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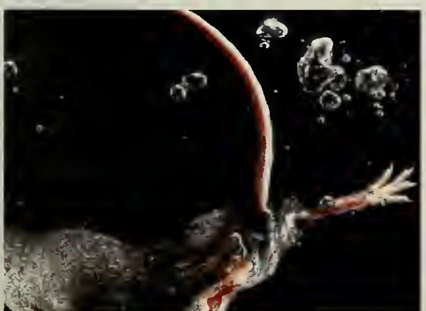
NATURAL HISTORY

MARCH 2008 VOLUME 117 NUMBER 2

FEATURES



ON THE COVER:
North American water shrew seizes a crayfish.
Photograph by Kenneth C. Catania

DEPARTMENTS

31

24

70

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THE NATURAL MOMENT

HANDS UP!

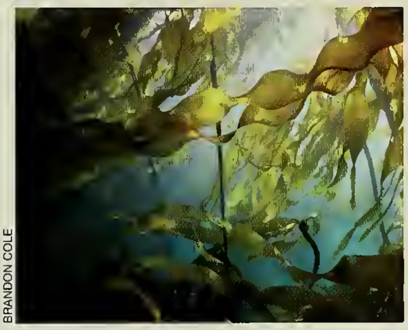
Photograph by Bruce Lichtenberger

◄ *See preceding two pages*

THE NATURAL EXPLANATION BY ERIN ESPELIE

Sea otters are "aww"-inspiring creatures. Just ask the more than 9 million YouTubers who in the past year have watched an amateur video shot at the Vancouver Aquarium in Canada. In it, two sea otters clasp "hands" as they float on their backs, then (alas) drift apart. In a touching denouement, one otter reaches out to link them up again. The crowd goes wild.

What's the appeal? The marine mammal (*Enhydra lutris*) belongs to the not-so-cuddly weasel family, the Mustelids. Yet something about a sea otter bobbing on its back, or the adroitness of its sleek little hands, brings out oohs and aahs in people.



BRANDON COLE

The sea otter's forelimbs are indeed unusual. For starters, a special pocket of skin under each arm provides storage for, say, a clam collected on a long dive. And the palms are bare, lacking the dense, waterproof fur that insulates most of the body. To warm up, the animal will often hold its paws out of the water—as the California sea otter on the previous two pages demonstrates.

When photographer Bruce Lichtenberger spotted this otter, it was with a few companions. But sometimes otters sun themselves in groups, known as "rafts," more than a thousand strong. They will link hands—as the Vancouver duo did—or wrap themselves in giant kelp (*Macrocystis pyrifera*), as Lichtenberger observed, to keep from drifting apart. The kelp strategy allows an otter to save energy by keeping its hands and head effortlessly above water.

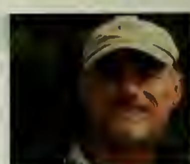
Beyond using the canopy to rest, the sea otters take full advantage of huge kelp forests. Their favorite delicacies are sea urchins, which feed voraciously on kelp. By vacuuming up urchins, the otters protect the kelp, and thus secure food and shelter for a vast array of species—from snails to whales.

The popularity of sea otters (or at least their fur) among humans nearly wiped out the species by the start of the last century. But all three subspecies—the Asian, northern, and California (or southern) sea otters—have been internationally protected since 1911. Their total population reached about 90,000 in 1985, but has declined alarmingly to less than 10,000 since then.

A few rogue killer whale pods may be curbing the northern sea otter population, as their usual prey of seals and sea lions dwindle. But that doesn't explain the stagnant southern otter population, according to U.S. Geological Survey ecologist Tim Tinker, based at the University of California, Santa Cruz. He sees a host of other threats to local otters, including fishnets, guns, pollution, and *Toxoplasma gondii,* a protozoan from cat waste that can cause brain infections.

Tinker identified the sea otter featured here as a female. "I say female because of the nose scar," he says, which is "a typical wound inflicted by males during mating or attempted mating."

Bruce Lichtenberger is an international wildlife photographer who specializes in polar bears, bald eagles, and Alaskan brown bears. He has published in *National Wildlife* magazine, among others. Visit www.lichtenbergerphoto.com for more of his photos.



WORD EXCHANGE

River Rifts

Sandra Postel's hopeful article on the water situation in Israel and Palestine "Sharing the River Out of Eden," [11/07] is, unfortunately, quite misleading. She notes that Palestinians use a quarter as much water per capita as Israelis do. This ratio grossly exaggerates Israel's water usage, since per capita water usage by Palestinians is underestimated owing to inflated population figures; and per capita water usage by Israelis is overstated without accounting for Israel's extensive use of recycled water. Furthermore, Postel omits the fact that neighboring Arab countries use far more water than does Israel. If one accounts for recycled water and Israeli water that is given to Palestine, Israel's annual per capita usage is around 237 cubic meters. According to the most recent UN figures, Syria's usage is 1,148, Egypt's is 969, and Lebanon's is 381. Would Postel say this is "inequitable"?

What is remarkable is not that Israel is unfairly taking Palestinian water, as Postel implies, but that despite chronic shortages Israel is so generous with water. For example, 83 percent of the drinking water for the major Palestinian city of Ramallah and its suburbs is piped in from Israel. Even as Palestinian missiles and mortar shells fly almost daily from Gaza into Israel, Israeli water for the Palestinians flows daily into Gaza, at a rate of 4 million cubic meters per year. It is hard to imagine that a country would supply water to its attackers, but that's exactly what Israel does. Many water experts have hoped that shortages in the region might spur cooperation and reconciliation rather than tension. But for this to happen, water myths must finally be overcome.

Alex Safian
Committee for Accuracy in Middle East Reporting in America (CAMERA)
Boston, Massachusetts

SANDRA POSTEL REPLIES: I must first point out that *Natural History* fact-checked my article extensively before publishing it, and Alex Safian's letter reflects only his opinion on the issue. In fact, Safian's remarks reflect a naiveté about water use, water statistics, and concepts of water sharing in international river basins, and I wish to respond to four of his more misleading points.

First, as I point out in my article, Israel is a leader in water recycling, but this in no way negates the fact that Israel appropriates more water from the Jordan basin than is deemed equitable by internationally accepted principles of water sharing. Second, comparing Israel's per capita water use with that of Egypt, Syria, or Lebanon is irrelevant to the issue of equitable water allocation within the Jordan basin. Egypt is not even located within the Jordan basin, while Syria and Lebanon obtain the bulk of their water supplies from sources outside the basin. A better comparison would be the Arab nation of Jordan, which, according to the most reliable international statistics, uses 42 percent *less* water per capita than Israel does. Third, across most of the West Bank, Israel has forbidden the Palestinians to drill new wells, and only occasionally allows them to replace old ones. Israel does sell piped water to some West Bank towns, but the Palestinians know they could be cut off at any time and would be more secure with their own water supplies. Fourth, it is unclear what Safian is counting as "Israeli water," since an equitable allocation among the parties has yet to be determined.

To repeat the main point of my article: For an enduring peace to be achieved between Israel and the Palestinians, the existing water inequities must be acknowledged and then corrected. Many scientists and civilians on both sides of the border are prepared to work constructively toward that end.

Continued on page 74

NATURAL HISTORY

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Natural History
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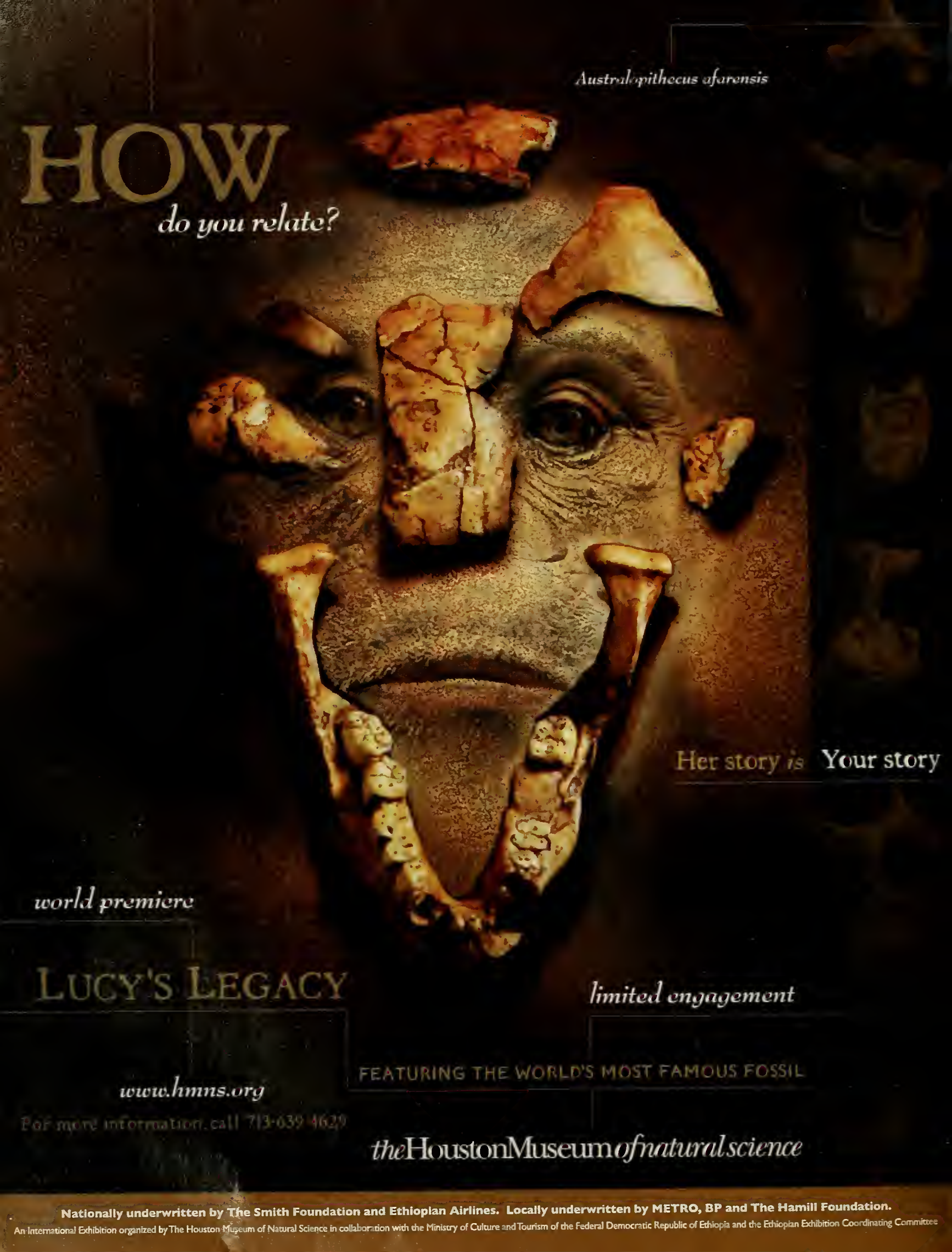
Natural History (ISSN 0028-0712) is published monthly, except for combined issues in July/August and December/January, by Natural History Magazine, Inc., in affiliation with the American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024. E-mail: nhmag@naturalhistorymag.com. Natural History Magazine, Inc., is solely responsible for editorial content and publishing practices. Subscriptions: $30.00 a year, for Canada and all other countries: $40.00 a year. Periodicals postage paid at New York, NY, and at additional mailing offices. Canada Publications Mail No. 40030827. If you would like to contact us regarding your subscription or to enter a new subscription, please write to us at Natural History, P.O. Box 5000, Harlan, IA 51593-0257. Postmaster: Send address changes to *Natural History*, P.O. Box 5000, Harlan, IA 51537-5000. Printed in the U.S.A.



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Fishing spider, Dolomedes triton

DEMBINSKY PHOTO ASS./FLPA

Multiple Personalities

Most people have no problem assigning personalities to beloved pets, but they stop short of extending the courtesy to invertebrates. New research suggests we should be more generous.

J. Chadwick Johnson, now at Arizona State University's West campus in Phoenix, and Andrew Sih of the University of California, Davis, studied *Dolomedes triton*, a species of fishing spider that hides underwater when threatened by predators. Hiding spiders may emerge for a gulp of air, but quickly return below if they're still afraid. Johnson and Sih induced sixty captive female fishing spiders to hide by poking them with a pencil, then either let them be or tempted them to the surface with food or a courting male. Individual females were remarkably consistent through all three tests in the percentage of time that they remained in hiding relative to other females. In other words, their ranking on a scale of "timid to bold" remained constant. What's more, juveniles' relative boldness tended to persist into adulthood.

More and more studies are revealing consistent character traits—personalities, if you will—in animals as disparate as fish, amphibians, birds, and bighorn sheep. What's next—self-assured slugs? (*Animal Behaviour*) —*Stéphan Reebs*

An Old Foe

The first early human species to migrate out of Africa, nearly 2 million years ago, was probably *Homo erectus.* Moving northward into temperate latitudes forced our relative to adapt to reduced sunlight—but when and how? Fossilized *H. erectus* skull bones bearing signs of disease, recently unearthed in Turkey, are helping to answer those questions.

Quarry workers discovered the fossils in travertine formed 500,000 years ago—but not before slicing the rock into tiles, thus preserving only thin cross sections of bone. John Kappelman of the University of Texas at Austin and five colleagues examined the skull fragments and discovered small indentations on the internal surface of one. The indentations' shape and location betrayed a case of tuberculosis of the meninges—the membranes surrounding the brain and spinal cord. (Tuberculosis, or TB, usually targets the lungs, but it can also attack other organs and can affect the growth of overlying bone.) The Turkish fossils thus represent the oldest known human case of TB.

Vitamin D, which is produced in skin exposed to ultraviolet light, appears to help the immune system fight the bacteria that cause TB. Kappelman speculates that the bones' original owner—probably a young man—had dark skin, which blocks UV rays. Away from sunny Africa, dark skin may have unduly hindered vitamin D production, exacerbating vulnerability to TB in some portion of the *H. erectus* population and eventually prompting selection for lighter skin. (*American Journal of Physical Anthropology*) —*S.R.*

Good News for Green Turtles

Of the world's seven species of sea turtle, six are considered endangered or threatened due to humankind's exploitation of their meat, eggs, and habitat. But despite that gloomy statistic, all is not lost: a recent paper announces the happy discovery that one of the endangered species is on the rebound.

The green sea turtle, *Chelonia mydas*, inhabits tropical waters worldwide. A team led by Milani Chaloupka of Ecological Modelling Services in Queensland, Australia, compiled the numbers of nesting *C. mydas* females recorded in long-term studies at six of the world's major rookeries: two in Australia and one each in Japan, Hawaii, Costa Rica, and Florida. In all six rookeries the team found the number of nesting females has been steadily increasing during the past twenty-five years, and with it the species' global population.

The team attributes the good news to extensive conservation of *C. mydas* habitat and to laws banning the use of turtle eggs, shells, and meat. Indeed, some populations of other sea turtle species are growing, too. Even so, all of them still have a lot of nesting to do before they achieve a full recovery. (*Global Ecology and Biogeography*) —*Lydia Bell*


Green sea turtle hatchling makes its way to the sea.

CLAIRE VARIAN

Dark beak and dull feathers signal a male fairy-wren's recent rise in status.

Mid-Season Switch

At the start of each breeding season, male red-backed fairy-wrens high enough on the social ladder darken their bills and shed their lackluster brown feathers for a flashy black-and-red set sure to impress the ladies. But what happens if a second-tier male rises to the top in the middle of the breeding season, after his plumage is set? Jordan Karubian of the University of California, Los Angeles, discovered that the fairy-wrens needn't wait another year to signal their newfound status: they can turn their bills from beige to jet-black in a matter of days.

Karubian studied a population of red-backed fairy-wrens (*Malurus melanocephalus*) in Queensland, Australia. Many of the showy, breeding males are accompanied by "helpers"—usually their year-old sons, who don't mate. Karubian noticed, however, that some dull-feathered males did breed, and they seemed to have darker bills than helpers did. So he started noting the breeding status and the bill and plumage colors of every male fairy-wren he encountered.

Over two years, Karubian identified eleven fairy-wrens who switched from helper to breeder mid-season, either because the dominant male died or a new female moved into the area. Within just three weeks, the birds' bills darkened significantly.

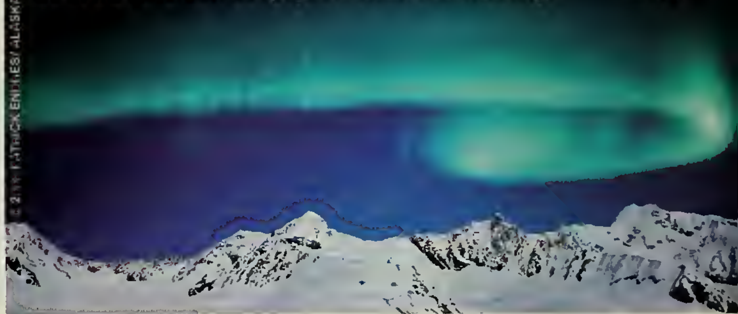
Karubian thinks ornithologists studying social signals should take a closer look at birds' bills, as well as their legs and eyes. Blood vessels enable those parts to mobilize pigments and change color faster—if less dramatically—than bloodless feathers can. (*Journal of Avian Biology*) —*Brendan Borrell*

The Great Rope in the Sky

Scandinavians of old thought northern lights were the reflection of giant schools of herring in the sea. Gone are those days: physicists now know that charged particles emitted by the Sun—the solar wind—interact with Earth's upper atmosphere near the poles to generate auroras. And satellites recently revealed the peculiar avenues the particles sometimes travel: gigantic electromagnetic structures called magnetic ropes.

The ropes are twisted bundles of magnetic fields temporarily generated when unusually strong solar winds buffet Earth's own magnetic field, 40,000 miles above the ground. Magnetic ropes stretch from the Sun into Earth's upper atmosphere and serve as conduits for solar-wind energy. But all that was just so much theory until last May 20th. That's when five NASA satellites mapped the first confirmed magnetic rope, as wide as Earth itself. Vassilis Angelopoulos and David Sibeck, two NASA scientists, say the rope formed for only a few minutes, but it conducted a massive amount of energy earthward that powered intense auroras.

NASA had launched the satellites several months earlier, as part of a mission called THEMIS, specifically to study such magnetic disturbances, which not only provoke spectacular sky shows, but can also fry satellites and mess up radio communication. (Presented at the American Geophysical Union's fall meeting) —S.R.



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THE WARMING EARTH

Not-So-North Sea

European fishers might initially be pleased to hear the results of at least one global-warming study: a rise in water temperature at the bottom of the North Sea is boosting the diversity of fish species there.

Jan Geert Hiddink of Bangor University in Wales and Remment ter Hofstede of Wageningen University and Research Centre in the Netherlands analyzed the results of yearly bottom trawl surveys. They discovered that since 1985, a temperature hike of almost 3 degrees Fahrenheit has caused the number of bottom-dwelling fish species in the North Sea to increase by half.

That's a big change, but it makes sense, the investigators say. In the world's oceans, fish diversity generally increases toward the equator. In the Northern Hemisphere, as the globe warms up, the richer fish communities of the south should start moving northward. Indeed, the newcomers to the North Sea are almost all southern species.

But the area's fishers shouldn't rejoice too quickly. Most of those new species are small, as southern bottom-dwellers tend to be, and therefore of little commercial value. Moreover, another reason for their sudden proliferation, in addition to warming water, may be the overfishing of the North Sea's large predatory fishes, which previously kept the little southerners in check. Hiddink and ter Hofstede think similar changes are probably under way in other northern waters. (*Global Change Biology*) —*S.R.*

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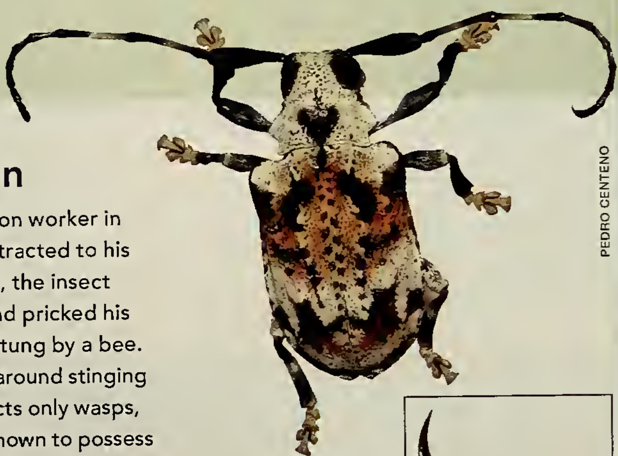
Clockwise starting top left: Caño Negro Wildlife Refuge; Tortuguero Park Canal Cruise; White Faced Monkey; Keel Billed Toucan; Manuel Antonio Park; Rainforest Hike

Soup Sandwich

Did life begin in a primordial "soup" or on the surfaces of minerals? There's no need to choose between those two leading theories, according to Helen Hansma of the University of California, Santa Barbara. She says the answer is both: the soup trickled into the slim spaces between sheets of mica, a mineral abundant in ancient oceans.

Hansma hypothesizes that the surfaces between two mica layers provided substrates to which molecules could stick, facilitating chemical reactions between them. Ocean water seeping through the sheets furnished the aqueous medium so favorable to chemical reactions. The movement of the mica sheets—powered by water currents and the expansion and contraction of bubbles trapped between the sheets—supplied energy for those reactions. And the layering of the sheets provided innumerable semi-isolated "habitats" in which distinct combinations of molecules could react or replicate, leading, by chance, to the development of biomolecules and, eventually, to life.

One piece of evidence Hansma points to is the atomic architecture of mica: a pattern of negative charges spaced one-half nanometer apart, which has seemingly left its signature in the present structure of RNA, a molecular relative of DNA fundamental to all life. Negatively charged phosphate groups that form the backbone of RNA molecules are also half a nanometer apart, a fact whose significance theoreticians on the origin of life will surely debate for years to come. (Presented at the American Society for Cell Biology's annual meeting) —*Graciela Flores*



PEDRO CENTENO

Sting Operation

Two years ago a conservation worker in Peru found a rare beetle attracted to his light trap. As he grabbed it, the insect jerked back its antennae and pricked his finger, which swelled as if stung by a bee.

Beetles don't usually go around stinging people. In fact, among insects only wasps, bees, and ants have been known to possess true stingers, specialized venom-injecting structures. So Amy Berkov of the City College of New York and two colleagues, including the beetle's victim, decided to investigate further. With a scanning electron microscope they examined the antennae of the offending beetle, *Onychocerus albitarsis*, and those of a related, nonstinging beetle, as well as the stinger of a scorpion (an arachnid more closely related to spiders than to beetles).

Each antenna of *O. albitarsis* ends in a bulbous enlargement that narrows to a hard, sharp tip—much like a scorpion's stinger does. Near the tip, the team discovered two pores, one of which housed traces of an unidentified secretion, possibly venom. The pores opened into narrow channels leading to the antenna tip. Similar pores and channels, part of a sophisticated venom-delivery system, are also present in the scorpion, but not in the nonstinging beetle.

Antennae of an Onychocerus albitarsis *beetle (top) end in stingers (inset) much like those of a scorpion.*

O. albitarsis thus appears to be the world's first-known stinging beetle. The similarities between the stingers of beetle and scorpion, two arthropods only distantly related, present a dramatic example of convergent evolution. (*Naturwissenschaften*) —*G. F.*

Emperor penguin

Blue in the Feathers

Emperor penguins surface from some of their dives with almost no oxygen left in their bodies, a new study shows. Their blood-oxygen level—the lowest ever recorded in a healthy, conscious bird or mammal—is less than a quarter of the level at which people black out. The birds are basically "returning on empty," says Paul J. Ponganis of the Scripps Institution of Oceanography in La Jolla, California, the study's leader.

In Antarctica, Ponganis and several colleagues inserted oxygen-sensitive probes into emperors' blood vessels, connected the probes to microprocessors carried on the birds' backs, then let the birds go fishing. The team measured the record-breaking oxygen lows after the longest dives, which lasted up to twenty-three minutes.

Many body tissues can survive for a while without oxygen, but not the brain. So how do emperors manage to stay conscious at the end of long dives? The answer may lie in special proteins in brain tissue, called neuroglobin and cytoglobin, that were discovered several years ago—and another recent study supports the idea.

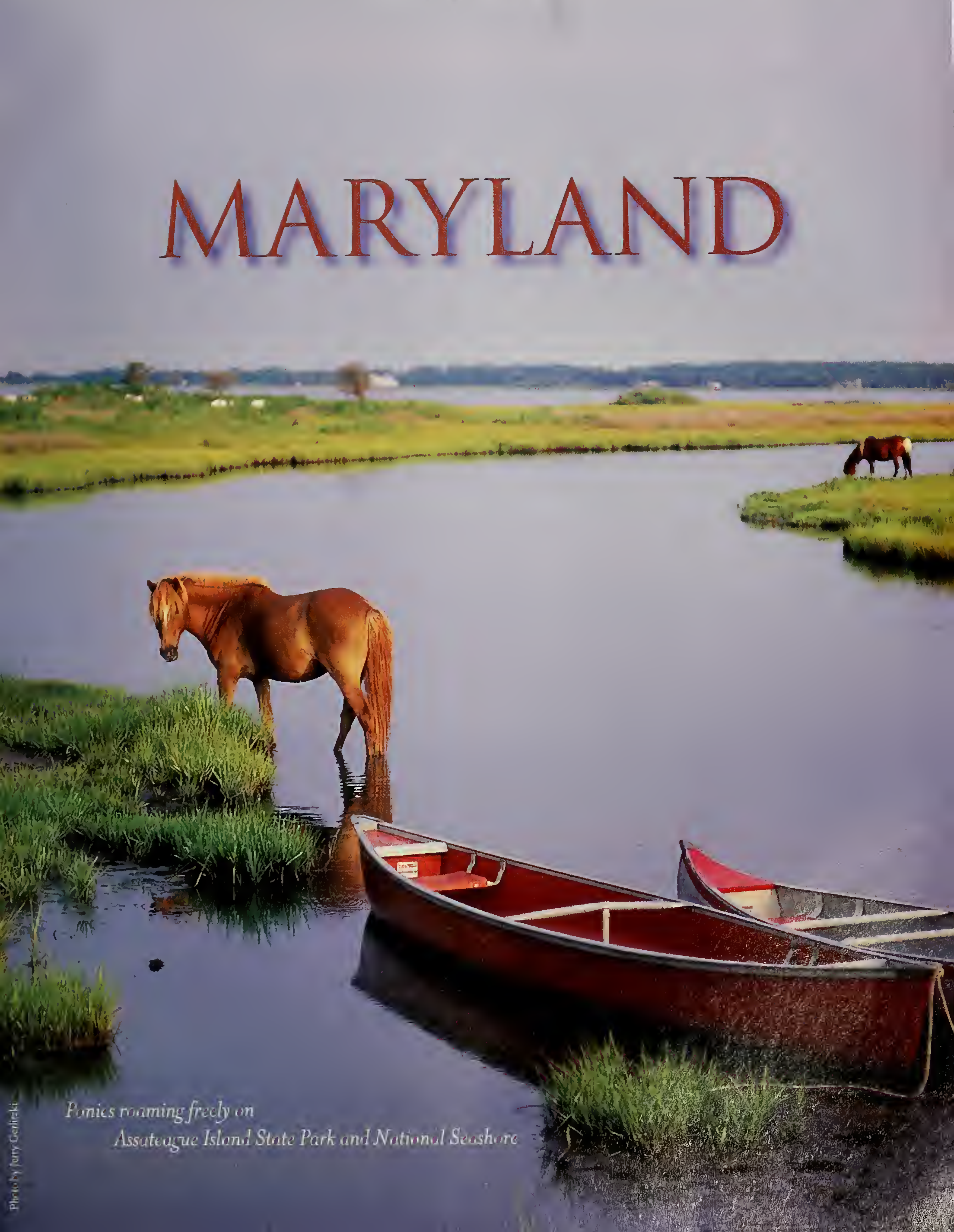
Terrie M. Williams of the University of California, Santa Cruz, and several collaborators compared levels of neuroglobin and cytoglobin in the brains of sixteen mammal species. Indeed, active divers that burn a lot of energy swimming, such as otters and certain dolphin species, have twice the levels of those proteins that terrestrial species do, the team discovered. It's likely that the proteins secure traces of oxygen and mobilize them to sustain brain activity.

Penguins aren't mammals, of course, but they are active divers and probably share some adaptations to a low-oxygen lifestyle. (*Journal of Experimental Biology*, *Proceedings of the Royal Society B*)

—*S.R.*

KATHERINE PONGANIS

MARYLAND



*Ponies roaming freely on
Assateague Island State Park and National Seashore*

Photo by Jerry Gerlicki

Maryland may be geographically small, but its diverse topography—from the Chesapeake Bay and Eastern Shore, to the majestic Allegheny Mountains, to the historic state capital of Annapolis—provides a range of vacation experiences, all within a short drive of one another.

Western Maryland

Head to the mountains of Western Maryland, perfect for hiking as well as for riding white-water rapids. Because the glaciers did not reach as far south as Maryland, the state has no natural lakes. But it does have 400 man-made ones, and Lake Habeeb is one of the largest in the state. It boasts a rustic lodge nestled in Evitts Mountain and surrounded by miles of hiking and wildlife watching trails. There's even a golf course for those that are looking for birdies of a different kind.

Capital Region

The area near Washington, D.C. is known as the Capital Region and includes the state's two largest counties, Frederick and Montgomery. Both are ideal for history buffs. Frederick, founded by Pennsylvania Germans in 1730, has a wealth of Civil War history. Montgomery also has a rich heritage, with 18th-century homes, preserved railroad communities from the late 1800s, horse farms, weathered barns, and notable Victorian architecture.

Central Region

For urban excitement, visit Central Maryland, home of Baltimore, the largest city, and Annapolis, the historic capital city known for its architectural integrity and naval history. The Central Region encompasses the Atlantic coastal plain and the Piedmont Plateau and is characterized by waterfront villages, mill towns, horse country, and the Chesapeake Bay.

Southern Maryland

It all began in 1634, when the first settlers landed in St. Mary's, in what is now Southern Maryland. Now called Historic St. Mary's City, the state's original capital is preserved as a living history museum, and signs of this early colonial past are everywhere. The Patuxent Wildlife Research Center, located midway between Washington, D.C. and Baltimore, is the largest science and environmental education center in the Department of the Interior and one of the largest forested areas in the mid-Atlantic region. It provides habitat for more than 200 species of birds, and is a key resting and feeding stop for many waterfowl species during the spring and fall migrations.

The Eastern Shore

The counties east of the Chesapeake Bay, including Worcester, Dorchester, Caroline, and Kent—are mostly flat farmland, perfect for cycling and hiking, and rivers, creeks, and inlets that can be explored by kayak or boat. Historic and natural landmarks dot the country roads, and the beloved Maryland blue crab—as well as fresh fish and oysters—is found in succulent abundance throughout the year.

Click VisitMaryland.org or call 1-800-984-9502 to start planning your trip to Maryland.

Photo: Bill Merlavage

Located just east of the only transportation portal west through the Allegheny Front during America's early expansion, Cumberland flourished as a commercial and cultural center through the mid-20th century. Much of its heritage has been preserved and redeveloped into a visitor-friendly getaway experience.

ALLEGANY COUNTY, in the mountainous region of Maryland, in the far western end of the state, straddles the line between the Atlantic and Mississippi drainage and provides for great outdoor explorations.

The natural history of Western Maryland is preserved in more than 120,000 acres of public lands from the Potomac River headwaters to the heart of Appalachian Ridge and Valley. Outdoor experiences include cliffs, caves, and many trails, including the Great Allegheny Passage, which connects Washington, D.C. to Pittsburgh via the C & O Canal Tow Path, and a continuous network of recently opened rail trails.

The Narrows was America's first gateway to the West, spawning a flourishing transportation and architectural heritage that entertains modern visitors with an operating steam railroad and restored arts and entertainment district.

CARROLL COUNTY, in Maryland's Central Region, was founded in 1837 and named for Charles Carroll, the only Roman Catholic signer of the Declaration of Independence. Both Union and Confederate troops trekked and camped along the county on their way to Gettysburg. Follow the Civil War Driving Tour to trace the troops' movements in 1863.

Stop along the way at Union Mills Homestead & Grist Mill, one of the few remaining operating mills in Maryland. Learn about the workings of a 19th-century farm at Carroll County Farm Museum, which also hosts the Maryland Wine Festival. Pick up a self-guided architectural/historic walking tour brochure at the Carroll County Visitor Center, then stroll Main Streets for unique shopping and wonderful restaurants. For outdoor fun, plan to visit both the Piney Run and Bear Branch nature centers.

CAROLINE COUNTY was created in 1773 from Dorchester and Queen Anne's counties and named for Lady Caroline Eden, the wife of Maryland's last colonial governor. Located in the state's Eastern Shore between the Tuckahoe River and the Mason-Dixon Line, Caroline County has more than 5,000 acres of parkland and wildlife preserves and miles of trails for hiking, cycling, or canoeing. The Museum of Rural Life, in Denton, preserves Caroline County's legacy as one of a handful of counties in the United States that existed for more than 300 years solely dependent on an agriculturally based economy. The museum preserves all or a portion of four historic houses, including a circa 1824 subsistence farmer's log cabin. Rich in heritage and natural resources, Caroline is ideal if you love the outdoors and early American history.

Near Preston in Caroline County, Linchester Mill is being restored for tours by the Caroline Historical Society.

DORCHESTER COUNTY boasts pristine rivers, marshlands, working boats, quaint waterfront towns, and villages dotting fertile farm fields. With an authentic Eastern Shore landscape, traditional ways of life still exist here, along 1,700 miles of Chesapeake shoreline. Dorchester is also the home of Blackwater National Wildlife Refuge, a blend of woodlands and tidal marshes, which provide a home to bald eagles. In March, the refuge hosts an eagle festival, featuring children's programs, exhibits, bird walks, and more.

On March 8, Harriet Tubman Day takes place at the Elks Lodge in the historic port town of Cambridge, with dinner and tours of historic sites.

From February 29 through April 12, a Smithsonian exhibit at the Dorchester County Historical Society in Cambridge looks at national and local culinary traditions. In support of the *Key Ingredients: America by Food* exhibit, local organizations will hold food-related events.

The 438-foot Monocacy Aqueduct is the largest aqueduct on the Chesapeake and Ohio Canal, crossing the Monocacy River just before it empties into the Potomac River.

FREDERICK COUNTY features 40,000 acres of public parkland, including city, county, state and national parks. The Chesapeake & Ohio Canal National Historical Park preserves America's colorful Canal era and transportation history. From 1836 to 1924, the Canal operated next to the Potomac River and includes eleven aqueducts. The 438-foot Monocacy Aqueduct was built from 1829 to 1833, and is the largest structure on the Canal along with being an icon of civil engineering. The Confederate Army tried twice, unsuccessfully, to destroy it during the Antietam campaign. Today the aqueduct is a great area for viewing wildlife, photography and outdoor recreation.

ThorpeWood, a mountain retreat located in a secluded portion of the Catoctin Mountain, offers unique nature and environmental education programs. Encompassing forests, mountain meadows, pastures, wetlands, and native trout streams, ThorpeWood also serves as a host to various scientific endeavors, one such is the Hybrid American Chestnut Orchard, which hopes to produce a hybrid of the American chestnut that is resistant to the American chestnut blight and to introduce this hybrid into eastern forests. To promote biodiversity, the retreat is planted with native plant gardens.

KENT COUNTY, settled in 1642 and lying on a scenic peninsula that juts out into the Chesapeake Bay, has retained its rural beauty. Chestertown, the county seat, on the banks of the Chester River, dates to 1706, when it served as a thriving mid-Atlantic port and prosperous shipbuilding and trading center. Its red-brick sidewalks and perfectly preserved 18th- and 19th-century homes, overlooking the river, have earned Chestertown a place on the National Trust for Historic Preservation's 2007 list of America's Dozen Distinctive Destinations. Rock Hall, facing west toward the Chesapeake (with spectacular sunsets views), has award-winning marina facilities and many historic inns and bed-and-breakfasts. The Rock Hall Museum houses Native American artifacts and nautical relics, and the Waterman's Museum has exhibits on oystering, crabbing, and fishing. The Tolchester Beach Revisited Museum remembers a thriving beach resort, from 1877-1962, where steamboat excursions brought thousands of visitors.

MONTGOMERY COUNTY is located on the western borders of the nation's capital and includes the communities of Bethesda/Chevy Chase, Rockville, Silver Spring, Gaithersburg, Germantown, and numerous other cities and towns.

In Glen Echo, visit the Clara Barton National Historic Site, home of the Red Cross founder. The Glen Echo Park for Arts & Culture, located next to the Clara Barton site, is home to the Dentzel Carousel, which has been in operation for 80 years. At the Chesapeake & Ohio Canal National Historical Park, take a walk along the tow path or see a breathtaking view of the Great Falls.

In Montgomery County, you'll find 200 miles of trails and paths, 33,000 acres of parkland, nine public golf courses, and 50 historic venues. Visitors can enjoy the historic charm, suburban appeal, and city excitement all within an easy metro ride to the nation's capital. And, for evening entertainment, the county has more than 900 restaurants, 60 galleries, and 22 theaters.

ST. MARY'S COUNTY

In 1634, 140 settlers landed on what is now St. Mary's County. Here you will find Historic St. Mary's City, site of the original settlement and the state's first capital, one of the nation's premier outdoor living history museums and archeological parks.

This 835-acre site—where you may board a tall ship, explore a Woodland Indian hamlet, help out in a tobacco field, or tour the 1676 State House—has just opened a new site, known as St. John's. State-of-the-art audio, video, and hands-on exhibits bring to light the story of this important 17th-century house, an official meeting place for the early government. Also opening, in spring, is an exhibit at the Van Sweringen site, the remains of the 17th-century lodging house built by a Dutch immigrant. The exhibit describes Van Sweringen's aspirations and experiences in the New World.

The Dove, *a replica of the ship that brought the first settlers to Maryland, sails past 1676 Statehouse.*

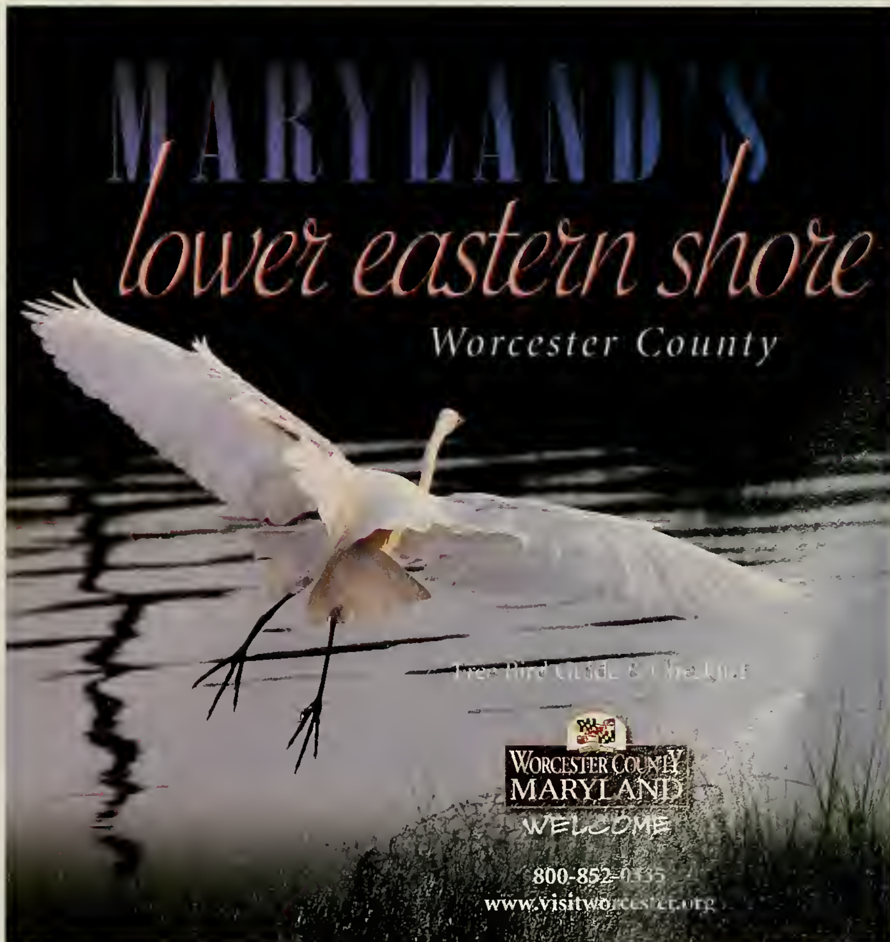
CHESAPEAKE BAY MARITIME MUSEUM

The Chesapeake Bay Maritime Museum, in the riverfront village of St. Michaels (Talbot County), is an 18-acre waterfront campus with the nation's most complete collection of Chesapeake Bay artifacts, visual arts, and indigenous water craft. The museum includes Navy Point, once the site of a busy complex of seafood packing houses, docks, and workboats, and Hooper Strait Lighthouse. Interpretive exhibits and public programs cover the range of Chesapeake Bay maritime history and culture, including the Bay's unique watercraft and boat building traditions, naval history, and seafood harvesting. The museum's working boat yard preserves, restores, and builds Chesapeake Bay wooden boats and is a favorite with visitors.

WORCESTER COUNTY is a small world of wonder. The state's only seaside county, Worcester is home to the year-round resort town of Ocean City, known for its boardwalk and white-sand beaches.

Just a few minutes south of Ocean City, Assateague Island State Park and National Seashore, a natural barrier island with abundant marshlands and sandy beaches, is home to a famous herd of wild ponies that roam wild among the dunes. Hikers, bikers, and sightseers can choose among several paths, both near the water and inland, to explore Assateague as well as other parts of the county.

In western Worcester, you'll find more than 13,000 acres of state forests. The deep Pocomoke River runs north to south along the length of the county, winding along bald cypress trees at their northernmost range. Worcester also claims the best birding in the state, an assertion supported by its ecological diversity. Its more than 350 recorded species include migratory birds, waterfowl, song birds, owls and harriers.



NATURALIST AT LARGE

Diana's Mountain Retreat

Named for the Roman goddess of woodlands, a singular butterfly survives in a shrinking habitat.

Text and Photographs by Gary Noel Ross

July 4, 1992, 5:30 P.M.: My pickup truck is parked off a lonely Forest Service road that loops around the rim of Mount Magazine, a loaf-shaped peak in Arkansas. Peering over the steering wheel, I have a panoramic view of a long valley 2,000 feet below, but my attention is focused on the nearby wildflowers. In front of me, bordered by patchy, stunted forest, is a small meadow yellow with coreopsis flowers, and off to the side, within a bright gap in the trees, purple coneflowers advertise themselves with droopy whorls of pink petals and yellow-orange pincushion centers. I've been holding vigil here since midday, hoping to spot a medium-size butterfly known as the Diana fritillary (*Speyeria diana*). So far I've counted nine species of butterflies, but no Dianas.

Then I realize a new butterfly has appeared atop one of the coneflowers. Its black and light-blue wings show it to be a female Diana. I grab my binoculars and watch as she walks slowly on the flower's spiky center, probing into the crevices to access the minute reservoirs of nectar. Occasionally she flies upward a few feet, circles the small patch of coneflowers two or three times, then resettles to resume feeding.

Past experience has taught me that temperate-zone butterflies depend upon warmth from the sun for flight energy and usually cease feeding long before the sun sets. But as one hour passes, then another, my Diana shows no sign of retiring. The sun sinks toward the western horizon

A male Diana basks on butterfly milkweed atop Arkansas' Mount Magazine.

and deep indigo tones advance from the east, but still she concentrates on her sugar fix. Fireflies begin to flicker in the darkness. My eyes are so tired and the light is so faded that I have difficulty discerning the Diana's dark silhouette.

Finally at 8:50 P.M., the butterfly launches straight up and alights upside down on a yellowing leaf of a nearby hickory tree. With her wings now closed, the dark brown of their underside is revealed. After a few seconds she tucks her two forewings partly into her hindwings. The overall effect is that of a frayed, dead leaf. I keep watch for another ten minutes to make sure she has indeed settled in. Then I retreat into the camper in the bed of my pickup, quickly down two cans of Ensure—my usual evening meal when in the field—and fall into my own nocturnal slumber.

The *S.diana* is the largest of some fourteen species in a genus of butterflies commonly referred to as the greater fritillaries. Members of the genus typically sport a checkerboard pattern of black spots on their wings—their name "fritillary" is from the Latin word for "dice box"—against an orangey background; the undersides of their wings are brown with silvery spots. In most species the males and females look similar, but the females are characteristically larger. All live in regions with cold winters and snowfall. The males emerge from their pupal stage (chrysalis) in early summer, usually a few weeks before the females, and die within two to three weeks after mating. The females, however, live for three or four months, and lay between 1,000 and 2,000 eggs during a three- to four-week period in the autumn.

That is an extraordinary number of eggs for a butterfly, a hint that the greater fritillaries must compensate for some hurdles in their life cycles. The eggs are deposited singly on ground litter, not on plants upon which the larvae, or caterpillars, can feed; violets, their host plants of choice, are usually desiccated by that time. Although the larvae hatch in late autumn and partly consume their egg casings, they do not feed on vegetation—instead they hibernate in the ground litter throughout the winter. In the spring, however, with the fresh growth of violets, the young caterpillars emerge and start munching away on the foliage.

After hibernating, the Diana caterpillars feast on spring violets.

Some of these features, such as the overwintering of very young larvae, are unusual for butterflies. Even among the cold-friendly fritillaries, however, the Diana is unusual, beginning with its coloration, which—atypically for fritillaries—is different in males and females. The upper surfaces of a female's wings are black with pale blue splashes and dots; the undersurfaces are a rich mottled mahogany color. By contrast, male wings are dark brown with extensive orange outer margins on top, while below they are a dull cinnamon color. And whereas most fritillaries are at home in sunlit meadows, Dianas are partial to heavily forested habitats (in Roman mythology, Diana was the goddess of woodlands, childbirth, and fertility).

First named in 1775 from specimens in Jamestown, Virginia, the species was historically common throughout the temperate deciduous forests of the southern Appalachian Mountains and westward to the Ozark-Ouachita Mountains of the Midwest. Presumably it once had a continuous range, but in *Butterflies East of the Great Plains,* published in 1984, Paul Opler and George Krizek recorded four separate populations. Two of those, they noted, had already disappeared:

> One group probably occurred in the Ohio River drainage from extreme western Pennsylvania to Illinois, but disappeared in the 1800s. Another group was known from the tidewater area of southeastern Virginia, including the species' type locality (Jamestown, Virginia), but has not been found there since the 1950s. The largest population occurs in the southern Appalachians from central Virginia and West Virginia southwestward in the mountains to northern Georgia and Alabama. A fourth population persists in the Ozark Mountains of Arkansas and Missouri.

To that I can add that the fourth population has since lost its Mis-


Deposited on the forest floor, a Diana egg falls prey to a carabid beetle.

souri contingent as well. But in any case, in 1990 I made it my business to learn how and why the Diana survives, in two regions separated by some 600 miles. I began my survey with several exploratory late-summer road trips from my home in Baton Rouge to northern Georgia and southwestern North Carolina. During my visits I saw only a few of the butterflies, all females, but enough to conclude that the Dianas living in that region prefer elevations between 2,100 and 2,500 feet—where summers are uncommonly cool and mornings often shrouded in pea-soup fog.

I found the Dianas along shadowy forest roadsides in patches of wildflowers such as butterfly milkweed, joe-pye weed, and fall-blooming thistles. The forests, consisting of hardwoods and hemlock, are tall and moist, and violets—ideal for hungry larvae—are common. Following that initiation, in mid-June of 1992 I drove to Mount Magazine in Arkansas to investigate the other Diana population.

Mount Magazine is essentially a 2,500-foot plateau, although it has a 2,753-foot knob that is the highest point in the state. As my truck began climbing up the mountain, I was surprised to find a very different forest cover from that of the southern Appalachians. Mount Magazine is drought-prone and dominated by oaks and hickories of only medium stature at best. I did find violet plants to be common, often growing in seemingly hostile places, such as the cracks in old asphalt roadbeds. Except for the violets, however, the Arkansas site seemed an unpromising home for Dianas.

After two weeks of looking in vain for Dianas on the mountain's lower slopes, I eventually headed up to the plateau proper. There I found sunny swaths of wildflowers, including butterfly milkweed, banking the untended roadsides. And before I knew it I saw, perched on one of the flowers, a butterfly that I instantly recognized to be a male Diana. During the rest of the day I logged six more males, some even helping themselves to minerals and salts from the scat of a coyote or fox. It took only another day or two to discover the "secret garden" where I was finally able to see my female Diana on a coneflower. Having since revisited Mount Magazine periodically for fifteen years, I am now privy to many aspects of the species' particular life cycle.

I began my investigations by concentrating on the obvious: the differences between the males and females. Once they emerge as adults, the males are relatively short-lived, needing to survive just long enough to mate. The marked contrast between the bright orange and dark tones on the upper surface of their wings may make them more vulnerable to predation by birds, but may also serve to attract females, particularly within the shade of forest cover. Still, the orange closely matches the pet-

One of the female Diana's favored sources of nectar in summer is the purple coneflower, a plant recognized to have strong medicinal properties.

The author targets a spicebush swallowtail perched on a butterfly milkweed blossom, a magnet for most butterflies.

als of the butterfly's favorite nectar source, butterfly milkweed, and so may also serve as camouflage.

A female Diana emerges in early to midsummer, mates while males are still on the wing, and survives into September and October, when she deposits her eggs. How does she manage? My first encounter with one of Mount Magazine's female Dianas provides part of the answer.

On warm, sunny days, females spend most of their time perched quietly atop leaves within deep forest shade. Although they station themselves near favored sources of nectar, they usually come out to feed during the coolness of morning (arising as early as 8:00 A.M.) and during late afternoon and early evening (retiring as late as 8:50 P.M.). Only on warm cloudy days are females likely to feed in the open regardless of the hour.

The female's habits, I have observed, change in autumn, when temperatures are cooler and she is laying her eggs. She begins feeding about 10:30 A.M., spending two or three hours on a single thistle flower head. By 1:00 in the afternoon, she flies into the canopy of the nearby forest, and from there descends to the shaded ground. Walking about and probing dried detritus with the tip of her abdomen, she finds a site that suits her and, curling her abdomen under dead plant material, deposits a single egg. Within four or five seconds, she moves a few inches and repeats the probing and egg laying.

After depositing up to a dozen eggs in the deep shade, she apparently needs warmth, and will fly to a sun-drenched spot to bask with her wings outstretched. She continues laying eggs and basking until about 3:00 P.M., by which time she will have laid a total of between thirty and forty-five eggs. She then abandons the forest to resume feeding, usually on the same thistle visited earlier in the day, until 4:45 P.M., when she seeks shelter.

I believe that the female's preference, in summer, for morning and evening hours helps her conserve energy during the most exhausting parts of the day. Her dark coloration, compared with the male's, enables her to absorb enough heat from less-direct sunlight and be active during cooler parts of the day.

That advantage continues to serve her when the cooler weather of autumn approaches. The dark color also provides camouflage in forest shade, likely reducing the risk of predation by birds. Those, at least, are my conclusions; many evolutionary biologists have hypothesized that the black and blue coloration mimics that of the pipevine swallowtail, a common butterfly species reputed to be unpalatable to birds.

While the males usually die before the supply of butterfly milkweed fades, the females draw nectar from a series of blooming species—purple coneflower, wild bergamot, narrow-leaved mountain mint, tall blazing star, tall thistle,

Continued on page 72

SPECIAL RESEARCH REPORT

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Now you can enjoy the pleasures of stress-free living and feel younger in just 15 minutes a day. It's surprisingly easy with the remarkable new medical device called the StressEraser.

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Medical researchers now know that the harmful effects of *ergotropic tuning* are intricately connected to the biological mechanisms of breathing. More importantly, they learned that you can actually regulate the stress-producing activity of this system by regulating this basic bodily function.

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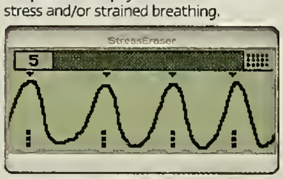

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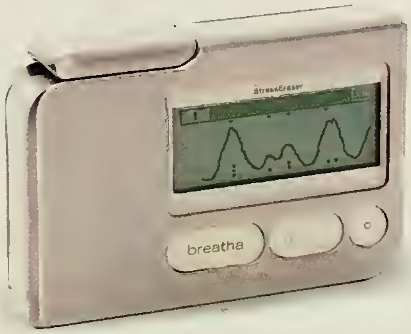

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LIFE ZONE BY OLIVIA JUDSON

Inside the Code

Our DNA contains layers of "extra" information that constrains the direction evolution can take.

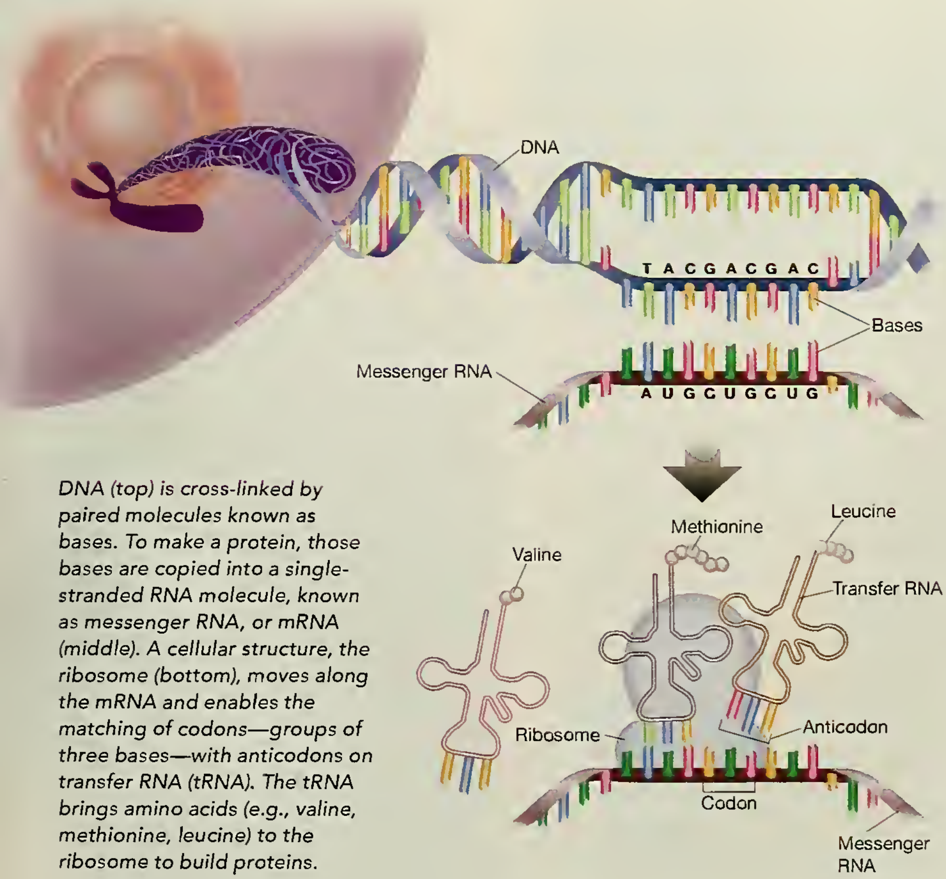
AUGCUGCUGCUGGCG . . . So begins the human version of the genetic instruction to make "sonic hedgehog," a protein essential for an embryo to grow properly. But how does that instruction work? The basic answer is that it codes for a string of amino acids—the small molecules that, linked together in long chains, form proteins. But there's a more complex answer, too. The instructions, it turns out, are more specific: they spell out how fast a protein should be made, which of several possible shapes it will take, and even which bits of a protein will be needed in a particular cell. Over the past several years, it's become clear that this "extra" information is extensive and important, both in terms of the role it can play in causing diseases, and for biologists' broader understanding of evolutionary processes.

To understand where all the extra information comes from and why it is important, it helps to know exactly how the machinery of the cell translates the different genes in a length of DNA into their corresponding proteins. So let's take a moment to brush up on the workings of what I consider to be one of the seven wonders of the natural world: the genetic code. Trust me, this will come in handy.

The genetic code reached its present form early in the history of life, sometime before the evolution of the last universal common ancestor—the being from which all life forms on Earth today are descended. As a result, almost all living organisms use the same genetic code to translate their genes into proteins. (Among the few exceptions are the yeast *Candida albicans*, famous for causing infections in humans, and that staple of Bio 101, the single-celled, lozenge-shaped *Paramecium;* but such exceptions, without exception, use codes that are plainly derived from the regular code.) The near universality of the genetic code is the reason genetic engineering is possible. Put a gene from a jellyfish into a rabbit and the rabbit will begin to make the jellyfish protein, because jellyfish and rabbits—along with just about everything else—read their genes the same way.

Making a protein from a gene is a two-step process. Genes are written in DNA, but before they can be used to manufacture proteins, they have to be copied, or "transcribed," into a related molecule known as RNA. The cellular machinery takes that RNA template, known as messenger RNA (mRNA), and "translates" it into an actual protein. (The message given at the start for the sonic hedgehog protein is, accordingly, presented above in its RNA form.)

The differences between RNA and DNA are small but significant. Whereas DNA usually exists as a stable double-stranded molecule—the iconic double helix—RNA usually exists as a single strand, is relatively unstable, and has a tendency to knot up on itself. In DNA, the struts of



DNA (top) is cross-linked by paired molecules known as bases. To make a protein, those bases are copied into a single-stranded RNA molecule, known as messenger RNA, or mRNA (middle). A cellular structure, the ribosome (bottom), moves along the mRNA and enables the matching of codons—groups of three bases—with anticodons on transfer RNA (tRNA). The tRNA brings amino acids (e.g., valine, methionine, leucine) to the ribosome to build proteins.

RNA code

CODON	AMINO ACID	CODON	AMINO ACID	CODON	AMINO ACID	CODON	AMINO ACID
UUU	Phenylalanine	UCU	Serine	UAU	Tyrosine	UGU	Cysteine
UUC	Phenylalanine	UCC	Serine	UAC	Tyrosine	UGC	Cysteine
UUA	Leucine	UCA	Serine	UAA	Stop	UGA	Stop
UUG	Leucine	UCG	Serine	UAG	Stop	UGG	Tryptophan
CUU	Leucine	CCU	Proline	CAU	Histidine	CGU	Arginine
CUC	Leucine	CCC	Proline	CAC	Histidine	CGC	Arginine
CUA	Leucine	CCA	Proline	CAA	Glutamine	CGA	Arginine
CUG	Leucine	CCG	Proline	CAG	Glutamine	CGG	Arginine
AUU	Isoleucine	ACU	Threonine	AAU	Asparagine	AGU	Serine
AUC	Isoleucine	ACC	Threonine	AAC	Asparagine	AGC	Serine
AUA	Isoleucine	ACA	Threonine	AAA	Lysine	AGA	Arginine
AUG	Methionine	ACG	Threonine	AAG	Lysine	AGG	Arginine
GUU	Valine	GCU	Alanine	GAU	Aspartic acid	GGU	Glycine
GUC	Valine	GCC	Alanine	GAC	Aspartic acid	GGC	Glycine
GUA	Valine	GCA	Alanine	GAA	Glutamic acid	GGA	Glycine
GUG	Valine	GCG	Alanine	GAG	Glutamic acid	GGG	Glycine

U=uracil A=adenine G=guanine C=cytosine

The RNA genetic code, read three bases at a time, specifies twenty amino acids and the instruction to "stop." The code has considerable redundancy, which led geneticists to think for decades that mutations changing a single base were "silent."

the double helix are made of pairs of flat molecules known as bases. There are four bases in DNA: adenine and thymine, cytosine and guanine, which are usually referred to by the shorthand of A, T, C, and G. In RNA, the bases occur not in pairs but singly, and thymine is replaced by uracil—hence the presence of the letter U in the message above.

The way the RNA code works is simple. The message is read in groups of three bases, called codons; each codon specifies either an amino acid, or a "stop"—a punctuation mark that says, "the gene ends here." Thus, the beginning of the sonic hedgehog sequence specifies a chain of five amino acids—methionine (AUG), three leucines (the three CUGs), then alanine (GCG). The codons are read by small RNA molecules, called "transfer RNAs" (tRNAs). The cell deploys an array of tRNAs to carry the various types of amino acids. A tRNA molecule is loaded up with a particular amino acid at one end; at the other, it has a three-base sequence, the anticodon, that complements a given codon. By means of its anticodon, each tRNA molecule attaches to an appropriate place on the long mRNA molecule. The amino acid it carries is thus dragged into the correct position to add to the growing protein.

So much for the review. Now let's look at the source of all that extra information. The RNA code has two striking features. First, it has a lot of redundancy: most amino acids can be specified by more than one codon. Both UUU and UUC specify the amino acid phenylalanine, for example [*see table above*]. The reason for the redundancy is that there are sixty-four possible codons—each of the four bases can occur in any of the three positions—but only twenty-one entities (twenty amino acids and "stop") to be assigned to them. Second, the redundancy has a pattern: codons that correspond to a particular amino acid tend to be related. For instance, all four of the codons that start with AC specify threonine. That means a cell doesn't need sixty-four different tRNAs: for some amino acids the tRNAs are quite generic, matching only the first two letters of the codon. This redundancy has an important consequence for the impact that mutations—random changes to DNA—have on the amino acid composition of proteins.

One of the most common mutations is the "point mutation," which changes a single base, say adenine, into another, such as guanine. This may alter the amino acid composition of a protein. A mutation from AAA to GAA, for example, will give you glutamic acid instead of lysine. Since amino acids interact with one another to twist the protein chain into spirals and other structures, thus giving proteins their shape, which in turn determines their function, changing one amino acid for another can alter the properties of the protein. Sometimes this is beneficial, leading to a more efficient protein. Sometimes the two amino acids are interchangeable, and the protein functions as well as it did before. More often, however, substituting one amino acid for another is harmful. But because of the redundancy in the code, many point mutations have no effect on the amino acid sequence of a protein.

Mutations that change a gene sequence without changing the amino acid content of the protein are known as silent, or synonymous. In the years after the code was first elucidated, it was supposed that silent changes would have no impact on an organism—that they didn't matter one way or another. That supposition is one of the tenets of perhaps the most influential abstract idea in molecular evolution: the neutral theory. Originally put forward in the late 1960s by the renowned Japanese biologist Motoo Kimura, the neutral theory does not dismiss natural selection. Yet it says that most genetic variation—most of the differences in DNA sequence between you and me, or between an oak tree and a chimpanzee—is noise. It means nothing; it has no impact on survival or the ability to reproduce; it is invisible to natural selection.

Certainly, some genetic variation is

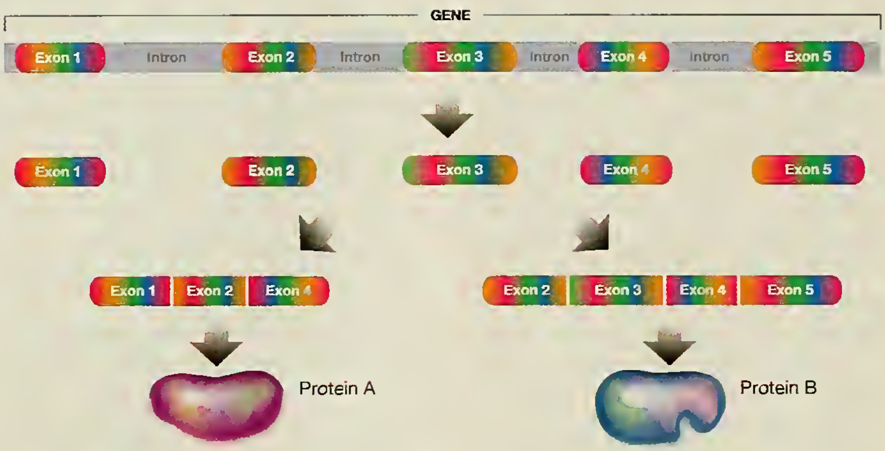
neutral—but far less than Kimura and his adherents initially supposed. Many silent changes, it turns out, have dramatic effects. They are, for instance, implicated in more than forty human diseases; in sensitivity to pain; and in the development of resistance to cancer drugs. For although silent changes do not alter the composition of the protein, they can have a variety of other effects.

For one thing, silent changes can alter how fast a protein gets made. Many organisms, from bacteria to fruit flies, have evolved a preference for one codon over another, even if both specify the same amino acid. The cells may even supply an abundance of tRNA molecules to interact with the "favorite" codon. If a non-preferred codon appears in the gene sequence, the cellular machinery responds more slowly. In the bacterium *Escherichia coli*, for example, the codon GAA is translated three times faster than the codon GAG, even though both specify the amino acid glutamic acid. Which codon is used can thus have a profound effect on how much of a particular protein a cell can make in a given time. If the protein is one that the cell needs to make quickly and in large quantities, a mutation that introduces a rare or non-preferred codon could put the organism at a disadvantage. Such a mutation could swiftly be removed by natural selection.

Silent changes can also alter the abundance of a protein by changing the shape of the mRNA molecule. As I noted earlier, one of the characteristics of RNA molecules is a tendency to knot up on themselves. Changes to an RNA sequence can cause it to knot more tightly. That can make it harder for the translation machinery to do its job; it can also change the rate at which the mRNA molecules are broken down and recycled (mRNA molecules normally get dismantled, sometimes just a few seconds after being translated).

Pain sensitivity in humans illustrates how knotting the messenger can have a big effect. One of the genes that mediates pain sensitivity is called *COMT* and it comes in three versions that confer low, average, or high pain sensitivity. You inherited one version from each of your parents, and which combination you have influences your chance of developing chronic joint pain.

The difference between high and low pain sensitivity should be due to big genetic differences, right? Yet recent work by Andrea G. Nackley, a research assistant professor at the University of North Carolina School of Dentistry's Center for Neurosensory Disorders, and her colleagues, shows that the difference between low and high pain sensitivity hinges on a single silent change. That silent change alters the stability of the mRNA, interferes with the translation machinery, and



Many genes have long stretches of non-protein-coding DNA, known as introns, that interrupt protein-coding DNA—exons. After the DNA has been translated into RNA, cell machinery chops the introns out and splices the exons together. Different combinations of exons can make completely different proteins.

reduces the amount of the specified protein you make, leaving you more vulnerable to pain.

But perhaps the longest roll call of important silent changes are those that influence how proteins are put together. Among eukaryotes—organisms, such as humans, fruit flies, yeast, and bamboo, which sequester their genes in the nucleus of the cell—most genes don't occur as long, uninterrupted stretches of DNA, as they do in bacteria. Instead, genes are split into segments known as exons that code for amino acids, and segments known as introns that do not. Introns can be huge. In the human genome, for example, the average exon is 150 bases long, while introns average 3,500 bases, and can be as many as 500,000.

This structure of introns alternating with exons is initially copied into the mRNA molecule as well. Before it can make a protein, therefore, the cell has to cut the introns out of the RNA message and stick the exons together—a procedure analogous to the way an editor cuts and tapes together film in the cutting-room, and known by the same name, splicing. Failure to remove the introns, or cutting the RNA in the wrong place, typically results in a protein that doesn't work.

A second consequence of having introns is that the exons of a single gene can, in principle, be spliced together in different ways to make different proteins. Suppose a gene comprises nine exons. Proteins could be composed of all nine, or of various subsets and combinations. Such "alternative splicing" is one of the ways that organisms such as humans generate large numbers of proteins from a fairly small number of genes (in our case, around 20,000).

But how does the cell know where an exon finishes and an intron starts? Or which exons to include in a given protein? Again, those instructions are written into the DNA and RNA. For instance, sequences of bases, toward the ends of both introns and exons, say "cut me here." In the exons, the "cut me here" sequences are also involved in specifying amino acids. Here again, then, a silent mutation may be more catastrophic than a mere change to one of the amino acids would be. The same goes for a silent mutation that causes a "cut me here" signal to appear in the middle of an exon.

These various discoveries are important for several reasons. From the point of view of health care, they show that silent changes to genes need to be considered as possible causes of disease. From the point of view of an evolutionist, they show that the neutral theory does not apply as widely as was once thought, and that natural selection does not simply act on DNA sequences based on their effects on amino acid sequences. But more than that, these discoveries suggest that evolutionary improvements to the amino acid composition of proteins will sometimes be inhibited.

That inhibition is real. Bioinformatician Joanna Parmley of the University of Bath and her colleagues there and at the University of Lausanne recently discovered that the rate of evolution of the parts of the protein coded near the ends of the exons is much slower than the rate of evolution in the middle of the exons. That suggests that if you could remove the introns and just have one long exon, the rate of evolution would speed up at the points where the introns used to be.

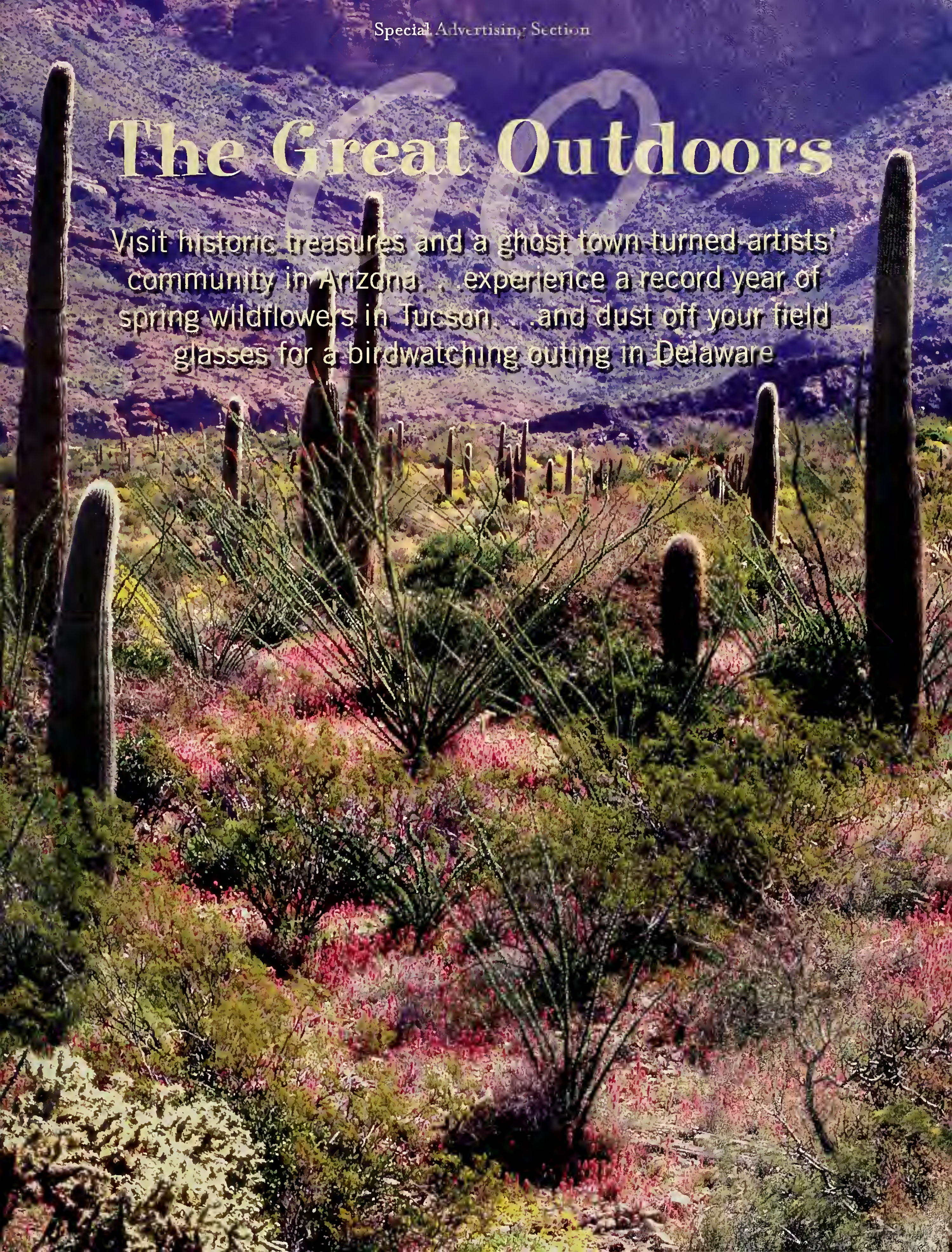
As it turns out, that is exactly what happens. Biologists can study it because, from time to time, RNA messages get copied back into DNA as one big exon after their introns have been snipped out. If the original, intron-laden version is still in the genome, then the two can be compared side by side. Parmley and her colleagues did just that: they compared forty-nine such gene-pairs in both mice and humans, and found that the sites near where the introns used to be—now freed—are evolving especially fast.

Those results are fascinating, for they start to address one of the most important questions in biology: to what degree are evolutionary processes constrained? And sometimes, it seems, evolution does indeed get stuck in a straitjacket.

Olivia Judson, a research fellow in the Division of Biology at Imperial College London, is the author of Dr. Tatiana's Sex Advice to All Creation: The Definitive Guide to the Evolutionary Biology of Sex *(Owl Books, 2003).*

The Great Outdoors

Visit historic treasures and a ghost town-turned-artists' community in Arizona. . .experience a record year of spring wildflowers in Tucson. . .and dust off your field glasses for a birdwatching outing in Delaware



ARIZONA

Whether your interest lies in art, theater, architecture, or a night out on the town, Arizona has something for everyone.

ARIZONA OFFERS A VIBRANT variety of entertainment options that will satisfy a taste for change. For a unique Southwest cultural experience, visit **La Posada Hotel** in Winslow. This National Historic Landmark is one of the last great railroad hotels, built by the Santa Fe Railway between 1928 and 1930. An architectural gem, La Posada was the career masterpiece of Mary Elizabeth Jane Colter, who meticulously designed every detail, inside and out—from the structure and landscape to the jackrabbit ashtrays, painted windows, and hand-built Southwestern furniture. Colter designed her buildings by developing a rich fantasy history for them. For La Posada, she envisioned the grand estancia of a wealthy Basque landowner whose family had occupied it for 120 years. Closed for four decades, La Posada has been painstakingly restored by its new owners, who have brought back the glory and magical fantasy of this Southwest treasure.

London Bridge

The **London Bridge**—built in 1824 and once spanning the Thames—now makes its home in Lake Havasu City. Robert McCulloch, an entrepreneur who founded the planned community in 1964, bought the bridge for $2.4 million from the city of London and had it reconstructed and dedicated in 1971. To avoid taxation when transporting it across the Atlantic on its

10,000-mile journey to Arizona, the bridge was declared an antique, becoming the world's largest antique, according to the Guinness Book of Records. The bridge was taken apart in 10,276 pieces and its granite weighed in at 22 million pounds. The three-year reconstruction of the bridge called for some innovative engineering, including forming the five arches using sand mounds as molds. Today the London Bridge is one of the state's most recognizable icons.

One of the largest and most visited ghost towns in Arizona, **Jerome** was once a booming copper town. Founded in 1876, it survived four disastrous fires, the Depression, and World War II, and today it is one of Arizona's premier art destinations. Visit on the first Saturday of the month and enjoy the Jerome Art Walk. The walk covers thirty galleries and private studios filled with jewelry, sculptures, glass and wood work, pottery, and much more.

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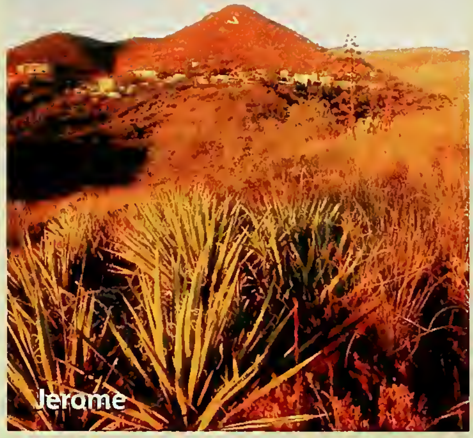
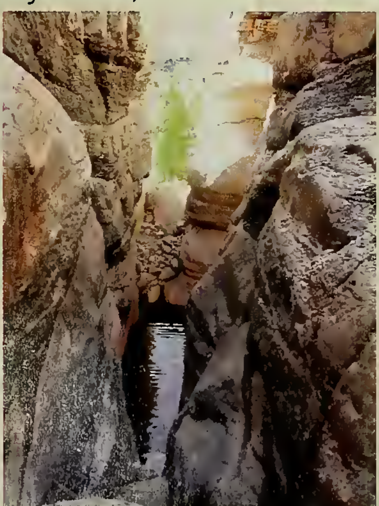


Jerome

Tucson's annual spring display of wildflowers varies from year to year, depending on late autumn rains—and this year promises to be one of the best showing in twenty years.

Tucson

LOCATED IN THE BIOLOGICALLY DIVERSE Sonoran Desert, Tucson has the right climate, topography, and varied habitats to support a profusion of wildflowers. They bloom yearround, but the peak months to see them are in March and April, when the hills, deserts, and roadsides are sprinkled with color. Look for African daisies, California and Mexican gold poppies, desert globe mallow, owl's clover, desert bluebells, paperflowers, desert marigold, penstemons, Indian blanket, and more. You'll find patches of wildflowers in town, including at the Sundial Plaza in Tohono Chul Park, a desert preserve with a 1937 Santa Fe-style home, and in the William McGinnies Wildflower Garden at the Tucson Botanical Gardens, which is planted with spring-blooming natives that peak in March-May. Outside of town, the Picacho Peak State Park has a lush, diverse selection of native wildflowers; visit the park in March, when it is covered with California poppies, and you can also catch the annual recreation of the Battle of Picacho Pass, Arizona's only Civil War battle. Hike the Sweetwater Trail in the Saguaro National Park to enjoy myriad wildflowers—including Coulter's lupine, Mexican gold poppy, desert rose mallow, larkspur, mariposa lily, and desert onion—set amid stands of saguaros. Sabino Canyon, Bear Canyon, Catalina State Park, and Kings Canyon are also great spots to see native wildflowers.



The spectacular rock formations at Milagroso Canyon are just one of Tucson's many hidden water features

Tucson also has several surprising aquatic finds, and you can hike many of them. Catalina is the site of the Romero Pools, with waterfalls and natural springs complimenting the high desert landscape. The Douglas Spring Trail, in the Rincon Mountains, takes you through classic desert scrub landscape—including saguaro, barrel cactus, prickly pear, ocotillo, and cholla—before you reach Bridal Wreath Falls. Look for roadrunners, jackrabbits, coyote, and javelina as you make your way. Hike to Hutch's Pool in the Santa Catalina Mountains, a popular swimming hole with a sandy beach on one end and low cliffs and a waterfall on the other. One of Tucson's most beautiful hikes takes you along Bear Canyon to Seven Falls. You'll see stunning Sonoran landscapes on your way to this seven-tier gorge and a group of small waterfalls and pools in the middle of the desert.

For more information visit www.visitTucson.org or call 1-888-2-Tucson.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Delaware

Located along the Atlantic Flyway, Delaware's tranquil ponds, protected wildlife areas, and ninety-plus miles of coastline make it the perfect stopover for migratory birds

BORDERING THE VAST AND RICH Delaware Bay, the First State is dotted with marshes, farmlands, and open spaces that attract migratory birds. Together with its scenic landscapes, the uncommon and rare shorebirds that appear on Delaware's sandy beaches and wildlife areas each year make the state an annual pilgrimage for birders during spring and fall migration.

Before heading out to the field, visit the Delaware Museum of Natural History's huge collection of about 4,000 bird species. When the sun goes down, go on an owl prowl at either Brandywine Creek or White Clay Creek state park, where naturalist guides will help you find barred and screech owls in the dense woods. Fort Delaware, on Pea Patch Island, is best known for its Civil War history as a prison, but it can also claim fame as one of the three largest heron rookeries on the East Coast, with 2,400 nesting pairs of herons, ibises, and egrets. In central Delaware, thousands of migratory birds take a refueling break in the wooded trails, freshwater ponds, and tidal marshes of Bombay Hook National Wildlife Refuge.

The DuPont Nature Center, overlooking Mispillion Harbor, opened in May 2007 and is one of the most important shorebird stopover sites along the Atlantic Coast during spring migration. Shorebirds are also attracted to its beaches in the fall.

Cape Henlopen State Park

On Swift Wings

What airplane designers could learn from the shape-changing wings of birds

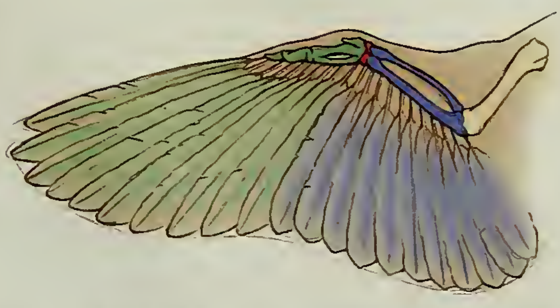
Illustrations by Jacqueline Mahannah

In 2006 when the U.S. military retired the F-14 Tomcat—of *Top Gun* fame—the most successful experiment in "swing-wing" airplanes was also grounded. Such planes rely on an intuitively appealing design idea: change the shape of the wing in flight and you can optimize the plane's performance over a range of speeds. Unfortunately, even as the best of its kind, the Tomcat was a poor imitation of its biological inspiration—birds that morph their wings in flight. It's been hard, though, for engineers to disentangle the wing changes in birds that are aerodynamically advantageous from the changes a wing must make for flapping. Now, thanks to an elegant study of swifts, investigators have their first empirical look at the effects of variable wing shape on bird flight.

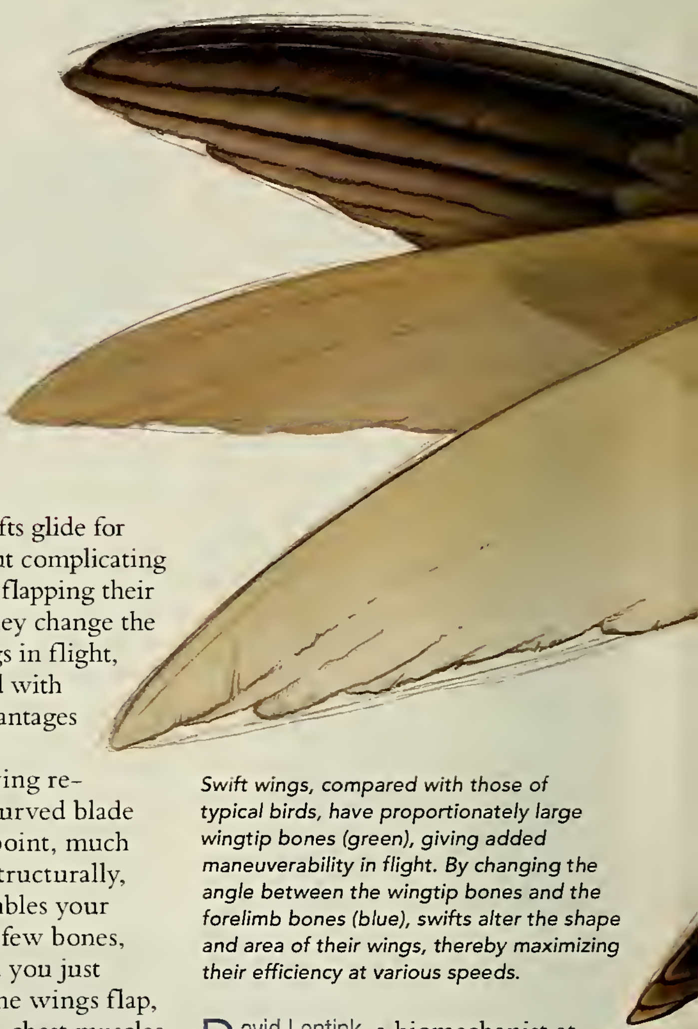
Swifts belong to the family Apodidae, which literally means "without feet" in Latin. Footless may be a bit of an exaggeration, but it's pretty near the mark. The birds' tiny feet seldom touch down because feeding, courting, and even sleeping all take place on the fly. Because swifts glide for long distances—without complicating things for observers by flapping their wings—and because they change the geometry of their wings in flight, they make an ideal bird with which to study the advantages of wing morphing.

Overall, the swift wing resembles a long, thin, curved blade that tapers to a sharp point, much like that of a scythe. Structurally, the wing closely resembles your arm: remove or fuse a few bones, add some feathers, and you just about have it. When the wings flap, as when your arms do, chest muscles power their motion.

In essence, those sets of bones give swifts, and all flying birds, two feathered airfoils on each wing, crucial to flapping in flight. One airfoil is made up of primary flight feathers attached to the wingtip bones. The other is formed by the secondary flight feathers attached to the forelimb bones. The swift, however, gains added maneuverability by having an unusually large proportion of its wing made up of the "hand," or wingtip, bones, compared with typical birds. By changing the "wrist" angle between the "hand" and forelimb, the swift can change both the shape of the wing and its area [*see illustrations on these two pages*].



Wingtip bones (green) and forelimb bones (blue)—corresponding to human hand and forearm bones, respectively—provide the typical bird with two feathered airfoils, critical to controlling flight.



Swift wings, compared with those of typical birds, have proportionately large wingtip bones (green), giving added maneuverability in flight. By changing the angle between the wingtip bones and the forelimb bones (blue), swifts alter the shape and area of their wings, thereby maximizing their efficiency at various speeds.

David Lentink, a biomechanist at Wageningen University in the Netherlands, and a team of aerodynamicists from the Netherlands and Sweden measured swift wings in a range of natural flight configurations. One of the most important factors, they discovered, is the aforementioned angle between the hand and the forelimb. Folding the wrist knocks a whopping 30 percent off the wing area.

Lentink and his colleagues also attached wings (from birds that had died in sanctuaries) to a finely calibrated balance in a wind tunnel, to measure how various wing geometries alter drag and lift. Drag is the force that acts in the same direction as the airflow, whereas lift acts perpendicular to airflow. Drag and lift, along with a bird's mass, determine the biologically important variables of gliding flight. For swifts with unfolded wrists and outstretched wings flying in a straight line, Lentink

and his colleagues determined that a speed of about twenty miles an hour gives the birds the maximum gliding time and the steadiest flight path for the least energy. So even though outstretched wings provide more drag, the wide spread gives a lot more lift for level flights.

That fits well with what is known about swift "roosting" behavior: tracking the birds on radar as they sleep on the wing shows that they glide and periodically flap to maintain an average speed of twenty miles per hour, and to minimize altitude lost per minute. In other words, they glide at a speed that requires minimum energy during their snooze time.

At high speeds, however, the advantage swiftly shifts to swept-back wings. Swifts are called swifts, after all, because their peak flight speed is so high. They have been clocked at more than sixty miles an hour—no wonder they fall asleep at twenty! It turns out that sweeping the wings back becomes key to energy efficiency at fast cruising speeds of more than forty miles an hour. At those higher speeds, the swept wings, which minimize drag, become more efficient both in maintaining a shallow-angle glide and in maximizing the time spent aloft.

If straight-line flying benefits from spread wings at lower speeds and swept wings at higher speeds, what about turning? The F-14 Tomcat spread its wings wide for increased maneuverability during dogfights, which demand lots of fast turns. Keeping the spread-wing shape when turning is also a good strategy for the swift—at least at twenty miles an hour. At that velocity, a swift can turn at least twice as fast by spreading its wings as it can by bending them.

In higher-speed turns, however—as simulated in the wind tunnel—it becomes impossible to measure the relative efficiency of spread and swept wings, because beginning around thirty-four miles an hour, spread swift wings become vulnerable to damage from aerodynamic stress. At high speeds they naturally flex and twist slightly in the turbulent air, and so avoid being damaged by the high forces. So, when pursuing fast-flying and fast-turning insect lunches, a swift bends its wings to keep up; the calories from such a meal warrant the extra effort.

Human attempts at variable wing geometry have always been hampered by the complexity and weight associated with a system engineered from hinges. Students working with Lentink are now building flexible, lightweight aircraft the size of swifts, capable of wing morphing. If such devices can be scaled up, fighter pilots could have a fast, agile plane that could slow down and spread its wings to hold station and maximize its time in the air. Even then, though, the pilots probably won't be dozing off.

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That GREAT *Beast* of a TOWN

In the 1770s, London became the epicenter for a great intellectual quest: discovering the incredible diversity of life on Earth.

by Richard Conniff

In November 1774, a cask of rum arrived in London spiked with four dead electric eels, the largest of them three feet eight inches long and up to fourteen inches around. They had smooth, snaky bodies, flattened heads, blunt snouts with a pronounced underbite, and two small fins, resembling ears, at the sides. Their eyes were small and round, and their dark facial skin was heavily pockmarked, as if by the point of a knitting needle.

The eels, actually knifefish of the species *Electrophorus electricus,* had been sent from the Suriname River in South America, and the sensation they caused in England was literally electric. A fifth eel had survived aboard ship all the way to the port of Falmouth, in southwestern England, and had duly delivered electric shocks to British thrill seekers before finally expiring. But even dead and consigned to rum, a standard preservative then, the specimens still had the power to excite educated minds.

John Hunter, master dissector (and avid client of grave robbers), surgeon extraordinary to King George III, and father of modern surgery, "danced a jig when he saw them, they are so compleat and well preserved," wrote his equally eminent naturalist friend Daniel Solander. John Walsh, a member of parliament and amateur scientist who had gotten rich in the East India Company, promptly paid sixty guineas for the three best-preserved eels—roughly two years' wages for the average London laborer then. Solander wrote to Joseph Banks, the botanist and naturalist, urging him to hurry to town, because Walsh and Hunter were sharpening their scalpels, "bent upon . . . opening one at least at the beginning of next week."

That those prize specimens should have found their way to London and elicited such delight there was unsurprising. Indeed, it was entirely within the means of the city's scientific circles to command the collection of additional electric eels from South America the following year—this time delivered live to Walsh's residence on Chesterfield Street, where an eel soon repeatedly demonstrated its ability to send a 600-volt charge through the joined hands of a ring of dozens of people at a time. No one seems to have suffered ill effects at these odd gatherings, though it is now known that even lower voltages can be fatal. Instead, visitors came away with a heightened sense of that era's characteristic excitement about the limitless possibilities of the natural world.

Science and giddy spectacle seemed to be everywhere in London, whose raucous population of 700,000 was crammed into seven square miles at a bend of the Thames River. The Thames itself was thick with the masts of ships serving a global empire, making London the place where the modern world of commerce, industry, urban living, and international trade was taking shape. Partly as a result, the city was also the nursing ground, if not the birthplace, for the science of natural history. Carolus Linnaeus had gotten things started by publishing and popularizing the first modern system for classifying species, beginning in 1735. But Linnaeus lived in the backwater of Uppsala, Sweden, a university town of just a few thousand people. Naturalists in Paris, Amsterdam, and other cities had also taken up the Linnaean cause. But London was the second biggest city in the world (soon to overtake Beijing) and the British passion for natural history soon made it the center of one of the greatest intellectual quests in human history: the discovery of the incredible variety of life on Earth.

PAGES 44–47 MARY EVANS PICTURE LIBRARY

AT THE START OF THE eighteenth century, the study of plants and animals had been an obsession of what Alexander Pope called the "virtuoso class," virtuosos being wealthy amateur naturalists vying to add the latest shell or skeleton to their private collections. But by midcentury, the rage for natural history had spread to the rest of the populace, becoming what cultural historian G. S. Rousseau has called "the universal British pastime, if not the national sport."

Then as now, naturalists came in for ridicule. The essayist Joseph Addison mocked them for hoarding up the "Refuse of Nature . . . such Creatures as others industriously avoid the Sight of." The critic and wit Samuel Johnson depicted a fictitious landowner named Quisquilius whose zeal for

London street scene, circa 1720. By the late 1770s, London's 700,000 inhabitants were crammed into seven square miles, a population density greater than that of modern Manhattan.

collecting was such that he let his tenants pay their rent in butterflies and "three species of earth-worms not known to the naturalists." But much as he disdained the menial labor of collecting specimens, even Dr. Johnson conceded that "there is nothing more worthy of admiration to a philosophical eye than the structure of animals."

The British people plainly agreed. Up to a thousand visitors a day came to ogle the vast natural history collection at the home of a virtuoso named Ashton Lever in Manchester. Charging admission would have been beneath his dignity, so Lever, clearly overwhelmed, attempted to discourage the carriageless lower classes by refusing entry to anyone arriving on foot. One spurned but determined visitor returned riding a cow. He was duly admitted.

In 1775, amateur naturalist Sir Ashton Lever opened a museum in London, shown here, called Holophusicon, Greek for "all of nature." His massive collection of specimens was presented in no particular order, drawing the contempt of devout Linnaean classifiers.

Why this sudden outburst of passion for the natural world? For more than a thousand years, nature had been locked away behind moral lessons and mythology. The Church, devoted to knowing the mind of God, had turned its back on nature. Common knowledge even about native European plants and animals had been handed down uncritically for centuries from Roman authors and medieval bestiaries full of imaginary creatures. So when the scientific revolution finally provided release from the fixed, allegorical medieval cosmos, people began to see nature as if for the first time.

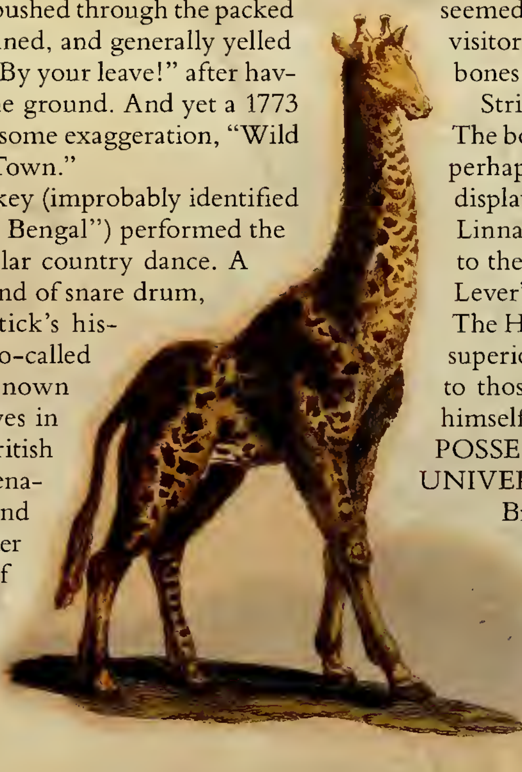
In England, the natural philosopher Isaac Newton had devised a new way of looking at the world in terms of astronomy, mathematics, and physics. The philosopher Francis Bacon had popularized the idea that knowing the Creation was the way to know God and to recover the intimate dominion over Nature lost at the gate of the Garden of Eden. A 1765 letter to London from Dr. Alexander Garden, a South Carolina naturalist, suggests that, after a century's gestation, this idea was now in full blossom. An ardent disciple of Linnaeus, Garden first griped about a rival stealing a species that he himself had actually discovered. But then he relented: "Yet, after all, he is an excellent man and I forgive him, because it is a matter of little moment who declares the glories of God, provided only they are not passed over in silence."

Some tradition-bound geographers still populated blank regions on their maps with such imaginary monsters as manticores (a blend of lion, scorpion, and human) and blemmies (headless humans whose faces were incorporated in their chests). But travelers were now actually visiting the farthest corners of the planet and discovering what really lived there. Linnaeus had provided the tools for bringing order to the overwhelming diversity they encountered. His system of classification made it possible to take any living thing, give it a simple name (like *Homo sapiens*), and place it in a neat hierarchy by species, genus, family, order, class, phylum, and kingdom.

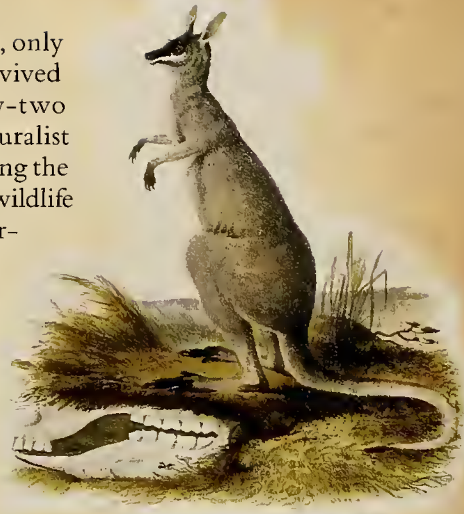
While not everyone could understand Newtonian physics, anyone could now approach the natural world, and for a time, according to the historian of science John R.R. Christie, almost everyone did—men and women, clergy and merchants, aristocrats and gardeners' boys. Studying nature required explorers willing to face the likelihood of death in some unknown land and also homebodies who could sit still and record minute details of natural behavior. It called for practical types skilled at hunting, drying, and stuffing, and also philosophical sorts who could make subtle distinctions about what connected different animals and what separated them. The new discipline required scholars trained to use the complex vocabulary of scientific description to name, classify, and describe the natural world. But it also required artists and writers who could bring new species to life for ordinary readers.

THROUGHOUT THE EIGHTEENTH CENTURY, astonishing creatures from distant regions seemed to turn up in London almost daily—the first zebra, the first giraffe, the first moose—each adding fuel to the raging national passion for the wonders of the natural world. In 1771, Banks and Solander themselves had brought back thousands of plant and animal specimens after three years traveling around the world with Captain James Cook on the *Endeavour.* Among their prizes were the skin and skull of a large creature with a head like a deer, said to rise up on two legs. It was also said to use those legs to go bounding across the grasslands of Australia like a hare, but with its long, heavy tail serving for balance. Banks announced it to the outside world with a borrowed Aboriginal name: "Kanguru."

New species arrived in London not just in the cause of science, but as entertainment. For a penny or two, gawkers could see a rhinoceros, a yak, a baboon, or a macaque monkey. Commercial menageries seemed to be everywhere, and taverns and coffeehouses attracted customers with "the living alligator or crocodile, lately arrived from the coast of Guinea," or "an Eel, the largest ever seen in London." It's hard now to imagine all of those creatures thrashing around the middle of eighteenth-century London. The human population density then already exceeded that of modern Manhattan—but without high-rise buildings, sewerage systems, or other means of making cities livable. Cartmen and porters pushed through the packed streets, one writer complained, and generally yelled "Make Room there!" or "By your leave!" after having just knocked you to the ground. And yet a 1773 visitor could remark, with some exaggeration, "Wild Beasts on every Street in Town."



Tame ones, too: A monkey (improbably identified as a "little Marmazet from Bengal") performed the Cheshire Rounds, a popular country dance. A hare played the tabor, a kind of snare drum, according to Richard Altick's history *The Shows of London.* So-called "Breslaw's birds," of unknown species, arranged themselves in ranks and marched liked British soldiers, with miniature grenadiers' caps on their heads and wooden muskets tucked under their wings. The baiting of bears and bulls was a common amusement, and in one popular event, the so-called Welsh main, only one fighting cock survived from among thirty-two combatants. The naturalist Gilbert White, savoring the relatively unmolested wildlife around his rural vicarage in Selborne, disparaged London as "that great beast of a town."



Private collections also catered to the ravenous British appetite for "prodigies," as wonders of the natural world were known then. In 1775, Ashton Lever, the virtuoso whose house in Manchester had been overrun with visitors, moved his collection to London, into twelve rooms of a former royal palace in Leicester Square [*see illustration opposite page*]. This time, dignity be damned, he charged admission. The collection featured preserved specimens, in no particular order, of squirrel monkey, coatimundi, opossum, leopard, osprey, bird of paradise, flamingo, sawfish, arctic fox, and thousands of other species. There was also "a Duck with a foot growing out of its head," a monkey in the pose of the Venus de' Medici, and a pair of hummingbirds displayed beside an ostrich, "by way of contrast."

Lever called his museum Holophusicon, "all of nature," and, like Dr. Johnson's Quisquilius, he nearly bankrupted himself in his quest "to possess all nature's wonders." But in the presence of his specimens, he and his public alike seemed to experience something sublime, what one visitor later called "a majestic awe for the power of bones and claws."

Strictly scientific collectors were less impressed. The botanist Joseph Banks apparently despised Lever, perhaps because the virtuoso's higgledy-piggledy displays blatantly flouted the beautiful order the Linnaean system of classification was just bringing to the natural world. Banks may also have resented Lever's knack for beating him to choice specimens. The Holophusicon's natural history collections were superior in variety, if not in scientific usefulness, to those of the British Museum itself. Or as Lever himself immodestly put it, "I am at this Time, SOLE POSSESSOR OF THE FIRST MUSEUM IN THE UNIVERSE."

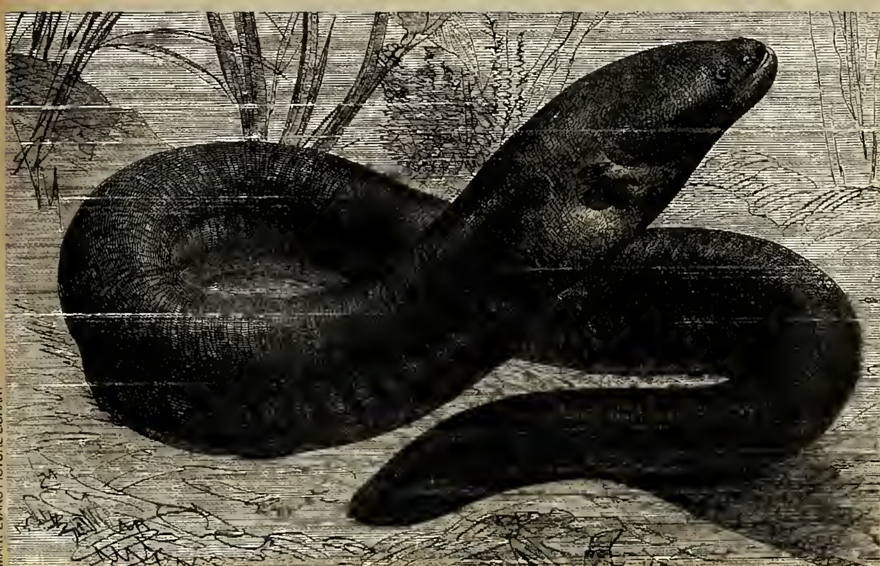
But if the showmen were colorful bordering on bizarre, so at times were the naturalists. And they sometimes depended intimately on the showmen for their best specimens. One night, for instance, George Stubbs, the master animal painter and anatomist, got word that there was a dead tiger at a traveling menagerie. "His coat was hurried on, and he flew towards the well-known place," a friend later wrote, "and presently entered the den where the dead animal lay extended: this was a precious moment." For three guineas, the carcass was delivered to Stubbs's home, where the artist spent the rest of the night (and probably many weeks thereafter) preparing and dissecting it. Well before human embalming was commonplace, Stubbs was a master at injecting a carcass with wax and other preservatives.

As a young man, he'd spent eighteen months meticulously stripping horse carcasses down to the skeleton and making detailed drawings at every anatomical level along the way, including five separate layers of muscle. According to a friend, his method was to suspend, from the ceiling, an iron bar lined with stout hooks, which he fastened between the ribs and under the backbone on the far side of the carcass. Then he lifted the animal up, with a platform under its feet, and began peeling back the skin and methodically working his way inward, spending six or seven weeks on each specimen. The result, apart from some of the greatest animal paintings and drawings the world has ever known, was a dawning sense of all the common elements connecting humans to other animals. Late in life, Stubbs made a drawing of a tiger skeleton running, and paired it with a drawing of a human skeleton hunched over like a sprinter leaving the blocks. The one echoed the other almost bone for bone. The quest for the glories of God was already leading some naturalists to think more carefully about the presumed glory of mankind.

Scientific research was also moving in the direction of comparative anatomy. John Hunter, London's leading surgeon and the likely model for the animal-loving Dr. Dolittle, and perhaps also for Dr. Jekyll and Mr. Hyde, dissected about 500 species over the course of his career, always with an eye to where each one fit in the larger biological picture. His method was to focus on some anatomical feature and present dissections from a variety of species side by side, in an orderly series of glass jars. For instance, his nervous system series includes marine worm, medicinal leech (still an important model in neurological research), earthworm, sea mouse, centipede, scorpion, lobster, slug, cuttlefish, sheep, ox, ass, porpoise, minke whale, and finally a human brain.

What Hunter learned in animals he soon applied to human patients. Among many other contributions to modern science, he demonstrated for the first time how bones grow, how the testicles descend in the fetus, and what course the olfactory nerves travel.

THE IDEA THAT NATURAL HISTORY might be an obscure or even irrelevant discipline, like collecting postage stamps, would have struck almost everyone in late-eighteenth-century London as utterly alien. Every species was astonishing in its way, and the naturalists who discovered, identified,



MARY EVANS PICTURE LIBRARY

Electric eels delivered shocks to London thrill seekers in the late eighteenth century. Research on the animals by John Hunter, the father of modern surgery, revealed that electricity might play a role in animal physiology and nerve function.

"Tiger" by George Stubbs, ca. 1769-1770, was inspired by a live tiger the artist sketched in a duke's menagerie in Oxfordshire. Stubbs's paintings and drawings owe their anatomical accuracy to his meticulous dissections of tiger, horse, and other animal carcasses.

labeled, and studied them were doing what Linnaeus called "immortal work."

That was true even with obscure species like the electric eel. By 1774 the London community of gentlemen scientists had an extensive network, bordering on espionage, in the most remote corners of the Earth. So they knew well in advance that the electric eels were coming. All five of the eels had been alive early that summer, when an enterprising British mariner carried them to Charlestown, South Carolina, and put them on display. Alexander Garden, the doctor and disciple of Linnaeus, had spied the eels. He promptly wrote to John Ellis, a London linen merchant and naturalist, who maintained an extensive correspondence with collectors in the American colonies. "The person to whom these animals belong, calls them Electrical Fish;" Garden reported, "and indeed the power they have of giving an electrical shock . . . is their most singular and astonishing property."

Garden naturally tried to buy them. And when the asking price proved too high, he sized up the likelihood of all five surviving the transatlantic voyage. (As an air-breather, *E. electricus* can live for months in a barrel of oxygen-depleted water, though not happily.) Then he advised the mariner "to get a small cask of rum, with a large bung, into which he may put any of them that may die, and so preserve them for the inspection and examination of the curious when he arrives."

The eels were thus perfectly prepared for London, and London for them. John Walsh and John Hunter had already done careful work on European torpedo fish, which can deliver a comparatively mild electrical shock of about fifty volts. Encouraged by that noted authority on electricity, Benjamin Franklin, Walsh and Hunter had determined that the electrical organs made up half the fish (and tasted like "insipid mucilage"). Hunter had characteristically taken note of the extensive network of nerves running through the electrical organs, and in an offhand phrase about the potential significance of bioelectricity, anticipated much of the future development of neurophysiology. "How far this may be connected with the power of the nerves in general," he wrote, "or how far it may lead to an explanation of their operations . . . future discoveries alone can fully determine."

Not everyone was ready to accept the idea of an animal producing electricity. So Walsh pasted tinfoil on a strip of glass and cut a narrow gap in the foil with the blade of a sharp knife. The idea was to get the electricity from the eels to visibly leap this gap. Soon after, a leading scientific journal reported, "It is with great pleasure that I inform you that they have given me an electric spark."

That spark was the beginning of the science of bioelectricity. A few years later, probably inspired by Walsh's work, the Italian physician Luigi Galvani began his celebrated research demonstrating the electrical nature of neural activity in ordinary animals, using an electrical stimulus to induce a muscle movement in a frog's leg. Soon after, working from animal models, the physicist Alessandro Volta invented the electric battery. In the new century, other researchers would go on to develop the science of neurophysiology, and to demonstrate the electrical basis of neural activity in the human brain.

Discovering new species wasn't anything like collecting postage stamps. On the contrary, the gifted community of naturalists gathered in London in the late eighteenth century lived and breathed with a knowledge we would do well to recapture even now. For them, each new species held the dazzling potential to reveal the secrets of life itself.

Richard Conniff, a 2007 Guggenheim Fellow, is at work on a book about the discovery of species. His award-winning articles have appeared in *Time, Smithsonian, The Atlantic, The New York Times Magazine, National Geographic,* and other publications. Conniff is the author of six books, including *The Natural History of the Rich: A Field Guide* (Norton, 2002) and *Spineless Wonders: Strange Tales of the Invertebrate World* (Holt, 1996).

Web links related to this article can be found at www.naturalhistorymag.com

Marine life off southern California 3.5 million years ago, depicted in a thirty-four foot-long mural by William Stout, includes auks diving from above and baleen whales feeding below.

Art for the Ages

PHOTOS BY BARRET OLIVER

New murals offer a glimpse of the Pacific Coast's extinct ecosystems.

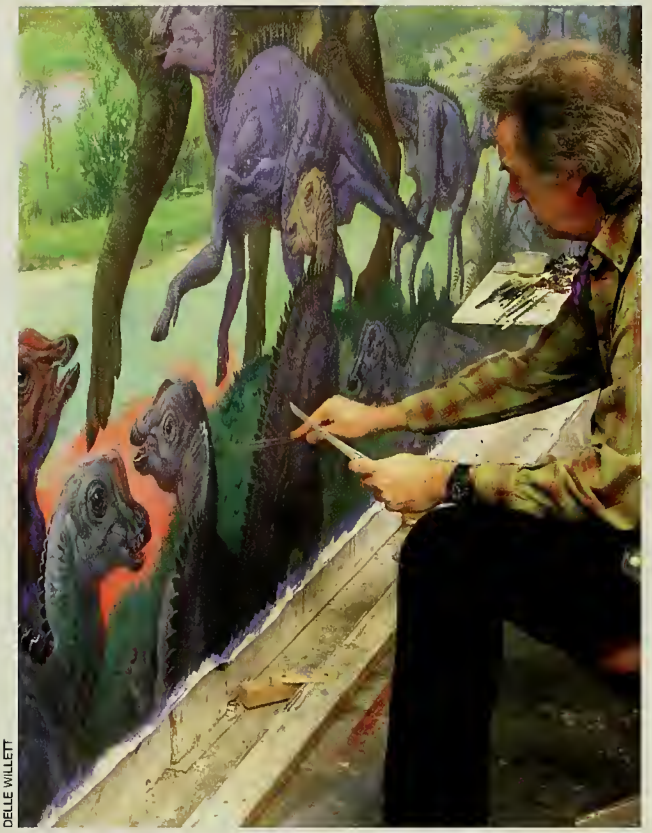
Interview Conducted by Richard Milner

Plants and animals in this mural detail lived near San Diego 30 million years ago; they are known from fossils recovered during excavations for new housing developments.

Fossils of plants and animals offer clues to what extinct creatures looked like, how they survived in their surroundings, and what finally killed them off. In "Fossil Mysteries," a new permanent exhibition at the San Diego Natural History Museum, fossils excavated and collected in southern California by the museum's paleontologists are brought to life in twelve murals created by William Stout. Among the spectacular scenes, which range in size from six to thirty-four feet long, are Ice Age vistas notable for their lack of ice, for even when great ice sheets blanketed much of North America, the climate in southern California (except for snowcapped mountain peaks) can best be described as Mediterranean. The detailed reconstructions, including some that show aquatic life along the Pacific Coast, complement the exhibition's three-dimensional models and mounted specimens.

Master paleoartist William Stout, who worked with scientists at the museum to portray the ancient animals and environments as accurately as possible, has had a long and eclectic career. He has drawn comic books, designed theme parks, and even contributed to the graphic satires of the legendary Harvey Kurtzman. His long list of Hollywood credits includes consulting on the pop classic *Jurassic Park* and creating Edgar, the giant alien bug in *Men in Black*. I spoke with him recently about his life, his work, and the creation of the San Diego murals.

Natural History: What do you consider the main purpose of your murals?
William Stout: Paleoart murals are a wonderful way of joining art with science. I see



DELLE WILLETT

Paleoartist William Stout adds finishing touches to baby lambeosaurs in his mural of dinosaurs that lived in southern California 75 million years ago.

"I scuba dive off the coast of Catalina Island near Los Angeles. I love to just sit on the bottom and watch the sea life swim by."

them as a conduit for the scientists to bring their ideas to the public.

NH: What do you strive for in these paintings, aside from scientific accuracy?

Stout: I try to come up with a concept that hits the viewers emotionally. Once they've been grabbed emotionally, they're intrigued and want to know more.

NH: How does one evoke emotion with a picture of prehistoric animals?

Stout: I use a number of devices. For instance, one of the Mesozoic scenes takes place underwater; I decided to set it at night. I'm a scuba diver, and my night dives were some of my most memorable. It's very eerie and spooky, and I wanted to have at least one mural that was scary. Kids love scary! With the mastodon that was found at Wanis, near Oceanside, California, I chose a low-angle view to convey the immense size and mass of the creature [*see illustration on opposite page*]. With the mural of extinct sea cows I was going for a completely different feeling. One of the places that I dive is off the coast of Catalina Island near Los Angeles. I love to just sit on the bottom and watch the sea life swim by. I wanted to capture that sense of serenity in a meditative piece that people could look at and feel tranquil.

NH: What else do you look for in a mural subject, besides emotion and accuracy?

Stout: I like to paint murals that are site-specific, so I included some local landmarks of San Diego. I want San Diegans to have a sense of ownership of these pictures. When they view the Pleistocene plant-eaters mural, they should be able to recognize Cuyamaca Peak, which can still be seen from San Diego freeways [*see illustration on page 55*]. I also used that landmark as a constant in three murals that depict one location at different times, from 2,000 to 20,000 years ago.

NH: Many of our readers are familiar with Charles R. Knight's murals that were done between the 1890s and the 1950s. Were you influenced by him?

Stout: I consider Knight the father of paleoart. The first to seriously combine art and science together, he visually defined prehistoric life for the world. If you pick up almost any dinosaur book written between 1920 and 1960, it's got his pictures in it, either from the American Museum of Natural History in New York, the Field Museum in Chicago, or the Natural History Museum of Los Angeles County. Many paleontologists have told me that it was Knight's murals, or Rudolph F. Zallinger's at Yale's Peabody Museum, that inspired them to choose paleontology as a profession.

NH: How did you go about constructing the new murals for the San Diego Natural History Museum?

Stout: I started with a series of one-inch-to-one-foot scale drawings. I got preliminary approval on those, and then I enlarged them as quarter-scale oil paintings. Once those were also approved, I took them to ThemeScape Art Studios, which produces gigantic graphics for casinos

PHOTO BY TAVO OLMOS

A mastodon treading warily through southern California wetlands is startled by a youngster.

A detail of one of Stout's murals depicts a saber-toothed cat defending its kill from a dire wolf.

and theme parks. They stretched the full-size canvases for me and then, using my quarter-scale paintings as a guide, they blocked in the full-size version with oils. That saves me from having to confront a huge blank canvas. They also have the space and equipment to execute paintings of this size. But I do have to go over every square inch revising, clarifying, and filling in details. Anatomy of prehistoric animals is highly specialized knowledge; I couldn't expect these guys to know this kind of stuff like I do.

NH: You have a variety of styles—a realistic style, a sort of dreamscape style, a sci-fi style, and a cartoon style. What determined your rendering?

Stout: I tried to make everything consistent with a realistic yet Impressionistic style. The museum staff indicated a strong affection for California Impressionism, a genre represented in San Diego by such painters as Maurice Braun, Charles Arthur Fries, and Alfred R. Mitchell. I was also influenced by my favorite nineteenth-century landscape painter, Thomas Moran. He's a gigantic hero of mine. Not just because of his art, but because of the great impact he had on our entire country. It was his paintings that inspired the national park system and helped to create Yellowstone as our first national park.

NH: What was your major difficulty on the project?

Stout: When I was about two-thirds of the way through the murals, in October, 2006, I was diagnosed with prostate cancer. The museum had every right to take back the commission and have the murals finished by someone else. But they rallied around me like family and stuck by me. I had successful surgery a few months later, and a few months after that I went back to work and finished them. I'll always be grateful to the museum staff for their unflagging faith and support.

NH: Why was it so important to you to complete the mural commission yourself?

Stout: I was also offered two other dream jobs at the same time—designing a movie about Edgar Rice Burroughs's fictional hero John Carter of Mars, and a children's television show. I wanted to do them all! But I asked myself, what's the first thing I do when I visit New York? I go to the American Museum of Natural History and look at the Charles R. Knight and William R. Leigh paintings. I knew from that answer I had to do the San Diego Natural History Museum's prehistoric murals as my own artistic and scientific legacy, one that will hopefully live on and inspire long after I'm gone.

Contributing Editor **Richard Milner**, an associate in the Division of Anthropology at the American Museum of Natural History, has written on Darwin, evolution, and paleoart, and has performed his one-man musical, *Charles Darwin: Live & In Concert*, worldwide. His new book, *Darwin's Universe: Evolution from A to Z*, will be published early next year by the University of California Press.

Web links related to this article can be found at www.naturalhistorymag.com

Camels, tapirs, horses, and early llamas roamed southern California 20,000 years ago, but none of those species—not even the horses—survived there after the end of the Ice Age.

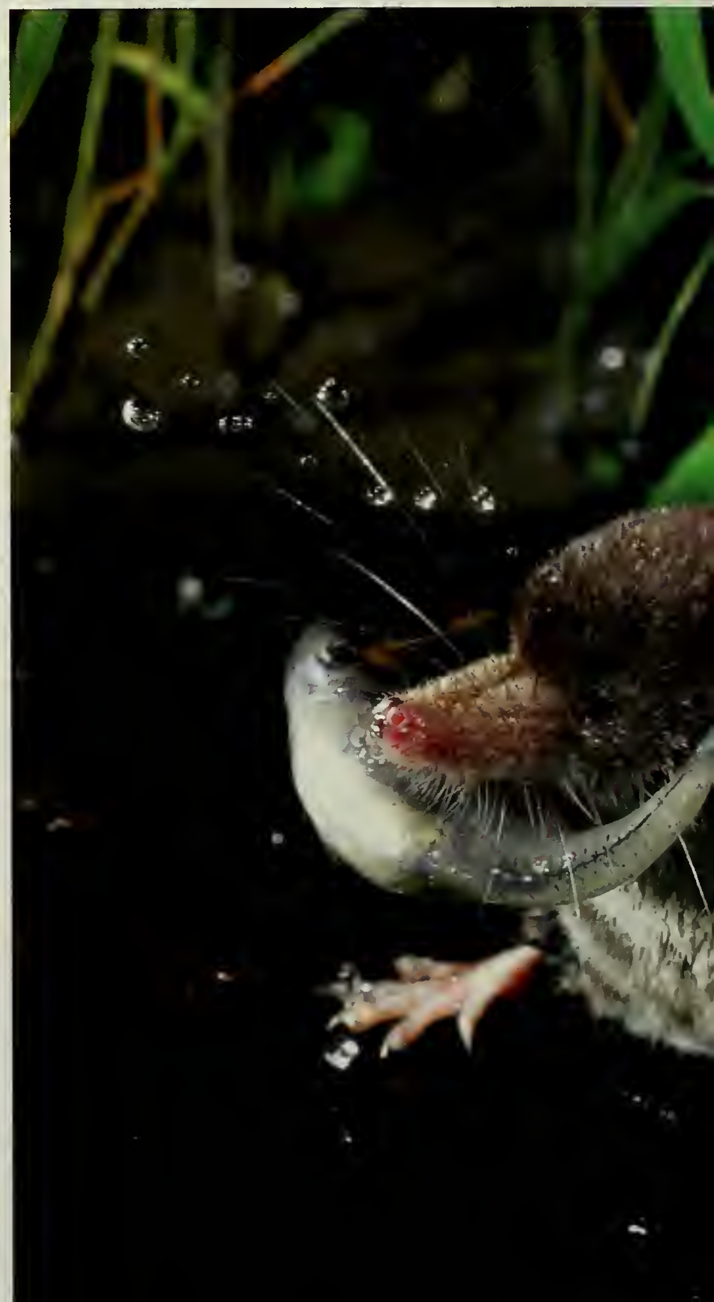
No Taming the Shrew

Good thing for us it's small, because this predator gives no quarter to its quarry.

STORY AND PHOTOGRAPHS
BY KENNETH C. CATANIA

I've been trapping star-nosed moles for two decades to study their behavior and anatomy, so I am used to the disappointment of finding an empty trap. But one trap I set about twelve years ago disappointed me in another way. I had placed it in a wetland to catch a mole, but found that another small mammal had the nerve to get caught. Recognizing that it was a North American water shrew, I released it at the edge of a nearby stream, wondering just how good it could possibly be at swimming (it doesn't look very different from its landlubber relatives). I was amazed to see it shoot straight down into a deep pool of water, swim across the stream, and disappear into submerged vegetation on the other side. It seemed more like a fish than a mammal. I never forgot the sight. Although my investigations of star-nosed moles continued to occupy me for years, eventually, in collaboration with Kevin L. Campbell and James F. Hare, biologists at the University of Manitoba, I set out to learn more about the North American water shrew, *Sorex palustris*. It is not only (at little more than half an ounce) the world's smallest mammalian diver, but also a predator with remarkable abilities to sense and capture prey. To be fair, you'll never have to worry about one latching onto your foot and dragging you into a lake. But I have come to think of water shrews as the great white sharks of their diminutive domain.

Shrews are members of the order Insectivora, which also includes moles and hedgehogs. Although they may look somewhat like mice, they are only distantly related to rodents. There are three subfamilies of shrews; the North American water shrew belongs to the Soricinae subfamily, the so called red-toothed shrews. This group



A North American water shrew, right, prepares to make a meal of a fish it has caught. The small mammals, which live in wetlands along streams and rivers, are expert divers. Opposite page, top: an unwary fish is ripe for ambushing.

gets its name from iron deposits in the animals' teeth that are thought to provide added strength to the enamel (tooth wear is a major problem for shrews, because their teeth don't grow continuously, as those of rodents do).

Water shrews by no means spend their entire lives in water. They live in wetlands and along streams and rivers, but pass much of their time on land, making their nests in dry areas and traveling through tunnels of grass, dirt, and mud. But as anyone who has flipped over a rock in a stream or pond can attest, there are plenty of creatures in the water to eat. Water shrews are well adapted to dive and swim for such prey. Their most obvious specialization is water-repellent fur. When diving, water shrews have a silvery, translucent appearance owing to a layer of air trapped by the fur. This keeps them dry and insulated—a critical ability, considering that they don't hibernate during the winter and so must feed by diving into icy water.

Their feet are also adapted for swimming, but not in the most typical way. Instead of webbing, water shrews have a fringe of broad, stiff hairs along the sides of their feet and toes [*see photograph on next page*]. These hairs rise up during the downstroke to increase the surface area of the foot, but fold down and out of the way during the upstroke. But perhaps most intriguing is how water shrews can find their food underwater—especially since their peak activity periods are at night, when vision is of limited use. It turns out they are able to use their sense of smell by sniffing air while submerged.

Logically that appears impossible: it is air that transports odorants to the olfactory receptors located in the nasal cavity, and there is no air underwater for a mammal to inhale. Water shrews, however, have evolved a simple and ingenious trick. While foraging underwater, they exhale air bubbles through their nostrils—often directly onto objects or prey they are investigating. They then inhale

Hairs give a water shrew's foot extra surface area, comparable to the webbing in some aquatic animals. On the upstroke the hairs fold down, offering less resistance.

the same bubbles to collect odorants. This ability had been overlooked because the sniffing occurs so quickly it requires slow-motion video to observe, and not many shrews have been filmed underwater with high-speed cameras [*see photographs on opposite page*]. I might have overlooked it, too, if I had not already discovered this trick in the star-nosed mole—another semiaquatic mammal that often forages underwater. That prompted me to test for the same ability in the water shrews, and I found it.

Do all shrews have this trick up their nostrils? It would be surprising indeed if terrestrial shrews did. I often catch terrestrial short-tailed shrews (*Blarina brevicauda*) while collecting star-nosed moles, and it was an easy task to train them to search for food in a shallow-water arena. As I anticipated, however, they were unable to sniff underwater.

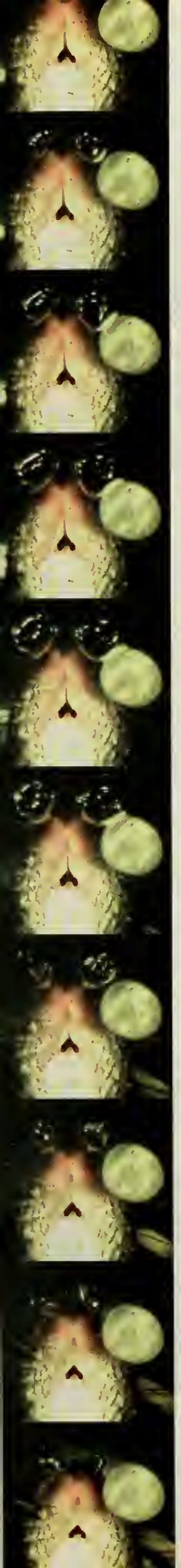
In their natural habitats, water shrews and star-nosed moles probably use underwater sniffing to explore their surroundings and to identify food encountered right under their noses. I have tested both species by training them to follow an underwater scent trail (earthworm- or fish-scented for the moles, fish-scented for the shrews) leading to a food reward. Both star-nosed moles and water shrews are able to perform this task with great accuracy. But when the bubbles they exhale during underwater sniffing are blocked by a fine steel grid placed over the scent trail, neither shrews nor moles can follow the scent.

Underwater sniffing is not a water shrew's only trick. In collaboration with my colleagues at the University of Manitoba, I've looked at other sensory abilities. Not surprisingly, we have found that, like most small mammals, water shrews also use their whiskers to detect prey. They have a dense array of whiskers geometrically arranged around their nostrils. Using those sensitive touch organs, they can detect prey shape and texture. To test those abilities, we made detailed model fish out of silicone. We then offered the shrews a series of silicone objects, both cylindrical and rectangular shapes, along with the fake model fish (all underwater and observed with infrared lighting to simulate night-foraging conditions).

The shrews investigated the different objects, rejecting the rectangular and cylindrical shapes but attacking the model fish. It was comical to watch them run back to their home cage with the model, uselessly chewing at the impervious silicone and then eventually stashing the model next to real food they had cached here and there in their cage. Although most of the shrews eventually stopped falling for this trick (perhaps because the silicone did not smell like a fish), the experiment demonstrated the importance of shape and texture for identifying food.

Observations of the animals' uncanny ability to detect and pursue fish, even in total darkness (evident in high-speed videos taken with infrared lighting), led to another experiment. We thought it likely that movement was an important cue that gave the fish away. To test that possibility, we prepared a small feeding chamber, which we equipped with four tiny water outlets connected to precisely controlled pumps. Once a shrew was accustomed to entering the chamber and finding a fish to catch and eat, we switched tactics by removing the prey. Instead, when the expectant shrew entered in search of a fish, an outlet pulsed water for less than a tenth of a second. Our goal was to imitate the disturbance caused by the tail-flick of a fleeing fish. In the absence of a fish, a shrew would attack the water movement as if pursuing a fish. In contrast, if the water was pumped in a continuous stream, the shrews ignored it.

Evidently water shrews can use their sense of touch to detect and pursue escaping animals. For such a strategy to work,



High-speed filming reveals that the water shrew can use its sense of smell underwater by exhaling air from its nose against an object it is investigating (here, a globule of wax on the right), then inhaling the bubble that has touched the object. The ten sequential photos, which run from top to bottom, represent a time span of just twenty milliseconds (about a fiftieth of a second).

an animal has to be fast, and that is certainly true of water shrews. By filming them at a thousand frames per second, we were able to precisely measure their response time. While foraging underwater, shrews began to turn toward a water movement in only twenty milliseconds (a fiftieth of a second), and in fifty milliseconds (a twentieth of a second) had moved as much as three-quarters of an inch while opening their jaws. That's about ten times faster than the human eye can begin to move to follow a movement in the visual field.

Imagine the quandary that puts you in as a fish. You can either sit still and be detected by an underwater sniff or the touch of the shrew's whiskers, or you can flee and give yourself away for sure by causing a disturbance in the water. Fleeing is probably the best option if you can get to open water. Fish are very difficult to catch when they have room to maneuver, and our observations suggest fish usually manage to escape in a large area. But a fish in a small space, in among rocks and vegetation, is apt to fall prey in only a fraction of a second.

Water shrews also feed on crayfish. That may seem a questionable strategy given the shrew's small size and the daunting claws of a crayfish. But a crayfish doesn't stand a chance. I suspect that is mainly because there is a fundamental difference between the nervous systems of mammals (vertebrates) and crayfish (invertebrates). All mammals, including water shrews, have nerve fibers covered with an insulating sheath called myelin. That greatly increases the speed with which nerve impulses are conducted, allowing for faster processing of sensory information and quicker reaction time. Invertebrate nerve fibers do not have myelin. The main invertebrate adaptation for speeding conduction and reaction time is to have large nerve fibers.

Because escape responses are so critical, the nerve fibers that control them in many invertebrates tend to be especially large. The tail-flick escape response of crayfish, which is often successful, is mediated by such "giant" nerve fibers. But even those giant fibers are no match for a shrew's myelinated fibers. And shrews have a second advantage as well: they are warm-blooded, and thus their nervous system is always at the optimum

Shrew seizes a fish; experiments show that the mammal senses when water is disturbed by moving prey, so a fish's attempt to escape often spells capture.

The daunting claws of a crayfish pose little challenge for the shrew. As a mammal, the shrew has a faster reaction time. Its warm-blooded nature maintains the nervous system at the optimum temperature for peak performance, and the nerve fibers are covered with myelin, an insulating sheath that speeds nerve impulse transmission.

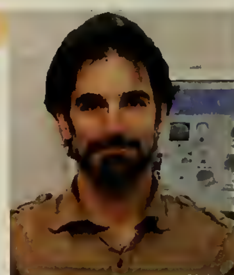
temperature for peak performance. The combination of those two attributes makes shrews formidable predators, at least from the perspective of a crayfish. If escape fails and a battle ensues, a shrew quickly prevails.

The shrew's brain is ultimately responsible for its sensory abilities, so we have sought to understand how the animal's brain is organized and how that might contribute to the shrew's skill as a predator. In all mammals, an outer six-layered sheet of tissue called the neocortex is the final processing station for visual, tactile, and auditory information. To investigate how the cortex is organized into different subdivisions for each of those functions, we can flatten it out, section it on a microtome, and stain it for anatomical markers that reveal the different areas. Along with recordings of brain activity, this technique enables us to map the size, shape, and location of brain regions devoted to the different senses and body parts.

In water shrews, a remarkable 85 percent of sensory cortex is devoted to processing information from touch. Vision and hearing take up only 8.5 percent and 6.5 percent of sensory cortex, respectively. Within the touch region of cortex, most of the area (about 70 percent) is devoted to processing sensory information from the whiskers, leaving only 30 percent for the trunk and limbs. That is an astounding mismatch between the size of body parts and the size of their representation in the neocortex—a phenomenon called cortical magnification. But it makes sense if one considers the importance of the whiskers, rather than their relative size. A similar "rule of thumb" governs body maps in human brains, where much of the touch region is devoted to the hands and lips, leaving only a meager area representing the trunk and legs.

The mammalian brain does not develop in isolation; rather, it is shaped by information from the body. A number of studies in different species suggest that inputs from the different senses compete for brain territory during development. We can get a clue to this process in shrews by peeking into the nest and observing the young. At early stages of development, just when the maps in the neocortex are being laid down, the skin housing the whiskers is swollen and vascular—standing out from the rest of the face. This reflects the enormous metabolic resources being devoted to whisker development. Thousands of touch receptors have been generated in the skin surrounding the nascent whiskers, and a massive cable of nerve fibers is already connecting them to the brain and sending signals to the developing neocortex. In developing water shrews, important inputs from the whiskers essentially carve out their large share of space in the neocortex. When the shrews finally emerge from the nest, at the age of three weeks, they are well-equipped with a keen sense of touch, and a week later they start diving for food on their own.

Kenneth C. Catania is an associate professor of biological sciences at Vanderbilt University. He studies the sensory systems, neurobiology, and behavior of specialized small mammals including water shrews, star-nosed moles, and naked mole-rats. His studies take him from his lab at Vanderbilt to the wetlands of Northern Pennsylvania. Catania is a 2001 Searle Scholar and a 2006 MacArthur Fellow.



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Great egret perches on a bald cypress.

Wetted Bliss

In a Louisiana refuge, different degrees of moisture create distinctive woods.

Just about any which way you cross Louisiana, you will pass through or beside wetlands, from swamps and marshes to bayous and oxbow lakes. Interstate 10, the main highway that runs through the low-lying southern portion of the state, including New Orleans, had to be elevated for eighteen miles just to bridge the swampy Atchafalaya River basin. Even in the north, where the land is higher, wetlands are abundant. One northern wetland that is a botanist's delight is Black Bayou Lake National Wildlife Refuge, about six miles north of Interstate 20. It was established in 1997 with the purchase of four and a half square miles of land surrounding Black Bayou Lake. Another two and a half square miles of property, comprising mostly the lake itself, has a free lease for ninety-nine years from the nearby city of Monroe.

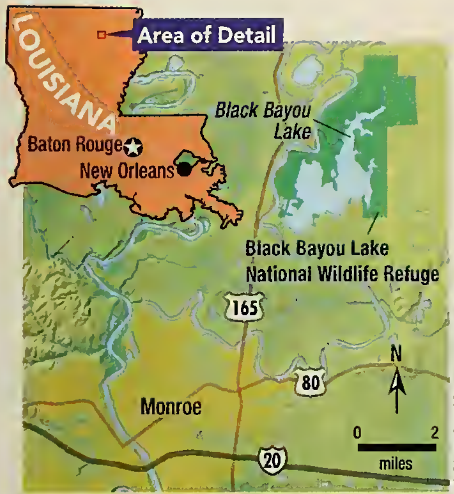
Much of the land surrounding the lake used to be farmland, but it is now being restored as woods and, in one place, as an example of Louisiana prairie. Amenities include a visitor center, an environmental education building, a wildlife observation deck, photography and bird-watching blinds, boat ramps, hiking trails, and a boardwalk over the deepest swampland. A list of birds that may be observed—including waterfowl, wading birds, and neotropical migrants—is available from the visitor center.

Close to the visitor center are three small ponds with typical aquatic and shoreline vegetation, as well as the recreated patch of prairie. North and east of there, refuge manager Kelby Ouchley has planted an arboretum of trees and shrubs native to Louisiana. A hard-surface, handicapped accessible trail has recently been completed through it. The various species and varieties, including some that do not occur naturally within the refuge, are carefully labeled. But the botanical gems

HABITATS

Mesic woods Dominant trees are black gum, black hickory, cedar elm, persimmon, sugarberry, sweet gum, and water oak. Less common trees include honey locust, pecan, white ash, wild black cherry, and winged elm. Vines include Carolina snailseed, graybark grape, ladies'-eardrops, peppervine, saw greenbrier, and the invasive Japanese honeysuckle. Among the shrubs are black elderberry, Louisiana blackberry, and saltbush. Herbaceous plants include butterweed, cleavers, spring forget-me-not, Virginia wild rye, and white panicle aster.

Wet woods American elm, cherrybark oak, eastern cottonwood, green ash, swamp tupelo, and willow oak dominate. Small trees and common shrubs include deciduous holly, green hawthorn, and swamp privet. Common vines are bristly greenbrier, frost grape, rattan-vine, trumpet creeper, and wisteria. Herbaceous plants include Carolina



JOE LEMONNIER

VISITOR INFORMATION
Black Bayou Lake National Wildlife Refuge
Highway 143
Farmersville, LA 71363
318-387-1114
www.fws.gov/northlouisiana/black bayoulake/

of the refuge are the three woodland habitats that depend upon different degrees of wetness.

Near the visitor center, where the land is slightly elevated, is a mesic (moist) woods. That grades down into a wet woods and finally an extensive swampy woods. Drier than the other two but still moderately wet, the mesic woods is distinguished by a forest floor carpeted with herbaceous plants. The wet woods, in contrast, has several shallow, bare depressions where water stands for considerable time following a rain. Merging with the wet woods, the swampy woods has standing water during the winter and spring. At those times of year it can be up to a few feet deep in places.

A remarkable characteristic of the three habitats is how the different degrees of wetness influence the distribution of closely related species. White ash, usually considered an upland species, occurs in the mesic woods, for instance, but is replaced in the wet woods by green ash, which in turn gives way to Carolina ash in the swampy woods. Similar tree progressions include: cedar elm to American elm to water elm; black gum to swamp tupelo to tupelo gum; water oak (not an aquatic tree, as the name would imply) to cherrybark oak and willow oak to overcup oak. A three-part habitat pattern is also evident in vines, as graybark grape gives way to frost grape and then catbird grape, and saw greenbrier gives way to bristly greenbrier and then round-leaved greenbrier.

As a rule, the reason the species tend to be naturally segregated is a twofold one. The roots of some species simply cannot tolerate substantial periods in standing water. And those species versatile enough to grow in more than one zone may lose out to species that are more finely tuned to a particular habitat.

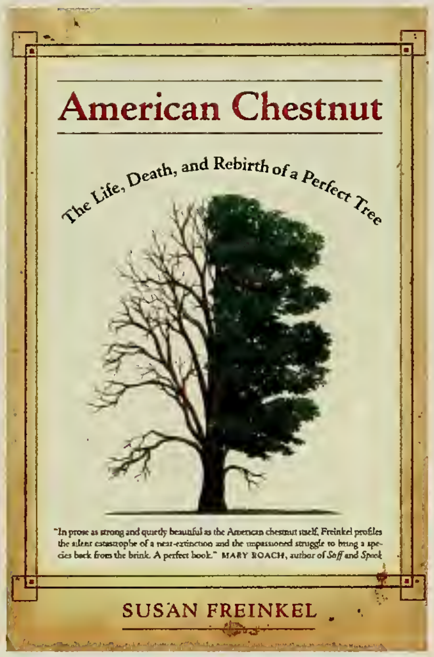

Flower head of a buttonbush

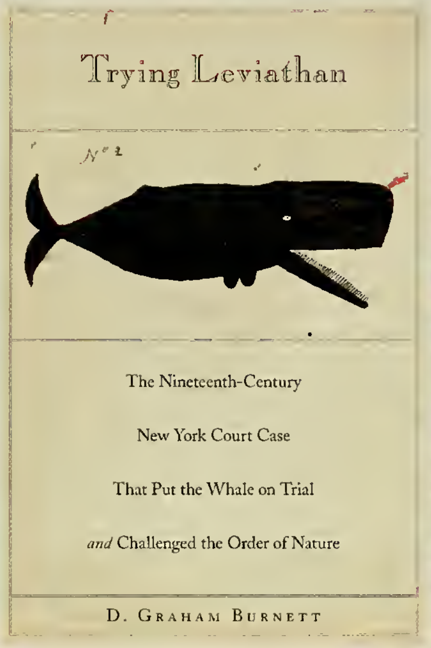
ROBERT H. MOHLENBROCK *is a distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.*


Common moorhen

buttercup, erect dayflower, marsh elder, pale smartweed, and woolly rose mallow, as well as some relatively rare members of the carrot family—finger dogshade, mock bishop's-weed, and whitenymph.

Swampy woods Bald cypress dominates, but Carolina ash, overcup oak, swamp cottonwood, tupelo gum, water elm, water hickory, and water locust also appear. Climbing hemp vine winds its way to the top of many trees, while catbird grape and round-leaved greenbrier are lower-growing vines. Buttonbush is the dominant shrub in the standing water. Few herbaceous plants live in the deeper waters, but shallow water provides a home for three kinds of beggar's-ticks, cutleaf water-milfoil, lizard's-tail, two kinds of pennyworts, two kinds of smartweeds, soft rush, spongeplant, and stingless nettle. The swamp also hosts large stands of southern wild rice.





American Chestnut

The Life, Death, and Rebirth of a Perfect Tree

By Susan Freinkel, University of California Press, 2007; $27.50

Some folks claim a squirrel used to be able to travel from Georgia to Maine without ever touching the ground or leaving the branches of a chestnut tree. That may be rural legend, but the fact remains that at the beginning of the twentieth century there were at least three to four billion American chestnuts, *Castanea dentata*, along the East Coast of the United States and the Appalachian mountain chain. The majestic trees dominated the thick hardwood forests, and were prized by mountain dwellers for their beauty and utility. Families in the southern Appalachians eagerly awaited the fall chestnut harvest, trading what they didn't eat to the local store to be shipped to big cities and roasted by street vendors. Manufacturers sought out chestnut wood for its strength and lightness, using it widely for both cabinetry and framing lumber. By 1909, some 600 million board feet of chestnut was being cut in southern forests annually, nearly one-fourth of all the hardwood lumber the region sent to market.

But by midcentury the American chestnut had virtually vanished, victim of a fast-moving fungal blight that invaded the bark, assaulted the cambium and sapwood, and cut off water and food to the leaves. Chestnut blight could kill a mature tree in less than three years, and its spores spread explosively through large stands of timber. Foresters watched in dismay as the epidemic surged outward from New York, where it first appeared, engulfing acre after acre much as a prairie fire eats up grassland. Only a few hardy specimens survived. All that remains of the tree are family stories, fading memories, and the names of countless Chestnut Streets and towns like Chestnut Hill, Mass., and Chestnut Ridge, N.Y. If you look closely among the oaks and poplars of the old forests, you can still see the stumps of fallen chestnuts, vainly trying to send out shoots, which are invariably cut down by the persistent fungus before they can flower.

Science journalist Susan Freinkel traveled into the mountains to collect oral histories from those who still remember the chestnuts of old. She creates a moving portrait in the first part of her book of those wondrous trees, how their bounty was enjoyed, and how so many mourned their passing. Yet, as its title suggests, her book is neither an elegy nor an exercise in nostalgia. Genetically, the American chestnut is not dead. Its DNA lives on in a few mature survivors, and in the immature shoots that struggle out of the root systems of fallen giants.

In the second part of her book Freinkel visits horticulturists who are trying to restore the trees to American forests, using a variety of methods. The most straightforward, in principle, is to breed a blight-resistant tree by crossing it with another type of chestnut. Since Chinese and Japanese chestnut trees carry genes that can fight off the fungus—which likely was imported from Japan—the trick is to create a hybrid of the American and Asian species. But in practice, it's not that easy. Chestnut trees, though relatively fast-growing, take seven to eight years to sexually mature, and numerous crosses need to be made over several generations to get the desired combination of traits. Other researchers, therefore, are trying quicker routes, seeking ways to disarm the fungus or to genetically engineer resistance into existing trees.

Freinkel's fine reportage sparkles here. Her interviews with hippie arborists, grizzled foresters, and academic botanists turn what might have been dry botanical tech talk into high drama. By the end of the book all but the most wooden-hearted readers will be rooting for the chestnut, not just as a spunky survivor, but as a symbol of the resiliency of nature as a whole. It's too soon, perhaps, to know if the American chestnut will ever make a full recovery, but if it does, concludes the author, "we will have gained back more than a perfect tree. We will have gained a new reason for hope."

Trying Leviathan:

The Nineteenth Century New York Court Case that Put the Whale on Trial and Challenged the Order of Nature

by D. Graham Burnett,
Princeton University Press,
2007; $29.95

There are many lessons to be learned from the 1818 trial of *James Maurice v. Samuel Judd*, not the least of which is that chutzpah—a Yiddish term for the sort of self-serving audacity often associated with New Yorkers—has a long and lively history in the Big Apple. Here's a brief summary of the case in question: On March 31, 1818, the New York State Legislature passed a law to ensure the quality of fish oils, which were widely used in the tanning and preservation of leather at the time. The law called for a corps of inspectors to "seek out any parcels of fish oil" and to certify the amount of water, sediment, and pure oil each cask contained. Three months later, a Mr. Samuel Judd, owner of the New-York Spermaceti Oil & Candle Factory at 52 Broadway, bought three casks of "fish oil" that had not been "gauged, inspected, and branded, according to law." Inspector James Maurice, seeking the statutory twenty-five-dollar fine for each uninspected cask, thereupon brought the case before the New York Court of Common Pleas.

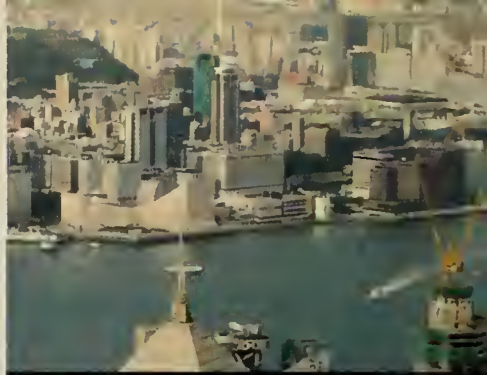
At the ensuing trial, Mr. Judd's crack defense team, with characteristic New York aplomb, did not deny that he had bought the uninspected oil. In all good faith, your honor—they argued—Mr. Judd believed the law simply did not apply in his case. For what he had purchased was spermaceti oil, obtained from whales. The whale, as was by then well known, breathed air, had warm blood, and nursed its live-borne young with milk. So was it a fish—traditionally defined as "an animal existing only in water"—or a mammal? If it wasn't a fish, how could its oil be fish oil?

The trial of Samuel Judd lasted three days, and the jury rendered its verdict after a mere fifteen minutes of deliberation, finding that before the law, at least, Mr. Judd was in the wrong. "A whale is a fish," wrote both the *New-York Gazette* and the *Evening Post,* as if the court had settled the matter. And so *Maurice v. Judd* earned its place in the annals of commercial chutzpah and judicial folly. Yet as Princeton historian D. Graham Burnett recounts it, the trial was also a forum for airing some of the major scientific issues of the time, chief among them the role of taxonomy in understanding the order of nature.

Although no one today considers the whale a fish, in the early 1800s Linnaean classification was a relatively new mode of thinking, regarded, at least by the general public, as an exercise in scholastic nit-picking. In the courtroom, physician and naturalist Dr. Samuel Latham Mitchill, chief witness for Judd's defense, presented the Linnaean argument from morphology: whales breathe air and have lungs, not gills; they have four-chambered hearts, like horses but unlike fish; their fins contain bones that are exact analogs of the hands and arms of apes and people.

Yet William Sampson, the lead prosecutor, challenged Mitchill at every turn, using arguments that have echoes in recent debates about Darwinian evolution. Was it not true, Sampson asked, that there was wide disagreement among scholars as to exactly how various animals should be classified? And what were common folk to make of the unlikely associations Linnaean taxonomy called upon them to make? "Now, is not man strangely mated or matched," Sampson mused, "when the whale and the porpoise are his second cousins, and the monkey and the bat his germans [close relations]? Other gentlemen may choose their company, I am determined to cut the connection."

Maurice v. Judd called upon the testimony of merchants, manufacturers, and whalemen to give their opinions on the fishiness of whales. Though Burnett's gloss on the testimony bristles with footnotes and academic references, his perspective on the intellectual and social climate of early-nineteenth-century America makes fascinating reading. The issues raised in *Maurice v. Judd* have surfaced again and again, right up to present-day battles over the teaching of intelligent design in public schools.



Earth Then and Now:

Amazing Images of Our Changing World

by Fred Pearce, Firefly Books, 2007; $39.95

Several hundred beautifully reproduced pairs of photographs face each other across the pages of this glossy coffee-table book, selected and arranged by journalist Fred Pearce to illustrate how landscapes and cityscapes around the world have changed over the past 100 years. The concept is simple, to be sure, but it is bound to evoke a wide range of complex responses from readers. On one level, leafing through some of the pages is a bit like browsing an album of old family photographs where faces are recognizable, but the styles and settings are quaintly, and sometimes uncomfortably, out of date. A 1925 photograph of Tokyo's Ginza shows only a few multistory buildings flanking a street jammed with trolleys. Across the fold is the Ginza of today, the facades of its steel-and-glass towers displaying luminous advertising signs and store marquees.

One of the major themes the pictures convey so graphically is the incredible pace of development over the past century. In a nighttime photo of Los Angeles taken in 1908 from nearby Mount Wilson (erroneously identified in the caption as Arizona's Kitt Peak), city lights are barely visible as a small glow in the distance. By 2007, the glow has spread, like mold on a Petri dish, to cover the entire prospect, from the foothills all the way to the horizon. On another two-page spread, the

span of only a quarter century between two aerial photos of the Brazilian rain forest shows a virtually unbroken field of greenery turned into an equally unbroken gridwork of logging roads littered with the detritus of downed timber.

The flip side of this overdevelopment is catastrophic destruction. Forces of nature have always been capable of immense violence, but as more people move into areas once considered dangerous, the potential for huge losses of life and of property grows. Sobering photographic pairs document the devastation of the October 2005 Pakistani earthquake, the Christmas 2004 tsunami in Sumatra, and the August 2005 flooding of New Orleans by Hurricane Katrina. One of the most affecting photographs shows Madagascar from the air, its rivers bleeding millions of tons of red silt into the Indian Ocean, a level of erosion unheard of before the clear-cutting of most of the island's forested hillsides.

Even more disturbing are scenes of war-ravaged terrain. There are before-and-after pictures of the Belgian village of Passchendaele, quite literally wiped off the face of the Earth by five months of heavy bombardment in World War I; before-and-after pictures of Hiroshima and Nagasaki from above; and before-and-after pictures along the Mekong River, illustrating the effects of Agent Orange, which turned rainforests into denuded wastelands.

The preponderance of photographs in this book document changes tied directly to human activity. For most concerned readers, a glance at a graph or table of data might suffice to understand the depth of the environmental crisis we face today. But these pictures drive the point home with a vengeance.

Yet there is some cause for hope to be found here. In some of the paired photographs (albeit not many), the "after" pictures are better than the "before" ones. A 1907 photo of a denuded mountain in Vancouver stands shoulder to shoulder with a photo of the parkland that occupies the space today. And a schematic view of the globe from above the Antarctic, based on satellite data from NASA, shows that the ozone hole can heal—in fact, it does every winter, offering a hopeful preview of what worldwide controls on ozone-destroying chemicals may accomplish year-round in about fifty years.

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.*

OUT THERE BY CHARLES LIU

Strength in Numbers

If you want to build a planet, you'd best begin with big bunches of boulders.

In November 2007, a team of California scientists announced yet another impressive milestone in the study of exoplanets, planets beyond our own solar system. The group, led for this particular study by Debra A. Fischer at San Francisco State University, has monitored the wobbling motions of a star, dubbed 55 Cancri, for eighteen years. Located forty-one light-years away from Earth in the direction of the constellation Cancer, the Crab, the star is quite ordinary, very similar in fact to our own ordinary star, the Sun. The star's wobbles are what's intriguing: after gathering more than 300 separate measurements of the minuscule (from our point of view) variations in its velocity and painstakingly modeling them mathematically, Fischer's team has confirmed that the star has at least five—count 'em, five—planets that orbit it. The existence of four of them has been reported previously; the newly discovered planet, the fifth, has half the mass of Saturn and makes one complete orbit every 260 days.

What is most noteworthy about Planet Number Five is that, given its mass and orbital period, it must lie just over 70 million miles from its parent star, a distance well within the range where liquid water could exist on a planet's surface. The newly discovered planet is probably a gas giant, like Saturn, without a solid surface; but if it has a big moon with an atmosphere, like Saturn's moon Titan, there could well be rivers, lakes, and oceans on that moon's surface, as well as other ingredients for life as we know it.

Number Five brought the growing catalog of exoplanets to as many as 237. In astronomy today there's an entire cottage industry devoted to finding exoplanets, and another one devoted to understanding them. Thanks to skillful telescopic observations, detailed theoretical models, and powerful supercomputer calculations, we're making strides faster than ever before in explaining how solar systems originate, age, and evolve; how stars and planets interact with one another in their systems; and how planets are born. Well, not quite: there's still a gigantic gap in explaining how planets, exo- or otherwise, are born.

For a planet to form, first a star must be born. That happens over a million-year-long timescale, as a cloud of cold interstellar gas and dust collapses under its own gravity, forming a dense, swirling "accretion disk," usually with an even denser core. As sufficient matter becomes concentrated in the core, the pressure and temperature at the center increase until nuclear fusion is triggered. That marks the moment of starbirth. It takes a little while longer for the star to settle into a mostly spherical blob of incandescent, ionized gas. That occurs when the forces pulling inward and pushing outward balance each other—a state called hydrostatic equilibrium.

If the baby star has a mass, say, about 300,000 times that of Earth, it will stay in equilibrium for about ten billion years. Meanwhile, within a few billion miles of the star, trapped within its gravitational influence, vast amounts of gas continue to feed the accretion disk, which swirls fast enough around the center not to fall into the star itself.

So how do planets form around such a star? Bits of dust and gas collide with one another throughout the accretion disk as they orbit the star. Some of them stick together, coagulating into grit, then gravel, then pebbles, then rocks. As the accretive process continues, the rocks start smacking into one another, combining their size and mass. Eventually the process builds planetesimals, bodies up to a few miles wide. Gravity now begins to play a crucial role. Smaller bodies fall toward, and eventually onto, the larger planetesimals with stronger gravitational pulls. The large ones thus grow larger still, giv-

ing rise to super-size chunks hundreds, then thousands of miles across. From myriad particles smaller than sand grains, the mighty planets of a brand-new solar system have sprung!

Alas, this soaring theoretical model of planetary birth is dragged down by a bit of reality—drag itself. Whether it's in a car engine or a stellar gravity engine, motion inevitably slows down and even grinds to a screeching halt when particles rub against one another. Without drag it's hard to explain how a swirling cloud of gas could slow down enough to fall inward and form a star [*see "Spin Control," the March 2007 "Out There" column*]. But once the star is already there, and planets start to form, friction becomes a problem.

An unimpeded solid body in orbit around a central star moves at a Keplerian velocity, a speed dictated by its mass, the mass of the star, and the distance between the two. But gas within a circumstellar accretion disk is sustained in orbit in part by the pressure of the star's light, and consequently moves at a slightly slower speed. Solid particles making their way through the slower gas experience a headwind—comparable to the headwind your hand feels if you stick it out the window of a moving car. The headwind slows those particles down, threatening to send them spiraling inward toward the star faster than they can combine into planets.

According to both theoretical calculations and computer simulations, itty-bitty particles in the disk are small enough to be swept up by the gas like dust in a windstorm. They stay with the slower-moving gas, avoiding the infernal infall. Meanwhile, large planetesimals at least half a mile or more across are big enough that they can push through that headwind without losing too much speed, and can remain in sustained orbits around the star. The problem is in an intermediate zone—rocks and boulders that range in size roughly between a marble and a mobile home. The theoretical calculations suggest that objects that size would feel the brunt of the headwind and so fall into the central star long before they could combine to form planetesimals. So the process of planet production should stop right there, and contrary to observational evidence, planets shouldn't exist!

That's the gigantic gap that needs to be bridged.

After we astronomers gnashed our collective teeth for years over this planet-busting quandary, a research team led by Anders Johansen at the Max Planck Institute for Astronomy in Heidelberg, Germany, appears to have taken a huge step toward solving the puzzle. Using novel computational techniques, the team filled up a virtual accretion disk with a whole lot of orbiting gumball- to beachball-size rocks and boulders, turned on the frictional headwind, and followed what would happen over thousands of years.

What they found was a remarkable example of how natural processes overcome what to a theoretician may seem an intractable obstacle. Although many of the boulders perished as predicted, some boulders wound up forming tight clusters that started orbiting together as a cohesive unit, growing toward mobile-home-size. Not yet big enough to resist the headwind alone, they collectively dragged the circumstellar gas along with them, speeding up the gas and thus reducing the headwind in their orbital path. (Picture a column of cyclists in the Tour de France: the lead bikers push the air in front of them, creating a "friendlier" pocket of air behind them that the others can ride in without expending as much energy.) When inward-falling boulders crossed into that orbit with the lower headwind, they stopped falling and started orbiting along the same path. Before long, enough individual boulders collected in the "safe zone" to attract one another, collide, and stick together, ultimately making planetesimals large enough to survive on their own.

If Johansen and his colleagues are correct, then the only major requirement for planets to form is that their accretion disks contain scads and scads of medium-size boulders. That's certainly a possibility, though it's not at all assured. Telescopes capable of confirming that prediction won't be up and running for a few years yet. Until then, we'll have to rely on the virtual cosmos—and hope that it accurately reflects the reality of the world-building enterprise.

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

SKYLOG BY JOE RAO

CHRIS SCHUR

Comet Holmes on November 3, 2007

This past October, amateur astronomers were amazed by a weird transformation. For most of the month, Comet Holmes, more than 150 million miles from Earth, was no brighter than magnitude 17—about 25,000 times fainter than the faintest star that can normally be seen without any optical aid. But on October 23, the comet's visibility suddenly began to rocket. In less than twenty-four hours, Comet Holmes brightened by hundreds of thousands of times—all the way up to magnitude 2.5, bright enough to be seen with the naked eye even from some urban areas! Viewed in binoculars and telescopes, the comet's head—an expanding cloud of dust, the *coma,* enveloping a tiny, icy nucleus—appeared as a perfectly round, bright little disk. Within just a few weeks, the dust spread out so that the coma, though now faint, became the largest object in the solar system, with a diameter greater than that of the Sun.

Comet Holmes was originally discovered by Edwin Holmes, an English amateur astronomer, during a similar flare-up in November 1892. The comet is periodic, returning to the Sun's vicinity at roughly seven-year intervals (though astronomers actually lost track of it between 1906 and 1964). During the 2007 rendezvous, the comet passed closest to the Sun—191 million miles—back in May, and was moving away when the outburst occurred. Perhaps a rich vein of volatile ices on the comet's nucleus was suddenly exposed to sunlight. Another possibility is that the comet's nucleus consists of low-density material that, through outgassing over time, developed a large region with a very tenuous structure, comparable to a honeycomb. At some point, the fragile bonds connecting the honeycomb of material failed and a crushing collapse occurred. Such a collapse might have expelled a gigantic volume of sunlight-reflecting dust into space, making the dim comet suddenly appear impressively bright.

JOE RAO (hometown.aol.com/skywayinc) is a broadcast meteorologist and an associate and lecturer at the Hayden Planetarium in New York City.

March Nights Out

5 Mercury, Venus, and a narrow sliver of a waning crescent Moon will rise about an hour before sunup to form a broad triangle about five degrees wide in the east-southeast. Your best bet is to use binoculars. Jupiter is easier to spot at this time, sitting high in the south-southeast. Look for Saturn in the evening, lying low in the eastern sky, below and to the left of the bright star Regulus.

7 The Moon is new at 12:14 P.M. eastern standard time (EST).

9 Daylight saving time returns to the United States and Canada. Clocks need to be set forward one hour at 2:00 A.M. EST, except in Arizona, Hawaii, and Saskatchewan.

14 The Moon waxes to first quarter at 6:46 A.M. eastern daylight time (EDT). Between nightfall and midnight, it slides to the north of Mars.

20 The equinox occurs at 1:48 A.M. EDT, as the Sun (from an earthly viewpoint) crosses the celestial equator moving north. Spring begins in the Northern Hemisphere and fall begins in the Southern Hemisphere. For those who live in the Mountain or Pacific time zones, the equinox occurs prior to midnight, and therefore on March 19.

21 The Moon grows full at 2:40 P.M. EDT. (This is the Paschal Full Moon.)

29 The Moon wanes to last quarter at 5:47 P.M. EDT.

Continued from page 28

and field thistle. All those plants (as well as butterfly milkweed) feature flower heads made up of multiple individual flowers, each with a nectar reservoir. The flower heads are spiky, geared to pollinators endowed with long legs and mouthparts.

Nearly all those plants contain substances that possess strong antibacterial or anti-inflammatory properties, or both. Such plant chemicals, known as phytochemicals, are all the rage among consumers these days, because they have various pharmacological effects on humans (familiar examples include beta carotene, caffeine, echinacea, ginkgo biloba, menthol, nicotine, Saint-John's-wort, saw palmetto, vitamin C, and so on).

Although analyses of the Diana's favored plants have not looked specifically at the nectars, I suspect that the female butterflies imbibe phytochemicals when they feed. I have proposed that they thus arm themselves, and perhaps their eggs and young larvae, against infection during their unusually lengthy life spans. If that is so, the present diminished geographical distribution of *S. diana* may not result from a loss of violet host plants in the East, as many ecologists assume. In fact, violets remain common throughout most of the butterfly's former range. Instead, the females may have been deprived of favored drug-rich nectar plants, species that require partial shade and that have lost out as forests have been thinned.

While it may be hard to prove my suspicions, so far Mount Magazine fulfills the Diana's stringent requirements. How this butterfly species with its fitting mythological name will fare in the future is anyone's guess. I wish her well.

A frequent contributor to Natural History, *GARY NOEL ROSS is a research associate at the McGuire Center for Lepidoptera and Biodiversity at the University of Florida, Gainesville, and director of butterfly festivals for the North American Butterfly Association.*

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BY ROBERT ANDERSON

Journey to the Core

Eighteen hundred miles beneath our feet, the outer core, a Mars-size sphere of churning molten iron, generates Earth's magnetic field. Exactly how the process works, and why the core's dynamo switches polarity—causing the planet's magnetic north pole to become the magnetic south pole at intervals ranging from 50,000 to tens of millions of years—is only now yielding to sophisticated computer models. Please go to *Natural History*'s Web site (www.naturalhistorymag.com), where this month I review Internet sites that explore the enigmatic outer core and investigate when it will next discombobulate our compasses. The last geomagnetic reversal was 800,000 years ago, and another is on the way.

ROBERT ANDERSON is a freelance science writer who lives in Los Angeles.

WORD EXCHANGE

Continued from page 6

Language Matters

In "At a Loss for Words" [12/07-1/08], Sarah Grey Thomason asks us to contemplate the value to humanity of a language that most of us will never hear, much less use. To the extent that humanity consists of a conversation among ethnic groups across the world, the loss of a language brings us ever closer to a monologue. We know that monoculture is not a good idea in agriculture: it's not likely to be a good idea in civilization. Although we may not see the benefits of Salish-Pend d'Oreille directly, the richer we keep our global conversation, the more robust human civilization will be.

Dennis Anthony
Los Angeles, California

NATURAL HISTORY *welcomes correspondence from readers. Letters should be sent via e-mail to* nhmag@naturalhistorymag.com *or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

At the Museum

AMERICAN MUSEUM of NATURAL HISTORY

www.amnh.org

Fossil Armored Mammal Found in Chile

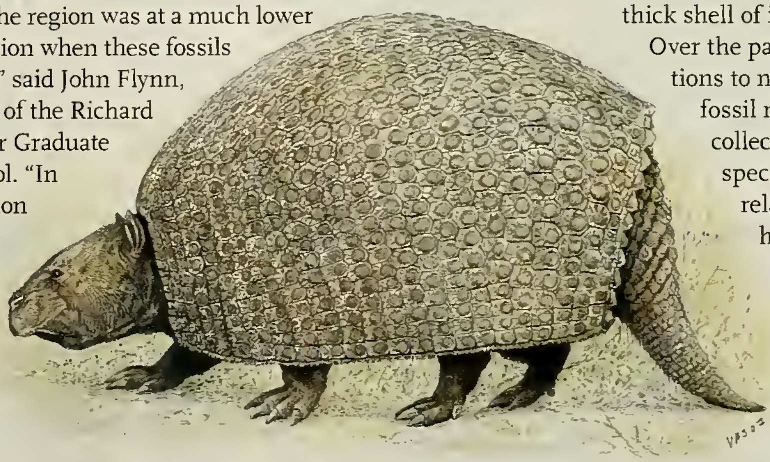
You probably won't be able to pronounce it, which is fine, because you probably won't be seeing one anytime soon. *Parapropalaehoplophorus septentrionalis* was a lumbering, armadillo-like mammal that lived 18 million years ago in what is now the arid desert of northern Chile's Andean Altiplano. The fossilized remains of this extinct cousin of the modern-day armadillo were first discovered in 2004 and described in 2007 as part of an ongoing project by AMNH researchers to study the structure and evolution of the unique animals that inhabited South America at a time when the continent was much different than it is today.

Their work extends beyond paleontology: these fossils indicate that what is desert today was open grassland 18 million years ago. "Our studies elsewhere on the Altiplano suggest that the region was at a much lower elevation when these fossils lived," said John Flynn, Dean of the Richard Gilder Graduate School. "In addition to providing a look at the paleoecology of the region, this has given us new insights into the timing and rate of uplift of the Andes."

The study, which was co-led by Flynn and Darin Croft, Assistant Professor at Case Western Reserve University in Cleveland, Ohio, and a Research Associate in the Museum's Division of Paleontology, took the team of U.S. and Chilean scientists to more than 14,000 feet above sea level. The thin air, scarce water, and frigid temperatures of the high Andes posed challenges to the researchers, but it's all in a day's work.

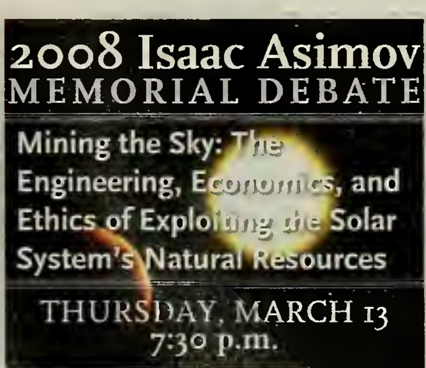
The partial skeleton that the group unearthed turned out to represent a new species of glyptodont—a family of hard-shelled, grazing mammals that may have occasionally tipped the scales at two tons. This new species likely weighed in at a mere 200 pounds and was covered with a thick shell of immovable armored plates.

Over the past decade, the team's fossil-hunting expeditions to northern Chile have uncovered several hundred fossil mammal specimens. These animals, known collectively as the Chucal Fauna, include at least 18 species of armadillos and glyptodonts, rodents, relatives of opossums, and a variety of extinct hoofed mammals. The new glyptodont was reconstructed from the jaw, shell, leg, and backbone. Based on these remains and other evidence, the team concluded that *P. septentrionalis* was one of the earliest-diverging members of a family that includes modern armadillos.



© VELIZAR SIMEONOVSKI

Artist's reconstruction of *Parapropalaehoplophorus septentrionalis*



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Planets, moons, asteroids, and comets contain natural resources such as water, minerals, and trace elements that may have survival value to visiting astronauts and economic value to life on Earth. How do we know these materials are there? How would we go about mining them? Who owns these resources, if anyone? And should they be mined at all? Join moderator Neil deGrasse Tyson, Frederick P. Rose Director of the Hayden Planetarium, for the popular annual panel in memory of the late Isaac Asimov in the Museum's Samuel J. and Ethel LeFrak Theater, to explore and debate the frontier of this subject with a panel of experts drawn from planetary science, aerospace engineering, environmental engineering, and space law.

Panelists and their expertise include:

John Lewis, Professor, Lunar and Planetary Lab, University of Arizona; cosmochemistry and planetary atmospheres

Cassie Conley, Acting Planetary Protection Officer, NASA Headquarters; international guidelines to prevent biological contamination while exploring the solar system

Murray Hitzman, Charles F. Fogarty Professor of Economic Geology, Colorado School of Mines; deposit scale

Henry R. Hertzfeld, Research Professor of Space Policy and International Affairs, Elliott School of International Affairs, George Washington University; legal and economic issues of space and high-technology industries

For an introduction to this topic, we recommend reading *Mining the Sky*, by John Lewis.

The late Dr. Isaac Asimov, one of the most prolific and influential authors of our time, was a dear friend and supporter of the American Museum of Natural History. In his memory, the Hayden Planetarium is honored to host the annual Isaac Asimov Memorial Debate—generously endowed by relatives, friends, and admirers of Isaac Asimov and his work—bringing the finest minds in the world to the Museum each year to debate pressing questions on the frontier of scientific discovery. Proceeds from ticket sales of the Isaac Asimov Memorial Debates benefit the scientific and educational programs of the Hayden Planetarium.

Coming Soon!

The Horse

Opens Saturday, May 17, 2008

Spectacular fossils and cultural objects from around the world—including many from the Museum's extraordinary collections—as well as videos, computer interactives, touchable casts, and more, tell the story of the horse in this evocative, trailblazing exhibition. It explores the evolution of the horse family over 50 million years, and considers the origins of the enduring bond between horses and humans that transformed trade, transportation, warfare, sports, farming, and many other facets of human life. Visit www.amnh.org/horse for details.

The Horse is supported, in part, by a gift from an anonymous donor.

Thirteenth Annual

Spring Biodiversity Symposium

Sustaining Cultural and Biological Diversity in a Rapidly Changing World: Lessons for Global Policy

Wednesday–Saturday, April 2–5

Next month, the Museum's Center for Biodiversity and Conservation (CBC) will host scientists, policymakers, educators, and others to explore the relevance of often-ignored links between cultural, linguistic, and biological diversity. Organized by the CBC with IUCN-The World Conservation Union/Theme on Culture and Conservation and with Terralingua, the goal of the symposium is to bridge the apparent divide between the social and life sciences and to inspire a long-term, cross-disciplinary approach to public policy and outreach in the service of the conservation of diversity in its many forms.

This symposium is supported in part by grants from The Christensen Fund, The Rockefeller Foundation, and The Wenner-Gren Foundation for Anthropological Research.

Refresher Course

Water: H_2O = Life

All of Earth's creatures depend on water for survival, and, in order to meet their needs, many have fine-tuned their average water intake to accommodate the varying, often extreme, conditions in their habitats. For example, did you know:

- Some creatures can survive without drinking any water at all. Kangaroo rats have super-efficient kidneys that are so good at recycling water they get all they need from just the food they eat.
- Albatrosses have evolved a way to drink seawater, which is too salty for most other birds and land animals. To get rid of excess salt from the water and food they ingest, albatrosses have glands just behind their eye sockets that absorb salt. The glands then excrete a concentrated salt solution that drains out a duct and off the tip of the beak.
- No bigger than a speck, tiny eight-legged creatures called tardigrades live in either ocean or freshwater habitats. If drought strikes, they essentially shut down their metabolism and shrivel up into a ball called a tun, waiting until water returns. They can last for years in this state and can also withstand oxygen deprivation, vacuum, and extreme heat or cold.

For these and more fascinating facts about one of the most essential ingredients to life on Earth, and the current challenges involving its use, safety, availability, and more, visit the Museum's informative exhibition *Water: H_2O = Life*, which runs through May 26, or check out the "Fast Facts" section of www.amnh.org/water.

At the Museum

AMERICAN MUSEUM ō NATURAL HISTORY

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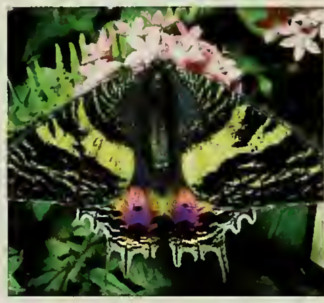
EXHIBITIONS

Water: H_2O = Life
Through May 26, 2008
Live animals, hands-on exhibits, and stunning dioramas invite the whole family to explore the beauty and wonder of water and reveal one of the most pressing challenges of the 21st century: humanity's sustainable management and use of this life-giving, but finite, resource.

Water: H_2O = Life is organized by the American Museum of Natural History, New York (www.amnh.org), and the Science Museum of Minnesota, St. Paul (www.smm.org), in collaboration with Great Lakes Science Center, Cleveland; The Field Museum, Chicago; Instituto Sangari, São Paulo, Brazil; National Museum of Australia, Canberra; Royal Ontario Museum, Toronto; San Diego Natural History Museum; and Singapore Science Centre with PUB Singapore. The American Museum of Natural History gratefully acknowledges the Tamarind Foundation for its leadership support of *Water: H_2O = Life*, and the Johns Hopkins Center for a Livable Future for its assistance.
Exclusive corporate sponsor for *Water: H_2O = Life* is JPMorgan.
Water: H_2O = Life is supported by a generous grant from the National Science Foundation.

The Museum extends its gratitude to the Panta Rhea Foundation, Park Foundation, and Wege Foundation for their support of the exhibition's educational programming and materials.



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Sunset moth

The Butterfly Conservatory
Through May 26, 2008
Mingle with up to 500 live, free-flying tropical butterflies, and learn about the butterfly life cycle, defense mechanisms, evolution, and conservation.

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

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

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

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

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

Public programs are made possible, in part, by the Rita and Frits Markus Fund for Public Understanding of Science.

LECTURES

FROM THE FIELD
Women of Discovery
Saturday, 3/8, 1:00 p.m.
Meet the extraordinary women explorers honored as 2008 WINGS WorldQuest's Women of Discovery Award winners.

This program is supported, in part, by Jacqueline Fowler and Natalee Lee Quay.

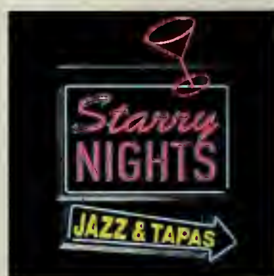
78TH JAMES ARTHUR LECTURE ON THE EVOLUTION OF THE HUMAN BRAIN
Humans, Apes, and Whales: Neuronal Specializations and the Origin of Brain Degenerative Disorders
Tuesday, 3/11, 6:00 p.m.
With Patrick Hof, professor of neuroscience, geriatrics, and ophthalmology at Mount Sinai School of Medicine.

FIELD TRIPS AND WORKSHOPS

©AMNH/C. CHESEK

Freshwater Pearl Jewelry
Six Thursdays, 3/6–4/10, 7:00–9:00 p.m.
With Reema Keswani and Marsha Davis.
Students must bring a light-colored pillowcase and a pair of small, sharp scissors to all sessions.

Animal Drawing
Eight sessions, starting Monday, 3/3, 7:00–9:00 p.m.
With Stephen C. Quinn, Department of Exhibition, author of *Windows on Nature.*



ROSE CENTER FOR EARTH AND SPACE
Sets at 6:00 and 7:30 p.m.
Friday, 3/7
Helen Sung Group

FAMILY AND CHILDREN'S PROGRAMS

World Water Day
Saturday, 3/22, 1:00–5:00 p.m.
An afternoon of activities, discussions, and a resource fair, all designed to increase awareness of this precious resource. www.amnh.org/worldwaterday

Proud sponsor is **The Paul Milstein family.** Exclusive corporate sponsor is **JPMorgan and Chase.**

Robotics III (Advanced)
Three Wednesdays, 3/5–19, 4:00–5:30 p.m. (Ages 8–10)
Create the robot rover that will take on the ultimate challenge of the series.

Dr. Nebula's Laboratory: Planetary Vacation
Sunday, 3/16, 2:00–3:00 p.m. (Recommended for families with children ages 4 and up)
Join Scooter as she tracks Dr. Nebula's voyage through our solar system.

Alien Workshop
Saturday, 3/29, 11:00–12:30 p.m. (Ages 4–5, each child with one adult) and Saturday, 3/29, 1:30–3:00 p.m. (Ages 6–7, each child with one adult)
Children will participate in astrobiology experiments and take home their own alien!

©AMNH

Wild, Wild World: Predators
Saturday, 3/29, 12:00 noon–1:00 p.m. and 2:00–3:00 p.m.
With Andrew Simmons, wildlife expert.

HAYDEN PLANETARIUM PROGRAMS

From the Big Bang to the James Webb Space Telescope
Monday, 3/24, 7:30 p.m.
With John Mather, NASA Goddard Space Flight Center, cowinner of the 2006 Nobel Prize in Physics.
www.amnh.org/hayden

TUESDAYS IN THE DOME

Virtual Universe
Cosmic Ages
Tuesday, 3/4

Celestial Highlights
Stars and Planets for Spring
Tuesday, 3/25

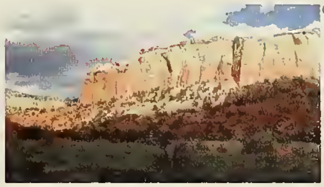
These programs are supported, in part, by the Sant'Angelo/Koval Family, Val and Min-Myn Schaffner, and an anonymous donor.

HAYDEN PLANETARIUM SHOWS

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

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

IMAX MOVIES



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The Piedra Lumbre mesa near Ghost Ranch, New Mexico. Dinosaur fossils from the Cretaceous, Jurassic, and Triassic Periods, reaching back 230 million years, have been found here.

Dinosaurs Alive!
Great dinosaur finds by AMNH scientists past and present come to life with archival and contemporary footage and scientifically accurate, computer-generated images.

LATE NIGHT DANCE PARTY

One Step Beyond
Friday, 3/28, 9:00 p.m.–1:00 a.m.
This monthly party in the Rose Center features the biggest names in techno, electronica, hip-hop, and indie rock. Cocktails keep the party going.

INFORMATION

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

TICKETS AND REGISTRATION

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

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

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ENDPAPER

Silk City

By Hank Guarisco

A gigantic mass of spider webs spun in Lake Tawakoni State Park, about fifty miles east of Dallas, lent recent proof to the saying that "everything is bigger in Texas." Discovered early in August 2007, the webs stretched more than 250 feet long and 30 feet high, shrouding trees and bushes, making visitors think they were on the set of a Hollywood horror film. I got involved by answering park superintendent Donna Garde's plea for a spider expert to study the event in person.

Heading due south from Lawrence, Kansas, in my old Chevy S-10 pickup truck, I mulled over the different theories set forth about the silken mass. Some scientists—speculating online, sight unseen—thought it was the result of a dispersal event. When weather conditions permit, large numbers of young spiders can take to the air on silken parachutes. That so-called "ballooning" behavior enables them to travel quickly and colonize new locations, even islands. Perhaps a mass of ballooning spiders had landed and left behind a fine blanket of silk.

Others, including Mike Quinn, an invertebrate biologist with the Texas Parks and Wildlife Department, believed a single species was largely responsible for building the impressive structure: a long-jawed spider named *Tetragnathia guatemalensis*. Since that species usually produces a relatively small spiral-shaped web, and the massive Tawakoni web appeared to be a jumble of silken strands, many of my colleagues and I were not convinced. I hoped to unravel the mystery for myself when, the day after Labor Day, I joined the approximately 4,000 people who had made the pilgrimage to northeastern Texas.

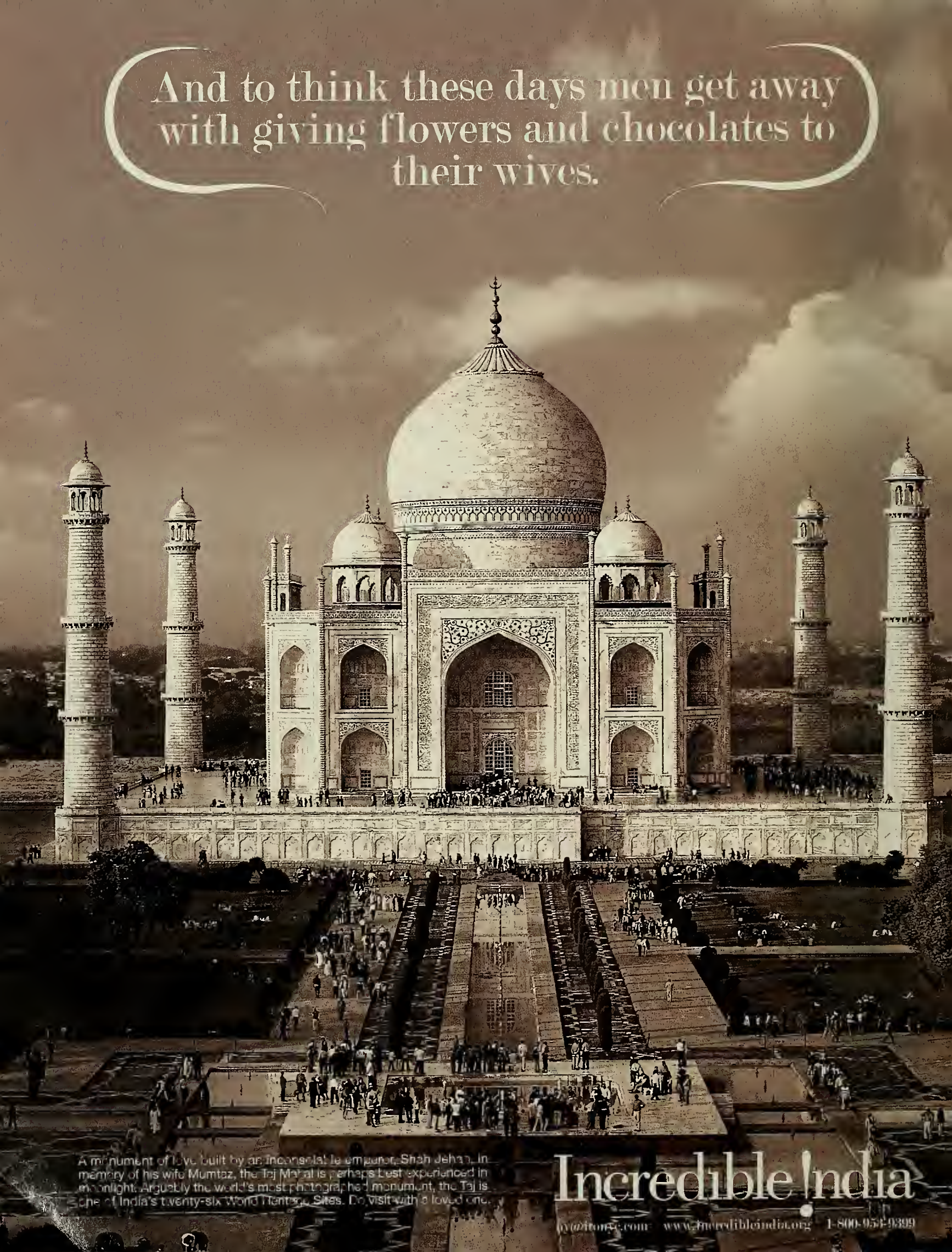
The Tawakoni mass web surpassed any I had seen before: the spiders in it, of multiple species, numbered in the tens of thousands. I was immediately certain that this was woven—not a result of ballooning. As Quinn had predicted, long-jawed spiders were the primary architects, with some help from other orb weavers, cobweb spiders, and funnel web weavers. Together they had created an arachnid urban area—and we visitors were not unlike tourists tilting our heads back to gaze at New York City skyscrapers. The older webbing, in the center of the giant web, was a deteriorating downtown, chock-full of dead midges and mosquitoes—remnants of past meals. There were pickpockets and murderers in abundance, too: black jumping spiders prowled the web in search of prey, and dewdrop spiders with shiny silver abdomens were stealing meals already secured by larger spiders.

So why were all these spiders in one location? Were they cooperating to build a communal web? Or was this some paranormal phenomenon, as one individual in England proposed? Actually, the explanation was simple enough. Spiders, like most creatures, follow abundant sources of food. Heavy rains had pummeled the region during the summer months, creating the perfect breeding ground for mosquitoes and midges—the long-jawed spiders' favorite prey. Every day, just before dawn and just before dusk, I could hear a high-pitched whine as millions of them rose into the trees. With so much food flying around, the normally territorial spiders didn't mind crowding together.

When I returned three weeks later, however, the situation had changed dramatically. The food supply had tapered off, and it was every spider for itself. Cannibalism was rampant, as neighbors became potential prey. Portions of the giant web had been vacated. By the end of the year, rains had destroyed the remnants, and freezing temperatures killed any remaining spiders.

Yet thousands of egg sacs remain in the trees. Will the emerging spiderlings create another grand metropolis, or a famine-prone slum? Lake Tawakoni, which captured the interest of people around the globe, may warrant another visit very soon.

HANK GUARISCO is adjunct curator of arachnids at the Sternberg Museum of Natural History at Fort Hays State University in Hays, Kansas. He is currently writing a field guide to Kansas spiders.


And to think these days men get away with giving flowers and chocolates to their wives.
A monument of love built by an inconsolable emperor, Shah Jehan, in memory of his wife Mumtaz, the Taj Mahal is perhaps best experienced in moonlight. Arguably the world's most photographed monument, the Taj is one of India's twenty-six World Heritage Sites. Do visit with a loved one.
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