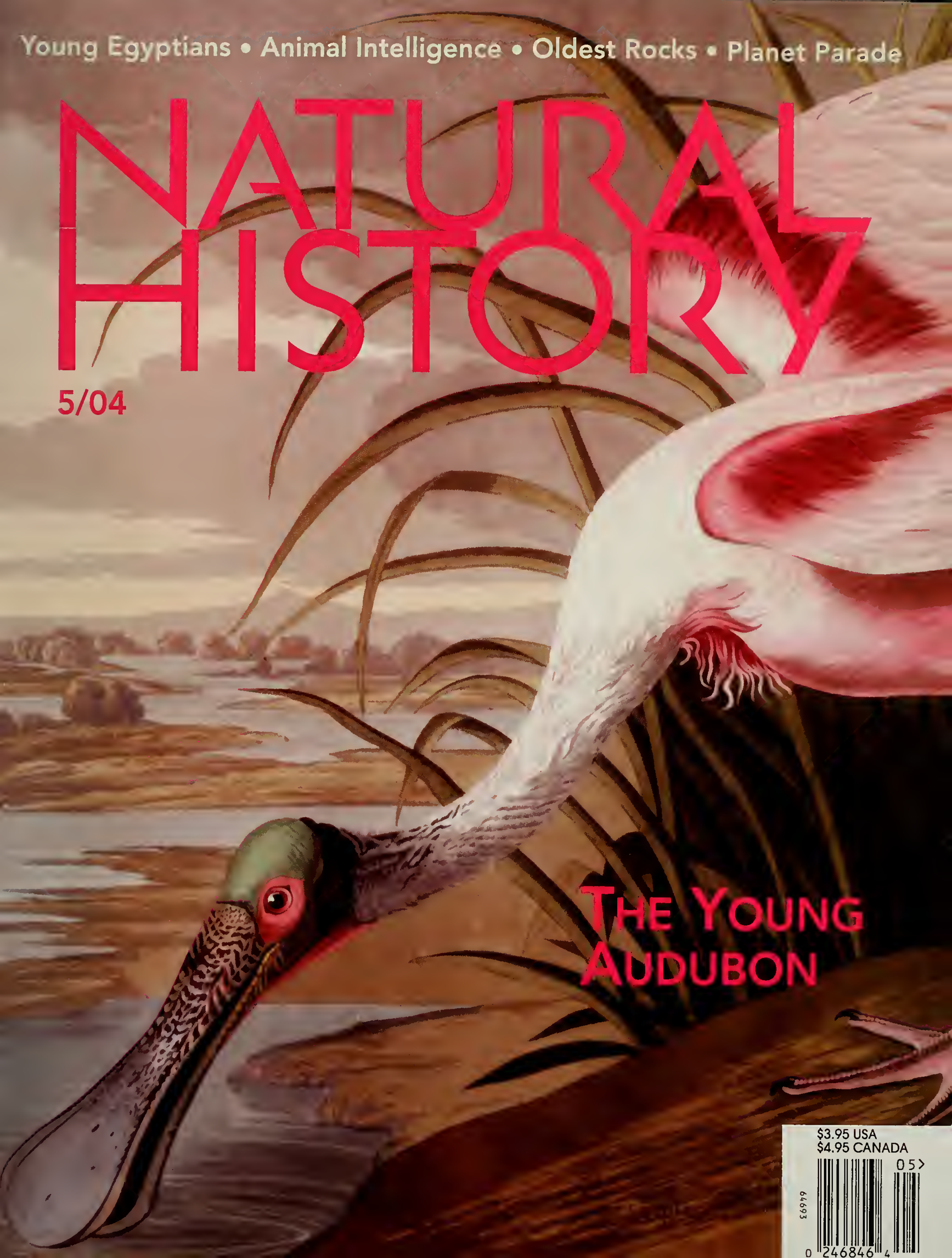
Young Egyptians • Animal Intelligence • Oldest Rocks • Planet Parade

NATURAL HISTORY

5/04



THE YOUNG AUDUBON

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NATURAL HISTORY

MAY 2004 VOLUME 113 NUMBER 4

FEATURES

ON THE COVER: John James Audubon, *Roseate Spoonbill* (Engraving and color print by Robert Havell), 1836

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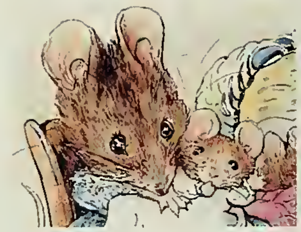
NATURAL HISTORY

DEPARTMENTS



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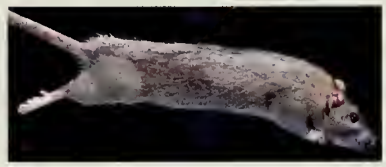

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CREDITS: Page 8


TELEPHONE
TELEPHONE

THE NATURAL MOMENT

Bloom On

Photograph by Andrew Davoll

THE NATURAL MOMENT

◄ *See preceding pages*

For a drought-ridden continent patched over with poor soil, Australia has a remarkable variety of flowering plants. Tough, resilient stalks, bedded in gravel and inured to the arid climate, repeatedly bear exotic blossoms, such as the yellow flowers of *Acacia glaucoptera*, or flat wattle, pictured here. Acacias are some of Australia's hardiest plants. More than 900 different species have evolved there, colonizing even the most desolate regions of the country.

Flat wattle has found its niche in a southwest pocket of the state of Western Australia. Each year, around the time Aussies celebrate their colorful acacias on National Wattle Day (September 1), photographer Andrew Davoll visits four *A. glaucoptera* bushes in John Forrest National Park, sixteen miles east of Perth. He is drawn to their spring colors, but above all, he likes to photograph the flowers.

The golden spheres seen here projecting at ninety-degree angles from the stem are made up of small, individual flowers. When one of the small flowers is pollinated and fertilized, it goes to seed and snakes outward in a fuchsia-colored curlicue. After five years of tenaciously returning to the same spot, Davoll finally saw the arrangement he had been hoping for: a fully intact sphere of flowers (upper left) alongside balding flower heads and seedpods, all the stages of bloom, decline, and birth on a single stem.

—*Erin Espelie*

UP FRONT

Reality Check

A couple of months ago, my friend Mary Knight, a visiting scholar at New York University and a consulting member of our staff, made a return trip to Cairo, Egypt, a city where she has lived on and off since 1994. What originally drew her to the Middle East was a scholarly interest in ancient Egypt, but while there she played an active role in Egyptian intellectual life. Since her first arrival in Egypt, of course, Western attention to the Arab world has lurched from casual neglect to riveted, hysterical dismay—with few stops for cool dialogue in between.

Knight made her return visit, in part, to give us all a reality check (see "Egypt's Young and Restless," page 34). She visited elementary schools, cafés, universities, research laboratories, and friends in low and in high places. Guiding her inquiries were the big, central questions about Egyptian society: What is it like nowadays to grow up among the wave of young adults who make up the elusive "Arab street"? Can young men find gainful, challenging employment? Do women have access to education, or do traditional values still block their way to economic independence? To what extent are liberalizing forces taking hold—forces such as education, scientific research, and competitive free markets? What drives some young people to embrace militant Islam?

Knight brought along her camera as well as her notebook, and our pictures of Egyptian life, by her and others, depict neither the rosy optimism of a society with a bead on its future, nor the grim, authoritarian fanaticism of a populace determined to reject liberal, Western values.

• • •

Twenty-first-century Cairo may look like the neighborhood right around the corner, compared with the exotic world of the western Appalachians in early-nineteenth-century America. As a young man, the future artist and ardent bird naturalist John James Audubon took his family to what is now western Kentucky (see "Audubon in Kentucky," by William Souder, page 46). Now, 200 years later, I walk in the woods whenever I can, and I know there are still plenty of places to find solitude and serenity out-of-doors. But Souder's account of the Kentucky wilderness, based on Audubon's acute observations, takes my breath away. The primeval abundance of the country must have seemed bottomless. The dimensions of American nature seem sheer Paul Bunyan, until a sober observer such as Audubon assures you it really did take three days for a single flock of passenger pigeons to fly past. That world is truly gone.

• • •

We are delighted to announce that *Natural History* has been nominated for a National Magazine Award for Essays, for Robert M. Sapolsky's "Findings" column, "The Pleasure (and Pain) of 'Maybe'" (September 2003). The award is the most prestigious prize in magazine journalism; the winner will be announced on May 5. Sapolsky's latest essay, "Of Mice, Men, and Genes," appears on page 21. Congratulations, Robert!

—Peter Brown

CONTRIBUTORS

After traveling to southern Australia each austral spring for five years to photograph the same cluster of acacia bushes, ANDREW DAVOLL ("The Natural Moment," page 4) hit the jackpot in his attempt to capture a stalk with both its flowers and its seedpods on display. A native of Great Britain, Davoll now lives and works in Perth, and specializes in photographing the rich flora of western Australia. When he is not plying his trade, he enjoys long-distance ocean swimming and marathon running.

MARY KNIGHT's interest in the lives of contemporary Egyptians ("Egypt's Young and Restless," page 34) was sparked during her tenure as a Fulbright scholar in 1994–95, studying the geography of ancient Egypt at 'Ain Shams University in Cairo. While pursuing that research, she also completed a study of the practice of female genital mutilation in antiquity, a project that led to discussions with modern Egyptians on how the practice is viewed today. Knight is a visiting scholar at New York University, and is co-editing a book on nudity in the ancient Mediterranean world.

A geologist and curator in the Department of Earth and Planetary Sciences at the American Museum of Natural History in New York City, EDMOND A. MATHEZ ("A Birthstone for Earth," page 40) is an expert in the geochemistry of the volatile elements.

His research interests include the solidification of large magma bodies, the electrical properties of rocks, and the early Earth. He was one of the team who recovered the underwater hydrothermal vents known as black smokers, which support sulfur-loving life-forms in the deep ocean, and which may resemble the structures that nurtured the first life on the planet. With his museum colleague James D. Webster, he co-authored *The Earth Machine: The Science of a Dynamic Planet,* forthcoming this month from Columbia University Press.

Minnesota-based journalist WILLIAM SOUDER ("Audubon in Kentucky," page 46) takes his inspiration from the living world. For his first book, *A Plague of Frogs,* Souder spent several years slogging through swamps and sitting through contentious scientific meetings to chronicle the environmental threat posed by crashes of amphibian populations. For his new book, about John James Audubon, he explored the quieter (and drier) confines of library archives in the United States and abroad, poring over the letters and journals of one of America's greatest ornithologists. Having written about both frogs and birds, Souder says the ocean may be the subject of his next book.

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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.

Browbeaten Ancestors

In "Headstrong Hominids" (2/04), Noel T. Boaz and Russell L. Ciochon propose that the prominent brow ridges of *Homo erectus* crania evolved to protect our contentious large male ancestors who were clubbing each other during combat. But large male gorillas also have heavy brow ridges, and they rarely (if ever) use clubs when altercations arise among them. Could large brow ridges have first evolved to protect large arboreal primates from damaging their brains by accidentally banging their heads while rapidly climbing trees?
Julian Kane
Great Neck, New York

Noel Boaz and Russell Ciochon give a number of possible explanations for male-male violence—individual or group conflict resolution, competition for mates, competition for dominance, and so on. Yet they cite a study of Australian Aboriginal skulls that found healed fractures in "59 percent of the female crania and in 37 percent of male crania." If more women than men were getting their heads bashed in, doesn't this suggest that men were beating up women—what we currently refer to as "domestic violence"?
Henya Rachmiel
Commerce Township, Michigan

I read "Headstrong Hominids" with a professional curiosity, because I work with the traumatically brain-injured. Whereas *H. erectus*'s injuries were inflicted by other club-wielding protagonists, my clients bear the scars mostly of vehicular accidents. They owe their survival to the evolution of a thick, bony mass that shielded the inner cortex. I wonder if we will evolve harder heads, better suited for modern traffic conditions.
Arnold Solinsky
Long Island Head Injury Association
Commack, New York

NOEL T. BOAZ AND RUSSELL L. CIOCHON REPLY: Julian Kane points out apparent similarities between gorilla and *H. erectus* brow ridges. Protection of the eye is certainly an important function of the brow ridge, but we would ascribe its extra robustness in gorillas and *H. erectus* to different causes. The gorilla's brow ridge is a bony response to chewing forces transmitted up to the (thin-walled) skull from a large face that supports huge canine teeth. *H. erectus* has a reduced face and relatively small teeth but a massive brow ridge connecting back to a thick skull.

Henya Rachmiel's question brings up an intriguing implication of our hypothesis of cranial bone thickness: if women in general have thinner skulls than men, then they will be more susceptible to cranial fracture when struck in the head. If we assume a 15 to 20 percent size difference between the sexes for *H. erectus* (about twice the difference between modern human males and females), it is likely that *H. erectus* males could have disabled or killed females more readily than they could other males. On the other hand, one cannot assume that males dealt all the fractures. The Australian ethnographic data indicate that many of the cranial fractures in women resulted from disputes with other women.

Arnold Solinsky notes that many cranial fractures result from motor vehicle accidents these days. *H. erectus*, with its thick skull, would undoubtedly have fared better in this regard. If the selective force of motor vehicle accidents remains the same for many thousands of years, skull thickness in *Homo sapiens* might increase as an evolutionary response, if not offset by such disadvantageous effects as increased head weight, poor scalp circulation, and neck musculoskeletal pain.

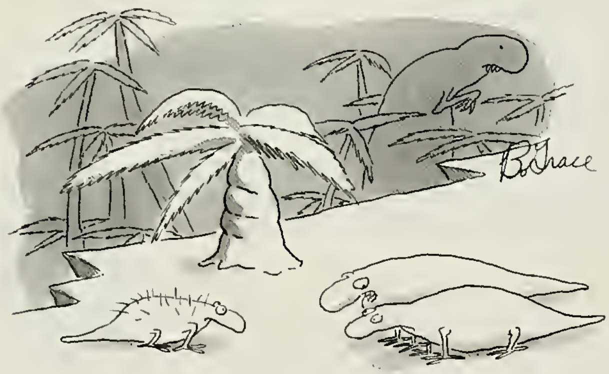
More Trash Talk

According to Charles Moore ("Trashed," 11/03), gyres have pulled our oceangoing plastic detritus into localized concentrations. Is there any reason the nations of the world couldn't organize a cleanup at appropriate intervals?

Steve E. Hartman
Saco, Maine

Charles Moore describes an appalling situation, but leaves some questions unanswered. How does the plastic get into the ocean? How fast is it building up? And what is being done—or what should be done—about it?

Guy Ottewell
Lyme Regis, England



"Call it evolution if you want. I say the kid needs a haircut."

I understand that some bacteria aid in cleaning up oceanic oil spills. Is there any such organism that can break down these oil-based pollutants?

Allan J. Sander
Trabuco Canyon, California

CHARLES MOORE REPLIES: Efforts are under way to accomplish something like what Steve E. Hartman envisions, principally as a way to protect the critically endangered Hawaiian monk seal from entanglement in derelict fishing nets.

Unfortunately, I do not believe this action will stop the buildup of plastic particulates, the photodegraded bits of plastic trash that now outweigh plankton in much of the ocean. Plastic particles, which are nearly the same density as seawater, are mixed into the entire ocean. No cleanup of the 1.37 billion cubic kilometers of seawater is possible. The only cleanup possible is to attack the problem at its source.

In reply to Guy Ottewell, the farther you get from civilization, the more closely associated plastic debris in the ocean is with the fishing industry. But 80 percent of the total debris comes from land-based sources, not all of them near the coast (much is carried to the ocean from far inland, by rivers). The plastic industry itself accounts for millions of preproduction plastic pellets, as well as much plastic dust and sawdust from transfer, molding, and recycling operations—small bits less than five millimeters across that are hard to control. During the 1990s, Haruo Ogi of Hokkaido University found a tenfold increase of plastic particles in his trawls off Japan.

Currently the gyre has an average of one particle per square meter in areas of high concentration. In windblown collections of debris, the surface is more than covered. Plastics need to be designed for recycling, and those who make them should be prepared to take on that responsibility.

In response to Allan J. Sander, I know of no bacteria that eat consumer plastics, but, in any case, toxic chemicals are too dispersed in the ocean to be addressed by the techniques that are used in concentrated spills.

To Persist in Error . . .

I, too, noticed the substitution of Cape Horn for the Cape of Good Hope in Adam Summers's "Biomechanics" column ("Like Water Off a Beetle's Back," 2/04), and correctly guessed that people would write in to point it out. But I believe that your published correction ("Amendment," 3/04) is not quite right either.

It is true that the Cape of Good Hope is the "milestone" you have to get past in sailing between the Atlantic and Indian Oceans, in terms of currents, weather, and its prominence as a geographical feature. But it is not, as you have it, "the southern tip of Africa." That, I believe, is Cape Agulhas, off to the east a bit and something like half a degree farther south.

(I must admit I was encouraged to write this note after reading Peter Brown's excellent editorial on fact-checking in the same issue.)

Eric Wolman
Potomac, Maryland

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SAMPLINGS

Cozy 1BR, Forest Vu

Come springtime, birds everywhere are busy nesting and reproducing. But not every bird gets to breed—

Male common starling in breeding plumage

before you can raise a family you usually need a place to call home, and young adults are often edged out of the housing market. Those birds become floaters, sitting out the breeding season and presumably moping. A recent study, however, suggests nonbreeders make the best of a bad situation.

Michael Tobler and Henrik G. Smith, both animal ecologists at Lund University in Sweden, watched common starlings and their attendant floaters throughout the starlings' breeding season, in May. The two investigators found that male floaters stay within specific areas, covering about one square mile, and often visit the nesting cavities (tree holes) used by the breeders, particularly when the young are still inside. Apparently the floaters are checking out real estate that may become available the following year.

Tobler and Smith also set up empty, nestworthy boxes in the fall, before the starlings migrated, so that the birds could visit them; the following spring those boxes were occupied. Other, equivalent boxes were installed in winter, when the starlings were gone. Yet despite the housing shortage, most of the unexplored boxes remained empty the following spring. Evidently the birds prefer advance planning. ("Specific floater home ranges and prospective behaviour in the European starling, *Sturnus vulgaris*," *Naturwissenschaften* 91:85–89, February 2004)

—*Stéphan Reebs*

Like Mother, Like Son

Thirty years ago Robert L. Trivers, an evolutionary biologist , and Dan E. Willard, a mathematician, formulated a sage hypothesis: if strong, healthy mothers tend to bear strong sons, and if those sons monopolize matings and tend to produce more young than strong daughters would, then stronger mothers should give birth to more male than female offspring. The hypothesis has proved true for certain insects and birds, but the verdict for mammals has been equivocal.

Now two zoologists, Ben C. Sheldon of the University of Oxford and Stuart A. West of the University of Edinburgh, have shown that the hypothesis holds for a large group of mammals: the ungulates (hoofed creatures such as deer and pigs). They also found that a mother's overall condition before conception can play a role in producing sons, but that the mother's social standing has a greater impact than do purely physical factors such as body weight. Motherhood is future-oriented, they argue, and social dominance is probably the better long-term indicator of a female's access to resources. The effect is mild, but dominant females do give birth to sons slightly more often than to daughters. ("Maternal dominance, maternal condition, and offspring sex ratio in ungulate mammals," *American Naturalist* 163:40–54, January 2004)

—*S.R.*

AFTERMATH OF OCCUPATION

Scattered across the Canadian High Arctic are the remains of small groups of dwellings, sunken partway into the ground and built out of whale bones. Nearby, generally, stands a freshwater pond, along with piles of decomposing bones from whales and other animals hunted by the residents. The sites are the abandoned villages of Thule Inuit whalers who emigrated from Alaska about a thousand years ago, and whose presence, activity, and refuse left an enduring mark in the region well before the arrival of Europeans.

Thule Inuit dwelling (reconstructed) in Canada's High Arctic. The whale-bone roof frame would originally have been covered with skins and sod.

Marianne S.V. Douglas, a paleoecologist at the University of Toronto, and a team of colleagues studied sediments from a quarter-mile-long pond in one Thule village, inhabited from the early thirteenth century through the end of the sixteenth. They discovered that during the whalers' occupation, moss and an associated diatom proliferated, replacing the bottom-dwelling diatom *Fragilaria pinnata* as the pond's dominant flora.

Douglas and her associates also found concentrations of nitrogen-15, an isotope characteristic of marine life, to be higher than in similar ponds. The investigators thus think nutrients from the processed whale carcasses must have fertilized the pond. Even today, as lingering whale bones continue to leach phosphorus into the pond, its chemistry remains quite different from that of ponds not situated near historical settlements. ("Prehistoric Inuit whalers affected Arctic freshwater ecosystems," *Proceedings of the National Academy of Sciences* 101:1613–17, February 10, 2004)

—*S.R.*


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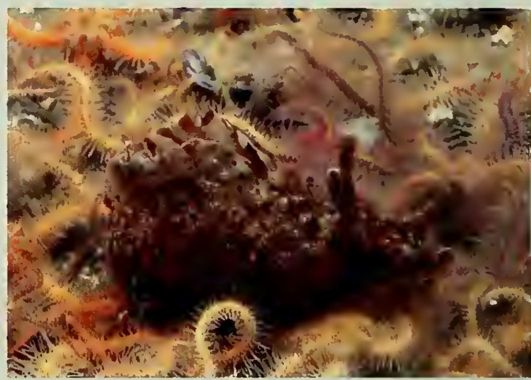
Prions Make Amends

Because one kind of prion causes "mad cow disease," prions in general get a lot of bad press. The very word "prion" may conjure horrific visions of saboteurs cascading through brain tissue. But not all prions are deadly. Kausik Si, a neurobiologist at Columbia University, and his colleagues propose that at least one protein that acts like a prion may do something positive: it may help store long-term memories in the sea hare, *Aplysia*, a marine invertebrate favored in neurological research because of its large neurons.

Memories seem to form when two stimulated neurons change the way they communicate across a synapse, the gap between them. The prion-like protein in *Aplysia* resides in the synapse. Si and his colleagues speculate that when the neurons are stimulated, the protein refolds itself and causes other, neighboring proteins of the same kind to follow suit—much like the self-perpetuating prions of ill repute.

Instead of wreaking havoc, however, the "domino effect" ends up strengthening the synaptic connection. The shape change in the prion-like proteins leads to the synthesis of other kinds of proteins that help stabilize the connection. The net effect is that *Aplysia*'s neurons retain memories for several days instead of just a few minutes. ("A neuronal isoform of CPEB regulates local protein synthesis and stabilizes synapse-specific long-term facilitation in *Aplysia*," *Cell* 115:893–904, December 26, 2003) —*Caitlin E. Cox*



Invertebrates have memories too.

ROLE REVERSAL

MAN BITES DOG; FROG FENDS OFF LION; PLANET HEATS STAR: silly headlines from the tabloids, right? But stow your skepticism about that last story: planets aren't always passive recipients of heat and light. Evgenya Shkolnik, an astronomer at the University of British Columbia in Vancouver, and her colleagues have spotted a feisty, Jupiter-size planet some ninety light-years from Earth whose strong magnetic field and close-in orbit excites a hot spot on the surface of its host star. As the planet whizzes around the star, the hot spot faithfully tracks its orbit. ("Evidence for planet-induced chromospheric activity on HD 179949," *Astrophysical Journal* 597:1092–96, November 10, 2003)

—*Joomi Kim*

Orbiting planet causes moving hot spot on host star.

Seeing Red

Stroll into a pet shop, and you'll find a host of colorful cages and toys for the rodent in your life. The colors, of course, are designed to appeal to (human) buyers, but it turns out that colors affect the animals as well. A recent study by Chris M. Sherwin and Elizabeth F. Glen, both behavioral biologists at the University of Bristol in England, suggests that mice are discombobulated by red.

Sherwin and Glen raised mice in "home cages" painted black, white, red, or green. Then they placed the mice in two test environments, each with a choice of places to go, and clocked the time the mice spent in each place. In one environment, the mice could enter one of four "preference cages," each painted the color of one of the home cages. In the second environment, a standard test of anxiety levels, they could enter either the walled or the wide-open arms of a cross-shaped maze.

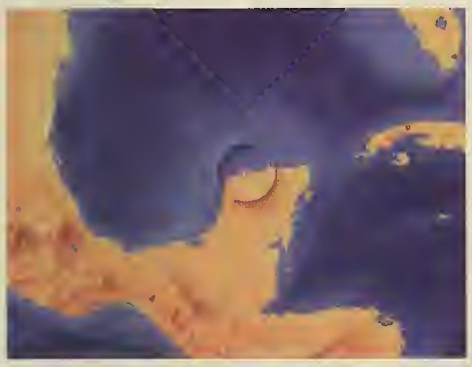
Results: no matter which color their home cages had been painted, the animals spent the least time in the red preference cage. And the animals raised in red home cages spent the least amount of time in the open, unprotected arms of the maze. Conclusion: red makes mice nervous.

You probably wouldn't feel too happy in a living room with bright red walls, but Sherwin and Glen are surprised that mice have a similar reaction. One possible trigger for the mice's distress is that red is often displayed on the body of toxic species, as a warning to leave them alone. ("Cage colour preferences and effects of home cage colour on anxiety in laboratory mice," *Animal Behaviour* 66:1085–92, December 2003) —*S.R.*

EVIDENCE OF IMPACT

Few scientists will disagree if you say that 65 million years ago, something killed off a large fraction of Earth's inhabitants—including those most spectacular of creatures, the dinosaurs. But nowadays, if you contend that the ultimate killer was the huge meteorite whose impact created the even huger Chicxulub crater, centered on Mexico's Yucatán Peninsula, some earth scientists will tell you you're wrong.

Since the early 1990s, it has been widely accepted that the Chicxulub crater was formed 65 million years ago, a date that coincides with the mass extinctions at the end of the Cretaceous period, often called the K/T boundary. To put that date to the test, a rock core measuring 4,950 vertical feet—dubbed the Yaxcopoil-1 core—was recently extracted from beneath the floor of the crater so that geologists could examine the stratigraphic evidence. Fair enough.



Chicxulub crater (circle), excavated 65 million—or more?—years ago by a massive meteorite impact centered on Mexico's Yucatán Peninsula

Trouble is, according to Gerta Keller, a geologist at Princeton University, and her colleagues, the core suggests the Chicxulub crater predates the K/T boundary by 300,000 years.

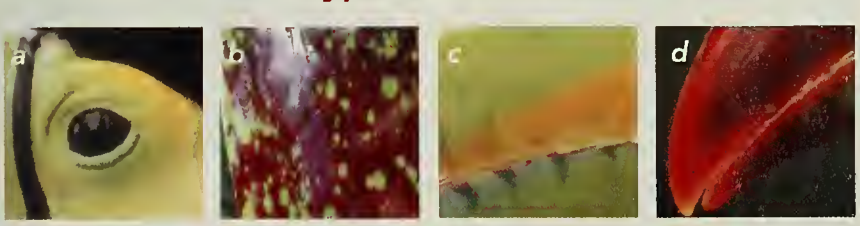
The geologists base their view on several factors. For example, glass formed during the impact occurs lower—that is, about 300,000 years earlier—in the core than does the familiar green clay that marks the K/T boundary worldwide. Additional signs that the impact predates the K/T boundary are embedded in rock layers all over northeastern Mexico.

What's more, Keller says, there's ample evidence that by the time the K/T extinctions took place, the Earth's flora and fauna were already struggling. Volcanic eruptions were probably extensive and greenhouse warming severe, and the biota may also have been exposed to a number of devastating meteorite impacts.

Not everyone is convinced by the new analysis. In spite of live and online debates, Jan Smit, for instance, a geologist at the Free University Amsterdam and an original proponent of the connection between Chicxulub and the K/T mass extinctions, remains unconvinced. A single impact, he says, explains all the known data. ("Chicxulub impact predates the K-T boundary mass extinction," *Proceedings of the National Academy of Sciences* 101:3753–58, March 16, 2004; www.geolsoc.org.uk/template.cfm?name=NSG2349857238495)

—*Jordan Paul Amadio*

Cryptic Creatures



Only three of these pictures are close-ups of the same animal. Which one doesn't belong?
(Answer on page 31)

Different Stroke

In turbulent waters, fish tend to "go with the flow." They save energy by slaloming back and forth between the vortices, or whirlpools. Now biologists have determined that when they slalom, fish adopt a previously unknown swimming style that enables them to maneuver more effectively.

Rainbow trout surfing whirlpools

James C. Liao, a biologist at Harvard University, and his colleagues made high-speed movies of rainbow trout swimming side-to-side in a pattern they call the "Kármán gait" (for the daddy of aerodynamics, Theodore von Kármán). The pattern, adopted by the fish in an agitated stream or within a fish school, calls on fewer muscles than does the undulatory swimming pattern the fish use in smooth-flowing water. Only certain muscles near the head are activated. The body flutters gently, like a flag flapping in the breeze, relaxed and ready to catch a boost from passing vortices.

Liao and his colleagues may have big fish to fry when it comes to applications of their work. Unmanned submarines, for instance, could reduce energy costs by traveling in a Kármán gait. And the new understanding might help engineers design innovative passageways to help migrating fish bypass dams. ("Fish exploiting vortices decrease muscle activity," *Science* 302:1566–69, November 28, 2003) —*J.P.A.*

The Planet Parade

For millennia, planets were just mysterious, wandering points of light in the night sky. Now they are destinations.

By Neil deGrasse Tyson

In the study of the cosmos, it's hard to come up with a better tale than the centuries-long history of attempts to understand the planets—those sky wanderers that make their rounds against the backdrop of stars. Of the eight objects in our solar system that are indisputably planets, five are readily visible to the unaided eye and were known to the ancients, as well as to observant troglodytes. Each of the five—Mercury, Venus, Mars, Jupiter, and Saturn—was endowed with the personality of the god for which it was named. Mercury, which moves the fastest against the background stars, was named for the Roman messenger god—the fellow usually depicted with small and aerodynamically useless wings on his heels or his hat. Mars, the only one of the classic wanderers (the Greek word *planete* means "wanderer") with a reddish hue, was named for the Roman god of war and bloodshed. Earth, of course, is also visible to the unaided eye. Just look down. But terra firma was not identified as one of the gang of planets until after 1543, when Nicolaus Copernicus advanced his Sun-centered model of the universe.

To the telescopically challenged, the planets were, and are, just points of light in the sky that happen to move. Not until the seventeenth century, with the proliferation of telescopes, did astronomers discover that planets are orbs. Not until the twentieth century were the planets scrutinized at close range, with space probes. And not until later in the present century are people likely to visit them.

The images on this and the opposite page are Roman gods as depicted by the Italian Renaissance painter Pietro Perugino, paired with photographs of the planets named after them. Left to right: Mercury, Venus, and Mars.

Humanity had its first telescopic encounter with the celestial wanderers during the winter of 1609–10, when Galileo, looking through an excellent telescope of his own design and manufacture, saw the planets as spheres—perhaps even other worlds. One of them, brilliant Venus, went through phases just like the Moon's: crescent Venus, gibbous Venus, full Venus. Another planet, Jupiter, had moons all its own, and Galileo discovered the four largest: Ganymede, Callisto, Io, and Europa, all named for assorted characters in the life and times of Jupiter's Greek counterpart, Zeus.

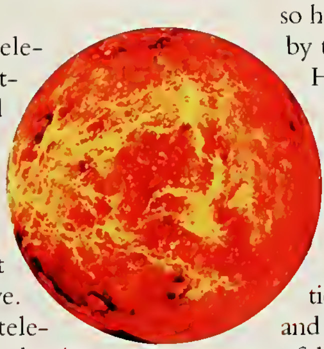
The simplest way to explain the phases of Venus, as well as other features of the planet's motion against the sky, was to assert that the planets revolve around the Sun, not the Earth. Indeed, Galileo's observations strongly supported the universe as envisioned and theorized by Copernicus.

Jupiter's moons took the Copernican universe a step further: though Galileo's twenty-power telescope could not resolve the moons into anything larger than pinpoints of light, no one had ever seen a celestial object revolve around anything other the Earth. It was an honest, simple observation of the cosmos, but the Roman Catholic Church and "common sense" would have none of it. With the aid of his telescope, Galileo discovered a contradiction to the dogma that Earth occupied the central position in the cosmos—the spot around which all objects revolve. In early 1610, in a short but seminal work he titled *Sidereus Nuncius* (Starry Messenger), Galileo reported his persuasive findings.

Once the Copernican model had become widely accepted, the arrangement of the heavens could legitimately be called a *solar* system, and Earth could take its proper place as one among six known planets. Nobody imagined there could be more than six. Not even the English astronomer Sir William Herschel, who discovered a seventh in 1781.

Actually, the credit for the first recorded sighting of the seventh planet goes to the English astronomer John Flamsteed. But in 1690, when Flamsteed noted the object, he didn't see it move. He assumed it was just another star in the sky, and named it 34 Tauri. When Herschel saw Flamsteed's "star" drift against the background stars, he announced—operating under the unwitting assumption that planets were not on the list of things one might discover—that he had discovered a comet. Herschel planned to call the newfound object Georgium Sidus ("Star of George"), after his benefactor, King George III of England. If the astronomical community had respected Herschel's wishes, the roster of our solar system would now include Mercury, Venus, Earth, Mars, Jupiter, Saturn, and George. In a blow to sycophancy, however, the object was ultimately called Uranus, in keeping with its classically named brethren—though some French and American astronomers kept calling it "Herschel's planet" until 1850, just several years after the eighth planet, Neptune, was discovered [*see "The Rise and Fall of Planet X," by Neil deGrasse Tyson, June 2003*].

Over time, telescopes kept getting bigger and sharper, but the planetary details astronomers could discern did not much improve. Because every telescope, no matter the size, viewed the planets through Earth's turbulent atmosphere, the best pictures were still a bit fuzzy. Nevertheless, intrepid observers managed to discover features such as Jupiter's Great Red Spot, Saturn's rings, Mars's polar ice caps, and dozens of planetary moons. Human knowledge of the planets was still meager, though, and where ignorance lurks, so too do the frontiers of discovery and imagination.

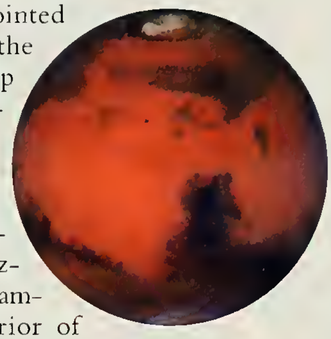


Consider the case of Percival Lowell, the highly imaginative and wealthy American businessman and astronomer, whose exploits took place at the end of the nineteenth century and the early years of the twentieth. Lowell's name is linked with the Lowell Observatory in Flagstaff, Arizona, the "canals" of Mars, the "spokes" of Venus, and the search for Planet X. Like so many other astrophiles around the world, Lowell picked up on the proposition by the Italian astronomer Giovanni Schiaparelli that linear markings visible on the Martian surface were *canali*.

The problem was that the word means "channels," but Lowell and many of his contemporaries chose to translate it as "canals," because the markings were thought to be similar in scale to major public-works projects under way on Earth. Lowell dedicated himself to the observation and mapping of the Red Planet's network of waterways, surely (or so he fervently contended) constructed by technologically advanced Martians. He believed that the cities of Mars, having exhausted their local water supply, had had to dig canals to transport water from the planet's polar ice caps to the more populous, equatorial zones.

Another object of Lowell's attentions was Venus, whose ever-present and highly reflective clouds make it one of the brightest objects in the sky. Venus orbits relatively near the Sun, and so as soon as the Sun sets—or just before the Sun rises—there's Venus, hanging gloriously in the twilight. And because the twilight sky can be quite colorful, there's no end of 9-1-1 calls reporting a glowing, colorful UFO hovering on the horizon.

Lowell maintained that Venus sported a network of massive, mostly radial spokes—more *canali*—emanating from a central hub. The spokes he saw remained a puzzle until quite recently, when a retired optometrist named Sherman Schultz, from Saint Paul, Minnesota, wrote a letter in response to an article on the spokes by William Sheehan and Thomas Dobbins in the July 2002 issue of *Sky and Telescope* magazine.



Schultz pointed out that the optical setup Lowell preferred for viewing the Venutian surface was similar to the gizmo used to examine the interior of patients' eyes. After seeking a couple of second opinions, the article's authors established that what Lowell seemed to see on Venus was instead the network of shadows cast on Lowell's own retina by his own ocular blood vessels. When you compare Lowell's diagram of the spokes with a diagram of the eye, the two match up, canal for blood vessel. And when you combine the unfortunate fact that Lowell suffered from hypertension—which often shows up in the vessels of the eyeballs—with his will to believe, it's no surprise that he had Venus as well as Mars teeming with intelligent, technologically capable inhabitants.

Alas, Lowell fared only slightly better with his search for Planet X, a planet thought to lie beyond Neptune. Planet X does not exist, as the astronomer E. Myles Standish Jr. decisively demonstrated a decade ago. But Pluto, discovered at the Lowell Observatory in February 1930, some thirteen years after Lowell's death, did serve as a fair approximation for a while.

Within weeks of the observatory's big announcement, though, some astronomers had begun debating whether or not Pluto should be classified as the ninth planet. Given the decision several years ago by my home institution to represent Pluto as a comet rather than as a planet, I've been drawn into that debate myself, and I can assure you, it hasn't let up yet. Asteroid, planetoid, planetesimal, large planetesimal, icy planetesimal, minor planet, giant comet, Kuiper Belt object, trans-Neptunian object, methane snowball, Mickey Mouse's dim-witted bloodhound—anything but number nine, we naysayers argue. Pluto is just too small, too lightweight, too icy, too eccentric in its orbit, too weird. And by the way, we can say the same about the most recent high-profile contender for tenth place, the ruddy object Sedna, with which Pluto may have more in common than either object has with the planets in our solar system.

Time and technology moved on. Come the 1950s, radio-wave observations and better photography began to bring fascinating facts about the planets to light. By the 1960s, people and robots had left Earth to take pictures of the planets. Each new fact and photograph lifted the curtain of ignorance a little bit higher.

Venus, named after the goddess of beauty and love, turns out to have a thick, almost opaque atmosphere, made up mostly of carbon dioxide and bearing down at nearly a hundred times the sea-level pressure on Earth. Worse yet, the surface air temperature approaches 900 degrees Fahrenheit. On Venus you could cook a sixteen-inch pepperoni pizza in nine seconds, just by holding it in the air. (Yes, I did the math.) Such extreme conditions pose great challenges to space exploration, because practically anything you can imagine sending to Venus will, within a moment or two, get crushed, melted, or vaporized. So you'd better be heatproof or just plain quick if you're collecting data from the surface of this forsaken place.

It's no accident, by the way, that Venus is hot. It suffers from a runaway greenhouse effect, induced by its atmospheric carbon dioxide, which traps infrared energy. So even though the tops of Venus's clouds reflect most of the Sun's incoming visible light, the rocks and soils on the surface absorb the little bit that makes its way through. That terrain then re-radiates the visible light as infrared, which builds and builds, eventually creating—and now sustaining—a remarkable pizza oven.

The rest of the solar system continues to become more familiar by the day. The first spacecraft to fly past Mars was *Mariner 4*, in 1965, and it sent back the first-ever close-ups of the Red Planet. Lowell's lunacies notwithstanding, before 1965 nobody knew what the Martian surface looked like, other than that it was reddish, had polar ice caps, and showed darker and lighter patches. Nobody knew it had mountains, or a canyon system vastly wider, deeper, and longer than the Grand Canyon. Nobody knew it had volcanoes vastly bigger than the largest volcano on Earth, Mauna Kea in Hawai'i.

Nor is there any shortage of evidence that liquid water once flowed on the surface of Mars: the planet has meandering riverbeds as long and wide as the Amazon, webs of tributaries, river deltas, and floodplains—all bone-dry. The Mars Exploration Rovers inching their way across the dust and rocks recently confirmed the presence of surface minerals that form only in the presence of water. Yes, signs of water everywhere, but not a drop to drink.

Something bad happened on both Mars and Venus. Could something bad happen on Earth, too? Our species is currently turning row upon row of environmental knobs, without much regard to long-term consequences. Who even knew to question those practices before the study of Mars and Venus, our nearest neighbors in space, forced us to look back on ourselves?

To get a better view of the more distant planets requires space probes. The first spacecraft to leave the solar system were *Pioneer 10*, launched in 1972, and its twin, *Pio-*

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neer 11, launched in 1973. Both passed by Jupiter within two years, executing a grand tour along the way. Today they're nearly 8 billion miles from Earth—more than twice the distance to Pluto.

When they were launched, however, *Pioneers 10* and *11* weren't supplied with enough energy to go much beyond Jupiter. How do you get a spacecraft to go farther than its energy supply will carry it? You aim it, fire the rockets, and then just let it coast to its destination, falling along the streams of gravitational forces set up by everything in the solar system. Orbital dynamicists have gotten so good at these "gravity assists" that they make billiard sharks jealous.

Pioneers 10 and *11* sent back better pictures of Jupiter and Saturn than had ever been possible, even with the best equipment on Earth. But the twin spacecraft *Voyagers 1* and *2*—launched in 1977 and equipped with a suite of scientific experiments and imagers—were what turned the outer planets into icons. *Voyagers 1* and *2* brought the solar system into the living rooms of an entire generation of world citizens. And one of the windfalls of those journeys was the revelation that the moons of the outer planets are just as different from one another, and just as fascinating, as the planets themselves.

As I write, a NASA orbiter named *Cassini* is homing in on Saturn, having reached the Ringed Planet's neighborhood after a four-cushion gravity assist. Soon *Cassini* will deploy a daughter probe named *Huygens* (designed by the European Space Agency) into the atmosphere of Saturn's largest satellite, Titan, the only moon in the solar system known to have a dense atmosphere. Another complex NASA mission now being planned is the Jupiter Icy Moons Orbiter—JIMO for short. Instead of executing a flyby, the JIMO probe will carry enough fuel to slow down when it reaches Jupiter and enter a series of loop orbits, enabling a sustained study of the planet's sixty-plus moons.

More paired images of Roman gods painted by Perugino, and the planets named after them. Top to bottom: Jupiter and Saturn.

In 1584, in his book *On the Infinite Universe and Worlds*, the Italian monk and philosopher Giordano Bruno proposed the existence of "innumerable suns" and "innumerable Earths [that] revolve about these suns." Moreover, working from the premise of a Creator both glorious and omnipotent, he claimed that each of those Earths has living inhabitants. For these and related blasphemies, the Catholic Church burned him at the stake.

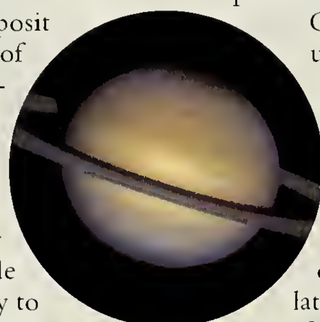
Yet Bruno was neither the first nor the last person to posit some version of those ideas. Others who espoused the concept of multiple inhabited worlds range from the fifth century B.C. Greek philosopher Democritus to the nineteenth-century French novelist Honoré de Balzac. Bruno was just unlucky to be born at a time when you could get executed for such thoughts.

During the twentieth century, astronomers figured that life could exist on other planets, as it does on Earth, only if those planets orbited their host star within the "habitable zone"—a swath of space neither too close nor too far. No doubt life as we know it requires liquid water, but it was just an assumption that life also requires starlight as its ultimate source of energy.

Then came the discovery that some objects in the outer solar system, such as Jupiter's moons Io and Europa, are heated by energy sources other than the Sun. In both cases, the stress of Jupiter's tides on the solid moons pumps energy to their interiors, melting ice and giving rise to environments that might sustain life independent of solar energy.

Even right here on Earth, new categories of organisms, collectively called extremophiles, thrive in conditions inimical to human beings. The concept of a habitable zone incorporated an initial bias that room temperature is just right for life. But some organisms thrive at several hundred degrees Fahrenheit, and find room temperature downright hostile. To them, we are the extremophiles.

So, armed with the knowledge that life can appear in places vastly more diverse than previously imagined, astrobiologists are broadening the earlier, and more restricted, concept of a habitable zone. And, just as Bruno and others had suspected, the roster of confirmed exosolar planets continues to grow by leaps and bounds. Their number has now risen past a hundred—all discovered in the past decade.



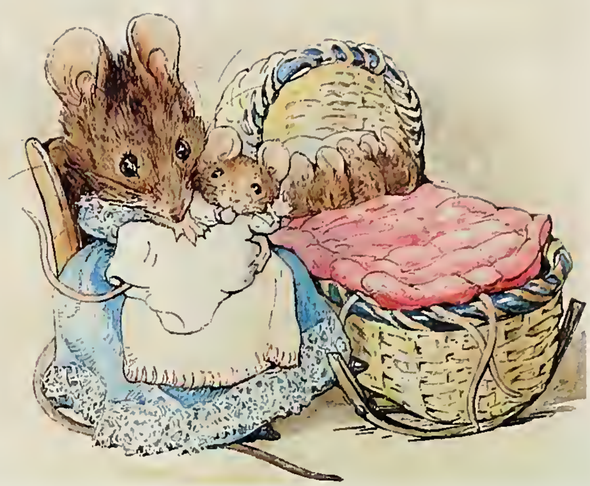
Once again we resurrect the idea that life might be everywhere, just as our ancestors had imagined. But today we do so without risk of being immolated, and with the newfound knowledge that life is hardy, and that the habitable zone may be as large as the universe itself.

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

Of Mice, Men, and Genes

The best-laid plans o' DNA gang aft agley.

By Robert M. Sapolsky



Beatrix Potter: *Hunca Munca* (from The Tale of Two Bad Mice), 1904

Don't you love urban legends, those outrageous stories everyone believes? There are academicians who study urban legends for a living; they catalogue them, track their origins in Norse mythology, get into arguments at conferences about them. But amid all that intellectualizing, it's just plain fascinating to hear some of the made-up stuff that lots of people fall for. There's the endlessly repeated one about the poodle stuffed into a microwave to get dried off, or the classic about the scuba diver who gets scooped up along with a lot of water into the giant bucket of a fire-fighting plane, then is dropped onto a forest fire. And there's the one about the woman who leaves groceries in her car on a sweltering day: a tube of cookie dough explodes from the heat just as she gets back in, splattering the back of her head, and she's convinced she's been shot and the dough is her splattered brains.

And then there's the one about a bunch of scientists who sequenced the human genome: they can explain everything about you; all they have to do is look it up in the sequence of your genes. But it just ain't so: we're back in the domain of urban legend.

Why are people such suckers for the idea that genes are the be-all and end-all? The tendency is particularly bad right now. Not only has the human genome recently been (mostly) sequenced, but we've also just come off the golden anniversary of the discovery of the structure of DNA. The celebrations have been replete with religious imagery about the genetic code as holy grail, the Code of Codes. And this imagery even gets trotted out by biologists, people who get paid to know better.

And biologists really should know better, because they've had the sobering concept of "gene-environment interaction" hammered into their heads for much of their lives. (In fact, "gene-environment interaction" is probably one of the first utterances most biologists made as infants, along with "doggie, doggie come.") The trouble is, it is a phrase so often repeated that it has become as reflexive and ingrained—and, ultimately, ignored—as the words to "Elmo's Song."

The idea that genes and environment interact can mean a number of things. At the least, it means that people who get into black-and-white arguments about nature versus nurture are a century out of date. Of more relevance, it means that though genes can (indirectly) instruct cells, organs, and organisms about how to function in the environment, the environment can also regulate which genes become active at particular times. Of greatest relevance here, though, is that the thing a particular gene most proximally produces—a particular protein—can function quite differently in different environments. So, in theory, you might have a gene that in one environment causes you to grow antlers and, in another, causes you to fly south for the winter.

For folks who still want to fight the nature-nurture wars, the question up for debate becomes: OK, just how powerful are these gene-environment interactions? At one extreme are those who scoff at contrasts as gaping as the one between growing antlers and flying south. In their view, a gene does something or other, and the environment perhaps alters how fast or how strong or how long the gene does that something or other. But none of those environmental influences lead to dramatically different effects. Framed in the context of genes and disease, it's like saying, Yeah, how windy it is may alter the precise speed with which the anvil drops from a ten-story building and lands on your toe, but who cares about that environmental interaction with the anvil? And at the other extreme are those who assert that interactions can be of huge consequence—say, if what is dropping is a feather and not an anvil.

And so the scientists happily argue and experiment away, squandering tax dollars that could otherwise go for Halliburton contracts. Amid these debates, it's useful to be reminded just how powerful gene-environment interactions can be. Two recent studies provide some terrific examples.

The first study investigated the effects of one of the subtlest, least appreciated environments: the prenatal one. For many years, strains of laboratory rodents have been bred for various traits—one strain gets a type of diabetes, another strain gets hypertension, and so on. Each strain is developed by inbreeding generation after generation of animals with some trait, until all the members of the strain are as close as possible to being genetically identical—like clones of one another. If all the members of that strain show the trait, regardless of which laboratory they're raised in, there's some reason to think that the animals are subject to a strong genetic influence.

All the inbreeding is then followed by an experiment known as a "cross-fostering study," regarded as critical for detecting a genetic influence. Suppose all the mice of the Coke strain grow up preferring Coke to Pepsi, and all the mice of the Pepsi strain grow up displaying the opposite persuasion. Take some Coke-strain mice at birth and let Pepsi-strain moms raise them in a Pepsi-strain colony. If the Coke-strain mice still grow up craving Coke, the typical interpretation is that you've found a behavior that strongly resists environmental influence; score one for nature over nurture. But are cross-fostering experiments the last word?

That's where one of the new studies comes in. Carried out by Darlene Francis, a neurobiologist at Emory University in Atlanta, and her colleagues, it was published in the prestigious journal *Nature Neuroscience*. The investigators looked at two mouse strains that differ across an array of behavior patterns. To simplify a bit, one strain is more anxious and skittish than the other. Compared with the more "relaxed" strain, the "timid" strain is slower to enter a scary or novel environment, and timid-strain mice have more trouble learning during a stressful task than relaxed-strain mice do.

Geneticists who study mice had known about those differences for a long time. They had also confirmed, apparently, that the differences were largely governed by genetics. True, there was some evidence that relaxed-strain mothers are more nurturing than timid-strain moms, licking and grooming their pups more. That evidence had raised the possibility that mothering style caused the differences between the two strains. But then the acid test had been performed: relaxed-strain mice that were raised from birth by timid-strain moms grew up to be just as relaxed as any other member of their strain.

Environmental influences don't begin at birth: the prenatal environment also interacts with genes.

But Francis and her team went a step further. With the same kind of technology used by clinics performing in vitro fertilization, the investigators cross-fostered mice as embryos. Specifically, they implanted fertilized eggs from relaxed-strain parents into timid-strain females, which then carried the relaxed-strain embryos to term. They also did the key

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control: they implanted relaxed-strain eggs into relaxed-strain females (just in case the process of in vitro fertilization and implantation distorted the results). After they were born, some relaxed-strain pups were raised by timid-strain moms, and others by relaxed-strain ones. (If all this isn't confusing enough, at least thank Francis and her colleagues for not bothering to implant fertilized timid-strain eggs into relaxed-strain females.)

And the result? When the supposedly genetically hardwired relaxed-strain mice went through both fetal development and early puphood with timid-strain moms, they grew up to be just as timid as any other timid-strain mice. Same genes, different environment, different outcome.

This result raises two points. First, environmental influences don't begin at birth. Some factor or factors in the environment of a timid-strain mouse mother during her pregnancy—her level of stress, perhaps, or the nutrition she gets—is affecting the anxiety levels and learning abilities of her offspring, even as adults. The mechanisms may have to do with alterations in their brain structure, hormone profiles, or metabolism. In fact, some of the same effects have already been documented in people. The second point? Relaxed-strain mice aren't relaxed only because of their genes; their fetal and neonatal environments are crucial factors.

A finding like this one could give panic attacks to mouse mothers the world over: Remember the time we got all stressed-out when we were pregnant? Remember that other time we got irritable with our newborn pup? One of them could be the reason the kid won't get into the best college.

Walking in the Rain, an American postcard from the early twentieth century

But such worries are far afield, of course, from human concerns. And that's where the other study comes in.

The second recent study is a landmark paper, published in the equally prestigious journal *Science*, by Avshalom Caspi, a psychiatrist at King's College, London, and his colleagues. These investigators have been doing work that puts to shame those studies that come out of watching some fruit fly with a twenty-four-hour life span. Caspi and company have been following a population of more than a thousand New Zealand kids, beginning at age three and continuing well into adulthood, nigh onto a quarter century. Among the things they've examined is who, as a young adult, suffers from clinical depression. That topic, by the way, is a useful one to get some insight about—given that depression can be life-threatening and afflicts between 5 and 20 percent of us.

Caspi's team examined patterns of depression in their subjects and dis-

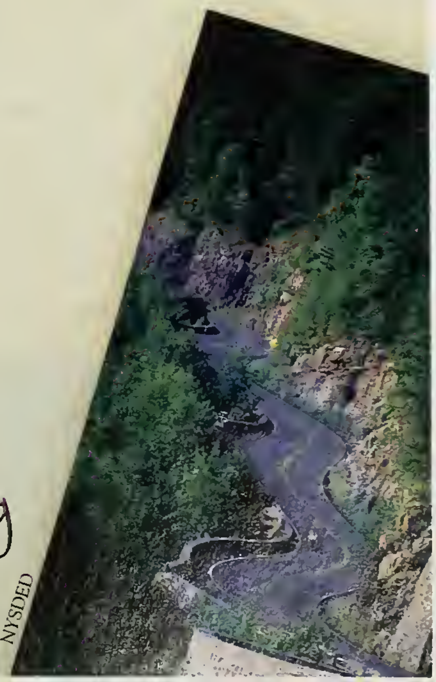
(Continued on page 31)

NYSDED

Golden Hills RC&D, Inc.

Scenic Byways

. . . through New York, Nova Scotia, and Wyoming



NYSDED

New York State

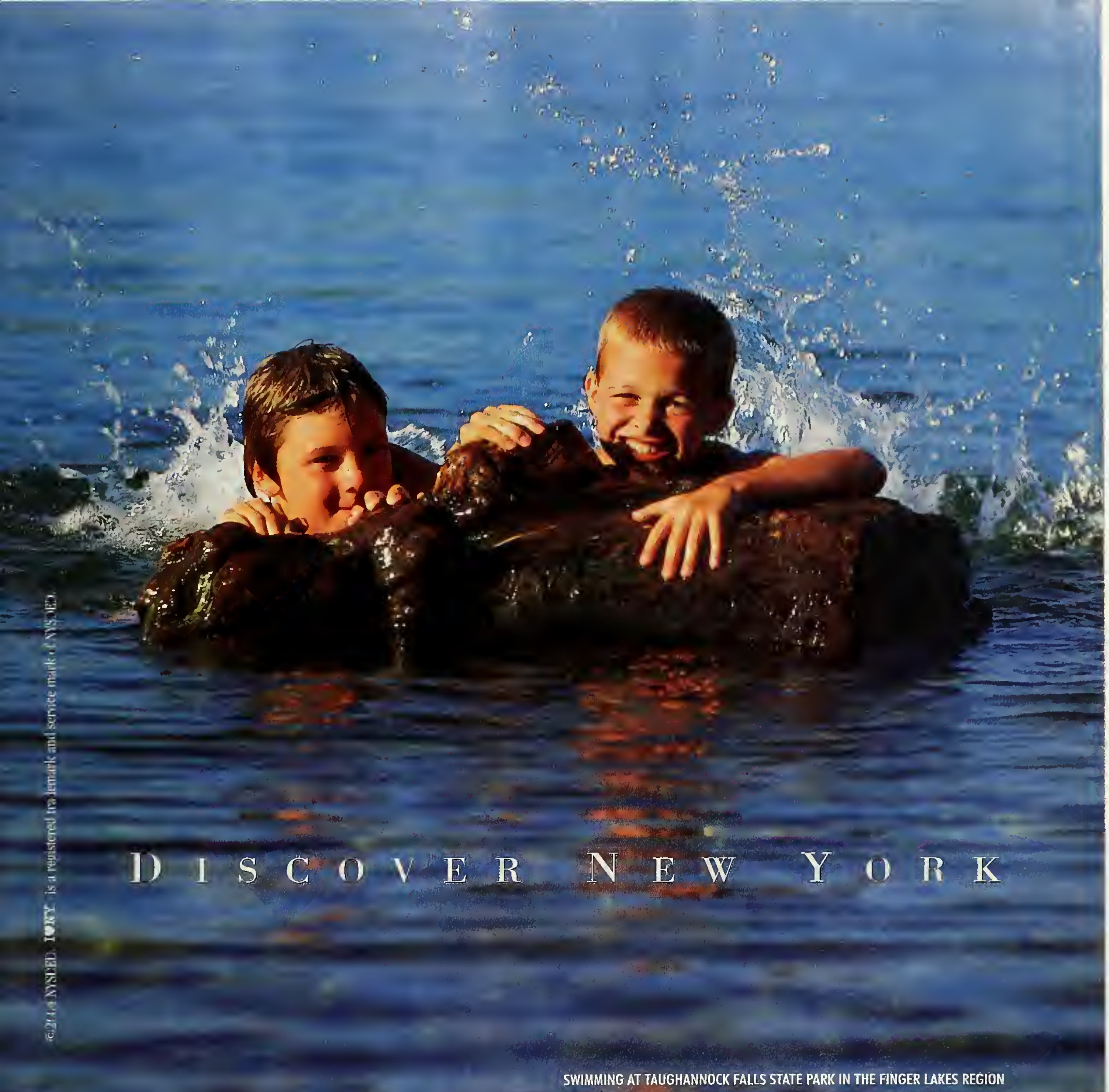
photos: New York State Department of Economic Development

From majestic mountains to shining seas, New York State is a world of scenic wonders. Its spectacular vistas include cascading waterfalls, mighty rivers, abundant lakes and streams, lush green forests, and sun-kissed vineyards. Stroll along a sandy Long Island beach at sunset, follow a scenic route along a Finger Lake, or be dazzled by the skyline of New York City. Come discover a land of astonishing beauty: See the grandeur of Niagara Falls; Letchworth Gorge, known as the Grand Canyon of the East; and the fantastic underground rock formations at Howe Caverns.

New York has two "America's Byways"—roads with a story to tell. The Lakes to Locks Passage, which parallels Lake Champlain and the Champlain Canal, takes visitors past lovely villages beneath the Adirondack Mountains, with plenty of history, hiking trails, lakeside beaches, and opportunities to explore nature. The Seaway Trail follows a series of state and county roads along the shores of the St. Lawrence River, Lake Ontario, Niagara River, and Lake Erie. You'll drive through naturally scenic landscapes, from Chautauqua's vineyards to Niagara Falls.

The state has many other, smaller byways, such as the Cayuga Lake Scenic Byway, which offers beautiful landscapes of farmland, vineyards, and historic small towns as it loops around this Finger Lake. Waterfalls and gorges are characteristic of the region's unique geology, and the lake itself provides almost limitless opportunities for fun, including swimming, boating, and fishing. The North Fork Trail, in Long Island's Suffolk County, carries visitors from Southold to Orient Point, through a series of charming hamlets, past wineries, farms, and wild wetlands, with glimpses of beaches and maritime life along the way. The tour ends with an uninterrupted view of the Atlantic Ocean stretching into the horizon.

Above, from left: Boldt Castle on Heart Lake in Thousand Islands; Letchworth State Park; Niagara Falls; below, from left: Ausable River with Whiteface Mountain in the background; Historic Dunkirk Lighthouse along Lake Erie; The Hudson's Valley's Mills Mansion


DISCOVER NEW YORK
SWIMMING AT TAUGHANNOCK FALLS STATE PARK IN THE FINGER LAKES REGION

Nova Scotia

Nova Scotia is a coast of contrasts. Our 4,600 mile shore ranges from rugged and challenging to gentle and sandy, bustling to charming and quiet. You're never more than 35 minutes from the sea here. No wonder we're a touring enthusiast's paradise.

The province boasts the most coastal cycling routes in all of Canada. Paddlers will love the pristine waterways of Kejimkujik National Park. And at low tide along our Bay of Fundy, you can actually walk on the ocean floor in the wake of the world's highest tides. It's a perfect place for beachcombing and one of the best on the eastern seaboard for whale watching.

You'll find the most authentic living history in Canada here in Nova Scotia. Visitors will marvel at Fortress of Louisbourg National Historic Site, the largest historic reconstruction in North America. Many will jump with surprise when the noon-day gun is fired from the star-shaped citadel overlooking Halifax. And Grand Pré National Historic Site is a peaceful, pastoral setting commemorating the deportation of the Acadians.

This year, Acadians from around the world will gather in Nova Scotia for the Congrès mondial acadien 2004. It's just one of hundreds of festivals we're throwing to celebrate our maritime and cultural traditions—including our Irish, Scottish, French and German peoples.

Along with all the other amenities you'd expect from a major center, Halifax, Nova Scotia's capital city, has the most and best variety of restaurants, pubs and bars in Atlantic Canada. Savor a "Taste of Nova Scotia" with a meal of Digby scallops.

Nova Scotia is just a day's drive from Boston—and you don't have to do all the driving! Ferries depart regularly for our coast from Portland and Bar Harbor. You can also fly direct from Boston to Halifax. Either way will leave you lots of time to enjoy your Nova Scotia vacation.

Above, from top: The Cabot Trail; Cape Chignecto Provincial Park; below, from left: Lunenburg, a UNESCO World Heritage Site; Come glide between sea and sky along Cape Breton's west coast


Relax, rush hour doesn't arrive for 6 hours.
This is
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Canada's Seacoast


Cape Breton Island
Saint John
Halifax
NOVA SCOTIA
Bar Harbor
Digby
Yarmouth
Portland
Boston
CANADA
UNITED STATES

Wyoming

Pete Saloutos

Above: Sunset over the Snake River and the Teton Range – Grand Teton National Park, Wyoming, below: The Chimney, North Fork of the Shoshone River, Wapiti Valley, Wyoming

A trek along Wyoming's scenic routes is the very antithesis of an urban commute. In the city, your time behind the wheel is basic transportation–getting from point A to B as quickly as possible with hopes of avoiding the glow of brake lights signaling things are about to grind to a halt.

In the country's least populated state, Wyoming road time is decidedly communal. You are joined by nature's bounty and share in her glory across high plains, along mountain meadows and between canyon walls. You will see playful herds of antelope, moose and elk, bighorn sheep and bounding deer along with a plethora of smaller creatures carrying on their daily tasks unimpeded.

Widened shoulders accompanied by expanded pullout and picnic areas all add immeasurably to the driving experience along the Buffalo Bill Cody Scenic Byway west of the town of Cody and on to Yellowstone National Park's east gate. Unique rock formations, called "hoodoos," and wildlife abound. In the south, Snowy Range Scenic Byway near Laramie offers breathtaking peaks reflected in glassy lakes. There's Mirror Lake in the southwest and a wide variety of choices to cross the Big Horn Mountains in the north. The Centennial Scenic Byway, in northwest Wyoming, provides passage through some of the most beautiful scenery in the United States with the quaint western towns of Dubois and Pinedale at either end–and the glorious Grand Tetons in between.

Wyoming Travel & Tourism

There's a 20-page scenic byway and backway booklet available free of charge to accompany Wyoming's in-depth vacation directory. Order yours today at: (800) 225-5996 or on the web: www.wyomingtourism.org.

 (Continued from page 24)

covered that it has something to do with possessing a certain variant of a gene. That's a nice finding, of course, but what makes it really exciting is that the gene in question is not just any random gene. It has already been implicated in biochemical theories about depression, coding for a protein that helps regulate how much serotonin gets into neurons. Serotonin is a neurotransmitter, one of scores of different kinds of neurotransmitter in the brain, but it is the one responsive to antidepressant drugs such as Prozac, Paxil, and Zoloft (collectively known as "selective serotonin re-uptake inhibitors"—SSRIs).

The serotonin-regulating gene—which for reasons not worth going into is called *5-HTT*—comes in two different "flavors." Both flavors code for the same kind of protein, but the two flavors differ in how much of the protein gets produced. Individuals can have two copies of either flavor (one from each parent) or one copy of both. At least some nonhuman primates can as well. Studies had already shown that a rhesus monkey's *5-HTT* makeup affects how readily the animal deals with stress.

So Caspi and his colleagues tabulated the two *5-HTT* gene flavors and how they correlated with the incidence of depression in their pool of New Zealand subjects. And what they discovered is worth stating carefully. Did they demonstrate that genes of a certain flavor actually cause depression? No. Did they show that having a certain *5-HTT* makeup significantly increases a person's risk of depression? Not really.

What they showed was that the *5-HTT* genes you inherit greatly increase your risk of depression, but only in a certain environment. What kind of environment? One with a history of major stressful events and traumas in childhood or early adulthood (such as the death of a loved one, the loss of a job, a serious illness). Those in their study with a "bad" *5-HTT* profile, who also suffered major stressful events, had almost twice the risk of depression, and nearly four times the risk of suicide or suicidal thoughts, as those with the "best" profile. But those who were spared a history of major stresses were no worse off for having a "bad" *5-HTT* profile. (Completing this picture is work by a group at the University of Wurzburg, in Germany, showing that stress hormones regulate the activity of the *5-HTT* gene, and do so differently, according to its flavor.)

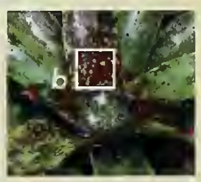
What lessons lurk here? Obviously, beware of simple explanations; it is rare that nature is parsimonious.

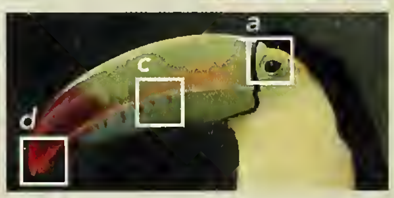
And keep genes in their proper place. Sometimes genetics is about inevitability. If you have the mutation for Huntington's Disease, for instance, there's a 100 percent chance you're going to have this awful neurological disease by middle age: no two ways about it. But genes are more often about vulnerabilities and potentials than they are about destiny.

What all this highfalutin molecular biology should teach us is that we can't just throw up our hands and say: "His genes made him do it." We all have a responsibility to create environments that interact benignly with our genes.

Robert M. Sapolsky *is a professor of biological sciences and neurology at Stanford University. He is the author of* A Primate's Memoir: A Neuroscientist's Unconventional Life among the Baboons. *His most recent article for* Natural History, *"The Pleasure (and Pain) of 'Maybe'" (September 2003), has been nominated for the 2004 National Magazine Award for Essays.*

Answer to "Cryptic Creatures" puzzle (page 15): b





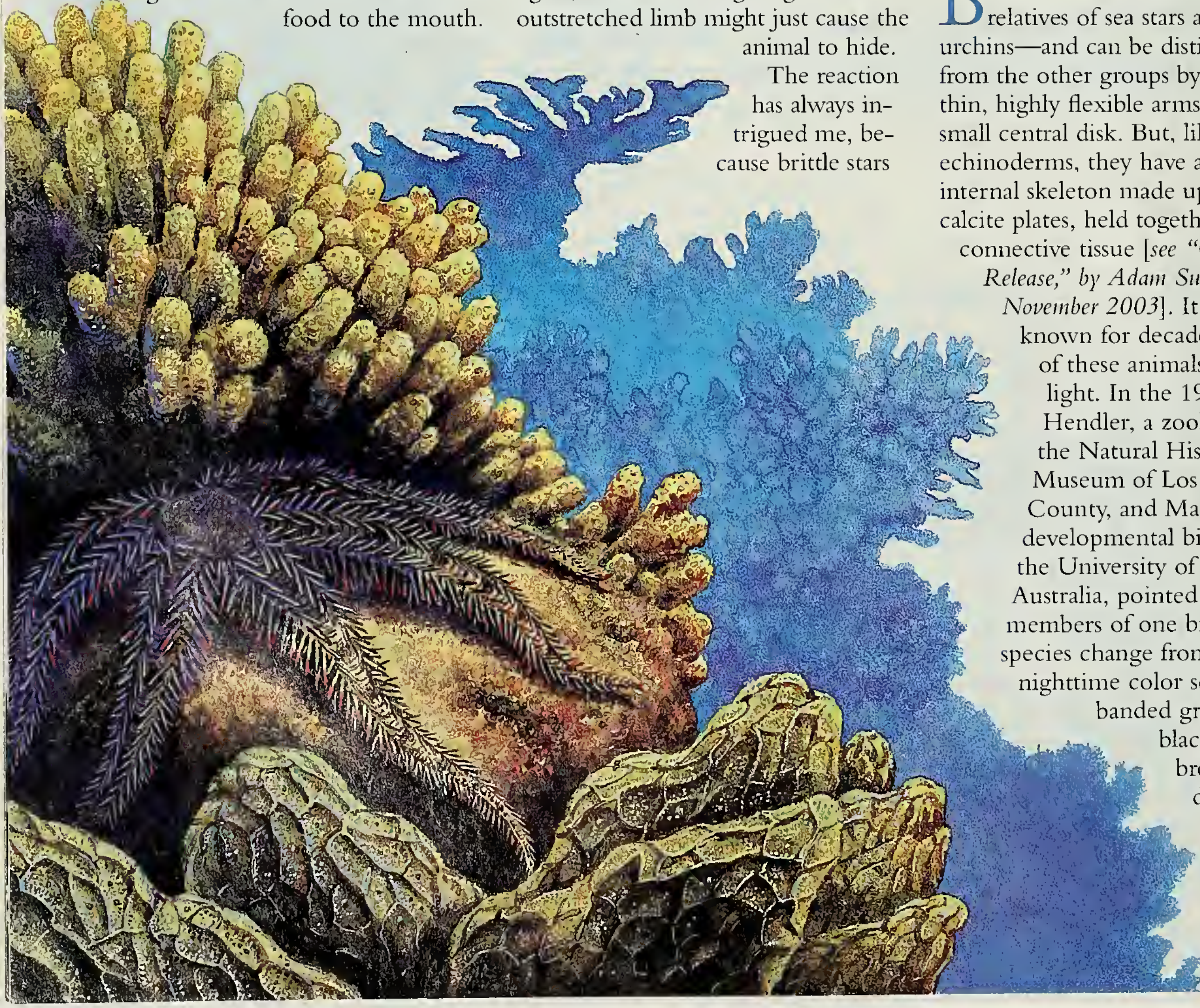
How a Star Avoids the Limelight

Some echinoderms have thousands of eyes on their backs. When the lights come on, they switch to wearing shades.

By Adam Summers ~ Illustrations by Roberto Osti

By day, gaudy reef fishes dominate the scene at a coral reef, but by night, invertebrates steal the show. Coral polyps—at least the ones that can't depend on nutrients provided by photosynthesizing symbiotic partners—extend their tentacles in the darkness to feed. Feather stars spread their arms, each grooved to direct the flow of food to the mouth. Spiny lobsters march on parade. And night is the time to get a good look at one of the shiest of all the reef dwellers: the brittle star.

Only at night does the brittle star venture out of its hiding place to snake across the surface of the reef in search of food. But divers looking for one should be careful with their lights, because shining a light on an outstretched limb might just cause the animal to hide. The reaction has always intrigued me, because brittle stars have no obvious eyes. Nevertheless, they can detect light, and a team of investigators has now figured out how they do it. It turns out the dorsal side of the brittle star is covered with microscopic lenses embedded in its skeleton, making the entire back of the creature into a compound eye.



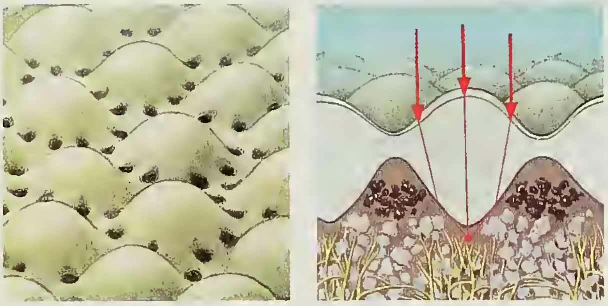
Brittle stars are echinoderms—relatives of sea stars and sea urchins—and can be distinguished from the other groups by their long, thin, highly flexible arms and their small central disk. But, like all echinoderms, they have a hard internal skeleton made up of small calcite plates, held together by catch connective tissue [*see "Catch and Release," by Adam Summers, November 2003*]. It has been known for decades that some of these animals can sense light. In the 1980s Gordon Hendler, a zoologist at the Natural History Museum of Los Angeles County, and Maria Byrne, a developmental biologist at the University of Sydney in Australia, pointed out that members of one brittle star species change from their nighttime color scheme of banded gray and black to deep brown in the daytime.

Responding to light does not require an eye. A sea snake in the subfamily Hydrophiinae, for instance, can perceive its tail being exposed as the snake forages on the reef, and move it out of the light. But that response would merely require the tail to have sensory neurons that respond to light—or to heat, the by-product of light on a dark surface. Some brittle stars, though, have responses to light that do seem to require an eye. When placed in bright sunlight, members of those species will make for a shadowed area as fast as their five little arms can carry them. Such behavior suggests they can detect shelter at a distance and even form an image of their surroundings.

Joanna Aizenberg, a materials scientist at Bell Laboratories in Murray Hill, New Jersey; Alexei Tkachenko, a physicist now at the University of Michigan in Ann Arbor; and Stephen Weiner and Lia Addadi, both structural biologists at the Weizmann Institute of Science in Rehovot, Israel, teamed up with Hendler to examine the hidden eye of the brittle star. The investigators used a scanning electron microscope to look at skeletal calcite plates from the upper surface of a member of the light-sensitive brittle star species *Ophiocoma wendtii*. What they saw was an unusual pattern of densely packed, crystal-clear bumps, each thinner than a human hair. Similar plates from a non-light-sensitive species *(O. pumila)* had no such bumps, and neither did plates from the underside of the arms of *O. wendtii*.

Might the bumps serve as lenses to focus light? Aizenberg and her colleagues established good theoretical reasons for thinking they could. The calcite crystal that makes up a bump is aligned so as to conduct light from the outside surface of the plate to the inside surface. Furthermore, because the bumps are not perfect spheres, they don't have the blurriness characteristic of spherical lenses. By measuring the shape and size of the bumps, the investigators calculated that they would focus light between four and seven micrometers (just a few ten-thousandths of an inch) beyond their inner surface.

Maria Byrne had previously examined a plate and surrounding tissue with a transmission electron microscope and found a bundle of nerves at the appropriate distance—at the calculated focal point—from each bump. Cells containing pigment reside alongside and below each bump. During the day, however, the pigmented cells migrate to the upper surface of the calcite ossicles, where they shield the top of the lens from the bright sun and, incidentally, darken the animal. The color change is not a camouflage response; rather, it is the echinoderm version of sunglasses.



Ophiocoma wendtii, a brittle star (opposite page), prefers the dark. But the entire dorsal side of the animal is covered with a matrix of calcite crystals (above left) shaped into bumps that act as lenses (above right). The lenses (supported by a layer of irregular calcite, shown in gray in the schematic diagram) focus incoming light on a network of nerves (yellow). Alongside each lens are pigment-bearing cells that migrate above the lens layer by day, acting as echinoderm sunglasses. Together, the lenses and nerves turn the animal's back side into a body-size compound eye.

Following up this work, Aizenberg exposed a sheet of film to light passing through the presumed array of lenses. Her results were striking. A small spot of light hit the film under each bump. The size of each spot varied with the size of the bump, and the brightness of the spot depended on the incident angle of the light with respect to the surface of the brittle star arm. In other words, each tiny, embedded bump acts as a directional light sensor, responding most strongly to light coming from a particular direction. The bump is thus a rudimentary lens.

If the brittle star had just one such lens on each arm, it could look around by waving an arm and assessing the patterns of light and dark. But the resolving power of a brittle star lens is extremely limited: relying on one would be a bit like looking through a peephole covered with tissue paper. Because the dorsal surface of the brittle star is covered with thousands of tiny "eyes," though, and each eye receives light from a slightly different direction and angle, the entire surface can act as one large compound eye. That compounding makes it possible, in some sense, for the brittle star to take in the whole scene. A computer monitor is a useful analogy. A single pixel holds information about the color and brightness of a single part of an image. But an entire array of pixels yields a coherent picture.

The brittle star's eye is a wonderful example of how basic science—in this case Hendler and Byrne's natural-historical observations—can give applied scientists insight into a problem with clear commercial impact. Investigators at Lucent Technologies (of which Bell Labs is a part) are excited because the brittle star makes better, smaller lenses than they do. They hope to learn the secret of depositing a well-patterned crystalline matrix, so they can then shrink fiber-optic junctions and advance toward the goal of building a completely optical computer. As for me, I know I'll never again look at a brittle star in quite the same way—now that I know they're looking back!

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

Zoology laboratory at Cairo University, part of the Egyptian national educational system. Males and females are treated equally when it comes to education, and many urban families encourage their daughters to pursue advanced studies rather than rush into marriage.

Egypt's Young and Restless

Through Islam and the Internet, a new generation seeks its fair share.

By Mary Knight

Osama 'Abd al-Raheem studies engineering at Helwan University, in the southern suburbs of Cairo. He is committed to his studies, and, like most young adults, he aspires to marry, to find a decent job that puts his hard-won skills to good use, to live a fulfilling life with his family, his friends, his culture, his country. But he looks with envy on those who are fifteen or twenty years older, who were able to buy homes and furnish them during the long-vanished days of easy money. When we talked, he expressed his frustration: "If a young man takes a job in Egypt, his salary will be about 500 Egyptian pounds [less than $100] per month, so he will have to work ten years to get married; if he goes abroad, he can get married much sooner."

The disadvantage Osama must live with is that going abroad today is not the solution it was for young men twenty or more years ago. In the 1970s and 1980s, when the prospects at home were little better than they are today, Egyptian laborers, mostly male, traveled to the oil-rich Gulf states and nearby Libya for work. The income they brought or sent back home enhanced living standards for many families. Overall, in fact, poverty declined.

Then, with the collapse of OPEC's power and the crisis brought on by the 1991 Gulf War, many would-be Egyptian migrants had little choice but to stay home. For men, the blow was particularly harsh: often they could find no work in their fields of study, and what little money they did earn was not enough for the down payment on an apartment, a prerequisite for marriage. For Osama, the foreign safety valve has closed shut.

Many young Americans can probably empathize with Osama's plight. Ambitious, highly educated graduates are often thrust, when they first enter the workforce, into low-paying and exhausting dead-end jobs, just to make ends meet. But the situation in Egypt is far more desperate than it is in the United States. With 72 million people, Egypt is the most populous of the twenty-two Arab states. Officially the nation's unemployment rate is only about 9 percent. Studies that specifically track youth unemployment, however—in a nation where the median age is twenty—estimate that 25 percent of men and 59 percent of women are without work. As in the U.S., these studies include only people who are actively seeking a job, and part-time workers are considered employed.

Unemployment, though, is only one way to understand the plight of the young people in this large Arab country. Another set of critical issues is the distribution of power—which in Egypt largely coincides with the distribution of wealth—and the perception that the distribution is unjust. The class difference is rarely discussed as such, but it is certainly noticed, and it plays a major role in gaining access to such basic social services as technical training. Social gaps everywhere—between rich and poor, young and old, educated and illiterate, urbanite and farmer—reinforce the corrosive perception that the society does not reward its citizens on merit alone. The resounding cries by youth of "it's unfair" often turn on income disparity.

Among those whose voices are raised are the Islamic militants, many of whom are men from relatively privileged backgrounds, familiar with Western ways. What often incites their anger is seeing their parents operate on principles other than those of idealistic fairness. And when these young men meet other, less privileged people who have substantial talents and abilities that are passed over by the likes of their parents, their outrage may grow to conspiratorial proportions.

Last fall I traveled to Cairo, a city where I've lived and worked on and off since 1994. Because I have many friends and contacts there and am reasonably fluent in the language, I was in a good position to take the pulse of the so-called Arab street. My aim was to sketch how ordinary lives are lived in a culture that Americans have largely ignored—ignored, that is, until they "learned" recently to regard virtually all Arab culture with fear and suspicion. The immediate questions that dog my fellow Americans—Why do they hate us? What

Girls take part in a science class taught in English, at al-Nozha Language School, an Islamic school on the outskirts of Cairo. Such schools are generally better equipped than the state schools, but their numbers are limited.

do they think of our policies?—were not my first priority, though. My focus was to understand Egyptian concerns; to learn how Egyptians were facing up to universal questions about access to high-quality education, women's evolving social roles, and career development; and to find out how their deeply held religious beliefs affect their interaction with the world at large.

At the root of Egypt's dismal unemployment statistics are the nation's weakness in the production and dissemination of knowledge and the government's inadequate commitment to science and technology. Yet there is tremendous energy and enthusiasm for learning among Egyptian students. Every young person I spoke with acknowledged the need for job-related computer skills and for better access to information in a country where libraries are only now becoming more widely accessible.

A bride, left, sports her wedding hairdo the night before the ceremony. Solemnization of the union is performed at a mosque, but the bride's family usually puts on a wedding reception. The groom is responsible for supporting himself and his bride, and—because a large deposit is required to establish their new residence—he must have accumulated considerable savings.

The Ministry of Education likewise recognizes the need for computer skills, and so it has provided every public school in Egypt with at least one computer, and occasionally more than one. But school enrollments usually number in the hundreds, and the presence of one or two computers normally restricts usage to demonstrations by teachers at the front of the class.

Perhaps even more detrimental is the lack of functioning, up-to-date laboratory apparatus in science education. Osama 'Abd al-Raheem and several of his friends told me that as many as sixty students typically crowd around their professor as he performs experiments for the class. The reason is that nearly all of the aging equipment is broken. "The classes are crowded," he says, "so it's hard for the students to understand. So we just memorize the lessons." Memorization is still the preferred method of learning in all disciplines, but in the sciences, the near total lack of hands-on experimental work suppresses the critical and creative skills needed to excel.

Painfully aware that their futures rest on the successful use of mouse and keyboard, Egyptian young people seek out the new technology. Cybercafés and computer training institutes now abound throughout Cairo, though all charge relatively high fees. Industrious youths save up the 2,000 to 3,000 Egyptian pounds (between $400 and $600) needed for a computer, then add peripherals, often secondhand, as their budgets permit. In the past few years, Egypt's relatively open society has helped the country surpass most of the rich Gulf states in factors that measure computer-related growth. Internet connections, for instance, are now free, though the phone charges, which are based on the amount of time spent online, are relatively expensive. That said, the percentage of all Egyptians who have ever accessed the Internet remains in the single digits.

Among those energetically devoting themselves to improving the lot of young people are what are coming to be called the "new Islamists"—Muslims who believe their primary duty is to live exemplary lives and thereby improve the community. (By contrast, militants strive first to rid the world of disbelievers, condoning violence in the process.) Hosam Muhammad, a sturdily built twenty-nine-year-old, and his colleague Hisham Muhammad, a fine-boned, quiet-mannered twenty-three-year-old, both teach English in al-Nozha Language School, a clean and orderly Islamic school on the northeastern outskirts of Cairo. The school serves about a thousand students, from kindergarten through high school. Both men use the Internet to enhance their knowledge and to make friends with English speakers around the world, particularly in the U.S.

In their jackets and ties, dress slacks, and polished shoes, the two Arabs, one clean-shaven and the other wearing a neatly trimmed beard, look like refined, educated young professionals anywhere. Polite and modest, they laugh readily and banter charmingly, in English or in Arabic. And both strongly maintain that Islam has a transformative, restorative power for their society. In the classroom they teach values through example, as a way to complement their curriculum of intensive language training. Their ultimate jihad is to push their students along the path to a better future, both economically and morally.

Another "new Islamist" is 'Abd al-Hafiz al-Sayyid Muhammad, the imam, or chief religious leader, at Omar Makram Mosque in downtown Cairo. In 1995, recognizing the need for knowledge and the traditional role of the mosque in education, 'Abd al-Hafiz initiated computer courses in rooms above the prayer hall, diverting some of the mosque's funding to the purchase of computers. (Literacy classes were already in place, for men and women.) Students—more than a thousand a year—flocked to the innovative program, not only to learn computer skills but also to learn English and a variety of vocational skills.

Women like Nermeen 'Abd al-Tawab, a vivacious twenty-eight-year-old at the University of Cairo's Faculty of Agriculture, exemplify another vibrant part of Egypt's young generation. Her specialization, agricultural research, is one of the few bright spots in Egyptian science, perhaps because 44 percent of Egyptian workers are employed in agriculture. She studies the fungal infection white rot in garlic. White rot has important economic consequences, because it often devastates the bulbs as the garlic goes to market. As part of her doctoral research, Nermeen is applying the tools of biotechnology to develop garlic that is resistant to the virus. Thus occupied, she is postponing marriage until she finds someone she loves and respects. Her family supports her plan completely.

Compared with urbanites, girls from rural areas are apt to find less family support for their education, particularly when one or both of their parents are illiterate. Rural parents encourage their daughters to marry at earlier ages, even if that means marrying a first cousin (usually not a girl's preference). But in Cairo education is a lifeline for many females, giving them hope and freedom no matter how humble (or how high) their origins. While they are in school, they don't have to compete for jobs that are unlikely to be offered to them anyway. And if they enjoy studies, they have the chance to learn more than any of their predecessors and to be respected for their achievements.

The social barriers to women in Egypt are by no means as stringent as they are in Muslim countries that impose a strict interpretation of Islamic law. Some Egyptian women even initiate divorce.

Mai Mostafa, a tall, slender thirty-two-year-old designer and artist, elaborated on the hazards of poor mate selection and divorce: "For every woman who lives in the East, marriage is very im-

A café, serving tea, light meals, and other refreshments, offers a place for young men to socialize. For some, though, the café is the introduction to a life of permanent idleness. Unemployment is high in the outsize generation of young adults, and the opportunities that once existed for work in the Gulf states and nearby Libya have been closed off.

portant. We've been brought up prepared to become wives later. We have a saying that the woman who dares to ask for a divorce helps the house collapse." Mai's father encouraged her to complete her education and to work for a few years, to become independent-minded and self-reliant. He did not exactly approve of her marriage partner, but assured her of his confidence in any choice she made. After the marriage failed, Mai was grateful that, again, her father supported her decision to get divorced.

In spite of the recognition of the need, attempts to establish world-class research and educational institutes in Egypt have foundered. Ahmed Zewail of the California Institute of Technology in Pasadena, the Egyptian-American who won the 1999 Nobel Prize in Chemistry, convinced the government to build a state-of-the-art university for science and technology. More than four years after the ground-breaking ceremony, however, his dream has yet to be realized.

For most young people, then, the only option is to leave the country, a choice that simply exacerbates the already pernicious brain drain. One student I met in Egypt two years ago, who received a grant to study in a computer sciences department at

Transit workers besiege their union headquarters, simply to press bureaucrats into processing their papers and applications for routine benefits such as medical care, life insurance, credit, pensions, and discounts on housing.

a U.S. university in the Midwest, assured me he would return to Egypt after completing his Ph.D. program. When I spoke with him more recently, he was equally fervent in his insistence that he has no plans to return. The reason? In the U.S. he can do research that builds on the latest developments and can produce work others will draw on. He'll stay in the loop, rather than outside it.

According to the 2003 Arab Human Development Report of the United Nations Development Programme, the uneven distribution of income is a critical obstacle to reform and progress. Estimates of extreme poverty in Egypt range from 30 to 40 percent of the population, much of it concentrated in the rural areas, where about 55 percent of the people live. In Cairo, perhaps 20 percent are truly poor; the vast majority of people are of modest means and must rely on free social services and education to improve their lot in life.

But their options are severely restricted. For example, on the basis of their grade on the *thanawiyya 'amma,* a single national test given at the end of secondary school, young people are assigned a profession, such as physician, accountant, tour guide, and so on. High scorers have the right to choose a "lesser" profession than the one they qualify for, but they normally don't, because of the social stigma attached. Nor do they have the option of taking a year off to think about career choices. Young people entitled to go on to higher education are assigned to a university, which often involves a two-hour daily commute in each direction (and studying is nearly impossible on the overcrowded buses or trains).

None of these problems exist, of course, for the tiny minority of people who have money. The influence of wealth only begins at school; it extends to the upper echelons in all walks of life, a fact that has provoked widespread concern. In particular, the unfairness of the yawning gulf between the haves and the have-nots has engendered the outrage that has led Islamic militants to pursue their restrictive interpretation of religious law. But in conversations with militants from both modest and privileged backgrounds, I have heard a common theme: many militants would relinquish their arms if the laws already in existence were applied fairly and equally.

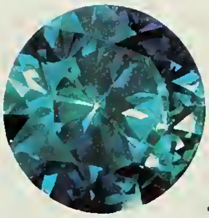
A comparison to the U.S. youth movement of the late 1960s and early 1970s—when, similarly, super-size cohorts of impatient, idealistic young people felt largely left out of the political process—is tempting. No, Egyptian youth are not staging sit-ins and crashing the gates of the political arena. But the reason they aren't may have more to do with the class barrier and the skewed demographics of sitting politicians than any lack of political will. A substantial number of Egyptian ministers are more than sixty-five years old, belonging to an age group that makes up just 2.2 percent of the population. Most youths cannot visualize themselves in positions of power. What they hope for is that someone they trust, whether judge or religious leader or someone else in tune with their needs, will demand and achieve for them the fairness that, in principle, the law asserts.

Although the government seems little moved by the youth crisis, there are promising signs of reform through the youth committee of the ruling National Democratic Party (NDP). The committee's head, Mohamed M. Kamal, is especially encouraged that though nearly 70 percent of the population is under thirty, qualified people are finding work in the private sector.

Leading citizens have also initiated projects not only through Islamic institutions but also through governmental and nongovernmental organizations (NGOs), and many of these reform efforts target the young. Approximately 16,000 NGOs now respond to the needs of civil society in Egypt. "We have proven as Egyptians, as Arabs, as Muslims that we can be very successful," asserts Hesham Dinana, a hard-driving thirty-nine-year-old engineer overseeing construction of a new children's cancer hospital in Cairo (it is dubbed Hospital 57357, after the number of the bank account that takes donations). Hesham spent more than a dozen years climbing the corporate ladder in the U. S. before returning to Egypt to contribute to this "people's project." With donations from across the classes, the cancer hospital, probably the largest NGO in Egypt, is proof that the Egyptian people are willing to share the burden to reduce the epidemic of childhood cancers.

Many young people do express hope for the future. Perhaps the most unusual source of optimism for the young is the media. Egyptian national television, long dominated by the monotonous recitation of news briefs and a parade of sleepy soap operas, faces a challenge in attracting the youth, who have turned to the satellite channel al-Jazeera, based in Qatar. Hussein 'Abd el-Ghani, Bureau Chief of al-Jazeera's Cairo office, boasts that the satellite channel "is the first reliable source of news for the young," and it is now the most-watched station among the youth of Egypt, according to the results of a recent survey. Young people told me they like its edgy style, its fast pace, and its no-sacred-cows approach to topics and people. Not only advertisers should be pleased by the numbers, because it's getting young people to think about politics, talk openly and critically about national and international events, and realize they deserve a place in shaping their nation's future. Although provocative for the region, al-Jazeera helps release some of the frustration felt by Egyptian youth. And it affirms their identity as young, strong, and Arab. □

Professor, left, teaches a class at the Women's Medical Faculty of Cairo's al-Azhar University. Because such state-run facilities generally face a shortage of modern laboratory equipment, instruction emphasizes lectures and demonstrations instead of hands-on learning.



A Birthstone for Earth

The oldest terrestrial material is a crystal of zircon, the sometime diamond substitute that can be a geologist's best friend.

By Edmond A. Mathez

With a wave, we bade good-bye to our helicopter and watched as it disappeared over the horizon. In the sudden stillness, the seven of us stood at the edge of Greenland's ice cap, in a remote corner of the world, cut off from the rest of humanity by many miles of impassable lakes, glaciers, and fjords.

Perhaps some people would be unnerved by the isolation, the stark surroundings, the cold wind blowing off the ice cap, and the prospect of living in tents in unpredictable weather. But we seven geologists were a happy crew. Some of us had been friends for years; others were new to the area and the people. But all of us shared the excitement of at last reaching this remote place. We had come to Greenland in search of the oldest rocks known to have originally formed on Earth's surface, deposited some 3.8 billion years ago. And now we shared a sense of anticipation that on this trip we might get lucky enough to satisfy our curiosity about conditions on Earth long ago.

The rocks we sought are embedded in a bow-shaped band known as the Isua supracrustal belt. The band runs about twenty-five miles long and a few miles wide, inland from and high above the spectacular fjords of southwestern Greenland. Originally the rocks of the Isua belt were mostly lavas between which were sandwiched a few sedimentary beds. In the billions of years since their deposition, they have been buried as deep as twelve miles, heated to temperatures as high as 1,000 degrees Fahrenheit, simmered in chemically reactive fluids, folded, and faulted. What's more, the process has taken place not once, but three times.

That tortured history, all part of what is commonly called metamorphism, has resulted in the creation of a completely new set of minerals made from the chemical components of the original ones. Stresses acting on the rocks caused the newly formed minerals to realign, completely destroying the original layering. The original rocks changed composition as they reacted deep in the Earth with passing fluids. After such a beating, it is the rare rock that is recognizable in the field, even to the most expert eye, as having once been a lava or a sediment at all.

Given the destruction of the original evidence, what basis do geologists have for claiming that the Isua belt is 3.8 billion years old, or that the rocks have been metamorphosed multiple times? The evidence, in part, is zircon. Zircon? The mineral best known as a jeweler's low-budget substitute for diamonds and other precious stones? But zircon turns out to be so durable in nature that, for students of the ancient Earth, it too is a symbol of "forever."

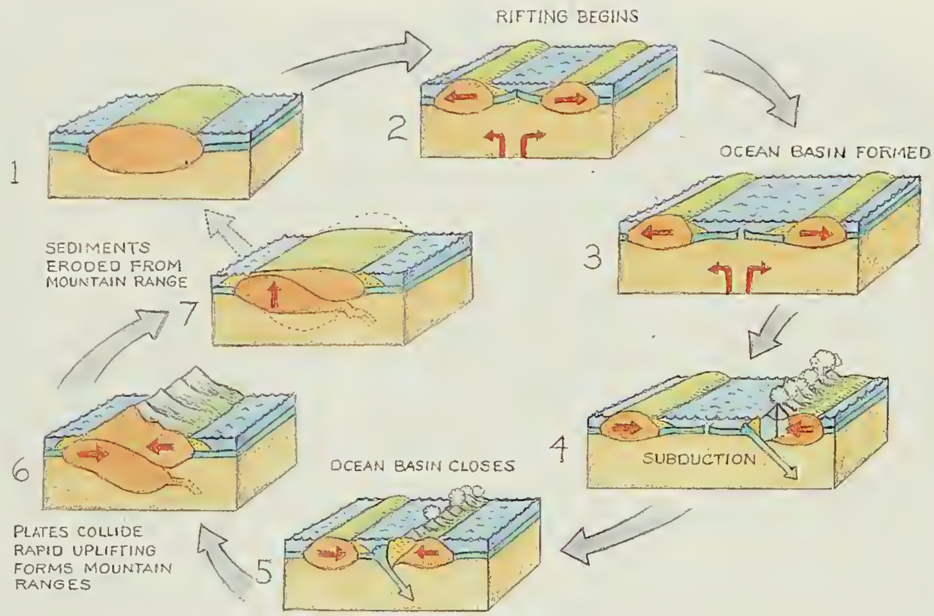
The name "zircon" comes from the Arabic *zarqūn,* which itself comes from two Persian words meaning "gold color"; thanks to trace quantities of iron, most zircon crystals are yellowish brown or gold in hue. (Most of the zircon used for jewelry is heated to render the crystals pale blue.) The ideal chemical formula is $ZrSiO_4$, or zirconium silicate. Zircon occurs widely in rocks—particularly granites, which are rocks comprised mainly of the minerals quartz and feldspar and which make up a large portion of the continental crust. But zircon is rarely present in large quantities in any one rock, making it what geologists call an

Rock constituting Greenland's Isua supracrustal belt was originally made up of lava sandwiched among a few sedimentary beds. After deep burial, chemical change, and uplift, the rock was substantially altered. But minuscule crystals of zircon, embedded in the rock, resisted the changes and so can help geologists reconstruct the process. A 208-carat zircon gemstone is pictured at the upper left of the opposite page.

accessory mineral: a mineral present in such meager quantities that geologists usually pay it little heed. But zircon has some important properties that together conspire to rescue it from obscurity and make it one of the most important tools geologists have for studying the long distant past.

Zircon's first important property is its resistance to weathering. It measures 7.5 on the Mohs hardness scale. By comparison, talc, the softest known mineral, has a hardness of 1; diamond, the hardest known mineral, rates a 10; and in between are materials such as glass (5.5) and the hardened steel used in making files (6.5). To appreciate the importance of that property, suppose a zircon crystal, one-ten-thousandth of an inch long, forms in a chunk of granite that has solidified twelve miles below Earth's surface. With time, the granite happens to be uplifted to the surface, perhaps even pushed high into a mountain range at the edges of two colliding tectonic places. Once exposed to air and water, though, the granite erodes, but the zircon within it usually survives. As the mountains gradually wear away, the zircon is washed down mountain streams and becomes part of the sediment accumulating in river beds or deltas, or along a coastline.

The second important property of zircon is that it resists chemical attack. As sandy sediment builds up, any zircon crystals in it are buried, and the sediment is compressed into brittle sedimentary rock. With deep burial, the rock is cooked by heat and



Episodes of mountain building commonly follow the so-called Wilson cycle. Continental crust (1) begins to rift under pressure from the mantle (2). The rifting splits the continent, and the upwelling magma creates an ocean basin (3). Eventually, the ocean basis begins to close again, forcing the denser oceanic lithosphere to subduct, or slide under, the more buoyant continental crust. The subducting lithosphere and overlying mantle partially melt, and the molten rocks punch upward through the overlying continental crust to create a chain of volcanoes (4), such as those found in the Andes of South America and the Cascades of North America. The ocean basin continues to close (5) until the two converging continents collide (6). Such collisions force rock upward along the continental-plate boundaries, creating massive, nonvolcanic mountain chains, such as the Himalaya. As the new mountains erode and shed their sediment into flanking basins (7), buried rock, no longer so weighed down, rises to the surface. The process begins anew when the continent is split apart by slow but unceasing motions of the underlying mantle.

pressure into a hard, crystalline, metamorphic rock. Indeed, the rock may partially melt if the temperature is high enough. In any case, at least part, and possibly all, of the original zircon grains, because of their chemical durability, usually survive.

The next stage in the process is critical to geologists' fascination with zircons today. At some point in the metamorphic process, a coating—a slow-growing rind that geologists call a rim—commonly grows around the original crystal. The new metamorphic rock, therefore, contains a zircon crystal with both a core that is older than the rock itself and a zircon overgrowth that formed at the same time as the new rock formed. It is not hard to imagine what happens when the new metamorphic rock is exposed at the surface by uplift and then becomes eroded. That same zircon crystal, with its old core and younger rim, may again rise into jagged mountains, and again get washed away as those mountains erode. Continuing to retrace its earlier history, the zircon may then become incorporated into sediment and, once more, find itself deeply buried in even younger metamorphic rock, and accreting a second, younger overgrowth.

The conclusion of the story is simple yet jawdropping. Each overgrowth is analogous to a tree ring—except that instead of recording annual episodes of growth, the rims on zircon crystals record multiple geologic cycles. Each cycle begins with uplift and mountain-building, continues with the erosion of towering mountain ranges, and concludes with the burial of the erosion-derived sediments as the mountains wear down to plains, setting the stage for the cycle to begin again. And each cycle commonly lasts hundreds of millions of years.

The fact that such cycles exist—let alone that they are recorded by such tiny, seemingly innocuous, crystals—may sound incredible, and so a brief digression is in order. The mountain-building stages of these cycles, as I suggested earlier, result from plate tectonics, the primary force shaping the surface of our planet. Like an egg, Earth possesses a relatively rigid outer shell, known as the lithosphere. Driven by the slow but inexorable convective motion of hot rock in the mantle below, the lithosphere breaks into plates that constantly move away from, collide with, and grind against each other. In the process the plates are continually destroyed and reformed. The lithospheric plates themselves are about sixty miles thick, and the lighter rock that makes up the continents, typically twenty-five miles thick, floats on top of them.

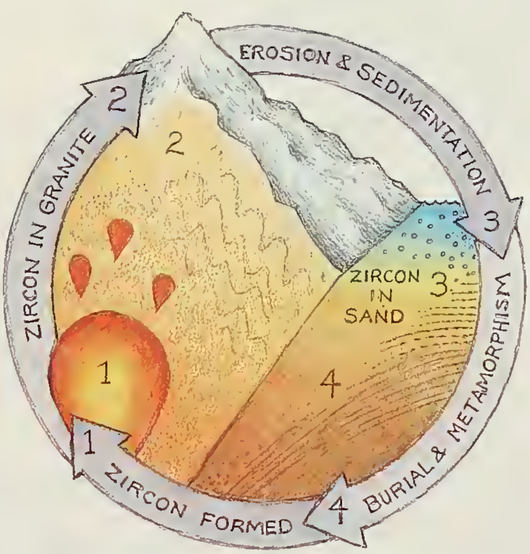
As the continental masses are carried about on the surface by the motion of the underlying plates, those masses, too, are continually crunching together and combining into large "supercontinents," then separating into smaller continents, and eventually recombining in some new arrangement. Great rifts open up where continents pull apart, and eventually seawater pours in to fill the rift; a good example is the Red Sea. Mountains rise along the margins of continents as material is squeezed upward where the plates collide. The Himalaya, for instance, are still rising at local rates of nearly half an inch a year as the Indian subcontinent grinds its way northward into Asia.

Rapid uplift is generally accompanied by rapid erosion, as well as the formation of flanking sedimentary basins. There the eroded material, including zircon, accumulates. When the converging plate motion ceases, the mountains stop growing, and erosion eventually wears them down. The Alps are an active mountain belt today that was created by a collision between the Eurasian and African plates. The Appalachians were once much like the Alps. Should the Atlantic Ocean begin to close in a hundred million years or so, the Appalachians will again become an active, growing mountain chain, and the deep, basement rock that supports them will be uplifted and exposed to the surface. The cycle is destined to continue.

This story of dynamic but cyclic change would be nothing more than empty hypothesis if rocks left no record of their ages. But zircon has a third important property that satisfies the need for evidence: it can accommodate atoms of certain radioactive elements into its crystalline structure, and those elements can act as long-running clocks from which the age of the zircon can be read. The most important of those elements is uranium, which readily substitutes for zirconium in the crystal structure because the ions of both elements have the same charge (+4) and roughly the same size. The radioactive uranium locked up in the zircon decays to lead at a fixed rate. By measuring the relative abundance of those two elements in the zircon today, one can determine how long ago it formed.

Perhaps unsurprisingly, the reality of dating a zircon is less simple than the foregoing explanation might suggest. One complication is that when zircon is heated during burial, some of the lead that had accumulated from radioactive decay can diffuse out of the crystal. The loss of that lead changes the ratio of lead to uranium, and so the new ratio, if measured, would give a spurious age.

Fortunately, there is a way around that problem. To date zircon geologists rely on two isotopes of uranium. The isotope uranium-238, with a half-life of 4.468 billion years, decays to lead-206, while uranium-235, with a half-life of 703.8 million years, decays to lead-207. (The half-life is the time it takes for half the original "parent" isotope—uranium, in this case—to decay to the "daughter" isotope—lead. In one half-life, half the parent isotope remains; in two half-lives, a half of a half, or one quarter, remains; and so on. Age is calculated by measuring the amounts of parent and daughter isotopes present.) Thus in zircon, two different clocks are ticking away at different rates, and comparing the ages measured from both clocks is a cross-check on each of them. If the two ages are mutually consistent, the dating is probably accurate; if they are not, the zircon has lost or gained uranium or lead some time since its formation, and so neither date can be trusted.



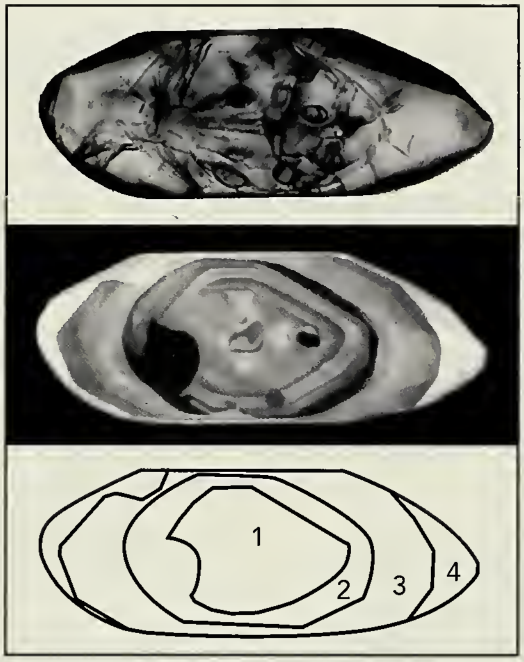
Zircon follows its own cycle, closely intertwined with the Wilson cycle. A zircon grain may first form in solidifying molten rock (1), such as granite. When the granitic body, with its enclosed zircon, is uplifted and exposed at the surface (2), erosion and deposition lead to zircon-bearing sedimentary rocks (3), which are buried and "cooked" into metamorphic rock (4). More zircon precipitates onto the existing crystals (1), and the process begins again.

A second complication for dating zircon is that analyzing isotope ratios only in a zircon overgrowth or only in a core is not so easy. The reason is that those features are usually just a few ten-thousandths of an inch across, and the layers of overgrowth are not always visible in cross section, even under a high-power microscope. Yet to get an accurate picture of the history of a zircon, distinguishing one region from another is critical. Analyzing a zircon made up partly of material from the 3.5-billion-year-old core and partly from the billion-year-old overgrowth would give a meaningless age.

Fortunately, there are now a few techniques, fairly simple (at least in principle), for imaging the different growth zones of zircon. One is to view the mineral in cathodoluminescence [*see photomicrograph on next page*]. When the zircon is bombarded by high-energy electrons, it emits visible light. Because of subtle variations in the zircon's composition, the brightness of the emitted light is not uniform, thus revealing the zircon's core and its growth zones in a photomicrograph.

To determine the concentrations of the uranium and lead isotopes in microscopic regions in the zircon, geologists rely on a technique known as secondary ion mass spectrometry. An instrument known as an ion probe bombards the polished surface of a zircon with a beam of narrowly focused high-energy oxygen ions. The ions erode the surface, a process that creates a shallow pit and causes secondary ions to emanate from the zircon.

The secondary ions are accelerated off the sample by an electric field and directed into a mass spectrometer, an instrument that collects, sorts, and counts the ejected ions according to their masses. The instrument's ability to precisely analyze and date specific, identifiable microscopic regions of a crystal is what makes zircon dating such a powerful geologic tool.



Photomicrograph of zircon crystal (top) is not particularly informative for a geologist hoping to date a rock that contains such a crystal. But if the crystal is bombarded with electrons, it emits light known as cathodoluminescence, revealing a layered internal structure (middle photomicrograph and lower diagram). Each layer is like a tree ring, representing one cycle in the process of deposition of zirconium silicate around an original seed crystal. Once the layer boundaries have been determined, geologists can sample and date each one. For the layers shown here, zones 1 and 2 are both 3.7 billion years old (zone 2 looks different because of corrosion); zone 3 is 3.6 billion years old; and zone 4 is 2.6 billion years old.

Our team had come to Greenland to explore Isua further and to seek more precise information than had been available before about the age of the belt. Our long-term ambitions were to read those ancient rocks closely enough to gain an understanding of the conditions on the surface of the early Earth and how and when the first continental crust was formed. Long ago, in our planet's earliest days, it became differentiated into distinct layers: a dense, metallic core, a silicate mantle, a less dense silicate crust, a water ocean, and an atmosphere. That differentiation remains one of the most significant events in the planet's history. The resulting architecture determined much of Earth's later development, and is one of the reasons we human beings and other animal life emerged here.

The ancient lineage of the rocks in the Isua belt makes them crucial in developing a picture of Earth's early history. Fortunately, zircons occur in many old crustal rocks, and the distribution of their ages suggests that only small bits of incipient crust existed at the time the Isua rocks formed, and that the crust grew rapidly thereafter. Hints about the extent and timing of the differentiation of the crust from the mantle can be coaxed from the detailed geochemistry of Isua lavas. But to make sense of the geochemistry, geologists need to become more certain about the age of the rock.

More accurate dating of the Isua belt may help fill in more than just the geological history of Earth; it can also give a better sense of when life originated. Direct evidence indicates that life was present on the planet at least 2.7 billion years ago and possibly as long ago as 3.5 billion years (though the fossil evidence for the earlier date is controversial). But certain Isua rocks indirectly suggest that life existed before then.

The evidence comes from yet another isotopic ratio. Carbon, which is a major part of all living tissue, occurs naturally in two stable isotopes, carbon-12 and carbon-13. And carbon incorporated in living tissue by photosynthesis presents an exception to a general rule of chemistry: that two isotopes of the same element are chemically indistinguishable. In fact, atoms of carbon-12 and carbon-13 bond with slightly different strengths to other elements. Photosynthesis creates a characteristic ratio of carbon-12 to carbon-13 in the organic carbon molecules it produces; the ratio differs from the ratio that occurs in inorganic sources of carbon. Hence if a rock contains carbon at all, a geologist will often measure the ratio of carbon-12 to carbon-13 to determine whether the source of the carbon is organic or inorganic.

The Isua rocks, it turns out, contain carbon, apparently mostly in the form of graphite, which is a pure form of the element. The ratio of the two carbon isotopes in the graphite suggests that the carbon came from an organic source rather than from, say, the ocean or the deep Earth. But we have learned from experience that nothing about the Isua rocks can be taken for granted. The same metamorphic processes that changed the rocks may also have changed the ratios of the two carbon isotopes.

Still, the carbon-isotope data are the only evidence so far for the possibility of life during Isua time. Fragile as the evidence is, geologists are keen to know as precisely as possible when that time was.

Dating the Isua belt is not simple, though, and we do not know the ages of all its rocks as precisely as we'd like. The belt rests on a substrate of metamorphic rocks of different ages. Those rocks contain zircons and so are readily dated, but the zircons indicate that the substrate rocks are younger than the Isua rocks (which, according to uranium-lead dating methods, first metamorphosed roughly 3.8 billion years ago). That inversion of the principle of stratigraphic dating—that older rocks should be below younger ones—implies that a fault separates the Isua belt from the underlying metamorphic rocks, and so the latter say nothing about the belt's age. Another problem is that the Isua belt appears to be made up of at least two, possibly unrelated successions of rock layers that were brought into contact by movement along faults.

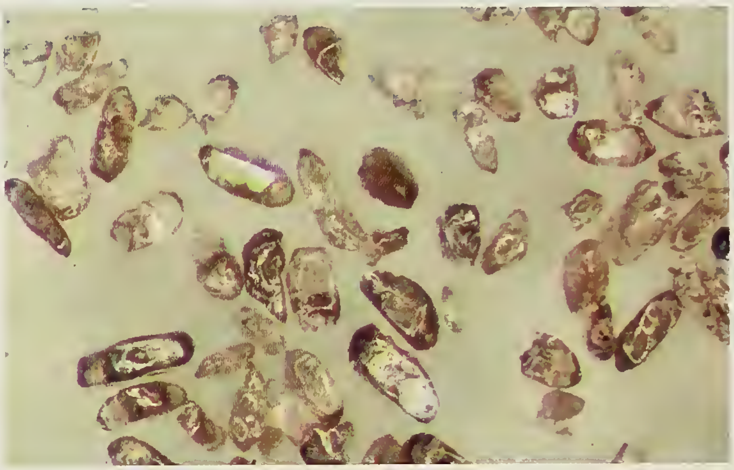
The most clear-cut way of dating such complex rock sequences is to find either zircon-bearing ash layers, formed during volcanic eruptions, or structures known as dikes, where magma intruded along a crack in the rocks. Ash layers are generally interleaved with beds of lava and sediment, and so a rock that contains such a layer was formed at approximately the time of the ash deposition. A granite dike, on the other hand, can give only a minimum age for the rock that the dike cuts across. (After all, the granite magma must have had something to intrude into.) The Isua rocks have been so severely modified that it is almost impossible to tell if a particular unit was an ash layer or a dike that just happens to run parallel to the other beds. Some dikes and possible ash layers have been found in the Isua belt, and they are the main source of current chronological knowledge. But in some parts of the belt these features are rare, so our team in Greenland was looking for previously unnoticed dikes and ash layers that could be dated.

Our expedition to Greenland was a fine adventure and, incrementally, a scientific success. We did find more old dikes, and returned to warmer climes with more zircon-bearing rocks.

When we began our expedition, all of us knew that the Isua rocks are by no means the oldest known rocks on Earth, let alone the oldest terrestrial material. The oldest rock discovered so far is from the so-called Acasta gneiss, a body made up of a variety of granitic rocks of various ages, located in Canada's Northwest Territories. The oldest rock in the Acasta gneiss, based on the age of its zircon crystals, solidified slightly more than 4 billion years ago.

It probably won't come as a surprise that the oldest known terrestrial material is a zircon. The crystal in question is a fragment just a few thousandths of an inch across. It and many other old zircons come from metamorphosed sediments deposited in river deltas some 3 billion years ago in what is now southwestern Australia. The rocks contain a variety of old zircons, and several percent of them are older than 3.9 billion years. At the corner of one of these crystals was the record-setting fragment, aged 4.404 billion years. Earth itself had formed less than 150 million years earlier.

The oldest zircons offer tantalizing hints about the state of that early Earth. The ratios of oxygen isotopes in some of the zircons are unlike the ratios in the mantle but similar to those occurring in con-



Zircon crystals, here magnified 100 diameters, are typically a few thousandths of an inch long.

tinental crust that formed in the presence of water. That finding has led to speculations that the zircons formed in magmas derived from continental crust, and that water was somewhere present. Water is essential for life, and so in principle life could have begun on Earth earlier than 3.8 billion years ago.

But the period from the birth of the Earth, 4.6 billion years ago, until 3.8 billion years ago was a violent time, richly deserving its name, the Hadean era (from "Hades"). At that time our planet was constantly bombarded by meteors. Perhaps the bombardment accounts for the absence of rocks older than about 4 billion years. Little from the Hadean other than zircons—hard, chemically durable, subject to growth, and datable—has survived for us to behold with wonder; they are our main windows into that distant era. □

John James Audubon (1785–1851) is best known, of course, for his exhaustively documented, life-size renderings of North American birds. But Audubon recorded his meticulous observations in notes and journals as well as in his art. His writings show in vivid detail that, less than 200 years ago, the American wilderness was inescapable fact, and that Audubon was very much a man of his times: frontiersman, husband, father of two boys, and, yes, hunter of birds.

In 1811 he became the proprietor of a general store in Henderson, Kentucky, and began to conceive the plan for the paintings that would become his life's work. The time seems almost as distant now as the America that Shakespeare's Miranda, in The Tempest, *called a "brave new world." In his new book,* Under a Wild Sky, *William Souder helps us re-imagine the setting, blissfully pastoral yet at times overwhelmingly violent. Most of the images that accompany this article are reproductions of paintings by Audubon, depicting some of the birds Souder mentions in the text.* —THE EDITORS

Audubon in Kentucky

The young painter and ornithophile conceived his life's work in a country so rich in birds that their flocks blackened the sky.

By William Souder

Once, as John James Audubon stalked the woods of Kentucky, he found a very young turkey cock separated from its brood-mates, and brought it home. The bird became tame and popular with the people of Henderson, following anyone who spoke to it. The turkey grew large, but refused to commune with Audubon's domestic turkeys. Every evening it could be seen silhouetted against the sky on the ridgetop of the Audubon house, the only place it would deign to roost.

Occasionally, the bird would retreat to the forest. During one of its disappearances Audubon was out hunting, and happened on the animal. He would have shot it had his dog not recognized the bird, which remained unperturbed while the two hunters, man and dog, walked up to it. His wife, Lucy, later tied a red ribbon around the bird's neck to alert local hunters that it was not a member of the wild flock. Nevertheless, it was eventually killed by a hunter who didn't see the ribbon until he picked up the dead bird. The man apologetically brought the turkey to Audubon, who probably ate it.

Audubon's determination, however vaguely formed in 1811, to survey the natural history of American birds was apparent in the attention he paid to the behavior and traits of every species he encountered. He thought goldfinches and purple finches among the smartest birds. Somehow they had learned a trick for escaping from "bird lime," a sticky substance commonly used to capture small birds. When a goldfinch landed on a twig Audubon had coated with bird lime, he saw that the bird recognized its predicament at once. Instead of struggling, the bird pressed its wings against its body and fell backward, causing itself to hang upside down. Gradually the glue began to give, stretching into a long strand, like the filament of a spider's web, until the goldfinch realized it was about to break. Then, with a flap of its wings, the bird flew off.

Another of Audubon's favorites was the American white pelican, which congregated around Henderson in the fall. Audubon observed the pelicans in large flocks, sitting on low islands or swimming in the river shallows, often packed together so densely that he could kill several at a time with a single discharge of his gun. Although Audubon found all birds beautiful, he considered the white pelican unusually handsome, in part because of the bird's meticulous grooming habits. He was impressed at how different the bird was from its cousin, the brown pelican, in the way it fished.

Wild turkey, perhaps similar to the one Audubon once kept as a pet

The white pelican, he noted, never dives on its prey from the air; instead, it swims after the fish and sweeps them up by extending its neck and thrusting its head underwater.

Sometimes a flock hunted together in a well-choreographed effort. One Indian summer afternoon, as the sun lowered in the western sky, Audubon watched a flock of white pelicans lazing about on a sandbar in the Ohio River. Suddenly a commotion started up in a small bay a little way off, and the flock instantly went on alert. The birds waddled into the water, where the ungainliness of their land movements ceased, and they began to glide forward across the current in a surging mass, toward the place where a school of small fish had begun thrashing the surface. The fish, Audubon said, seemed at play. They made the water sparkle. As the pelicans approached, the splashing continued. The birds swam closer together and, nearing the shoal, spread out their wings so that they formed a solid wall pushing forward. Now the pelicans propelled themselves faster still, sending the fish fleeing ahead, into ever shallower water, herding the school toward its demise. When the fish were at last trapped against the shore, the pelicans moved in, heads lowering, and devoured them by the thousands.

Passenger pigeons in flocks could number in the billions, according to Audubon's personal observation. Hunting them to extinction seemed as likely as emptying the ocean by the spoonful.

Years later, when he was writing about North American birds, Audubon consulted his records for the behavioral traits and the descriptions of each species, sometimes in conjunction with an examination of more recently killed specimens.

But he relied on memory, too. However far he traveled from Kentucky, his days there in its lush forests went with him. He could recall how white a pelican appeared in the afternoon sun, and how cool he felt in the shade of a towering sycamore as he leaned against its smooth trunk. He took with him the feel of his gun pounding into his shoulder, its stock pressed against his cheek. He remembered how the stillness of a pallid dawn was split by the whistle of wings cutting through the air, sometimes like a gentle breeze, other times like the sound of silk tearing. Long after he left, Audubon could still hear the calls and songs that rang through the trees, mixing with the sounds of rivers and storms and horses. He could feel the pull of a swamp against his shins and call to mind the torment of mosquitoes and withering heat spells and terrible winters when life seemed to stop. Much of what Audubon saw and remembered now survives only in remnants, and some of it is gone.

In the fall of 1813, while traveling on horseback from Henderson to Louisville, Audubon saw a low smudge in the sky. It resembled a dark cloud at first, but it pulsed with movement at the edges and rapidly grew larger. He heard a rumble, and at once the smudge became a surging mass of dark points in the sky. A flock of passenger pigeons was flying directly toward him.

The passenger pigeon was a darkly beautiful, medium-size bird that looked like a slightly larger version of the rock dove—the bird better known today as the common city pigeon—only more richly colored. Its shoulders, back, and sleek, rounded head were slate blue. That coloration blended into a deep reddish brown on its chest. Seen at a glance, the bird looked purple.

Today, of course, the passenger pigeon is extinct [*see "The Face of Extinction," by Hanna Rose Shell, page 72*]. In its day, though, it was almost certainly one of the most abundant bird species that ever lived. From the moment European settlers arrived in North America, they were awestruck by the incredible numbers of "wild pigeons" that traveled in immense groups, ceaselessly traversing the continent in search of food. So huge were the flocks that they acted more like storm systems than assemblages of birds, and they moved with the speed and power of hurricanes.

The flock coming toward Audubon seemed to include a great many birds, even by passenger-pigeon standards. As he dismounted his horse, he began to count what at first seemed to be successions of discrete flocks. But he soon lost track, as the flocks merged into an endless, indistinguish-

Passenger pigeons (female, top, and male, above) became extinct in the wild in 1900.

able black column across the sky, stretching from horizon to horizon. Mounting his horse again and moving on, Audubon found the pigeon numbers increasing. Although it was midday, the sky darkened—as if, he later recalled, the sun had been eclipsed. Pigeon droppings fell like snow. The sound of rushing wings overhead lulled him into something like a trance.

He rode on, surprised that not a single bird landed or even strayed near the earth. Once he tried a rifle shot into the flock, which was far out of range of his fowling gun. To his amazement, he could not hit a single pigeon or even startle the flock with the gun's report. When he reached Louisville at the end of the day, the pigeons were still flying, their ranks undiminished. Near the Ohio River the pigeons descended, not alighting but merely flying low. Audubon found the riverbanks at Louisville "crowded with men and boys incessantly shooting." The entire population was "all in arms," he said, destroying pigeons by the "multitudes." When he went to bed that night the pigeons were still flying, the arc of the great flock spanning the sky. The next morning, they were still passing overhead. So it went for three consecutive days, with no pause as the birds streamed past. Nobody in Louisville could talk of anything else. Everyone ate pigeon meat all day. The air smelled of pigeons.

Some years after seeing the big flock in Kentucky, Audubon made a series of ingenious observations about passenger pigeons that probably constitute as good a description of the species as anyone will ever have. Audubon, who sometimes dissected birds and sketched their internal organs, determined that passenger pigeons completely digested their food in about twelve hours. He also learned that pigeons killed in New York were sometimes full of undigested rice. Because rice grew only as far north as the Carolinas, Audubon was able to make a rough calculation of the birds' sustained speed. To arrive in New York with rice still in their crops, he figured, the pigeons would have to maintain an average speed of about a mile a minute.

Audubon could now estimate how many birds might assemble into a "typical" flock. If you knew how fast they flew, he reasoned, you could figure the size of the flock. Imagine a column of passenger pigeons one mile wide—a modest premise, he said. Now assume the flock passes overhead in three hours: that, too, would be conservative. If the birds were flying at sixty miles an hour, the entire flock could be visualized as occupying a rectangular area a mile wide and three-times-sixty miles long: 180 square miles. Assuming a density of two birds per square yard, Audubon concluded that the number of birds in his 180-square-mile "layer" of pigeons was roughly 1.1 billion. If Audubon's estimates were even close to the truth, the big flock he observed to take three days passing over Kentucky might have numbered more than 25 billion birds.

The passenger pigeon seems to have been a force of nature that even the sometimes imaginative Audubon was unable to exaggerate. When a flock of passenger pigeons dropped out of the sky to feed, great havoc ensued. The birds denuded and destroyed large sections of forest, and when a flock's presence was discovered, people would travel from far away to harvest the birds by the thousands.

Once, near the Green River in Kentucky, Audubon happened upon such a killing field. It was in a stand of old forest, with little understory, where a flock of pigeons had come to roost each night after foraging in the area by day. Audubon arrived on the scene about two weeks after the birds' first appearance. He found a section of forest three miles wide and nearly forty miles long, littered with broken branches and limbs that had sheared off beneath the weight of the birds. Some trees as wide as two feet in diameter were broken off just above ground level.

Dispersed across this devastated landscape was a band of hunters and farmers armed with guns and long poles. Wagons were parked in lines, waiting to carry away the spoils of the imminent hunt; some of the farmers had brought their hogs to feast on freshly killed birds. As the afternoon wore on, debris was piled into pyres, to be set afire after dark. The piles were augmented with smudge pots filled with sulfur, and torches made from tarry pine knots.

The sun set and the sky went black. At last Audubon heard the cry: "Here they come!" With a deafening roar of wings, a torrent of pigeons poured into the forest, searching for places to alight. Soon what remained of the trees filled with birds. The flock was so thick they seemed to land on top of one another, their dark forms congealing into throbbing masses that rocked precariously above the earth until the limbs beneath them splintered, gave way, and came crashing down. Everything below was swept away, and the forest floor became carpeted with a tangle of fallen and crushed birds.

The fires and torches were lit. An evil light filled the woods. The air was acrid and thick with smoke; pigeons flew in all directions, passing and repassing through their own shadows. People flayed at the birds with poles, knocking them down by the hundreds. As men began firing into the flock, the chaos was so overwhelming that

American white pelican was one of the handsomest of birds, according to Audubon, not least because of its fastidious grooming habits.

Audubon could not even hear the reports of their guns. Appalled yet transfixed by the scene, he reminded himself that the populations of these birds could quadruple in a single breeding season.

In fact, Audubon thought it inconceivable that hunting—even the kind of slaughter he had witnessed at the Green River—could diminish the numbers of passenger pigeons. Only the continued clearing of the North American forest, he thought, could threaten this remarkable bird, which seemed to him a mobile but permanent part of the American landscape.

Populations of animals that go extinct typically shrink to very small numbers before vanishing, as isolated groups and then individuals are wiped out one by one. Usually the process is a natural one. A typical species persists about a million years on earth, and many more species have already gone extinct than exist today. But the passenger pigeon lived in huge numbers right up to the time it went very suddenly extinct. Ornithologists now think the species was adapted to survive and breed only in massive flocks of millions upon millions of individuals. Even when many remained, there were not enough.

Another American icon of Audubon's day, the Carolina parakeet—or parrot, as it was also known—met much the same fate. The Carolina parakeet was already in decline when Audubon began observing it in Kentucky, though its numbers were still so great in the early nineteenth century that the bird was seen in immense flocks across much of eastern North America. Yet, like the passenger pigeon, the Carolina parakeet would be gone in less than a century—disappearing in defiance of the usual precondition for extinction, which is rarity. The last time anyone saw a passenger pigeon in the wild was in 1900. The Carolina parakeet disappeared from the wild five years later. The very last individuals of both species died in zoos not long thereafter.

Carolina parakeet, a pest to farmers and an easy target for hunters, became extinct in the wild in 1905, a victim of the gun and the loss of its home.

Loss of habitat and a great continuing slaughter—by hunters seeking to supply a market hungry for the Carolina parakeet's extravagant feathers, and by farmers trying to save their crops from marauding flocks—devastated a magnificent species that many regarded as a pest. Audubon, whose published drawing of the Carolina parakeet was done from specimens he shot in Louisiana, wrote that these birds were fond of cockleburs, the small, spiny fruit that is found plentifully—perhaps, as a prickly Audubon noted, "much too plentifully"—across the eastern and southern parts of America.

The problem for the parakeet, Audubon said, was that it also loved nearly every kind of fruit and grain "indiscriminately." Corn was just about the only farm crop it wouldn't eat. A flock of Carolina parakeets—think of a roiling, deep-green ocean falling out of the sky—could lay waste to a large area of cropland. When feeding, the birds were oblivious to their surroundings and easily approached. Even after being shot at, they remained easy targets. Younger parakeets, Audubon reported, were "tolerable" table fare. But mainly the birds were shot just to get rid of them.

Carolina parakeets issued a sharp, screeching call—a "scream" to Audubon's ears—that was hard to abide at close range. Although they could be tamed by being repeatedly dunked in water—a lamentable practice with which Audubon was evidently familiar—they could not mimic human speech and never gave up their own call. To the man who made a pet of a turkey and became virtually the American patron saint of all things ornithological, Carolina parakeets were still "so disagreeable as to render them at best very indifferent companions." The bird was wild and destined to stay that way, but, like Audubon's recollections of his younger years in the backwoods, only as a memory. □

Adapted from Under a Wild Sky: John James Audubon and the Making of *The Birds of America, by William Souder, to be published in June by North Point Press, a division of Farrar, Straus and Giroux, LLC.*

REVIEW

Stephan Balkenhol, *Hybrids*, 1995

Brains and the Beast

Can the behaviorist's insistence on distinguishing animal from human cognition be reconciled with evolutionary continuity?

By Frans B.M. de Waal

If your dog drops a tennis ball in front of you and looks up at you with tail wagging, do you figure she *wants* to play? How naive! Who says dogs have desires and intentions? Her behavior is merely the product of reinforcement: she has been rewarded for it in the past.

Many scientists have grown up with the so-called law of effect, the idea that all behavior is conditioned by reward and punishment. This principle of learning was advocated by a dominant school of twentieth-century psychological thought known as American behaviorism. The school's founders, John B. Watson and B.F. Skinner, were happy to explain all conceivable behavior within the narrow confines of what Skinner called "operant conditioning." The mind, if such a thing even existed, remained a black box. In the early days, the behaviorists applied their doctrine in equal measure to people and other animals. Watson, for instance, to demonstrate the power of his methods, intentionally created a phobia for furry objects in a human baby. Initially "little Albert" was unafraid of a tame white rat. But after Watson paired each appearance of the rat with sharp noises right behind poor Albert's head, fear of rats was the inevitable outcome. Even human speech was thought to be the product of simple reinforcement learning.

> ***Do Animals Think?***
> *by Clive D.L. Wynne*
> *Princeton University Press, 2004; $26.95*
>
> ***Intelligence of Apes and Other Rational Beings***
> *by Duane M. Rumbaugh and David A. Washburn*
> *Yale University Press, 2003; $35.00*

The behaviorists' goal of unifying the science of behavior was a noble one—but alas, outside academia the masses resisted. They stubbornly refused to accept that their own behavior could be explained without considering thoughts, feelings, and intentions. Don't we all have mental lives, don't we look into the future, aren't we rational beings? Eventually, the behaviorists caved in and exempted the bipedal ape from their theory of everything.

That was the beginning of the problem for other animals. Once cog-

nitive complexity was admitted in people, the rest of the animal kingdom became the sole standard-bearer of behaviorism. Animals were expected to follow the law of effect to the letter, and anyone who thought differently was just being anthropomorphic. From a unified science, behaviorism had become a dichotomous one, with two separate languages: one for human behavior, another for animal behavior. Human rationality and superiority are not really the issue, however—one only needs to read the latest Darwin Awards to notice that our species can be less rational than advertised. The issue is the dividing line between us and the rest of nature.

Radical behaviorists adamantly insist on this line, and look across it with entirely different eyes than the ones they reserve for their fellow human beings. They speak about animals as "them" and compare "them" with "us," as Clive D. L. Wynne does at the beginning of *Do Animals Think?* ("What are animals—really? What should we make of them?"). Other behaviorists, however, intentionally blur the line. They apply the same well-tested behaviorist methodology to reconnect human and animal behavior, daring to mention the words "animal" and "cognition" in the same breath. They write books such as Duane M. Rumbaugh and David A. Washburn's *Intelligence of Apes and Other Rational Beings.*

Of the two, Wynne's book is by far the more readable. Wynne has a pleasant writing style and a knack for engaging the reader. He begins with the story of a mad animal-rights activist who threatened the lives of people on the Isle of Wight, where Wynne grew up. The man was convinced that animals are sentient beings, a certainty Wynne says he wishes he could share.

This story sets the tone of doubt and reserve that permeates the book. Wynne includes numerous insightful accounts of remarkable animal behavior, but he invariably concludes on a note of caution: one should not infer too much from these accounts. He is not so radical a behaviorist that he excludes all forms of reasoning by animals, but he takes greater pleasure in explaining what animals cannot do—monkeys fail to understand relations between cause and effect, apes can sign but lack the syntax that defines human language—than in describing what they *can* do. Capacities unique to a particular species, such as echolocation in bats, get Wynne's full admiration. But anything that seems to elevate other animals close to the lofty cognitive level of humankind he regards with utmost skepticism. He seems to take delight in animals, and possesses great knowledge about them, yet he prefers them at arm's length. The constant message is that animals are not people.

Fifty years ago a female macaque began washing sweet potatoes before eating them; now her entire group has picked up the practice.

That much is obvious. But it is equally true that people are animals. The dichotomy Wynne advocates is outdated, lending his book a pre-Darwinian flavor. Take the case of animal culture, currently one of the hottest areas in the study of animal behavior. The idea goes back to the pioneering work of Kinji Imanishi, who proposed in 1952 that if individuals learn from one another, their behavior may grow so different from behavior in other groups of the same species that they seem to have their own culture. Imanishi thus reduced the idea of culture to its most basic feature: the social rather than the genetic transmission of behavior.

Many examples of animal culture have been documented. The classic case emerged among wild macaques on Japan's Koshima Island. During their fieldwork with the monkeys there, investigators provisioned them with sweet potatoes, which a juvenile female named Imo soon began washing; she would bring her potatoes to a small river and clean them off before eating them. Imo's washing behavior spread first to her mother and then to her age peers, before affecting the rest of the group. Later Imo moved her operation to the shoreline, washing the potatoes in the ocean, and, again, the other monkeys followed.

Some psychologists have objected to this example, pointing out that it is uncertain whether the monkeys learned their skill by copying others or by discovering the behavior individually, without anyone's help. Wynne supports the second view. But instead of basing his opinion on the actual data published by a team of Japanese primatologists, who have worked on the problem for fifty years, he relies on the word of a skeptical Westerner who has never set foot on the island. This scientist, a specialist in rat behavior, suggested that potato washing spread because performers were selectively rewarded by the people who handed out the potatoes.

A few years ago I went to Koshima Island to verify the idea of selective rewarding. I talked with some of the people who had actually witnessed Imo cleaning her first spud. They told me that initially the monkeys were fed far away from any water, so there was no question of rewarding any washing behavior. Imo herself came up with the idea of transporting the potatoes to the river for cleaning. They also pointed out that one cannot feed a group of monkeys any way one wishes. The dominant males have to be fed first, the females second, and the little ones last; changing the order sparks bloodshed. Thus, except for Imo's mother, the monkeys that learned the behavior first, the juveniles, were the last to be rewarded. In fact, the only monkeys on the island that never learned potato washing were the adult males: precisely the best-rewarded group.

Wynne invariably favors interpretations that widen the assumed cognitive gap between human and animal. For example, he uncritically accepts the uniqueness claim *du jour:* that only human beings possess a theory of mind (ToM), or the cognitive ability to understand that others, too, have mental states such as thoughts and knowledge. Ironically—given Wynne's dismissal of an ape ToM—the concept got its start with a 1970s study of chimpanzees. A female showed she had grasped the intentions of others by, for example, selecting a key from among several tools if she saw a person struggling to open a locked door.

Evidence for a theory of mind in apes has gone through its ups and downs ever since. Some experiments have failed spectacularly, leading the proponents of one school of thought to contend that apes simply lack the capacity. Negative results are inconclusive, though: as the saying goes, absence of evidence is not evidence of absence. Furthermore, the performance of apes is often assessed by comparing it with that of children. Because the experimenter is invariably human, however, only the apes face a species barrier. When an ingenious experiment conducted at Emory University's Yerkes National Primate Research Center in Atlanta got around that problem, the evidence for an ape ToM was more positive: chimpanzees seemed to realize that if a member of their species had seen hidden food, this individual knew where the food was, as opposed to one who had not seen it. That finding threw the question of a ToM in nonhuman animals wide open again.

In an unexpected twist (because the debate has focused on humans versus apes), a capuchin monkey in a laboratory at Kyoto University in Japan recently passed a series of seeing-knowing tasks with flying colors. The least one can conclude is that it is premature to settle on ToM capabilities as the ultimate Rubicon.

In spite of Wynne's dismissal of an ape ToM, his book offers many insightful descriptions of animal behavior. A wonderful chapter on the role of messenger pigeons during the First World War includes a picture of the stuffed body of Cher Ami, a genuine war hero. The pigeon kept flying after its leg had been shot off, delivering its message and thus rescuing an entire battalion.

Rumbaugh and Washburn are considerably more open-minded about the mental accomplishments of animals than Wynne is. Their book celebrates Rumbaugh's lifetime of research on monkeys and apes. In fact, what fascinates me the most about *Intelligence of Apes and Other Rational Beings* is its historical overview of experimental work with primates, first with the Wisconsin General Testing Apparatus (WGTA) and later with joysticks and computers.

The WGTA was developed at the University of Wisconsin in the 1940s, and is still being used today. In this set-up, a primate subject in a cage faces an experimenter across a platform, on which differently shaped or colored stimuli are arrayed. Both experimenter and primate can reach the stimuli; the experimenter baits them with rewards, and the primate selects among them. I remember working with such an apparatus as a student, testing chimpanzees to see if they could discriminate shapes by touch alone. The task was so incredibly simple and repetitive that the apes invariably got tired of the whole thing five minutes into the testing. In fact, they got so bored that they performed worse than macaques tested on the same stimuli.

I mention this episode because test performance is often taken as a measure of intelligence, even though attention and motivation are equally important to the outcome. As a result, failure is open to interpretation. Rumbaugh and Washburn understand these points better than most scientists, and they are at pains to remind the reader how the questions one asks tend to constrain the answers one gets.

Indeed, some testing paradigms positively suppress the phenomena being tested. When Rumbaugh replaced the WGTA with an innovative testing setup in which the monkeys move a joystick to select stimuli on a computer screen, their performance improved dramatically. Rumbaugh's work on the connection between method and outcome should be required reading for anyone who attaches significance to negative evidence.

One learning paradigm discussed by Rumbaugh and Washburn has special interest. Some animals learn how to learn—that is, once they have mastered a particular task, they can more quickly learn future tasks that have the same design but rely on different stimuli. Trial-and-error learning cannot explain improved performance in reaction to new stimuli, hence the level of learning must be higher. But generalization across tasks is precisely what the founders of behaviorism thought animals could not do.


Stephan Balkenhol, *Man with Lions*, 1994

Rumbaugh and Washburn discuss many forms of advanced problem-solving, which they classify as "emergents." The term is slightly awkward, but the authors apply it to cases in which animals flexibly apply accumulated knowledge to new situations, resulting in an "emergent" solution. The classic example is the chimpanzee in a room with a few sticks and boxes in one corner and, for the first time in the chimp's experience, a banana hanging from the ceiling. The solution emerges as the old bits of previous knowledge combine until, as if a lightbulb suddenly goes on in the chimpanzee's head, he climbs on top of the boxes and reaches for the banana with a stick.

The two authors rightly speak of reasoning and rationality, and so adopt a terminology that is anathema to radical behaviorism. They discuss the behaviorist view at length but choose to deviate from it, stressing continuity between animal and human. For the reader, though, it is frustrating that they focus almost entirely on apes and other primates, without examining how the concept of emergents could apply equally well to other animals. Crows, dolphins, elephants, and parrots have been credited with creative problem-solving as well.

There will always be tension between those who view animals as only slightly more flexible than machines and those who see them as only slightly less rational than human beings. The views discussed in these two books are by no means as far apart as they could be; both, after all, come out of the same tradition of experimental psychology. Throw in a few naturalists and neuroscientists, and the debate gets even more complex. That said, however, the two books range widely enough across the spectrum of views to make a powerful case that there is still plenty to be discovered, and that human uniqueness is largely in the eye of the beholder.

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By Laurence A. Marschall

Rats: Observations on the History and Habitat of the City's Most Unwanted Inhabitants
by Robert Sullivan
Bloomsbury, 2004; $23.95

In his memorable 1998 book *The Meadowlands,* about the New Jersey wetlands just west of the Lincoln Tunnel, Robert Sullivan emerged as the Thoreau of blighted ecosystems. Traveling by canoe along oil-slicked bayous, Sullivan uncovered treasures of both natural and industrial history no passing commuter would have suspected.

Now Sullivan has crossed the Hudson River and relocated his eclectic wanderings to the back alleys of lower Manhattan, where the dumpsters of Chinese noodle joints, Irish pubs, and Salvadoran chicken takeouts are the real happening places for urban wildlife. Happening, that is, if you're a rat.

Rattus norvegicus: *urban success story*

"Four seasons spent among vermin" is how Sullivan describes his sojourn. His Walden Pond was Edens Alley, a narrow defile a few blocks from Wall Street. Equipped with both binoculars and a night-vision monocular, he arrived in the evenings after dark to watch the rats as they emerged to feed and, in the notebook he'd brought along, to wax lyrical about nature, civilization, and the meaning of life. A typical entry from his winter journal:

> 5:44—The rats retreat suddenly. The reason: three men enter the alley, though when I see the men I wonder which creature left the alley for which creature—sometimes it seems as if the rats' departure is a courtesy extended by the rats. . . . I think of all the rats that have crawled through this alley before, the history of this alley's previous inhabitants. Oh, to know—to really know—this pellicle of rat-infested ground.

Such deadpan effusiveness over creatures commonly regarded as loathsome may border on sick humor, but elegies to *Rattus norvegicus* make up only a small part of Sullivan's book. There are many stories about the ethology, natural history, and social importance of rats, and, overall, plenty of evidence that people and rats have a lot more in common than most people would like to admit.

Sullivan cites Martin W. Schein, for instance, the co-author of a 1953 paper on the eating habits of rats captured on Baltimore backstreets. Schein conducted laboratory studies using authentic garbage from the alleys where the rats were trapped. He learned that rats hate raw beets (I sympathize) and that scrambled eggs and macaroni and cheese are popular rat comfort foods, just as they are for human Baltimoreans. In Edens Alley, according to Sullivan, the rats also seem to like chicken pot pie.

In spite of some strong dislikes, though, rats are not picky eaters. By and large, they are omnivorous and highly adaptable—the same traits that make people so successful—and they show uncanny cleverness in finding food and avoiding peril. Ann Li, an epidemiologist with the New York City Department of Health, takes Sullivan on a rat-trapping expedition to Brooklyn, and tells him she thinks rats are "so underappreciated." Even the exterminators who show Sullivan how to outsmart the rodents express a grudging admiration for their prey.

As much as he shares the rodentophilia of his informants, Sullivan is unsparing when he recounts the misery rats cause. Sometimes they attack directly: in 1979 a large pack surrounded a woman on a street in downtown Manhattan. And of course they carry infectious diseases such as plague. Yet unless people find a way to steam-clean each crevice of the city every day, rats will continue to cohabit with us in uneasy harmony. "If you killed every rat in New York City," Ann Li remarks, "you would have created new housing for 60 million rats."

Running with Reindeer: Encounters in Russian Lapland
by Roger Took
Westview Press, 2004; $27.50

Few places in Europe are as far off the beaten track as the Kola Peninsula, a potato-shaped carbuncle of land at the top of the Scandinavian Peninsula, east of Finland. Russian Lapland, as the Kola is also known, has one large city (Murmansk), a few subsidiary industrial centers and mining towns, and a scattering of isolated villages in the hinterlands. One passable highway runs through the province. But beyond that right-of-way, for hundreds of kilometers in every direction, the hardy traveler encounters nothing but tundra, taiga (boreal forest), and vacant shoreline.

Roger Took is just such a hardy traveler—perhaps even a foolhardy one. When he arrived in the Russian northland in the early 1990s, the entire country was teetering on the edge of anarchy, and it was not clear which disaffected group a lone Englishman should be more afraid of: suspicious Sami tribesmen, the military attached to the remnants of the Russian Northern Fleet, or the legendary Russian Mafia. Just in case, Took offhandedly notes, he learned how to fire, strip, and reassemble a nine-millimeter semiautomatic pistol before he left London.

We never learn whether Took ever fired the pistol, but readers can be grateful that he survived, met many fascinating characters, and kept coming back, year after year, for more than a decade. The Kola, he discovered, is a land of contrasts and contradictions, shaped by history and politics as much as by geography. Its first inhabitants were nomadic Sami, who roamed freely through northern Scandinavia. In the Middle Ages, settlers called Pomors arrived from the more populated regions of Russia, to the south. A brisk fur trade with Europe developed be-

Sami School (Lapland): Everyday life of the Sami people, nineteenth century

cause the Kola Peninsula's best harbors, warmed by the northernmost hook of the Gulf Stream, are more or less ice-free throughout the year.

Only after the Russian Revolution did the area begin to take on its current look of emptiness. In a procrustean attempt to collectivize the Sami economy, Stalin had villagers herded into hastily built urban areas and industrial farms. Much of the coastline was declared off-limits. The discovery of rich mineral resources in the Khibiny mountain range, near the center of the peninsula, only made matters worse; soon "special settlers" were being shipped from various parts of the Soviet Union to provide forced labor.

For the most part, today's inhabitants huddle in charmless concrete apartment blocks, largely ignorant of the region's rich history and remarkable resources. Took, however, has grown to love the place. Armed with

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little more than a backpack and a fishing rod, he boldly wandered through military reservations, floated down rivers with salmon poachers, sledged to hunting and herding excursions with descendants of the Sami, and accompanied wildlife biologists and archaeologists on expeditions to the interior. In one memorable episode he hitched a ride through the backcountry on a clanking, tanklike all-terrain vehicle (minus the gun turret), accompanying a human-rights activist who was documenting a gulag of prison barracks.

Took reports signs of a new life for Russian Lapland. Environmentalists in Russia and Scandinavia have begun to throw their weight behind efforts to clean up the damage caused by the nuclear fleet. Shops in Murmansk now display the latest fashions. And foreign sportsmen have begun to discover that some of the world's greatest salmon streams run through the Kola's remote countryside. Russian Lapland may not come off as a vacation paradise, but Took's book is a marvelous introduction to a region of rich but almost forgotten heritage.

Sequoia: The Heralded Tree in American Art and Culture
by Lori Vermaas
Smithsonian Books, 2003; $39.95

Just as Lebanon is famous for its cedars, so North America is known for its redwoods. Not only are they among the largest and most stately trees on earth, but they thrive in settings of surpassing scenic beauty. Strolling beneath a towering canopy of *Sequoia sempervirens,* the most common redwood along the northern coast of California, one experiences a world of subtle twilight just a few steps from the glare of a sunlit, rocky shoreline. The rarer *Sequoiadendron giganteum,* whose ponderous trunks make their coastal cousins seem almost willowy, grow farther inland, in sheltered groves in Yosemite and other isolated valleys.

It is no wonder, then, that the giant sequoias have assumed symbolic importance far out of proportion to their restricted habitat. Lori Vermaas, a cultural historian, has written an insightful new survey of American art and literature on redwoods from the nineteenth and early twentieth centuries.

The most widespread early depictions of the giant trees, in the years during and just after the Civil War, were made by enterprising commercial artists who used twin lenses on their cameras to create so-called stereo-view cards. Many of the pictures focused on the immense scale of the trees; a favorite subject was the Grizzly Giant, a tree in Yosemite National Park whose trunk soared straight

Coastal redwood (Sequoia sempervirens)

skyward but whose upper branches seemed painfully gnarled, like the rheumatic joints of an old man.

To a nation still smarting from the horrible conflict between the states, the redwoods, far removed from the scene of battle, seemed serene, impassive, and impervious to harm. They epitomized the part of the nation that had remained intact and functional despite the fires of war and social turmoil. Huge paintings of sequoias by such landscape artists as Albert Bierstadt were all the rage (oversize landscape paintings being the functional equivalents of IMAX films).

Yet few envisioned the giant trees as symbols of an endangered environment. Toward the end of the nineteenth century, logging them was even seen as an example of humankind's ability to bend nature to its will. Woodsmen were "no puny impersonations of men," but men who swung "heavy, keen-edged axes as though they were mere trifles." Logging teams were typically photographed in the yawning notches of trees they were about to topple. In one particularly striking print, an entire troop of U.S. cavalrymen, mounted on horseback, stand like conquering gladiators atop and along the length of the trunk of a fallen giant.

Exuberantly expansive, the American imagination invoked sequoias as a natural treasure, but a treasure to be expropriated and spent. Even John Muir, one of the nation's first conservationists, waxed enthusiastic over the use of redwood lumber in construction. Redwood housing was "almost absolutely unperishable."

The onslaught of logging operations, among other abuses of the era, sparked the modern environmental movement, and redwoods came to be seen as treasures to preserve. Although groves of redwoods are continually threatened, the trees still stand, and pictorialists in the tradition of Ansel Adams have continued to use the image of the redwood as an emblem of strength and endurance. Vermaas helps us understand the symbolism of sequoias, but even she must admit that the best way to appreciate them is on foot and close-up. "No one has ever successfully painted or photographed a redwood tree," wrote John Steinbeck in 1962. "The feeling they produce is not transferable."

LAURENCE A. MARSCHALL, author of The Supernova Story, *is the 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.*

nature.net

Moving Mountains

By Robert Anderson

California's Santa Monica Mountains, where I live, are a mere 5 million years old. Like most mountains, they are comprised of rocks formed during complex and repeated sequences of uplift, sedimentation, and volcanism [*see "A Birthstone for Earth," by Edmond A. Mathez, page 40*]. In the case of the Santa Monica range, the process began about 200 million years ago, when the first dinosaurs were roaming the planet.

A summary of the processes that make mountains rise can be found at www.physicalgeography.net, a Web site created by Michael J. Pidwirny, a geographer at Okanagan University College in Kelowna, British Columbia. (On the home page click on "Fundamentals: Online Textbook" from the menu bar at the top; in "Chapter 10: Introduction to the Lithosphere," click on "Mountain Building.") For an overall view of how colliding tectonic plates transform the planet, go to "Dynamic Earth" (earth.leeds.ac.uk/dynamicearth), developed by Robert Butler, a geologist at the University of Leeds.

Illustrations of the way tectonics has changed the distribution of land and sea can also be found at a Web site run by Christopher R. Scotese, a geologist at the University of Texas at Arlington. For thirty years, Scotese and his collaborators have been working on a series of paleogeographic atlases. The latest of them, the Global Plate Tectonic Model, is available at "PALEOMAP Project" (www.scotese.com). From the home page you can choose 3-D movable paleoglobes and paleogeographic animations that show the positions of the continents and the shapes of the ocean basins for various periods of geological time. Select "Earth History" from the menu at the left on the home page. There you'll find full-color maps depicting details such as mountain ranges, shorelines, and active plate boundaries during those same periods—beginning with the breakup of the first supercontinent, Rodinia, and extending through the present and into the future for 250 million years, when the supercontinent Pangea Ultima will trap what is now the Atlantic Ocean in a small, inland basin.

Antonio Schettino, a geologist in Milan, Italy, worked with Scotese to re-create plate motions in the Mediterranean region (www.itis-molinari.mi.it/Intro-Med.html). The accompanying QuickTime animation provides an excellent graphic explanation of how the Alps arose. A similar presentation of tectonic processes shows the ancient mountain chains in greater regional detail (www4.nau.edu/geology). Click on "Popular Departmental Links" and look at the three items created by Ronald C. Blakey, a geologist at Northern Arizona University. The site www.jamestown-ri.info/northern_appalachians.htm provides a rundown of the northern Appalachian chain's geological history, which stretches back a billion years.

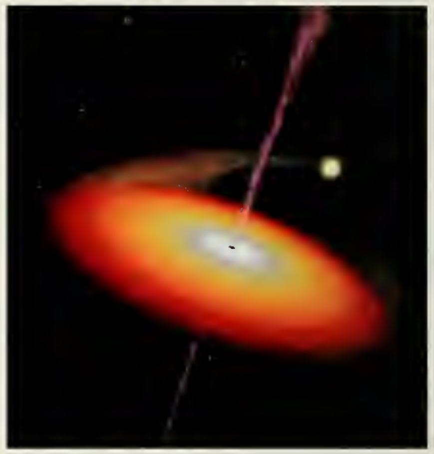
Geologists can now watch mountains grow, thanks to new satellite and radar technologies that measure minute movements of the Earth's crust and slight changes in the stresses that cause earthquakes. Go to the "Active Tectonics" site, run by a group from the University of California, Berkeley (www.seismo.berkeley.edu/~burgmann/EDUCATION/InSAR.html), for more information.

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

Too Many X Rays

In a sky visible only from outer space, astronomers may have found the first example of an intermediate-size black hole.

By Charles Liu



Artist's conception of proposed mechanics of an ultraluminous X-ray source (ULX). An intermediate-mass black hole (black dot at center of image) acts as a gravitational sink. Matter falls into the hole from the surrounding accretion disk, here exaggerated in size because of the angle of view. The star in the background supplies the matter that fuels the accretion disk at a rate of 10 trillion tons a second.

Astronomers possess X-ray vision, even though none of my colleagues, to my knowledge, hails from the planet Krypton. Telescopes designed to collect and focus X rays from space provide that vision. X rays are highly energetic—that's why they so readily penetrate matter—and so an X-ray telescope offers the chance to observe cosmic phenomena powerful enough to generate highly energetic radiation.

In the past four decades a succession of orbiting X-ray telescopes has opened up the high-energy X-ray window on the universe to eager astronomers. Today, two X-ray observatories shoulder most of the load: Chandra, run primarily by NASA; and XMM-Newton, managed by the European Space Agency.

Among the most puzzling denizens of the X-ray sky are the so-called ultraluminous X-ray sources, or ULXs. The objects generate so much X-ray flux that they seem to violate the laws of physics. They don't, of course—so what is it that supercharges their X-ray power? A recent study led by Luca Zampieri of the Astronomical Observatory in Padua, Italy, suggests an intriguing candidate: a black hole several hundred times the mass of the Sun that drags matter from an orbiting star and then converts that matter into energy.

Ordinary stars almost never emit many X rays. Another, more powerful mechanism is needed to generate that kind of high-energy radiation—gravity. When matter from an orbiting star falls toward a massive, compact object, such as a black hole whose mass is roughly the mass of a star, it doesn't fall directly onto the object's surface. Instead, the matter collects into a rotating disk of gas around the black hole, before it spirals downward into the hole, like water swirling into a bathtub drain.

The disk of swirling gas releases gravitational potential energy as it falls inward. That energy is dispersed into rapid, random motions of the particles that make up the gas, superheating the falling gas. As its temperature rises to millions of degrees, the gas glows like the filament inside an incandescent lightbulb—except that, unlike the filament, which emits visible light, the disk of gas emits mostly X rays.

Plausible as it may sound, that mechanism still has trouble accounting for the torrent of X rays from ULXs. The puzzle arises because an object powered by the accretion of matter can theoretically emit energy only up to the so-called Eddington limit, named for the English astrophysicist Arthur Eddington, who first studied the problem. An object whose energy output exceeds this limit would push away any infalling matter, cutting off the fuel supply that generates its luminosity in the first place. So its brightness, including its X-ray output, should top out at the Eddington limit.

The Eddington limit for any object is directly proportional to its mass; for a black hole the mass of a few solar masses, it's about 50,000 times the luminosity of the Sun. Imagine, then, the surprise in the 1980s when astronomers started to find X-ray sources with far greater luminosity than that. For such sources at the centers of distant galaxies, the X-ray emissions could be explained only by the existence of a supermassive black hole, millions or billions of times the mass of the Sun [*see "Peering at the Edge of Time," by Fulvio Melio, June 2003*]. But for objects on the outer fringes of galaxies—which presumably are star-size and not supermassive—these Eddington-busting ultraluminous sources have remained a mystery.

Zampieri and his colleagues have joined the discussion on the side of a recently proposed hypothesis. Some ULXs, they maintain, are not stellar-mass objects that exceed the Eddington luminosity. They are bright because they are much more massive than any typical star. Such a ULX would be powered by a black hole of intermediate size—perhaps a few hundred times the mass of the Sun, rather than millions or billions. The hypothetical model requires the companion star that supplies the infalling matter to be nearby.

Zampieri's group supports this model with their analysis of a ULX in the spiral galaxy NGC 1313. They combined data from the XMM-Newton telescope with data from past X-ray telescope observations to measure the X-ray luminosity of the ULX. Then, with data from Chandra, they determined the precise position of the X-ray source and matched that position with visible-light observations. Thus they identified a star that corresponds to the position of the ULX—thereby specifying the fuel source for the black hole. According to their calculations, the mass of the unseen black hole is between 100 and 700 times the mass of the Sun.

That result, if it stands up to scrutiny, would be tremendously exciting—and not just to X-ray astronomers. Intermediate-mass black holes have long escaped detection, and definitively confirming the existence of even one would be a major advance. But interpreting these data is tricky. Just because a visible star corresponds with the telescopic position of an X-ray source doesn't mean the two objects are truly associated. Nor can the observations rule out other proposed physical models for ULXs that do not require the presence of an intermediate-mass black hole. The X rays, for instance, could be generated by focused jets of matter shooting toward Earth, duping us into thinking the ULX is more luminous than it actually is. The jury on the real identity of the ULX, alas, is still out.

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

THE SKY IN MAY

By Joe Rao

Mercury reaches its greatest western elongation, 26 degrees from the Sun, on May 14. The planet nonetheless presents a crummy apparition this month for viewers at mid-northern latitudes, because it rises less than an hour before the Sun. The farther south you are, the better your chances of seeing Mercury.

Saturn, in the constellation Gemini, starts the month well up in the northwestern sky at dusk, and sets just after midnight. By month's end, however, it sets by around 10:30 P.M. local daylight time. Mars, much dimmer than the ringed planet, passes less than 2 degrees north of Saturn on the evening of the 24th.

Venus is the first "star" to appear at dusk, and by late twilight it is truly dazzling. On the 2nd Venus reaches its greatest brilliancy for this apparition: magnitude −4.5. The planet is so bright it can easily be seen with the naked eye in a deep-blue, haze-free afternoon sky. After nightfall at a very dark site, the planet's light can cast Venus-shadows. Venus begins the month more than 35 degrees above the western horizon at sunset and doesn't set for another three hours; by month's end, though, it plummets to a sunset altitude of less than 10 degrees and sets only an hour later. This month is an exciting time to follow Venus with a telescope; it's a beautiful crescent that grows bigger and (somewhat counterintuitively) thinner week after week.

Dim Mars is low in the west-northwestern sky at dusk and sets in the northwest between 11 P.M. and 11:30 P.M. local daylight time.

After Venus, Jupiter is the brightest starlike object in the sky, shining this month high in the south-southwest at dusk. It overpowers the first-magnitude star Regulus, 9 or 10 degrees to the planet's west. Examine the two after it gets dark enough to compare their colors: Regulus shines with a bluish hue, whereas Jupiter appears silvery white. The Moon can be found to the right of Jupiter on the 26th, and above and to the left of the planet the following night.

The Moon waxes full on the 4th at 4:33 P.M. There is a total lunar eclipse that day, not visible from North America, though part or all of the eclipse can be seen in Africa, Antarctica, most of Asia (including the Middle East), Europe, and South America. Our satellite wanes to last quarter on the 11th at 7:04 A.M. It becomes new on the 19th at 12:52 A.M. and waxes to first quarter on the 27th at 3:57 A.M.

In the first week of May, early risers might get a glimpse of Comet C/2002 T7 (LINEAR) just above the eastern horizon, about an hour before sunrise. Thereafter, the comet moves too far south for observers to see it from the northern hemisphere.

On the 5th, about an hour after sunset, Comet C/2001 Q4 (NEAT) should be hovering about 10 degrees to the left of Sirius, in the constellation Canis Major. (Your clenched fist, held at arm's length, spans roughly 10 degrees.) Look low in the southwest for blue white Sirius, the dog star; it's the brightest star in the night sky. On the following nights the comet climbs progressively higher in the southwestern sky and becomes correspondingly easier to see.

Both comets could reach first magnitude or brighter. But both also seem to be making their first approach to the vicinity of the Sun, and past experience has shown that "first timers" usually fall far short of brightness expectations.

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

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EXPLORER GUIDE

Museum Scientist Takes On Bugs of the Southern Hemisphere

LEADS TEAM AIMING TO STUDY 5,000 SPECIES OF PLANT-EATING BUGS

Bugs "down under" will take center stage in a new collaborative five-year project between scientists at the American Museum of Natural History and colleagues at other prominent research institutions. Funded by the National Science Foundation (NSF), the $3 million initiative will involve collecting and compiling global biodiversity information on plant-feeding insects of the family Miridae, with a focus on the Australian and South African species of these bugs. Randall T. Schuh, Curator and Chair of the Museum's Division of Invertebrate Zoology, is coleading the project with Gerry Cassis, head of the Centre for Biodiversity and Conservation Research at the Australian Museum. Teams of entomologists led by Drs. Schuh and Cassis will oversee this multipronged effort together with Thomas J. Henry of the U.S. Department of Agriculture's Systematic Entomology Laboratory and Michael D. Schwartz of Agriculture and Agri-Food Canada, also leading specialists on these insects.

Aurantiocoris cuneotinctus feeds on manzanita.

The project's goal is to create a world taxonomy and database for these bugs that feed by sucking the juices from host plants. Because the biodiversity of all life is generally better known in the Northern Hemisphere than in the Southern, this project will focus on the tremendous plant and insect biodiversity concentrated in the Southern Hemisphere, especially in Australia and South Africa.

"Australia's insect biota is virtually unknown to many entomologists outside that country," said Dr. Schuh. "To understand the world's insect biota, you have to understand Australia's insect biota. Prior to 1995, one might have concluded that Australia had a very limited fauna. But with the collecting that Dr. Cassis and I have done in the past seven years, we are finally getting a decent representation of these creatures. Now, with this grant project, the broad outlines of the Australian and Southern Hemisphere biota overall will be well known."

Dr. Cassis calls this project "the research opportunity of a lifetime," and believes it will make a spectacular contribution to the international understanding of biodiversity. "The Miridae, a family of sap-sucking insects, is one of the most diverse groups of life on the planet," he says. "These bugs—some barely bigger than a pinhead—were here before the dinosaurs, and have not only survived, but have flourished to the point where you find them everywhere."

AMNH

Randall Schuh in Central Australia, October 2001

Insects are estimated to comprise 75 percent of Earth's biodiversity at the species level. Plant bugs, including the Miridae, represent a tremendous amount of that biodiversity.

Data for the plant bugs project, which also involves scientists from Canada, Colombia, Germany, Russia, and the United States, will consist of about 550,000 specimens already in museums and another 100,000 specimens—mainly of the relatively unknown insect biota of Southern Hemisphere locations like Australia, Chile, South Africa, and parts of Asia—to be acquired through 15 to 20 field expeditions such as the 2002 Constantine S. Niarchos Expedition to Australia. The investigators plan to ramp up collection efforts extensively in these locations, as they have been poorly sampled in the past.

All told, the specimens studied will represent more than 5,000 species with nearly 25 percent of them to be described as new. (For comparison, most individual taxonomists are lucky to describe 30 new species in a year.) About 800 of the species collected will come from Australia, where there is a high degree of insect endemism, or insects that live only on this continent. The scientists also will note the species of plants on which each of the collected insects is found to create a database that indicates the host plants for each group of bugs.

Drs. Schuh and Cassis are renowned experts on plant bugs and have collaborated for several years in collecting and studying them. With this grant, they can increase their description and analytic efforts to an "industrial" scale, involving more than a dozen entomologists. Analysis of family-group relations among the greatly expanded inventory of species resulting from this project will involve use of the Museum's cluster supercomputer to search for the simplest family tree to describe all these bug species' evolutionary transitions from the tree's base to its farthest reaches. The supercomputer, one of the fastest in the world, is used Museum-wide to analyze complex arrays of biological data and arrive at the best tree formation among many possible trees that could describe the evolutionary relationships among groups of species.

AMNH

Gerry Cassis and Christiane Weirauch in South Africa's Western Cape Province, October 2003

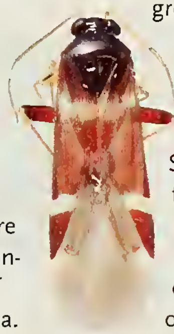
On the plant side, the project will double the number of known bug hosts to about 6,000, and boost the number of bug species with known hosts to more than 4,000. With this large body of information, theories of host association can be tested with the aim of understanding whether bugs have coevolved with their plant hosts, whether host affiliation is the result of ecological association, or whether the evolution of host associations is driven by chemicals in plants.

The project's goal is to create a world taxonomy and database for bugs that feed by sucking the juices from host plants.

AMNH

Gerry Cassis collecting plant bugs in South Africa's Western Cape Province, October 2003

Improved knowledge of these insects will be helpful in making decisions about where conservation actions might best be directed. The project will also allow scientists to test theories about biodiversity hotspots and theories of when insects radiated from place to place throughout Earth's history. Both these areas of study are helpful to efforts to conserve what remains of the world's insect biota.



Tuxedo elongatus feeds on oaks.

A major component of the research for the project will involve taxonomic and systematic biology training of Ph.D. candidates and postdoctoral fellows, an element of particular importance given the global decline in taxonomists and natural resource managers even at a time of rapid commercial development. The project results will be distributed through a searchable Web site featuring images, a complete taxonomic catalog, interactive mapping of distributions, and interactive identification keys and will eventually be made available to the public via a traveling museum exhibition.

The ambitious project brings many of the world's great natural history museums together to solve global biodiversity problems. Collaborators include the Smithsonian Institution, the Canadian National Insect Collection, and the Zoological Institute of the Russian Academy of Sciences, along with the American Museum of Natural History and the Australian Museum. The grant for the project was made under the NSF's Planetary Biodiversity Inventory initiative, the objectives of which include documenting all Earth's species.

INSECT PHOTOS BY S. THURSTON/AMNH

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY

D. FINNIN/AMNH

Sea of Clouds

EXHIBITIONS

Exploratorium/AMNH

Through August 15

This exhibition invites visitors to explore fundamental concepts and phenomena in the natural sciences. Fun, hands-on displays clustered around four themes—Earth processes, rotation, mirrors and illusion, and pendulums—encourage audiences of all ages and all levels to investigate and play.

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

Petra: Lost City of Stone

Through July 6

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

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

The Bedouin of Petra

Through July 6

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

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

The Butterfly Conservatory: Tropical Butterflies Alive in Winter

Through May 31

R. MICKENS/AMNH

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

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

Seasons of Life and Land: Arctic National Wildlife Refuge

Through September 6

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

Art for Heart

Through September 26

Paintings by children who lost loved ones in the attacks on New York City's World Trade Center on February 26, 1993, and September 11, 2001, create a powerful and poignant memorial.

Made possible by the Lower Manhattan Development Corporation.

LECTURES

Adventures in the Global Kitchen

Tuesday, 5/4, 7:00 p.m.

Culinary collaboration between Museum entomologist Lou Sorkin, Citarella's celebrated pastry chef Bill Yosses, and Gene Rurka of the Explorers Club.

The Beast in the Garden

Thursday, 5/13, 7:00 p.m.

David Baron's new book considers implications of wildlife protection laws: can humans learn to coexist with large predators that have been brought back to abundance?

Art/Sci Collision: An Evening with Ned Kahn

Tuesday, 5/18, 7:00 p.m.

At the intersection of science and art, Ned Kahn's work draws from a palette of natural phenomena.

S. HORENSTEIN

FIELD TRIP

Around Manhattan Island

Thursday, 5/25, 6:00 p.m.

A three-hour cruise with geologist Sidney Horenstein.

STARRY NIGHTS
Live Jazz

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

Houston Person Quartet

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

FAMILY AND CHILDREN'S PROGRAMS

Oceanophony
Saturday, 5/1, 1:00–2:00 p.m. or 3:00–4:00 p.m.
Join Bruce Adolphe and his PollyRhythm Players for a weird and wonderful musical voyage to the mysterious deep.

Earthly Adventures
Sunday, 5/2, 12:30–2:00 p.m. (Ages 4–5, each child with one adult) or 3:00–4:30 p.m. (Ages 6–7)
Explore earthquakes, tornadoes, and other forces of nature in this hands-on workshop.

Space Explorers: Transit of Venus
Tuesday, 5/11, 4:30–5:45 p.m. (Ages 10 and up)
On the second Tuesday of each month, kids can learn under the stars of the Hayden Planetarium Space Theater.

I Want to Be an Astronaut
Sunday, 5/16
12:30–2:00 p.m. (Ages 4–5, each child with one adult) or 3:00–4:30 p.m. (Ages 6–7)
Three, two, one, blast off! Find out what life is like 250 miles above Earth on the International Space Station.

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

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

All programs are subject to change.

Julie of the Wolves
Sunday, 5/16, 2:00 p.m.
A musical adaptation of the children's classic about a young Eskimo girl who runs away and is protected by wolves.

Red Rover to Mars
Tuesday–Thursday, 5/18–20 4:00–5:30 p.m. (Ages 12–15)
Students learn about the history of NASA's rovers and what we learn from them, and then design and build their very own "rovers."

The vehicle carrying the Mars rover *Opportunity* poised for launch

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe: The Big Bang and Cosmic Construction
Tuesday, 5/4
6:30–7:30 p.m.

This Just In. . . May's Hot Topics
Tuesday, 5/18
6:30–7:30 p.m.

Celestial Highlights: Transit of Venus
Tuesday, 5/25
6:30–7:30 p.m.

COURSE

Eclipses and Transits
Four Mondays, 5/3–24
6:30–7:30 p.m.
Explore the mechanics behind impressive celestial phenomena, and prepare for the much-anticipated transit of Venus.

LECTURES

Life, the Universe, and SETI in a Nutshell
Monday, 5/3, 7:30 p.m.
SETI's Jill Tarter leads this discussion on the future of our search for life elsewhere in the universe.

The Book Nobody Read
Monday, 5/10, 7:30 p.m.
Astronomer Owen Gingerich's new bibliographic detective story revisits Copernicus's *De Revolutionibus*, which first proposed that Earth revolved around the Sun.

PLANETARIUM SHOWS

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

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ENDPAPER

The Face of Extinction

By Hanna Rose Shell

Martha in death: the last passenger pigeon

Until the middle of the nineteenth century, as documented by no less an eminence than John James Audubon, passenger pigeons by the billions turned day to night as they passed overhead in the American skies [*see "Audubon in Kentucky," by William Souder, page 46*]. Yet by the turn of the twentieth century, all that had changed: fifty years of relentless extermination forever banished *Ectopistes migratorius* from the Earth. The last passenger pigeon in the wild was reportedly shot by a boy in Ohio in 1900.

But the species officially went extinct only with the death of Martha, a denizen of the Cincinnati Zoo. Martha had been born in about 1894, and, in her youth, she had a female passenger pigeon's classic good looks: pale cinnamon-rose breast; long, pointed tail feathers; a graceful head and neck. By the year of her death, the news of an incipient extinction, together with clamorous announcements of unclaimed cash rewards for locating a passenger pigeon nest or colony, was attracting visitors from far and wide to Martha's red-roofed aviary in Ohio.

In the following years, many more visitors turned out to admire Martha's taxidermied mount in the Birds of Our World gallery, at the National Museum of Natural History in Washington, D.C. Martha's presentation there, in fact, was carefully planned. Her body had been promised to the Smithsonian, and when she finally expired, in September 1914, the zookeepers rushed her corpse to the Cincinnati Ice Company. There, held by her feet, she was lowered into a tank of water, frozen upside down in a 300-pound block of ice, and shipped by express train to the capital.

Martha was officially signed into the Smithsonian collections as a "passenger pigeon in the flesh." Her accession card is by turns blunt, then sentimental: "The death of this individual marks the complete extinction of the genus and species, of the countless hordes of other days." She was unpacked, thawed, and autopsied. Several organs—including her eyes, brain, and liver—were examined and placed in separate jars of ethyl alcohol.

Once Martha's taxidermic treatment was complete, she was perched on a model "branch," enclosed in a glass case, and given a post of prominence in the gallery, surrounded by other extinct and endangered avians from North America. In her new, postmortem role, she even went on the road several times on behalf of species that were facing the threat of extinction. She served as a tabletop mascot at a conservation conference for the San Diego Zoo at the zoo's golden jubilee, in 1966, and at a Cincinnati Zoo fund-raiser, in 1974. She always flew first class, coddled by the flight crew and protected, at least financially, by a hefty insurance policy.

Almost five years ago, though, around the turn of the millennium, Martha's perch went dark. The Smithsonian Institution closed its bird gallery indefinitely to the public at the end of 1999. And now the last exemplar of a vanished species is hidden away in a storage cabinet in the bird division's research collections.

Yet without reminders such as Martha, how are people to visualize, materialize, and memorialize the Earth's destroyed and extinguished species? After eighty-five years in the public eye, the figure of Martha has become an organic monument, biologically continuous with the living bird she commemorates, the embodiment of extinction itself. In the words of the naturalist Aldo Leopold, effigies such as Martha's "live forever by not living at all."

HANNA ROSE SHELL is a historian of science at Harvard University and a filmmaker. She recently edited the new edition of William T. Hornaday's 1889 book, Extermination of the American Bison *(Smithsonian Institution Press, 2002).*