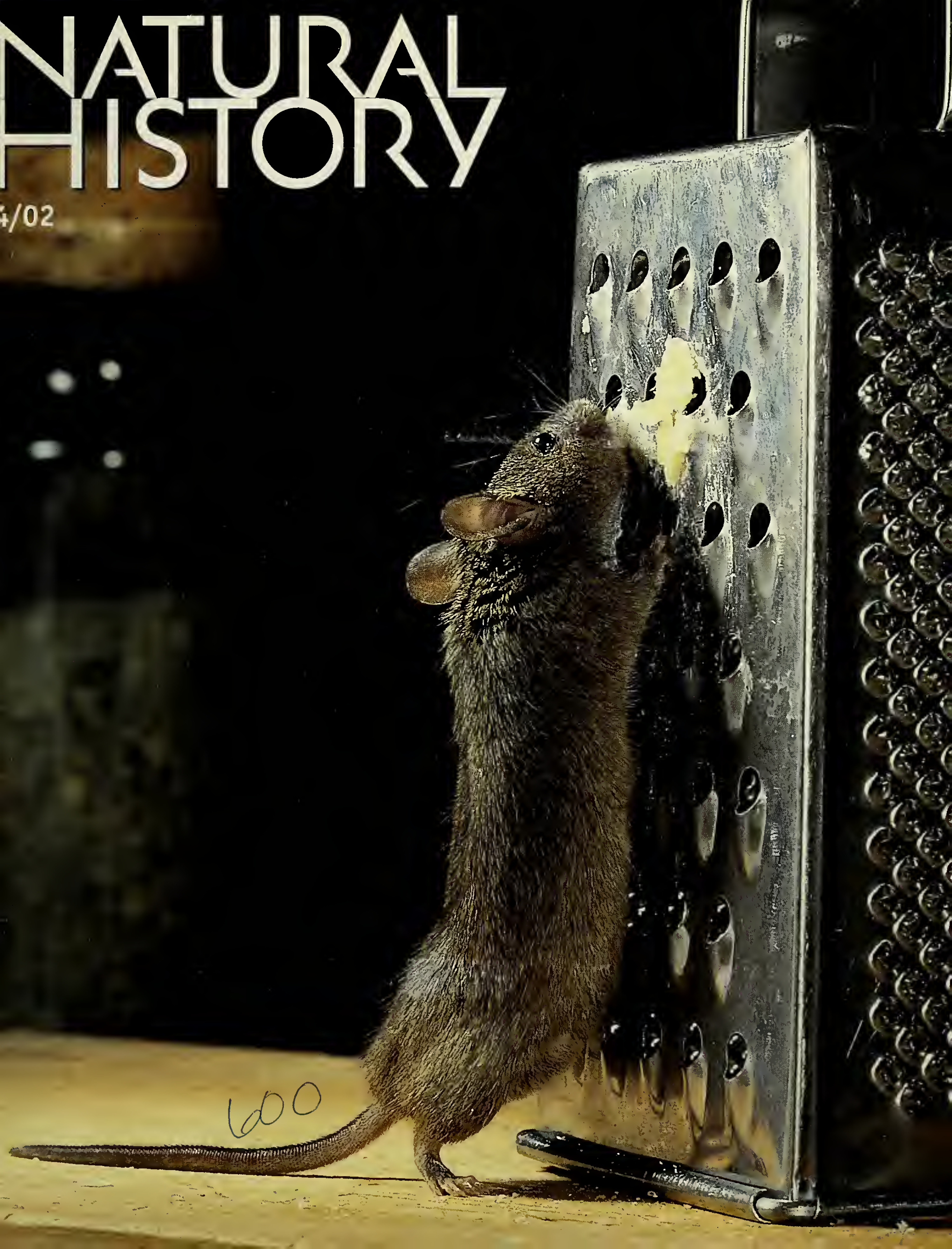
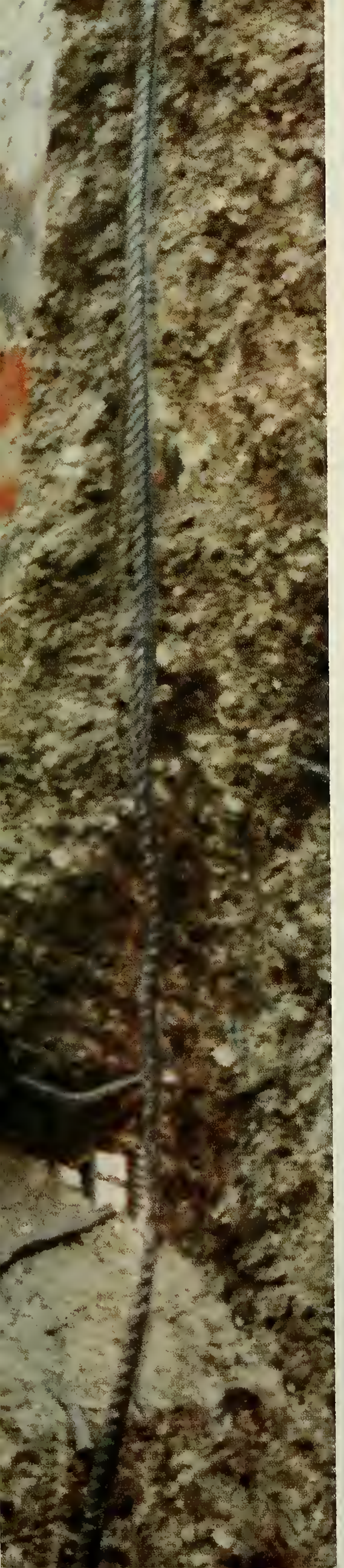
NATURAL HISTORY

4/02



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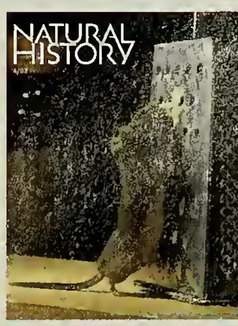
NATURAL HISTORY

APRIL 2002 VOLUME 111 NUMBER 3

FEATURES

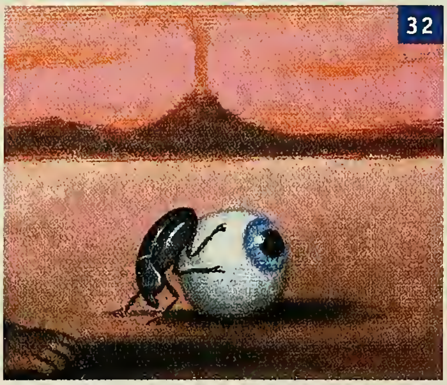


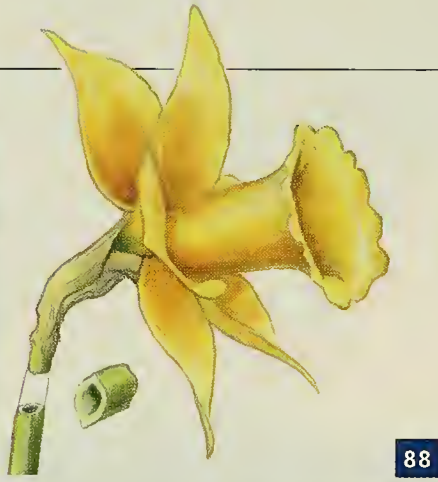
COVER *Mus musculus*, the house mouse, has been associating with *Homo sapiens* for at least 10,000 years.

STORY BEGINS ON PAGE 64

PHOTOGRAPH BY STEPHEN DALTON

DEPARTMENTS





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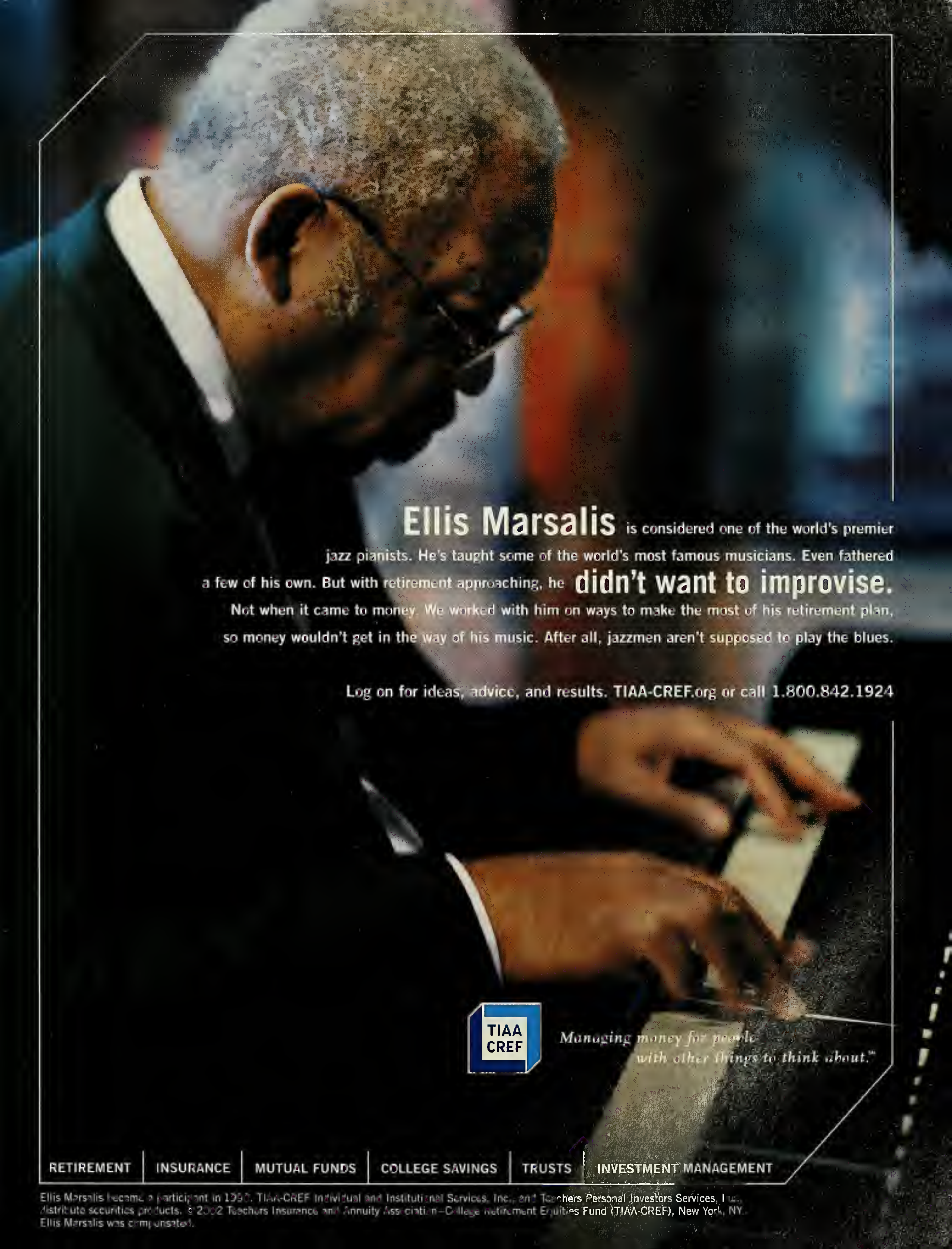
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UP FRONT

After All These Years

I cannot look upon the Universe as the result of blind chance, yet I can see no evidence of beneficent design, or indeed design of any kind in the details. As for each variation that has ever occurred being preordained for a special end, I can no more believe in it, than that the spot on which each drop of rain falls has been specially ordained.
—Charles Darwin, 1870

A scientific theory stands or falls by its ability to explain and predict. Darwin's idea of evolution by natural selection rapidly persuaded scientists because it offered a brilliant and thoroughgoing explanation of the oddities, cruelties, irregularities, and patterned intricacies of the natural world. Like all successful scientific theories, the Darwinian paradigm has been modified and expanded. But its basic premise—that species have descended from common ancestors and have been modified over immense periods of time—remains unrivaled in making sense of many disparate lines of evidence.

Unlike the equally revolutionary theories of Copernicus and Galileo, however, Darwin's idea still provokes opposition in some quarters. Most recently, this resistance has been embodied by the "intelligent design" (ID) movement, whose supporters maintain that the complexity of the natural world is evidence of planning by a higher intelligence. This line of argument, familiar to theologians, is now being put forth as a scientific challenge to Darwin.

In this issue, *Natural History* has made the unusual move of allotting space to three of ID's leading proponents. Some of our friends and colleagues have asked why a magazine such as ours, grounded in evolutionary biology, should give ID advocates a voice in our pages. The argument goes: "You wouldn't think of having astrologers, alchemists, or Flat-Earthers write in the magazine, so why make an exception for antievolutionists?"

Our answer is simple. The latest efforts to influence the teaching of biology in the nation's classrooms are being spearheaded by those who assert that ID theory is, in fact, science. "Intelligent Design?" (page 73) offers readers the chance to evaluate, unfiltered by secondhand reports, the scientific quality of ID's propositions and to judge for themselves whether or not these propositions differ from those of evolution's old foe, creationism. In this section, each ID statement is analyzed by a respondent in the Darwinian camp. To further assess the design argument, we draw your attention to Barbara Forrest's brief overview of the intelligent-design movement (page 80) and to columnist Carl Zimmer's report on recent findings relevant to the evolution of the eye ("Crystal Balls," page 32).

Why is our culture still torn apart by these evolution wars? We leave the last, and most philosophical, word on that subject to Museum anthropology curator Ian Tattersall ("Science Versus Religion? No Contest," page 100).

—Ellen Goldensohn

NATURAL HISTORY

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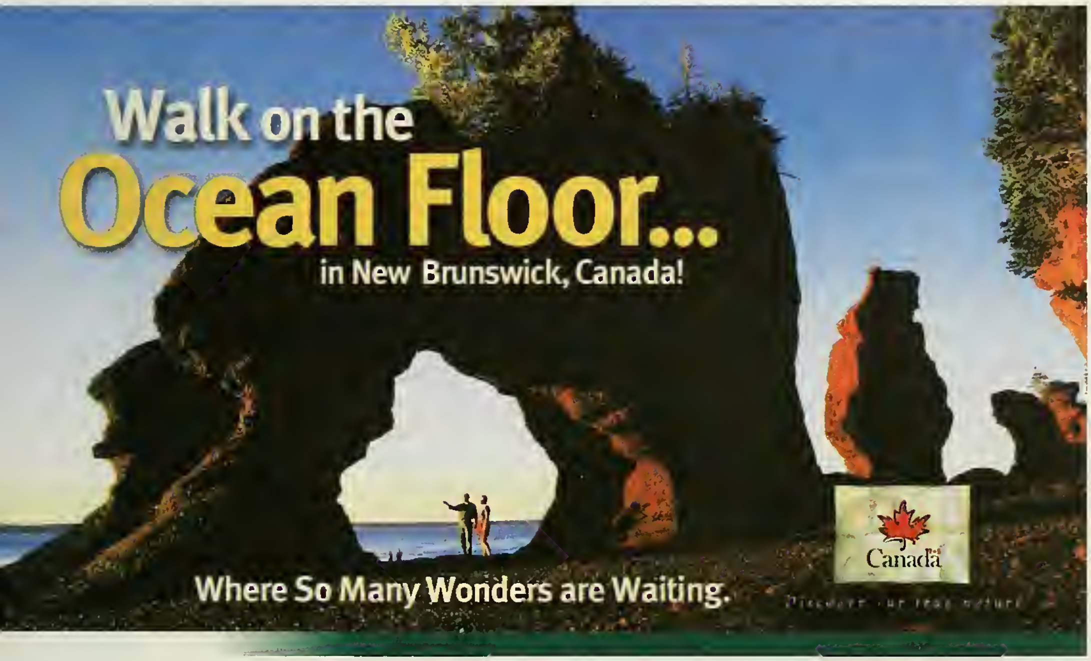
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LETTERS

Leaves and Needles

I found Bernd Heinrich's "Grand Opening" ("In the Field," 2/02) very illuminating and enjoyable. Heinrich pointed out the advantage of a tree's delaying the production of leaves until the danger of frost has passed. But I have noticed that on rare occasions, trees can also suffer from a late, heavy snowfall. While evergreen needles are clearly adapted to dealing with snow cover, the large leaves of some trees, such as the sugar maples in my backyard, are not.

Kriss Replogle
Brookside, New Jersey

THE EDITORS REPLY: For more on the phenomenon you describe, check out Bernd Heinrich's article "When the Bough Bends," which appeared in "The Biomechanics of Trees" in the February 1996 issue of *Natural History.*

Cutting Remarks

In "The Unsung Ancients" (2/02), David W. Stahle comments on ancient trees being "sent to the guillotine" and on "our misperception of their value and our continued disregard" threatening their survival. I would prefer to read about these majestic survivors without being given a lecture on the evils of exploiting natural resources.

Also, I would be interested to know how the ages of the trees cited were determined. Does one have to cut down a tree to get that information, or has science progressed beyond that point?

Sue Sommers
Pinedale, Wyoming

DAVID W. STAHLE REPLIES: Dendrochronologists use a Swedish increment borer to extract a 5-mm-diameter core of growth rings from bark to pith. This manually operated tool leaves a 2-cm-diameter wound to the living cambium. Most species of trees easily survive the insult. Rarely do dendrochronologists cut down trees to determine their age.

Birds in Living Color

I enjoyed reading J. Albert C. Uy's article on bowerbirds ("Say It With Bowers," 3/02) but was surprised that the author states that male Vogelkops sort the objects around the bowers by color. I thought color vision was an exclusive trait of primates.

B. Adam
New York, New York

J. ALBERT C. UY REPLIES: Color vision is not restricted to primates. In fact, various other animals have better color vision than primates. While the males of some New World primates have only two types of cones in their retinas, in general primates have three, allowing them to see color in the short, medium, and long wavelengths. Other animals with three cone types include some freshwater fish, diurnal reptiles and amphibians, crustaceans, many insects, and certain spiders. Birds, turtles, some freshwater fish, and butterflies possess four cone types in their retinas, enabling them to see in the ultraviolet range as well.

THE EDITORS ADD: For more on color and vision, read "Seeing Red . . . and Yellow . . . and Green . . . and," also in our 3/02 issue.

Immune Response

Like other articles I've read in recent years, T. V. Rajan's "Remembrance of Pathogens Past" ("Findings," 2/02) suggests that the devil makes work for idle immune systems, leading to autoimmune diseases. Might a solution be to create "work" for our immune systems by using some sort of "vaccinations" with immune-response-stimulating proteins?

George Bergman
Orinda, California

T. V. RAJAN REPLIES: The idea that vaccines may give the immune system sufficient work and thus redirect its potential to attack itself is a good one, but two issues have to be considered. The universe of infectious agents is significantly larger than the universe of vaccines we have. In addition, data are showing that the immune system responds differently to vaccines than it does to pathogens. This raises the possibility that vaccines may not adequately mimic an encounter with an infectious agent.

Riding the Train

I liked Steven Vogel's article "A Short History of Muscle-Powered Machines" (3/02). At one time, my family had an HO model railroad circling the basement of our house, and we hooked up a bicycle on rollers as an optional power source (rigged so the front wheel could be removed, for stability). The power demand changed as the model went up or down grade, and with different engines and lengths of trains. Some of the engines were power hogs. It made the ride feel much more like being on the road.

C. A. Freeman
via e-mail

Off the Map

The Namib Desert is on the west coast of southern Africa, not the east coast, as stated in "Beetle Juice" ("In Sum," 2/02). The dense fog that blows across this desert does come from the Atlantic Ocean but certainly doesn't have to cross the entire continent.

Irwin Marks
Acushnet, Massachusetts

Natural History*'s e-mail address is nhmag@amnh.org.*

CONTRIBUTORS

Adrian Bailey ("All for One," page 50), a South African native, held a position as an architect before trading in his drawing table for a camera and a career in freelance photography. His wife, **Robyn Keene-Young,** earned a law degree from South Africa's University of the Witwatersrand and worked as an attorney until deciding she'd prefer a life of freelance nature and travel writing. Since 1995, the pair has traveled throughout southern Africa and beyond, collaborating on books and magazine articles about wildlife, wild destinations, and conservation issues. While working on *Wild Kruger* (Sunbird Publishing, 2001), a book about Kruger National Park, they came across a herd of buffalo. According to Bailey, "the sheer spectacle of these intimidating animals and their extensive retinue made them an easy choice" for further examination. Buffalo are the subject of their photoessay in this issue.

Rainer Willmann, who holds the chair in morphology, taxonomy, and evolutionary biology at Göttingen University's Institute of Zoology and Anthropology, put together a team of specialists to write the text for the formidable (588 pages and standing nearly a foot and a half high) facsimile edition of *Albertus Seba, Cabinet of Natural Curiosities,* on which "A Diverse & Marvelous Collection" (page 56) is based. **Irmgard Müsch,** an independent scholar who specializes in scientific illustration and the *Kunstkammer* (cabinet of curiosities) tradition, contributed the book's introductory essay, placing an Amsterdam apothecary's enormous collections of natural curios in the context of scientific and mercantile life in early-eighteenth-century Europe. Willmann, with **Jes Rust,** identified and discussed the zoological and botanical specimens. Rust, whose doctoral thesis treated the evolution of fossil snails, is a professor of invertebrate paleontology and insect phylogeny at the University of Bonn. The facsimile, a project that took years to realize, is based on a rare, hand-colored original housed in the National Library of the Netherlands in The Hague.

Steven N. Austad ("A Mouse's Tale," page 64) dates his interest in laboratory mice back to the first time he saw a lab technician pick one up without gloves. When the placid mouse didn't try to bite or escape, Austad asked himself, "What kind of self-respecting animal would allow itself to be handled like that?" As interested as he is in the history of the house mouse, however, he is even more intrigued by his own species. As he says, "Any species that would turn a wolf into a pug bears close watching." A professor in the Department of Biological Sciences at the University of Idaho in Moscow, Austad conducts research on aging and the physiology of stress as well as on the biology of domestication. On the lighter side, he is the co-author, with his wife, veterinarian Veronika Kiklevich, of *Real People Don't Own Monkeys: And Other Stories of Pets, Their People, and the Vets Who See It All,* to be published this spring by Sourcebooks.

Primatologist **Joyce A. Powzyk** ("Findings," page 82) started out as a children's book author and illustrator. While traveling in Africa in 1986, she was disappointed when her guided tour to Madagascar was canceled. "I found out the cost of a round trip from Nairobi was just $200," she says, "so I took my chances and went solo." Powzyk spent a month observing the island's lemurs and was so captivated by them that she went back to school to study primate behavior and earned a Ph.D. at Duke University. She is currently a visiting scholar at Wesleyan University. Powzyk's most recent children's book is *In Search of Lemurs: My Days and Nights in a Madagascar Rain Forest* (National Geographic Society, 1998).

Fred Bavendam ("The Natural Moment," page 98) was a commercial photographer before he began a full-time career as an underwater photographer sixteen years ago: "I needed a way to justify the amount of time I was spending diving and the money I was spending on underwater photo gear." Bavendam now travels, dives, and takes photographs about ten months a year. His favorite cold-water site is British Columbia, Canada, where he shot the sea star featured this month (he used a Canon camera with Aquatica housings, 28mm lens, and two Ikelite 150 strobes). Above all other warm-water sites, he likes those of northern Sulawesi, Indonesia. The cephalopod mollusks—octopuses, cuttlefishes, and squid—are his favorite subjects.

The glacier-carved freshwater fjord at Western Brook Pond.

AT THE MUSEUM

String Theory

The tradition of spinning raw fibers dates back at least 28,000 years.

By Meredith F. Small

A woman in Amazonia weaving a hammock from chambira palm fiber

Wandering one day through the Museum's Hall of South American Peoples, I noticed a case with the label "Amazonian Rain Forest." Against the backdrop of a mural of bright green vegetation are all sorts of material goods from several Amazonian Indian tribes. Some items are curios, such as a necklace of peccary teeth and a piranha jaw fashioned into a cutting tool. Others are spectacular creations, such as a headdress made of iridescent blue and green birds strung together. But what struck me most was a mundane ball of string, about ten inches in diameter—yards and yards of fiber sitting there as if at the ready for wrapping packages.

As with many simple household objects, the ball of string tells a more complicated story. This particular sample was made from chambira palm fiber by the Tukano people of Brazil and Colombia. Laila Williamson, a senior scientific assistant in the Museum's anthropology department, tells me that in Amazonian cultures, it is mostly the men who make natural string. They first strip the thin cuticle layer from the middle rib of a young palm leaf, then soak the fibers for pliability. To make continuous string, the fiber strips are dried and spun together, end overlapping end. Imitating the process, Williamson slides the flat of her right hand quickly up and down her thigh to demonstrate the motion that twists the raw ends together in an entangled bond. As one fiber rib after another is added, the string grows in length, snaking to the ground and piling up into a coil.

Hand-spun palm-fiber string is so strong that it is used by the Tukano to weave hammocks (each requires a mile of twine) and purses, to make bowstrings, and to tie feathers securely to headdresses. This kind of string is a cultural marker for anthropologists, something that separates South American forest peoples from their neighbors on the open plains to the south. The more southerly cultures make their string from animal sinew, but forest dwellers prefer palm and other vegetation because it's abundant and serviceable.

Across South America, fiber string is traditionally made not only from palms but also from sedges, succulent plants, cotton, and even a wild relative of the pineapple. This pineapple string can be spun fine enough to be used for necklaces and bracelets. String made by people living at higher elevations also incorporates alpaca and vicuna hair and sometimes human hair.

The making and use of plant-fiber string is of course not restricted to Amazonia. The Inca, who had no written language, used the quipu—a device made of a series of strings with colored knots—to record census findings and tallies of animal herds and other resources. The Chinese, with a string vocabulary of more than a dozen different knots, have used macramé cord since antiquity to fasten and wrap things and also to record events and to fashion distinctive patterns. The Eskimos were enthusiastic practitioners of string games like cat's cradle, while the Polynesians had a tradition of using string maps for navigating from island to island.

The people of Kiribati, an island nation in the western Pacific, use technology similar to that of the Tukano, according to anthropologist Bernd Lambert, of Cornell University, who has been observing the Kiribati, including their string making, since the 1950s. He has collected various wooden and shark-tooth weapons that are tied together by twists of fiber interlaced with human hair. In the Gilbert Islands, string making is integral to understanding the division of labor. "Women make the flexible items, like cordage, and men work with the harder materials, such as wood," Lambert explains. Women, according to Lambert, appear to be spinning string all the time, and they produce so much that they often roll it into large balls and store it for later use.

"These people are always going to need cordage," he says. "They use it to tie houses together—even huge meeting houses—and to make canoes, not to mention making small items such as belts and fishing nets. They need a lot of it." Today, even though they have access to machine-made nylon or cotton string, the people of Kiribati prefer handmade cord. "When tying canoe planks together, they use coconut fiber because it swells up and plugs the holes. It's cheap and does the job well, sometimes even better than the modern alternatives."

South American forest peoples make palm-fiber string. This distinguishes them from the inhabitants of the open plains, who make string from animal sinew.

It seems that people all over the world have been making string for a very long time. From impressions of fiber cordage on fired clay, archaeologists have discovered evidence of string and of rope-making technology in Europe that dates back 28,000 years. In southern France, Paleolithic peoples used rope to climb into the cave of Lascaux. And since string is highly perishable, the evidence we have of it in the archaeological record probably only hints at its actual uses. Our ancestors may have spun string long before our earliest record of it.

In modern Western societies, string is fading into memory. We used to carry baked goods home in pink boxes tied with string, and our mail often came held together with twine. These days, string has been set aside in favor of nifty plastic packaging, Velcro, and duct tape. Our headgear, hammocks, and purses are made of other materials and in faraway countries. In most households, at least one ball of twine still survives in the junk drawer, but when was the last time we needed it?

In that sense, string (or lack of it) is a cultural statement in Western cultures as well. We no longer have time to sit and weave our own goods. We no longer go to the bakery to bring home special treats. In an electronic age, our mail comes not in piles but in bytes. And so, stringless, we are set apart from the forest people. It is left to the museums—collectors of the mundane—to remind us of this significant technological invention that helped us tie life together.

Meredith F. Small is a professor of anthropology at Cornell University and the author of a number of books, most recently, Kids: How Biology and Culture Shape the Way We Raise Our Children *(Doubleday, 2001).*

MUSEUM EVENTS IN APRIL

JOHN BURROUGHS ASSOCIATION

Annual award ceremony and luncheon 4/1: Burroughs Medal award for nature writing (*Wilderness and Razor Wire,* by Ken Lamberton); Burroughs List of Nature Books for Young Readers awards, and Natural History Essay award. For reservations, call (212) 769-5169. Hall of Asian Peoples, 12:00 P.M.

"BASEBALL AS AMERICA"

Exhibition in Gallery 3 through 8/18.

Lecture 4/4: "Baseball Behind Barbed Wire." Kerry Yo Nakagawa, author of *Through a Diamond: 100 Years of Japanese American Baseball.* Linder Theater, 7:00 P.M.

Lecture 4/6: "Nisei Baseball." Kerry Yo Nakagawa. Linder Theater, 2:00 P.M.

Lecture 4/6: "Baseball: The New York Game." Tony Morante, stadium tours director, New York Yankees. Kaufmann Theater, 2:00 P.M.

Roundtable 4/15: Sportswriter Jack Lang, former Mets players Ed Kranepool and Art Shamsky. Linder Theater, 1:00–2:30 P.M.

Lecture 4/19: "A Native American in the Major Leagues." Jack Aker (Potawatomi), former major-league player and coach. Linder Theater, 7:00 P.M.

HOT TOPICS IN SCIENCE AND CULTURE

Performance 4/9: "Charles Darwin: Live and in Concert." Anthropologist-songwriter Richard Milner. Kaufmann Theater, 7:00 P.M.

Panel and lecture 4/23: "Blind Evolution or Intelligent Design?" Eugenie Scott (moderator), National Center for Science Education; Michael Behe, author of *Darwin's Black Box;* William Dembski, author of *The Design Inference;* Robert Pennock, author of *Tower of Babel;* Michael Shermer, Skeptics Society. Co-presented with *Natural History.* Kaufmann Theater, 7:00 P.M.

REPORTS FROM THE FIELD

Lecture 4/10: "Wondrous Difference: Cinema, Anthropology, and Turn-of-the-Century Popular Culture." Alison Griffiths, Baruch College. Kaufmann Theater, 2:00 P.M.

Lecture 4/24: "Life With Leeches." Invertebrate biologist Mark Siddall, AMNH. Kaufmann Theater, 2:00 P.M.

Lecture 4/30 (Revolutionizing Medicine in the 21st Century series): "Viral Diseases and Host Defenses." Physiologist and cellular. biophysicist Samuel Silverstein, Columbia University College of Physicians and Surgeons. Caspary Auditorium, Rockefeller University, 1230 York Avenue, at 66th Street, 7:00 P.M.

"PAPER TRAILS . . . IN REAL TIME!"

Art installation through 4/21 (weekends): "The Path of Paper." Sculptor Helen Evans Ramsaran. Leonhardt People Center, 1:00–5:00 P.M.

Field trip 4/13: Center for Book Arts. Artist Benjamin Rinehart. Meet at Rotunda entrance. 4:00–6:00 P.M.

Workshops 4/14: Papermaking. Artist John Curie, Dieu Donné Papermill. Calder Lab, 1:00–2:30 P.M. and 3:30–5:00 P.M.

Gallery tour 4/20: "Mexico From Ancient Times to the Present Through Paper." Artist Miguel Cossio. Meet at Hall of Mexico and Central America, 1:00 P.M.

Workshop 4/20: "Paper Traditions of Mexican Rituals and Celebrations." Calder Lab, 3:00–4:30 P.M.

Performances 4/21: "Stories of the Creation of the World From the Popol Vuh." Leonhardt People Center, 1:00 P.M. and 4:00 P.M.

AMNH BOOK CLUB

Monthly meeting 4/14: *Great Waters: An Atlantic Passage,* by Deborah Cramer. Details at (212) 769-5200. Portrait Room, 3:00 P.M.

"CREATING ETHNICITY"

Photographic self-portraits through 4/21: Artist Margaret Francis. Charles A. Dana Education Wing.

Pearl Diver, 2000

MARGARET FRANCIS

Panel 4/12: "Misperceptions—Representation and Media Imagery." Warrington Hudlin, Black Filmmaker Foundation; Margaret Francis; Sheryl Levart, Face to Face Press and We Interrupt This Message; Jack Shaheen, author of *Reel Bad Arabs: How Hollywood Vilifies a People.* Linder Theater, 6:30 P.M.

Lecture and Workshop 4/13: "Changing Images . . . Creating Ethnicity," 1:00 P.M. "Cultural Heritage," 2:30 P.M. Margaret Francis. Linder Theater.

Workshop 4/21: "Identity Exercise." Artist Margaret Francis. Linder Theater, 2:30 P.M.

ASTRONOMY & COSMOLOGY

Planetarium courses: 4/2–4/30 (five Tuesdays): "The Science of the Rose Center." 4/3–6/5 (eight Wednesdays): "Introduction to Space Science." 4/15–5/13 (four Mondays): "How To Use a Telescope." Complete schedule at (212) 769-5200 or www.amnh.org/hayden/.

Lecture 4/8 (Frontiers in Astrophysics series): "In Search of Our Origins." *Cassini* Mission imager Carolyn Porco, Southwest Research Institute and University of Colorado at Boulder. Space Theater, Hayden Planetarium, 7:30 P.M.

Lecture 4/22 (Distinguished Authors in Astronomy series): "How the Universe Got Its Spots." Cosmologist Janna Levin, University of Cambridge. Space Theater, Hayden Planetarium, 7:30 P.M.

Upcoming sky events 4/30: May's celestial highlights. Joe Rao, meteorologist and *Natural History* columnist. Space Theater, Hayden Planetarium, 6:30 P.M.

SCIENCE MEETS FILM

3-D film 4/25: "Shadowland or Light From the Other Side." Filmmaker Zoe Beloff. Kaufmann Theater, 7:00 P.M.

ALSO IN APRIL

Tours: 4/20 (Many Religions: One City series): "Hindu Temples." Karen Kane, AMNH. 9:30 A.M.–2:00 P.M. Information about tours, workshops, and field trips at (212) 769-5200.

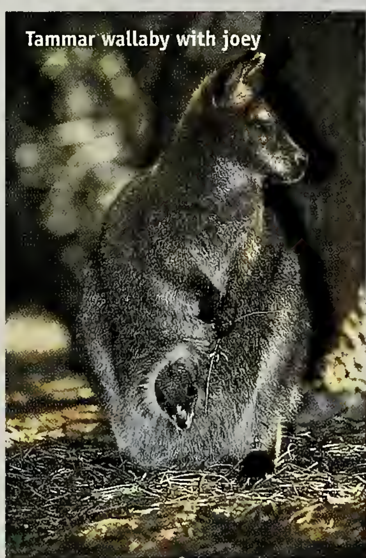
Moveable Museum: "Discovering the Universe." A new exhibition about astronomy and astrophysics. Begun in 1993, this program provides walk-in exhibition space in a specially designed RV that visits schools and community groups throughout the city. Information at www.amnh.org/moveable.

The American Museum of Natural History is located at Central Park West and 79th Street in New York City. For listings of events, exhibitions, and hours, call (212) 769-5100 or visit the Museum's Web site at www.amnh.org. Space Show tickets, retail products, and Museum memberships are also available online.

IN SUM

By Stéphan Reebs

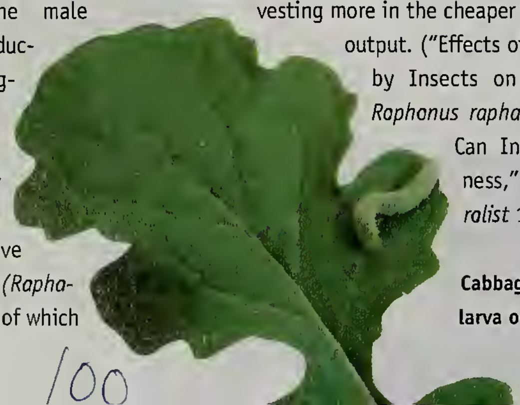
FEAR OF FOXES As a result of predation by introduced cats and foxes, tammar wallabies are rare on mainland Australia, but plans are afoot to reintroduce them, using individuals from offshore island populations. Foxes and feral cats still roam the mainland, however, and concerns have been raised that the wallabies may not recognize these predators as dangerous. After all, neither the island wallabies nor their evolutionary ancestors were ever exposed to these foreign species. To help the tammars, a team of Australian and American researchers led by Andrea Griffin, of Macquarie University in Sydney, investigated the possibility of teaching them to fear foxes. Housed within enclosures at the university, the wallabies ran away in fear whenever a person entered an enclosure and tried to catch one of them. The researchers decided to take advantage of this response. On four different days, they presented a stuffed fox just moments before the arrival of a net-wielding person; the wallabies learned to associate the appearance of the fox with the person they already feared. A few days later, when the fox was presented on its own, the tammers showed alarm. Control wallabies that had initially seen fox and human separately, rather than simultaneously, appeared more relaxed around the fox later on. And wallabies that learned to fear foxes extended their wariness to cats, even though they had not seen cats before, suggesting that tammars may be able to learn certain general features of predators. ("Learning Specificity in Acquired Predator Recognition," *Animal Behaviour* 62:3, 2001)



Tammar wallaby with joey

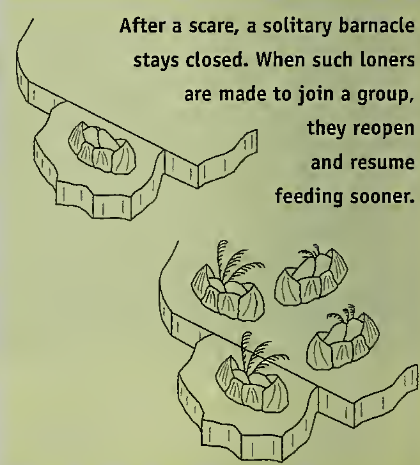
LAURA RILEY; BRUCE COLEMAN INC.

PLANT ECONOMICS Life can be hard for a plant whose leaves are being munched on by insects. Part of its photosynthetic machinery is lost, reducing its energy supply. To measure how this affects a plant's reproductive capacity, biologists have traditionally focused on the female side of things, counting the number of seeds produced (damaged plants typically mature fewer seeds). Now researchers from the University of California, Davis, and the Kellogg Biological Station of Michigan State University have shown that the male counterpart, pollen production, should not be ignored. Working at a site with relatively poor soil, Sharon Strauss, Jeffrey Conner, and Kari Lehtilä studied the reproductive success of wild radishes *(Raphanus raphanistrum)*, some of which had lost a third of their leaf cover to larvae of the cabbage white butterfly. The biologists observed the expected seed loss, but molecular tests also revealed that the pollen of damaged radish plants fertilized more of the seeds that developed on their neighbors than did the pollen of intact plants. This increased male success was linked to earlier flowering by damaged plants. At least on poor soils, a plant under attack may be able to make the best of a bad situation by skimping on seed production and investing more in the cheaper process of pollen output. ("Effects of Foliar Herbivory by Insects on the Fitness of *Raphanus raphanistrum:* Damage Can Increase Male Fitness," *American Naturalist* 158:5, 2001).



Cabbage white butterfly larva on wild radish leaf

UNITED THEY WAVE Safety in numbers is a principle that applies to many animal groups. Members of bird flocks and fish shoals check for predators less often and spend less time hiding in shelters than do solitary individuals. Now two researchers from Kenyon College in Ohio have shown that barnacles, too, profit by togetherness. Working at the Bowdoin Scientific Station on an island in the Bay of Fundy (between New Brunswick and Nova Scotia), Robert Mauck and Kelly Harkless collected barnacle-bearing rocks from the intertidal zone and set them up in a shallow tank. Once the barnacles extended their cirri (fanlike, food-gathering appendages) and started waving them about to collect nutritious particles in the water, the researchers cast a shadow over them with a piece of cardboard. Alarmed, all the barnacles retreated underneath their protective plates, but those that lived as part of an aggregation resumed feeding sooner than the loners did. Moreover, by attaching rocks that held a solitary barnacle to rocks that held twenty or more, Mauck and Harkless forced solitaries to become part of a group. These former loners then adjusted their behavior accordingly. The researchers think that barnacles may detect chemicals or rock-borne vibrations coming from neighbors and thus sense that a crowd has formed. ("The Effect of Group Membership on Hiding Behaviour in the Northern Rock Barnacle, *Semibalanus balanoides*," *Animal Behaviour* 62:4, 2001)



After a scare, a solitary barnacle stays closed. When such loners are made to join a group, they reopen and resume feeding sooner.

STÉPHAN REEBS

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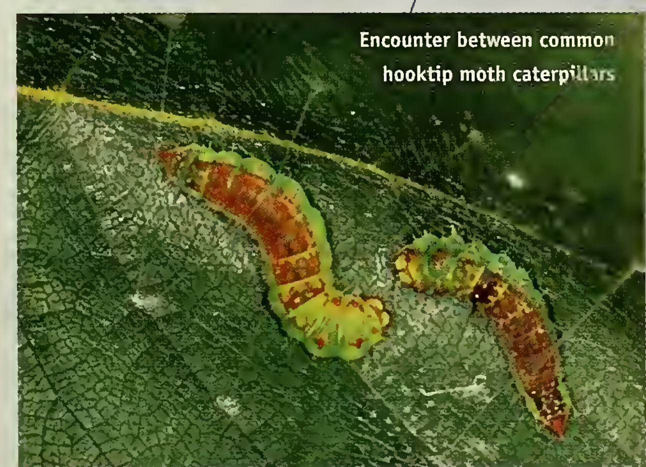
TRUNK TOOLERY

The trunk of an Asian elephant is so exquisitely prehensile that it can pick up a dime from a concrete floor. This dexterity, coupled with a large brain, may predispose elephants to the manufacture and use of tools. Indeed, Benjamin Hart, of the University of California, Davis, and colleagues have documented behavior suggesting just such a predisposition. They observed Asian elephants, both wild and captive, tearing off leafy side branches from trees or from unwieldy limbs already on the ground. Each elephant then held the branch by its base and used it as a fly swatter, slapping at flies on its flanks. Two babies, nine and eighteen months old, were seen to imitate their mothers. And the elephants were good recyclers: once the job was done, they did not always throw the leafy branch away—if it was edible, they ate it. ("Cognitive Behaviour in Asian Elephants: Use and Modification of Branches for Fly Switching," *Animal Behaviour* 62:5, 2001)

LEAN, MEAN, AND FAST MACHINE

The Atlantic silverside is a small shoaling fish that lives in estuaries all along the eastern seaboard. Northern populations have evolved a tendency to eat a lot and grow fast. Even with the same amount of food available to them, a silverside from Nova Scotia grows twice as fast as one from South Carolina. Entering the lean times of winter at a good size, with ample reserves of lipids, is crucial for northern fish but less important for those inhabiting warmer climes. There are other advantages to rapid growth, however, such as the enhanced reproductive output usually associated with a large size. So why don't southern fish grow as fast as their northern cousins? Three biologists from the State University of New York at Stony Brook believe they have the answer: gluttonous silversides are slow. Thomas Lankford Jr., Jean Billerbeck, and David Conover raced silversides in the laboratory and found that the South Carolinian fish swam faster and had more endurance than the Nova Scotians. Moreover, the skinny southerners were more likely to survive staged encounters with natural predators, such as bluefish and striped bass. The same differences showed up in comparisons of recently fed and food-deprived individuals from within the same population. A full stomach appears to divert energy to digestion at the expense of locomotion; it also temporarily increases a fish's girth and, as a result, the amount of drag on it in water. So, happy diners may sometimes pay a stiff price for their meal: becoming someone else's. ("Evolution of Intrinsic Growth and Energy Acquisition Rates. I. Trade-offs With Swimming Performance in *Menidia menidia*," *Evolution* 55:9, 2001, and "Evolution of Intrinsic Growth and Energy Acquisition Rates. II. Trade-offs With Vulnerability to Predation in *Menidia menidia*," *Evolution* 55:9, 2001)



Encounter between common hooktip moth caterpillars

JAYNE YACK

Caterpillar's oar-shaped noisemaker

JAYNE YACK

To see and hear the encounter, go to www.naturalhistory.com

KNOCK, KNOCK, WHO'S THERE?

Biologists Jayne Yack, Myron Smith, and Patrick Weatherhead, of Carleton University in Ottawa, Ontario, have recently studied the remarkable drumming abilities of some woodland caterpillars. Larvae of the common hooktip moth *(Drepana arcuata)* build silk nests that they must then defend against members of their own species. When a homeless caterpillar approaches a nest, the resident produces rasping sounds by dragging its oar-shaped anal structures or its opened mandibles across the surface of the leaf on which the nest lies. It may also strike the leaf in a staccato rhythm. These sounds are often enough to persuade intruders to depart, though big ones sometimes start drumming and scraping as well, engaging in an acoustic duel with the resident. The largest intruders may succeed in displacing the resident. The sounds broadcast during these territorial encounters are transmitted both through the air and through the leaf, but only the latter is important for communication, as caterpillars lack organs to hear airborne sound. The possibility remains, however, that birds might hear the commotion and rudely interrupt it by eating both contestants—an incentive to keep fights short, as they normally are. ("Caterpillar Talk: Acoustically Mediated Territoriality in Larval Lepidoptera," *Proceedings of the National Academy of Science* 98:20, 2001)

Stéphan Reebs is a professor of biology at the Université de Moncton in New Brunswick, Canada. He is the author of Fish Behavior in the Aquarium and in the Wild, *recently published by Cornell University Press.*

Photo: VisitScotland/Scottish Viewpoint

DISTINCTIVE DESTINATIONS

Photo: Swan Hellenic Cruises

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Scotland

Photo: VisitScotland/Scottish Viewpoint

The mountains of Glen Coe in the Scottish Highlands

Scotland's combination of beautiful scenery and art and culture make it one of Europe's most desirable destinations, but it is especially alluring for naturalists. Whether you are a birdwatcher, a whale watcher, or just a general wildlife enthusiast, you will enjoy the unspoiled Scottish countryside. You will see a wide variety of birds, mammals, and other wildlife in this dramatic and beautiful setting.

Scotland's geology is among the most varied and ancient in the world, resulting in dramatically different landscapes, from the mountains of the Highlands to the rolling hills of the Lowlands. The Arctic plateau of the Cairngorms, the wilderness of Wester Ross, and the woods and lake scenery of Loch Lomond and the Trossachs National Park are not only outstandingly beautiful but also among the most important sanctuaries for characteristic Scottish wildlife.

> There's more to Scotland than world-class golf courses, Georgian and Victorian architectural treasures, and the Loch Ness monster.

Birdwatchers come to Scotland to spot golden and sea eagles, the rare and large-billed Scottish crossbill, and the rare capercaillie. They can also see puffins, ospreys, ptarmigans, gannets, and a springtime explosion of breeding birds on the coastal cliffs. One of the great spectacles of Scotland is the flight of wintering geese, moving daily from roosting to feeding grounds. Some of the best areas to see this amazing sight are Gruinart Bay on Islay, Caerlaverock in the Solway Coast, and Loch of Strathbeg in northeast Scotland.

If you are a seasoned birdwatcher, then the internationally renowned Fair Isle bird observatory, between Orkney and

(continued on following page)

Photo: VisitScotland/Scottish Viewpoint

Melrose Abbey, Scottish Borders

Shetland, is a must-see. Visit during spring and autumn and see many transients as they take a break from their long-distance journeys.

When you're done with the skies, head for the sea. Scotland boasts twenty-four species of whales and dolphins — almost a third of the world's total. According to the Hebridean Whale and Dolphin Trust, the western seaboard of Scotland is the most important cetacean habitat in Europe. Good spots for whale sightings include Ardnamurchan Point, Gairloch, as well as the islands of Coll, Tiree, Islay, and Lewis.

For culture, don't miss Edinburgh, Scotland's capital, which is built upon a jumble of hills and valleys. Edinburgh Castle, the most famous castle in Scotland, overlooks the city and dominates its skyline. Edinburgh boasts more restaurants per capita than anywhere else in Scotland, as well as plenty of pubs, cafes, and bistros. With such diversity of land and activities, it's no wonder Edinburgh is the most popular tourist destination in Britain after London.

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Wales

Wales combines ancient and natural wonders like no place else in the world.


Photos: British Tourist Authority

One of the oldest places on Earth, Wales is known for its culture and language, which originated even before the pyramids were built. The Welsh language is the oldest known language in the world. However, it is the country's reputation as "Britain's great outdoors" that attracts many visitors. Wales offers stunning natural and unspoiled scenery —ranging from mountains and valleys to coastal rock formations — which provides a variety of walking, cycling, and water sport opportunities.

Outstanding attractions with unique charm include Mount Snowdon, the highest point in England and Wales, where you can ride on the narrow gauge railway up the summit. Travel by steam train through the breathtaking scenery of the Snowdonia National Park, or discover the magical Italianate village of Portmeirion on a wooded hillside overlooked by the mountains and sea. Pass through the Beacons National Park in southern Wales, or take an easy stroll along the marked trails of the Carmarthen Bay Coast Walk.


Above and top right: Snowdonia National Park, Gwynedd

Wales also is home to such wonders as the National Botanic Garden of Wales, including the largest single-span glasshouse in the world plus a garden that showcases plant life in all its forms. The magnificent Cardiff Castle is just a short trip from the new Millennium Stadium. Both are remarkable feats of engineering — past and present.

The National Museum and Gallery of Wales features a world-renowned selection of Monet's work and a remarkable collection of sculptures.

Add good food and wonderful accommodations, and you'll see why Wales is a destination of singular appeal.

Costa Rica

With miles and miles of untouched beaches, remote rain forests filled with abundant flora and fauna, not to mention golf courses and spas, Costa Rica is a favorite destination for travelers.

Photos: Costa Rica Tourist Board

In Costa Rica you can raft down raging river rapids, climb a volcano, explore a cloud forest, scuba dive in coral reefs, or relax in soothing hot springs located at the base of a volcano.

Bordered by both the Pacific and Atlantic Oceans, with a spine of volcanic mountains down the center, Costa Rica is one of the most biologically diverse places on earth. Its twelve distinct ecological zones are home to more fauna than any place on earth, more butterflies than in Africa, and more than twice the number of bird species than the whole of the United States. Monkeys, tapirs, sloths, anteaters, and bats abound, all in an area the size of West Virginia.

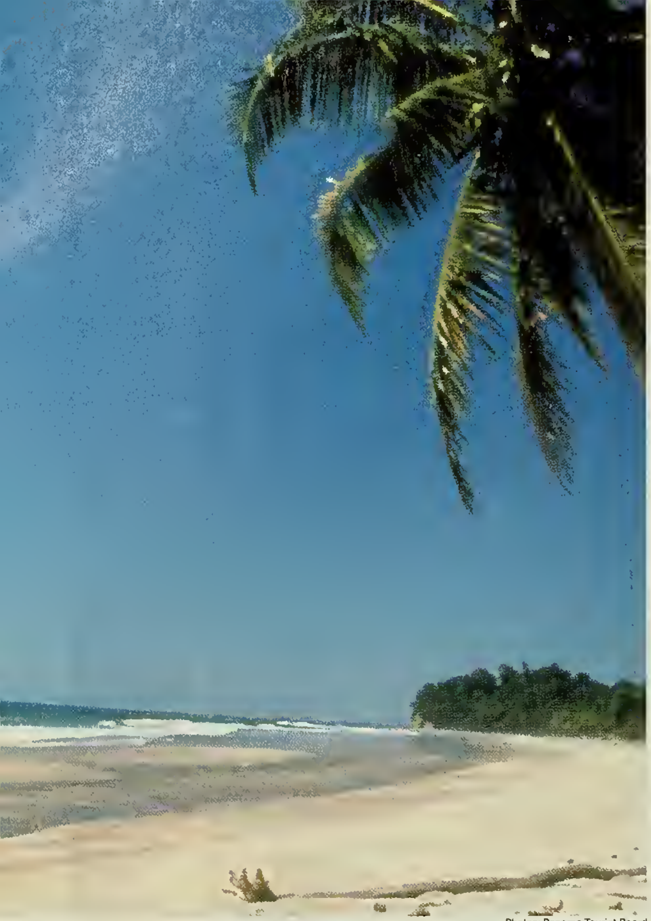
Because of Costa Rica's small size, its prolific animals and plants are easily accessible — and quite easy to see. One hour from San José, the capital city, you will be immersed in a remote wonderland where jaguars prowl, scarlet macaws squawk, giant morpho butterflies flutter, and vibrant tree frogs, coatamundis, toucans, and other exotic species live in abundance.

The best way to fully enjoy Costa Rica's unsurpassed natural beauty is by taking a natural history guided tour. Many ecotours are available, focusing on a specific area of interest such as wildlife, birding, flora, or fauna. Experienced guides can help you spot resplendent quetzal, emerald toucan, green sea turtle, and howler monkey.

Resorts in Costa Rica are almost as diverse as the land, spanning the spectrum from luxurious hotels to rustic lodges. You can settle into a cabina, dramatically overlooking the Pacific Ocean, or head to Tabacón Hot Springs, nestled amid lush tropical vegetation at the base of the Arenal Volcano. There, you can soak in therapeutic hot mineral water pools, fed by cascading waterfalls, while the towering volcano above glows red against the night sky.

Whether you enjoy nature, scuba diving, golfing, spas, whitewater rafting, or hiking, escape to Costa Rica and enjoy an unparalleled tropical paradise.

Because of Costa Rica's small size, travelers may find that its exotic and abundant animals and plants are easily accessible.



Photos: Panama Tourist Board

Panama

A bridge between South and Central America and a passageway between oceans, Panama borders Costa Rica to the west and Colombia to the east. The famous canal cuts the country right through its center, and it is here where rain forests dominate the countryside.

Panama's rain forests are home to some of the most exotic and rare species in the world. With 10,000 varieties of plants and 1,000 species of birds — that's more than in North America and Europe combined — Panama is an ideal spot for all types of nature enthusiasts. Plus, Panama has set 24 percent of its land aside for preservation, allowing unequaled opportunities for viewing wildlife.

For the best birding, head to Cana, deep in the heart of Parque Nacional Darién. There you are likely to find yourself alone with a variety of macaws, including the green, scarlet, blue, and yellow and chestnut-fronted.

Hundreds of islands off both coasts of Panama offer wonderful opportunities for marine adventures. Because the coasts are only one hour's drive apart, you could take a morning dip in the Caribbean then head over to the Pacific for afternoon snorkeling. The best snorkeling, diving, and deep-sea fishing are to be found in the Pacific, particularly near Coiba Island and the Pearl Islands.

Visit Panama for its unequaled natural beauty, its rich Spanish legacy, a cosmopolitan capital city, incredible rain forests, and some of the finest snorkeling, birding, and deep-sea fishing in the world.

For a truly unique experience, try diving in the Panama Canal. There you can explore submerged wrecks as well as a variety of equipment left by the French when they worked on the railroad many decades ago. Surfers should check our Santa Catalina Beach, on the Azuero Peninsula, where waves can reach twenty feet.

Fishing enthusiasts will be pleased to know that more deep-sea fishing records have been set at Piñas Bay, on the Pacific coast, than anywhere else in the world. You can see sea turtles in large numbers along both Panamanian coasts.

In addition to natural beauty, Panama offers a rich history and urban attractions. Temperatures do not vary much throughout the year, ranging from 70°F to 90°F in the lowlands to 50–64°F in the mountains.

After a visit to the rain forest to see wildlife, relax on one of Panama's serene beaches.

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With its variety of must-see and unusual destinations, full program of excursions, and knowledgeable guides, Swan Hellenic guarantees care-free cruising.

Photos: Swan Hellenic Cruises

Visit the Alhambra, a Moorish citadel in Granada, Spain, or enjoy the magical beauty of Lipari, the largest of Italy's Aeolian Islands.

Norway

The land of the Midnight Sun and the Northern Lights, the home of the Vikings, Henrik Ibsen, Edvard Grieg, and Edvard Munch — Norway offers a vast array of both natural and cultural history. Whether you enjoy museums, nature tours, or adventure vacations, Norway has something for everyone.

Photo: Per Eide/NTR

The puffin is easy to spot along the Norwegian coast.

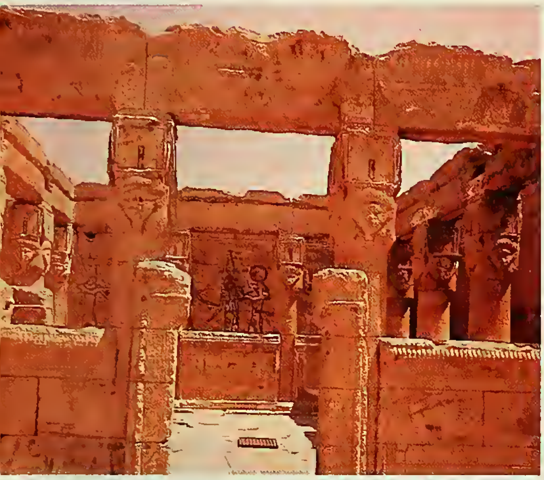
Norway's natural beauty is unlike that of anywhere else in the world. From glacial fjords to vast forests, from endless rivers to powerful waterfalls, the country has a spectacular range of scenery. Twenty-one national parks provide opportunities to enjoy untouched nature. You can hike along a vast network of marked hiking trails, enjoying the incredibly fresh air and variety of flora and fauna. You can take a photo safari and see moose, musk ox, whale, beaver, and eagles. Or go birdwatching and see thousands of sea birds along the craggy coasts. Almost all year-round you can go skiing, diving, fishing, climbing, glacier walking, rafting, or sledding with reindeer.

Photo: Pål Bugge/NTR

National Day, May 17, Oslo

Egypt

An ancient civilization with many modern conveniences



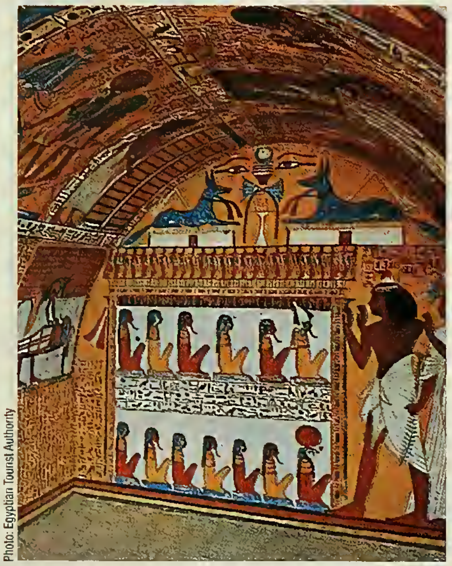


Photo: Egyptian Tourist Authority

Visitors to Egypt expect to be awed by ancient monuments. What is often pleasantly unexpected is the ease of the experience and the abundance of nature-related activities. Here, in the "cradle of civilization," you can cruise down the Nile, scuba dive in the Red Sea, bask on the beach, or trek in the mountainous region of the Sinai.

The sand, sun, and sea of the Sinai, Sharm el Sheikh, the Red Sea coast, El Gouna, and Hurghada attract thousands of visitors each year.

The Red Sea also offers some of the best scuba diving in the world. Here, you can explore untouched reefs and many shipwrecks. Great places to dive include Sharm el-Sheik, Taba, Dahab, and Nuweiba on the Sinai and El Gouna, Hurghada, Soma Bay, and Safaga on the Red Sea coast.

For fishing, head anywhere along the Nile and join the natives fishing along its banks. For a different and unique experience, try Lake Nasser, home of the largest freshwater fish in the world.

Bird watching, too, is possible in Egypt, as it is on the migratory path of many species of birds. While birds may be found throughout the Nile Valley and the Sinai, the most popular areas for birding are near Aswan and the northern Sinai.

Top to bottom: Osiris Shrine in Hator Temple, Dendera; Deir El-Madina Tomb, Luxor; pyramids

THE EVOLUTIONARY FRONT

Crystal Balls

Borrowed genes can help anything evolve—even the eye.

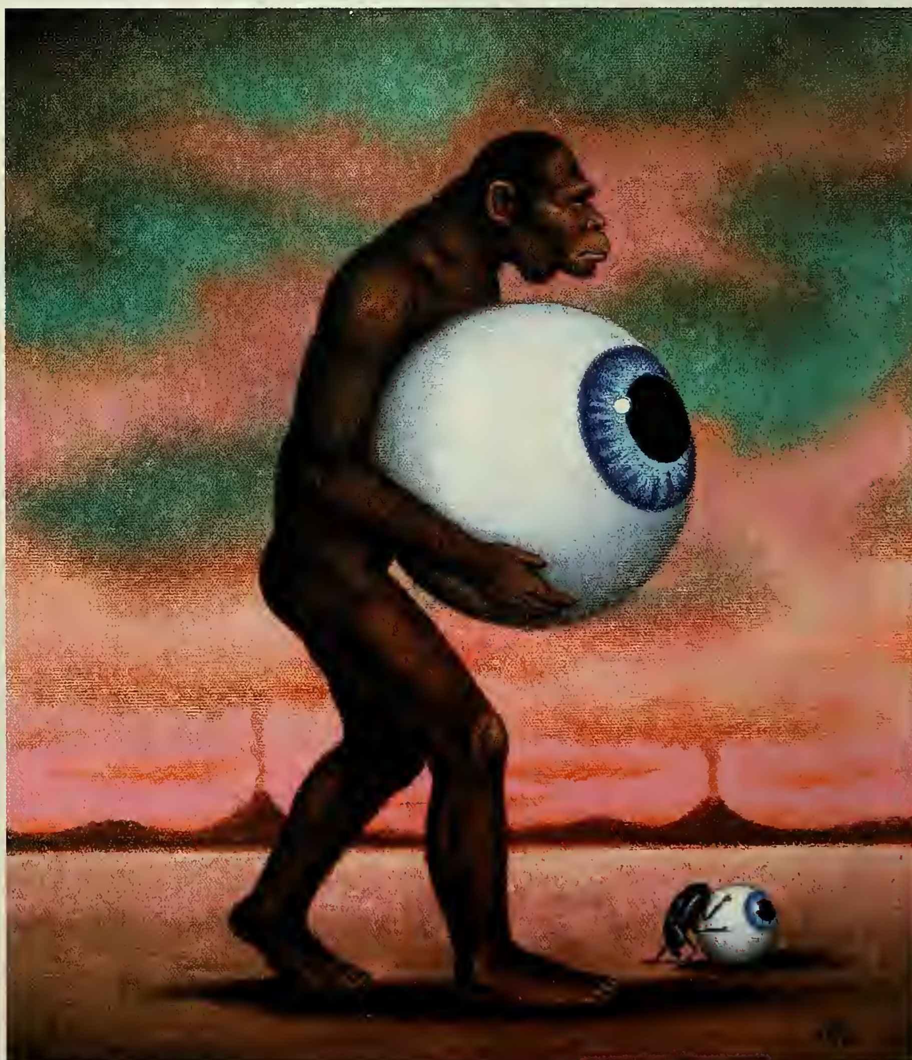
By Carl Zimmer

"The eye to this day gives me a cold shudder," Charles Darwin once wrote to a friend. If his theory of evolution was everything he thought it was, a complex organ such as the eye could not lie beyond its reach. And no one appreciated the beautiful construction of the eye more than Darwin—from the way the lens was perfectly positioned to focus light onto the retina to the way the iris adjusted the amount of light that could enter the eye. In the *Origin of Species,* he wrote that the idea of natural selection producing the eye "seems, I freely confess, absurd in the highest possible degree."

But Darwin also knew that a cold shudder was not reason enough to abandon a scientific theory. He looked at the eyes of many different animals—from flatworms to crustaceans to vertebrates—and found among them a gradation of forms, from a simple patch of light-sensitive tissue all the way to an elaborate image-forming organ complete with lens, iris, and retina. He decided there was no reason that evolution could not have led gradually from one arrangement to another.

Darwin considered only the anatomy of the eye, because the biochemistry of vision was still a mystery in his day. Of course, an eye is far more than just what can be seen by another eye. All the work involved in vision—bending and catching light, fine-tuning the image that gets sent to the brain, keeping the eye clear and firm over the years—is carried out by an army of specialized molecules, produced in turn by specialized types of cells. And these cells contain genes and proteins that interact with one another in a dense web of cooperation and control, of feedback and inhibition. If Darwin could have seen the molecular complexity of the eye, his shudder might well have turned even colder.

But before too long, the shudder would fade. As scientists have uncovered the biochemical intricacies of the eye, they've also made great strides in understanding how it has evolved. In the process, they've come face-to-face with evolution's remarkable laziness. Instead of giving rise to entirely new genes, evolution has in many cases simply borrowed old ones.



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Sharing solutions is our way of sharing the best of all human endeavor.

Sincerely,

Walter B. Kielholz
Chief Executive Officer
Swiss Re

The story of this discovery begins in the 1960s, when scientists started to study the molecules that make up one important part of the vertebrate eye, the lens. The lens is essentially a blob of clear skin cells. As an embryo develops, a patch of cells on each side of its head begins to differentiate from the surrounding tissue. These cells start producing protein molecules called crystallins, which make up 90 percent of the protein in the lens. Soon the cells become little more than bags of crystallin.

Thanks to their structure, crystallins make a lens act as if it were made of glass. They bend the light as it passes through, and because they pack tightly together in an orderly way, rather than sticking together in irregular clumps, they don't scatter the rays randomly. Crystallins are also incredibly tough—and they need to be, because they can't be replaced once they've been formed. They are the longest-lived proteins in the body; many of the crystallins in the eyes of a centenarian were there when he or she was an embryo. If they become damaged and start clumping together, cataracts form.

When scientists first began investigating various vertebrate lenses, they expected to find at most just a few kinds of crystallins. Other molecules that carry out equally specialized jobs—light-sensitive rhodopsin in the retina, for example, and oxygen-ferrying hemoglobin in red blood cells—are pretty much identical in any vertebrate you care to examine, from a parrot to a python. But by the 1970s it became evident that crystallins are unusual in this respect: they come in a surprising variety of different structures, each of which interacts with light in a unique way. And the different crystallins are not mixed together randomly; as the lens grows, it builds up rings like an onion, and each new ring is made up of distinctive proportions of the various crystallins. These different combinations give each ring the ability to bend light at a particular angle. As a result, the entire lens can focus light onto a small spot on the retina.

If not for genetic switches, our bodies would be a mess. Red blood cells might be filled with bone instead of hemoglobin; our teeth might be made of hair instead of enamel.

But an even bigger surprise was in store for researchers. It turns out that certain vertebrates possess unique types of crystallins, present in no other eyes. Birds and reptiles, for example, all have lens proteins (dubbed delta-crystallins) that mammals and amphibians lack. Amphibians have crystallins of their own, as do mammals. These discoveries hinted that the vertebrate eye has had a turbulent evolutionary history.

The fossil record suggests that the first full-blown vertebrate eye arose 530 million years ago in a primitive fish. As the fish's descendants diverged into new forms, new crystallins evolved in their eyes. Birds and reptiles, for example, descend from a common ancestor that lived about 300 million years ago—an ancestor that amphibians and mammals do not share—and this ancient creature presumably evolved delta-crystallins and passed them on to its descendants. New crystallins did not simply evolve as minor variations on old ones, however. Biologists can group the proteins into distinct "families," and these families bear little resemblance to one another. Somehow, evolution devised transparent proteins again and again.

A clue to how this reinvention took place came in the 1980s, when scientists learned how to read the sequence of amino acids in crystallins. They discovered that alpha-crystallins, which are found in all vertebrate eyes, are

strikingly similar to the common molecules known as heat-shock proteins. Heat-shock proteins help other proteins function at high temperatures and under other kinds of stress. Without the help of heat-shock proteins, a stressed-out protein may unfold and lose its intricate shape. But a heat-shock protein can cradle other proteins and protect them from assaults on their structure. Heat-shock proteins are crucial to every organism on earth; in our own bodies they are at work in almost every cell.

Before long, researchers found that, just as alpha-crystallins have a similarity to heat-shock proteins, other families of crystallins bear a striking similarity to other common proteins. Their closest matches are enzymes that help with the basic metabolism of cells. Some of these enzymes turn food into energy, while others detoxify poisonous wastes that would otherwise build up in the blood.

At first, scientists had only a rough idea of the similarity between crystallins, on the one hand, and these enzymes and heat-shock proteins on the other. But by the end of the 1980s they had an answer, and a surprising one at that. In many cases, a crystallin and its related protein aren't produced by two similar genes; both are encoded by a single gene.

These double-duty genes did not start out making crystallins. Heat-shock proteins can be found not just in mammals but in other animals as well as in plants and microbes. They must have evolved early in the history of life, long before eyes came into existence. The same goes for the crystallin-like metabolic enzymes. So how could proteins adapted for these primitive sorts of functions later wind up moonlighting as transparent crystallins? The gulf may seem wide, but the evolution required to cross it is actually minimal.

A gene consists of more than just a code for building a specific protein. At the beginning of its sequence are short stretches of DNA that act like on-off switches. The gene's code can be read only if certain proteins grab onto its switches and activate the gene, and these particular proteins are produced only under particular circumstances. This system guarantees that genes will become active only at the right place and the right time. If not for these switches, our bodies would be a proteinaceous mess. Red blood cells might be filled with bone instead of hemoglobin; our teeth might be made of hair instead of enamel.

As scientists have uncovered the biochemical intricacies of the lens, they've come face-to-face with evolution's remarkably lazy habit of building new structures with old genes.

Because these switches are made of DNA, they can mutate like any other part of a gene. In one common kind of mutation, these switches are accidentally sliced off one gene and pasted onto another. Getting an extra switch this way gives the recipient gene the power to become active under an additional set of conditions. This seems to be how lens crystallins came into existence. Some of the genes that make heat-shock proteins and metabolic enzymes accidentally picked up extra switches, and as a result they started to become active inside the cells of developing eyes.

In most cases, these moonlighting genes produced proteins whose structure was poorly suited for a lens. But in a few cases, they made a protein that could bend light without absorbing it. At first the protein may not have done a very good job, but even a lousy crystallin is sometimes better than none at all. Natural selection would have favored these genes with their new switches, and they would have become widespread. Through later mutations, these genes might have produced proteins better adapted to the eye, with a structure that was more durable or that improved their owner's eyesight.

But Graeme Wistow and Joram Piatigorsky, two crystallin experts with the National Eye Institute of the U.S. National Institutes of Health, have pointed out that such two-switch genes may face a conflict of interest. Say that a detoxification gene has a part-time job producing lens crystallin. A mutation that improves the crystallin—making it more durable, for example—could make the protein do a worse job at detoxifying cells. The benefit brought by the mutation might not be favored by natural selection because of the harm it caused at the same time. This trade-off, which Wistow and Piatigorsky have dubbed "adaptive conflict," may make genes evolve more slowly than scientists would otherwise expect.

A striking example of this sort of adaptive conflict can be found in the blind mole rat (superspecies *Spalax ehrenbergi*), which lives in dark underground tunnels in the Middle East. This mammal's ancestors began living underground about 40 million years ago and probably lost the ability to see fairly soon thereafter. As an embryo, a blind mole rat begins to develop eyes, but they quickly degenerate and get buried in the surrounding tissue. If a blind mole rat acquires a mutation that damages one of its lens genes, it won't pay a penalty. So you'd expect that after millions of years underground, a lot of mutations would have accumulated in *Spalax*'s crystallin genes.

Yet that's not the case. The crystallin produced in the blind mole rat's eyes is still surprisingly similar to the crystallin found in the eyes of other rodents that can still see. The genes haven't changed much, apparently because they remain active in other parts of *Spalax*'s body. They must provide some other sort of

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Wistow and Piatigorsky have suggested that one escape from an adaptive conflict is for a crystallin gene to get duplicated. It's relatively common for an extra version of a gene to be accidentally produced while DNA is being copied. Once there are two copies of a shared gene, one of them can become better adapted for one job, while the other can devote itself to the second. This seems to have happened many times over in the vertebrate lens. It's not unusual for scientists to come across two versions of a crystallin gene, one of which still makes its protein in other parts of the body, and a nearly identical copy that is active only in the lens.

If you tinker with a gene to cure a defect in one part of the body, you may discover that the gene plays a different role elsewhere in the body and that its important function there is damaged by the gene therapy.

Scientists are finding that evolution has borrowed genes to create new crystallins many times in the history of life—not only in vertebrates but also in squid, octopuses, and insects. Invertebrates have radically different kinds of eyes; insect eyes, for example, are made up of hundreds or thousands of columns, each of which captures a tiny fragment of the surroundings. To fill those columns with crystallins, insects have borrowed the gene for one of the proteins in their exoskeleton. Scientists have even found shared genes making crystallins in the eyes of jellyfish, although these eyes—tiny photoreceptors connected not to a brain but to the surrounding muscles—barely fit the meaning of the word.

Once vertebrate and invertebrate eyes were established hundreds of millions of years ago, evolution continued borrowing genes and fine-tuning them for new situations. For example, fish have hard lenses focused for seeing at close range, which makes them well suited to the ocean, where visibility is limited. When vertebrates came on land, they acquired new crystallins that softened up their lenses and allowed them to focus on objects much farther away.

One of the most fascinating examples of a newly borrowed lens gene can be found in the eyes of geckos. Perhaps 100 million years ago, the ancestors of today's geckos became nocturnal predators. Their eyes changed dramatically in the process. Their pupils became permanently locked at their widest opening, and their eyelids fused to their eyes to become transparent spectacles. (Unable to blink, geckos use their tongues to clean their eyes.) Later on, a few lineages shifted back to life in the sun. Their descendants can be found in Africa, the Middle East, and Latin America. Living in deserts and other open spaces, they are bombarded by damaging ultraviolet rays. But as a result of their nocturnal heritage, they can't use their eyelids to shade their eyes, nor can they narrow their pupils to cut down on the ultraviolet rays.

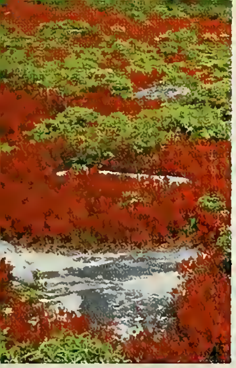
Beate Röll, a biologist at Ruhr-Universität Bochum in Germany, and her colleagues have discovered the gecko's solution: just borrow another gene. The one in question, named *CRBP1*, makes a protein (found in all animals) that can store vitamin A and ferry it around a cell. Röll discovered that in several different gecko lineages, *CRBP1* has been slightly altered to produce new crystallins. Thanks to their structural heritage, these proteins can hold on to a version of vitamin A, which absorbs ultraviolet rays. Equipped with the new crystallins, the lens acts as a filter, shielding the eye from harmful radiation and letting visible light pass though.

Röll has shown that after the *CRBP1* gene was co-opted by the gecko eye, it adapted to its new role by producing a more compact protein, one that may last longer and refract light more effectively. But these changes haven't interfered with the protein's old job as a vitamin ferry; Röll can detect the gene at work within other organs in the gecko.

The remarkable history of crystallins offers many important insights. By tracing how crystallins have come into existence, scientists can learn how they function in the eye. It turns out, for example, that some crystallins descended from heat-shock proteins may still be able to help protect other proteins in the lens from stress. At the same time, the story of double-duty proteins such as crystallins should be taken as a warning by those who hope to treat diseases with gene therapy. One can't assume that each gene does only one job. If scientists try to cure a defect in one part of a patient's body by tinkering with a faulty gene, they may be surprised to discover that the gene actually plays a completely different role in another part of the body—and this role may be compromised by the therapy.

But the most profound lesson is that evolution works in quirky ways. Almost half our genes are duplicates, and many of them have been copied so often that they now form giant gene families. The kinds of gene borrowing and adaptive conflict that have created our lenses have probably been at work throughout our bodies. This sort of evolution is both playful and pragmatic: it experiments with new uses for existing genes and leaves the precision tuning for later. It's enough to turn a cold shudder into a smile.

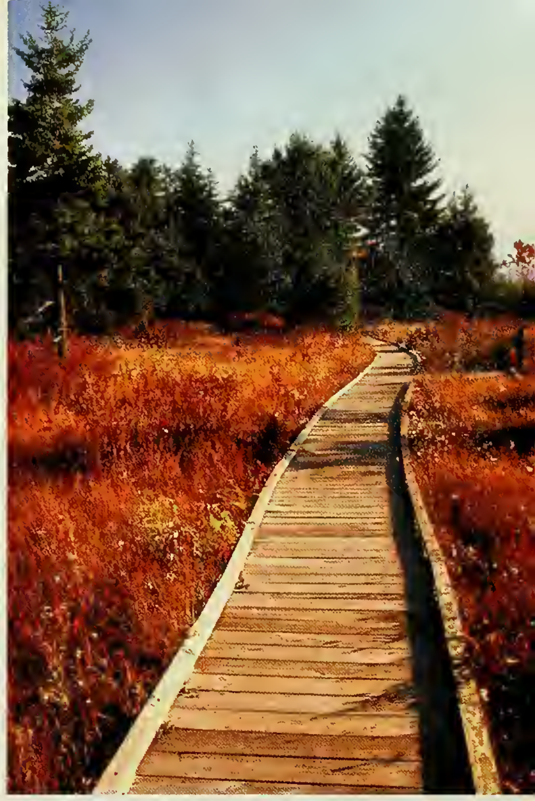
Science writer Carl Zimmer is the author of Evolution: The Triumph of an Idea *(HarperCollins, 2001). His book* Parasite Rex: Inside the Bizarre World of Nature's Most Dangerous Creatures *has recently been published in paperback.*



Cranberry Glades

West Virginia

This spring as the snow begins to melt, discover the beauty of West Virginia.



Dolly Sods

Whitewater rafting is an amazing way to see this beautiful state, and the rivers of **Southern West Virginia** (800-VISIT-WV) offer some of the best whitewater rafting east of the Colorado. Take a trip down the "Grand Canyon of the East," the New River, or challenge the rapids of the mighty Gauley River. When swollen by spring rains, the Bluestone provides an exhilarating class I through IV ride through a spectacular narrow gorge.

For a bit of history, visit the coal mining towns of Thurmond and Beckley. In Beckley, you can ride a "man trip" car guided through the Beckley Exhibition Coal Mine by veteran miners for an authentic view of low-seam coal mining.

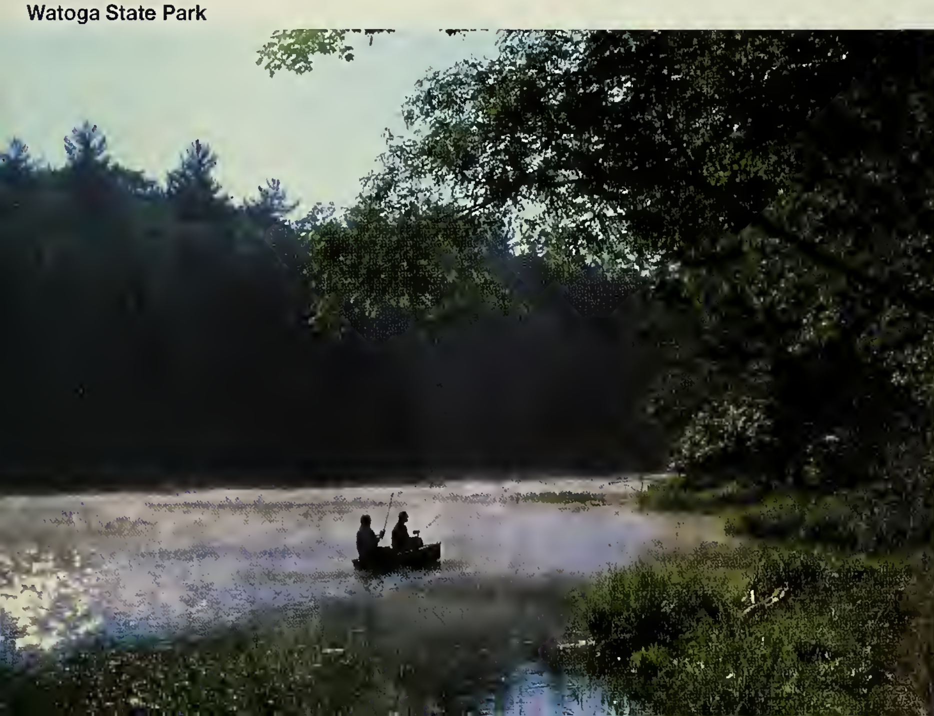
The Glade Springs Resort (800-634-5233), just eight miles from Beckley, is one of West Virginia's most relaxing getaways. Golfers won't want to miss the sprawling highland plateau course, designed by George W. Cobb, with forty-eight sand bunkers, eight lakes, and rolling fairways bordered with majestic maples, oaks, and native pines. Guests at the resort may also enjoy horseback riding, mountain biking, or hiking along twenty-six miles of backcountry trails.

Outdoor enthusiasts will enjoy hiking and biking along the Greenbrier River Trail in **Greenbrier County** (800-833-2068), a seventy-five-mile trail along a former railroad route built at the turn of the century to serve the booming timber industry. The trail passes through numerous small towns as well as thirty-five bridges and two tunnels. For most of its length, it runs directly adjacent to the beautiful Greenbrier River. For lodging in this county, try the award-winning Greenbrier Resort (800-453-4858) in the scenic Allegheny Mountains.

During your stay, take a canoe trip along the Greenbrier River, which flows through **Pocahontas County** (800-336-7009), meandering through some of the most beautiful country in the United States. Or you might try some fishing in one of Pocahontas County's eight rivers or countless streams. These cold, clear streams and rivers offer the finest trout fishing in the state, and many are on the state trout-stocking program.

The Mid-Ohio Valley features an intriguing blend between the western frontier and the Victorian legacies of the nation's oil and gas boom. Here, within the rolling foothills of the Appalachian Mountains, you'll find charming villages such as **Parkersburg** (800-752-4982), nestled along the Ohio River. Stop by the town's many historical sites and museums, tour a handcrafted glass factory, and take a ride on a stern wheeler. Make your home base at the Historic Blennerhassett Hotel (800-262-2536) and visit Blennerhassett Island Historical Park.

Watoga State Park



Photos: Stephen J. Shaluta

West Virginia's largest state park, **Watoga**, is a sprawling woodland located in the Allegheny highlands of Pocahontas County. The Monongahela National Forest, with more than 909,000 acres, includes **Cranberry Glades**, whose unique plants are descended from seeds that took root over 10,000 years ago, and **Dolly Sods**, known for its extensive rocky plains, upland bogs, and sweeping vistas.

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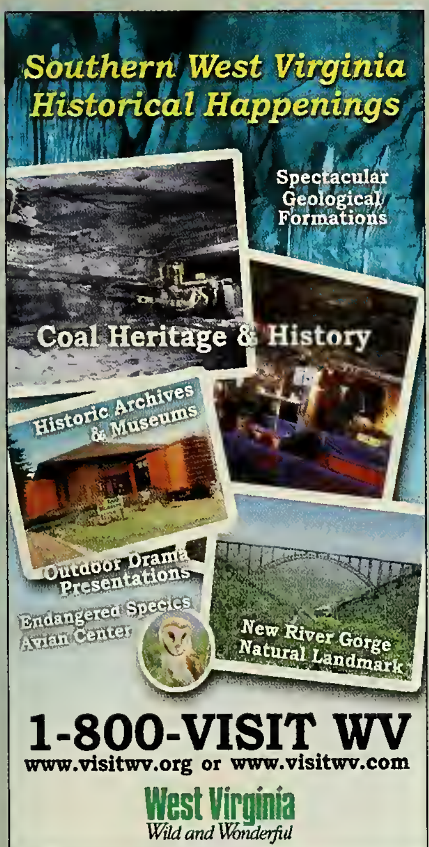

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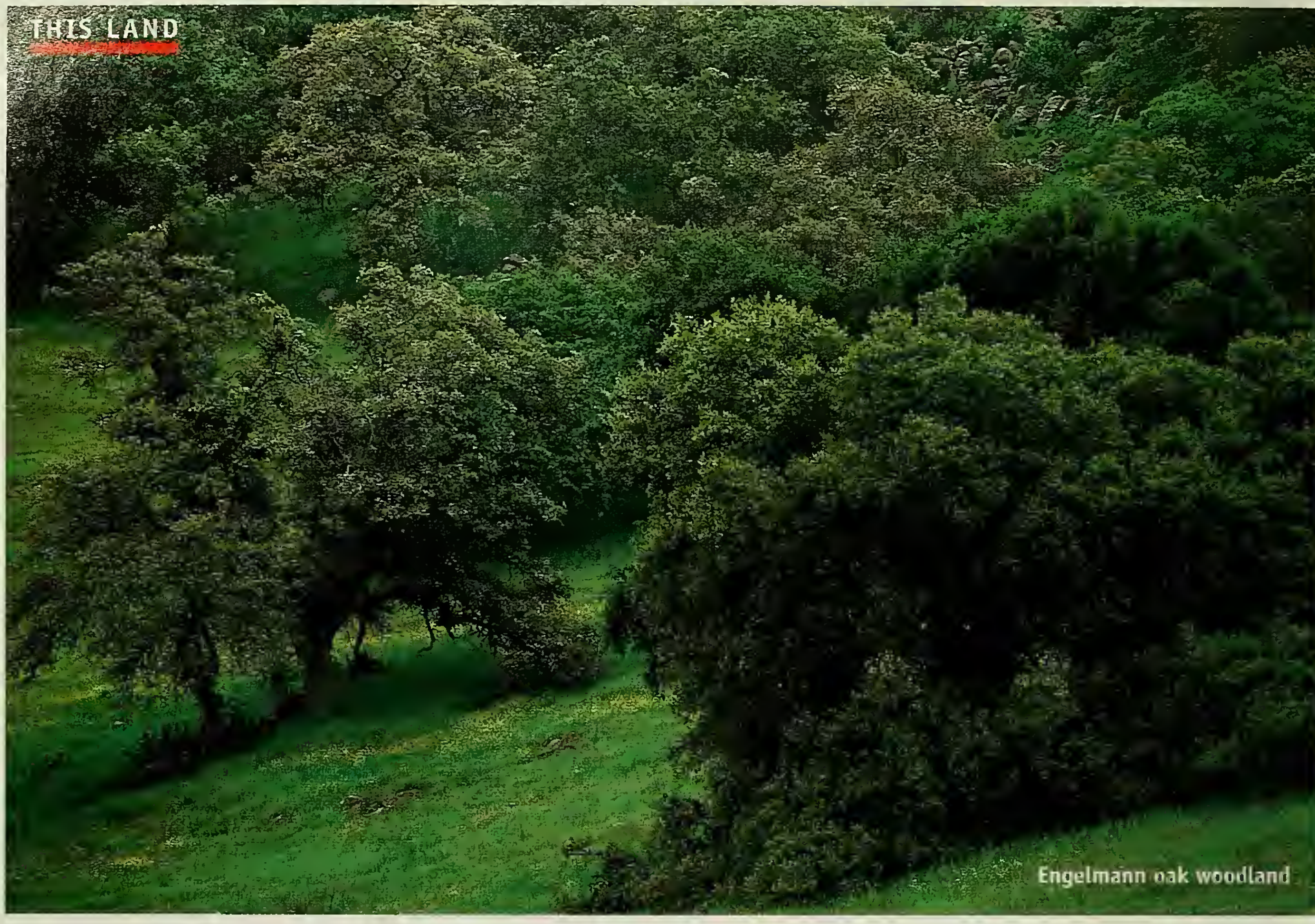

RICHARD HERRMANN

Engelmann oak woodland

Parks and Pools

A southern California reserve protects vanishing habitats.

By Robert H. Mohlenbrock

Southeast of Los Angeles, the Santa Ana Mountains extend northwest to southeast for approximately forty miles. Though the Santa Anas' highest point is 5,687-foot Santiago Peak, the elevation along the crest of this narrow range averages about 3,800 feet. At its southern end, the terrain drops down to the Santa Rosa Plateau, a 2,000-foot-high tableland with canyons, mesas, and low hills. Much of the land is capped by basalt from ancient lava flows, but outcroppings of granite and shale appear throughout the plateau.

One attraction of the area is its animal life. Most likely to be seen are red-tailed hawks, American kestrels, Aleutian Canada geese, and golden eagles. Bobcats, foxes, and mountain lions are present but more secretive. The coastal rosy boa, a gray snake with brown longitudinal stripes, occasionally shows itself. Rare species include the Pacific pond turtle, the California red-legged frog, the California newt, and the California tree frog.

The jewels of the plateau are two habitats—Engelmann oak woodland and vernal (springtime) pools—that are now quite rare elsewhere in southern California as a result of suburban development. Fortunately, more than half of the twenty-three-square-mile plateau is protected as the Santa Rosa Plateau Ecological Reserve. This reserve, for which land was acquired beginning in 1984, is a cooperative management project of the Nature

JOE LEMONNIER

Goldfields bloom around a vernal pool.

GEORGE OSTERTAG

Conservancy, the Riverside County Regional Park and Open-Space District, the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the Metropolitan Water District of Southern California.

The Engelmann oak woodland, located near the base of the hills, has a parklike appearance. Enough moisture is available below ground to support the canopy of trees, but the habitat is generally so dry that the undergrowth consists largely of grass.

Thirteen vernal pools, ranging in size from a quarter acre to nearly twenty-five acres, develop mostly on the tops of mesas. They fill with water during winter storms, and since the hardpan beneath them prevents drainage, they dry up only through evaporation. As the pools gradually shrink during the warm days of spring and early summer, successive waves of annual wildflowers bloom along their margins. By late July or early August, these die out, and all that is left of the vernal pools are cracked, dry depressions.

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

For visitor information, contact:
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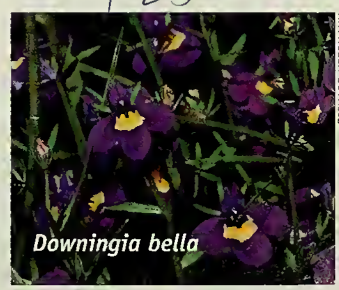
(909) 677-6951
www.santarosaplateau.org

HABITATS

Engelmann oak woodland. Engelmann oaks, with their oblong, wavy-edged leaves, are joined by coastal live oaks, with elliptical, smooth-edged leaves. Deergrass is the main species in the understory. Shrubs: holly-leaf cherry, sugar bush, laurel sumac, white-flowered currant, *Acourtia microcephala*. Wildflowers: Parry's larkspur, flax-leaved linanthus, lace pod, two lavender-flowered species of *Phacelia*.

Vernal pools. In spring, the wetter margins are dominated by *Downingia bella* and *D. cuspidata,* two blue-flowered species in the same family as bellflowers. In drier, outer zones grow rings of *Blennospermum nana* and goldfields; both are members of the aster family, with daisylike yellow flower heads. Two diminutive plants—pillwort, a grasslike fern that grows in the drier zones, and waterwort, a plant with spatula-shaped leaves that is found in some of the vernal pools—are species that live in this California habitat as well as in Chile, but not in between. In the vernal pools, along with the waterwort, grows San Diego button celery, a dwarf member of the carrot family.

Grassland. Deergrass, purple needlegrass, and Malpais bluegrass are the principal species. Wildflowers: grape soda lupine, lilac Mariposa lily, checker mallow, California blue-eyed grass (not actually a grass but a plant in the iris family).



Downingia bella

RICHARD HERRMANN

Chaparral. The slopes of some hills and mesas support a community of shrubs and wildflowers; the only tree of significance is scrub oak. At the higher elevations, manzanita is the abundant shrub, while midslope shrubs include chamise, coffeeberry, redberry, and two kinds of mountain mahoganies. Near the bottom, California buckwheat and California sagebrush dominate. Wildflowers: various penstemons and lupines.

Streamside and aquatic habitats. Watercourses flow seasonally through the major canyons. Within the streams are deep pools, called *tenajas,* that persist throughout most years. Sedges, rushes, and cattails border the streams. Whitewater crowfoot and the tiny aquatic mosquito fern grow in the water, while monkeyflower is common nearby. Trees: western sycamore, red willow, Fremont's cottonwood.

UNIVERSE

The Five Points of Lagrange

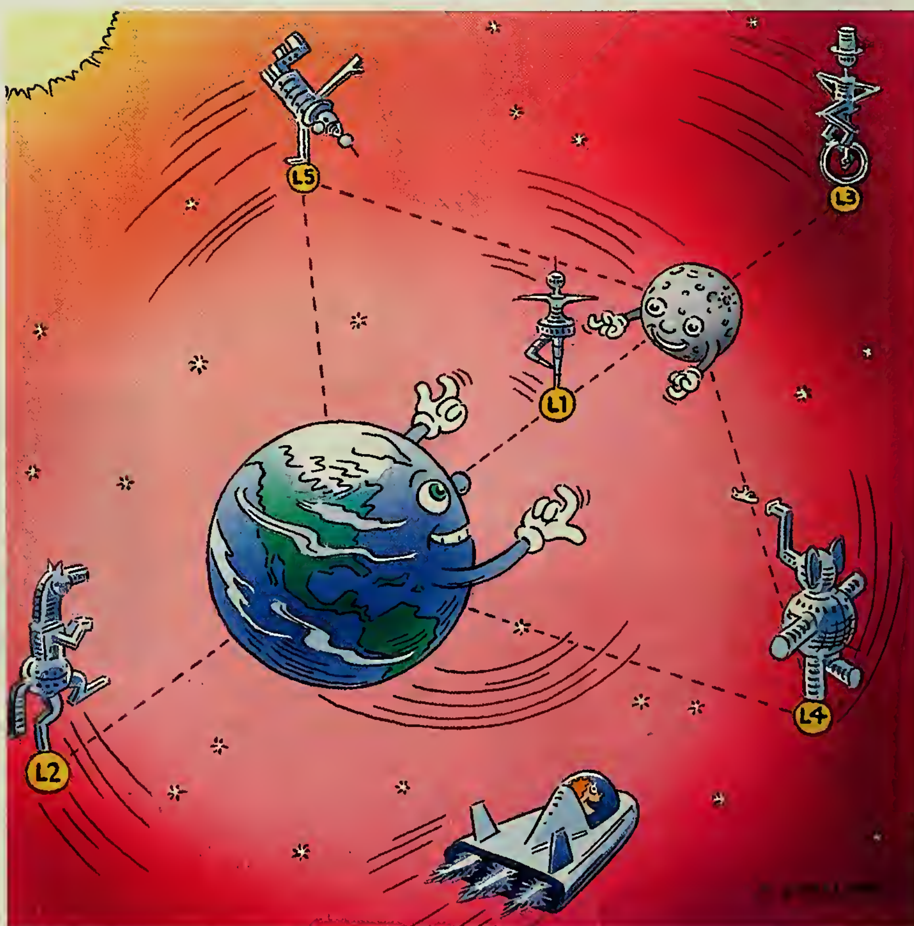
At some very special spots in the Earth-Moon gravitational system, all forces are in balance.

By Neil deGrasse Tyson

The first manned spacecraft ever to leave Earth orbit was *Apollo 8*. This achievement remains one of the most unappreciated firsts of the twentieth century. When that moment arrived, the astronauts fired the third and final stage of their mighty Saturn V rocket, and the spacecraft and its three occupants rapidly reached a speed of nearly seven miles per second. Half the energy needed to reach the Moon had already been expended just to achieve Earth orbit. At about the same moment, a well-known television news anchor declared that the astronauts had just left Earth's gravity. But the astronauts were on their way to the Moon. And last anybody had checked, the Moon was in orbit around Earth by the action of mutual gravitational forces. So Earth's gravity must extend at least as far as the Moon. Fact is, the force of gravity for any object extends to the infinite reaches of space, even as it grows ever weaker.

After the third stage fired, engines were no longer necessary except to tune the midcourse trajectory so that the astronauts did not miss the Moon entirely. For most of its nearly quarter-million-mile journey from Earth to the Moon, the spacecraft gradually slowed as Earth's gravity continued to out-tug the Moon's gravity. Meanwhile, as the astronauts neared the Moon, *its* force of gravity was growing stronger and stronger. Obviously, a spot must exist, en route, where the Moon's and Earth's opposing forces of gravity balance precisely. When the command module drifted across that point in space, its speed increased once again, and it accelerated toward the Moon.

If gravity were the only force to be reckoned with, then this spot would be the only place in the Earth-Moon system where the opposing forces cancel. But Earth and the Moon orbit a common center of gravity, which lives about a thousand miles beneath Earth's surface along the length of an imaginary line connecting the center of Earth to the center of the Moon. When objects move in circles of any size and at any speed, they create a new force that pushes outward, away from the center of rotation. Your body feels this "centrifugal" force when you make a sharp turn in your car or when you survive amusement park attractions that turn in circles. In a classic example of these nausea-inducing rides, you stand along the edge of a large circular platter, with your back against a perimeter wall. As the thing spins, rotating faster and faster, you feel a stronger and stronger force pinning you against the wall. It's the



ROBERT GROSSMAN

sturdy wall that prevents you from being flung through the air. Soon you can't move. That's when they drop the floor from below your feet and turn the thing sideways and upside down. When I rode one of these as a kid, the force was so great that I could barely move my fingers: they stuck to the wall along with the rest of me.

If you actually got sick on such a ride and you turned your head sideways, the vomit would fly off at a tangent. Or it might get stuck to the wall. Worse yet, if you didn't turn your head, it might not make it out of your mouth, owing to the extreme centrifugal forces acting in the opposite direction. (Come to think of it, I haven't seen this particular ride anywhere lately; I bet they've been outlawed.)

Centrifugal forces arise as the simple consequence of an object's tendency to travel in a straight line after being set in motion, and so are not true forces at all. But you can use them in calculations as though they were. When you do, as the brilliant French mathematician Joseph-Louis Lagrange (1736–1813) did, you discover spots in the rotating Earth-Moon system where the gravity of Earth, the gravity of the Moon, and the centrifugal forces of the rotating system all balance. These special locations are known as the points of Lagrange, and there are five of them.

The first point of Lagrange (affectionately called L1) falls slightly closer to Earth than the point of pure gravitational balance. Any object placed at L1 can orbit the Earth-Moon center of gravity with the same monthly period as the Moon's orbit and will appear to be locked in place along the Earth-Moon line. Although all forces cancel there, L1 is a point of precarious equilibrium. If the object drifts away from the Earth-Moon line in any direction, the combined effect of the three forces will return it to its former position. But if the object drifts along the Earth-Moon line ever so slightly, it will irreversibly fall toward either Earth or the Moon. It's like a cart atop a mountain, barely balanced, a hair's width away from falling down one side or the other.

The second and third Lagrangian points (L2 and L3) also lie on the Earth-Moon line, but L2 lies far beyond the Moon, while L3 lies far beyond Earth in the opposite direction. Once again, the three forces—Earth's gravity, the Moon's gravity, and the centrifugal forces of the rotating system—cancel in concert. And once again, an object placed in either spot can orbit the Earth-Moon center of gravity in a lunar month.

Lagrangian points 4 and 5 represent areas where one might decide to establish space colonies.

The gravitational balance points at L2 and L3 are quite broad. So if you find yourself drifting down to Earth or the Moon, a tiny investment in fuel will bring you right back to where you were.

Although L1, L2, and L3 are respectable space places, the award for best Lagrangian points must go to L4 and L5. One of them lives far off to one side of the Earth-Moon centerline, while the other lives far off to the opposite side; each represents one vertex of an equilateral triangle, with Earth and the Moon serving as the other two vertices. At L4 and L5, as with their first three siblings, forces are in equilibrium. But unlike the first three Lagrangian points, which enjoy only unstable equilibrium, the equilibria at L4 and L5 are stable: no matter which direction you lean, no matter which direction you drift, the forces prevent you from leaning farther, as though you were at the bottom of a bowl-shaped crater surrounded by a high, sloped rim. For each of the Lagrangian points, if an object is not located exactly where all forces cancel, then its position will oscillate around the point of balance in paths called librations. (Not to be confused with the particular spots on Earth's surface where one's mind oscillates from ingested libations.) These librations are equivalent to the back-and-forth path a ball takes when it rolls down one hill yet doesn't pick up enough speed to climb the next.

More than just orbital curiosities, L4 and L5 represent special areas where one might decide to establish space colonies. All you need do is ship some raw construction materials (mined not only from Earth but perhaps from the Moon or an asteroid) to the area; leave them in place, since there's no risk of their drifting away; and return later with more supplies. After all the raw materials are collected in this zero-G environment, you could build an enormous space station—tens of miles across—with very little stress on the construction materials. By rotating the station, you induce centrifugal forces that can simulate Earth gravity for its hundreds (or thousands) of residents and their farm animals. Space enthusiasts Keith and Carolyn Henson founded the L5 Society in 1975 for just that purpose, although the society is best remembered for its informal association with Princeton physics professor Gerard K. O'Neill, who promoted space habitation through such visionary writings as his 1976 book *The High Frontier: Human Colonies in Space.* The L5 Society was founded on one guiding principle: "to disband the Society in a mass meeting at L5." Presumably this would be done inside a space habitat during a party in celebration of their mission accomplished. In 1987 the L5 Society merged with the National Space Institute to become the National Space Society, which continues today.

The idea of locating a large structure at libration points appeared as early as 1961, in Arthur C. Clarke's novel *A Fall of Moondust*. Indeed, Clarke was no stranger to special orbits. In 1945 he was the first to calculate, in a four-page, hand-typed memorandum, the altitude above Earth's surface at which a satellite's orbital period would exactly match the twenty-four-hour rotation period of Earth. A satellite with that orbit "hovers" over Earth's surface and can thus serve as an ideal relay station for radio communications from one part of Earth to another. Today, hundreds of communication satellites do just that. How high is this magical place? Objects in low Earth orbit, such as the Hubble Space Telescope and the International Space Station, take about ninety minutes to circle Earth. Objects at the distance of the Moon take about a month. Logically, an intermediate distance must exist where an orbit of twenty-four hours can be sustained. That distance lies about 22,000 miles above Earth's surface.

Actually, there is nothing unique about the balance points in the rotating Earth-Moon system. Another set of five Lagrangian points exists for the rotating Sun-Earth system (as well as for any pair of orbiting bodies anywhere in the universe). The Sun-Earth Lagrangian points all take a year to orbit the Sun-Earth center of gravity. For objects in low orbits, such as the Hubble, Earth continuously blocks a significant chunk of the view. However, a million miles from Earth, in the direction opposite that of the Sun, a telescope at the Sun-Earth L2 will have a twenty-four-hour view of the night sky, because it would see Earth at about the size we see the Moon in Earth's sky. The recently launched *Microwave Anisotropy Probe* (*MAP* for short) reached L2 for the Sun-Earth system in a couple of months and is now librating there, busily taking data on the cosmic microwave background—the omnipresent signature of the big bang itself. Having set aside a mere 10 percent of its total fuel, the *MAP* satellite has enough to hang around this point of unstable equilibrium for nearly a century.

The next-generation space telescope, now being planned by NASA as the follow-on to the Hubble, is also being designed for the Sun-Earth L2 point. And there is plenty of room for more satellites to come: the real estate for the Sun-Earth L2 occupies more than a quadrillion cubic miles.

Another Lagrangian-loving NASA satellite, known as *Genesis*, will librate around the Sun-Earth L1 point. This L1 lies a million miles out between Earth and the Sun. For two and a half years, *Genesis* will face the Sun and collect pristine solar matter, including atomic and molecular particles from the solar wind. A canister containing this captured stardust would then return to Earth to be studied for its isotopic composition, providing a window to the contents of the original solar nebula from which the Sun and planets formed.

Trojan asteroids are locked in place by the gravitational and centrifugal forces of the Sun-Jupiter system.

Given that L4 and L5 are stable points of equilibrium, one might suppose that space junk would accumulate near them, making it quite hazardous to conduct business there. Lagrange, in fact, had predicted that space debris would be found at L4 and L5 for the gravitationally powerful Sun-Jupiter system. A century later, in 1905, the first of the Trojan family of asteroids were discovered. We now know that for L4 and L5 of the Sun-Jupiter system, thousands of asteroids follow and lead Jupiter around the Sun, with periods that equal one Jovian year. As though they were gripped by tractor beams, these asteroids are forever held in place by the gravitational and centrifugal forces of the Sun-Jupiter system. (These asteroids pose no risk to life on Earth or to themselves, being stuck in the outer solar system and out of harm's way.) Of course, we would expect space junk to accumulate at L4 and L5 of the Sun-Earth and Earth-Moon systems, too. And it does.

As an important side benefit, interplanetary trajectories that begin at Lagrangian points require very little fuel to reach other Lagrangian points or even other planets. Unlike a launch from a planet's surface, where most of your fuel goes to lift you off the ground, a Lagrangian launch would be a low-energy affair and would resemble a ship leaving dry dock—cast into the sea with a minimal investment of fuel. Today, instead of thinking about establishing self-sustained Lagrangian colonies of people and cows, we can think of Lagrangian points as gateways to the rest of the solar system. From the Sun-Earth Lagrangian points, you are halfway to Mars—not in distance or time but in the all-important category of fuel consumption.

In one version of our space-faring future, imagine fuel stations at every Lagrangian point in the solar system, where travelers refill their rocket tanks en route to visit friends and relatives living on other planets or moons. This mode of travel, however futuristic it sounds, is not without precedent. If it were not for the gas stations scattered liberally across the United States, your automobile might require the proportions of the Saturn V rocket to drive coast to coast: most of your vehicle's size and mass would be fuel, guzzled primarily to transport the yet-to-be-consumed fuel for your cross-country trip. We don't travel that way on Earth. Perhaps the time will come when we no longer travel that way through space.

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

All for One

In southern Africa, thousands of Cape buffalo offer a lesson in the ups and downs of group living.

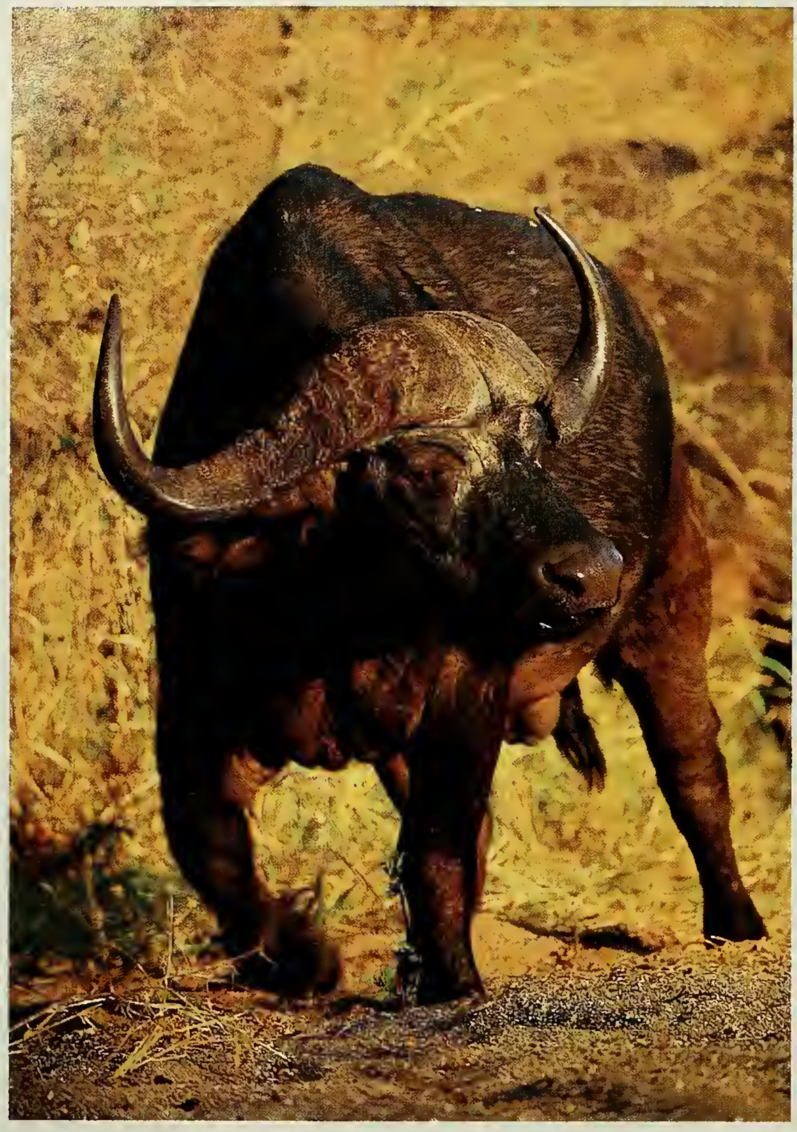
Photographs by Adrian Bailey URORA ~ *Text by Robyn Keene-Young*

Above: A buffalo herd may contain as many as 3,000 animals. Below: On a late afternoon, a herd trudges out of shady scrub woodlands before plunging into the Chobe River to head for an evening's grazing on islands that emerge during the dry season. Right: In the Mala Mala Game Reserve, the distress bellow of a buffalo cow downed by a lion alerts the herd to her plight. Snorting and bawling, herd members repeatedly rush the lion, which eventually retreats.

At the height of the dry season in Botswana's Chobe National Park, when the hot, desiccated land resembles a nuclear test site, thousands of African, or Cape, buffalo *(Syncerus caffer)* find relief along the floodplain of the Chobe River. As dusk falls over this wasteland, I marvel at a single herd of more than 2,000 buffalo trudging past me in a dark ribbon of black coats and hooked horns, en route to a river crossing that will take them into neighboring Namibia. Thousands of legs, like a giant millipede crawling across the floodplain, kick up puffs of blush-colored dust. Here and there, immature bulls fall out of the procession to knock horns in friendly contests that hone their fighting skills. Clouds of oxpeckers chirp above the buffalo, while cattle egrets, a series

of white splashes, rise and fall at their feet. On the fringe of the floodplain, a pride of lions waits to pick off old, lame, or sick buffalo struggling to keep pace with the herd. (Lions, the buffalo's major predator, are seldom able to catch an adult that is within the herd.)

Buffalo will go to great lengths to protect one of their own from attack as they run the gauntlet through lion territory during daily treks to and from water and grazing areas. A single buffalo distress bellow is enough to turn a docile, ruminating herd into a battalion of warriors, ready to charge and chase off an entire pride of lions. Battles between them can last several hours, until the demise of a buffalo or the defeat of a lion signals the end.



Even a lone buffalo can be intimidating for would-be attackers, and nineteenth-century European hunters were quick to include the species on their "big five" list of dangerous quarry. Shooting parties that wounded an animal often did not stalk it to finish it off, knowing that to do so could be fatal for the hunters.

In recent years, the buffalo has been canonized by the safari set as an animal of supernatural strength, famous for being undaunted by lions and for its readiness to defend itself at all costs.

Singularly bullish: A male, above, typically reaches sexual maturity by age five and a half, but is prevented from mating for at least another eighteen months by older, high-ranking bulls. Below: Birds such as the red-billed oxpecker thrive on the skin-dwelling parasites hosted by buffalo. Right: The animals not only graze together but huddle in groups while resting, habits that allow airborne pathogens, such as the one that causes bovine tuberculosis, to move quickly through a herd.

Despite the buffalo's strength, however, this cousin of the North American bison is plagued by a multitude of parasites and diseases—a characteristic that has earned it the hostility of the region's cattle farmers. Because of their bovine family ties, cattle and buffalo turn out to be vulnerable to many of the same pathogens, such as foot-and-mouth disease and bovine tuberculosis. South Africa's national veterinary service has responded by confining buffalo to pockets where game-proof fences check the threat of transmission to domestic animals.

To reintroduce buffalo into parts of their former range, South African National Parks and several commercial breeding operations have initiated ambitious projects and have successfully produced agriculturally friendly, disease-free buffalo. As a result, the animal that the South African writer Laurens van der Post considered "a living expression of the inarticulate character of the African earth" is again grazing the grasslands where its ancestors once roamed. □

A Diverse & Marvelous Collection

By Irmgard Müsch, Rainer Willmann, and Jes Rust

THREE CENTURIES AGO, SAILORS CALLING AT THE BUSY PORT OF AMSTERDAM WERE COMMISSIONED BY A LOCAL APOTHECARY TO BRING BACK NATURAL CURIOS FROM DISTANT LANDS.

Albertus Seba, below, in a contemporary painting. Right: An American crocodile and an unidentified lizard. Like most images in Seba's *Thesaurus*, these were based on dead specimens.

Albertus Seba, an apothecary in early-eighteenth-century Amsterdam, was proud indeed of his collection of natural history specimens, or cabinet of curiosities. In a letter to a potential buyer, he wrote that it included "all sorts of exquisite pieces from the East and West Indies," among these no less than "700 jars containing the rarest exotic animals and many particularly rare snakes. Also brought together thus are every exceptional sort of beautiful and rare conch, the finest and most complete butterflies from the 4 corners of the Earth [and samples] of all the plants, some familiar pieces, but unfamiliar ones too." Seba commissioned several artists to meticulously record these diverse objects, and their drawings, supplemented by commentary, were collected in a magnificent

From Albertus Seba, Cabinet of Natural Curiosities. *Text by Irmgard Müsch, Rainer Willmann, and Jes Rust. Published by TASCHEN GmbH, 2001.*


Fig. 1.

Individual plates depicting diverse animals—such as reptiles and amphibians, above—were attempts to produce attractive symmetrical compositions. Right: Although from different parts of the world, a brown "four-eyed" opossum, a three-banded armadillo, a black-capped lory, and a king bird-of-paradise are grouped together in a single painting. In Seba's day, biogeographical principles had not yet been formulated.

four-volume set entitled *Loccupletissimi Rerum Thesauri Accurata Descriptio* (*Thesaurus* for short). The work incorporated an impressive total of 446 copperplates and was published between 1734 and 1765.

Cabinets of curiosities first began to appear in the courts of Italian princes in about 1500. They consisted of multifarious and disparate objects and attempted to bring together all knowable things. In the seventeenth and eighteenth centuries, the cabinets became more specialized; through the description, comparison, and ordering of their pieces, the collectors strove to reach a scientific understanding of nature.

Seba, born in 1665, had chosen a profession with close ties to natural history. Doctors and apothecaries were pioneers of the empirical sciences, and their passion for collecting and research often extended beyond immediate pharmaceutical applications. Many apothecaries started significant natural history collections and contributed personally to the growing knowledge of nature.

Amsterdam, the flourishing center of international maritime trade, was an ideal location for a collector of natural curios. One of Seba's favored tactics was to buy items from sailors who were just returning from distant seas; sometimes he commissioned a seafarer to bring back specific samples. The apothecary was part of an international network of scholars and researchers who exchanged information and debated questions without regard for social class or national boundaries. Seba's achievements were rewarded with membership in the Bologna Academy of Science and the Royal Society of London, among other honors.

We know the extent of Seba's first collection because of a fortunate transaction he made in 1717. Having learned of an impending visit by the Russian czar Peter the Great—who wanted to see the

Dutch Republic and at the same time shop for his own cabinet of wonders—the adroit apothecary sent the czar a written inventory of his collection, including such items as 72 drawers full of shells, 32 drawers displaying 1,000 European insects, and 400 jars of animal specimens preserved in alcohol. The sale took place, and Seba immediately set about establishing a second, even larger collection.

Exhibited in a specially designated room of his house, Seba's second cabinet became famous far afield. In 1731, he and two publishers agreed to produce a major work depicting the collection.

Corals, like the carnation and black varieties depicted at right, excited scientific interest because they seemed to be neither animal nor plant, and, once out of the water, they harden to stone like a mineral.

Seba was obliged to put up one-third of the money himself, and discounted subscriptions helped fund the initial production costs of the enterprise. The first two volumes of the *Thesaurus* appeared in 1734 and 1735 (the year before his death); the last two were published more than twenty years later.

Volume I depicts plants and animals from South America and Asia, although a few fantastical creatures are also included. Volume II is devoted primarily to snakes, volume III to an imposing variety of sea creatures, and volume IV to insects, minerals, and fossils. Seba himself wrote most of the text for the first two volumes, but other naturalists assisted him in identifying the

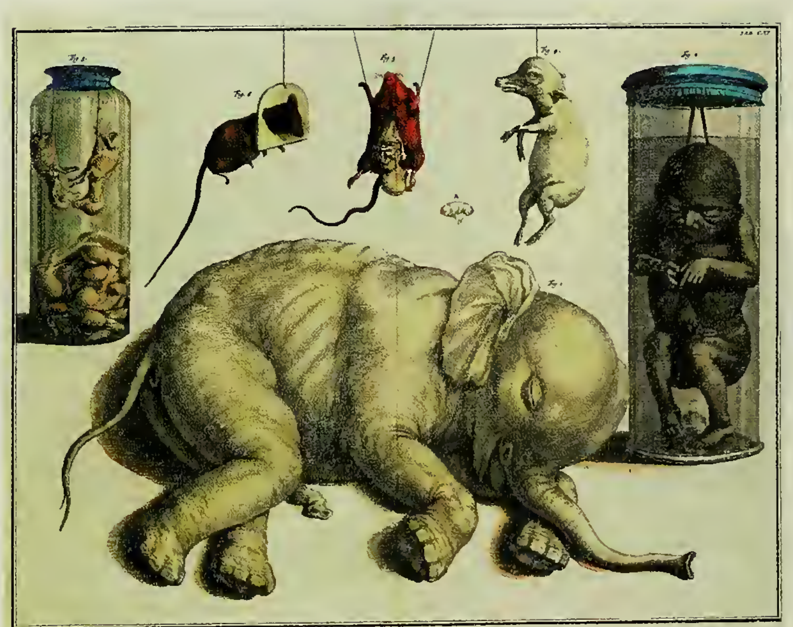
snakes and the fish. At his death, he had completed notes for the fourth volume; in order to ensure publication of the still incomplete *Thesaurus,* his heirs eventually found it necessary to sell the collection, parts of which fetched considerable sums. Some items have survived in zoological institutes and natural history museums in Saint Petersburg, Stockholm, and Amsterdam, as well as in the British Museum in London.

This lavish work was illustrated by no less than thirteen artists and was initially published in black-and-white, though many buyers presumably paid extra to have the volumes painted by skilled colorists. Because he signed his work, an artist named J. Fortuÿn can be identified with several of these colored copies, including the source of the images reproduced here.

Seba's compendium appeared during a transitional period in the history of science. Superficial observation of nature was being increasingly replaced by close examination of the diversity of biological forms. Comparative anatomy and morphology became the new tools of study, and empiricism began to gain the upper hand. In his *Methodus Plantarum* of 1703, for example, English botanist John Ray had recommended: "The best arrangement of plants is that in which all genera, from the highest to the subordinate and lowest, have several common attributes or agree in several parts or accidents." Ray's concern with addressing the diversity of living organisms left its mark on the *Thesaurus* in Seba's presentation of a number of varieties of a single species. Ray was a friend of Hans Sloane, a wealthy London doctor, and Sloane's collection—from the same period as Seba's and considered to have been the largest ever amassed by a private individual—became the cornerstone of collections in the British Museum.

It was not Sloane's friend John Ray but a personal acquaintance of Seba's, Carolus Linnaeus,

Seba's *Thesaurus,* as an instrument of learning, spotlighted such laboratory "curiosities" as a pig embryo and a human fetus preserved in alcohol, sheep and Asiatic elephant embryos, and mouse specimens (one partially dissected).

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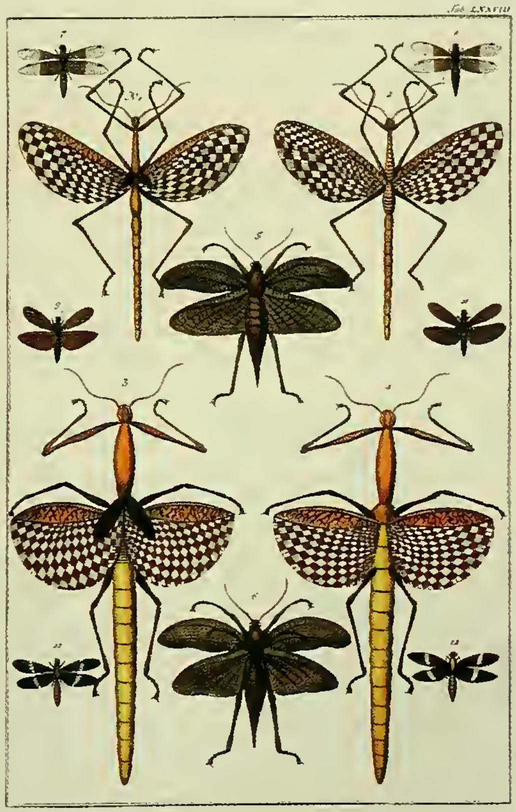
who designed the generally accepted classificatory method that still forms the basis of modern taxonomy. Linnaeus was very familiar with Seba's collection and used the *Thesaurus* for his own research. In the first edition of his *Systema Naturae,* published in 1735, Linnaeus records 549 species and in many cases makes reference to the fact that they are illustrated in Seba's work; in total, he cites the *Thesaurus* 284 times. If one considers that about 1.5 million species have been identified to date and that millions more exist, it is no wonder that during the first half of the eighteenth century, naturalists and collectors were often uncertain about exactly what types of animals they had in hand.



Opposite page: Dorsal and ventral views of a female cuttlefish are seen with egg clusters (far left) and cuttlebones. Left: Male walking sticks (above) and females (below) form a symmetrical composition with katydids in the center and dragonflies at the sides.

Although Linnaeus's system of classification was not available to him while he worked on his *Thesaurus,* Seba nevertheless went beyond the mere presentation of isolated specimens in his magnum opus to establish interconnections and provide information about how plants and animals live. Virtually unique in comprehensiveness and quality, the *Thesaurus* offers unrivaled insight into the biological knowledge of its day. □

A Mouse's Tale

By Steven N. Austad

Some house mice must forage for themselves, below, while others, like the matched pair of Seal Point Siamese Satin fancy mice on the opposite page, lead more pampered lives.

STEPHEN DALTON; ANIMALS ANIMALS

IT'S A LONG AND TORTUOUS ROAD from the steppes of Asia to a rustic New England farmhouse and thence to superstardom in the world of modern science, but that is exactly the journey made over thousands of generations by the humble house mouse. This small creature, known to science as *Mus musculus,* adopted humans about 10,000 years ago, when the development of agriculture led to the invention of grain storage bins, and permanent settlements grew up around the fertile swath formed by the Tigris and Euphrates Rivers in what is now Iraq. Every crack and crevice in the new civilization provided the tiny rodents—able to squeeze through spaces less than half an inch wide—access not only to a cornucopia of food but to relative safety as well. Such a life must certainly have been a pleasant change from searching out seeds on open, unpredictable, and hazardous Asian grasslands.

From that time on, the house mouse has earned its common name, splitting its time between living with us and seeking adventure in the wild. *M. musculus* spread across the steppes of Asia from Turkey to China and hitchhiked with humans to colonize much of the rest of the world. Today house mice are found from the equator to subpolar islands. They span the climatic range of modern civilization, too, having been discovered living, and even breeding, everywhere from heating ducts to refrigerated meat lockers.

Their zeal for cohabitation has not been generally reciprocated. Over the centuries, much human energy has been expended to keep mice out of homes and cupboards—to build a better mousetrap. Eventually, though, some humans began to think of house mice less as pests and more as pets. Our own species' compulsion to selectively breed any animal that can be kept as a pet led to a trade in "fancy" mice, those with odd coat colors and forms (including tailless, Manx mice). Bred for centuries in China, fancy mice caught on in a big way in Victorian England. Clubs promoted, and continue to promote (see "Fancy That!" page 69), officially recognized varieties. Fanciers hold regular competitions and shows in many countries, where ribbons, trophies, and prestige are awarded to the proud owners of the best-bred mice.

Breeding fancy mice became popular in the United States as well. Around the turn of the last century, Abbie Lathrop, a retired schoolteacher, turned her hobby into a business when she began to sell fancy mice from her farmhouse near Granby, Massachusetts. In 1902 Harvard geneticist William Castle purchased some of them to test new theories of mammalian inheritance. Thus was born the laboratory mouse. Today these descendants of house mice are indispensable to biomedical genetic research. It has become commonplace to turn individual mouse genes on and off or to soup up their normal activity in order to understand their function. As part of the research into the role of specific genes, researchers even insert human genes into the mouse genome. The mouse has indeed become an international superstar.

The two stages of our relationship with the house mouse have had very different biological

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CRAIG ROBBINS

House mice share our taste for whole grains but are less fussy about preparation and are content to eat right out of the bag.

consequences for the little creature. Stage one, the commensal stage, when mice lived furtively among us, probably did not change them very much. The warmer temperatures indoors and the steady supply of food did allow them to reproduce throughout the year, but as an opportunistic species, they had always been able to respond quickly to changes in their environment. Stage two, domestication, when we took control of their breeding to favor certain traits, was a different story. Selective breeding is the essence of evolutionary change. Usually nature provides the selection, but humans can as well. Animals evolve under domestication. They may grow larger

STEPHEN DALTON; PHOTO RESEARCHERS, INC.

or smaller than their wild ancestors. They may develop faster, become more fertile or docile, produce richer milk, a thicker coat, or more tender meat. This sort of evolution is obvious: these are the traits for which we breed.

The trait that breeders of fancy mice wanted first and foremost was docility. When handled, wild mice bite and attempt to escape. Anyone who has been the recipient of such a bite knows that the mice tend to hang on with the tenacity of bulldogs. And the escape jump of a wild house mouse is reminiscent of overheated popcorn. However, over the years, mice that bit ferociously usually came to a bad end at the hands of breeders, and escape artists soon found themselves back hiding among the cracks and crevices—leaving behind their less agile, gentler relations to form the next generation of pets.

Another trait selected for by the pet trade was an ability to thrive in comfortable confinement—a shoe-box-sized cage, for example. We humans have bred for gentleness, tolerance of confinement, and bizarre appearance in a number of other species, such as chickens, guinea pigs, and dogs. (How else does one explain the existence of the pug?) Observations of this sort of selective change under domestication were pivotal to Charles Darwin's work on his theory of evolution by natural selection.

Once fancy mice became popular in the laboratory, their commercial success was directly proportional to the rate at which the animals could produce offspring. Those that reached sexual maturity fastest, reproduced most frequently, and had the largest litters were favored by standard husbandry practices.

What are the results of all this tinkering? Are there other, less obvious traits that we may have inadvertently selected for as well? Richard Miller and Robert Dysko, of the University of Michigan, and I have been looking at differences between lab mice and their wild relatives. When we began, in 1996, we were particularly interested to see whether life in the laboratory accelerated the aging rate. This appears to be the case; recently we lost what may have been the world's oldest mouse—a codger from Idaho who, when he expired a few days short of his fourth birthday, was more than seven months older than the oldest lab mouse in a comparative longevity experiment. In the course of our studies, however, we began to notice lots of other differences as well. Most laboratory mice are highly inbred, the product of so many generations of brother-sister mating that each individual in a so-called strain is virtually identical to all the others. In order to produce a generic laboratory mouse for our own studies, Miller, Dysko, and I interbred four commonly used strains. Then we compared our lab mice with the laboratory-raised offspring of animals caught in the wild. (To control for differences in early life conditions—life in a field or barn versus life in the lab—the "wild mice" in our experiments are actually the offspring or grand-offspring of the original captives. For all intents and purposes, though, they are still wild.)

We found, as have others, that laboratory mice grow faster than wild mice and are much bigger as adults. In nature, mice generally weigh between ten and twenty grams, depending on where they live. Laboratory mice can weigh more than fifty grams (not quite two ounces). Even the immediate descendants of our wild mice—which had been born in the laboratory and had unlimited access to food their entire lives—weighed only about half as much as lab mice. Wild mice also take twice as long to reach sexual maturity (two months versus one month) and produce litters of about half the size (five versus ten pups).

Other traits of laboratory mice have changed in ways that might be characterized as "use it or lose it." Physical fitness has deteriorated over the generations. With a steady supply of food and no predators, lab mice had no need for qualities such as strength, speed, and endurance; genetic mutations that compromised physical fitness were thus not weeded out by selection. Consequently, compared with wild mice, lab mice are wimps—slower, weaker, and less active—even if both have lived their entire lives in cages the size of a shoe box. Given an exercise wheel, wild mice voluntarily run faster and longer than lab mice. Experimenters in the laboratory of physiologist Ted Garland, of the University of Wisconsin, discovered that if forced to exercise, wild mice can sprint about 50 percent faster, but they consume only about 20 percent more oxygen at maximum exercise intensity than do laboratory mice. Even heart ventricles are about 12 percent larger in wild mice.

Compared with their wild relatives, laboratory house mice are real wimps—slower, weaker, and less active.

The greater strength of wild mice makes it impossible to subject them to some behavioral tests designed for the comparatively feeble lab mice. For instance, a standard test of muscle endurance is called the cord drop. The test is quite simple: a mouse is dangled from a taut cord by its front feet—your basic pull-up position—and scored according to how many seconds it can hang on before dropping to the ground. A robust young laboratory mouse is doing well to hang on for thirty or forty seconds. When we tried this test with our wild mice, they simply pulled themselves up onto the top of the cord and walked off. We didn't actually see them sneer with contempt, but they may have.

STEPHEN DALTON; NHPA

A wild house mouse easily passes the "squeeze through a small hole" test, above. Pull-ups are more of a challenge, at least for lab mice. Below, one scrambles to hang on to a monofilament line.

There are other use-it-or-lose-it stories among domesticated animals. Wolves, for instance, have greater visual acuity and larger teeth with broader, deeper roots than dogs do. Broiler chickens have smaller leg bones than their ancestor the red jungle fowl. We've noted that laboratory mice have smaller eyes than wild mice. And just about every domesticated mammal you can think of has a smaller brain than its wild ancestor.

Do domesticated animals lose these traits passively—that is, simply because the advantage of maintaining them has disappeared—or actively, because something in the domesticated environment favors such a reduction? The latter scenario requires that there be some kind of cost, however subtle, associated with maintaining a trait. For instance, reduction in eye size has occurred again and again in mammals that have evolved to live largely underground. Blind mole rats have eyes about one-hundredth the size of their aboveground relatives' eyes. They have lost the pupil, as well as the muscles associated with focusing the lens, and even the lens no longer has a functional shape. Eviatar Nevo, of Israel's University of Haifa, has calculated that blind mole rats use 1 to 2 percent fewer calories as a consequence of not

CENTER FOR DEVELOPMENTAL AND HEALTH GENETICS, PENN STATE UNIVERSITY

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Generations of careful breeding have produced a kaleidoscopic variety of "fancy" mice—spotted ones, long-haired ones, even curly-coated ones that resemble tiny sheep.

having to maintain large functional eyes and the considerable brain structures that go along with them. And as the mole rat's visual cortex has been reduced, some of its other brain structures, associated with touch and smell, have expanded. Selection has favored a reallocation of brain space.

It's difficult to imagine how laboratory conditions could favor active selection for smaller eyes in mice. Neither energy savings nor the expansion of other sensory capabilities would lead to an obvious reproductive advantage in animals occupying a small cage that is regularly replenished with food. Mouse eyes, thus, have probably shrunk passively in the laboratory.

The loss of melatonin production in laboratory mice, however, may be the result of *active* selection. Melatonin is a hormone produced by the pineal gland, a small organ deep in the mammalian brain that conveys information to the rest of the brain and body about the length of light-dark cycles. The pineal gland is thought to be involved in the maintenance of daily and seasonal biorhythms as well as in the timing of reproduction. (Some researchers also think melatonin is an immune-system stimulant that plays a role in cancer resistance, although the evidence for such a function is not strong.)

Because of mutations affecting two brain enzymes, most laboratory mouse strains are unable to manufacture any melatonin whatsoever. These mutations could have been favored by chance alone, but they might also have conferred an advantage. Animals lacking melatonin are less likely to be strictly nocturnal or diurnal. Instead of feeding and being active primarily in the dark, as are most mice, melatonin-deficient mice might feed during both dark and light hours and might thus grow faster and reproduce sooner and more often. Since rapid reproduction is favored by breeders of lab mice, standard laboratory husbandry may favor the loss of melatonin production.

But some trends in laboratory evolution defy even the most imaginative explanations. Wimpy muscles are easy to understand. Wimpy chromosomes are not.

Chromosomes, the long stretches of DNA composing our genome, routinely break and refuse, particularly when eggs or sperm are formed by the division of their precursor cells. During this process, pairs of chromosomes (one inherited from the mother, the other from the father) align themselves side by side and are then pulled apart, with one going to each new descendant cell. (This way, sperm and egg end up with only half the number of chromosomes in the original cell. Later, when an egg is fertilized by sperm from another individual, the number of chromosomes doubles, yielding the original chromosome number again in the new generation.) Before being pulled apart, however, each chromosome breaks in one or more places and then joins up, not with pieces of its former self but with pieces of its counterpart, creating a new chromosome that contains a mixture of genes from both parents.

Over the years, mice that bit their breeders usually came to a bad end, leaving their gentler relations to form the next generation.

During the routine process of egg and sperm formation, chromosomes from laboratory mice break and re-fuse more frequently than do those of wild mice. Exposure to radiation and certain chemicals can increase the rate of chromosome breakage—again, more frequently in lab than in wild mice. And this pattern isn't confined to domesticated mice. Domesticated dogs, cats, pigs, cows, sheep, and goats all have more routine chromosome breakage than their wild ancestors do. Why domestication should have such a uniform effect remains a mystery.

Just as mysterious are data that we, and also researchers in several other laboratories, have recently collected about another chromosome trait that differs between laboratory and wild mice: the length of telomeres. Telomeres are long stretches of DNA that protect the ends of chromosomes, much as the plastic tips on shoelaces keep their ends from fraying. Each time cells divide, telomeres shorten a bit; eventually the telomeres become too short to provide protection. At that point, a cellular emergency-response program kicks in and either shuts down the cell division or forces the cell to commit suicide. In either case, telomere shortening seems to operate as a mechanism to prevent out-of-control cell division—cancer, in other words.

Laboratory mice have proved of little use in

Fancy That!

The fancy mouse lives on today in England, America, Australia, New Zealand, and probably elsewhere. At English shows, fancy mice are judged according to standards published by the National Mouse Club. The London and Southern Counties Mouse & Rat Club summarizes these general standards of excellence as follows:

> *The mouse must be long on body with long clean head, not too fine or pointed at the nose. The eyes should be large, bold and prominent. The ears large and tulip shaped, free from creases, carried erect with plenty of width between them. The body should be long and slim, a trifle arched over the loin and racy in appearance; the tail, which must be free from kinks should come well out of the back and be thick at the root or set-on, gradually tapering like a whip lash to a fine end, the length being about equal to that of the mouse's body.*

Beyond this general standard, there are five recognized types of fancy mice in England (Americans, Australians, and New Zealanders have their own standards and types). Those known as Selfs are always a single color, which may be blue, champagne, chocolate, cream, dove, fawn, lilac, red, silver, or white. The other varieties are Tans (which are required to have a tan belly), Satins (which have smooth, glossy coats that shine like, well, satin), Marked (which sport different patterns of spots), and AOV, an acronym for Any Other Va-

Members of the Calder Valley Mouse Club, England

ANNIE GRIFFITHS BELT; CORBIS

riety. Among the AOVs are Silver Agouti, Marten Sable, Argente, and my favorite, Astrex (which, according to the standards, must have "a coat as curly as possible and like the Astrex rabbit," and its whiskers "must be curly"). To see more fancy mice, go to www.miceandrats.com.

studying telomere dynamics, because their telomeres are so long—two to ten times as long as human telomeres—that they never shorten appreciably during the life of an animal. When we began looking at telomeres from wild mice, however, we were surprised to find that their telomeres were much shorter, just a bit longer than human ones. So far, no one has come up with a convincing explanation for why telomere length has increased under laboratory conditions. One might speculate that early on in their laboratory existence, mice—which are prone to developing a wide variety of cancers—attracted the attention of cancer biologists. Perhaps commercial demand from cancer biologists led to greater production of cancer-prone mice and, perhaps as an unintended consequence, to longer telomeres (the shortening of which, you'll remember, is associated with cancer prevention).

A second speculation is that telomere lengthening may have something to do with guaranteeing male fertility. Like other mammals, female mice manufacture prenatally all the eggs they will ever have. Sperm production, however, requires continuing cell division throughout a male's life. If telomeres shorten too much in the precursors of sperm cells, the emergency response kicks in, cell division ceases, and sperm production stops.

A lab house mouse in an exercise wheel, right, doesn't run as fast or as long as its wild relatives. But given the chance, most mice will seek out their own exercise, opposite page.

TOM SCHIERLITZ; GETTY IMAGES

Carrie Bickle, a graduate student of mine, has found some tantalizing evidence that telomere lengthening in the lab might have some benefit—though what that might be is anybody's guess at this point. She discovered that mice brought into the laboratory only a couple of decades ago have telomeres intermediate in length between those of wild mice and those of long-established strains of lab mice (whose forebears were bred as fancy mice for who knows how many generations and then bred in the laboratory for about 200 generations more). Telomere length thus seems to increase with each generation that animals have lived in the laboratory. To see if this was a general trend of laboratory domestication or was something specific to the house mouse, she investigated a second species, the deer mouse *(Peromyscus maniculatus)*. During the late 1940s, just after World War II, deer mice were domesticated in the laboratory for use as an alternative to house mice in genetic and physiological research. For reasons no one understands, deer mice have exceptionally short telomeres—shorter than those of almost any animal we know, even humans. Bickle studied tissues from two groups of laboratory-bred deer mice: in one, telomeres had indeed lengthened, but in the second, telomere length was the same as in wild deer mice. Perhaps significantly, the second group had developed breeding problems and died out (working with this group involved using tissues that had been frozen years before). Were the breeding problems somehow associated with an inability to evolve longer telomeres in the lab? And if so, what is the nature of the connection? More questions to be answered, we hope, in the future.

To understand* Mus musculus *in its full glory, we need to decipher the genomes of both wild and lab house mice.

It is more than a simple oddity that laboratory mice have smaller eyes and brains, faster development, larger bodies and litters, weaker muscles and chromosomes, and longer telomeres than their wild relatives. In an unintended genetic experiment, laboratory researchers have created genetic blueprints of the transformation from strong muscles and chromosomes to weak ones, rapid reflexes to slow ones, good eyes to poor ones. If we could read these blueprints properly, they should reveal the steps necessary to reverse these trends. Given the rapid progress being made in mapping and sequencing the genome of the laboratory mouse, that day may not be far off. But, of course, if we want to understand *Mus musculus* in its full glory, we will also need to decipher the genome of the lab mouse's wild brethren, the free-living descendants of the little mouse that slipped through a tiny crack thousands of years ago in search of a bite to eat and thus joined its fate with ours. □

AMNH Volunteer Supports the Museum's Future and Her Own Retirement

"Growing up in New York, of course some of my earliest and happiest childhood memories are of visits to the Museum." Thus for Selma Wiener began a life that has been closely intertwined with science, including professional experience as a high school science teacher, a technician for medical research, and assistant to the editor of a major medical publication.

Over the past few years, Selma has expressed her love for the Museum in several important ways. She strengthened her membership support by participating in the Patrons Circle. Joining the Museum's corps of dedicated volunteers, she became editorial assistant to the Director of the Micropaleontology Press. She also included a bequest to the Museum in her estate plan.

Most recently, she realized that a Charitable Gift Annuity would be a great way to give the Museum a portion of her future legacy right now and, in addition, receive an annuity at an excellent rate. As Selma says, *"The Museum reflects my true interests, so I decided to put my money where my mouth is."*

Here are sample rates and benefits for one person with a $10,000 gift:

Age	Annuity Rate	Income Tax Deduction	Annuity Payment
65	6.7%	$3,446	$670
70	7.2%	$3,827	$720
75	7.9%	$4,223	$790
80	8.9%	$4,652	$890
85	10.4%	$5,046	$1,040
90	12.0%	$5,630	$1,200

For more information, please call (800) 453-5734 or reply by mail to: Office of Planned Giving, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024-5192

Please send information on:

- ◯ Gifts that provide lifetime income.
- ◯ A bequest to the Museum in my will.
- ◯ I have already included a provision for the Museum in my estate plans.

American Museum of Natural History

Name:

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Telephone Home: Office:

My (our) birth date(s):

Your reply is confidential and implies no obligation.

04/02

SPECIAL REPORT

INTELLIGENT DESIGN?

The idea that an organism's complexity is evidence for the existence of a cosmic designer was advanced centuries before Charles Darwin was born. Its best-known exponent was English theologian William Paley, creator of the famous watchmaker analogy. If we find a pocket watch in a field, Paley wrote in 1802, we immediately infer that it was produced not by natural processes acting blindly but by a designing human intellect. Likewise, he reasoned, the natural world contains abundant evidence of a supernatural creator. The argument from design, as it is known, prevailed as an explanation of the natural world until the publication of the *Origin of Species* in 1859. The weight of the evidence that Darwin had patiently gathered swiftly convinced scientists that evolution by natural selection better explained life's complexity and diversity. "I cannot possibly believe," wrote Darwin in 1868, "that a false theory would explain so many classes of facts."

In some circles, however, opposition to the concept of evolution has persisted to the present. The argument from design has recently been revived by a number of academics with scientific credentials, who maintain that their version of the idea (unlike Paley's) is soundly supported by both microbiology and mathematics. These antievolutionists differ from fundamentalist creationists in that they accept that some species do change (but not much) and that Earth is much more than 6,000 years old. Like their predecessors, however, they reject the idea that evolution accounts for the array of species we see today, and they seek to have their concept—known as intelligent design—included in the science curriculum of schools.

Most biologists have concluded that the proponents of intelligent design display either ignorance or deliberate misrepresentation of evolutionary science. Yet their proposals are getting a hearing in some political and educational circles and are currently the subject of a debate within the Ohio Board of Education. Although *Natural History* does not fully present and analyze the intelligent-design phenomenon in the pages that follow, we offer, for the reader's information, brief position statements by three leading proponents of the theory, along with three responses. The section concludes with an overview of the intelligent-design movement by a philosopher and cultural historian who has monitored its history for more than a decade.

This section was prepared by senior editors Richard Milner and Vittorio Maestro.

INTELLIGENT DESIGN

The Challenge of Irreducible Complexity

Every living cell contains many ultrasophisticated molecular machines.

Michael J. Behe

Scientists use the term "black box" for a system whose inner workings are unknown. To Charles Darwin and his contemporaries, the living cell was a black box because its fundamental mechanisms were completely obscure. We now know that, far from being formed from a kind of simple, uniform protoplasm (as many nineteenth-century scientists believed), every living cell contains many ultrasophisticated molecular machines.

How can we decide whether Darwinian natural selection can account for the amazing complexity that exists at the molecular level? Darwin himself set the standard when he acknowledged, "If it could be demonstrated that any complex organ existed which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down."

Some systems seem very difficult to form by such successive modifications—I call them irreducibly complex. An everyday example of an irreducibly complex system is the humble mousetrap. It consists of (1) a flat wooden platform or base; (2) a metal hammer, which crushes the mouse; (3) a spring with extended ends to power the hammer; (4) a catch that releases the spring; and (5) a metal bar that connects to the catch and holds the hammer back. You can't catch a mouse with just a platform, then add a spring and catch a few more mice, then add a holding bar and catch a few more. All the pieces have to be in place before you catch any mice.

Irreducibly complex systems appear very unlikely to be produced by numerous, successive, slight modifications of prior systems, because any precursor that was missing a crucial part could not function. Natural selection can only choose among systems that are already working, so the existence in nature of irreducibly complex biological systems poses a powerful challenge to Darwinian theory. We frequently observe such systems in cell organelles, in which the removal of one element would cause the whole system to cease functioning. The flagella of bacteria are a good example. They are outboard motors that bacterial cells can use for self-propulsion. They have a long, whiplike propeller that is rotated by a molecular motor. The propeller is attached to the motor by a universal joint. The motor is held in place by proteins that act as a stator. Other proteins act as bushing material to allow the driveshaft to penetrate the bacterial membrane. Dozens of different kinds of proteins are necessary for a working flagellum. In the absence of almost any of them, the flagellum does not work or cannot even be built by the cell.

Another example of irreducible complexity is the system that allows proteins to reach the appropriate subcellular compartments. In the eukaryotic cell there are a number of places where specialized tasks, such as digestion of nutrients and excretion of wastes, take place. Proteins are synthesized outside these compartments and can reach their proper destinations only with the help of "signal" chemicals that turn other reactions on and off at the appropriate times. This constant, regulated traffic flow in the cell comprises another remarkably complex, irreducible system. All parts must function in synchrony or the system breaks down. Still another example is the exquisitely coordinated mechanism that causes blood to clot.

Biochemistry textbooks and journal articles describe the workings of some of the many living molecular machines within our cells, but they offer very little information about how these systems supposedly evolved by natural selection. Many scientists frankly admit their bewilderment about how they may have originated, but refuse to entertain the obvious hypothesis: that perhaps molecular machines appear to look designed because they really *are* designed.

I am hopeful that the scientific community will eventually admit the possibility of intelligent design, even if that acceptance is discreet and muted. My reason for optimism is the advance of science itself, which almost every day uncovers new intricacies in nature, fresh reasons for recognizing the design inherent in life and the universe.

Michael J. Behe, who received his Ph.D. in biochemistry from the University of Pennsylvania in 1978, is a professor of biological sciences at Pennsylvania's Lehigh University. His current research involves the roles of design and natural selection in building protein structure. His book Darwin's Black Box: The Biochemical Challenge to Evolution *is available in paperback (Touchstone Books, 1998).*

EVOLUTION

The Flaw in the Mousetrap

Intelligent design fails the biochemistry test.

Kenneth R. Miller

To understand why the scientific community has been unimpressed by attempts to resurrect the so-called argument from design, one need look no further than Michael J. Behe's own essay. He argues that complex biochemical systems could not possibly have been produced by evolution because they possess a quality he calls irreducible complexity. Just like mousetraps, these systems cannot function unless each of their parts is in place. Since "natural selection can only choose among systems that are already working," there is no way that Darwinian mechanisms could have fashioned the complex systems found in living cells. And if such systems could not have evolved, they must have been designed. That is the totality of the biochemical "evidence" for intelligent design.

Ironically, Behe's own example, the mousetrap, shows what's wrong with this idea. Take away two parts (the catch and the metal bar), and you may not have a mousetrap but you do have a three-part machine that makes a fully functional tie clip or paper clip. Take away the spring, and you have a two-part key chain. The catch of some mousetraps could be used as a fishhook, and the wooden base as a paperweight; useful applications of other parts include everything from toothpicks to nutcrackers and clipboard holders. The point, which science has long understood, is that bits and pieces of supposedly irreducibly complex machines may have different—but still useful—functions.

Behe's contention that each and every piece of a machine, mechanical or biochemical, must be assembled in its final form before *anything* useful can emerge is just plain wrong. Evolution produces complex biochemical machines by copying, modifying, and combining proteins previously used for other functions. Looking for examples? The systems in Behe's essay will do just fine.

He writes that in the absence of "almost any" of its parts, the bacterial flagellum "does not work." But guess what? A small group of proteins from the flagellum *does work* without the rest of the machine—it's used by many bacteria as a device for injecting poisons into other cells. Although the function performed by this small part when working alone is different, it nonetheless can be favored by natural selection.

The key proteins that clot blood fit this pattern, too. They're actually modified versions of proteins used in the digestive system. The elegant work of Russell Doolittle has shown how evolution duplicated, retargeted, and modified these proteins to produce the vertebrate blood-clotting system.

And Behe may throw up his hands and say that *he* cannot imagine how the components that move proteins between subcellular compartments could have evolved, but scientists actually working on such systems completely disagree. In a 1998 article in the journal *Cell*, a group led by James Rothman, of the Sloan-Kettering Institute, described the remarkable simplicity and uniformity of these mechanisms. They also noted that these mechanisms "suggest in a natural way how the many and diverse compartments in eukaryotic cells could have evolved in the first place." Working researchers, it seems, see something very different from what Behe sees in these systems—they see evolution.

If Behe wishes to suggest that the intricacies of nature, life, and the universe reveal a world of meaning and purpose consistent with a divine intelligence, his point is philosophical, not scientific. It is a philosophical point of view, incidentally, that I share. However, to support that view, one should not find it necessary to pretend that we know less than we really do about the evolution of living systems. In the final analysis, the biochemical hypothesis of intelligent design fails not because the scientific community is closed to it but rather for the most basic of reasons—because it is overwhelmingly contradicted by the scientific evidence.

Kenneth R. Miller is a professor of biology at Brown University. His research work on cell membrane structure and function has been reported in such journals as Nature, Cell, *and the* Journal of Cell Biology. *Miller is co-author of several widely used high school and college biology textbooks, and in 1999 he published* Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution *(Cliff Street Books).*

EDITORS' NOTE: See "Crystal Balls" (page 32) to learn how borrowed and duplicated genes contributed to the evolution of the lens of the eye.

INTELLIGENT DESIGN

William A. Dembski

Detecting Design in the Natural Sciences

Intelligence leaves behind a characteristic signature.

In ordinary life, explanations that invoke chance, necessity, or design cover every eventuality. Nevertheless, in the natural sciences one of these modes of explanation is considered superfluous—namely, design. From the perspective of the natural sciences, design, as the action of an intelligent agent, is not a fundamental creative force in nature. Rather, blind natural causes, characterized by chance and necessity and ruled by unbroken laws, are thought sufficient to do all nature's creating. Darwin's theory is a case in point.

But how do we know that nature requires no help from a designing intelligence? Certainly, in special sciences ranging from forensics to archaeology to SETI (the Search for Extraterrestrial Intelligence), appeal to a designing intelligence is indispensable. What's more, within these sciences there are well-developed techniques for identifying intelligence. Essential to all these techniques is the ability to eliminate chance and necessity.

For instance, how do the radio astronomers in *Contact* (the Jodie Foster movie based on Carl Sagan's novel of the same name) infer the presence of extraterrestrial intelligence in the beeps and pauses they monitor from space? The researchers run signals through computers that are programmed to recognize many preset patterns. Signals that do not match any of the patterns pass through the "sieve" and are classified as random. After years of receiving apparently meaningless "random" signals, the researchers discover a pattern of beats and pauses that corresponds to the sequence of all the prime numbers between 2 and 101. (Prime numbers, of course, are those that are divisible only by themselves and by one.) When a sequence begins with 2 beats, then a pause, 3 beats, then a pause . . . and continues all the way to 101 beats, the researchers must infer the presence of an extraterrestrial intelligence.

Here's why. There's nothing in the laws of physics that requires radio signals to take one form or another. The sequence is therefore contingent rather than necessary. Also, it is a long sequence and therefore complex. Note that if the sequence lacked complexity, it could easily have happened by chance. Finally, it was not just complex but also exhibited an independently given pattern or specification (it was not just any old sequence of numbers but a mathematically significant one—the prime numbers).

Intelligence leaves behind a characteristic trademark or signature—what I call "specified complexity." An event exhibits specified complexity if it is contingent and therefore not necessary; if it is complex and therefore not easily repeatable by chance; and if it is specified in the sense of exhibiting an independently given pattern. Note that complexity in the sense of improbability is not sufficient to eliminate chance: flip a coin long enough, and you'll witness a highly complex or improbable event. Even so, you'll have no reason not to attribute it to chance.

The important thing about specifications is that they be objectively given and not just imposed on events after the fact. For instance, if an archer shoots arrows into a wall and we then paint bull's-eyes around them, we impose a pattern after the fact. On the other hand, if the targets are set up in advance ("specified") and then the archer hits them accurately, we know it was by design.

In my book *The Design Inference*, I argue that specified complexity reliably detects design. In that book, however, I focus largely on examples from the human rather than the natural sciences. The main criticism of that work to date concerns whether the Darwinian mechanism of natural selection and random variation is not in fact fully capable of generating specified complexity. More recently, in *No Free Lunch*, I show that undirected natural processes like the Darwinian mechanism are incapable of generating the specified complexity that exists in biological organisms. It follows that chance and necessity are insufficient for the natural sciences and that the natural sciences need to leave room for design.

William A. Dembski, who holds Ph.D.'s in mathematics and philosophy, is an associate research professor at Baylor University and a senior fellow with the Discovery Institute in Seattle. His books include The Design Inference: Eliminating Chance Through Small Probabilities *(Cambridge University Press, 1998) and* No Free Lunch: Why Specified Complexity Cannot Be Purchased Without Intelligence *(Rowman and Littlefield, 2001).*

Mystery Science Theater

The case of the secret agent

Robert T. Pennock

William A. Dembski claims to detect "specified complexity" in living things and argues that it is proof that species have been designed by an intelligent agent. One flaw in his argument is that he wants to define intelligent design negatively, as anything that is not chance or necessity. But the definition is rigged: necessity, chance, and design are not mutually exclusive categories, nor do they exhaust the possibilities. Thus, one cannot detect an intelligent agent by the process of elimination he suggests. Science requires positive evidence. This is so even when attempting to detect the imprint of human intelligence, but it is especially true when assessing the extraordinary claim that biological complexity is intentionally designed.

In this regard, Dembski's archery and SETI analogies are red herrings, for they tacitly depend on prior understanding of human intellect and motivation, as well as of relevant causal processes. A design inference like that in the movie *Contact,* for instance, would rely on background knowledge about the nature of radio signals and other natural processes, together with the assumption that a sequence of prime numbers is the kind of pattern another scientist might choose to send as a signal. But the odd sequences found within DNA are quite unlike a series of prime numbers. Dembski has no way to show that the genetic patterns are "set up in advance" or "independently given."

Dembski has been promoted as "the Isaac Newton of information theory," and in his writings, which include the books he cites in the essay here, he insists that his "law of conservation of information" proves that natural processes cannot increase biological complexity. He doesn't lay out his case here, and a refutation would require too much space. Suffice it to say that a connection exists between the technical notion of information and that of entropy, so Dembski's argument boils down to a recasting of an old creationist claim that evolution violates the second law of thermodynamics. Put simply, this law states that in the universe, there is a tendency for complexity to decrease. How then, ask the creationists, can evolutionary processes produce more complex life-forms from more primitive ones? But we have long known why this type of argument fails: the second law applies only to closed systems, and biological systems are not closed.

In the evolutionary process, an increase in biological complexity does not represent a "free lunch"—it is bought and paid for, because random genetic variation is subjected to natural selection by the environment, which itself is already structured. In fact, researchers are beginning to use Darwinian processes, implemented in computers or in vitro, to evolve complex systems and to provide solutions to design problems in ways that are beyond the power of mere intelligent agents.

If we really thought that genetic information was like the signal in *Contact,* shouldn't we infer we were designed by extraterrestrials? Intelligent-design theorists do sometimes mention extraterrestrials as possible suspects, but most seem to have their eyes on a designer more highly placed in the heavens. The problem is, science requires a specific model that can be tested. What exactly did the designer do, and when did he do it? Dembski's nebulous hypothesis of design, even if restricted to natural processes, provides precious little that is testable, and once supernatural processes are wedged in, it loses any chance of testability.

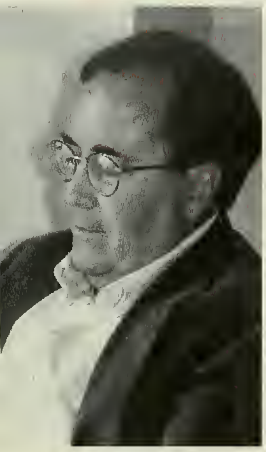
Newton found himself stymied by the complex orbits of the planets. He could not think of a natural way to fully account for their order and concluded that God must nudge the planets into place to make the system work. (So perhaps in this one sense, Dembski *is* the Newton of information theory.) The origin of species once seemed equally mysterious, but Darwin followed the clues given in nature to solve that mystery. One may, of course, retain religious faith in a designer who transcends natural processes, but there is no way to dust for his fingerprints.

Robert T. Pennock is an associate professor of science and technology studies and associate professor of philosophy in Michigan State University's Lyman Briggs School and department of philosophy. He is the author of Tower of Babel: The Evidence Against the New Creationism *(MIT Press, 1999) and editor of* Intelligent Design Creationism and Its Critics: Philosophical, Theological, and Scientific Perspectives *(MIT Press, 2001).*

INTELLIGENT DESIGN

Elusive Icons of Evolution

What do Darwin's finches and the four-winged fruit fly really tell us?



Jonathan Wells

Charles Darwin wrote in 1860 that "there seems to be no more design in the variability of organic beings and in the action of natural selection, than in the course which the wind blows." Although many features of living things appear to be designed, Darwin's theory was that they are actually the result of undirected processes such as natural selection and random variation.

Scientific theories, however, must fit the evidence. Two examples of the evidence for Darwin's theory of evolution—so widely used that I have called them "icons of evolution"—are Darwin's finches and the four-winged fruit fly. Yet both of these, it seems to me, show that Darwin's theory cannot account for all features of living things.

Darwin's finches consist of several species on the Galápagos Islands that differ mainly in the size and shape of their beaks. Beak differences are correlated with what the birds eat, suggesting that the various species might have descended from a common ancestor by adapting to different foods through natural selection. In the 1970s, biologists Peter and Rosemary Grant went to the Galápagos to observe this process in the wild.

In 1977 the Grants watched as a severe drought wiped out 85 percent of a particular species on one island. The survivors had, on average, slightly larger beaks that enabled them to crack the tough seeds that had endured the drought. This was natural selection in action. The Grants estimated that twenty such episodes could increase average beak size enough to produce a new species.

When the rains returned, however, average beak size returned to normal. Ever since, beak size has oscillated around a mean as the food supply has fluctuated with the climate. There has been no net change, and no new species have emerged. In fact, the opposite may be happening, as several species of Galápagos finches now appear to be merging through hybridization.

Darwin's finches and many other organisms provide evidence that natural selection can modify existing features—but only within established species. Breeders of domestic plants and animals have been doing the same thing with artificial selection for centuries. But where is the evidence that selection produces *new* features in *new* species?

New features require new variations. In the modern version of Darwin's theory, these come from DNA mutations. Most DNA mutations are harmful and are thus eliminated by natural selection. A few, however, are advantageous—such as mutations that increase antibiotic resistance in bacteria and pesticide resistance in plants and animals. Antibiotic and pesticide resistance are often cited as evidence that DNA mutations provide the raw materials for evolution, but they affect only chemical processes. Major evolutionary changes would require mutations that produce advantageous *anatomical* changes as well.

Normal fruit flies have two wings and two "balancers"—tiny structures behind the wings that help stabilize the insect in flight. In the 1970s, geneticists discovered that a combination of three mutations in a single gene produces flies in which the balancers develop into normal-looking wings. The resulting four-winged fruit fly is sometimes used to illustrate how mutations can produce the sorts of anatomical changes that Darwin's theory needs.

But the extra wings are not new structures, only duplications of existing ones. Furthermore, the extra wings lack muscles and are therefore worse than useless. The four-winged fruit fly is severely handicapped—like a small plane with extra wings dangling from its tail. As is the case with all other anatomical mutations studied so far, those in the four-winged fruit fly cannot provide raw materials for evolution.

In the absence of evidence that natural selection and random variations can account for the apparently designed features of living things, the entire question of design must be reopened. Alongside Darwin's argument against design, students should also be taught that design remains a possibility.

Jonathan Wells received two Ph.D.'s, one in molecular and cell biology from the University of California, Berkeley, and one in religious studies from Yale University. He has worked as a postdoctoral research biologist at the University of California, Berkeley, and has taught biology at California State University, Hayward. Wells is also the author of Icons of Evolution: Science or Myth? Why Much of What We Teach About Evolution Is Wrong *(Regnery Publishing, 2000).*

The Nature of Change

Evolutionary mechanisms give rise to basic structural differences.

Eugenie C. Scott

Without defining "design," Wells asserts that "many features of living things appear to be designed." Then he contrasts natural selection (undirected) with design (directed), apparently attempting to return to the pre-Darwinian notion that a Designer is directly responsible for the fit of organisms to their environments. Darwin proposed a scientific rather than a religious explanation: the fit between organisms and environments is the result of natural selection. Like all scientific explanations, his relies on natural causation.

Wells contends that "Darwin's theory cannot account for all features of living things," but then, it doesn't have to. Today scientists explain features of living things by invoking not only natural selection but also additional biological processes that Darwin didn't know about, including gene transfer, symbiosis, chromosomal rearrangement, and the action of regulator genes. Contrary to what Wells maintains, evolutionary theory is not inadequate. It fits the evidence just fine.

Reading Wells, one might not realize the importance of the Grants' careful studies, which demonstrated natural selection in real time. That the drought conditions abated before biologists witnessed the emergence of new species is hardly relevant; beak size does oscillate in the short term, but given a long-term trend in climate change, a major change in average size can be expected. Wells also overstates the importance of finch hybridization: it is extremely rare, and it might even be contributing to new speciation. The Galápagos finches remain a marvelous example of the principle of adaptive radiation. The various species, which differ morphologically, occupy different adaptive niches. Darwin's explanation was that they all evolved from a common ancestral species, and modern genetic analysis provides confirming evidence.

Wells admits that natural selection can operate on a population and correctly looks to genetics to account for the kind of variation that can lead to "*new* features in *new* species." But he contends that mutations such as those that yield four-winged fruit flies do not produce the sorts of anatomical changes needed for major evolutionary change. Can't he see past the example to the principle? That the first demonstration of a powerful genetic mechanism happened to be a nonflying fly is irrelevant. Edward Lewis shared a Nobel Prize for the discovery of the role of these genes, known as the *Ubx* complex. They are of extraordinary importance because genes of this type help explain body plans—the basic structural differences between a mollusk and a mosquito, a sponge and a spider.

Ubx genes are among the *HOX* genes, found in animals as different as sponges, fruit flies, and mammals. They turn on or off the genes involved in—among other things—body segmentation and the production of appendages such as antennae, legs, and wings. What specifically gets built depends on other, downstream genes. The diverse body plans of arthropods (insects, crustaceans, arachnids) are variations on segmentation and appendage themes, variations that appear to be the result of changes in *HOX* genes. Recent research shows that fly *Ubx* genes suppress leg formation in abdominal segments but that crustacean *Ubx* genes don't; a very small *Ubx* change results in a big difference in body plan.

Mutations in these primary on/off switches are involved in such phenomena as the loss of legs in snakes, the change from lobe fins to hands, and the origin of jaws in vertebrates. *HOX*-initiated segment duplication allows for anatomical experimentation, and natural selection winnows the result. "Evo-Devo"—the study of evolution and development—is a hot new biological research area, but Wells implies that all it has produced is crippled fruit flies.

Wells argues that natural explanations are inadequate and, thus, that "students should also be taught that design remains a possibility." Because in his logic, design implies a Designer, he is in effect recommending that science allow for nonnatural causation. We actually *do* have solid natural explanations to work with, but even if we didn't, science only has tools for explaining things in terms of natural causation. That's what Darwin did, and that's what we're trying to do today.

Eugenie C. Scott holds a Ph.D. in physical anthropology. In 1987, after teaching physical anthropology at the university level for fifteen years, she became executive director of the National Center for Science Education. She is currently also the president of the American Association of Physical Anthropologists.

The Newest Evolution of Creationism

Intelligent design is about politics and religion, not science.

Barbara Forrest

The infamous August 1999 decision by the Kansas Board of Education to delete references to evolution from Kansas science standards was heavily influenced by advocates of intelligent-design theory. Although William A. Dembski, one of the movement's leading figures, asserts that "the empirical detectability of intelligent causes renders intelligent design a fully scientific theory," its proponents invest most of their efforts in swaying politicians and the public, not the scientific community.

Launched by Phillip E. Johnson's book *Darwin on Trial* (1991), the intelligent-design movement crystallized in 1996 as the Center for the Renewal of Science and Culture (CRSC), sponsored by the Discovery Institute, a conservative Seattle think tank. Johnson, a law professor whose religious conversion catalyzed his antievolution efforts, assembled a group of supporters who promote design theory through their writings, financed by CRSC fellowships. According to an early mission statement, the CRSC seeks "nothing less than the overthrow of materialism and its damning cultural legacies."

Johnson refers to the CRSC members and their strategy as the Wedge, analogous to a wedge that splits a log—meaning that intelligent design will liberate science from the grip of "atheistic naturalism." Ten years of Wedge history reveal its most salient features: Wedge scientists have no empirical research program and, consequently, have published no data in peer-reviewed journals (or elsewhere) to support their intelligent-design claims. But they do have an aggressive public relations program, which includes conferences that they or their supporters organize, popular books and articles, recruitment of students through university lectures sponsored by campus ministries, and cultivation of alliances with conservative Christians and influential political figures.

The Wedge aims to "renew" American culture by grounding society's major institutions, especially education, in evangelical religion. In 1996, Johnson declared: "This isn't really, and never has been, a debate about science. It's about religion and philosophy." According to Dembski, intelligent design "is just the Logos of John's Gospel restated in the idiom of information theory." Wedge strategists seek to unify Christians through a shared belief in "mere" creation, aiming—in Dembski's words—"at defeating naturalism and its consequences." This enables intelligent-design proponents to coexist in a big tent with other creationists who explicitly base their beliefs on a literal interpretation of Genesis.

"As Christians," writes Dembski, "we know naturalism is false. Nature is not self-sufficient. . . . Nonetheless neither theology nor philosophy can answer the evidential question whether God's interaction with the world is empirically detectable. To answer this question we must look to science." Jonathan Wells, a biologist, and Michael J. Behe, a biochemist, seem just the CRSC fellows to give intelligent design the ticket to credibility. Yet neither has actually done research to test the theory, much less produced data that challenges the massive evidence accumulated by biologists, geologists, and other evolutionary scientists. Wells, influenced in part by Unification Church leader Sun Myung Moon, earned Ph.D.'s in religious studies and biology specifically "to devote my life to destroying Darwinism." Behe sees the relevant question as whether "science can make room for religion." At heart, proponents of intelligent design are not motivated to improve science but to transform it into a theistic enterprise that supports religious faith.

Wedge supporters are at present trying to insert intelligent design into Ohio public-school science standards through state legislation. Earlier the CRSC advertised its science education site by assuring teachers that its "Web curriculum can be appropriated without textbook adoption wars"—in effect encouraging teachers to do an end run around standard procedures. Anticipating a test case, the Wedge published in the *Utah Law Review* a legal strategy for winning judicial sanction. Recently the group almost succeeded in inserting into the federal No Child Left Behind Act of 2001 a "sense of the Senate" that supported the teaching of intelligent design. So the movement is advancing, but its tactics are no substitute for real science.

Barbara Forrest is an associate professor of philosophy at Southeastern Louisiana University.

Great Minds of the Western Intellectual Tradition

SOCRATES * PLATO * ARISTOTLE * CICERO * PAUL * AUGUSTINE * AQUINAS * LUTHER * CALVIN * MACHIAVELLI * MORE * ERASMUS * GALILEO * BACON * DESCARTES *HOBBES * SPINOZA * PASCAL * NEWTON * LOCKE * MONTESQUIEU * BERKELEY * HUME * SMITH * ROUSSEAU * KANT * BURKE * MILL * KIERKEGAARD * NIETZSCHE * FREUD * HEGEL * MARX * HUSSERL * DEWEY * HEIDEGGER

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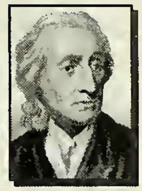
Locke


Descartes

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Ever since the dawn of civilization, certain crucial questions have preoccupied thoughtful people: What is the purpose of life? What is the best kind of life? Who or what is God? How can we tell truth from falsehood? What is the essence of justice? When is it legitimate for one person to have power over others? Can these questions even be answered?

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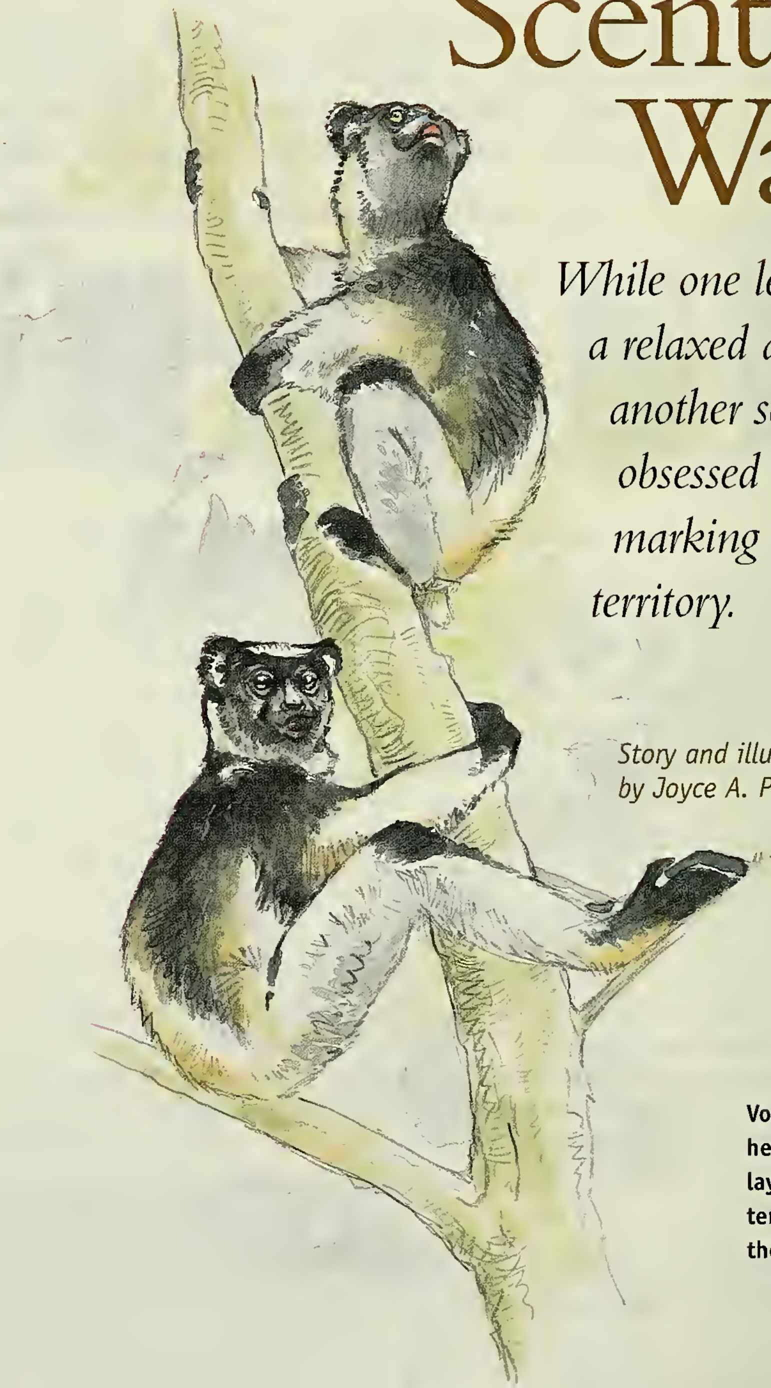
FINDINGS

Scent Wars

While one lemur takes a relaxed attitude, another seems obsessed with marking its territory.

Story and illustrations by Joyce A. Powzyk



Vocal calling helps indri pairs lay claim to their territory within the forest.

I still remember my anxiety the first day Ndrina Kotonirina and I hacked our way into the wall of green vegetation that is Madagascar's Mantadia National Park. But just as my French-speaking guide had promised, the forest was in pristine condition and overflowed with *les lémuriens,* eleven species in all. It was also home to animals that preyed on lemurs, among them the large, catlike fossa, which I was to encounter many times. As planned, I set up a base camp in the north of the park and set out to study the two largest lemurs, *Propithecus diadema diadema* (commonly known as the diademed sifaka) and *Indri indri* (commonly known as the indri). My research focused on their dietary habits, but as happens to many fieldworkers, I stumbled upon something else, an aspect of their behavior that could not easily be explained.

Yet my first concern was with the animals' eating habits. The question was, How could the two lemurs coexist? Both were members of the same family (Indriidae), had similar-sized territories, occupied the same strata of the same forest, were active by day, had the same body size (weighing in at about fourteen pounds), and were reputed to eat leaves and fruit. Yet in theory, two species will not occupy the same feeding niche while sharing the very same habitat. There was likely to be some difference in their respective diets, and I wanted to pin it down.

Other researchers had already noted differences in the animals' mating systems. Indris are monogamous, with each group consisting of an adult mated pair and perhaps an infant or an older maturing offspring. Diademed sifakas instead live in groups of three to seven individuals. These groups typically include more than one adult of each sex, and mating is polygamous. Adult females are dominant members of the group, and thus they choose which males they will mate with.

After a few months spent observing four groups of lemurs (two of each species), I was able to determine some distinct feeding preferences and was well on my way to answering the diet question. Although both species primarily ate young leaves, the sifakas had a stronger taste for fruit, fruit seeds, and flowers, whose simple

sugars and fats can be assimilated quickly into the bloodstream. The indris ate relatively more foliage, a fiber-rich food that is low in simple sugars and fats and that ferments slowly in their digestive system. These food preferences have repercussions on other aspects of their behavior. Sifakas exert themselves physically to defend their territories, constantly patrolling and "scent marking," whereas indris lay claim to their territory through vocal calls, a form of behavior that conserves precious energy.

The way the lemurs carved up the resources of the forest appeared rather straightforward, but soon I was wondering about the role of scent marking in the two species—especially after seeing male sifakas make as many as a hundred marks in a single day. To an animal with a well-developed olfactory system, a scent mark provides a series of cues in a chemical code. It may reveal the sex and individual identity of the animal that left the mark and, in the case of a female, whether she is coming into estrus. All lemurs rely a good deal on their sense of smell, and all have scent glands, located in different regions of the body depending on the species (a male ring-tailed lemur, for example, has scent glands on its forearms). By rubbing a glandular area against a surface such as a tree trunk, a branch, or even another lemur, the animal deposits a scent mark. Whatever their other specializations, most lemurs also have glands at their hind ends and deposit what are called anogenital scent marks, composed of urine and other fluids.

Both species I was observing deposited anogenital marks, but the sifakas were exceptionally diligent in spreading scent throughout their territory. Keeping a daily tally of this activity, I found that during nonbreeding periods, sifaka males and females marked, on average, about sixteen and six times a day, respectively. During the annual breeding season, which can last from January through March, males quadrupled their rate of marking, while breeding females doubled theirs. In comparison, when not breeding, male indris marked about once a day and females three times a day. During the season when one of my indri groups was breeding, the male marked on average ten times a day and the female thirty-two.

A male diademed sifaka, left, watches intently as a female leaves her anogenital scent mark on a tree.

than do other lemurs. When I examined the sifakas, however, I found much more well-developed anogenital glandular tissue. Adult male sifakas also have a conspicuous gland on the upper chest that feels and looks like a big greasy smear. This chest gland is used for "overmarking," a sequence of actions in which the male places a scent mark directly on top of a female's scent mark.

Like humans, lemurs have two types of scent glands: sebaceous (oil excreting) and apocrine (sweat producing).

During the course of my study, I had occasion to tranquilize individuals of both my study species so that I could place radio collars around their necks for tracking purposes. When I examined indris for scent glands, I found only small patches of glandular tissue around the anogenital region. Previous research on the brains of these animals had shown that indris have a much smaller olfactory bulb

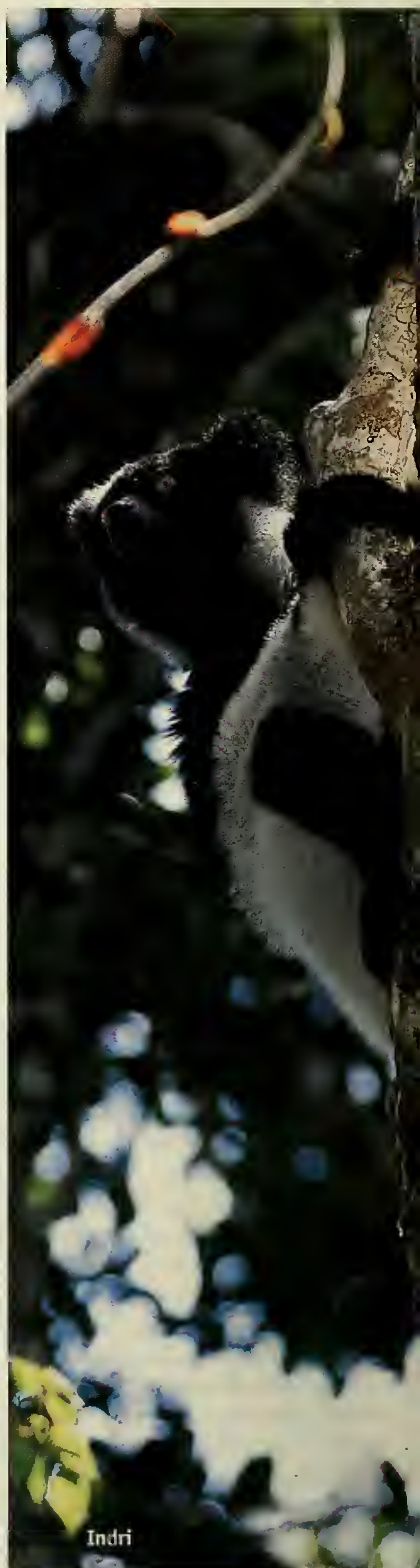
Typically, when a female sifaka finishes feeding in a tree, she will leave her anogenital scent mark on a vertical branch or on the trunk before departing. Seeing this, a male sifaka will stop eating and rush over to her scent mark. (Sometimes an over-eager male will station himself right beneath the female before she is finished, and the annoyed female may reach down and cuff him to make him back off.)

After the female has left, the male will carefully sniff the site and perhaps bite at it, removing several chunks of tree bark in the process. He will rub his chest gland over that exact spot and then, adjusting his position, deposit his own anogenital mark over the female's mark. Although in other circumstances males sometimes left their marks elsewhere—and were, of course, not always around to spot a female marking—this overmarking sequence was very common. During the breeding season, 94 percent of the female scent marks were overmarked by a male. I wondered why the male expended so much energy in these overmarks, even taking the risk of annoying the female. Why not mark near the female's mark, creating a "bulletin board" of scent marks, much as foxes and wolves do?

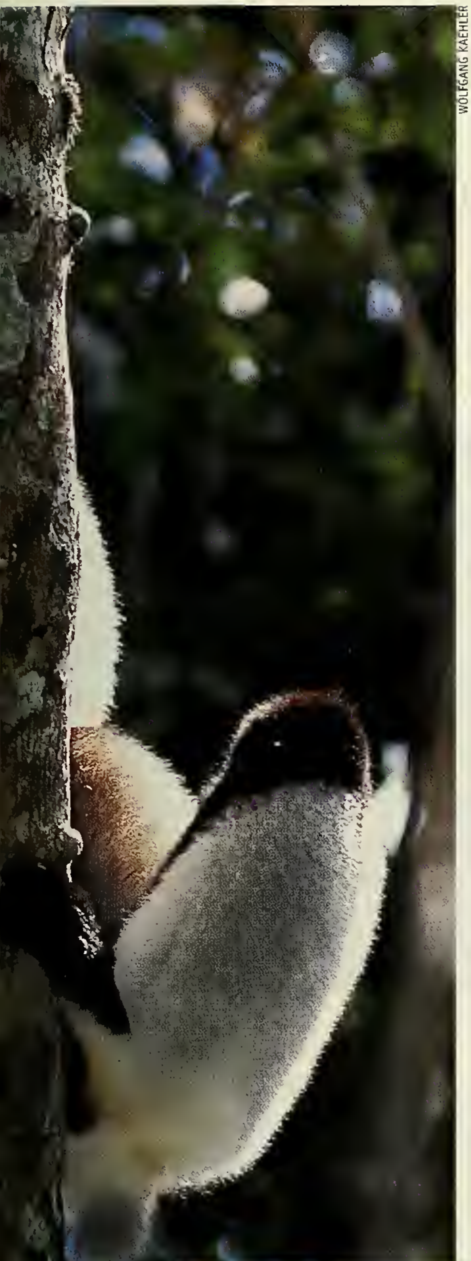
A male diademed sifaka rubs his oily chest over a female's scent mark (left) and then repositions himself (right) to leave his own anogenital mark.

By contrast, not only did indris do much less scent marking in general, but also, during all my hours of observation, I never saw a single instance of overmarking. Perhaps, I thought, an important clue about the differences between the two species' marking behavior could be gleaned from the scent glands themselves. Like humans, lemurs have two types of scent glands on their bodies: sebaceous (oil excreting) and apocrine (sweat producing). (Human armpits, for example, are rife with apocrine glands, while our scalp is embedded with sebaceous glands that can cause oily hair.) The skin around the anogenital region of both species contains predominantly apocrine tissue, but the male sifaka's chest gland is sebaceous and conspicuously exudes oil. Suddenly I realized that perhaps the male sifaka was doing something very sneaky.

The female's scent mark is full of volatile substances (much like the acetic acid in vinegar) that waft through the air, proclaiming a spot to be within her territory and announcing whether or not she is sexually receptive. When a male sifaka bites into the tree bark on which a female's scent mark is deposited, he may remove much of her mark, and the oil smear from his chest gland may act as a barrier to prevent any remaining volatile gases from escaping. The male then leaves his own anogenital mark as the end note. By blocking or scrambling messages from females, he may be keeping competing males from realizing that a receptive female is nearby. This could well be an



Indri



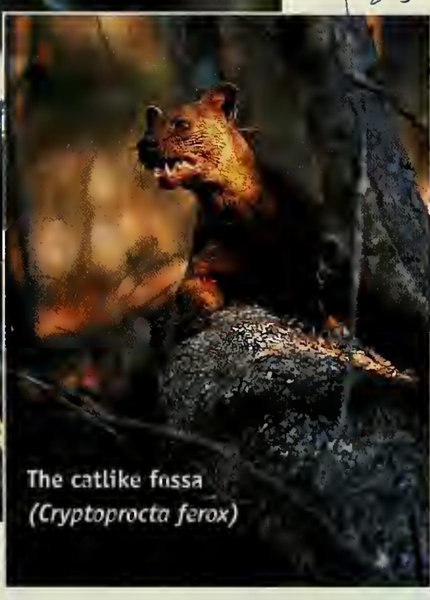
WOLFGANG KAEHLER

adaptive trait, one that could ultimately increase the male's evolutionary fitness: more exclusive matings, more offspring.

This scenario seems likely, especially when we take into account that adult sifaka females choose which males they will mate with. In fact, male sifakas have reason to be concerned. Outside males do sometimes visit a group during breeding season, and females do sometimes mate with them. Not surprisingly, resident males are intensely vigilant, and I've seen them chase away such intruders.

When out hiking, I also often stumbled upon lone males trespassing on the territory of one of my study groups. Although unaccustomed to my presence, these males did not give out an alarm call or flee when they saw me. Instead they continued to move slowly through the vegetation, spending all their time meticulously sniffing tree trunks and tree limbs. Sniffing for recent scent marks may be a way to learn about the animals living in a particular territory and, especially, to establish whether any of the females are estrous.

Here we have a classic battle of the sexes: females putting out information about themselves, and males that may be attempting to put a lid on it. Although overmarking has been studied in rodents, which also rely heavily on olfaction, this behavior warrants more investigation in primates.



The catlike fossa *(Cryptoprocta ferox)*

PETER OXFORD; BBC NATURAL HISTORY UNIT

Indri behavior provides a sharp contrast to this incessant anogenital scent marking. They engage instead in what is known as long calling—that is, emitting a type of call that carries a long distance and can be heard by neighboring groups. Although long calling undoubtedly communicates the caller's sex and individual identity, it is essentially a spacing mechanism for indri pairs, conveying the message that "we're in this spot, so this area is occupied." Indri calls are duets, with either the male or female leading off and the other chiming in. Long calling is also rather contagious, because as one group finishes its call, the neighboring group starts up, until all the animals on down the mountain have announced themselves.

Diademed sifaka

PETER OXFORD; BBC NATURAL HISTORY UNIT

Years of research by various investigators have shown indri pairs to be very stable. There are no reports of an outside indri coming into a territory to steal another's mate. These lemurs have nothing comparable to the scent wars of the sifaka males and females and, in fact, rely less on olfactory cues in general. Still, with an interval of two to three years between births, sexual activity between mates receives some special notice. A breeding pair do step up their scent marking to signal their readiness to mate, but this seems to be a private dialogue, not directed to the indri world at large. □

NOW HEAR THIS

Four Ears to the Ground

For an elephant, the foot may be a powerful listening device.

By Alan Burdick

From time to time, leaving the American Museum of Natural History after hours, I pass the elephants in the Akeley Hall of African Mammals. They occupy the center of the room: a cluster of them, on a wide dais, milling eternally in the state of taxidermy. Aside from them and me and a savanna of glass-eyed ungulates, the hall is empty. My footsteps produce the only sound, which seems somehow amplified by the elephants' great mass.

We share a regular, wordless dialogue, the elephants and I, but only lately have I come to understand what they have to say. For years now, scientists have understood that elephants communicate at a frequency typically too low for the human ear to perceive—about twenty hertz. Propagating through the air, these vocal calls can reach an elephant five miles away. For better reception, the listening elephant spreads its earflaps forward, effectively transforming its head into a satellite dish.

As it turns out, that is only half the story. Recently a Stanford University researcher, Caitlin O'Connell-Rodwell, discovered that an elephant's vocal call actually generates two separate sounds: the airborne one and another that travels through the ground as a seismic wave. Moreover, the seismic version travels at least twice as far, and seismic waves generated by an elephant stomping its feet in alarm travel farther still, up to twenty miles. What's most remarkable, however, is how elephants presumably perceive these signals: they listen, it seems, with their feet.

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TIM FITZHARRIS; MINDEN PICTURES

Walking, talking, listening? A male African elephant crosses a salt pan in Kenya.

Seismic communication is widespread. Creatures from scorpions to crocodiles rely on ground vibrations to locate potential mates and to detect (and avoid becoming) prey. The male fiddler crab bangs territorial warnings into the sand with its oversized claw. A blind mole rat pounds its head against the walls of its underground tunnels, thus declaring its dominance over the blind mole rat two tunnels over, which may or may not be listening with its own head pressed to the wall.

O'Connell-Rodwell was first inspired by the seismic songs of planthoppers, tiny insects she studied early in her career. The planthopper sings by vibrating its abdomen; this causes the underlying leaf, and ideally all nearby planthoppers, to tremble. She observed that planthoppers in the peanut gallery would lift a foot or two, presumably for better hearing: the other feet, bearing more weight, thus became more sensitive to vibration. Years later, O'Connell-Rodwell saw similar behavior among elephants at a waterhole in Namibia. Minutes before a second herd of elephants arrived, members of the first group would lean forward on their toes and raise a hind leg, as if in anticipation. "It was the same thing the planthoppers were doing," she says.

Was it? Several elegant experiments by O'Connell-Rodwell demonstrate that elephants do indeed generate long-range seismic signals. But can other elephants hear them? Early evidence from northern California's Oakland Zoo, where an elephant named Donna is being trained to respond exclusively to seismic cues, strongly suggests that the answer is yes. "We haven't sealed the deal," says O'Connell-Rodwell, "but it looks promising."

As a communication medium, she notes, seismic waves would offer the elephant several advantages. They dissipate less quickly than airborne waves, they aren't disrupted by changes in weather or temperature, and they aren't swallowed by dense jungle foliage. Complex vocal harmonics don't translate well into seismic waves. But even the simplest long-range message—"I'm here" or "Danger!"—beats a fancy one that can't be heard at all.

Air is the faster medium: an airborne elephant call will reach a distant listener before the seismic version does. The delay between signals may confer its own advantage, however, O'Connell-Rodwell proposes. The delay increases with distance; an astute listener would soon learn to gauge distance from the delay. Combined with its airborne counterpart, a seismic signal would enable the animal to coordinate its movements with faraway colleagues, to forage more effectively, and to detect unseen danger. It is compass, yardstick, and e-mail in one—an elephantine Palm Pilot.

And the elephant's palm is the key, O'Connell-Rodwell believes. It may be that the seismic vibrations propagate from the elephant's feet to its inner ear—a process known as bone conduction. That would explain some of the odder features of elephant anatomy, including the fatty deposits in its cheeks, which may serve to amplify incoming vibrations. In marine mammals, similar deposits are called "acoustic fat."

But O'Connell-Rodwell thinks the elephant ear may be tuned even more acutely to the ground. "They do have nerves connected to their toenails, and they do lean on them. It could be a direct line to their head." A colleague is now exploring whether the fleshy pad of an elephant's foot contains Pacinian and Meissner corpuscles, specialized nerve endings that detect faint motion and vibration. The tip of an elephant's trunk has more of these structures per square inch than does any other animal organ, and it is supremely touch-sensitive. (In addition to lifting a foot to improve its hearing, an elephant sometimes holds its trunk to the ground, as if it were an amplifier, says the Stanford biologist.)

All of which raises the question, Which is doing the hearing here—the elephant foot or the elephant ear? The truth is, "hearing" is a semantic distinction, a construct of human language. To us, a "sound" is what happens when airborne acoustic waves vibrate tiny hairs inside our head. An "ear" is an acoustic organ that looks like ours.

The fatty deposits in elephants' cheeks may serve to amplify incoming vibrations.

Properly defined, however, sound is a series of compression waves in any medium: air, liquid, solid matter. Animals have evolved all manner of translating these mechanical waves into neural signals. A fish senses motion with a line of specialized receptors on both sides of its body. Walk toward a fish tank, and your footsteps startle the fish. Did it hear you, or feel you? To the fish, there's no difference.

Perhaps, in our ear-o-centric view of the world, we have constrained our senses. "The animals have been paying attention to something that we haven't been noticing," O'Connell-Rodwell says. Lately she has begun exploring the possibility that other large mammals—bison, rhinoceroses, hippopotamuses, lions, giraffes—rely on seismic cues in their daily lives.

Paradoxically, the discovery that elephants and perhaps other large mammals may communicate seismically comes at a time when it is increasingly difficult for us to hear them. Just as the night sky is slowly becoming obscured by "light pollution" from countless streetlights and other artificial sources of illumination, so the sounding board of earth has become muddled with "bioseismic noise": rumbling trucks, electric generators, jet vibrations, the hum and trundle of civilization and commerce. Does this human static disrupt elephant conversations in the wild? Does it drive them nuts in captivity? The zoo environment is stressful enough without having to hear from every pothole within a twenty-mile radius. Then again, I manage to sleep through the most fearsome Manhattan traffic. "My guess is, elephants in urban environments have become desensitized to seismic signals, as people have," suggests O'Connell-Rodwell.

In the end, the primary casualty of bioseismic noise is us. The human foot happens to be a remarkably sensitive listening device. It is nearly as dense with pressure receptors as is the elephant's trunk. O'Connell-Rodwell suspects that once upon a quieter time, we paid closer attention to seismic signals than we do today. Vibrations from instruments such as the talking drum or the didgeridoo, or even from foot-stomping dances, may have spoken volumes to distant, unshod listeners. Then came telephones, automobiles, asphalt—and footwear. We hardened our soles to the world of sound.

The echo of my footsteps haunts me now. When last I strolled through the darkened Akeley Hall, it struck me that this is what it would be like to be entombed in a shoe. The silent elephants, the hushed lions, the stilled giraffes—a continent of primordial instincts urged me toward the exit: Loosen, unlace, enter the world barefoot.

Alan Burdick is writing a book about nature for Farrar, Straus and Giroux.

BIOMECHANICS

Twister!

Hit by a gusty spring breeze, the daffodil turns its back.

Story by Adam Summers ~ Illustrations by Sally J. Bensusen

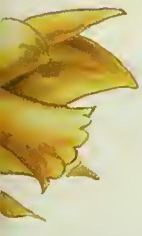
Consider a field of daffodils: A carpet of gaudy yellow flowers dancing in the breeze, revealing in their movements the direction of each puff of wind. The contrast between the sunny petals and the vibrant green of the stems; the joyous waggle of each flower. This is the stuff of poetry and art.

Hidden away in the interplay between flower and stem, however, is also an elegant morsel of biomechanics that explains how this flower can act like a weather vane while others just sway back and forth. The petals of the daffodil, as well as those of many other plants in the genus *Narcissus,* do not point skyward (as do those of the tulip blossom, for instance) but droop to one side of the stem. This makes the flower appear to be gazing downward, giving it a charming air of contemplation. (The genus, of course, is named after the beautiful young man of Greek mythology who became so enamored of his reflection in a pool that, according to one version of the myth, he fell in and drowned.)

Not surprisingly, the reality is less romantic. Shelley Etnier, now at the University of North Carolina at Wilmington, and Steven Vogel, of Duke University, have studied the daffodil's nodding posture—which enables it to reorient in a breeze, essentially turning its back to the wind—and found that the explanation for this ability lies in the material properties and cross-sectional shape of the daffodil's stem.

Spider legs, bat wing bones, flower stems, and many other structures are subject to two different sorts of deformation: torsion (twisting along the long axis) and bending. A garden hose, for example, is not given to twisting but bends quite easily. (This can be frustrating to gardeners who use a long hose to water plants far from the faucet: pulling the hose often bends it, shutting off the flow of water and thus requiring the gardener to walk back along the hose to straighten out the kinks.) A flat plastic coffee stirrer, by contrast, resists bending but twists easily. A long, flat roadway suspended in a windy canyon above a river is not very good at resisting torsion either—as evidenced by the famous collapse of the Tacoma Narrows suspension bridge. On November 7, 1940, just one year after it was built, this bridge began twisting back and forth in the wind with such force that it broke apart and fell into the water below.

The main reason a garden hose doesn't twist much is that it has a circular cross section. Resistance to torsion is (sorry, math phobes) set by the fourth power of the distance of each bit of material in the cross section from the central axis, with all those fourth powers added together. For a given amount of material and for both hollow and solid structures, a circular cross section maximizes that number and thus gives the best resistance to twisting.



Slice across a tulip stem, and you will see that it, too, has a circular cross section. In contrast, a cross section of a daffodil stem looks more like a football, or a lemon, cut the long way. This lenticular shape is less able to resist torsion but does resist bending (flexing) quite well, as long as the force hits it on the narrow edge. (For example, a floor joist—often a two-foot by eight-foot pine board—is always set with its narrow edge up, which gives it a tall and narrow cross section. If the joist were set the other way—with the wide edge up—the floor would bounce like a trampoline.)

To measure torsional stiffness in daffodil and tulip stems, Etnier and Vogel used an ingenious device that holds one end of a stem still while twisting the other end with a known force. The stiffer the stem, the fewer degrees it rotated. The scientists also measured bending stiffness by propping the ends of the stem up on a couple of blocks and then hanging a weight from the center. The stiffer the stem, the less it drooped. These two measurements gave the ratio of twistiness to bendiness. Not surprisingly, the twistiness of the daffodil was much higher (fourteen times higher, in fact) than its bendiness, explaining why these plants are far more likely to turn in the wind than to bend over. This ratio was nearly twice that of the upward-gazing tulip.

Etnier and Vogel also conducted experiments to find out why daffodils don't merely twist in the wind but do so with their blossoms facing downwind. Placing cut flowers (on intact stems) in a wind tunnel, they showed that the force on the bloom is highest when it is facing into the wind and lowest when it has rotated 180°. Flowers started to twist in response to the wind when it hit speeds of about 12 miles per hour; by 22 mph, they had completely turned their faces away from the wind. As wind speed increased, the petals consolidated themselves into a tighter and tighter bundle. Even at nearly 35 mph, the flowers remained undamaged. Above 20 mph, however, the stem began to bend over in addition to twisting, bringing the flower closer to the ground, where wind speed is lower.

I would like to think that these observations might have a positive influence on the design of useful objects—umbrellas, for instance. Most of us know from soggy personal experience that umbrellas, like daffodils, have a tendency to reorient themselves according to wind direction and, subsequently, to assume a shape far less suited to keeping us dry. Perhaps there are enough differences between umbrellas and daffodils to stop me from rushing out to line up investors for the "antidaffobrella" (for one thing, umbrellas don't swivel along the length of their "stems"), but I wish someone would do something about this problem. The only other step I can envision, drawing on the daffodil's example, is to crawl on my belly during a rainstorm, hoping to keep my umbrella out of the worst of the wind.

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

The lemon shape of the cross section of a daffodil stem, above, helps the flower twist away from, rather than bend in, a breeze. In stronger winds, though, the stem bends over as well.

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CELESTIAL EVENTS

The Producers

Now playing: the original stars in nature's longest-running hit

By Richard Panek

And now it's springtime for galaxies and nebulae!

No, this isn't just one more gratuitous magazine reference to the biggest Broadway hit in decades, a pathetic attempt to sprinkle a little show-biz glitter on a thoroughly unglamorous topic. Well, maybe it is, but at least it's not *entirely* gratuitous or pathetic. Springtime, in fact, provides one of the best seasons for sky watchers to go exploring outside the Milky Way Galaxy. And what they'll find there—galaxies, globular clusters, and other cosmic exotica—ain't exactly chopped liver.

As this column explained back in September 2001, our home galaxy is in the shape of a disk. Proportionally speaking, it's flatter than a pancake—if you consider that pancakes really aren't all that flat. They have something inside, only the Milky Way is thick with stars instead of heated batter. Now imagine you're standing on a microscopic crumb inside that pancake, about two-thirds out from the center. What would you see if you looked toward the center, along the disk? If you were inside a galaxy instead of a flapjack (which, fortunately, you are, at least according to the latest astronomical observations), what you'd see is the dense, seemingly impenetrable spill of stars and dust in our night sky that, somewhat confusingly, we also call the Milky Way.

Now imagine you're looking away from the plane of the disk—straight "up" or "down," so to speak. You'd still see stars, the ones that lie between our solar system and the "top" or "bottom" of the galaxy. But they would be nowhere near as numerous as those you saw when you were looking directly along the disk's edge. These stars wouldn't appear densely packed at all. In fact, what you'd mostly see would be the gulfs between the stars, the black expanses that serve as our windows on the rest of the universe.

Not that those gaps are exactly empty. As I said in that same September column, our galaxy seems to be surrounded by something that astrophysicists call dark matter—the unknown material that's detectable only indirectly, through its gravitational effects on "normal" matter (which is the kind we *can* detect directly). It's the presence of this kind of material that challenges traditional definitions of what galaxies are and how they look and where they extend. Hence the title of that earlier article: "Milky Way Mystery."

Since then, the plot has only thickened—and so has our galaxy. This past January, a team of astronomers announced that they've discovered what they termed a "corona" of hot gas surrounding the Milky Way. This is *not* the mysterious dark matter. Nor is it the previously identified "halo" that reaches about 5,000 to 10,000 light-years in every direction from the plane of the galaxy; for years astronomers have speculated that this halo, in part a repository of gas from the Milky Way's exploding stars, operates on the same principle as the water cycle on Earth, seeding future generations of stars.

The corona, however, is wholly other. It serves as an outer atmosphere of sorts for the Milky Way, encapsulating it in a "shell" at least 100,000 light-years thick. Astronomers detected its existence by observing hydrogen clouds (perhaps gas left over from the formation of the galaxy) that are barreling into it at nearly a million miles per hour and, in the process,

Galactic pancake

DON DIXON

being heated to between 100,000° and 1,000,000° F. In other words, the Milky Way might still be growing. As one astronomer observed at the press conference announcing the discovery of the corona, "Any formation models of galaxies will now have to include this."

None of this activity will affect your view out of the galaxy. The galactic corona and halo can be detected only through telescopes that operate at wavelengths that the eye doesn't—ultraviolet and X-ray, for instance—and dark matter isn't observable in any band of the electromagnetic spectrum. So when you look through the "top" or "bottom" of the galaxy—the parts that swing overhead on spring and fall nights—your window on the rest of the universe will be clear.

To experience in a particularly dramatic fashion the feeling of being on the inside of the galaxy looking out, try observing in the first hours after nightfall this month. If you can find a spot where the horizon is unobstructed in every direction, you'll see a whitish wash entirely encircling you. That's the disk of the galaxy, flat as the proverbial pancake, and you're part of it. Now look up—and therefore out. Equipped with a sky chart and binoculars or a telescope, you'll have more galaxies to choose from than you could possibly manage to see in one night.

What's true of our own galaxy applies to all those other galaxies as well. They're seething with unseen activity, they're bigger than they appear at first sight, and they might be constantly replenishing themselves. They are, in a word, producers—and you can see them on any clear night, no lines, no waiting, for free.

Richard Panek's next book, The Invisible Century: Einstein, Freud, and Our Search for Hidden Universes, *will be published in 2003 by Viking.*

THE SKY IN APRIL

By Joe Rao

Mercury begins April hiding in the Sun's glare—coming to superior conjunction on the 7th—but then moves on to its best apparition of the year. By April 18 you'll see it above the west-northwestern horizon, shining nearly as bright as Sirius (the brightest star in the sky) and setting nearly an hour after sunset. Mercury gets higher every evening; by the end of the month, it stands 13° above the horizon thirty minutes after sunset, with Venus, Mars, and Saturn above and to its left.

Venus, at magnitude -3.9, creeps through the western sky this month, climbing higher and moving farther north. A very thin sliver of Moon sits several degrees to its left on the evening of the 14th. Toward the end of the month, it rapidly approaches two dimmer planets, Mars and Saturn. By April 30, Venus stays up for two hours after sunset.

Mars now shines at magnitude +1.6. All month it crawls eastward through Taurus, apparently trying to keep pace with the Sun, and sets two and a half to three hours after sunset. During the latter half of the month, it approaches Saturn while being pursued by Venus. A slender crescent Moon passes a few degrees below and to the left of Mars on the evening of the 15th.

Jupiter shines brilliantly in Gemini at magnitude -2.1. Appearing high toward the southwest at dusk, the planet is prominent all month. As the sky darkens on the evening of the 18th, Jupiter sits less than 2° below and to the left of a fat crescent Moon.

Saturn is well placed for evening observation during April. High in the southwestern sky as night falls, it sets four and a half hours after the Sun at the start of the month and just over two hours after it by the 30th. Saturn appears below and to the right of the crescent Moon on the 16th.

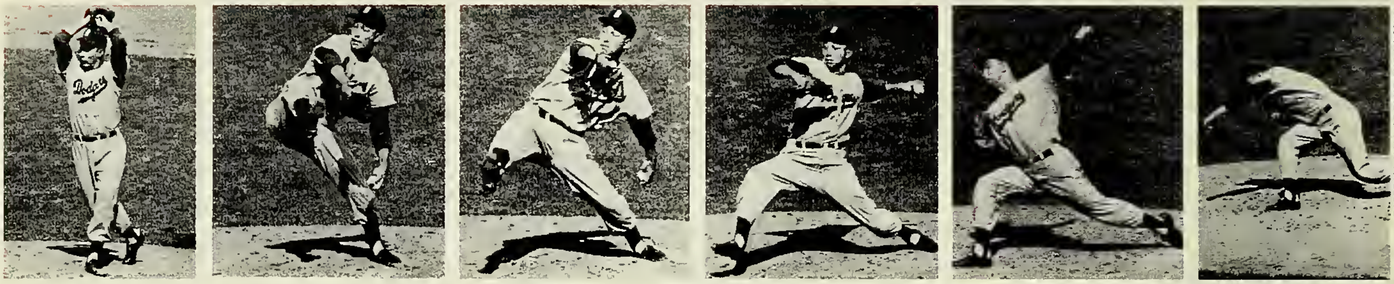
The Moon wanes to last quarter on April 4 at 10:29 A.M. EST. New Moon falls on the 12th at 3:21 P.M. EDT. First-quarter Moon comes on the 20th at 8:48 A.M., and full Moon on April 26 at 11:00 P.M.

A bright comet in April? On February 1, Kaoru Ikeya of Japan and Daqing Zhang of China discovered a comet on its way toward the Sun. Its closest approach to the Sun occurred on March 18, when it was 47 million miles away, or midway between the orbits of Mercury and Venus. As we went to press, astronomers were suggesting that this object could be the return of a bright comet that appeared in the year 1661. If so, the April sky may be graced by a comet easily visible to the naked eye. The only way to know is to go out and look. During April, comet Ikeya-Zhang will be low above the north-northwestern horizon about an hour after sundown. After the first week of April, it will also be visible in the morning sky, getting progressively higher above the northeastern horizon an hour before sunrise. In fact, from mid-April through the end of the month, it will remain above the horizon all night long for most northern localities.

Daylight saving time returns on Sunday, April 7, for much of Canada and the United States. Remember to set your clocks ahead one hour.

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

REVIEW



BASEBALL HALL OF FAME AND MUSEUM

Johnny Podres, World Series, 1955

Baseball by the Books

This season's lineup offers some interesting reflections on the game. **By George Gmelch**

Baseball has become a global game. Long a national passion in Japan and in some parts of the Caribbean and Latin America, it has more recently been adopted elsewhere in Asia as well as in Europe, particularly the Netherlands and Italy, and Australia. Some excellent books have been written about baseball in the Dominican Republic, Nicaragua, and Cuba. Now, Joseph A. Reaves, who once covered Asia for the *Chicago Tribune,* writes about the development of baseball in Korea, the Philippines, China, and Taiwan in *Taking in a Game: A History of Baseball in Asia.* After Americans introduced baseball to Japan in the 1870s, the Japanese transformed the game and became the dominant missionaries of baseball across Asia. "Little ball," as the Asian game is sometimes known, involves playing for one run at a time; it prizes discipline, conformism, hierarchy, control, sacrifice for the good of the group, harmony, respect for management, and a reluctance to criticize. America's "big ball," of course, favors personal achievement, innovation, creativity, and individualism.

More than 200 books about our national pastime appear each year. Many are fluff—trivia, statistics and records, profiles of particular teams. But there is also some fine scholarship, much of it done by historians. Charles C. Alexander's *Breaking the Slump,* for example, describes pro ball during the hard times of the Great Depression. Back then, baseball games were played during the day and, because of few pitching changes, were quick (about one and three-quarter hours). Only sixteen major-league teams existed (today there are thirty), and all were in cities on or east of the Mississippi River.

During the 1930s, major-league organizations were just beginning to build minor-league farm systems as a source of big-league talent. Conditioning and sports medicine were in their infancy, with the treatment of injuries seldom going beyond massage or Mercurochrome—although some physicians, curiously, prescribed the removal of teeth or tonsils as a cure for sore throwing arms. Baseball stadiums were called parks or fields. Built with private capital, Wrigley Field, Comiskey Park, Ebbets Field, and Shibe Park bore the names of the men who financed their construction. Sadly, at the very time that the United States was preparing to fight a war against totalitarian regimes and their doctrines of racial supremacy, our national game at the highest level was reserved for whites only.

The postwar years are taken up in *Late Innings: A Documentary History of Baseball, 1945–1972,* the third volume in a series of anthologies of news articles, private letters, legal decisions, and league communications that have been compiled by baseball historian Dean A. Sullivan. Topics include everything from Jackie Robinson's assault on the color bar to the effects of television on fan attendance and the labor unrest in baseball during the 1970s.

Safe by a Mile is the story of Charlie Metro, a colorful minor- and major-

Baseball, A Celebration, *by James Buckley Jr. and Jim Gigliotti (DK Publishing, 2001; $50)*

Baseball As America: Seeing Ourselves Through Our National Game, *developed by the National Baseball Hall of Fame and Museum (National Geographic Society, 2002; $40)*

Breaking the Slump: Baseball in the Depression Era, *by Charles C. Alexander (Columbia University Press, 2002; $29.95)*

Late Innings: A Documentary History of Baseball, 1945–1972, *edited by Dean A. Sullivan (University of Nebraska Press, 2002; $29.95)*

Safe by a Mile, *by Charlie Metro with Thomas L. Altherr (University of Nebraska Press, 2002; $29.95)*

Taking in a Game: A History of Baseball in Asia, *by Joseph A. Reaves (University of Nebraska Press, 2002; $29.95)* league player, coach, manager, and scout whose career spanned the 1940s through the 1980s. This excellent oral history was conceived by historian Thomas L. Altherr (who, in my opinion, takes too little credit for his role in the book). Among Metro's many coaching assignments was the Carolina League's Durham Bulls (FYI, he makes clear that he never allowed the clubhouse hanky-panky portrayed in the popular movie *Bull Durham*). I was intrigued with Metro's spring training experiences at the Detroit Tigers complex known as Tiger Town, because I was a minor-league player there at about the same time. One of Metro's friends in Tiger Town was Bernie DeViveiros, a master of sliding and the man who scouted me. On the night I signed a contract with the Tigers, Bernie (to my mother's horror) demonstrated the hook leg slide on my parents' new living-room carpet.

Baseball and photography have evolved together since the 1800s, and *Baseball, A Celebration* is a lavishly illustrated account of that history. Since early cameras and film were too slow to capture the action of a player swinging a bat or diving for a ground ball, posed portraits of individuals and teams were the standard, and many were taken in studios rather than on the field. Once portable cameras with faster shutter speeds were introduced, photography became an everyday part of baseball reporting. I wish there had been more photographs of minor-league baseball, however, because the game there is as colorful and as American as the big-league version.

Baseball As America, the official companion volume to the National Baseball Hall of Fame and Museum's traveling exhibition (on view at the American Museum of Natural History through August 18), explores the relationship between baseball and American culture through a collection of vivid illustrations and essays. David Rockwell writes on designing stadium interiors; chef and cookbook author Molly O'Neill, on the primal importance of the hot dog in baseball; filmmaker Penny Marshall, on the making of *A League of Their Own*. In "The Mills Commission and Doubleday," Tom Sheiber and Ted Spencer reveal how sporting-goods mogul A. G. Spalding manipulated the 1908 special commission investigating the origins of baseball, pushing the commissioners to support his view that Abner Doubleday invented the uniquely American game and that it had not evolved from rounders, an English schoolboys' game.

Many of my academic colleagues still don't understand why such scholars as Alexander, Reaves, or I study baseball. They seem to adhere to an old-fashioned, elitist view that sport is of the body, not of the mind, and is therefore not intellectual enough to merit serious attention. A sociologist friend dismisses organized sport as "mere play." I like to remind him that the space given to sports coverage in our nation's newspapers now surpasses that of any other single topic. The games we play, and how we play them, seem to be as valid a reflection of our culture as are our politics, religion, or literature.

Anthropologist George Gmelch played professional baseball in the 1960s and has published In the Ballpark: The Working Lives of Baseball People *(1998, with J. J. Weiner) and* Inside Pitch: Life in Professional Baseball *(2001).*

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The Human Presence

By Robert Anderson

NASA GSFC/NOAA NGDC

In the March 1996 issue I mentioned Earth Observatory, a NASA Web site. Now I urge you to visit it again for a single new image, "Earth's City Lights" (earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=4333). Craig Mayhew and Robert Simmon, of the agency's Goddard Space Flight Center, created it by piecing together hundreds of images from defense satellites designed for tracking moonlit clouds to aid aircraft navigation. During the low light of new moons, the satellites are sensitive enough to capture the network of electric lights girdling the globe. The resulting image is not only spectacularly beautiful but also a powerful reminder of humanity's expansion.

To appreciate the image fully, download the larger version. You can then scroll down or across to look at different regions of the planet. The lights reveal urban centers but are not always a reliable gauge of population density: India and eastern China, for example, show up dimmer than western Europe and the eastern half of the United States. Or compare North and South Korea, or follow the bright thread of Egypt's densely packed population along the banks of the Nile River, from the Aswān Dam to the Mediterranean.

More than pretty pictures, these satellite images are now being used to measure global rates of urbanization. Read the accompanying article, "Bright Lights, Big City," to learn more.

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

BOOKSHELF

The Rainbow Bridge: Rainbows in Art, Myth, and Science, *by Raymond L. Lee Jr. and Alistair B. Fraser (Pennsylvania State University Press, 2001; $65)*
A mathematician and a meteorologist team up to examine the optics of the rainbow and the manner in which its spectrum has been incorporated into culture and mythology.

Olafur Eliasson: Surroundings Surrounded: Essays on Space and Science, *edited by Peter Weibel (MIT Press, 2002; $34.95)*
The evocative works of a contemporary Icelandic artist are the catalyst for this collection of essays—by chemists, geologists, physicists, architects, and cultural theorists—on our conceptions of nature and the scientific tools we use in its observation and measurement.

Genes, Girls, and Gamow: After the Double Helix, *by James D. Watson (Knopf, 2002; $26)*
In the April 25, 1953, issue of *Nature,* twenty-five-year-old American geneticist James Watson and his English collaborator, Francis Crick, announced the discovery of the structure of DNA. Underlying Watson's account of people and places in the heady years that followed is his search for love.

Sudden Music, *by David Rothenberg (University of Georgia Press, 2002; $29.95; includes audio CD)*
Weaving memoir, travelogue, and reflection, philosopher and musician Rothenberg describes the world as a musical place, where he has found "a way to hear the whole world as a musical happening, making each step forward a musical gesture, a part in the song of the world."

Lost Languages: The Enigma of the World's Undeciphered Scripts, *by Andrew Robinson (McGraw-Hill, 2002; $34.95)*
Deciphering writing systems, whether the Etruscan alphabet or Zapotec glyphs, is comparable in complexity to cracking the genetic code.

The Moment of Complexity: Emerging Network Culture, *by Mark C. Taylor (University of Chicago Press, 2001; $32)*
A humanities professor at Williams College and founder of the Global Education Network (a distance-learning program), Taylor examines digital currents in art, architecture, philosophy, and science and argues that what he calls "network culture" has a distinctive logic and dynamic.

Digital Biology: How Nature Is Transforming Our Technology and Our Lives, *by Peter J. Bentley (Simon & Schuster, 2001; $24)*
"The digital entities I want you to meet," writes Bentley, a specialist in evolutionary computation, "are not incomprehensible collections of numbers or equations. They are just the same as you and the natural world that surrounds you. They may live and die within digital domains, but they are every bit as biological as you."

Paper Before Print: The History and Impact of Paper in the Islamic World, *by Jonathan M. Bloom (Yale University Press, 2001; $45)*
In the Middle Ages, Muslims spread the technology of paper making from China across Islamic Asia and North Africa (and eventually to Europe), transforming literature, science, and the arts and serving as a bridge between cultures.

Earthly Remains: The History and Science of Preserved Human Bodies, *by Andrew T. Chamberlain and Michael Parker Pearson (Oxford University Press, 2001; $26)*
From ancient Egyptian mummies to Iron Age bog bodies found in northern Europe, human remains reveal much about past cultures.

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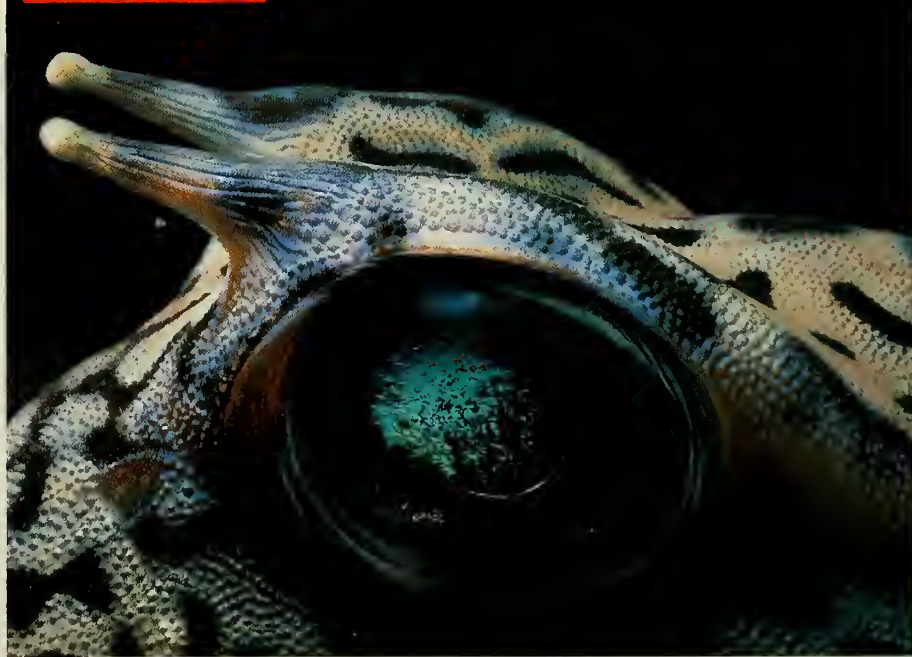

JEFF ROTMAN

Eyes Into Secret Seas, *by Jeffrey L. Rotman (Rizzoli, 2002; $75)*

EXPLORER GUIDE

THE NATURAL MOMENT

Arms Control

Photograph by
Fred Bavendam MINDEN PICTURES

Off the coast of British Columbia, a sunflower sea star prepares to spawn, using a dozen or so arms to hoist its fleshy central mass free of the seafloor. The hunched posture is typical of female stars, which shoot a stream of eggs upward to be fertilized by drifting sperm. But this static pose belies the mobility of the species. Fleet, large, and voracious, the sunflower sea star roams cool, shallow Pacific waters hunting down assorted shellfish, urchins, and fishermen's bait. "You can often see a whole gang of them under a dock," reports one biologist, ominously.

The sunflower sea star can be a full thirty inches in diameter. Despite its proportions, it is the cheetah of its habitat, flexible and—carried on tube feet, the many tipped bristles on its underside—able to reach speeds of five feet a minute. Prey is first enveloped, then digested by the star's everted stomach. "I have seen swimming scallops scattering in front of a large star," says photographer Fred Bavendam, who also witnessed cannibalism: "I lifted up a sunflower sea star that was on top of another. On the bottom one I could see a 'munched' area."—*Judy Rice*

ENDPAPER

Science Versus Religion? No Contest

By Ian Tattersall

Why do some (only some) of those with profoundly felt religious beliefs feel threatened by aspects of the very science that has brought them the material comfort and security they appear happy to accept? Presumably it is because they think that in some sense, scientific and religious beliefs are in conflict. Nothing, though, could be further from the truth. Science and religion deal in totally different forms of knowledge. Religions seek ultimate truth and do so in a variety of ways. But no really honest scientist would claim to be doing anything like the same thing. Science is a matter of honing our perceptions of ourselves and of the world around us, of producing an increasingly accurate description of our physical and biological environments and how they work. What science emphatically is *not* is an absolutist system of belief. Rather, it is constantly subject to rearrangement and change as our collective knowledge increases. How can we make progress in science if what we believe today cannot be shown tomorrow to be somehow wrong or at least incomplete? Religious knowledge is in principle eternal, but scientific knowledge is by its very nature provisional.

Being human, some scientists clearly like to bask in an aura of authoritativeness, and certainly nothing is more intimidating to the average person than the stereotypical image of a white-coated figure covering a blackboard with incomprehensible symbols. But in actual fact, scientists are in pursuit of knowledge about mundane realities and are not in the business of revealing timeless truths. And because science is self-correcting, its practitioners can often find themselves pursuing blind alleys.

Some scientists who dispute Darwinian theory apparently do not understand or accept this distinction between scientific knowledge and religious knowledge. Interestingly, many such people are involved in the physical sciences and engineering, areas in which hypotheses tend to be more directly testable than are hypotheses in biology. Indeed, intelligent design, which is offered as an alternative to evolution by natural selection, is essentially an engineering concept. But just look at nature with an engineer's eyes: undoubtedly it works, but this does not mean that organisms are optimized in the way that an intelligent engineer would strive to ensure.

There is no better way to illustrate this than by considering our own much-vaunted species, *Homo sapiens*. As a result of our upright, bipedal posture, we suffer a huge catalog of woes, including slipped disks, fallen arches, wrenched knees, hernias, and aching necks. No engineer, given the opportunity to design human beings from the ground up, would ever dream of confecting a jury-rigged body plan such as ours. But our innumerable afflictions can be understood as the consequence of adapting an ancestral four-legged body to a new, bipedal lifestyle.

Rather like the myriad infuriating versions of Windows, we humans have been cobbled together from preexisting components. Of course, there may be upsides to this, too. Thus I would guess that our extraordinary human consciousness results not from any specific structures we have acquired but rather from the complex accretionary history of our brain and its consequent untidy nature. Artificial intelligence—specifically *because* it is engineered—is unlikely ever to match our own strange but unique brand of smarts.

Given the current social climate and the unease that science often engenders, scientists would do well to insist on educating students better about what the profession actually involves. For if our young people think of science as monolithic and authoritarian, they are likely to have excessively high expectations for it and to be disappointed by the inevitable cases in which scientific hypotheses turn out to be wrong. Evolutionary theory is deficient because it is "just a hypothesis"? If so, then we might as well throw out all of science, for the same is true of all scientific knowledge.

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