisely abandoned Europe's tumult for the New World. Settling in Uruguay in 1937, they at last found a society relatively free from violence and persecution. Here young Tom began pursuing two passions that have stayed with him throughout his life: music and science. Both came to him quite naturally. Music was a staple of the Eisner household, and his father, a chemist, was also an accomplished pianist.

From his book we learn that Eisner's quest for the company of classical music makers led, later in his life, to the flutist (and chemist) Jerrold Meinwald. Their association grew into the most satisfying and productive interdisciplinary collaboration of his career, and one that has continued to this day. Another lifelong collaboration has grown from shared passions for the keyboard and field biology, and eventually included shared domicile and offspring: the collaborator is Maria Eisner.

His fascination with insects, particularly with "kept caterpillars," Eisner tells us, was part of his earliest consciousness. At a young age he learned to keep lepidopteran larvae alive and well by supplying them with forage from their host plants. His developing intellectual appetite for everything Insecta was well nourished by the immensely diverse insect fauna of his Uruguayan home. The family garden probably served as his earliest laboratory, where he first encountered the strange behaviors and odors of insects while netting tropical butterflies for his collection. Long before his family finally moved to the United States, in 1947, Tom Eisner was hooked on bugs.

Oddly, he got a bumpy start in higher education. He was rejected by several colleges, including Cornell, where he eventually became one of that university's most famous professors, and he spent two years at Champlain College in Plattsburg, New York. But he ended up at Harvard, where he majored in biology. Then, staying on for graduate work under the tutelage of the remarkable entomologist and insect paleontologist Frank Carpenter, he wrote a dissertation on the anatomy of ants. That useful, if slightly stodgy, topic fulfilled the requirements for his Ph.D. degree, but in no way did it presage the spectacular series of research adventures on which the young Dr. Eisner was about to embark.

The real beginning of Eisner's career was a chance field encounter with a beetle. The animal is small and nocturnal, and it spends its days resting in

aggregations with others of its kind under rocks near ponds and streams. At night, it sallies forth in search of flesh, usually that of dead or stranded amphibians, fish, or aquatic insects, which all occur in abundance at the interface of land and water. Aside from their interesting coloration, the beetles are unremarkable in appearance, but they possess a mind-blowing secret weapon after which they are named. They were to become the standard-bearer for Eisner's research life, and they have lent their name to the first chapter of Eisner's book: "Bombardier."

Eisner was drawn to the bombardier beetle through his olfactory sense. In the letdown after he completed his dissertation, Eisner writes, he began thinking about what he really wanted to do with his research career. His father had been fascinated by the chemical bases of scents, particularly the floral fragrances used in making perfumes, and he often worked in a home laboratory. The Eisner house was filled with exotic smells.

That environment apparently tuned Eisner's nose to fine acuity. He had always been aware of the odors associated with the insects he examined; in fact, he had often been able to discriminate subtle differences in odors among different insect species. Before he finished his degree, he had been thinking about how to combine entomological research with chemistry, an unconventional idea for the time. But when Eisner first plucked up a bombardier beetle and witnessed its powerful discharge of odorous spray, accompanied by an audible "pop!", his somewhat idle musings exploded into in-your-face reality.

Eisner became fascinated with insect weaponry. Insects are diminutive creatures, and their size has no doubt contributed to their success. Not only can a lot of them crowd into a given physical space, but, in the course of evolutionary time, new species can partition physical space and other available resources into many ecological niches—the conceptual compartments species need to coexist in the same habitat.

Nevertheless, small size, vast numbers, and stupendous diversity have been accompanied by a pervasive and deadly force: the huge collective appetite of other terrestrial animals for insects. Everybody loves to eat bugs: birds, fish, frogs, lizards, salamanders, and a host of mammals from bats to people are constantly on the lookout for these animated, rich nuggets of protein. But the group that exerts the most intense predatory pressure on insects is, naturally, other insects.

As a consequence of the constant threat of becoming a meal, natural selection has favored the evolution of a mind-boggling array of insect defensive mechanisms. Many of them include chemical weapons, such as the one deployed by the bombardier beetle. Discovering the nature of those defensive mechanisms and teasing out just how they work became the unifying theme of Eisner's research.

The bombardier beetle discharged its odorous spray with an audible "pop!"

Here, for instance, is how he typically spends his summers: At the end of the Cornell spring semester, he packs up family, graduate students, provisions, and equipment, and sets off for one of his "wonderlands." Among the best-known of his destinations are the Archbold Biological Station, in central Florida, and the American Museum of Natural History's Southwestern Research Station, in the Chiricahua Mountains of southeastern Arizona. Once his caravan reaches its summer research home, Eisner's modus operandi is to go on walks.

With eyes and mind wide open, and with his inquisitive habits of observation, his walks have never failed to turn up arthropods engaged in something of interest—whether in their own defense, in capturing prey, or in finding and wooing mates. Then, when he observes something spectacular that seems to involve chemicals, the performing species is instantly elevated to the subject of his penetrating scrutiny. At the end of each summer, Eisner inevitably has a menagerie of arthropod species to pack up and transport back to his laboratory in Ithaca, New York, where over the long, cold winter, he amuses himself by unraveling their secrets.

Eisner's tenacity and enthusiasm are legendary—and the latter is contagious. When he is trying to solve a research problem, the mission consumes him. His charisma and determination to do "whatever it takes" have fostered a host of partnerships with such unlikely collaborators as cinematographers, engineers, and inventors. And when such an extra-disciplinary contributor helps find a solution to a problem, Eisner typically recognizes the person with the co-authorship of a research paper—rather than with the more usual acknowledgment in a footnote. That academic generosity extends to a string of exceptional graduate students, whose work he highlights in the pages of this book.

Another side to Tom Eisner is on prominent display in the photograph he has chosen for the dust jacket of his book. Here the author, a younger man than he is today but with a still-familiar wide grin on his face, is riding a bicycle backwards—"no hands." The message could not be clearer: Eisner is a showman. He has chosen to work with the largest group of animals on Earth, and among them he has selected some of the fanciest species for his studies. He works at the interfaces of traditional disciplines, and he has an uncanny ability to interest non-entomologists in insects. He publishes profusely and in the highest-profile journals, but he also never misses the chance to popularize his work.

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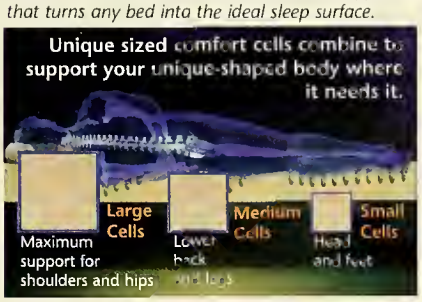

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ence be presented to the nonscientist?

Eisner's showmanship is on display throughout the book. He lures the reader, for instance, with cryptic chapter titles and chapter contents that are refreshingly varied in format. "Bombardier," the chapter I mentioned earlier, is almost exclusively about its namesake beetles. But chapter 3, "Wonders from Wonderland," is a collage of discoveries, all having to do with various arthropods from Archbold Biological Station. In chapter 7, "The Circumventers" (one of my favorites), Eisner turns his usual theme on its head by describing the tactics predators use to undermine the successful defensive strategies of their prey. These anecdotes are snapshots of the ceaseless co-evolutionary tango. Other chapters pull together many examples of convergent evolution: how one kind of adaptation evolved in diverse groups of animals, each group responding independently to similar pressures.

Each chapter embodies the chronology of the story it has to tell, corresponding to the stop-and-go progress of science. For example, Eisner often raises questions early in a chapter, only to leave them unanswered or partly answered, because of limits in the current technology. As his narrative proceeds, though, he describes how the applicable techniques are perfected—often in response to unrelated needs, and often years after the original questions were asked. His story then circles back to the earlier problems, showing how the technology for solving them can reshape them, or create entirely new questions to address.

What Eisner presents so well in words is reinforced by the compelling illustrations that accompany the words: the book is visually dazzling. Diagrams, line drawings, scanning electron micrographs, and a plethora of stunning color photographs of insects fill two-thirds of the volume. And every piece of artwork seems carefully selected to help the reader understand the science.

In chapter 5, for instance, Eisner begins with a shaggy-dog story about the Romanian engineer and would-be aviator Henri Coanda, who failed in the first-ever attempt to fly a jet-powered airplane. Metal plates Coanda installed to deflect the exhaust flames actually attracted the flames toward the fuselage. Such an attraction, now known as the Coanda effect, is the familiar propensity of fluids to stay in contact with curved surfaces. But, what in the world does that have to do with insects?

Accompanying the text is a simple line drawing that shows a liquid being poured from a pitcher, with a portion defying gravity as it spills down the curved side of the vessel. Instantly, the Coanda effect became understandable, because it happens to me almost every morning in our department's coffee lounge. On the facing page is another line drawing, this one of an ozaenine beetle directing a jet of noxious fluid from a posterior gland to a target directly ahead of the animal. Eisner explains that the beetle owes this remarkable feat to a small flange in its wing covers and, you guessed it, the Coanda effect! Thus, I painlessly understood the working of a perplexing biophysical adaptation.

After reading the book several months ago, and again at the beginning of this writing, I resolved to commend it to all my fellow entomologists. But I've since learned that most of them have already purchased and read a copy. Clearly, Thomas Eisner speaks to his academic colleagues. But more important, I think, is that he speaks *for* us. If you happen not to be an entomologist, and you'd like to know what we entomologists do—why our discipline brings us such joy—by all means read *For Love of Insects*. The book is really written for you.

Robert L. Smith is an associate professor of entomology at the University of Arizona in Tucson, and director of the Sonoran Desert Station for Arthropod Research, a biological preserve in the Tucson mountains. His most recent article for Natural History, *"On the Scent," appeared in the March 2003 issue.*

By Laurence A. Marschall

Scurvy: How a Surgeon, a Mariner, and a Gentleman Solved the Greatest Medical Mystery of the Age of Sail
by Stephen J. Bown
St. Martin's Press, 2004; $23.95

The seventeenth and eighteenth centuries, golden years for European imperial sea powers, were ghastly times for sailors. Ships' quarters were crowded, tours of duty stretched on for months or years, and the threat of attack by pirates or by hostile navies was ever present. The worst threat, however, was scurvy, a wasting disease with no known cause and no sure cure. Long into a voyage, when a sailor was weary and longed for home, his joints would begin to ache, his gums would go soft, and his breath would smell of dank decay. Then, bit by bit, his body would rot away. Masters of vessels in those years, certain that half the crew would die, many from scurvy, routinely signed on twice the men needed to run the ship. On the journey out, the crew's quarters stank of overcrowding; on the journey home, they stank of death.

Sailors on an Arctic expedition, getting their daily dose of lime juice (hence the slang term "limey"); illustration by J. Nash, 1875

Today, in an age of nutritional supplements, it seems remarkable that it took so long to pinpoint a dietary deficiency (of vitamin C, as we now know) as the cause of scurvy, and that the disease is so readily avoided by a daily spot of citrus juice. Part of the problem, writer Stephen J. Bown suggests, is that medical theories of the time had no concept of dietary requirements, or any notion of preventative medicine. Many doctors thought scurvy was caused by bad air or insufficient exercise in cramped crew quarters, both of which disturbed certain body fluids (or "humors") and threw them out of balance. Everyone knew that a scorbutic (scurvy-suffering) sailor could recover by coming ashore, but the recovery was only seen as confirmation that shipboard life was intrinsically unhealthy.

In time, however, a few freethinkers did come close to understanding the disease. In 1747 James Lind, a young naval surgeon with England's coastal fleet, conducted a controlled experiment aboard the HMS *Salisbury*. He administered six of the most frequently prescribed scurvy "remedies" to a selected group of suffering sailors: two men drank a quart of cider a day; two gargled elixir of vitriol (a strong acid); two got spoonfuls of vinegar; two downed seawater; two ate oranges and lemons; and two ate a paste made of balsam, garlic, mustard seed, myrrh, and radish root, all washed down with barley water. Lind carefully recorded the results. The citrus eaters, of course, made a full recovery; the cider drinkers showed a slight improvement (cider, according to a table at the back of Bown's book, contains a trace of vitamin C). The other sailors showed no improvement at all. Lind's findings were borne out a decade and a half later on the round-the-world voyages of Captain James Cook, who kept his men virtually scurvy-free by providing a regular diet of fresh fruits and vegetables.

Both Lind and Cook wrote about their experiences with scurvy remedies, and though their works were published and widely circulated, in multiple editions, their findings had surprisingly little immediate effect on the health of the men in the navies. Many doctors found Lind's theory of the disease unconvincing—his idea that it was caused by blocked perspiration was even wilder than the prevailing theory of unbalanced humors.

The effectiveness of citrus as a cure did not quickly gain wide acceptance either. Some doubters may have confused Lind's recommendation for small doses of citrus, as a preventative, with the much larger doses needed to cure critically ill patients. At any rate, vinegar, malt drinks, and a host of other useless remedies continued to be doled out to sailors throughout the 1800s. Only through the growing weight of shipboard experience, plus the efforts of a few influential naval officers, did bad theory give way to sound practice, and scurvy begin to vanish from the sailor's life. Today it is consigned largely to the pages of history—none more informative and readable than those of Stephen Bown.

This Is Not a Weasel: A Close Look at Nature's Most Confusing Terms
by Philip B. Mortenson
John Wiley & Sons, Inc., 2004; $16.95

Here is a reference book for those who can't tell an ass from a burro. The designation "ass," for *Equus asinus*, includes a large number of horselike breeds of mammal, from the striped-legged Somali wild ass to the domesticated ass, commonly called a donkey. *Burro* (originally the Spanish word for donkey) is simply American English for a donkey that lives in the

western United States, Mexico, or Latin America. And "donkey," in turn, is a word that probably derives from the animal's Old English description as small and dun-colored. So though all burros are asses, not all asses are burros.

Philip B. Mortenson, who produced this useful and entertaining volume (his first published book, we are told), studied philosophy of science at the University of Minnesota, in Minneapolis, and he clearly had a lot of time on his hands after graduation. He has schooled himself in the intricacies of plant and animal taxonomy and digested a sizable library of lore on natural history (the dense bibliography at the back of the book goes on for seventeen pages). All this effort has not gone to waste, however: Mortenson has helped bring order to the jumbled world of biological nomenclature.

Consider how many everyday disputes grow out of a confusion of terms: Is the porpoise mistakenly netted in the same catch that provided the tuna for your lunchtime sandwich a fish or a mammal? Does the tomato on your tuna sandwich count as a fruit or a vegetable? Does the boss who scheduled your sadly abbreviated lunch break deserve to be called a weasel or a stoat? Mortenson's handy reference provides detailed and thoughtful answers, in chapters arranged roughly by taxonomic category.

Be cautioned, though: one can learn too much from a book like this, and newfound knowledge should be doled out sparingly. The host at a festive dinner might not be particularly gratified to learn that the candied yams he has just brought to the table are not yams at all but sweet potatoes, quite a different kind of plant. Sweet potatoes are true roots belonging to the morning-glory family, and they do not develop "eyes." Yams, like ordinary potatoes, are tubers, and they do. Sweet potatoes are sweet and small enough to fit in a baking dish. Many yams have a bitter taste that only boiling can dispel, and some species can grow as long as eight feet and weigh more than a hundred pounds. And whereas yams are important foods in the tropics and in Asia, they are seldom sold in North America, and almost never appear on dinner tables—especially the eight-foot-long variety.

You could easily suffer taxonomic overload if you read this book straight through—there's enough lore in the section "Caterpillar Grub Larva Maggot Nymph" alone to occupy an idle afternoon. And because the book is not illustrated, you may need a stack of field guides and illustrated encyclopedias close by. None of the entries is more than a few pages long, however, so true nature lovers may want to locate a copy in the bathroom, or wherever else the browsing opportunities are frequent but short.

Profusion of reptilian species, from Larousse Encyclopedia, 1913

Even with *This Is Not a Weasel* at hand, of course, clear distinctions may often be impossible. Unfortunately for taxonomy, nature does not readily shoehorn herself into mutually exclusive categories, and the subtle variety she offers up seems almost infinite. Moths are generally distinguished from butterflies by their drabness, yet the luna moth is almost flamboyant. Moths have antennae that don't look like the stalky antennae of butterflies—but there are exceptions. And though most butterflies have slender bodies, some are as pudgy as moths. So, is that a butterfly or a moth on the screen door? If it really matters, even Mortenson's book may not provide the definitive answer.

The Curious Life of Robert Hooke: The Man Who Measured London
by Lisa Jardine
HarperCollins, 2004; $27.95

According to Robert Hooke's diaries, in the first five days of September 1672 he invented a musical instrument; constructed a device to view the upcoming passage of the Moon in front of a star; surveyed half a dozen lots for the reconstruction of buildings destroyed in the Great Fire of London; observed the planet Mars through a telescope; discussed the rental of a stable with a tenant; performed several optical calculations for designing microscopes (a time-consuming process in the pre-electronic age); visited a coffeehouse to catch up on the latest gossip; sampled a friend's bottle of absinthe; and dosed himself with a wide variety of nostrums ranging from raw milk to an emetic made, apparently, from the scrapings of rusty iron. It was a typical week for a man who, like his more famous contemporary Isaac Newton, was "never at rest," and who seamlessly blended intellectual tours de force with the practical labor of the workaday world.

Hooke was one of the great public figures of seventeenth-century London. Yet he is rather obscure today, remembered mainly by physics students for the law of elastic deformation that bears his name, and by book collectors for his magnificent *Micrographia*, first printed in 1665. The book, a large folio-size volume illustrated with exquisite drawings by the author, made Hooke an instant celebrity. What's more, it raised public awareness of the intricate, minute worlds that lie unseen below the resolution limit of the unaided eye. (A CD-ROM edition of the original volume, available from

EXPLORER GUIDE

nature.net

It's Elemental

By Robert Anderson

Dwindling fossil fuels, declining biodiversity, overtaxed freshwater supplies—what's next? Well, what about the reserves of the chemical elements, the basic building blocks of matter? Is there enough chromium, cobalt, helium, and manganese—not to mention erbium, europium, and gadolinium—on the planet to last indefinitely? Could future shortages stop technological progress in its tracks?

One way—perhaps the best way—to begin to appreciate the rarity of some of the so-called naturally occurring elements is to collect all ninety-two of them, in as pure a form as possible. Or—next best thing—you can visit Theodore W. Gray's Web site (www.theodoregray.com/periodictable/). Gray's pursuit of the elements is wonderfully obsessive, and his wooden periodic table is a work of art.

Don't miss his extensive comments on sample collecting (at the top of his home page, click on "samples"). And under "Events," click on "museum displays" to view and read about the first commercially produced periodic table Gray collaborated on, now installed at DePauw University in Greencastle, Indiana.

To peruse individual elements, scroll down Gray's home page and click on one of the labeled blocks in the image of his custom-built table. You'll find a comprehensive explanation of that element, as well as additional Web links (see the list at the right of each page, titled "Compare at other websites") for further information on other excellent chemistry Web sites.

Click the "Minerals" entry in any element's "Compare" list, for instance, and you'll be transferred to the largest mineralogy database on the Internet (www.mindat.org), specifically to a page with a catalog of the minerals that contain atoms of that element. If you then click on any of the minerals in the list, you'll be taken to a page with extensive mineralogical data.

Among the other good resources in the "Compare" list is the WebElements Periodic Table (www.webelements.com/). Run by Mark Winter, a chemist at the University of Sheffield, England, it is available in both "professional" and "scholar" editions. Or check out the link for the Royal Society of Chemistry. The society's science network, Chemsoc (www.chemsoc.org/viselements) has a table of the elements with a more modern look. Don't miss the link, at the bottom of the Chemsoc page for each element, to the "Chemsoc Timeline," which recounts key events in the history of science "with a particular emphasis on chemistry."

The United States, by the way, is now entirely dependent on imports for such vital elements as chromium, cobalt, and manganese. An overview of the situation can be found at www.environmentaleducation ohio.org/Case%20Studies/minerals.html, a page from the Web site of the Biosphere 2000 Project. To find out more about U.S. mineral reserves, click on the site of the U.S. Geological Survey Mineral Resources Program (minerals.usgs.gov/). USGS also tracks global supplies.

At a second USGS site (geopubs.wr.usgs.gov/fact-sheet/fs087-02/), you can find a report on rare earth elements (REEs), key ingredients in many high-tech components. Most of the world's REE supplies come from only a few sources, and in the past decade the U.S. has become dependent on imports from China.

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

Octavo Editions at octavo.com, includes the book's stunning oversize foldout plates.)

Jardine, who teaches history at Queen Mary University of London, places Hooke squarely at the center of the intellectual ferment of his time. Hooke came into his prime at the

Robert Hooke's drawing of a louse, from Micrographia (reduced to a sixth the size of the original drawing)

height of the scientific revolution in Great Britain, when the newly formed Royal Society was meeting every week. Hooke, an exceptional craftsman, became the official curator for the meetings: it was his job to build the equipment suggested by others and to run the shows. But he was also expected to come up with his own ingenious ideas. Both the chemist Robert Boyle and the architect Christopher Wren sought his advice and friendship, and London's intellectual elite held him in the highest regard.

The Royal Society provided both an outlet for Hooke's writings and a showcase for his many projects. He gained even greater renown, however, in the aftermath of the Great Fire of London. Hooke was appointed chief surveyor for the rebuilding pro-

ject, and he and Wren set about designing many of the buildings that are now part of reconstructed London.

Many of their works—including the official monument to those who died in the fire—are still standing. Wren is the more well known of the pair, in large part because of his design of Saint Paul's cathedral. Hooke was no less responsible for raising London from the ashes, yet he managed, at the same time, to run the regular shows at the Royal Society and carry on with a variety of other enterprises.

It was Hooke's exceptional energy, Jardine suggests, that was his eventual undoing. He picked up on things so clearly, and got involved in projects so quickly, that he was often unable to carry them through to completion. In his later years he felt an unremitting pressure to perform, and tried to allay his anxiety with a variety of drugs that probably killed him in the end. He became increasingly paranoid, quarreling bitterly with Newton over the discovery of the law of gravitation. Newton, as vindictive as he was brilliant, did his best to ensure that Hooke would not be remembered kindly by future generations. Yet Hooke (like Newton, an eccentric bachelor) left a legacy in architecture, invention, and ideas that stands to this day.

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.*

Answer to "Cryptic Creatures" puzzle (page 13): c

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Ghosts of Suns Past

Quasar hunters have accidentally discovered the largest planetary nebula ever seen in the night sky.

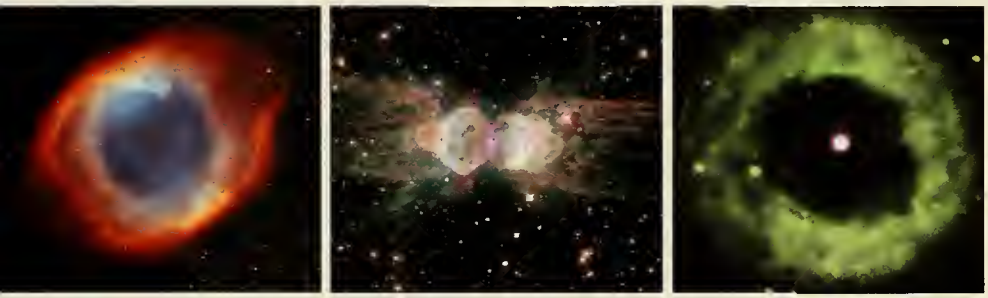
By Charles Liu

When our Sun dies, it won't go quietly. Sometime not so soon, after it lives out an adult life of relative serenity, it will swell to become a red giant star, nearly 100 times its current size, swallowing Mercury and Venus and sterilizing Earth in the process. (Don't worry—this calamity won't take place for another 5 billion years.) This brutal Sun won't last long before running out of fuel and collapsing under its own weight. Its central parts will compress into a blazingly hot ball of dense matter called a white dwarf. And, at about the same time, its outer layers will expand ever farther outward, maturing into an expanding bubble of glowing gas called a planetary nebula.

Millions, perhaps billions of stars in our own Milky Way galaxy have aged and died in just this way. As the nebula expands for a few thousand years, such factors as the temperature, mass, composition, and rotational speed of the former stellar material give rise to remarkable patterns in the gas, including such eye-catching designs as rings, helixes, cat's eyes, and hourglasses. For those with small telescopes, planetary nebulae are among the most beautiful objects in the sky.

But planetary nebulae are as ethereal as they are beautiful. After their bright beginning they quickly fade, and after at most 100,000 years or so—the blink of a cosmic eye—their constituent gases dissipate and they disappear. In their final years they probably spread out over a hundred trillion miles or more, becoming so distended that they're nearly impossible to pick out.

So imagine the surprise of Paul C. Hewett, an astronomer at the University of Cambridge, and his collaborators: while searching for objects billions of light-years away, far beyond our Milky Way, they discovered quite by accident an extremely faint planetary nebula close by, in the foreground of their search. Remarkably, the nebula, which lies in our own stellar neighborhood, may be the largest, and one of the oldest, planetary nebula ever seen.



Planetary nebulae are among the most beautiful objects in the sky. They come in a variety of shapes, as shown in these images of, from left, the Helix, the Ant (both enhanced-color optical images), and the Little Ghost (a false-color infrared image). A planetary nebula is formed when the inner layers of a red giant star collapse, while its outer layers expand as a cloud of hot, glowing gas.

Serendipity has always played a celebrated role in science. But such accidental breakthroughs don't really just happen out of dumb luck. Rather, they arise out of smart luck—the "chance [that] favors only the prepared mind," as Louis Pasteur once put it elegantly. Smart-luck workers carefully set up the conditions that make scientific discovery possible; then, when the unexpected takes place, they understand enough to realize that something new is going on—following up with further experiments for confirmation.

The discovery of the giant planetary nebula nicely conformed to the pattern. Paul Hewett is widely known for his studies of quasars—titanic gravitational engines in faraway galaxies, powered by black holes billions of times the mass of the Sun. To study the large-scale distribution of matter in the universe, he and his collaborators decided to search the Sloan Digital Sky Survey for gravitationally lensed galaxies and quasars [*see "The Quest for the Golden Lens," by Charles Liu, September 2003*].

Quasars are so far away that they appear as pinpricks of light in astronomical pictures. But as Hewett and his colleagues combed through the Sloan database, they noticed an area where almost all the distant pinpricks seemed to have glowing gas in front of them. The patch of sky was unusually large, fifteen times the area covered by the full Moon—suggesting the glowing gas must be very close by. Furthermore, the spectra of all the hot foreground gas were glowing with the signals of ionized hydrogen, nitrogen, and oxygen in exactly the proportions expected from a planetary nebula.

Intrigued by the possibility that they had found a large, thinly spread planetary nebula, Hewett and his colleagues took a closer look. With the 100-inch Isaac Newton Telescope in the Canary Islands, they looked for the patterns and colors of nebular gas in their patch

of sky. Sure enough, there was a huge shell of clumpy, hole-riddled gas that looked like a nearly dissipated planetary nebula. And they found another strong piece of evidence: a white dwarf near the center of the shell.

The huge size of the gaseous shell suggests that, depending on how far it is from Earth, the planetary nebula is between ten and twenty light-years across. And Hewett's estimate of its distance is rather uncertain: between 300 and 700 light-years. The closest known planetary nebula is 430 light-years from Earth, so future observations may confirm that the newly discovered gas bubble is not only the largest and one of the oldest, but also our nearest planetary nebula. Those attributes make it a valuable laboratory for studying the final stages of the future in store for our Sun—how the guts of a star, enriched by billions of years of nuclear fusion, finally blend into the surrounding interstellar gas to become raw material for future generations of stars.

In keeping with astronomical tradition, the new planetary nebula will probably be named after its lead discoverer. Future generations of astronomers, seeing "Hewett 1," may be reminded that a well-designed experiment, combined with an open mind, can reveal the unexpected, something new even right next door.

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

THE SKY IN MARCH

By Joe Rao

From March 15 through April 5, all five of the planets readily seen without a telescope will be visible simultaneously in the early evening sky. Throughout that period, about an hour after sunset, they will be stretched across the sky, in this order from west to east: Mercury, Venus, Mars, Saturn, and Jupiter.

Swift Mercury passes behind the Sun on March 4, reaching what is known as superior conjunction, then races around our star toward Earth. By the 16th Mercury is readily visible a little above the western horizon, shining at magnitude −1.3; it sets an hour after the Sun. The planet should be easy to find during the second half of March; in fact, for viewers in the northern hemisphere, this apparition is its best of the year. It reaches its greatest elongation (the farthest east it gets from the Sun) on the evening of the 29th. By that time it shines at magnitude zero and sets shortly after twilight ends.

Venus grows ever more brilliant during March, reaching magnitude −4.4 by month's end. The planet reaches its greatest elongation on the 29th (forty-six degrees from the Sun)—the same day as Mercury's. Venus remains in view for about four hours after the Sun goes down. On the evening of the 24th, Venus is about two degrees from a lovely crescent Moon; by month's end the planet shines south of the Pleiades.

Mars begins March in the constellation Aries, the ram, and crosses into the constellation Taurus, the bull, on the 13th. It appears high in the west-northwestern sky at dusk and sets between 11 P.M. and 11:30 P.M. local time all month. The Red Planet continues to dim as it moves away from Earth. On the evenings of the 20th and 21st, Mars shines about three degrees south of the Pleiades. On the evening of the 25th, the fat crescent Moon passes closely to the north of Mars. For those living across northern Canada, in Greenland, and in Iceland, the Moon appears to occult, or hide, Mars.

Jupiter, in the constellation Leo, the lion, shines as a brilliant silver "star" low in the eastern sky as dusk arrives. The giant planet reaches opposition to the Sun on the 4th. At the beginning of March, Jupiter is some thirty degrees above the eastern horizon by 8:30 P.M. local time; it rises earlier as the month progresses.

A small telescope—or even steadily held seven-power binoculars—reveals Jupiter's prominent cloud belts as well as its four brightest satellites. Make a special effort to have a look on the evening of the 4th; around 10 P.M. the four satellites appear as similarly spaced pairs on the same side of Jupiter. Europa and Io are the closest in, whereas Ganymede and Callisto appear farther out.

Saturn, in the constellation Gemini, the twins, shines high in the east-southeastern sky at dusk all month. It sets shortly after 3 A.M. local time on the 1st, and about two hours earlier by month's end. The planet is at east quadrature (ninety degrees east of the Sun) on the 26th, and so from Earth we can more readily see the dark shadow the planet casts on its rings, giving greater depth of appearance to both.

The Moon waxes full on the 6th at 6:14 P.M. and wanes to last quarter on the 13th at 4:01 P.M. Our satellite is new on the 20th at 5:41 P.M. and waxes to first quarter on the 28th at 6:48 P.M.

The equinox occurs at 1:49 A.M. on the 20th.

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

At the Museum
American Museum of Natural History

Computer Model Predicts Chameleon Distribution in Madagascar

SATELLITE DATA AND MUSEUM SPECIMENS CAN ACCELERATE EFFORTS TO COMPLETE SPECIES INVENTORIES, AID IN THE DESIGN OF FUTURE RESERVES, AND HELP FIND NEW SPECIES.

Christopher J. Raxworthy, Associate Curator in the American Museum of Natural History's Division of Vertebrate Zoology, and six colleagues have developed a modeling approach for studying biodiversity that combines satellite data with specimen locality data from museum collections and which has successfully predicted the geographic distribution of 11 chameleon species in Madagascar. In an unanticipated result especially useful to conservation efforts, the model also correctly predicted the existence of previously unknown areas of chameleon distribution, where 7 new chameleon species were found. This discovery suggests that for poorly explored regions, satellite data and data from museum collections can help identify promising places to survey for new species—an exciting development, especially beneficial to the conservation community.

Understanding the distribution of a species is one of the most important and basic requirements for effective conservation and ecological and evolutionary research. Yet most tropical species have not been surveyed well enough to allow an accurate assessment using conventional methods, in which biologists visit a region in an intensive effort to locate and count species. Dr. Raxworthy and his colleagues have demonstrated that existing museum collections and satellite measurements of Earth's surface and climate can be used to accurately predict species distributions anywhere on Earth—even in poorly explored tropical regions. This study is the first to successfully predict the distribution of any species in Madagascar using satellite imagery and information from museum specimens, and the first to evaluate the predictive usefulness of historical museum specimens in collections (dating back to the 1800s) versus recently collected field data from Madagascar.

The acquisition of detailed descriptions of exactly where Earth's rich biodiversity lives, species by species, requires decades of dedicated fieldwork. In Madagascar, teams of highly trained biologists visit often remote sites to do this work. A paucity of data on the regional distribution of species, especially in more

C.J. RAXWORTHY

Dr. Raxworthy surveying for chameleons in 2003 at Tsaratanana (the highest mountain in Madagascar)

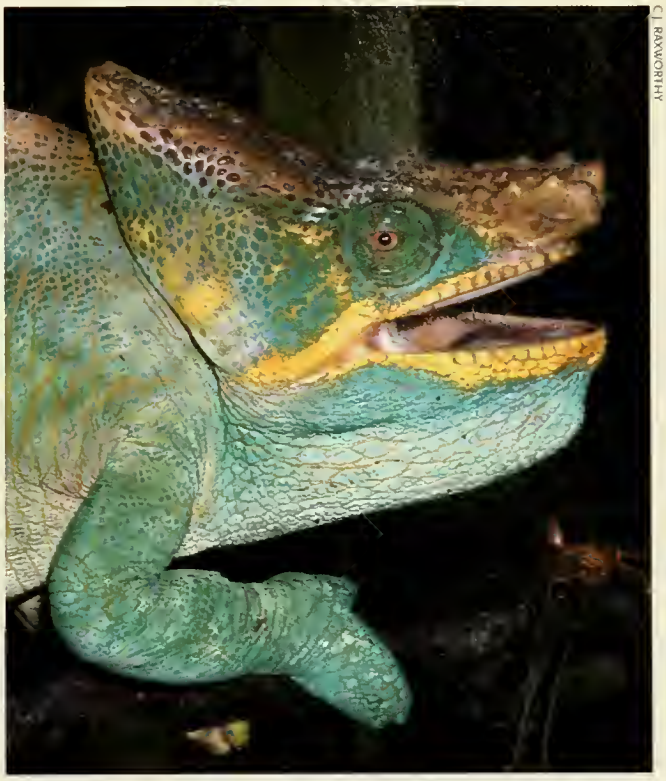
remote areas, is one of the major factors that complicates and potentially delays conservation decisions that could save threatened flora and fauna. This new research by Dr. Raxworthy and his associates, published in a recent issue of the journal *Nature*, demonstrates conclusively that a technological solution exists that can speed up the process of regional species inventories and thereby prevent unnecessary loss of threatened animals, especially in tropical environments with diverse habitats and climates. The research also shows that both historical and modern field data can be extremely useful for predicting chameleon species distribution in Madagascar, although contemporary field data used in concert with satellite data provides the most accurate biogeographic distribution predictions.

This new chameleon prediction study tested the accuracy of several other distribution models—including one based on information gathered from historical museum specimens, and one based on data from more recently collected specimens—against other locality data that was set aside for testing purposes, and against recent inventories of 11 sites where chameleons were also surveyed. Although the historical data alone prove to be predictive in ways that are useful to conservation decision-makers, and accuracy improved with the combination of modern and historical data, the team found that modern data alone were the best predictor of where the 11 chameleon species live.

All of the models rely on environmental data collected

by several satellites and the Space Shuttle, provided by the National Aeronautics and Space Administration (NASA), U.S. Geological Survey, and National Oceanic and Atmospheric Administration (NOAA). Environmental data include land cover (as viewed from space), rainfall, cloud cover, average and seasonal temperatures, and topographic data, which were input into GARP (Genetic Algorithm for Rule-set Prediction), a software package for biodiversity and ecology research that allows users to predict species distributions.

The model's intriguing ability to predict the location of previously undiscovered chameleon species arose unintentionally. When Dr. Raxworthy and his colleagues examined the models, they found overlapping areas of error where the models incorrectly predicted that 4 species lived. Examining their field data collected in two of these regions, they realized that these areas actually contained 7 other closely related species that are new to science. The areas that initially seemed to represent "error" in the models pointed to regions that are of critical conservation importance because they provide habitats for locally confined species that had not been previously recognized. Identifying neglected areas with unique biodiversity currently has enormous value in Madagascar, because the Malagasy Government recently announced plans to expand the protected area network, thus providing a new opportunity to conserve species currently excluded from the island's existing reserves.



C.J. RAXWORTHY

A male Parson's chameleon *(Calumma parsonii)* from Madagascar

"Our results show that distribution models can help scientists and those who make conservation decisions determine areas with potential unrecognized biodiversity," Dr. Raxworthy said. "In many tropical areas on Earth, time is running out to make important conservation decisions for threatened species. This approach, combining museum specimen locality data with data from satellites, now gives us a fast-track way to obtain an informative biogeographic understanding of species distributions, opening the door to more effective conservation planning and allowing biologists to better explore big questions in tropical ecology and evolutionary biology. The ability to predict areas with good potential for species new to science is especially exciting."

A technological solution exists that can prevent the loss of threatened animals.

Dr. Raxworthy has nearly 20 years of experience conducting herpetological fieldwork in Madagascar, which includes a wide range of habitats and an exceptional diversity of species, many of which are found nowhere else. Although reserves are already in place to conserve Madagascar's biodiversity, current rates of deforestation underscore the urgent need to further expand the reserve network, which requires accurate distribution information that policy-makers can use to make informed and timely conservation decisions.

As Dr. Raxworthy and his colleagues have demonstrated in this new paper with chameleons, continued modeling with many more species could significantly speed up and advance efforts to prevent the loss of species and their habitats in Madagascar, despite the lack of detailed information on much of the country's biodiversity. Significantly, this same approach can be applied anywhere else on Earth. For poorly surveyed regions requiring urgent conservation action (typical, unfortunately, for most tropical countries), existing museum specimens may thus represent a powerful resource for conservation planning.

Several other Museum curators and scientists have conducted extensive fieldwork on Madagascar's wealth of diverse animal species, including Eleanor Sterling (lemurs), Director of the Center for Biodiversity and Conservation (CBC), Ian Tattersall (lemurs), Curator in the Division of Anthropology, Melanie Stiassny (fish), Axelrod Research Curator in the Division of Vertebrate Zoology, Ross MacPhee (mammals), Curator in the Division of Vertebrate Zoology, Mark Siddall (leeches and crocodiles), Associate Curator in the Division of Invertebrate Zoology, John Sparks (fish), Assistant Curator in the Division of Vertebrate Zoology, and Howard Rosenbaum (whales), Conservation Associate with the CBC.

The chameleon prediction project was supported by NASA under award No. NAG5-8543 and by the Center for Biodiversity and Conservation at the American Museum of Natural History. NASA also provides support for the RS/GIS Facility.

Museum Events

AMERICAN MUSEUM & NATURAL HISTORY

EXHIBITIONS

Exploratorium/AMNH

Through August 15

This exhibition invites visitors to explore fundamental concepts and phenomena in the natural sciences. Hands-on displays clustered around themes such as motion, light, pendulums, and rotation encourage audiences of all ages and all levels to investigate and play.

Exploratorium/AMNH is funded in part by a grant from the Small Business Association. For information regarding accessibility, call 212-769-5100.

Seasons of Life and Land: Arctic National Wildlife Refuge

Through September 6

SUBHANKAR BANERJEE

Polar bear; Bernard Harbor

Over 40 large-format color photographs by conservationist Subhankar Banerjee focus on the interdependence of land, water, wildlife, and humanity in Alaska's Arctic Refuge.

Petra: Lost City of Stone

Through July 6

This exhibition tells the story of a thriving metropolis at the crossroads of the ancient world's major trade routes.

In New York, *Petra: Lost City of Stone* is made possible by Banc of America Securities and Con Edison. The American Museum of Natural History also gratefully acknowledges the generous support of Lionel I. Pincus and HRH Princess Firyal and of The Andrew W. Mellon Foundation. This exhibition is organized by the American Museum of Natural History, New York, and the Cincinnati Art Museum, under the patronage of Her Majesty Queen Rania Al-Abdullah of the Hashemite Kingdom of Jordan. Air transportation generously provided by Royal Jordanian.

The Bedouin of Petra

Through July 6

Photojournalist Vivian Ronay's evocative color photographs document the Bedoul group of Bedouin tribes living near the archaeological site of Petra in Jordan.

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

The Butterfly Conservatory: Tropical Butterflies Alive in Winter

Through May 31

The butterflies are back! This popular exhibition includes more than 500 live, free-flying tropical butterflies in an enclosed tropical habitat where visitors can mingle with them.

The Butterfly Conservatory is made possible through the generous support of Bernard and Anne Spitzer.

SYMPOSIUM

Expanding the Ark: The Emerging Science and Practice of Invertebrate Conservation

Thursday and Friday, 3/25 and 26

9:00 a.m.–5:30 p.m.

A dialogue on the fate of invertebrate biodiversity and concrete approaches to conservation action.

LECTURES

The Gods Must Be Crazy Revisited

Thursday, 3/11, 7:00 p.m.

With Daniel Riesenfeld, filmmaker, Rupert Isaacson, writer and journalist, and Megan Biesle, Kalahari People's Fund.

Voyages of Discovery: Deep Sea Robots

Thursday, 3/18, 7:00 p.m.

With Craig McLean, National Oceanic and Atmospheric Administration's Office of Ocean Exploration.

FAMILY AND CHILDREN'S PROGRAMS

ID Day: Trinkets or Treasures?

Saturday, 3/13, 1:00–4:00 p.m.

Museum scientists will attempt to identify the trinkets and treasures you bring from home at this annual event.

It's a Wild, Wild World: Predators

Saturday, 3/20, 12:00 noon–1:00 p.m.

Get a close-up look at a black bear cub, a golden eagle, and an African lion cub.

IN AND OUT OF JORDAN

GLOBAL WEEKENDS

The Petra Great Temple

Sunday, 3/14, 2:00 p.m.

Slide-illustrated lecture with Martha Sharp Joukowsky, Brown University.

Petra and Contemporary Artists

Sunday, 3/14, 3:30 p.m.

Learn how Petra remains an inspiration to artists working today.

Middle Eastern Fashion and Textiles

Sunday, 3/21, 2:00 p.m.

Hanan Munayyer discusses and illustrates antique and contemporary clothing, headdresses, and jewelry.

Middle Eastern Embroidery

Sunday, 3/21, 3:30 p.m.

Narmin Kurzum will demonstrate traditional and contemporary techniques of Middle Eastern embroidery.

STARRY NIGHTS *Live Jazz*

Friday, March 5,
5:30 and 7:00 p.m.
Rose Center for
Earth and Space

Terrell Stafford Quintet

JIMMY KATZ

Starry Nights is made possible by Lead Sponsor Verizon and Associate Sponsors CenterCare Health Plan, Constellation NewEnergy, and WNBC-TV.

Growing Up Arab American
Sunday, 3/21, 4:00 p.m.
Filmmaker Ghazi Albuliwi presents clips from his feature film, West Bank Brooklyn. Discussion follows.

Bedouin Hospitality, Old and New
Sunday, 3/28, 1:00 p.m.
Andrew Shryock and Sally Howell, both of the University of Michigan, discuss hospitality among Jordanian Bedouin.

Near Eastern Music Ensemble
Sunday, 3/28, 2:30 p.m.
A musical performance and demonstration of the *oud* (Arabic lute), *nye* (reed flute), *qanun* (zither), and *riqq* (frame drum).

Global Weekends are made possible, in part, by The Coca-Cola Company. The American Museum of Natural History wishes to thank the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt for their support of these programs.

FAMILY AND CHILDREN'S PROGRAMS

Petra: Architecture
Sunday, 3/14, 11:30 a.m. or 1:30 p.m. (Ages 4 to 6, each child with one adult)
Hands-on activities teach children about the properties of the rock-cut structures of Petra.

Petra: Water Engineering
Sunday, 3/21, 11:30 a.m. or 1:30 p.m. (Ages 4 to 6, each child with one adult)
Children will design their own waterways to learn how to solve an ancient problem: access to flowing water.

Arabic Calligraphy
Sunday, 3/28, 11:30 a.m. or 3:30 p.m. (All ages; children 6 and under must be accompanied by an adult)


COURTESY ELINOR AISHA HOLLAND

Salaam (peace) in early eastern Kufic style

Experiment with creative calligraphic techniques.

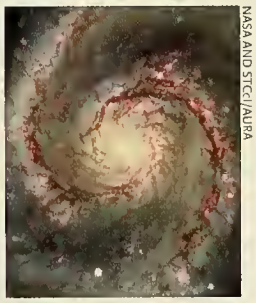
Arab Folktales
Sunday, 3/28, 1:00 p.m. (Ages 7 and up)
Stories capture the spirit of everyday life.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe: A Messier Trip
Tuesday, 3/2, 6:30–7:30 p.m.

This Just In...March's Hot Topics
Tuesday, 3/16, 6:30–7:30 p.m.


NASA AND STSCI/AURA

The Whirlpool Galaxy, M51

Celestial Highlights: What Solar Eclipse?
Tuesday, 3/30, 6:30–7:30 p.m.

COURSES

Stars, Constellations, and Legends
Five Wednesdays, 3/31–4/28, 6:30–8:00 p.m.

The Rose Center: Wonders of the Zeiss
Two Tuesdays, 3/9 and 23, 6:30–8:30 p.m.

The Modern Solar System
Saturday, 3/6, 10:00 a.m.–4:00 p.m.

The Search for Life
Saturday, 3/27, 10:00 a.m.–4:00 p.m.

LECTURES

Gamma Ray Burst Extinction
Monday, 3/1, 7:30 p.m.
With Adrian Melott, University of Kansas.

Cosmic Genesis
Monday, 3/22, 7:30 p.m.
With Fred Adams, University of Michigan.

PLANETARIUM SHOWS

SonicVision
Fridays and Saturdays, 7:30, 8:30, 9:30, and 10:30 p.m.
A mind-warping musical and visual roller-coaster ride.

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

The Search for Life: Are We Alone?
Narrated by Harrison Ford

Made possible through the generous support of Swiss Re.

Passport to the Universe
Narrated by Tom Hanks

LARGE-FORMAT FILMS

LeFrak Theater

Volcanoes of the Deep Sea
Explore Earth's most hostile environments and its strangest creatures, and consider the implications for our search for life.

India: Kingdom of the Tiger
A glorious tribute to this magnificent land and its greatest ambassador—the mighty Bengal tiger.

INFORMATION

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

TICKETS AND REGISTRATION

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

All programs are subject to change.

Spring

All day the flicker
has anticipated
the lust of the season, by
shouting. He scouts up
tree after tree and at
a certain place begins
to cry out. My, in his
black-freckled vest, bay body with
red trim and sudden chrome
underwings, he is
dapper. Of course somebody
listening nearby
hears him; she answers
with a sound like hysterical
laughter, and rushes out into
the field where he is poised
on an old phone pole, his head
swinging, his wings
opening and shutting in a kind of
butterfly stroke. She can't
resist; they touch; they flutter.
How lightly, altogether, they accept
the great task, of carrying life
forward! In the crown of an oak
they choose a small tree-cave
which they enter with sudden quietness
and modesty. And, for awhile,
the wind that can be
a knife or a hammer, subsides.
They listen
to the thrushes.
The sky is blue, or the rain
falls with its spills of pearl.
Around their wreath of darkness
the leaves of the world unfurl.

—*Mary Oliver*

From Owls and Other Fantasies.
by Mary Oliver (Beacon Press, 2003)

Illustration by Mick Ellison

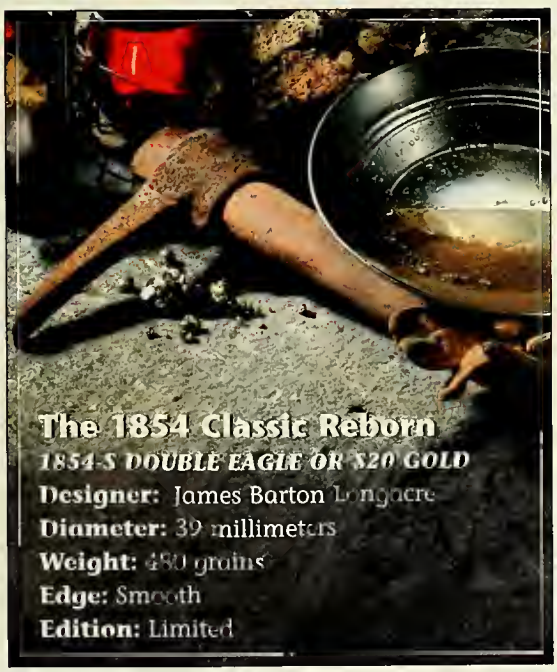
Accidental Discovery of Mysterious "Gold Rush" Coin Stuns Experts

World's Rarest U.S $20 Gold Proof Found: The San Francisco Mint 1854 Double Eagle Proof!

WASHINGTON, D.C—A one-of-a-kind U.S. Treasury gold proof coin has been accidentally discovered within the vaults of the Smithsonian Institution. This 1854-S gold Double Eagle $20 coin was struck by the San Francisco Mint in its first year of operation. The San Francisco Mint was born out of the need for a Western Frontier Mint when, in January of 1848, gold flakes were discovered at Sutter's Mill triggering one of the most important chapters in U.S. History—The California Gold Rush! To the surprise of historians, this single "S" mint Proof coin was individually struck from specially polished minting dies. How this unique Proof Double Eagle made its way across the continent and then into the hands of the Smithsonian Institution is an unsolved mystery to this day.

Today the First Federal Mint announces the public release of the first ever gold Proof commemorative honoring this rarest U.S. Government $20 gold piece This 10mil gold Proof has a frosted image against a deep mirror field, creating a breathtaking work of art in gold. This 150th anniversary Mint release honors the legacy of a true historic masterpiece.

The magnificent 10mil gold proof measures a full 39mm diameter to truly showcase the beauty and intricacy of this legendary coin design. The 10mil gold proof is available only through this limited edition, private release from the First Federal Mint at the advance issue price of $19.95 each.



Fabulous Rarity Valued at $12 Million

Only one original proof coin is known to have been struck. Even the foremost rare coin experts were unaware of its existence until it was accidentally found deep in the vaults of the museum. America's foremost authority on U.S. gold coins, David Akers, has written, "the 1854-S Double Eagle is easily the most significant and desirable branch mint proof coin in existence". With the recent auction sale of one of the three 1933 St. Gaudens Double Eagles for $7.9 million, senior numismatist Nicholas Bruyer estimates the unique 1854-S Proof Double Eagle would bring at least $12 million if it ever becomes available at auction.

The "Gold Rush" Coin.

2004 marks the 150th anniversary of this historic mint striking. The First Federal Mint is releasing this mint quality 10mil gold Gem Proof collectors coin to honor the legend, lore and legacy of the 1854-S Double Eagle!

Special Discount for Advance Orders.

The issue price for the special 150th anniversary 1854-S Gold Proof commemorative coin has been set at $50.00. However during the advance release period only, you may reserve your own 10mil 24k gold Gem Proof for only $19.95.

Your 1854-S Double Eagle 150th Anniversary Gold Proof will be protected in a clear acrylic holder and mounted in a deluxe presentation case. A signed and numbered Certificate of Authenticity will attest to the specifications and Limited Edition status of this exclusive private mintage.

Your order must be placed during this advance issue period to qualify for the $19.95 price. Multiple orders of five or more will be priced at $17.95 per Gold Proof. You must be 100% satisfied with your order, or simply return it within 30 days by insured mail for a prompt refund of the purchase price.

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All prices are guaranteed during the advance order period, regardless of any increases in the price of gold. Order your 150th Anniversary Gold Proof Double Eagle today to ensure these prices before the advance order period is closed!

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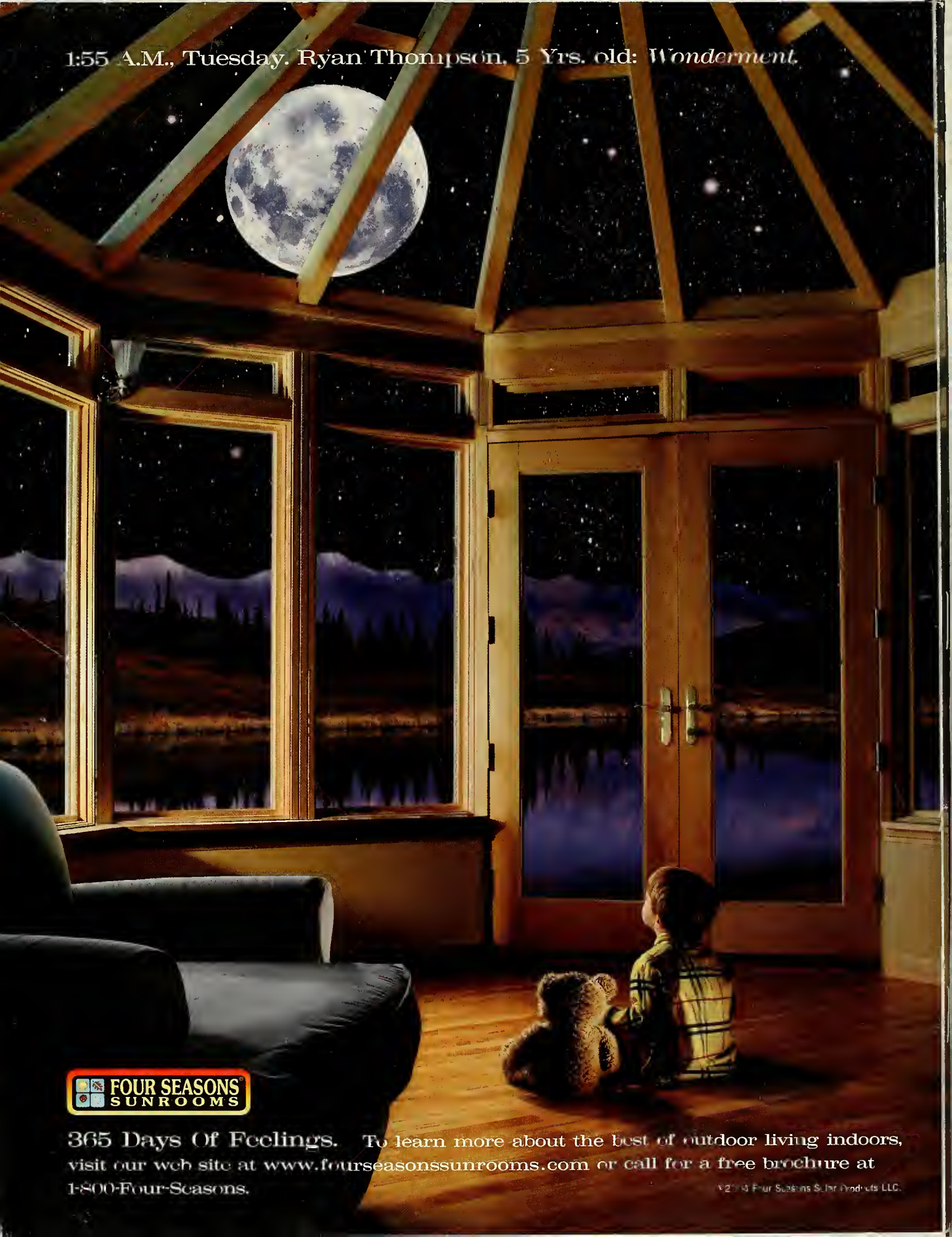
1:55 A.M., Tuesday. Ryan Thompson, 5 Yrs. old: *Wonderment.*
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