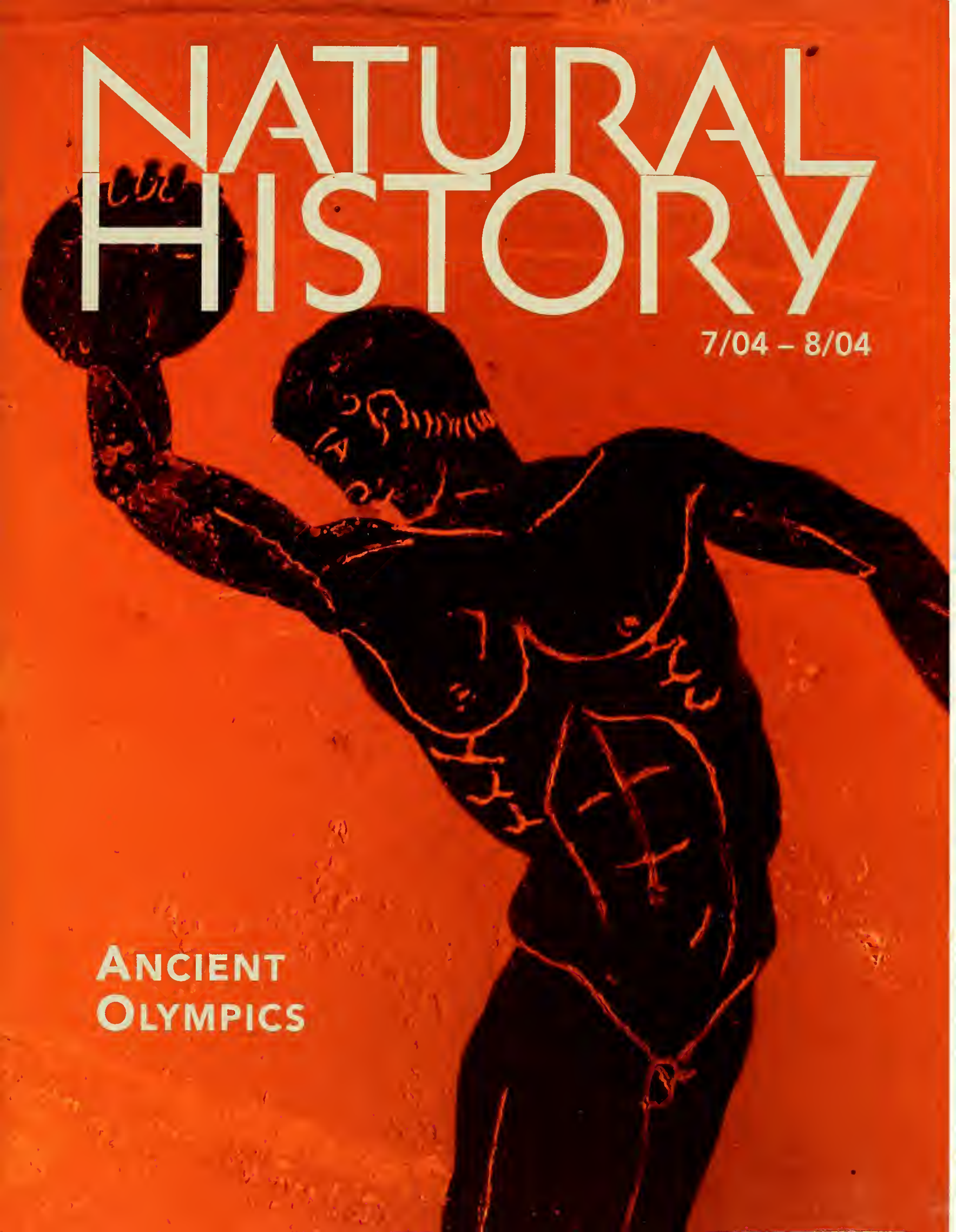
NATURAL HISTORY

7/04 – 8/04



ANCIENT OLYMPICS

NATURAL HISTORY

JULY/AUGUST 2004 VOLUME 113 NUMBER 6

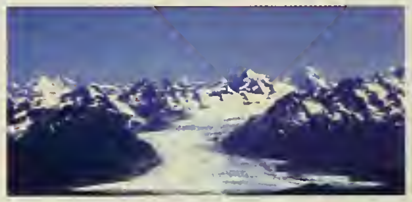
FEATURES

ON THE COVER: The Achilles Painter, discus thrower, detail from red-figure Panathenaic amphora, fifth century B.C.

NATURAL HISTORY

DEPARTMENTS


22


50


56


71

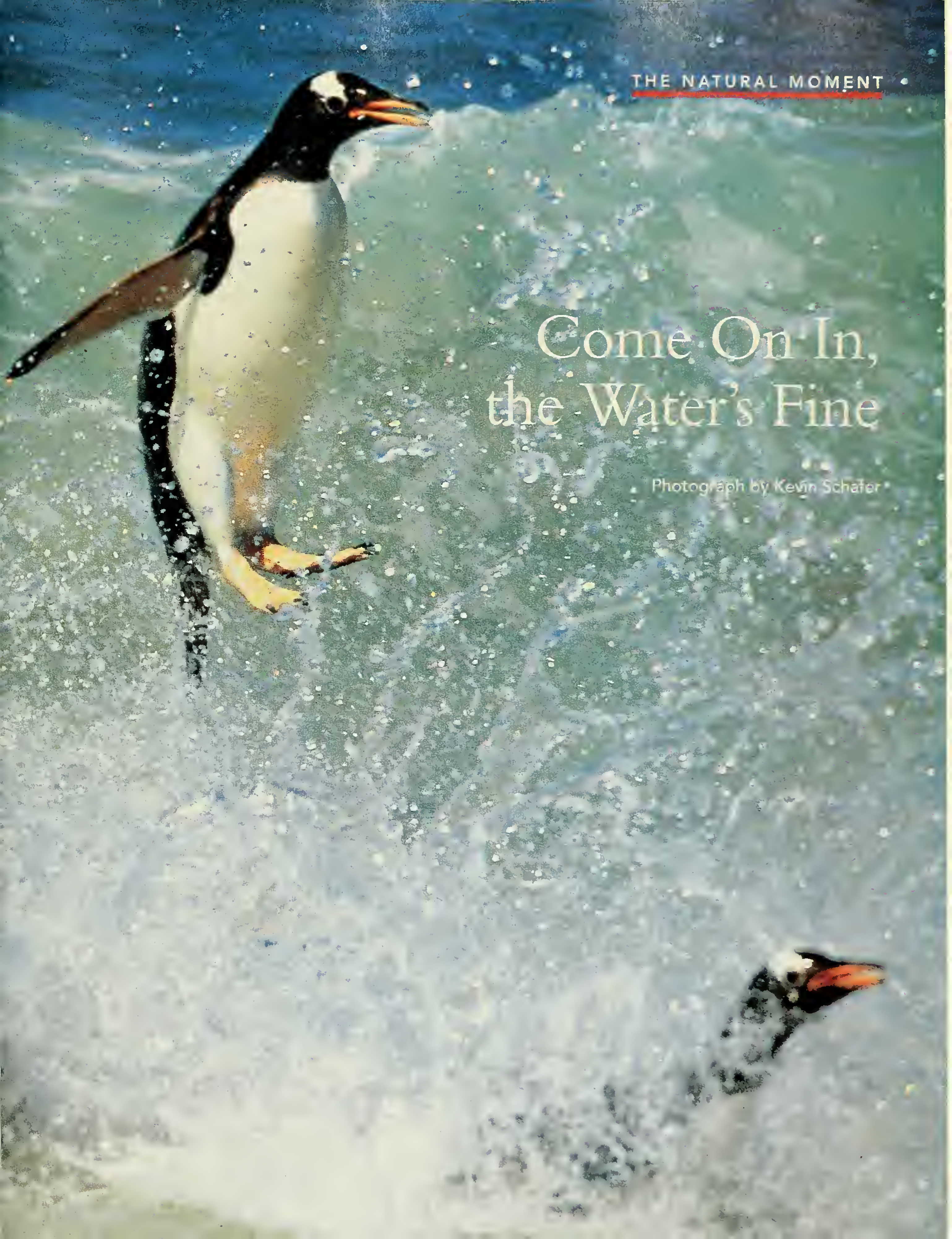

12


16


4

PICTURE CREDITS: Page 55

Visit our Web site at
www.naturalhistorymag.com

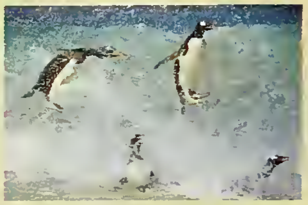


Come On In, the Water's Fine

Photograph by Kevin Schafer

THE NATURAL MOMENT

◄ *See preceding two pages*



On sunny afternoons in the Falkland Islands, the South Atlantic Ocean turns into a roller coaster for gentoo penguins *(Pygoscelis papua)*, as they ride the breakers home from a day of diving. For his photograph, Kevin Schafer camped out for a week on New Island, which shelters more than 5,000 gentoos (and only four humans) year-round. Every day, in what Schafer calls "return rush hour," the penguins tumble onto the beach en masse—a defense against stalking sea lions.

To Schafer, the New Island coast is a "sandy, un-polar place," where penguins might seem out of place. Yet penguins have not always been cold-loving creatures. Fossils recently examined by Julia A. Clarke, a paleontologist at North Carolina State University in Raleigh, show that an ancient relative of penguins was swimming in these same waters 40 million years ago. Clarke's finding doubles the age of the oldest comparable fossil, pushing the penguins' roots back to an epoch when these waters were warm and polar ice caps were nonexistent.

Today most penguin species would have a tough time doing an evolutionary back-paddle and coping with a hotter habitat. The population Schafer observed recently suffered when a warm-water bloom of algae poisoned thousands in the colony. Another penguin species, the Adélies, were cut off from their breeding grounds by unusually large icebergs, calved from the continental ice shelf. Let's hope for a cool summer. —*Erin Espelie*

UP FRONT

The Whole World Is Watching

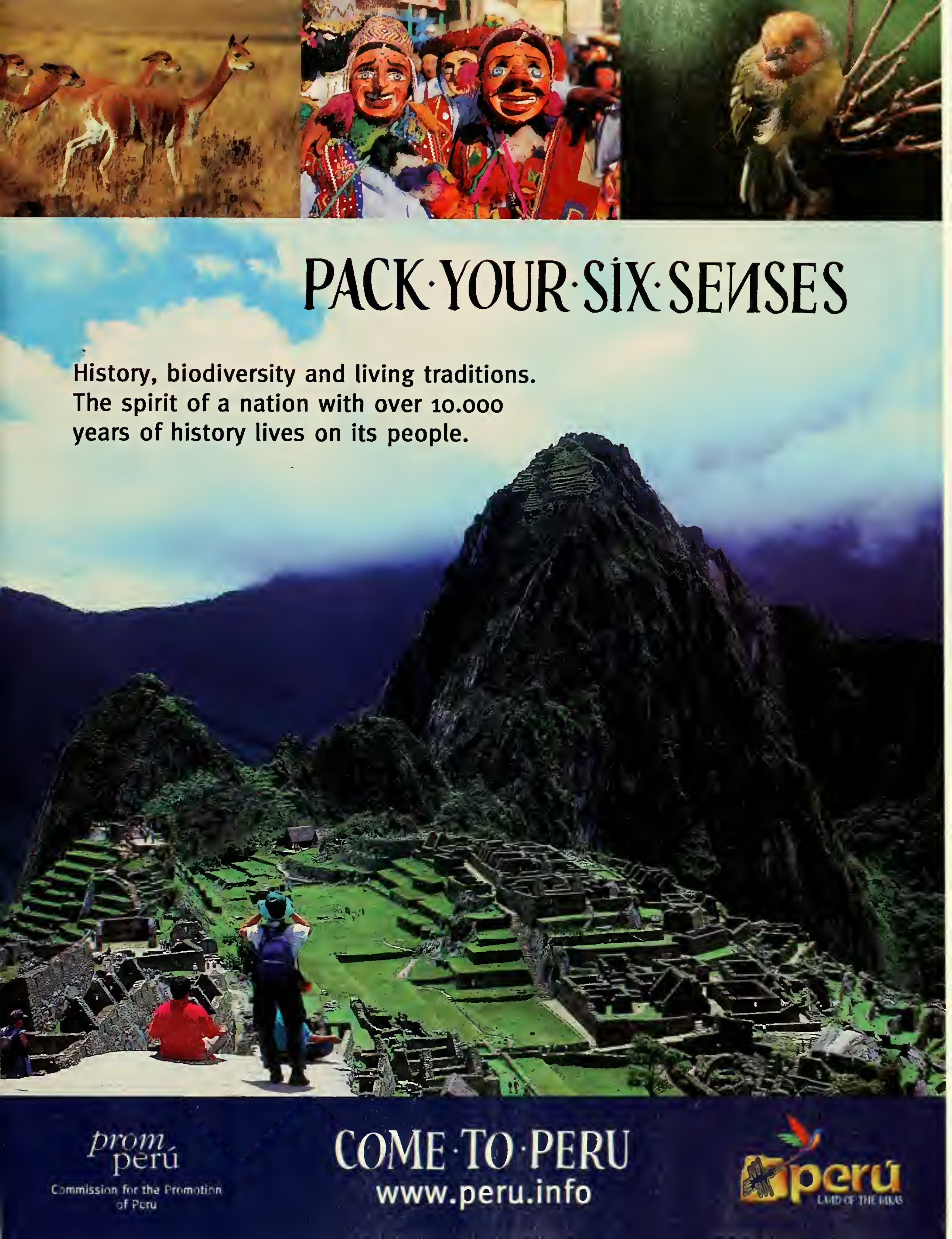
What does *Natural History* have to do with the Olympics? Plenty. The modern Games, which return to Athens this August 13 for the first time in more than a century, have always made explicit appeal to their classical antecedents. And, in fact, a wealth of information about the ancient Olympic Games has been preserved and transmitted to the present day—along with a lot of myth and hyperbole. Disentangling myth from ground truth, of course, is part of this magazine's stock in trade. David C. Young, an expert on the Greek poet Pindar and a student of the Olympics for much of his academic life, brings readers the latest scholarly thinking and the results of meticulous archaeological research to bear on the ancient Greek Games. His article is titled (with a nod to Pindar) "With Hands or Swift Feet" (page 24).

Maybe I'm being naive, but I find it remarkable that so much about the ancient Games foreshadows important issues that have played out prominently in the modern Olympics: the tensions that arise when the politics of the competing states clash with maintaining the integrity of the athletic competitions; the substantial material rewards some winning athletes receive; the burdens on public funds that new stadiums and facilities impose on the state that hosts the games; and, clearly, the intensity of the sporting events themselves. Billions of people—a substantial fraction of the people on the planet—will be watching the events and festivities this August. Slightly fewer will be privy to the insights you'll gain from Professor Young.

• • •

The failure to find biological weapons in Iraq hardly implies that bioweapons have vanished from the face of the earth. The civilized world proclaimed them gone more than thirty years ago, with the signing, by more than a hundred nations, of the Biological and Toxin Weapons Convention. But wishing they would go away doesn't make it so. In the former Soviet Union, smallpox samples that were supposed to be kept under lock and key wound up in bioweapons labs—and in stockpiles for loading into missile warheads.

A naive person hardly knows where to begin in responding to the story Wendy Orent tells about recent breakthroughs in the bioengineering of a "more virulent" form of mousepox ("A Most Dangerous Game," page 38). The questions it raises are deep and longstanding: How much responsibility should scientists bear for the foreseeable social consequences of their work? To what degree should the potentially dangerous nature of scientific research become a factor in the decision to publish it? Those questions take on special urgency here, because the results of the work with mousepox could have implications for a bioweapon based on smallpox. Read this article, talk over the dilemmas it raises with someone you trust, then read it again. It's that important. —PETER BROWN


PACK·YOUR·SIX·SENSES
History, biodiversity and living traditions.
The spirit of a nation with over 10.000
years of history lives on its people.
prom perú
Commission for the Promotion of Peru
COME·TO·PERU
www.peru.info
perú

CONTRIBUTORS

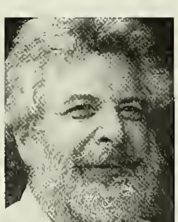
The professional career of KEVIN SCHAFER ("The Natural Moment," page 4) has taken him to all seven continents to document issues in wildlife, conservation, and ecotourism. He was the 1997 recipient of the BBC–Natural History Museum of London's Gerald Durrell Award for Endangered Wildlife. Schafer's work has appeared in *National Geographic*, *Smithsonian*, and *Audubon*, as well as previously in this magazine. His most recent volume is *The Falkland Islands: Between the Wind and Sea* (Coach House Publications, 2003); his book *Penguin Planet* (NorthWord Press) won the National Outdoor Book Award for the year 2000.

Combining an academic specialty in ancient Greek poetry with a lifelong enthusiasm for sports, DAVID C. YOUNG ("With Hands or Swift Feet," page 24) has spent many years investigating the Olympics, both early and modern. Young's article in this issue is based on his new book, *A Brief History of the Olympic Games*, which is being published this summer by Blackwell Publishing. His previous works include *The Olympic Myth of Greek Amateur Athletics* (Ares, 1984) and *The Modern Olympics: A Struggle for Revival* (Johns Hopkins, 1996). Young is a professor of classics at the University of Florida in Gainesville.

Now a biology professor at Central Washington University in Ellensburg, Washington, DANIEL D. BECK ("Venomous Lizards of the Desert," page 32) says he found his calling as a boy in Utah's Wasatch Front, where he kept chickens and caught snakes. His research on the ecology, physiology, and behavior of monstersaurs—Gila monsters and beaded lizards—spans twenty-two years. Beck's book *Biology of Gila Monsters and Beaded Lizards* is scheduled for publication by the University of California Press in the summer of 2005.

WENDY ORENT ("A Most Dangerous Game," page 38) is a freelance writer based in Atlanta, Georgia. Trained as an anthropolgist, her interest in the genetic engineering of germs developed out of her interviews with Igor V. Domaradskij, one of the principal designers of the bioweapons program for the former Soviet Union. She co-authored Domaradskij's memoir *Biowarrior: Inside the Soviet/Russian Biological War Machine* (Prometheus Books, 2003). Orent's latest book is *Plague: The Mysterious Past and Terrifying Future of the World's Most Dangerous Disease* (The Free Press, 2004). She is currently at work on an article about the evolutionary biology of flu and SARS.

Trained as both a research astronomer and an attorney, DONALD GOLDSMITH ("The Best of All Possible Worlds," page 44) devoted himself to popularizing astronomy thirty years ago. Since then he has written more than twenty books and collaborated on many PBS television programs, including the 1991 series *The Astronomers*. He also recently co-authored, with Neil deGrasse Tyson, the companion volume to the upcoming PBS *NOVA* series *Origins: Fourteen Billion Years of Cosmic Evolution*, which will be broadcast in September. The book is scheduled for publication by W. W. Norton in August.



NATURAL HISTORY

PETER BROWN *Editor-in-Chief*

Mary Beth Aberlin *Managing Editor*
Elizabeth Meryman *Art Director*

Board of Editors
T. J. Kelleher, Avis Lang, Vittorio Maestro

Michel DeMatteis *Associate Managing Editor*
Thomas Rosinski *Associate Art Director*
Erin M. Espelie *Special Projects Editor*
Graciela Flores *Editorial Associate*
Hannah Black, Aimee Cunningham, Adam Rathe *Interns*

Contributing Editors
Robert Anderson, Charles Liu, Laurence A. Marschall, Richard Milner, Robert H. Mohlenbrock, Joe Rao, Stéphan Reebs, Adam Summers, Neil deGrasse Tyson

CHARLES E. HARRIS *Publisher*
Gale Page *Consumer Marketing Director*
Maria Volpe *Promotion Director*
Edgar L. Harrison *National Advertising Manager*
Sonia W. Paratore *Senior Account Manager*
Donna M. Lemmon *Production Manager*
Michael Shectman *Fulfillment Manager*
Jennifer Evans *Business Administrator*

Advertising Sales Representatives
New York—Metrocorp Marketing, 212-972-1157, Duke International Media, 212-986-6098
Detroit—Joe McHugh, Breakthrough Media, 586-360-3980
Minneapolis—Rickert Media, Inc., 612-920-0080
West Coast—PPW Sales Group/Sue Todd, 415-543-5001
Toronto—American Publishers Representatives Ltd., 416-363-1388
Atlanta and Miami—Rickles and Co., 770-664-4567
National Direct Response—Smyth Media Group,646-638-4985

TODD HAPPER *Vice President, Science Education*

Educational Advisory Board
Myles Gordon *American Museum of Natural History*
David Chesebrough *Buffalo Museum of Science*
Stephanie Ratcliffe *Natural History Museum of the Adirondacks*
Ronen Mir *SciTech Hands On Museum*
Carol Valenta *St. Louis Science Center*

NATURAL HISTORY MAGAZINE, INC.
CHARLES E. HARRIS *President, Chief Executive Officer*
CHARLES LALANNE *Chief Financial Officer*
JUDY BULLER *General Manager*
CHARLES RODIN *Publishing Advisor*
RUSSELL CHERAMI *Publishing Advisor*

To contact us regarding your subscription, to order a new subscription, or change your address, please visit our web site www.naturalhistorymag.com or write to us at Natural History, P.O. Box 5000, Harlan IA 51593-0257
For advertising information, call 646-356-6555.

Natural History (ISSN 0028-0712) is published monthly, except for combined issues in July/August and December/January, by Natural History Magazine, Inc., in affiliation with the American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024. E-mail: nhmag@naturalhistorymag.com. Natural History Magazine, Inc., is solely responsible for editorial content and publishing practices. Subscriptions: $30.00 a year; for Canada and all other countries: $40.00 a year. Periodicals postage paid at New York, NY, and at additional mailing offices. Canada Publications Mail No. 40030827.

If you would like to contact us regarding your subscription or to enter a new subscription, please write to us at Natural History, P.O. Box 5000, Harlan, IA 51593-0257. Postmaster: Send address changes to *Natural History*, P. O. Box 5000, Harlan, IA 51537-5000 Printed in the U.S.A

Egyptian Riddles

Mary Knight ("Egypt's Young and Restless," 5/04) fails to mention in her bland article that Egypt gets $2 billion a year in aid from the United States. Where has that money gone? To a bloated military and security apparatus that enforces the authoritarian rule of an aged president who certainly does not provide computer services, or much else, to his population. Information is power, and Hosni Mubarak is not a sharer by any means.

Egypt has runaway population growth, Cairo is a heavily polluted city, the country's wildlife is vanishing, the irrigated areas are shrinking owing to increasing salinity of the soil (because the Nile's flow is now restricted by the unfortunate Aswan Dam). Ms. Knight barely scratched the surface of a nation with a glorious past and a most uncertain future.
Susan Addelston
New York, New York

Although Mary Knight's depiction of poverty and despair in Egypt certainly rang true, I was astounded by her breezy endorsement of the al-Jazeera satellite TV channel. Al-Jazeera has repeatedly been criticized for its inflammatory anti-Western, anti-Israel programming. Many American leaders have condemned al-Jazeera for inciting Arabs to hatred and violence. Yet Ms. Knight calls al-Jazeera a "source of optimism" that "helps release some of the frustration felt by Egyptian youth." Better yet, she says, "it affirms their identity as young, strong, and Arab."

You owe your readers an apology for allowing Ms. Knight to disguise her own political views as neutral reporting on modern Egypt.
Michael W. Steinberg
Bethesda, Maryland


"Now this *dance means she found the gardenia floating in a pitcher of mint juleps.*"

As brief as it was, Ms. Knight's piece enlightened me, and I was pleased to find some positive views, including her discussion of an Islamic school that does not engage in rote learning, and her report on the somewhat positive plight of women, at least in Egypt's big cities.
Bruce Rosen
New York, New York

Mary Knight replies: I don't think Natural History is the proper forum in which to argue the failures or successes of U.S. aid to the Middle East. But apart from the political issues, Susan Addelston points to several serious problems Egypt faces.

Overpopulation is crippling the nation's economy and threatening its human habitat. But what do young Egyptians—the ones who most have to face the consequences of overpopulation—have to say about it? When I asked married women who had at least one child about their views on contraception, they almost universally regarded it as a godsend; overall, though, remarkably few young Egyptians are willing to think about family planning. Nevertheless, behavior patterns tell an important story: Young men are resigned to late marriage, when they will have saved up enough money; women postpone marriage while getting more education and entering the workforce in ever greater numbers. As a result, in recent years population growth has in fact slowed dramatically.

Pollution is another grave threat to the health and future of the populace, as Ms. Addelston notes. Unfortunately, space prevented me from including information about the work of several small NGOs (nongovernmental organizations) that are addressing these and similar problems, nor could I discuss grassroots educational efforts in the "popular" (poor) districts.

I did not endorse (or repudiate) al-Jazeera. Contrary to what Michael W. Steinberg suggests, the television channel often presents opposing points of view, and American and even Israeli positions are aired. What I am endorsing is the response I have noted among young people who view al-Jazeera programming. Some love it, some hate it, some even think the U.S. controls it. But, significantly, it's getting them to think about politics. Egyptian leaders appear on al-Jazeera, but in contrast to the way they are treated on state-run media, they face hard questions from which the camera offers no escape. Granted, talking about politics cannot be equated with democracy, but it's a start.

Home Alone

In his article "No Place to Call Home" (4/04), Takeyuki Tsuda brought out the painful realities of Japanese who choose to leave "home." Return migrants are distinguished from the native born to the point that even their names must be written in a distinct phonetic system that identifies them as foreigners *(gaijin)*. Former Peruvian president Alberto Fujimori himself could not avoid such treatment.

For that reason, I disagree with Mr. Tsuda's conclusion that the children of the returnees "will be able to bridge the ethnic gap." Yes, they are learning Japanese and adopting Japanese customs, but their names and the way they are written will always identify them as having once left the country.
Winifred C. Chin
New York University
New York, New York

TAKEYUKI TSUDA REPLIES: I appreciate Winifred C. Chin's remarks, but I would note that the Japanese Brazilians have Japanese last names, unless they happen to be of mixed descent. Many have Brazilian first names, but a number have both Japanese and Brazilian first names. The students I met who had assimilated to Japanese culture generally use their Japanese first names. They also write these first and last names with Japanese characters—not with the phonetic syllabary used for foreign names. I'm sure some of them use their Brazilian names in Japan, but that practice seems to be based on their own preference to assert their Brazilian origins.

Here's Mud in Your Eye

A toast to Douglas Fox's article on fiddler crabs ("Mud's Eye View," 4/04). Although I am a lepidopterist, not a visual ecologist, I am often asked just what colors in flowers best attract butterflies. On testing, most butterflies turn out to be particularly sensitive to ultraviolet light, which we humans cannot register. For example, some flowers that look white to us sport ultraviolet markings, showing butterflies exactly where to land and insert the proboscis for nectar.

In recent years, enthusiasts have compiled lists of plants that various butterfly species find appealing (see the North American Butterfly Association's regional butterfly gardening brochures, available at www.naba.org/pubs/bgh.html or write NABA Program for Butterfly Gardens & Habitats, 909 Birch Street, Baraboo, WI 53913).

Gary Noel Ross
Baton Rouge, Louisiana

Douglas Fox writes that a fluorescent light "blinks on and off sixty times a second." But fluorescent lights go off each time the voltage goes to zero. Since (at least in North America) alternating current goes back and forth between positive and negative voltage sixty times a second, in that second the voltage passes through zero 120 times.

George Yanos
Oak Park, Illinois

Science and Politics

Peter Brown's unseemly wanderings in the political thicket of this election year was the real "unwelcome distraction" of his editorial ("Unwelcome Distraction," 6/04). The "debasement of the habits of mind on which scientific inquiry is founded" that he mentions could be said to be well illustrated by his presentation of unquestioned personal assumptions. There may be some who do not believe that all wars are morally equivalent, and who feel that the present struggle is against a threat that must be faced so that scientific inquiry may continue to be pursued. Some, while not condoning mistreatment of

(Continued on page 61)

Caustic Comfort

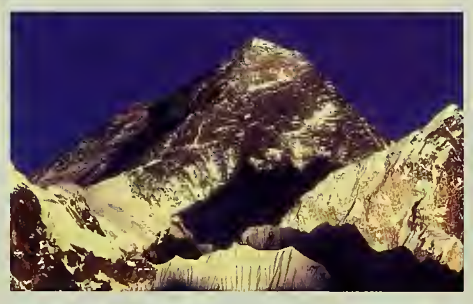
Compared with a great many microorganisms, people live in fairly boring conditions. But imagine taking a turn as a hyperthermophile basking in an undersea thermal vent, or swapping spots with an acidophile lounging in the equivalent of battery acid, or trading places with an extreme alkalinophile whiling away the hours in a bath of oven cleaner.

George S. Roadcap, a hydrogeologist at the Illinois State Water Survey, and his colleagues could tell you something about that last scenario. They recently discovered a microbial community thriving in what seems to be a record-breaking caustic solution. At a century-old iron slag dump in the Lake Calumet area of Chicago, the groundwater registers a pH of 12.8. That makes it nearly a million times as alkaline as a neutral solution. The Chicago microorganisms' closest competitors for surviving the world's most caustic conditions live in a pH of "only" 11. (www.geosociety.org/news/pr/03-38.htm) —*Aimee Cunningham*

RAISING MOUNTAINS

Even in the Himalaya, not all mountains are created equal. The Higher Himalaya, which form the northern part of the range, include the world's tallest peaks—Mount Everest, for instance, exceeds 29,000 feet. In contrast, the Lower Himalaya, to the south, are generally no more than a third as high. Dense forests have long obscured the transition between the two ranges, preventing geologists from understanding the abrupt change in elevation.

Enter modernization: Road-building crews in north-central Nepal near the Marsyandi River, at the heart of the "transition zone" between the Higher and Lower Himalaya, stripped away some of the vegetation and exposed first-rate geologic outcrops. Seizing the opportunity, Kip V. Hodges of the Massachusetts Institute of Technology and a host of colleagues descended on the Marsyandi.



Mount Everest

The investigators found that the transition zone is marked by major, recently active faults. It also seems to have exceptionally high rainfall during summer monsoons—possible evidence, the geologists speculate, of the "self-organization" of the system.

Formed by the collision between the Indian and Eurasian tectonic plates over the past 45 million years, the Himalayan ranges store excess potential energy. Hodges and his colleagues suggest the excess energy is dissipated by both the fracturing of the crust and intense, rain-driven erosion. The rapid erosion weakens the crust and leads to rapid uplift; the uplift, in turn, creates even more rainfall as clouds meet the abrupt transition between the Lower and Higher Himalaya. That positive feedback may have been shaping the ranges for millions of years. ("Quaternary deformation, river steepening, and heavy precipitation at the front of the Higher Himalayan ranges," *Earth and Planetary Science Letters* 220: 379–89, April 15, 2000) —*David Forest*

CO_2: Still Guilty As Charged

In 1845 a forward-thinking French chemist and mining engineer named Jacques Joseph Ebelmen set forth in print the concept that increasing levels of carbon dioxide in the atmosphere could bring about global warming. Yet today, after a century and a half of industrial productivity and population growth, the question of whether increased atmospheric CO_2 causes higher temperatures still often takes center stage in debates about the future of Earth.

Cores extracted from glaciers and ice sheets show that increases in atmospheric CO_2 do coincide with increases in global temperatures—at least for the past 420,000 years. But most ice formed in earlier times probably melted long ago, and so the earlier CO_2 levels must be estimated from geologic proxies or mathematical models. As for the temperatures of such distant epochs, one way to estimate them is to look at geologic formations that bear the telltale traces of advancing glaciers (colder eras) or retreating glaciers (warmer eras).

Another way to estimate surface temperatures of the distant past is to measure the ratios of certain oxygen isotopes in the sediments of shallow seas. But temperature estimates derived from oxygen isotopes have posed a big problem of inconsistency. Not only do they not match the estimates from the glacial records; they don't correlate with the estimates of CO_2 levels yielded by the proxies and mathematical models. Instead, the isotopic temperature estimates seem to rise and fall with the cycles of cosmic rays reaching Earth. Is CO_2 therefore blameless for global warming?

No, say Dana L. Royer, a paleoclimatologist at Pennsylvania State University in University Park, and his colleagues. Shallow water absorbs more CO_2 from the atmosphere and is therefore more acidic. That acidity can create misleading isotopic temperature estimates. When the estimates are corrected for acidity, and compared with the well-accepted, glacier-based temperature estimates, as well as with the mathematically modeled CO_2 estimates and with the investigators' compilation of a wealth of available geologic estimates of CO_2 in fossils and soils, the consistency of all four measures returns.

Royer and his colleagues conclude that cosmic rays play second fiddle to CO_2 as a driver of long-term climate change. Sorry, you'll have to keep apologizing for driving that SUV after all. ("CO_2 as a primary driver of Phanerozoic climate," *GSA Today* 14:4–10, March 2004) —*Stéphan Reebs*

Discovery Channel Book Club

Enrich your understanding of the world

Choose 3 Books for $1.99 each with membership

VALUES UP TO $127.40

1000 Wonders of Nature: Amazing Facts About the Earth Above, Around, and Below Us
Reader's Digest
4945
Publisher's Price $30.00

Greek Fire, Poison Arrows & Scorpion Bombs: Biological and Chemical Warfare in the Ancient World
Adrienne Mayor
0596
Publisher's Price $27.95

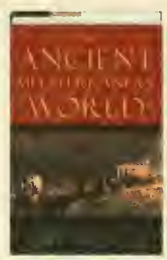
The World through Maps: A History of Cartography
John Rennie Short
1180-9999*
Publisher's Price $40.00
Counts as 2 choices

Chased by Sea Monsters: Prehistoric Predators of the Deep
N. Marven & J. James
1941
Publisher's Price $25.00

Darwin and Design: Does Evolution Have a Purpose?
Michael Ruse
0174
Publisher's Price $29.95

© PhotoDisc

The Moundbuilders: Ancient Peoples of Eastern North America
George R. Milner
1859-9999*
Publisher's Price $40.00
Counts as 2 choices



The Ancient Mediterranean World: From the Stone Age to A.D. 600
R. Winks & S. Mattern-Parkes
1891
Publisher's Price $49.95

The Long Summer: How Climate Changed Civilization
Brian Fagan
1917
Publisher's Price $26.00

Alexandria & the Sea: Maritime Origins & Underwater Explorations
Kimberly Williams
1925
Publisher's Price $23.95

Mapping Human History: Discovering the Past Through Our Genes
Steve Olson
4242
Publisher's Price $25.00

A Brief History of the Mind: From Apes to Intellect and Beyond
William H. Calvin
1289
Publisher's Price $25.00

Charles Darwin: The Power of Place
Janet Browne
1966
Publisher's Price $37.50

The Future is Wild
D. Dixon & J. Adams
5538-9999*
Publisher's Price $35.00
Counts as 2 choices

www.discoverychannelbookclub.com

Discovery Channel Book Club

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST-CLASS MAIL PERMIT NO. 41 CAMP HILL, PA

POSTAGE WILL BE PAID BY ADDRESSEE

DISCOVERY CHANNEL BOOK CLUB
PO BOX 6304
CAMP HILL PA 17001-9006

Trading Floor

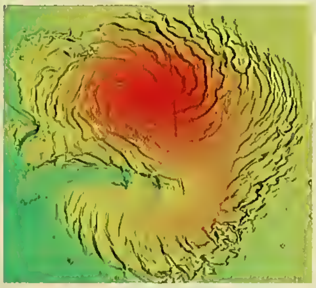
There's more going on in a chicken house than just the raising of chickens. Anne O. Summers and Sobhan Nandi, both microbiologists at the University of Georgia in Athens, and their colleagues decided to check out the bacterial residents of the wood shavings that cover the floor for the six-week lifespan of a flock of broiler chickens. What they found was ecological bad news.

Since the 1940s, the feed given to farm animals has routinely been dosed with antibiotics, which promote weight gain and seem to minimize chronic infections among the crowded animals. As with humans, however, the antibiotics have also spawned drug resistance in bacteria hosted by the animals. In addition, as investigators have learned in recent years, bacteria—even unrelated bacteria—do exchange genes, and so one microbe's genes for drug resistance can get passed around to its neighbors. And a floor covered in six-week-old wood shavings brimming with chicken waste is loaded with multiple species of microbes, and is thus a perfect place for a swap meet.

In the chicken-litter bacteria, the microbiologists found a huge reservoir of mobile genetic organizers called integrons, which assemble genes into clusters—including the genes that code for antibiotic resistance. Carrying out their appointed task in both the chickens and the chicken litter, the integrons enable the bacteria to become resistant to many antibiotics. The vast majority of those bacteria are harmless, but those that are pathogens can cause obdurate infections. ("Gram-positive bacteria are a major reservoir of Class 1 antibiotic resistance integrons in poultry litter," *Proceedings of the National Academy of Sciences* 101:7118–22, May 4, 2004) —*S.R.*

As the Whirl Turns

Liquid water apparently vanished long ago from the surface of Mars, but the planet still has lots of other water locked up in the ice at its poles. Oddly, that ice is riddled with a number of huge chasms that collectively form logarithmic spirals around the planet's poles. What could have caused them?



Chasms in the Martian ice

Jon D. Pelletier, a geomorphologist at the University of Arizona in Tucson, thinks he has a model that can account for the chasms. Start with a small crack in the ice. If the side of the crack facing the Sun is dusty, it absorbs sunlight rather than reflecting it. The crack warms up, and the ice in it sublimates—that is, it changes directly into vapor at thirty-two degrees Fahrenheit. As heat diffuses into the ice, separate cracks start to link up and grow into a chasm.

At some point, however, the ice at the bottom of the chasm stops sublimating, because it doesn't get warm enough. And the shaded side of the chasm stays cold enough to recapture some of the sublimated ice. Eventually the sublimation and recapture reach equilibrium, and the chasm attains a stable size. But because the sunlit side of the chasm continues to sublimate and the dark side continues to refreeze, the trough gives rise to a self-sustaining wave that continually and ever so slowly migrates toward the pole.

Why spirals? The closer you get to the poles, the colder the temperatures. That slows the poleward migration of each chasm. The combined effects happen to give rise to the spiral patterns. And why just on Mars? Thin atmosphere, and the tilt of the planet's rotational axis toward the Sun. ("How do spiral troughs form on Mars?" *Geology* 32:365–67, April 2004) —*T.J. Kelleher*

STUFFED

Few species of fish take care of their young, but the dedication among the ones that do can reach heroic levels. Consider the cardinalfish. Once the male has fertilized a clutch of eggs, he carries them in his mouth for one to two weeks, until they hatch. But because the clutch is so large (as many as 2,000 eggs), his mouth is so full he can't eat—except for snacking on the occasional egg.

A fish has his limits, though. Sara Östlund-Nilsson and Göran E. Nilsson, both biologists at the University of Oslo in Norway, caught males of two species of cardinalfish native to Australia's Great Barrier Reef and monitored their responses to decreasing concentrations of dissolved oxygen (a situation found in some recesses of a coral reef). When the oxygen dropped to about a third of the normal level, boom! the incipient dads started spitting out their broods. Dads of the species whose broods are relatively large (as a fraction of the male's weight) were the first to spit out their eggs. Having a big family may sound like a good insurance plan, but plans can falter when times get tough. ("Breathing with a mouth full of eggs: Respiratory consequences of mouthbrooding in cardinalfish," *Proceedings of the Royal Society of London* B **271**:1015–22, May 22, 2004) —*S.R.*

The sacrifices I make!

The First Garfield

With the beginnings of farming in the Middle East and surrounding regions some 11,000 years ago came the need to store grain in quantity. With stored grain came the rodent, and with the rodent, most likely, came the domesticated cat. Sure enough, figurines and painted images of cats dating to 4,000 B.C. have been found in the Middle East. But earlier evidence of a bond between people and their cats has been hard to come by.

Grain warden takes a break.

Now ailurophiles can rejoice. Jean-Denis Vigne, an archaeologist at the National Museum of Natural History in Paris, and his colleagues have unearthed the skeletal remains of a person and a cat buried just sixteen inches apart in a 9,500-year-old grave on the Mediterranean island of Cyprus, accompanied by polished axes, a stone pendant, and other accoutrements. According to Vigne and his co-workers, the cat's burial along with ceremonial grave goods shows how highly esteemed the animal must have been. In fact, they suggest, the cat may have been killed to join its owner in the afterlife. ("Early taming of the cat in Cyprus," *Science* 304:259, April 9, 2004) —*S.R.*

Work Incentive

Some bosses use pep talks to motivate their workers; others use threats. Wasps—at least paper wasps—apparently take a middle path.

Native to North America, the paper wasp *Polistes fuscatus* lives in colonies of one or two queens, and usually fewer than a hundred workers. Within the colony, though, there is a further social hierarchy, sometimes maintained by biting and chasing. A milder and more common interaction known as darting—in which one wasp, either a queen or a worker, lunges suddenly toward another but avoids making physical contact—has long been regarded as another way of enforcing dominance.

Now two entomologists have called the standard interpretation of darting into question. In a study of sixteen paper-wasp colonies, Annagiri Sumana and Philip T. Starks, both at Tufts University in Medford, Massachusetts, have found darting to be a nonaggressive management strategy—communication rather than coercion.

Inactive workers, they observed, receive more darts than their busy nestmates do, and targeted workers, whether active or not, are more likely to change their behavior after being darted. But only queens manage to spur do-nothing workers to get going, whereas both queens and workers seem to get results when they signal a busy worker that a change of activity would be desirable. ("The function of dart behavior in the paper wasp, *Polistes fuscatus*," *Naturwissenschaften* 91: 220–23, May 2004) —*S. R.*

RISK AND REWARD

As plants have evolved, they have had to pick a lifestyle and marshal their resources accordingly: to grow woody or not, to live as annuals or perennials, to adapt to wet climates or dry.

Another forced choice has been even more fundamental: Do you live fast (and die young), or take it slow (and survive to old age)? Do you accept the risks of investing for quick returns, or do you aim for slow but steady augmentation of capital? Ian Wright, a biologist at Macquarie University in Sydney, Australia, and thirty-two colleagues throughout the world recently completed the most comprehensive global plant survey ever made. And one of their most surprising findings is that both "day traders" and the most risk-averse, long-term "bondholders" coexist in every kind of climate.

Leaf in the fast lane

Focusing only on leaves, the team found that some plants invest a lot in photosynthesis but little in defense. Their leaves have a large surface area compared with their dry mass, and they require a generous supply of enzymes and nutrients. Such leaves are good at responding rapidly to growth opportunities, and they produce a lot of energy. Their downside is that they dry out more readily and are vulnerable to disease, herbivores, pollution, or weather. The leaves of other species invest less in photosynthesis and more in defense: they're tougher, and make various nasty chemicals that deter consumers. Those are the leaves that produce energy at a slower rate, but they do live longer.

The biologists' key discovery is that all species of plants, regardless of habitat or climate type, take their primary cue from one central trade-off—maximizing photosynthesis versus ensuring survival. Once that choice is made, the remaining spectrum of choices is really rather narrow. ("The worldwide leaf economics spectrum," *Nature* 428:821–27, April 22, 2004) —*S.R.*

Vagabonds in Space

Asteroids, comets, and moons, oh my!

By Neil deGrasse Tyson

For many centuries the inventory of our celestial neighborhood was quite stable. It included the Sun, the stars, the planets, a handful of planetary moons, and the comets. Even the addition of a planet or two to the roster didn't change the basic organization of the system.

But on New Year's Day, 1801, a new category arose: the asteroids, so named a year later by the English astronomer Sir William Herschel, the discoverer of Uranus. During the next two centuries, the family album of the solar system became crammed with the data, photographs, and life histories of asteroids, as astronomers located vast numbers of these vagabonds, identified their home turf, assessed their ingredients, estimated their sizes, mapped their shapes, calculated their orbits, and crash-landed probes on them. Some investigators have suggested that the asteroids are kinfolk to comets, and possibly even to planetary moons. And at this very moment, some astrophysicists are plotting methods for deflecting any big ones that may be planning an uninvited visit.

To understand the small objects in our solar system, one should look first at the big ones, specifically the planets. A curious fact about the planets is captured in a relatively straightforward mathematical rule proposed in 1766 by a German astronomer named Johann Daniel Titius. A few years later, Titius's colleague Johann Elert Bode, giving no credit to Titius, began to spread the word about the rule, and to this day it's often called the Titius-Bode law or even, erasing Titius's contribution altogether, Bode's law. This handy-dandy formula yielded pretty good approximations of the distances between the planets and the Sun, at least for the ones known in Titius's time: Mercury, Venus, Earth, Mars, Jupiter, and Saturn. Herschel's discovery of Uranus, in 1781, in an orbit that matched the expectations of the Titius-Bode law, lent the formula credibility and spurred astronomers to look around carefully for more planets in the solar system . So either the law is just a coincidence, or it embodies some fundamental fact about how solar systems form.

It's not quite perfect, though. At least three shortcomings plague it.

Problem number 1: You have to cheat a little to get the right distance for Mercury, by inserting a zero where the formula calls for 1.5. Problem number 2: Neptune turns out to be much farther out than the formula predicts, orbiting more or less where a ninth planet would go. Problem number 3: Pluto, which some people persist in calling the ninth planet (for our exhibits at the Rose Center for Earth and Space, we think of icy Pluto as the "king of comets"), isn't even close to where the Titius-Bode law predicts.

In addition, the law would have a planet orbiting in the space between Mars and Jupiter—at about 2.8 astronomical units, or AU, from the Sun (one AU is the average distance between Earth and the Sun). Encouraged by the fact that the newly discovered Uranus orbited at more or less the distance Titius-Bode said it would, astronomers in the late eighteenth century thought it would be a good idea to check out the zone around 2.8 AU. And sure enough, on that first day of 1801, the Italian astronomer Giuseppe Piazzi, founder of the Observatory of Palermo, discovered something there. Subsequently that something disappeared into the glare of the Sun, but exactly one year later, with the help of brilliant computations by the German mathematician Carl Friedrich Gauss, the new object was rediscovered in a different part of the sky. Everybody was excited: a triumph of mathematics and a triumph of telescopes had led to the discovery of a new celestial object. Piazzi himself named it Ceres (as in "cereal"), for the Roman goddess of agriculture, in keeping with the tradition of naming planets after ancient Roman deities.

By now, many tens of thousands of asteroids have been catalogued, and they're still being discovered. Altogether there are probably many more than a million that measure more than half a mile across. As far as anyone can tell, even though Roman gods and goddesses did lead complicated social lives, they didn't have 10,000 friends; astronomers had to give up on that source of names long ago. So asteroids are now named after actors, painters, philosophers, and playwrights; cities and countries; dinosaurs, flowers, seasons, and all manner of miscellany. Even regular people have asteroids named after them. Harriet, Jo-Ann, and Ralph each have one: they are called 1744 Harriet, 2316 Jo-Ann, and 5051 Ralph, with the number indicating the sequence in which each asteroid's orbit became firmly established. David H. Levy, a Canadian-born amateur astronomer who is the patron saint of comet discoverers but has discovered plenty of asteroids as well, was kind enough to pull an asteroid from his stash and name it after me: 13123 Tyson.

Most asteroids are made entirely of rock, though some are entirely metal and some are both; most inhabit what's often called the main belt, a zone between Mars and Jupiter. Asteroids are usually described as being formed of material left over from the earliest days of the solar system—material that never got incorporated into a planet. But that explanation is incomplete at best: some asteroids are pure metal. To account for their metallic composition, it helps once again to begin with the planets—specifically, how they formed.

The planets coalesced from a cloud of gas and dust enriched by the scattered remains of element-rich exploding stars. A collapsing cloud forms protoplanets—each a solid blob that gets hot as it accretes more and more material. Two things happen with the larger protoplanets. One, the blob tends to take on the shape of a sphere. Two, its inner heat keeps the protoplanet molten long enough for the heavy stuff—primarily iron, with some nickel and a splash of such metals as cobalt, gold, and platinum mixed in—to sink to the center of the growing mass. Meanwhile, the much more common light stuff—hydrogen, carbon, oxygen, and silicon—floats outward. Geologists (who never shy away from sesquipedalian words) call the process "differentiation." Thus the core of a differentiated planet, such as Earth, Mars, and Venus, is metal; its mantle and crust are mostly rock, and take up a far greater volume than the core.

Once it has cooled, if such a planet is then destroyed—say, by smashing into one of its fellow planets—the fragments of both will continue orbiting the Sun in more or less in the same trajectories that the original, intact objects had. Most of those fragments will be rocky, because they come from the thick, outer, rocky layers of the two differentiated objects. A small number will be purely metallic. And that's exactly what's observed with real asteroids. Moreover, a hunk of iron could not have formed in the middle of interstellar space, because the iron atoms it's made of would have been scattered throughout the gas clouds that formed the planets, and gas clouds are mostly hydrogen and helium. To concentrate the iron atoms, a fluid body must first have differentiated.

But how do solar system astronomers know that most main-belt asteroids are rocky? How do they know anything about asteroids at all? The chief indicator is an asteroid's albedo, or reflectivity. Asteroids don't emit their own light: they only absorb

Eros, three views: In February 2001, twenty-one-mile long Eros became the first asteroid to be explored by a spacecraft, NEAR Shoemaker. *Each view is a composite, assembled from images made before the spacecraft touched down.*

and reflect the Sun's rays. Does 1744 Harriet reflect or absorb infrared light? What about visible light? Ultraviolet? Different materials absorb and reflect the various wavelengths of light differently. If you're thoroughly familiar with the spectrum of sunlight (as astrophysicists are), and if you carefully observe the spectra of the sunlight reflected from an individual asteroid, you can figure out just how the original sunlight has been influenced and thus identify the materials that make up the asteroid's surface. And from the material, you can know how much light gets reflected. From that figure, and from the known distance to the main belt, you can then estimate the asteroid's size. Ultimately you're trying to account for how bright an asteroid looks on the sky: it might be really dull and big, or highly reflective and small, or something in between, and you can't know the answer simply by looking at how bright it is. You have to understand the material.

This method of spectral analysis led initially to a simplified three-way classification scheme, with carbon-rich C-type asteroids, silicate-rich S-type asteroids, and metal-rich M-type asteroids. But more precise measurements have since spawned an alphabet soup of a dozen classes, each identifying an important nuance of the asteroid's composition, and betraying multiple parent bodies rather than a single mother planet that had been smashed to smithereens.

Asteroid 243 Ida, thirty-five miles long, and its mile-wide roundish moon, Dactyl—the first satellite to be discovered orbiting an asteroid

If you know an asteroid's composition, you have some confidence that you know its density. Curiously, some measurements of the size of asteroids and their masses yielded densities that were less than that of rock. One logical explanation was that those asteroids weren't solid. What else could be mixed in? Ice, perhaps? Not likely. The asteroid belt orbits close enough to the Sun that any ice (water, ammonia, carbon dioxide—all of whose density falls below than that of rock) would have evaporated long ago from the Sun's heat. Perhaps all that's mixed in is empty space, with rocks and debris all moving in tandem.

The first bit of observational support for that hypothesis appeared in images of the thirty-five-mile-long asteroid Ida, photographed by the space probe *Galileo* during its flyby on August 28, 1993. Half a year later, on February 17, 1994, Ann P. Harch, an operations engineer who helped program the Galileo mission's imaging software, saw a speck about sixty miles from Ida's center that proved to be a mile-wide, pebble-shaped moon! Dubbed Dactyl, it was the first satellite ever seen orbiting an asteroid. Are satellites a rare thing? If an asteroid can have a satellite orbiting it, could it have two or ten or a hundred? In other words, could some asteroids turn out to be heaps of rocks?

The answer is a resounding Yes. Some astrophysicists would even say that these "rubble piles," as they are now officially named (astrophysicists prefer pith over polysyllabic prolixity), are probably common. One of the most extreme examples of the type may be Psyche, which measures about 150 miles in overall diameter and is reflective, suggesting its surface is iron. From estimates of its overall density, however, its interior may well be more than 70 percent empty space.

When you start studying objects that live somewhere other than the main asteroid belt, you're soon tangling with the rest of the solar system's vagabonds: Earth-crossing killer asteroids, comets, and myriad planetary moons. Comets are the snowballs of the cosmos. Usually no more than a couple of miles across, they are made up of a mixture of frozen gases, frozen water, dust, and miscellaneous particles. In fact, they may simply be asteroids with a cloak of ice that never fully evaporated. The question of whether a given fragment is an asteroid or a comet might boil down to where it formed and where it's been.

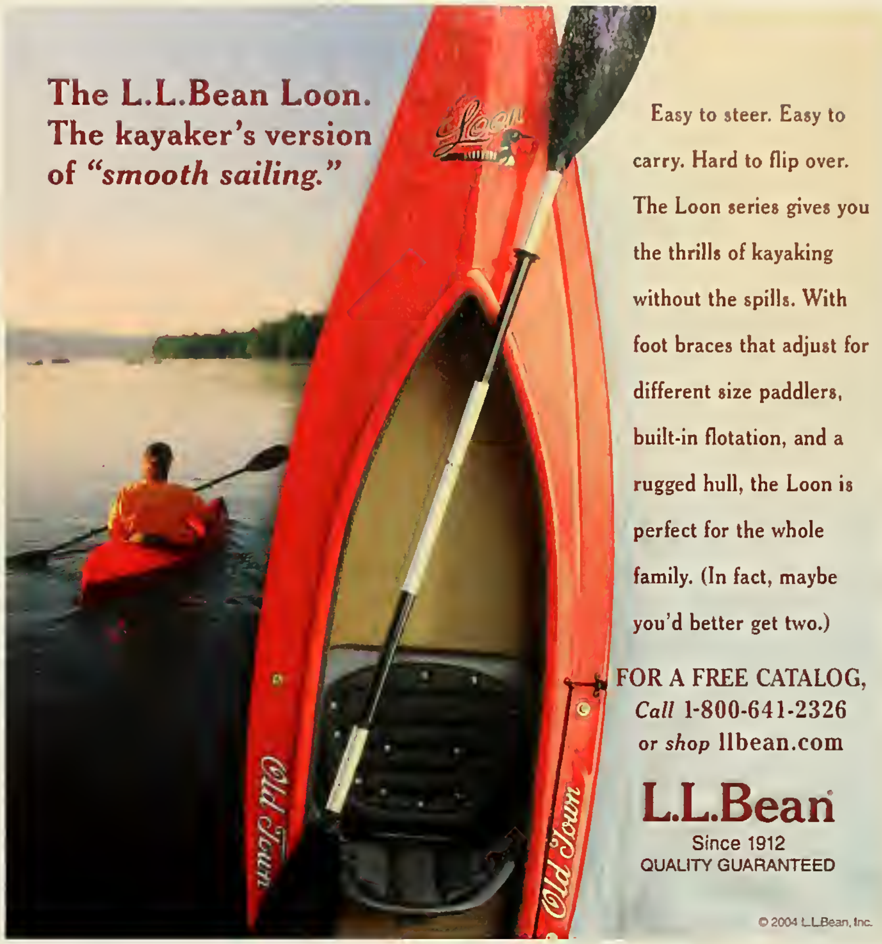
Before Newton published his *Principia* in 1687, no one had any idea that comets lived and traveled among the planets, making their rounds in and out of the solar system in highly elongated orbits. Icy fragments that formed in the far reaches of the solar system, whether in the Kuiper Belt or beyond, remain shrouded in ice. If they are found on a characteristic elongated path toward the Sun, they will show a rarefied but visible trail of water vapor and other volatile gases when the comet swings inside the orbit of Jupiter. Eventually, after enough visits (could be hundreds or even thousands) to the inner solar system, such a comet can lose all its ice, ending up as bare rock. Indeed, some, if not all, the asteroids whose orbits cross that of Earth may be "spent" comets, whose solid core remains to haunt us.

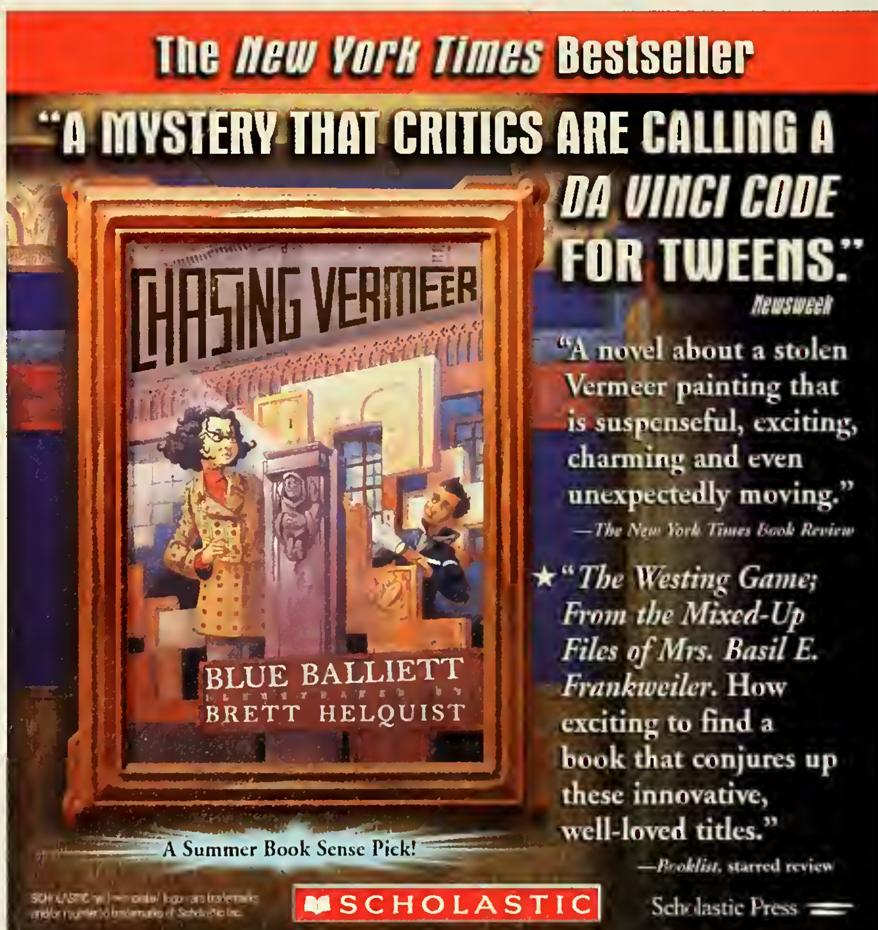
Then there are the meteorites, flying cosmic fragments that land on Earth [*see "Bolts from Beyond," by Donald Goldsmith, September 2003*]. The fact that, like asteroids, meteorites are mostly rock and occasionally metal suggests strongly that the asteroid belt is their country of origin. As planetary astronomers studied the asteroids in increasing numbers, it became clear that not all of their orbits stick to the main asteroid belt. As Hollywood loves to remind us, someday such asteroids (or comets) might collide with Earth. But that eventuality was not accepted as fact until 1963, when the astrogeologist Eugene M. Shoemaker conclusively demonstrated that Arizona's vast Barringer Meteorite Crater, drop-forged some 50,000 years ago, could have resulted only from a meteorite impact, not from volcanism.

Shoemaker's finding triggered a new wave of curiosity about the possibility of an intersection between the Earth's orbit and the orbits of the asteroids. In the 1990s, space agencies began tracking near Earth objects, or NEOs—comets and asteroids whose orbits, as NASA politely puts it, "allow them to enter the Earth's neighborhood." This past March, NASA announced the discovery of a mansion-size asteroid only three days before it passed within 26,500 miles of Earth—the closest approach ever recorded. As with the vast majority of NEOs, though, it posed no danger whatsoever.

The planet Jupiter plays a mighty role in the lives of the more distant asteroids and their brethren. A gravitational balancing act between Jupiter and the Sun has collected families of asteroids sixty degrees ahead of Jupiter in its solar orbit and sixty degrees behind it, each making an equilateral triangle with Jupiter and the Sun. (If you do the geometry, it places the asteroids 5.2 AU from both Jupiter and the Sun.) These trapped bodies are known as the Trojan asteroids. Once an asteroid drifts into either of those regions, it's hard for it to get out.

Jupiter also deflects plenty of comets that are headed Earth's way. Most comets live in the Kuiper Belt, beginning with, and extending far beyond, the orbit of Pluto. But any comet daring enough to pass close to Jupiter gets flung out in a new direction. Were it not for Jupiter guarding the moat, Earth would be pummeled by comets far more often than it is. In fact, the Oort Cloud—a vast population of comets that is the most distant part of the Sun's gravitational embrace—is widely thought to be made up of Kuiper Belt comets that Jupiter flung hither and yon. Pluto





and the newfound objects Quaoar and Sedna each orbit in and around the Kuiper Belt, whereas the orbits of Oort Cloud comets extend halfway to the nearest stars.

What about the planetary moons? Some of them look like captured asteroids, such as Phobos and Deimos, the small, dim, potato-shaped moons of Mars. But there are also the several icy moons of Jupiter. Should those be classified as comets? And Pluto's moon Charon is not much smaller than Pluto itself, and both of them are icy, so perhaps they could be regarded as a double comet. I'm sure Pluto wouldn't mind that one either.

Spacecraft have explored only twelve comets and asteroids so far. The first to orbit one was the car-size robotic U.S. craft *NEAR Shoemaker* (NEAR is the clever acronym of "near earth asteroid rendezvous"), which visited the nearby asteroid Eros just before Valentine's Day (cute, eh?) in 2001. It touched down at just four miles an hour and, instruments intact, unexpectedly continued to send back data for two weeks after landing, enabling planetary geologists to say with some confidence that twenty-one-mile-long Eros is an undifferentiated, consolidated object rather than a rubble pile.

This past January 2 another small spacecraft, *Stardust*, flew through the coma, or dust cloud, surrounding the nucleus of Comet Wild 2 so that it could capture a swarm of minuscule particles in its aerogel collector grid. The goal of the mission is, quite simply, to find out what kinds of space dust are out there, and to collect the particles without damaging them. NASA is using a wacky and wonderful substance called aerogel—the closest thing to a ghost that's ever been invented. It's a dried-out, spongelike tangle of silicon that's 99.8 percent thin air. When a particle slams into it at hypersonic speeds, the particle bores its way in and gradually comes to a stop, intact. If you tried to catch the same dust grain with a catcher's mitt, it would slam against the surface of the mitt and vaporize.

The European Space Agency, too, is exploring comets and asteroids. Its *Rosetta* spacecraft, launched on March 2 of this year, has both an orbiter and a lander; the former will orbit a single comet for a year, thereby amassing more information at close range than has ever been gathered before. Altogether, the mission will last eleven years and will also take in a couple of asteroids in the main belt.

Each of these missions seeks to gather highly specific information. At the same time, each morsel of information can have far-reaching implications—about the formation and evolution of the solar system, about the kinds of objects that populate it, about the possibility that organic molecules were transferred to Earth during impacts, or about the size or shape or solidity of NEOs. Deep understanding comes not from how well you describe an object, but from how that object connects with the larger body of acquired knowledge and its moving frontier. For the solar system, that moving frontier is the search for other solar systems. What astronomers want next is a thorough comparison between our planets and vagabonds and their counterparts in a distant solar system. Only in that way will we know whether we live in a normal or in a dysfunctional solar family.

If Jupiter wasn't guarding the moat, the Earth would be pummeled by comets far more often than it is.

Astrophysicist NEIL DEGRASSE TYSON *is the Frederick P. Rose Director of the Hayden Planetarium in New York City. He is currently finishing work as host and narrator of a four-part PBS* NOVA *miniseries on cosmic origins, which will air this fall.*

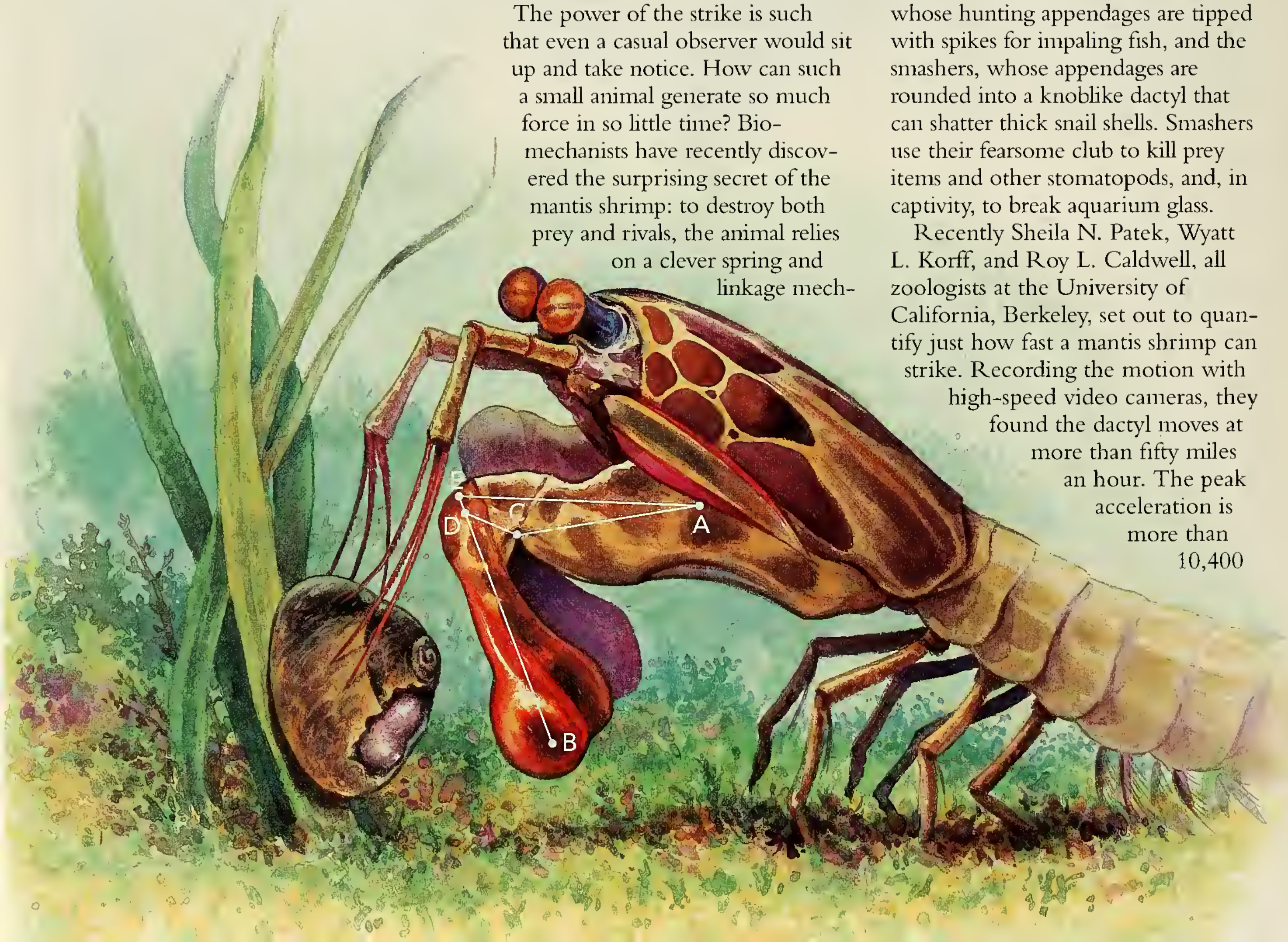
Knockout Punch

A boxer who could jab like a mantis shrimp could win every match with a single blow.

By Adam Summers ~ Illustrations by Roberto Osti

A three-inch-wide reef crab, straying near the entrance of a mantis shrimp's burrow, has made its last mistake. The mantis shrimp comes boiling out of its home, its colorful, paddle-like appendages signaling hostile intent. Two arms, adapted for hunting, are held folded, "chest" high, against its thorax. The mantis descends on the crab rapidly. After two movements—so fast as to be nearly imperceptible—accompanied by quite audible pops, there is a gaping hole in the thick shell of the crab. The mantis, itself six inches long, settles over the crustacean and with several more blows opens up the soft body of its prey.

The power of the strike is such that even a casual observer would sit up and take notice. How can such a small animal generate so much force in so little time? Biomechanists have recently discovered the surprising secret of the mantis shrimp: to destroy both prey and rivals, the animal relies on a clever spring and linkage mechanism that makes it the fastest "puncher" in the animal world.



Mantis shrimp, which comprise an order of crustaceans also known as stomatopods, inhabit near-shore waters all over the world. From the biomechanist's point of view there are two main kinds: the spearers, whose hunting appendages are tipped with spikes for impaling fish, and the smashers, whose appendages are rounded into a knoblike dactyl that can shatter thick snail shells. Smashers use their fearsome club to kill prey items and other stomatopods, and, in captivity, to break aquarium glass.

Recently Sheila N. Patek, Wyatt L. Korff, and Roy L. Caldwell, all zoologists at the University of California, Berkeley, set out to quantify just how fast a mantis shrimp can strike. Recording the motion with high-speed video cameras, they found the dactyl moves at more than fifty miles an hour. The peak acceleration is more than 10,400 times the acceleration of gravity. The fist of a boxer able to jab with such acceleration throughout his punch would be traveling at escape velocity from the Earth after just eleven-hundredths of a second!

Patek found that the mantis shrimp delivers its smashing blow with a hundred times more power than its own "arm" muscles can generate. To focus such explosive power the mantis shrimp cheats by slowly storing muscular energy with a spring and catch mechanism, then suddenly releasing the energy.

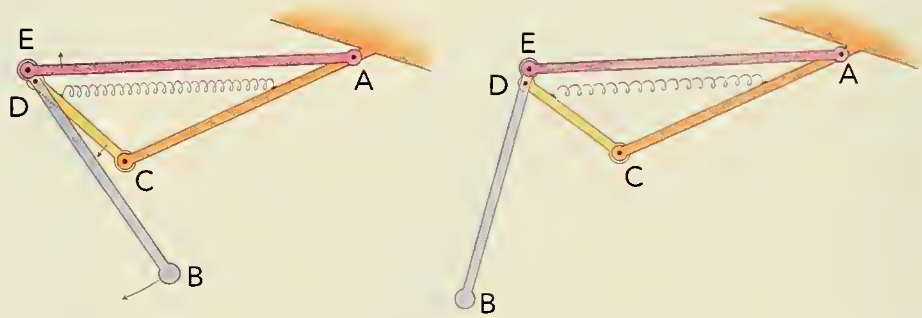
Catch mechanisms are responsible for the ability of some predatory fishes to rapidly open their mouths. But the spring of the mantis shrimp, a saddle-shaped piece of chitin that stores the muscular energy, is unique. The striking muscles squash together the ends of the saddle, causing it to rise up. When the catch is tripped, the saddle snaps back to its original shape, and the dactyl is propelled forward with devastating effect. The force of the spring is transmitted by what is essentially a long lever that connects the dactyl to the rest of the shrimp's arm; far from the fulcrum, the dactyl moves much faster than the spring does [*see diagrams at right*].

There is more at work here than just the action of saddle springs, though. When the dactyl strikes a target, distinctive bubbles form and collapse, a telltale sign that some of the devastation is caused by a phenomenon known as cavitation. Cavitation is the bane of the drive propellers on powerboats. When an object moves so fast through water that the pressure in its wake is lower than the vapor pressure of water, the water near the object, in effect, boils, and minuscule bubbles of water vapor form around the moving object. When the surrounding water returns to its normal, higher pressure, the bubbles collapse with such force that they cause pitting on surfaces as hard as stainless steel.

Mantis shrimp attacks a marine snail with its knoblike dactyl. A saddle-shaped "spring" made of chitin (above and to the right of point C and above the flexed muscle AE) enables the shrimp to deliver a blow much more rapidly than its muscles could do alone.

Cavitation is explained by Laplace's law, which will be empirically familiar to anyone who has ever blown up a balloon. Laplace's law states that the pressure inside a bubble is proportional to the tension in the wall of the bubble divided by the bubble's radius. Thus the smaller the radius, the higher the vapor pressure inside. Remember how hard it is to get that first puff of air into the balloon? The radius is small and so the pressure must be high to swell the balloon. As the balloon inflates, though, the pressure needed to expand it further decreases dramatically.

The cavitation bubbles formed during the strike of the dactyl range in size from a quarter of an inch to just a few hundredths of an inch in radius, and the pressure inside can be thousands of pounds per square inch. As the bubbles wander from the low-pressure region where they formed, higher pressures compress them; their decreasing volume drives the pressure inside the bubble, as well as the temperature of the water vapor, higher still. Such hot, high-pressure water can cause a lot of damage.



Schematic diagram of the striking mechanism of the mantis shrimp comprises three bars of fixed length (one of which, bar AC, is stationary), a contracted muscle (AE) that acts like a fixed-length bar, and a spring, linked together as shown. (Note, however, that in reality the spring lies above the muscle.) The labeled points A through E in the diagrams correspond to the points marked on the drawing of the shrimp on opposite page. In the cocked phase (above left) the spring is compressed. When the mechanism is released, the spring pushes against bar CD, causing point D to rotate counterclockwise around point C. Because of the rigidity of the bars, that rotation forces a slight clockwise rotation of bar AE about point A. The small, simultaneous movements of points D and E, which are both locked onto bar BE, translate into a large movement of point B—the business end of the mantis shrimp's striking mechanism—propelling it toward the shrimp's target with devastating effect (above right). An animated model of the mechanism can be viewed on the Web at ist-socrates.berkeley.edu/~korff/stomatopods.html

The bubbles form between the mantis shrimp's dactyl and the shell of its prey, so cavitation may play an important role in destroying hard targets. It also poses a problem for the mantis shrimp. The dactyl itself becomes pitted and scuffed, even on parts of its surface unlikely to have hit the prey directly. The cavitation bubbles may be causing the damage.

Whatever the source of the damage, the stomatopod compensates for it by shedding its hard outer skeleton periodically. Vulnerable but still feisty, the mantis shrimp continues to rush from its burrow when provoked, even though it's not much of a threat. But as the exoskeleton hardens, the animal once more becomes the peerless puncher of the sea, and probably the miniweight champion of the world.

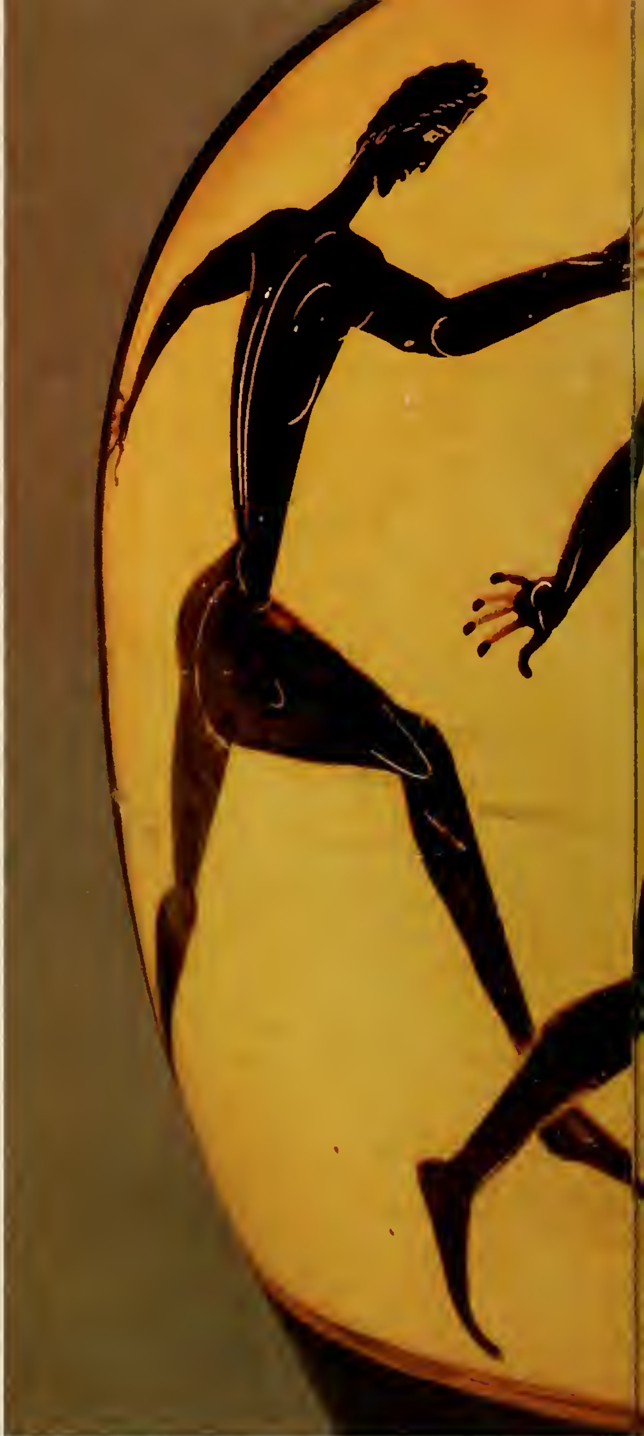
ADAM SUMMERS (asummers@uci.edu) *is an assistant professor of ecology and evolutionary biology at the University of California, Irvine, and fearlessly keeps small stomatopods in his aquarium.*

NATURAL HISTORY
JULY/AUGUST 2004

With Hands or Swift Feet

The ancient Greek city-states were rarely as united as they were at the Olympic Games.

By David C. Young



In any society and time, a group of boys with leisure time will naturally test who can jump or throw a stone the farthest, who can wrestle another to the ground, who can run first to the other end of a field. But the ancient Greeks elevated such competitions to serious activities for grown men. Their quadrennial Olympic Games, a showcase for human physical excellence, were the explicit inspiration for the modern Olympiads, initiated in Athens in 1896 and returning to Athens again this August. Our modern games are, in fact, the brainchild of a Greek poet, Panagiotis Soutsos, who first proposed the revival in 1835. The modern games, too, represent the height of excellence and prestige, and in most significant ways they are not much different from the ancient version. The principal difference, I think, is how much the modern extravaganzas dwarf their forerunner in size and scope. At Sydney in 2000, more than 10,000 male and female athletes from 200 countries competed in 300 events. That's big. In the heyday of the ancient Olympics, say in the fifth century B.C., maybe 300 men from the Greek city-states and colonies competed in about fourteen events. In antiquity, perhaps as many as 40,000 spectators could watch the games. Today, because of modern electronic communication, the whole world watches.

For the poet Pindar of Thebes, whose victory odes immortalized the greatest contenders of the Hellenic world between 498 and 446 B.C., the athletic contest served as a microcosm of the human struggle to surpass ordinary achievements.

In athletic games the victor wins the glory
his heart desires
as crown after crown is placed on his head,
when he wins with his hands or swift feet.
There is a divine presence in a judgment
of human strength.
Only two things, along with prosperity, advance
life's sweetest prize:
if a man has success and then gets a good name.
Don't expect to become Zeus. You have everything
if a share of these two blessings comes your way.

—*Isthmian Odes* 5.8–15

Three runners compete in the stade, a sprint of about 210 yards. For many years the race was the only athletic event at Olympia, and it remained the most prestigious one even after other events were added. The vase or jar, known as an amphora, dates to the sixth century B.C.

"Don't expect to become Zeus," warns Pindar—after all, men are not gods. But with these words he is also bestowing the greatest praise on the winning athletes, for they have reached the highest mortal pinnacle.

Archaeology tends to confirm—approximately—that the Olympics, the most renowned of the ancient contests, began when the Greeks claimed they did, in 776 B.C. The Olympics then took place every four years well into the latter days of the Roman Empire, until about 400 A.D. Their golden age, however, lasted from the late sixth to the early fifth centuries B.C., and if there was a special golden epoch of the golden age, it came with the games of 476 and 472 B.C.

In 490 B.C. and again in 480, a large Persian army had invaded Greece, seeking to subdue it and turn it into a vassal state. The vast Persian Empire already encompassed not only present-day Iran, but also Afghanistan and Pakistan in the east, part of Iraq, and, in the west, Turkey, Syria, Lebanon, Israel, and northern Egypt. If the invaders had succeeded, Western history would have taken a decidedly different turn. But the Greeks expelled the enemy after the naval battle of Salamis, fought in 480 in a strait west of Athens, and the battle of Plataea, fought in 479 on the mainland northwest of Athens. It was the first time so many Greek city-states, which were often at war with one another, had banded together. A Panhellenic spirit began to surge throughout the land, most of all at Olympia, the seat of the Olympics. People flocked there in unprecedented numbers, all in jubilation. More contestants came than ever before, and the athletes of the period were among the best and best known in Greek history.

Tethrippon, or four-horse chariot race, was introduced into the Olympics in 680 B.C. Victory in equestrian events was awarded to the owners of the horses, not to the jockeys or charioteers. The amphora dates to the sixth century B.C.

By the time of the 476 B.C. games, nearly the full complement of athletic events had been incorporated into the festivities. Present-day knowledge of them comes from the excavation of Olympia and other sites, from artistic depictions (most notably on vases and in sculpture), from contemporary inscriptions on vases and monuments, and from the various odes, histories, and other texts that scribes have copied and handed down through the centuries. The historical texts often include quite vivid and detailed descriptions. But the texts present many problems as well. Many were compiled by writers who lived centuries after the events, which they did not witness themselves; many conflict with each other (or are internally inconsistent); and, even taken together, the texts fail to clarify certain essential points. As a result, modern scholars are still sorting out and debating many issues.

The signature contest of the 476 B.C. games, as it was throughout Olympic history, was the *stade*, a sprinting race that was run the length of a straight track (from *stade* comes our word "stadium"). The distance, measured from the actual track archaeologists have uncovered at Olympia, was about 210 yards. From the very beginning of the games until the games of 724 B.C. the *stade* was the only recorded event. In the latter games the *diaulos* was added, a race of two laps, or about 420 yards. Four years later a distance race called the *dolichos* was introduced, though ancient sources do not specify the exact number of laps. The most widely accepted number is twelve, which equates to a race of about 2,520 yards, or a bit more than 1.4 miles.

Events became much more diverse beginning with the Olympics of 708 B.C., which included wrestling and the pentathlon. Pentathletes com-

Olympia was the site of the ancient Olympic Games, held every four years from about 776 B.C. until about 400 A.D. In those twelve centuries the political landscape inevitably underwent many changes, but Olympic events continued to attract athletes and spectators from Greek city-states and colonies throughout the Mediterranean world.

peted in discus, javelin, long jump, and their own *stade* race, and finished with their own wrestling bouts. How the overall winner was determined is not really known. In some rather rare cases, a winner was declared if a contestant won the first three events, and the contest was then finished. But more often the outcome hinged on the wrestling final.

The discuses excavated at various ancient sites are made of metal, usually cast bronze, or stone and—except for small ones possibly intended for children—weigh between four and nine pounds. The main debate about the discus throw is whether ancient athletes executed a full rotation of the body, using centrifugal force to help launch the discus, as do modern competitors. The prevailing opinion is that they used arm strength, perhaps with some body twist, but not a full spin. I disagree. I find the textual evidence at best ambiguous, but certain artistic depictions tip the balance in favor of a full rotation, because they make little sense otherwise.

The nature of the long jump has been a special a source of controversy. Much of the confusion has its inception in reports that two early athletes, Phayllos of Croton and Chionos of Sparta, jumped farther than fifty feet. A single jump of that distance is beyond credibility, and accordingly, many scholars have concluded that this Olympic event comprised multiple jumps, such as a triple running jump or five standing broad jumps. I believe such conclusions are misplaced, however, and that the event was a single running jump. First, I am convinced that both of the reports in question are false: they appear in unreliable texts dating six or seven centuries after the supposed achievements. Second, ancient artistic depictions, as well as other literary evidence, are consistent with a single running jump. Additional controversy surrounds the hand-held weights, known as halteres, that were swung upward and forward on take-off, presumably to help the jumper gain extra momentum [*see "Throwing Yourself into It," by Adam Summers, April 2003*].

The Olympic javelin was made of wood; for that reason, no doubt, no example survives. Artistic evidence suggests the implement was lighter and slightly shorter than the standard modern javelin for men. A short leather thong was wrapped around the middle of the shaft and secured with a loop to the thrower's fingers. As the throw was made, the thong was allowed to unreel, extending the effective point of release and imparting a spin that made the javelin fly farther and truer than it would without the thong.

Wrestling, both for the pentathletes and for the single-event competitors, was a contest of strength, balance, and technical know-how. The object was to throw the opponent so that his back, hip, or shoulder touched the ground. Victory went to the first man to achieve three falls. Wrestling was the one athletic activity practiced by almost all freeborn men in Greek society, and it was a rich source of metaphor for playwrights, orators, and philosophers. Authors could assume their audience was knowledgeable about the techniques employed.

New Olympic events were introduced shortly after wrestling and the pentathlon. Boxing was added in 688 B.C., and the *tethrippon*, a four-horse chariot race, followed in 680 B.C. Boxers wound leather thongs around the forearm and hand; the fingers were left open. Once two competitors faced off, they would continue fighting until one

Pancration, a combination of boxing, wrestling, and street fighting, became an ancient Olympic event in 648 B.C. Contestants fought until one of them gave up or could not continue; there were no rounds or weight divisions. The amphora, which portrays a pancration bout, dates to the sixth century B.C.

of them could no longer continue or formally admitted defeat. All the punches appear to have been directed at the head. Olympic history records the deaths of several boxers—though surprisingly few overall, given the brutality of the contest.

In the *tethrippon* and other horse races, the charioteer or jockey was a professional, but the owner—who was, of necessity, a rather wealthy person—enjoyed the honor of victory if it came. Equestrian events were the only ones in the Olympic games that women could—and did—win. Teenage girls and young women apparently had very few athletic contests of their own in the ancient Greek world, perhaps only in Sparta. At least during the Roman Empire, they did participate in events at Olympia, but their contests did not fall at the same time as the Olympic Games.

Wrestling was the one athletic activity practiced by almost all freeborn Greek men. The first wrestler to throw his opponent to the ground three times won the event. The amphora dates to the sixth century B.C.

Were women allowed to watch the games? The relevant evidence remains murky. Pausanias, a Greek traveler and geographer who lived in the second century A.D., reports that women were banned from becoming spectators, and that violators were to be thrown to their deaths off a cliff. But Pausanias also asserts that the punishment was never invoked. And elsewhere, he even seems to contradict himself. After referring to a special seat from which the priestess of Demeter watched the games, he writes: "They [the officials] do not prevent unmarried women from watching."

Much has been made of the distinction Pausanias makes between married and unmarried women. But it seems out of context. In my view, some later scribe inserted the sentence while copying the text, thinking it clarified why the Greeks allowed the priestess to watch the games. The scribe was probably assuming that a proper priestess had to be a virgin, but in fact, the priestess of Demeter was invariably a married woman. Even if women were not altogether banned from the Olympics, chances are that few could have attended, unless they were local inhabitants.

No doubt one reason this side issue evokes such interest today is that the Olympic athletes competed in the nude—even the jockeys, who rode bareback. (The only exceptions were the charioteers, who wore long, white gowns.) In modern Western culture, the idea that female spectators watched the competitions of naked men is titillating or scandalous. But nudity in itself was not so remarkable to the ancient Greeks, nor did it evoke the same reactions (they wondered why "barbarians"—non-Greeks—thought it embarrassing or shameful). Nudity also had the practical advantage of making it easier to massage and oil the body, both integral parts of athletic training.

Among the other notable events that had swelled the festivities by the time of the 476 B.C. games were the *pancration*, or no-holds-barred fighting (all manner of wrestling holds, kicks, and blows were permitted; only eye-gouging and biting were prohibited); the *hoplites*, a two-lap race in which each runner wore a helmet and carried a shield; a horse race; a mule-cart race; and contests for boys (*stade*, wrestling, and boxing). Only a few events were added later on: a *pancration* for boys, competitions to select the official trumpeter and herald, and some additional equestrian events.

The Olympic games were attached to a festival in honor of Zeus, and may have originated with contests among pilgrims who had come to take part in the god's cult. But by 476 B.C., indeed much earlier, religious fervor was not what drew athletes to Olympia. Money no doubt was a factor. Although victors received no prizes of value at Olympia itself, just the olive crown, winning was frequently a ticket to high profit from other sources. The cities from which the athletes came often bestowed cash payments on their champions. Still, for the best athletes the main incentive was the pursuit of excellence in itself, to compete and win at the highest level, with all the fame and glory that bestowed.

The ancient Greeks kept no records in the modern sense; they never measured performances in meters and minutes (for one thing, they lacked stopwatches). But they did keep records of other kinds: Who was the first to win a particular combination of events? Who won the greatest number of victories in a particular event? The first-known runner with multiple victories, for instance, was Pantacles of Athens, who won the *stade* in 696 and 692 B.C. Chionis of Sparta won both the *stade* and *diaulos* for three Olympiads in a row, in 664, 660, and 656 B.C. In 480 B.C., Astylos, representing Syracuse, Sicily, not only matched Chionos by winning for a third time in the *stade* and *diaulos*, but also demonstrated his versatility by winning the *hoplites,* the race with armor. (Defending the honor of their countryman, the Spartans added to the inscription on Chionos' memorial stele in Olympia, pointing out that there was no *hoplites* event in his time.)

Astylos' record stood for three centuries, until Leonidas of Rhodes won those three races for four Olympiads in a row, from 164 until 152 B.C. After that, what record could an athlete aspire to? Polites of Caria (a region in what is now southwestern Turkey) trained for the *stade* and the long-distance race, defying the odds that a runner could excel both in sprinting and endurance. He won both on the same day, in 69 A.D.

At the games of 476 B.C., there was special interest in boxing and *pancration*. Euthymos of Epizepherian Lokris, a Greek colony in southern Italy, sought to regain the boxing crown he had lost to Theogenes of Thasos in the previous (480 B.C.) Olympiad. In that earlier Olympiad Theogenes had also qualified for the *pancration* final, but he had become so exhausted from his boxing victory over Euthymos that he did not compete in the *pancration*. Olympic officials fined him for forfeiting the event and disqualified him from the boxing contest in the 476 B.C. Olympiad. Euthymos took advantage of his rival's absence and won the boxing in 476. Theogenes won the *pancration*, however, allowing him to proudly claim a record: "First man ever to win both boxing and *pancration* at the Olympics."

The 472 B.C. Olympiad was marked by an extraordinary upset when a civic entry owned by all the citizens of Argos won the chariot race. In what must have been an exciting contest, they defeated the winner from the 476 games, Theron, the king of Acragas, an important Greek city in Sicily. The victory finally broke the elitist monopoly of that expensive event.

The cult of Zeus at Olympia during the 476 B.C. games was the happy recipient of many valuable donations, as people and states dedicated their booty from the Persian War to the god. Elis, the loose confederation of neighboring villages that

Depiction of a javelin thrower shows that javelins were shorter than the ones used in the modern Olympics, which measure at least eight and a half feet. No examples of the ancient wooden javelins survive. The pitcher dates to the fifth century B.C.

hosted the Olympics, gained new affluence, and the Eleans finally built themselves a true town. An ambitious building program also began at Olympia. The stadium was moved slightly, and both the track and the spectator facilities were improved.

Within twenty years of the 476 games, a new temple to Zeus was completed. It measured about 100 feet wide, 230 feet long, and seventy feet high, and was roofed with the finest marble, topped by a golden statue of Nike, goddess of victory. For four years beginning in 437 B.C., the Athenian sculptor Pheidias directed the construction of a forty-foot-high statue of Zeus, seated on his throne inside the temple. Marble or cast bronze would have been too heavy for such an enterprise, so Pheidias made it of gold and ivory plates over a wooden framework. A system of pipes was devised for carrying oil to the wood, to keep it from rotting. The oil also helped to preserve the ivory for more than seven centuries. The statue has not survived, yet it is still famed as one of the Seven Wonders of the Ancient World.

But by the time it was finished, the statue was already a relic of another age. Flush with their united victory over the Persians, in 476 B.C. the Greeks had moved to end wars among themselves. Many of the Greek city-states agreed to allow Olympic officials to form a kind of judicial appeals board, which would settle political disputes by arbitration instead of by arms.

Within a few years, though, the member states ceased to recognize the authority of the Olympic appeals board, and no longer submitted cases to it. Hostile actions began taking place until the region fell into the Peloponnesian War of 431–404 B.C., one of the bloodiest and cruelest in ancient history. Greeks perpetrated brutal atrocities on one another, and the two principal combatants, Athens and Sparta, refused to tolerate neutrality from other city-states. The games continued, nonetheless, throughout the war, attracting citizens from all parts of a strongly divided Greece. The warring city-states accepted the Olympic truce, abiding by its prohibitions against invading Olympia or stopping athletes or spectators on their way to or from the games.

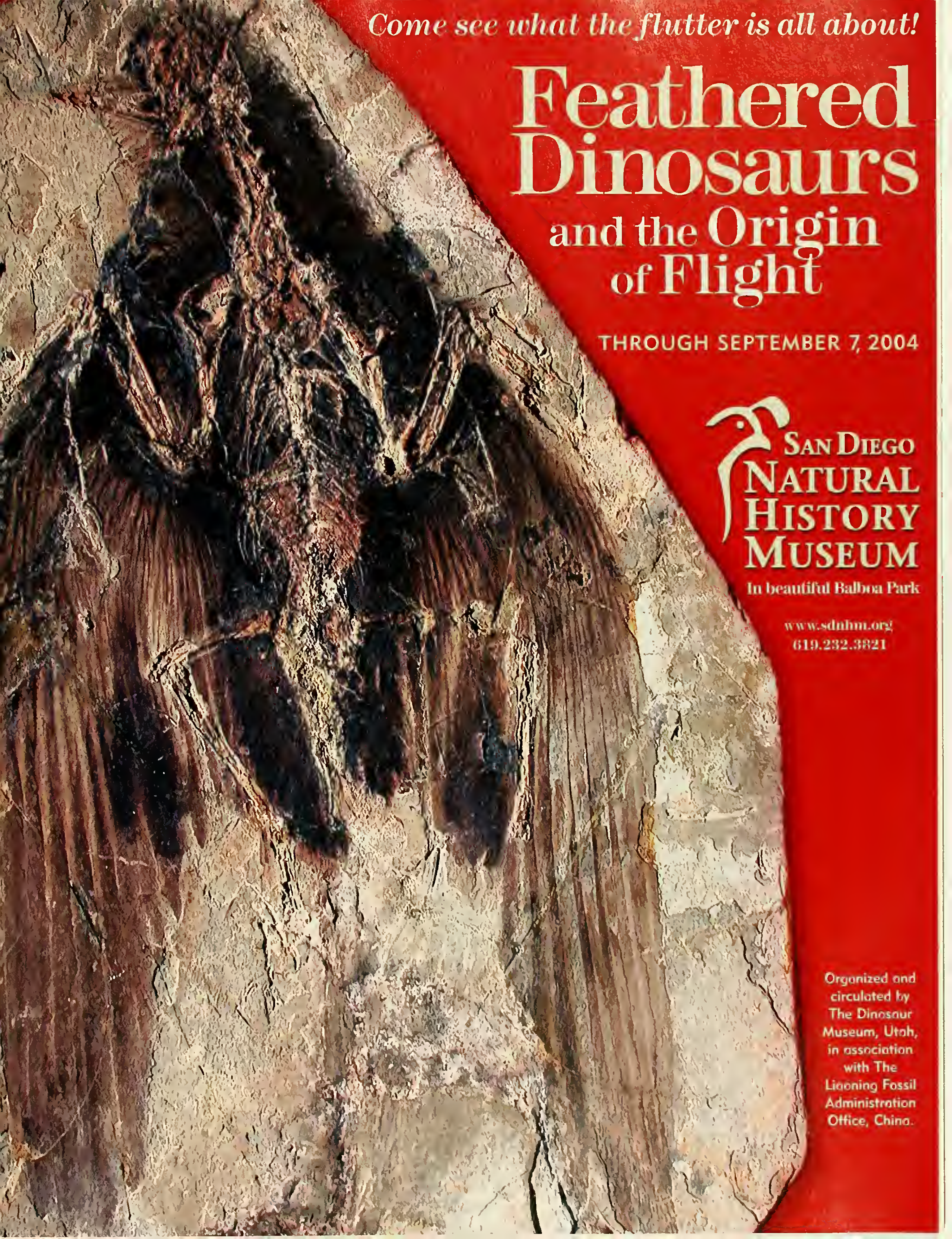
Nike, the Greek goddess of victory, crowns a winning athlete. Her name is preserved in the French city of Nice. The vessel, known as a krater, dates to the fifth century B.C.

Eventually, though, even the Olympics fell victim to hostilities. In 364 B.C., an army from the region of Arcadia (the Eleans' traditional foe) invaded Elis and occupied Olympia. When it was time to hold that year's games, the Arcadians usurped the role of sponsor. In retaliation, the Elean army invaded Olympia, arriving while the wrestling final of the pentathlon was in progress. The armies joined the battle immediately, reaching into Olympia's most sacred precincts. They fought into the night, the Arcadians and their allies occupying the roofs of the buildings and raining missiles down upon the Eleans. The Eleans were driven back, and the games were completed. Subsequently a multinational truce gave Olympia back to Elis, and the Eleans hosted the 360 B.C. games as usual.

The Olympics underwent their biggest ups and downs after the Romans took over Greece, in 146 B.C. Augustus, who effectively became emperor in 27 B.C., subsidized Greek athletics and saw to the renovation of the stadium at Olympia. In contrast, the notorious Nero decided that he himself should participate in the chariot race in 67 A.D. Nero fell off his chariot but claimed victory anyway, and the olive crown was presented to him by the bribed and terrified judges. (Not long afterward, Nero was assassinated, and the results of the 67 games, including Nero's "victory," were voided.) The Olympics enjoyed a renaissance in the second century A.D., once again drawing many athletes and spectators and sparking renewed building at Olympia. But after the games of 217, interest in the games steadily declined.

Although the names of many of the later Olympic victors have not come down to us, just ten years ago a large portion of a bronze plaque was unearthed at Olympia, which lists some winning athletes from the first century A.D. to almost the end of the fourth. The last two entries are for two brothers from Athens: Eukarpides won the boys' *pancration* in 381, and Zopyros won boys' boxing in 385. □

This article has been adapted from David C. Young's forthcoming book, A Brief History of the Olympic Games, *which is being published by Blackwell Publishing this summer.*


Come see what the flutter is all about!
Feathered Dinosaurs and the Origin of Flight
THROUGH SEPTEMBER 7, 2004
SAN DIEGO NATURAL HISTORY MUSEUM
In beautiful Balboa Park
www.sdnhm.org
619.232.3821
Organized and circulated by The Dinosaur Museum, Utah, in association with The Liaoning Fossil Administration Office, China.

Venomous Lizards of the Desert

Studies of Gila monsters and beaded lizards have uncovered an array of surprising characteristics, from odd fighting rituals, to extreme energy efficiency, to a venom useful in treating diabetes.

By Daniel D. Beck

In June 1986 my brother Jon and I pulled out of Tucson for a road trip to Chamela, Jalisco, in the heart of Mexico's searingly hot tropical dry forest. It was no tourist trip. I was a graduate student, eager to begin the first intensive field study of the beaded lizard *(Heloderma horridum)*. I had my gear, my letters of permission, and four years of field experience observing the beaded lizard's sister species, the Gila monster *(H. suspectum)*. Along with those essentials, my baggage also included a variety of assumptions about the creatures I was studying, assumptions drawn from my own limited experience and from the conventional wisdom about "monstersaurs," as the two species of *Heloderma* are known. I assumed, for instance, that Gila monsters are strictly creatures of daylight. The vast majority of monstersaur activity I had observed in southwestern Utah's Mojave Desert, the site of my previous work, had taken place during the day, particularly in the morning.

As a result, seeing a Gila monster was the last thing on my mind when I turned in on our first night. We had set up camp in a quiet spot in the desert north of the town of Guaymas in the Mexican state of Sonora. To avoid overheating while I slept, I pulled my sleeping bag up only to my waist. Soon I was dreaming. I had a fairly typical dream—for a herpetologist. In it I found a beautiful green iguana and picked it up, holding it in the prescribed manner, one hand supporting the body, the other grasping the neck, to avoid being bitten. My dream turned real as I awoke to find that I actually was holding something. It took me a second to take it all in, but there in my hands was a large adult Gila monster. I was holding it gently, but snugly, just as I had held the iguana in my dream. I sat up and stared at the lizard, trying to disentangle dream and reality. The Gila monster had crawled into my sleeping bag, and I had picked it up in my sleep. "Jon," I called out to my brother, "a Gila monster." Shaken from slumber, he replied, "Shut up and go back to sleep, you're just dreaming." "No, look," I hollered excitedly until he had to pay attention. "I can't believe it—a Gila monster!"

Gila monsters are rarely encountered in the wild, even by experienced field biologists, let alone by a man in a dream. As the shock wore off, I was forced to confront one of those assumptions I had carried to Mexico with me—the assumption that Gila monsters are strictly daylight animals. I had been fooled into thinking I knew the species' full pattern of behavior, when in fact I had witnessed only a fragment of the big picture.

Monstersaurs seem to have inspired an awful lot of this kind of thinking, what I call "overinterpreting experience." Perhaps that's not surprising; the animals almost invite confusion. To look at a Gila monster—four legs, long tail, triangular head, blunt snout—one might think it's simply a lizard like any other. But monstersaurs actually share a more recent ancestor with snakes than they do with most other lizards. It might be even more accurate to think of monstersaurs as "snakes with legs" than as another group of lizards. But the expression "snakes with legs" doesn't capture their intriguing qualities either. Several lines of ongoing research show that these animals display unusual metabolic levels, remarkable aerobic abilities, and dramatic dominance contests, all of which are connected in a pattern that offers a whole new twist on what it means to be a lizard.

In thinking about monstersaurs, snakes do provide a tempting point of reference. Consider an experience I had in April 1984, a few years before I

Male beaded lizard in tree, its large tongue exposed, samples the air for chemical traces of other animals, whether female lizards to mate with, males to fight, or prey to be caught.

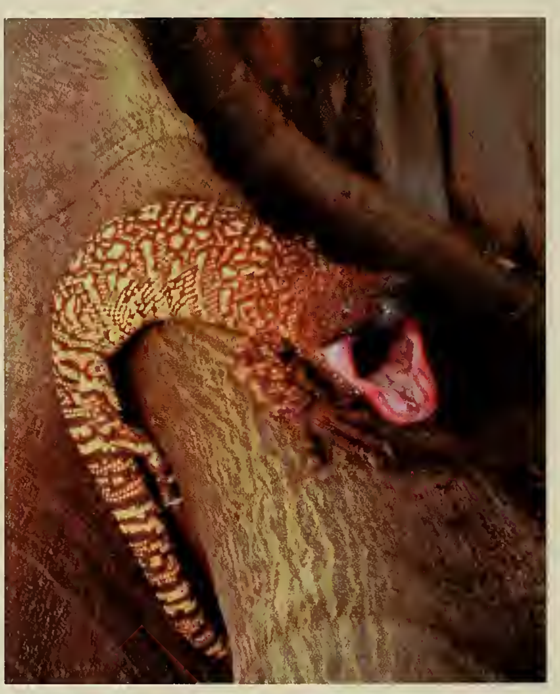
woke up with a Gila monster in my hand. During the preceding summer at my study site in the Mojave Desert, I had outfitted several Gila monsters with internal radio transmitters. That spring, after one of "my" males emerged from winter dormancy in March, I began following him closely. Like Elmer Fudd, the lizard went hunting for cottontail rabbits in their nests. His meticulous search of boulders and burrows paid off; by mid-April he had added a third of a pound, or 22 percent of his fall weight, to his lumpy frame. Fur in his feces attested to his success as a rabbit hunter.

One April day, though, rather than hunt, he walked nearly a mile in a straight line to a shelter that a female had occupied the preceding summer. In the next three days he visited two more shelters, before settling into one that another male had used the previous spring. A few days later a second male Gila monster confronted him outside his new den. The two grappled and twisted in a strenuous series of ritualized postures. Just past dusk, they separated, having spent three hours in nearly continuous combat. The struggle left each lizard coated with a thin film of blood, and each appeared exhausted. The resident male crawled back into his shelter while the intruder lumbered out of sight. Three days later, a female joined the victor in his den.

The entire episode of ritualized combat was strongly reminiscent of the entwining combat "dance" of snakes. Moreover, like many snakes—but unlike any other lizards—Gila monsters and beaded lizards are venomous. Those similarities make it tempting to lump the monstersaurs with snakes, yet the differences between the two groups are every bit as pronounced.

The venom systems of monstersaurs and snakes evolved independently, and they function quite differently from each other. For one thing, monstersaurs' venom comes from glands in the lower jaw rather than in the upper jaw, as it does in snakes. For another, in most venomous snakes the venom acts to subdue, and in some cases to predigest, the prey. Both Gila monsters and beaded lizards, by contrast, feed almost exclusively on eggs and helpless juveniles found in vertebrate nests, which obviously do not need a lot of subduing.

So what does venom do for a monstersaur? Defense may be the answer. When danger threatens, most lizards sprint out of harm's way. Gila monsters and beaded lizards, however, are not sprinters. The best they can manage is a fast shuffle. And though the lizards' mottled skins blend well with their surroundings in the deserts and tropical dry forests where they live, at close range their camouflage can fail. If so, a venomous bite is the lizards' last recourse. And painful it is; a herpetologist I know describes the bite as the worst pain he has ever experienced. The bite is not usually fatal for a healthy person, but monstersaur venom includes compounds that cause severely reduced blood pressure, inflammation, and excruciating pain, bad enough for an adversary to consider death the preferred alternative.



Threatened beaded lizard confronts danger by showing its most fearsome asset: its mouth. Both Gila monsters and beaded lizards come armed with a series of venom-washed teeth, capable of causing severe distress to any mammal—including a person—foolhardy enough to tangle with them.

Notwithstanding its defensive uses, monstersaur venom, like snake venom, might still play some role in digestion. Certain peptides, or small chains of amino acids, in *Heloderma* venom mimic vertebrate hormones that, in mammals at least, help the animals digest food and metabolize carbohydrates.

The best-known lizard peptide is called exendin-4, which occurs naturally only in Gila monster venom. Exendin-4 has become widely recognized as a promising new drug, called exenatide, for treating type-2 diabetes, which afflicts more than 17 million Americans. Exendin-4 mimics a mammalian hormone known as glucagon-like peptide, which regulates insulin release and glucose uptake from the blood after a meal. The concentration of exendin-4 in a Gila monster's blood increases thirtyfold just after a meal—certainly a strong hint that the peptide plays a role in digestion for the lizard. Intriguingly, the salivary glands that produce the venom develop in the Gila monster embryo from the same cells that give rise to the pancreas. And the pancreas in mammals produces the same hormones—insulin and glucagon—that exendin-4 mimics.

If monstersaurs are not "snakes with legs," another group of animals can serve as a useful point of reference: their closest living relatives, the monitor lizards. Monitors are a diverse group, native only to the Old World, with some remarkable abilities: they can count and remember faces, among other skills [*see "The Lizard Kings," by Samuel S. Sweet and Eric R. Pianka, November 2003*]. Monitors are tireless walkers when they search for prey or mates. Likewise, the male Gila monster I tracked in the Mojave in 1984 was certainly a steady pedestrian. And both monstersaurs and monitors engage in a strategy in which the animal, guided by finely honed abilities to sense chemicals, searches large territories. Beaded lizards and Gila monsters are opportunistic foragers, just as monitors are, eating any palatable thing they find. Perhaps, then, monstersaurs are best thought of as "monitors by another name."

As usual, though, when one tries to lump the monstersaurs into one category or another (daytime animals, for instance), contradictions emerge. Lizards that forage widely, such as the monitors, are generally more active and have higher resting metabolic rates than sit-and-wait predators. Monstersaurs buck the trend: Even though they do forage over wide ranges, their overall activity levels and their resting metabolic rates are remarkably low. Rather than being steady performers, they are like athletes who perform superbly in bursts, then spend the rest of their time on the bench.

Even in the spring and summer, when monstersaurs are most active, they spend more than 90 percent of their time hidden in shelters. And over an entire year they spend far less energy in activity than most sit-and-wait predators do. Such apparent sloth is the result of extreme seasonal fluctuations in the monstersaurs' environment. Food, when available, needs to be gorged on, stored as fat, and used slowly. Compared with monitors, monstersaurs can feed only infrequently, but when they do, they can eat meals that put supersizing to shame. I once watched a Gila monster eat four nestling rabbits in a single "sitting," an Easter dinner with portions equal to a third of the lizard's weight and providing a third of the energy it needs for a year. (For a 140-pound person, that would be the energy equivalent of downing 325 twelve-ounce sirloin steaks or 450 fast-food double cheeseburgers at one sitting.)

Of course, monstersaurs don't use up all that energy right away; they store it in their sausagelike tails and within their body cavities. Because the capacity to store energy is directly proportional to body mass, the larger the lizard, the longer it can subsist between meals. Gila monsters and beaded lizards, two of the largest lizard species in the New World, therefore have impressive abilities to store energy.

But if monstersaurs are good savers of energy, they're even better at spending it very, very slowly. At rest, Gila monsters and beaded lizards have among the lowest metabolic rates ever measured in lizards—far lower than the rates in monitor lizards. Furthermore, because monstersaurs spend so much time at rest—much of it in shelters where reduced temperatures confer even greater energy savings—the stored energy is used frugally. Monstersaurs are ectotherms (or, as they are sometimes erroneously known, cold-blooded animals), lacking internal mechanisms to regulate their body temperatures. With each drop in body temperature of eighteen degrees Fahrenheit, their metabolic rates decrease threefold.

The resulting energy conservation makes frequent foraging unnecessary, and enables the monstersaurs to occupy a feeding niche exploited by few other lizards. Indeed, their frugal lifestyle is causing herpetologists to rethink what they know about lizards, some of which turns out to be based on—you guessed it—overinterpretations of experience. Contrary to the received wisdom, predators that search widely can have low rates of overall activity—provided they have the right combination of high storage capacity, large meals, and low metabolic rates.

Nothing about the foregoing should be taken to imply that monstersaurs are always sluggish. On the contrary, they have striking aerobic capacities. On a treadmill, beaded lizards can walk at half a mile per hour for hours. Both monstersaur species display some of the highest capacities for sustained aerobic activity of any lizard ever measured, right up there with their monitor cousins. Large capacities for aerobic activity have traditionally been interpreted as adaptations to the needs of foraging. But why would inactive lizards have such remarkable endurance? For monstersaurs, endurance may fit into a different context: competition for mates.

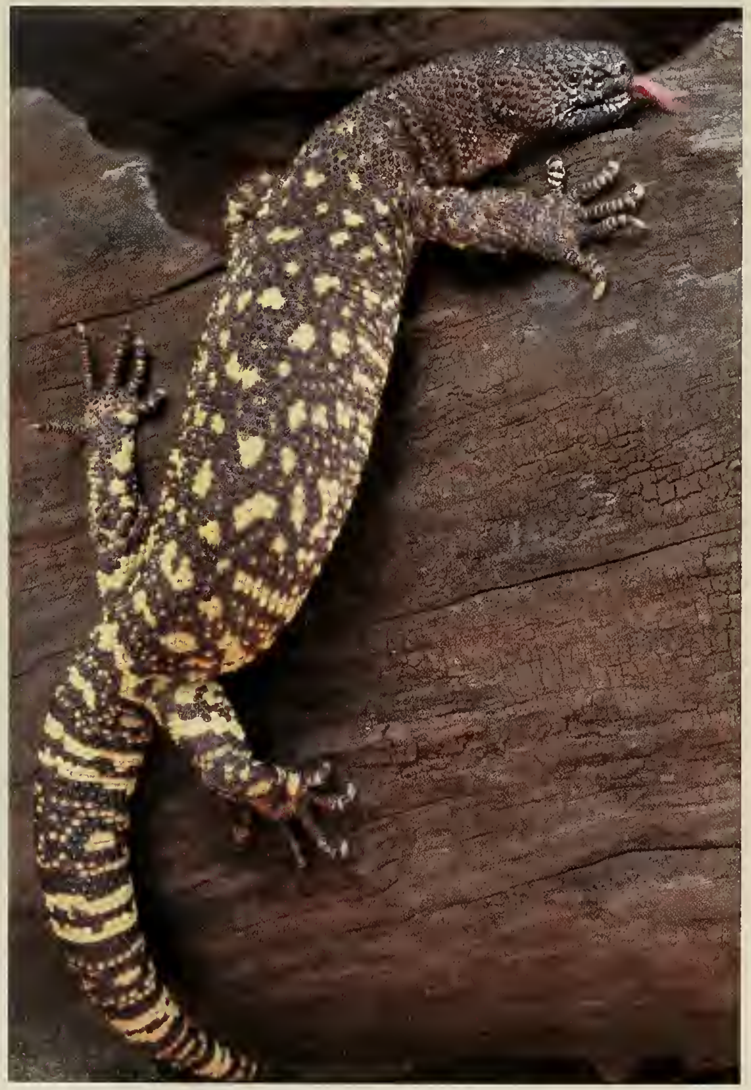
As that Gila monster and his intruding rival demonstrated to me in the Mojave back in 1984, monstersaurs can sustain prolonged bouts of ritualized combat. Males of both species engage in hours

For male Gila monsters, the first step to success in love is to grapple with a competitor (upper photograph). The animals twist and curl over each other, each trying to pin his foe to the ground. (Although fighting lizards may bite, they are immune to the venom.) The battles are fought over territory, shelter, and, in consequence, mates; a male in a shelter may soon find himself visited by a female. The ultimate goal of the fighting is to father a nest full of hatchlings (lower photograph).

of snorting, head pressing, and body twisting, all aimed at claiming access to a breeding female. Could their ritualized combat be the evolutionary spur to the monstersaurs' tremendous aerobic capacity? It looks as though the answer could be yes.

Gila monster wrestling matches have been observed repeatedly near shelters where males pair with females in the spring, when both sexes are primed for mating. In such a bout, one male climbs on top of his adversary and tries to remain there, while his opponent twists around in an effort to reverse their positions.

Male beaded lizards have even more spectacular combat rituals. The two challengers begin by pressing against each other, first side-to-side, then belly-to-belly, gradually creating a lizard arch with only snouts and tails contacting the ground. Larger size and a stronger, longer tail may give one lizard an edge. A bout ends when one male topples the arch and forces the other onto his back; the two competitors repeat the contest until one lizard gives up. Beaded lizards have been observed to continue wrestling for more than fifteen hours.



Sausagelike tail of the beaded lizard (and its Gila monster kin) enables the animals to store fat for long periods when food is scarce and activity is low.

Ritualized battles are all about dominance. For both species, remaining on top and forcing the opponent to the ground appear to be the primary objectives. Consistent losers retreat from the fight, while the winner gets access to a shelter housing a female. The exhausting contests test the limits of endurance, giving obvious advantages to the animal with the higher aerobic capacity.

Intriguingly, male monstersaurs have higher aerobic capacities than females do, suggesting that sexual selection—the shaping of a trait as a direct result of some mating behavior—has acted on the males. Christopher M. Gienger, a graduate student at the University of Nevada, Reno, and I have also found that male Gila monsters have wider heads than females and that male beaded lizards have longer tails than females—traits that may have evolved because they are useful in combat.

Although day-long battles for females are full of drama, it must be recalled that most of the time monstersaurs must rest quietly in their burrows. Such shelters—usually abandoned mammal burrows, rocky crevices, or, in the case of the beaded lizards, tree cavities—are crucial to survival in regions of great seasonal extremes of climate. Until recently, little has been known about these safe havens or how desert animals select them. Much of my recent work has focused on the physical conditions of the burrows and their role in the monstersaurs' life cycle.

Randy Jennings, a herpetologist at Western New Mexico University in Silver City, and I followed eight Gila monsters for six years, monitoring their use of more than 250 shelters. At our study site in the Chihuahuan Desert of New Mexico we found that Gila monsters are selective: They focus their activities where potential shelters are plentiful.

Moreover, they aren't looking for just any old hole in the ground; their preferences depend strongly on the season. When they emerge from dormancy in late winter and early spring, Gila monsters tend to choose rocky shelters facing the rising sun. The entrances to east-facing shelters warm quickly in the morning, and the Gila monsters occasionally bask in the warmth at this time of year. In winter, monstersaurs choose shelters on south-facing slopes, which catch the maximum amount of sunlight; winter shelters tend to be rockier, deeper, and better insulated than the ones occupied during other seasons. In the hottest, driest periods Gila monsters choose burrows in cool soil, which retain precious moisture better than rocky burrows do.

Dale F. DeNardo, a herpetologist and veterinarian at Arizona State University in Tempe, has shown that at temperatures higher than ninety-five degrees Fahrenheit, Gila monsters lose water five times faster than would be predicted for lizards of their size. Most of the water is lost through the cloaca, a body opening that serves for both excreting wastes and for reproduction. But Gila monsters also lose water faster across the skin than other lizards do. Choosing the more humid shelters in the dry season may be particularly important for Gila monsters in avoiding dehydration.

Strikingly, Gila monsters return year after year to the same shelters, some of which appear to be little more than inconspicuous crevices in a rock. Jennings and I found that Gila monsters seem to be most drawn to the shelters they have inhabited during extreme periods: winter and the driest part of the summer, before quenching rains arrive. In the Sonoran Desert in Arizona, the late Brent E. Martin and Charles H. Lowe, both herpetologists at the University of Arizona in Tucson, observed one individual returning to the same overwintering site for more than seventeen years! Perhaps, on reflection, it is unsurprising that once a shelter has helped an animal survive during a season of extremes, the animal tends to return to it again and again.

Gila monster inspects a suburban swimming pool. The single greatest threat to the Gila monster is the sprawling development around cities in the southwestern United States, which reduces the lizards' habitat and leaves them stranded in the human-built terrain.

But to return faithfully to a particular burrow, a monstersaur must be able to find it year after year. Like snakes and monitor lizards, monstersaurs can follow extremely faint chemical trails. In Utah I have watched males rub the bases of their tails on rocks, a behavior that looked like an effort to mark the entrance to a shelter with a chemical signal. A keen sensory system for following chemical cues, along with good spatial memory, would help explain how monstersaurs can return to a specific hiding place every year.

It was that system of senses and stored memories that guided the Utah male back to those previously used shelters in the spring of 1984—and set the stage for the wrestling match that captivated me. Alas, if he is still alive, he may find part of his home has disappeared. Many of my former study areas in Utah are being converted to recreational and housing developments. And though efforts are being made to transplant and protect monstersaurs, they may be to little avail. Brian K. Sullivan at Arizona State University West in Phoenix, Gordon W. Schuett of Zoo Atlanta, and Matthew A. Kwiatkowski at Colorado State University in Fort Collins, all herpetologists, have studied the effects of upscale suburban growth on Gila monsters near Phoenix. When Gila monsters are relocated to areas away from development, the investigators have found, the lizards usually perish, despite the great care taken in finding habitat that seems appropriate. Apparently, little "empty" habitat remains.

It would be sad if these remarkable creatures disappeared. Back in graduate school, whenever I was asked why anyone would care about venomous monsters, the only rejoinder I could muster was: "They're cool!" I still think monstersaurs are cool. But after years of study I can add to my answer. Beaded lizards and Gila monsters display a unique combination of evolutionary tenacity, energy efficiency, and endurance—a solution to the problem of life unlike that of any other lizard. From a more human-oriented perspective, I can point out that peptides from their venom are helping to treat diabetes. I don't think it's an overinterpretation of experience to say that without them, the world would be a poorer place. □

Worker Ludmilla Dorofeyava, who ran the scientific library and translated secret documents at a former Soviet Union bioweapons production facility at Stepnogorsk, Kazakhstan, displays the breathing mask she would have used in case of an accidental release of deadly pathogens. The valves in the foreground are part of the ventilation-isolation system.

A Most Dangerous Game

By Wendy Orent
Photographs by Lynn Johnson

chimera 1 a *cap* **:** a fire-breathing she-monster in Greek mythology having a lion's head, a goat's body, and a serpent's tail **b :** an imaginary monster compounded of incongruous parts **2 :** an illusion or fabrication of the mind . . . <a fancy, a chimera in my brain, troubles me in my prayer—John Donne> **3 :** an individual, organ, or part consisting of tissues of diverse genetic constitution.

—*Merriam-Webster's Collegiate Dictionary*
(Eleventh Edition)

Smallpox was the deadliest of all contagious human diseases, an exquisitely calibrated killer. No other human disease combined such virulence, or deadliness, with such transmissibility, the ease with which a germ can move from host to host. Before smallpox was eradicated from the natural environment, its "hottest" strains killed as many as 50 percent of the people they infected. Why, then, would anyone seek to create a smallpox chimera—a genetically hybrid virus deliberately engineered to increase smallpox's killing power? The virus known as variola would seem to be deadly enough on its own. Why would anyone, even a bioterrorist, want to "improve" it?

The moment the question is asked, the answer seems, unfortunately, self-evident. There is a "logic of developing weapons," according to Ken Alibek, former deputy director of Biopreparat, the "civilian" arm of the biological weapons, or bioweapons, program of the former Soviet Union. Weapons-making logic ensures that wherever a weakness exists in a potential weapon—the natural smallpox virus, for instance—weapons makers will do all they can to "correct" it.

From the point of view of a bioweapons maker, natural smallpox has two major shortcomings. First, an outbreak can be stopped through vaccination, the very tool that enabled the disease to be driven out of nature in the first place. Second, other diseases exist that are even more lethal than smallpox: inhalation anthrax and pneumonic

Refrigerated vials containing live disease cultures are displayed by a worker at the Scientific Center for Quarantine and Zoonotic Diseases in Almaty, Kazakhstan.

Guinea pig is infected with plague, as part of an experiment at the Center. Although the institution's mandate has always been to develop drugs, during the Soviet era the facility's resources were secretly diverted to research on bioweapons incorporating any number of pathogens.

A bioweapon loaded with a smallpox chimera—part virus, part human DNA—has become a nightmarish vision for virologists. But anticipating genetically "enhanced" diseases by building defenses against them poses troubling risks of its own.

plague, for instance, can kill close to 100 percent of the people they infect. If a vaccine-resistant, deadlier smallpox can be engineered by inserting foreign DNA into the virus, without compromising the contagiousness of the natural disease, the resulting chimera would make a truly terrible weapon—a weapon against which, as of now, there is no certain means of defense.

Unfortunately, the means to engineer such a chimera may be closer at hand than most people think. Modern molecular biology and genetic engineering have opened up diabolical possibilities that make smallpox a more dangerous threat than it ever was in the days before it was driven off the earth. The current smallpox vaccine, once used to eradicate the disease, may offer little protection to anyone against a smallpox chimera. I hasten to add that there is no evidence that anyone, anywhere, has actually produced a genetically modified smallpox capable of overcoming immunity. But the technology, and the knowledge, for doing so exists.

Genetically engineered smallpox has become, as the poet John Donne might have said, a chimera in the brain. The threat of such a chimera is forcing scientists to join new battles on new terrain. In his memoir, *Biowarrior,* Igor V. Domaradskij, one of the principal designers of the bioweapons program for the former Soviet Union, puts the matter bluntly: "In order to defend oneself one has to be in possession of what one must defend against. Otherwise there is nothing to be done." So, fearing pox chimeras in the hands of rogue scientists or rogue states, Western investigators have gone a fair way towards creating such chimeras themselves. And no one knows whether such purely defensive research is part of the solution or part of the problem.

The genetic engineering of infectious agents for use in bioweapons is nothing new. The Soviet bioweapons program worked for many years with smallpox and other lethal agents, including plague and anthrax. Genetic engineering of such agents began as long ago as 1973, in the shadow of the 1972 Biological and Toxin Weapons Convention, signed by the Soviet Union and by more than a hundred other countries, including the United States. In recent years it has come to light that the Soviets used the treaty as a screen for giving deep cover to what was already an ongoing, secret bioweapons program. In the following decades they would grow the smallpox virus by the ton, learn to dry it, harden it, and prepare it to be packed into refrigerated ballistic missiles designed to preserve the virus during reentry into the atmosphere.

As early as 1971, they tested their initial smallpox weapon by spraying a virulent strain of the virus into the air off Vozrozhdeniye Island, in the Aral Sea. The invisible plume drifted across the water. Nine miles away, Bayan Bisenova, a twenty-four-year-old icthyologist, was working on the deck of a research boat as it sailed through the plume. Bisenova had been vaccinated, but she came down with smallpox anyway, then passed it along to several other people. Eventually nine other people contracted the disease, three of whom had never been vaccinated. All three died of hemorrhagic smallpox, the rarest and deadliest form of the disease. In November 2001, recalling that outbreak in an interview in *Moscow News,* the old Soviet bioweaponeer General Pyotr Burgasov remarked, "Smallpox! Now that's a real biological weapon!"

And that was before genetic engineering was ever attempted in the Soviet Union.

"Smallpox!" General Burgasov remarked. "Now that's a real biological weapon!"

In the 1970s and 1980s the tools of what was then known as recombinant DNA technology were developed, offering the Soviet bioweapons program a way to build a "better" version of smallpox. As I noted earlier, even the hottest strains, the ones from India or Bangladesh, did not kill more than half of those infected. If you wanted a "real biological weapon," you ought to be able to do better than 50 percent lethality.

In the late 1980s Soviet molecular biologists at Vector Laboratories in Koltsovo, Siberia, applied recombinant DNA technology to add strands of mammalian DNA to vaccinia, the relatively harmless relative of variola virus that is used for vaccination against smallpox. In those days the laboratory had to synthesize the strands of mammalian DNA "by hand"—a long and tedious process. But the goal was deemed well worth the effort: a host infected with the genetically altered vaccinia might be induced to pump out quantities of mammalian proteins, specifically toxins or chemicals that play a role in the workings of the immune system, that would subvert the host's normal immune response and make the disease more lethal.

Sergei Popov, the former head of a department at the Vector Laboratories, says his group's intent was to march through the genes that coded for a large number of known immune-system peptides, or short proteins. By inserting those genes one by one into the vaccinia genome, then infecting the host with the genetically altered virus, the virologists could determine which protein was the most potent in suppressing the host's immune system.

Popov left Vector in 1987. By that time, he says, Vector had already synthesized DNA that codes for interferon-alpha, a peptide that has antiviral functions, including the activation of immune-system killer cells. Popov notes that the work at Vector continued after he left. He also makes it clear that vaccinia was just a convenient experimental stand-in—a proof of principle—for the real target: smallpox.

In the West, recombinant work with vaccinia virus has gone on for years—mostly as a vehicle for delivering recombinant vaccines. Vaccinia is a giant virus, as is variola and the other viruses in the genus *Orthopoxvirus.* Perhaps because of their size, orthopox viruses are more hospitable than other viruses are to the insertion of "foreign" genes, and thus to the formation of a recombinant vaccine strain—in effect, a chimera. The gene-splicing technique has been effective in creating a vaccine against rabies in foxes, and it is central to some efforts to develop vaccines against respiratory syncytial virus, AIDS, and certain cancers.

In 1996 Australian virologists spliced the gene that codes for an immune-system protein known as interleukin-4, which promotes the release of antibodies by white blood cells, into vaccinia virus. To their surprise, the virologists found that the recombinant virus "profoundly suppresses" cellular immunity in the infected host—the ability of the host's body to fight off viral infections. In 2001 another team, including some of the investigators from the 1996 study, reported that they had added the gene for interleukin-4 (the gene itself is known as *IL4*) to ectromelia, or mousepox virus.

Given the immune suppression noted in 1996, the 2001 team might have had good reason to expect a calamitous result with their *IL4*-mousepox chimera. But they were not really trying to create a lethal agent. Their goal was to create a kind of birth control for mice, which overrun granaries in Australia. The effect they observed, however, was overwhelming: the chimera overcame immunity not only in mice that had previously been vaccinated, but also in strains of mice known to be naturally resistant to mousepox. Sixty percent of the immunized or resistant mice died of the genetically modified mousepox. The implications were clear: if such a deadly strain of mousepox could be built, what would prevent performing the same kinds of genetic manipulations, with the same chilling effects, with the virus that causes smallpox?

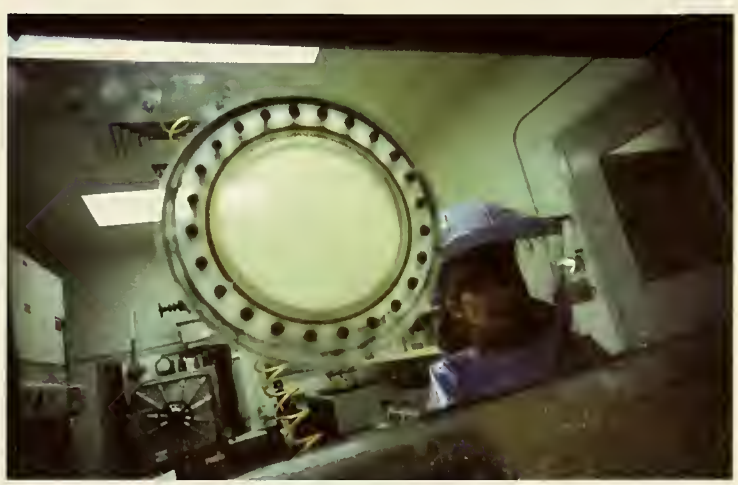
Strains of pathogens from infected animals are cultured by Lena Yakusheva, a worker at the Scientific Research Agricultural Institute in Otar, Kazakhstan. The facility receives U.S. funding from the Defense Threat Reduction Agency (DTRA); the support is intended to reduce the likelihood that staff and material will be dispersed.

Disturbed by the Australian results, an American poxvirus expert, R. Mark Buller of Saint Louis University in Missouri, set out to create a lethal mousepox chimera of his own. Unlike the Australian team, though, Buller chose an insertion point that would promote the production of interleukin-4 protein without disturbing the essential functions of the virus. His aim was not to duplicate the Australian chimera, but to develop an effective treatment against it. His first experiments, in 2003, suggested that simply vaccinating mice with fresh vaccinia protected them against a recombinant mousepox similar to (but less potent than) the one the Australian team had created. That finding was encouraging. It suggested that immunizing humans against smallpox might protect them against genetically engineered variola as well.

Camp 12, formerly a recreation hall at the Nevada Test Site, was converted to a mock bioweapons laboratory as part of a secret research effort by DTRA to see how hard it would be to accumulate the equipment, technology, and substances—all purchased on the open market—necessary for producing a bioweapon.

Then Buller raised the ante. Could the virulence, or deadliness, of the virus depend on more than just where the *IL4* gene was inserted in the viral genome? He introduced various kinds of "promoter" DNA—short sequences of spliced DNA that influence how much interleukin-4 protein is produced by the chimeric virus.

In the end, Buller made six chimeras, one of which maintained the full virulence of the mousepox virus, yet also yielded large quantities of interleukin-4. When he infected mice with the new, fully virulent chimera, the results were startling. It made no difference whether the mice were naturally resistant to ordinary mousepox infection, or that they had been freshly immunized against mousepox with vaccinia virus. All of them died. Buller even treated one group of naturally resistant mice with cidofovir, an antiviral agent best known as an anti-AIDS drug, which interferes with poxvirus replication. Yet those mice, too, all succumbed to the new chimera.



Ebola virus is studied by an investigator at the U.S. Army Medical Research Institute of Infectious Diseases in Fort Detrick, Maryland. Though highly virulent, the pathogen is not as infectious as smallpox.

Buller had to devise some way to defeat his new and alarmingly successful chimera. He injected chimera-infected mice with a monoclonal antibody, a molecule specifically engineered to bind directly to the interleukin-4 molecule. The antibody acted like a molecular sponge, soaking up the excess interleukin-4 produced by Buller's lethal chimera. And combining all the treatments worked: if the mice were naturally resistant to normal mousepox, and were treated with cidofovir and the monoclonal antibody, they all survived the lethal chimera.

Isolation suits for protecting workers from hazardous materials are on display, in a range of styles, at an administrative office associated with the Camp 12 project, the mock bioweapons laboratory DTRA assembled at the Nevada Test Site.

As I noted earlier, the virulence of a germ is not the same thing as its transmissibility. When Buller tested the transmissibility of his *IL4*-mousepox chimera, he found that it did not seem to spread as well as natural mousepox. One problem was simply that the infected animals died faster, thereby shortening the contagious period, during which the infected animals could pass the virus along to other hosts. Even during the contagious period, the natural virus seemed to spread more quickly than the chimera did. Buller describes his chimera as a double-edged sword: "increased lethality for the host, . . . lessened ability to transmit for the virus."

But mousepox transmission is not a perfect model for the transmission of smallpox. Mousepox spreads by direct, skin-to-skin contact. Smallpox spreads when a new victim inhales particles shed from an infected person's throat or skin. No one knows how an *IL4*-smallpox chimera would behave, though presumably, like the mousepox chimera, it would subvert the appropriate mammalian immune response to a poxvirus.

Mousepox is not smallpox, either: it kills mice, not men. But Buller's work with mousepox shows how, by experimenting with various combinations, virologists could create an *IL4*-smallpox chimera. Would such a chimera really act like smallpox? The natural virus is, in effect, both front- and back-end-loaded. At the "front end," the inhaled particles from an infected person lodge in the throat or upper respiratory tract of the new victim. Then, before the victim becomes too sick to move, sores form on the mucus membranes of the throat, from which live virus can be coughed or otherwise propelled into the air and circulate among new victims.

At the "back end," smallpox is a systemic disease, eventually settling in the skin and forming pocks, or pus-filled blisters, which eventually scab over. The pocks teem with virus particles. Scabs shed by the victim can last a long time in the external environment. Indeed, smallpox virus is one of the most stable and durable of all viruses, a perfect exemplar of what Paul W. Ewald, an evolutionary biologist at the University of Louisville, in Kentucky, calls "a sit-and-wait pathogen." Virus particles could simply lie in wait for the next host to happen by.

Would an *IL4*-smallpox chimera cause early lesions in the throat? Would it be as durable as natural smallpox? No one knows. If released into a human population, would it spread and evolve, or would it drop out under pressure from natural selection? No one knows. All one can infer from Buller's experiments is that its victims would probably die quickly, reducing the window of transmissibility. Would that prevent an epidemic? No one can say.

Nor can anyone say, just yet, whether any treatment, even one as elaborately put together as Buller's, would work against bioengineered smallpox. The whole point of Buller's research is to answer that question, to see whether protective therapies can be devised against a potential vulnerability. Buller himself is not satisfied with his current solution: administering both cidofovir and monoclonal antibodies, he admits, would be difficult. Furthermore, in the event of a chimeric smallpox attack, he notes, "you would have to know what the target gene, or the toxin, or the cytokine [immune system protein] used is. You wouldn't know in advance what somebody is going to use in a construct of this kind."

And the bioweaponeers are nothing if not inventive. In the 1980s, for instance, Popov placed conotoxin, a deadly poison derived from marine snails, in vaccinia and tested it at the Vector Laboratories. Smallpox combined with other toxins is easy to imagine, once the technology has developed. Buller argues that what is needed is a treatment regime designed to confront a large number of possible chimeras. The goal, he says, should be to find an antiviral drug that interrupts viral replication at a different stage than cidofovir does. Administered together, the two antivirals might be effective in clearing even a bioengineered virus from the body. No such second drug yet exists, and Peter B. Jahrling, also at USAMRIID and the army's leading virologist as well as a poxvirus expert, is not optimistic that two antivirals will work better than one. "If cidofovir doesn't work, why would it work any better if you combine it with another antiviral?" he asks.

"The moment this construct [*IL4*-mousepox chimera] was made, the vulnerability was opened," says Richard H. Ebright, a microbiologist at Rutgers University in Piscataway, New Jersey. "That vulnerability will close only when the requisite two antivirals are stockpiled and ready."

The window of vulnerability is now open—and a lot of difficult questions emerge. How many new chimeras must be created and tested, if people are to be safe? Should research laboratories take even one more step in that direction? Does the very research seeking to protect against chimeras make them more likely, not less likely, to emerge from the mind and into reality? Is the National Institutes of Health, which sponsors Buller's work, really "turning into the research wing of al-Qaeda," as Ebright puts it?

But there clearly is another horn to the dilemma. What was reportedly done in the research laboratories of the former Soviet Union—after the Soviets signed the bioweapons convention—is sobering. And what happened at that time took place in the days before gene synthesizers, when novel genetic material had to be assembled by hand. Are we deluding ourselves if we do not try to protect against novel genetic threats? After all, if Buller is right, joint therapy with two antivirals might work against all smallpox chimeras, even ones no one has yet imagined.

Buller's research—an effective proof of principle for smallpox bioengineering—continues. Not everyone accepts that the Soviet bioweaponeers did what they say they did—some people have brushed off their accounts of genetic engineering as, well, chimerical. But Buller has demonstrated the truth of the matter: Genetically engineered diseases can kill, even if they can't spread. The window of vulnerability will remain open whether chimeric research ceases or continues.

We had better figure out, and quickly, how to close it. □

Makeshift isolation barrier was built by the Camp 12 project out of readily available materials. Harmless organisms were grown at the facility, to see if signs of fermentation could be detected by satellite.

The Best of All Possible Worlds

The anthropic approach to cosmology asks, What makes the universe compatible with intelligent life? Was it just the luck of the draw?

By Donald Goldsmith

Alfredo Castañeda, *At the Midpoint of Our Life*, 2003

"*Cogito ergo sum,*" wrote René Descartes in 1641: "I think, therefore I am." Anyone who has a thought, in other words, must actually exist—quite a relief for those who had their doubts. Three and a half centuries later scientists and philosophers are investigating an intriguing, related question that Descartes passed over: *Sum ergo . . . ?* What conclusions, if any, can be drawn from the fact that we do exist?

Attempts to answer that question have given increased support to a line of thought that scientists and philosophers have termed the "anthropic principle," the idea that the simple fact of our existence offers fundamental insights and information about the entire universe. First named in 1973 by the cosmologist Brandon Carter, now at the Paris Observatory in Meudon, France, the anthropic principle can be better described as the "anthropic approach" to the cosmos, examining the universe for what can be deduced from the fact that we are here. (To emphasize that the "we" in question could be any form of intelligent life, some prefer the term "biophilic [life-loving] principle" to the terms "anthropic principle" or "anthropic approach.")

The anthropic principle rests on the assumption—maintained by almost all physicists and cosmologists—that a single set of physical laws holds true throughout the universe. All of modern cosmology, including the theory of the expanding universe, rests on that assumption. The principle itself has at least two forms. One, called the weak anthropic principle, notes that for us to exist and thus to observe the universe, the values of the parameters that describe the cosmos must be consistent with the fact that we have evolved within the universe.

The second version, called the strong anthropic principle, requires that the basic parameters describing the cosmos—the strengths of fundamental forces, for instance—cannot have random values, but instead *must* have values that enable life to develop at some stage in cosmic history. In other words, no universe could exist that did not allow the possibility of life.

What can either or both of these versions add to science? Some scientists find them no more than a tautology: We're here because we're here. Certainly from a biological viewpoint, the fact that so many possible sites for life exist in the cosmos, and the fact that life as we know it thrives in a range of environments, suggest at most a weak connection between cosmic conditions and the evolution of life on Earth. The story of life on Earth is the story of how life has evolved to be fit for our planet. The biologist Paul P. Ehrlich of Stanford University makes the same point for the universe in general: "To say that 'the universe is fit for life,'" he writes, "has things exactly backward: We are fit for the universe, not the other way around. Had things been different, we would have evolved differently."

Yet some scientists—though certainly not all—are convinced that the anthropic principle has intrinsic scientific worth. Certain facts, or clusters of facts, about the universe as a whole—once again, assuming that the same laws of physics hold sway throughout its extent—suggest that the physical parameters of our universe do not have random values.

Until recently, the "cosmic coincidences" most frequently cited as being favorable to life included the following three items:

- The development of structure in the universe during its first billion years gave rise to galaxy clusters and to individual galaxies made up of hundreds of billions of stars. That process depended critically on minute deviations from a totally smooth distribution of matter at the time clumps of matter could first form, about 380,000 years after the big bang. If those deviations had been a trifle smaller, galaxies would never have formed as the universe expanded; if they had been a bit larger, almost all the matter in the universe would have ended up in supermassive black holes.

Is it only a "cosmic coincidence" that matter in the early universe was just lumpy enough for galaxies to form?

- The strong nuclear force holds protons and neutrons together. If that force were more than 2 percent stronger than its actual value, protons would bind themselves in pairs to form "di-proton nuclei"—a state of matter that does not occur in the universe we inhabit. In that case, nuclear fusion during the first few minutes after the big bang would have left nearly all the protons in the universe bound up in di-proton nuclei. Those nuclei would have quickly become deuterium nuclei (each made up of one proton and one neutron) as one of the two fused protons turned into a neutron. The deuterium nuclei would then have rapidly paired off and fused to form helium nuclei, each made up of two protons and two neutrons. As a result, most of the ordinary matter in the universe would have become helium, not hydrogen. In our universe, about a quarter of the ordinary matter did end up in helium, but almost all the rest remained in the form of protons (hydrogen nuclei). A helium-dominated universe could never have given birth to stars that generate energy by fusing hydrogen into helium. Nor could it have produced water, the solvent that many scientists think is essential to life.

- Even more fortuitously, the range of conditions inside stars happens to include those suitable for creating carbon nuclei. Each nucleus of carbon's primary isotope includes six protons and six neutrons. At the high temperatures inside aging stars, two helium nuclei can move toward each other fast enough to overcome the mutual repulsion of their positive electric charges. If the nuclei collide, they become bound together by the strong nuclear force and fuse, creating a nucleus of beryllium, which has four protons and four neutrons.

Simple arithmetic suggests that one more helium nucleus could then fuse with the beryllium to make carbon (four protons plus two make six). The beryllium nucleus is unstable, however, and seems far more likely to decay rapidly than to fuse with another helium nucleus. Since carbon is in fact abundant, the fusion must actually prevail, but why?

In 1954 the English cosmologist Fred Hoyle argued that the existence of large numbers of carbon nuclei in the universe implies a serendipitous property of the carbon nucleus. Specifically, Hoyle argued, a carbon nucleus must be able to exist in an excited state in which its energy closely matches the energy of the nucleus formed when a helium nucleus collides with a beryllium nucleus at the temperatures (and therefore the impact speeds) common within aging stars. The energy of the collision produces carbon nuclei in a "resonant state," some of which can shed excess energy to yield a stable form of carbon.

Soon after Hoyle's prediction, nuclear scientists discovered that carbon does indeed possess such a resonant state. Because carbon is the basic structural element that enables complex molecules to form in virtually infinite variety, a universe without carbon might well be a universe without life.


René Magritte, *Les Memoires d'un Saint*, 1960

None of these three coincidences can be regarded as definitive for concluding that the parameters of the universe are not random. But taken together, they seem to confirm the idea of a "Goldilocks" universe: the conclusion that the universe must be "just right" for complex forms of life to appear. Other examples of cosmic "fine tuning" exist, but until recently none of them seemed to add much to the anthropic argument. Then cosmologists found evidence for a non-zero cosmological constant.

The cosmological constant was first introduced by Einstein into the equations he created in 1917 to describe the overall evolution of the cosmos. The constant describes—to use today's terminology—the amount of "dark energy" that resides in each cubic centimeter of apparently empty space [*see "Gravity in Reverse," by Neil deGrasse Tyson, December 2003/January 2004*]. Dark energy, an invisible kind of energy, tends to make the universe expand, so its effects become more pronounced with time. As the cosmos expands, more space is born, with its own additional dark energy. The newly created dark energy makes the universe expand even more rapidly, which in turn gives birth to still more dark

energy, . . . and so on. What the future holds in that scenario, for a time so distant that almost all the stars will have burnt themselves out, is a universe in a state of runaway expansion, a cosmos so vast that the matter in it will be entirely insignificant.

No observational evidence favored a cosmological constant until the final years of the 1990s; indeed, the lack of evidence led Einstein to regard his introduction of the cosmological constant as the "greatest blunder" of his scientific life. Hence most cosmologists tended to assume that the constant must be zero; dark energy, they agreed, does not exist. In 1998, however, astronomers announced that their observations of supernova explosions in far-off galaxies show that the expansion of the universe is actually accelerating. The acceleration implies not only that dark energy exists, but also that it exists in such quantities that, if measured by its mass equivalent, it dominates all the rest of the matter and energy in the universe by a ratio of almost three to one. And the domination of dark energy will only increase as time passes.

But why does the cosmological constant have the value that now characterizes the universe? Cosmologists may know some day, but for now, as the physicist Thomas Banks of the University of California, Santa Cruz, and Rutgers University in New Brunswick, New Jersey, has written, "Explaining the value of the cosmological constant remains the outstanding problem of theoretical physics." A relatively straightforward calculation does yield a theoretical value for the cosmological constant, but that value is greater than the measured one by a factor of about 10^{120}—probably the largest discrepancy between theory and observation science has ever had to bear.

If the cosmological constant had a smaller value than that suggested by recent observations, it would cause no trouble (just as one would expect, remembering the happy days when the constant was thought to be zero). But if the constant were a few times larger than it is now, the universe would have expanded so rapidly that galaxies could not have endured for the billions of years necessary to bring forth complex forms of life.

What makes this result particularly relevant to the anthropic principle, besides adding one more parameter to the list of "cosmic coincidences"? Its significance lies in promoting the concept of the "multiverse," an idea that has been dear to cosmologists' hearts for several decades—perhaps because it boggles the mind so thoroughly that ordinary people tend to shake their heads for relief or from disbelief, or possibly both. The concept suggests that what people usually call the universe, traditionally defined as everything that exists, actually amounts to just one of an infinite number of universes. Taken together, these multiple universes constitute an infinitely larger multiverse (sometimes called the metauniverse). You might think that some of the universes would run into each other, like cosmic bumper cars, but the theorists who created the concept assure us that such things cannot happen.

The anthropic approach fits together well with the concept of the multiverse. Multiverse cosmology suggests that each of the many universes comes into existence with its own, randomly generated parameters and laws that govern the motions and interactions of space and matter. Many such universes, for instance, would be born with a cosmological constant so large that each of them would quickly expand into emptiness, leaving no chance for galaxies or stars to form. Still other universes might resemble our own cosmos more closely, but have strong forces so much stronger than ours that all their hydrogen would fuse into helium early on. If we do live in a multiverse, it should surprise no one that we find ourselves in a particular universe that enables us to exist—one in which the laws of nature provide world enough and time for intelligent life to evolve. The multiverse approach seems to reduce the strong anthropic principle to the assertion that at least one of these universes had to be born with conditions that would allow life to exist.

The multiverse concept does not, of course, arise from, or depend on, the fact that the cosmological constant has turned out not be zero. But the recently discovered non-zero value does provide special impetus to the idea of a universe within a multiverse. Many theorists already suspect that even the finest minds on the planet may find no other way to explain that value. Explaining the strength of the strong nuclear force, or the fact that carbon nuclei have a resonant state that enables them to form readily in stars, may require "no more" than a subtler application of the basic laws of physics. Cosmologists hope to do the same with the cosmological constant, but so far all efforts have proved fruitless. Some have concluded that the anthropic approach to a multiverse has the best chance of providing a satisfactory answer.

The anthropic principle, says the cosmologist Laurence Krauss, is an "excuse in the absence of good science. . . . It's just a way of killing time."

Satisfaction, of course, remains in the mind of the beholder. Perhaps the most remarkable feature of the anthropic approach is its ability to provoke strong opinions and controversy, not only among the public, but also—even more so—among cosmologists. A sampling among the latter shows that opinions run across a broad spectrum.

Unsurprisingly, the anthropic approach gets its most favorable reception among those who seek to explain the laws of nature in terms of "intelligent design": as the work of a creator whose goals included bringing forth life on Earth. But no one of that persuasion needs a multiverse, and the chief remaining issue becomes one of wondering why such a wild and wacky universe was needed to bring forth life on a single planet. Virtually no scientists, however, are drawn to explanations that presuppose intelligent design, because all of science is motivated by attempting to explain the cosmos without invoking processes that lie beyond the human ability to understand them.

Among the cosmologists who reject the intelligent-design approach but do favor the anthropic principle, probably the best known is the cosmologist Martin J. Rees of the University of Cambridge. Rees emphasizes that we have already adopted an anthropic approach toward explaining some aspects of our existence. The size of the Earth's orbit around the sun, for instance, which plays a crucial role in the existence of life on our planet, does not follow from any physical law: it just is what it is. According to Rees, then, science must simply decide which cosmic questions can be answered without appealing to an anthropic principle, and which must, by default, be resolved by the anthropic approach.

A sizable group of cosmologists find Rees's attitude a bit too easygoing. Though not actually disgruntled about the anthropic principle, they are, nonetheless, in P. G. Wodehouse's phrase, far from being gruntled with it. The most prominent of the middle-grounders, the physicist Steven Weinberg of the University of Texas in Austin, provisionally accepts the anthropic principle as a disappointing last resort, provoked by the failure to find a better explanation for the value of the cosmological constant. As Weinberg writes in his book *Facing Up:*

> I would personally be much happier if we could precisely calculate the values of all the fundamental constants of nature on the basis of fundamental principles, rather than having to think about what values are favorable to life. But nature cares little about what physicists prefer.

A third group of experts comprises those who despise the anthropic principle. The cosmologist Michael S. Turner of the National Science Foundation describes the anthropic approach as "narcissistic" and a "principle of last resort." "Set your goals high," he urges, "and try to solve cosmic puzzles on the basis of physics." The physicist David Gross of the University of California, Santa Barbara, notes that "science has managed to explain lots of other weird numbers—so why shouldn't we expect eventually to explain the cosmological constant and other key parameters?" Unlike cosmologists who enjoy contemplating the multiverse, Gross finds the concept irksome, since it posits a multitude of universes with which we can never interact, even in theory. Such a state of affairs does not provide a firm basis for further scientific research.

Perhaps the most outspoken opponent of the anthropic approach is the cosmologist Lawrence Krauss of Case Western Reserve University in Cleveland, who calls the principle "always a sort of excuse in the absence of good science—never a proof of anything. It's just a way of killing time." He adds, "If we don't have a good idea about how to explain the cosmological constant, let's say so!" He derides the anthropic principle as "dangerous twice over." For one thing, confusing its approach with fundamental understanding may be "dangerous to science"; furthermore, "the public will imagine that science is no different from religion if [science] relies on the principle to explain anything."

If you adopt the idea of the multiverse, the anthropic principle may seem to furnish one of the oddest proofs for the existence of God yet promoted by human minds. Could it be that for us to live on our speck of dust within this vast cosmos, a benevolent creator made an infinite number of cosmoses so that one of them would enable us to exist, somewhere within its confines? Wouldn't it have been simpler to skip some of the bells and whistles—to stick to one universe, for instance?

Not necessarily. As the cosmologist Max Tegmark of the University of Pennsylvania in Philadelphia has wondered, what seems so wasteful about our puny existence in a multiverse made up of an infinite number of infinite universes. Is it space? But a single infinite universe already wastes an infinite amount. Is it matter? The same objection applies. Perhaps it is the waste of information, the additional description of universe upon universe required in a multiverse. But Tegmark points out that describing the totality of universes—the multiverse—may be simpler than describing just one universe, just as describing the full set of integers can be simpler than specifying a subset of them.

For now, the idea of a multiverse seems here to stay, at least among cosmologists and so long as they have no good explanation for the cosmological constant. The anthropic principle likewise will continue to be debated pro and con, as much on the grounds of philosophical acceptance or repugnance as on the basis of scientific logic. The debate will focus on cosmic issues that Descartes apparently never dreamed of.

Einstein, though, met those issues head on, when he said to his assistant:

> What really interests me is whether God could have created the world any differently; in other words, whether the demand for logical simplicity leaves any freedom at all. □

Giorgio de Chirico, *The Enigma of a Day*, 1914

THIS LAND

Delta Delights

Glacial meltwater, tides, winds, and waves conspire to mold an Alaskan coastline.

By Robert H. Mohlenbrock

Two hundred fifty miles east of Anchorage, the glacier-fed waters of the Copper River spread across a fifty-mile-wide delta before emptying into the Gulf of Alaska. The surrounding landscape is alluvial fan and low-lying wetlands, which extend inland as far as thirty-seven miles, all interleaved with glacial moraines and spurs of the Chugach Mountains to the north. Although bordered by glaciers, the delta is sheltered by the mountains and faces the warm Alaska Current, making its climate unexpectedly moderate: summers are mild, winters are cool but not cold, and all the seasons are wet.

Largely under the management of the Chugach National Forest, the delta is a breeding ground or resting place for 6 million migratory birds, including American wigeons, dusky Canada geese, green-winged teal, mallards, northern pintails, trumpeter swans, and western sandpipers. Salmon—chinook, coho, and sockeye—run at various times from late May through September, and Dolly Varden char and cutthroat trout are plentiful in the streams. Beavers, black bears, brown bears, harbor seals, moose, sea lions, sea otters, and wolves are among the local mammals.

The main obstacle to anyone who wants to explore the delta is getting there. To reach Cordova, the nearest town, you can take a commercial flight, then rent a vehicle locally. Ferries in the Alaska Marine Highway system also haul passengers and vehicles to and from Cordova year round. My wife Beverly and I had our van, so we and van took the eleven-hour ferry ride from Seward.

The largest earthquake ever recorded in North America, rated at 9.2 on the Richter scale, was centered only 150 miles west of Cordova. It struck at 5:36 P.M. on March 27, 1964, causing 115 deaths in Alaska alone, 106 of them attributable to the ensuing tsunamis. The quake damaged the so-called Million Dollar Bridge, built across the Copper River in 1908, at the then-exorbitant cost of about $1.5 million, for the transport of copper ore by rail to Cordova. (The bridge was later converted to carry road traffic, and is now preserved largely as a curiosity.) The quake also lifted the entire Copper River delta between six and twelve feet, elevating large zones of brackish marshes above the influence of the tides.

Fed by meltwater from Sheridan Glacier, in the distance, Tiedeman Slough empties into Alaganik Slough (large body of water in the foreground), which lies within the southern reaches of the Copper River Delta.

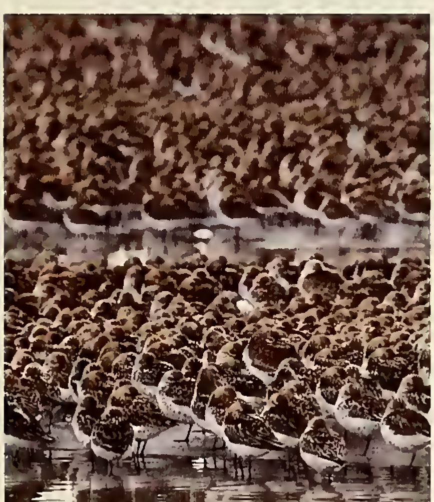
The Copper River alluvial fan is an outwash plain, that is, formed from sediments deposited by glacial meltwater. It is made up mostly of streams, abandoned stream channels, tree- or shrub-dominated terraces, and scattered ponds. Inland, nearer the glaciers, the terrain is rougher, with more distinct terraces. Peat lands appear on the terraces wherever a growth of sphagnum moss has accumulated in shallow depressions. Closer to the sea, where the terrain is smoother, forests of Sitka spruce and western hemlock have developed. Keith Boggs, an ecologist and the manager of the Alaska Natural Heritage Program at the University of Alaska Anchorage, has defined and described those and other plant communities of the Copper River delta.

Within the marshland uplifted by the earthquake, shrubs and trees now grow on the levees that border ponds. The ponds are three to four feet deep and range in area from an acre to more than ten acres. Tidal creeks still form a branching pattern within the uplifted marshland, nearly overflowing their banks at high tide but often turning into freshwater streams when the flow is reversed at low tide. Fronting the area are sea cliffs as high as six feet, which were formed prior to the earthquake by the action of ocean waves. Between the cliffs and the sea, the rhythmic movement of the tides is forming a new tidal marsh that includes mudflats, tidal creeks, tidal marshes, and tracts of shrubs.

Mixed in among the terraces, levees, and ponds are long, narrow dunes formed by onshore winds funneled upriver. They range between twenty and 250 feet high and run as long as nine miles. Although they are wider and steeper upwind, vegetation grows on all sides; the tops, however, are usually bare sand.

The wind as well as the ocean currents and waves also create beaches and back dunes at the edge of the mainland. The same forces have formed small barrier islands and spits of sand offshore, which help shelter the mainland. The beaches are ideal for beach combing, clamming, and observing brown bears and other wildlife.

The forty-eight-mile-long Copper River Highway, which extends east of Cordova and ends at the Million Dollar Bridge, provides an easy route across the delta. The first section, a twelve-mile stretch, is paved; the rest is gravel. Along the way, visitors have access in the Chugach National Forest to various campgrounds, cabins, observation platforms, and boardwalks. In addition, several side roads and trails lead to close-up views of glaciers and other attractions. One side road, on the approach to Million Dollar Bridge, ends at an observation platform overlooking Childs Glacier. The glacier frequently calves huge chunks of ice into the Copper River.



Western sandpipers rest on the mudflats during their spring migration stopover.

HABITATS

Outwash plain On alluvial soil, Sitka spruce is the dominant tree, and the ground is usually carpeted with mosses. Shrubs include Alaska blueberry, devil's club, and salmonberry. Oak fern and spinulose wood fern are common, along with strawberryleaf raspberry, threeleaf foamflower, and twisted-stalk. Where conditions are somewhat wetter, marsh horsetail is common beneath a dense growth of Sitka alder. If the soil is sometimes inundated by river water, either black cottonwood dominates above a shrub layer of Sitka alder, or shrub-size Sitka alder simply grows along with a fairly continuous ground cover of bluejoint (a grass). In ponds, Sitka sedge often forms dense stands; other common species are bluejoint, buckbean, marsh five-finger, and marsh horsetail.

Uplifted marsh Where there is saturated peat, sweet gale grows above a ground layer of Lyngbye's sedge or Sitka sedge. Where the water level fluctuates, Barclay's willow and sweet gale tend to dominate above an understory of buckbean, marsh five-finger, and Sitka sedge, but undergreen willow often abounds. Mats of roots in the uplifted marshes support a growth of Alaska bent grass, bluejoint, Lyngbye's sedge, threepetal bedstraw, and vetchling, usually with a substantial amount of sphagnum. In areas where there are permanent or semipermanent ponds, the aquatic communities may be dominated by buckbean, mare's tail, marsh five-finger, or water horsetail.

Linear dunes Dune willow, salmonberry, and Sitka alder grow vigorously above common cow parsnip, field horsetail, and lady fern.

Tidal marsh Lyngbye's sedge and sweet gale occur throughout the tidal marsh. In drier areas they are often joined by Barclay's willow and undergreen willow, whereas wetter areas often support Gmelin's buttercup and pure stands of tundra alkali grass.

Barrier islands and sand spits American dunegrass is usually the first plant to colonize newly formed sand spits and newly deposited sands on the barrier islands, forming pure stands around the bases of the slopes. Common yarrow mixes in with the grass upslope; higher up, fireweed becomes a dominant species along with bluejoint, lady fern, and seacoast angelica. Sometimes a zone of Virginia strawberry occurs just below the fireweed community. The highest portions of dunes lifted by the 1964 earthquake support open Sitka spruce forest with a thick undergrowth of moss.

ROBERT H. MOHLENBROCK is professor emeritus of plant biology at Southern Illinois University in Carbondale.

For visitor information, contact:
Forest Supervisor
Chugach National Forest
3301 C Street, Suite 300
Anchorage, Alaska 99503
907-743-9500
www.fs.fed.us/r10/chugach

REVIEW

Dad's Not Lost

But his steadfast refusal to ask for directions—despite the jokes—need not be explained as an evolutionary trait of the human male.

By Deborah M. Gordon

Here we are in our car
We've been driving ever so far,
We've been circling round and round,
Shall I tell you what we've found?
. . . .
Dad's not lost,
No he's not,
This is Daddy's favorite spot. . . .
—"Dad's Not Lost" by Tom Paxton

Everyone knows the stereotype: Even when lost, men grimly drive on without asking for directions. Evolutionary psychologists would like to explain this behavior by appealing to the romantic lives of ancient hunter-gatherers and, even further back, to the hippocampus of small rodents. The analogy between lost men and lost voles may be silly, but there seem to be intriguing links between human and animal behavior. In *Why Men Won't Ask for Directions*, Richard C. Francis suggests that physiological explanations of behavior—about how brains work—are often more informative than accounts of why the behavior evolved.

Evolutionary psychology, which focuses on the evolution of human cognition, emerged in the 1980s out of sociobiology, a perspective that encompasses all behavior. Both sociobiology, which the evolutionary biologist Edward O. Wilson of Harvard University introduced in the 1970s, and evolutionary psychology adhere to the idea that every characteristic of every species is adaptive—that is, each characteristic has enhanced reproductive success. Applied to explain the evolution of human behavior, the idea proceeds with appealing but misleading simplicity: Animals are depicted as doing something people also do. Next comes an account of the evolutionary advantage of the behavior for the animals. The conclusion is that it is natural, and therefore inevitable, for people to behave that way, too.

Ever since sociobiology was introduced, critics such as the the late Stephen Jay Gould and evolutionary biologist Richard C. Lewontin of Harvard University have pointed out that the basic reasoning of sociobiology and evolutionary psychology relies on mistaken evolutionary thinking. Not all characteristics of organisms, the critics note, come about as a result of natural selection. Before natural selection can operate, there must be some original variation among individuals in a trait, such as good versus poor spatial ability. Furthermore, the trait must be genetically inherited, and one or another version of it must enable some individuals to reproduce more than others. But there are plenty of traits around today that don't satisfy those criteria. Some traits have simply accompanied other traits that natural selection did favor, some are still hanging around as a result of a related trait in some distant ancestor, and some may persist purely by accident.

> *Why Men Won't Ask for Directions: The Seductions of Sociobiology*
> *by Richard C. Francis*
> *Princeton University Press, 2003, $29.95*

The most general objection to the idea that all traits are adaptive is that it results in stories about evolution that cannot be proved wrong. If someone develops a good reason that natural selection led to a certain trait, the explanation may be accepted merely because it is plausible or comforting or clever. If someone else gives a good counterargument to the explanation, a different adaptive reason can always be invented.

Critics of sociobiology have also pointed out another problem: the difficulty of establishing genetic inheritance of a trait. The action of genes depends both on the development and the environment of the organism. Behavior, furthermore, is social, developed in the context of our interactions with others. Children imitate the behavior of the adults they live with, and everyone modifies behavior according to circumstances. A man might be willing to ask for directions at some times but not at others.

Now, in *Why Men Won't Ask for Directions*, Richard C. Francis takes on evolutionary psychology and sociobiology from a new perspective—as a neurobiologist. He describes accounts of how sexual behavior works—par-

Arthur Tress, *Role Models*, 1992

ticularly the neural and hormonal processes involved in the behavior—to rebut simple adaptive explanations for its evolution. He contrasts questions about what goes on inside an animal's body with questions about why natural selection favored a certain behavior. Francis shows that the answers to the "why" questions of evolutionary psychology ignore plausible, alternative "how" explanations.

Each chapter of the book describes one aspect of sexual behavior, outlines the adaptive explanation for it, and then offers a different account, on the basis of the physiology behind the behavior. Francis often argues that a particular behavior is a consequence of bodily processes rooted in evolutionary history, processes already in place when the behavior arose. Some sexual behavior, for instance, is a consequence of ancestral physiological pathways, rather than an innovation selected for its own sake.

Why, for example, do women have orgasms? According to the convoluted stories of evolutionary psychologists, because sperm enters the uterus more efficiently during orgasm, it is adaptive for women to be able to influence whose sperm can fertilize an egg, which they can do by choosing with whom they have an orgasm. Francis then describes an alternative explanation for female orgasm suggested by Elisabeth Lloyd, a philosopher of science at Indiana University in Bloomington, and others. Their idea is to look at the constraints imposed by development: the clitoris is derived from the same ancestral genitals as the penis. Natural selection for the ejaculation of sperm has favored the male orgasm, and having a clitoris leads, as does having a penis, to orgasms.

Most examples in the book are about animal, not human, behavior. (Francis's own research has focused on the astonishingly varied and flexible sexual behavior of fish.) He explains why fish change sex, and how some cichlid males can change from being small males without territories to large, dominant males with territories, and then back again. Those changes are probably not determined by natural selection on territorial behavior, Francis explains. Instead, they can be traced to the gonadotrophin-releasing hormone (GnRH) and its effects on the brain and body.

In another chapter Francis outlines research on sex differences in spatial ability, which investigators have studied in many animals, including kangaroo rats, voles, and people. The studies have discovered that males do better than females in various tests of spatial ability (though Francis argues that the data on people are dubious). In kangaroo rats and some vole species, investigators have found that male brains have a slightly larger hippocampus. Evolutionary psychologists maintain that natural selection has promoted a large hippocampus in male voles and kangaroo rats because spatial ability provides more reproductive advantages to males, who move long distances to mate, than to females, who stay home and let the males come to them. But, Francis reasons, in rodents the hippocampus is the site of GnRH production. To develop male gonads, a male must develop a larger hippocampus as well. Thus hippocampus size is related to sexual development, not to navigation, and there is no reason to imagine that selection on spatial ability has favored the large hippocampus of male rodents.

For some kinds of sexual behaviors, Francis combines physiological and adaptive explanations. He traces the weird sexual anatomy of female hyenas, whose clitoris looks like a penis, back to selection for female dominance. Female dominance, he notes, may be adaptive among hyenas, and selection for dominance would select for unusually high levels of androgen hormones in the developing female fetus. The female sexual anatomy thus need not be adaptive at all; instead, it probably originated as just a by-product of high female levels of androgen.

Francis gives a similar explanation for the exceptional mimicry of mockingbirds, suggesting that mimicry itself was not favored by natural selection. Mockingbirds belong to a lineage of birds that learn new songs throughout their lives. In some members of the lineage, males learn the song to which females are most receptive. Mockingbirds share with the rest of their lineage the neurological structures that make this learning possible. Francis suggests that in mockingbirds, this capacity leads to learning all the time, not just during mating behavior.

Francis is at his best when explaining physiological processes: his explanations are clear, straightforward, and step by step. In one section titled "Testosterone Rex," he outlines the effects of testosterone on the brain. In a few pages he debunks the idea that testosterone makes men behave as they do. He notes that the action of testosterone actually depends on its access to the brain's receptors for estrogen. And its action, in turn, depends on which genes have been turned on during early development. "Testosterone itself does not organize anything," he concludes:

> The credit for the organizing that gets done as a result of testosterone's organizing effects should go primarily to the target tissues. . . . Next in importance, if we are ranking the developmental actors with respect to the magnitude of their causal role, are the androgen receptors. Testosterone comes in a distant third.

Francis debunks the idea that testosterone makes men behave as they do. Its action actually depends on its access to the brain's receptors for estrogen.

The descriptions Francis offers of animals and their behavior are vivid. Naked mole rats, he writes, are "shaped like late-season yams that have begun to sprout. . . . They seem to have been plucked from the womb much too early and then freeze-dried." His sarcasm is usually lighthearted. In what Francis calls the "Fred and Barney" story—the names refer to characters in *The Flintstones*—he recasts the account of the behavior of our hunter-gatherer ancestors invoked by evolutionary psychologists: the men go out hunting while the women stay home cooking and cleaning. The story is supposed to explain why men don't ask for directions: the idea is that women back then strongly preferred sexual partners who didn't get lost on the hunt. If sons inherited the spatial abilities of their fathers, and women persisted in this preference, not getting lost would increase—until somehow, now, men prefer not to appear lost. Along with this far-fetched story, the imagined lives of Fred, Barney, and their friends have also been invoked to explain, Francis writes:

> Why we are so prone to kill each other and why we die for each other, why we exhibit fidelity to our mates and why we are adulterous, why we court and why we rape, why we are doting parents and why we commit infanticide, why we are ethical creatures and why we are sociopaths, why we have rock stars, why we have art, why we have religion, why we have language, and why we wage war.

All this may seem a heavy burden to put on Fred and Barney.

Francis's emphasis on "how" rather than "why" questions points to the direction in which evolutionary biology will move. As more is learned about how organisms work, explanations based on physiological and ecological processes will replace hand-waving stories about how natural selection might have worked.

But I think Francis concedes too much when he accepts an adaptive explanation, if plausible, as probably correct. Empirical testing of evolutionary hypotheses is difficult, but not impossible. At least sometimes, it is already possible to do more than decide which explanation is more appealing. Research in evolutionary ecology can demonstrate how natural selection is acting now. The hope is that the more data available on the ways natural selection is currently working, the more realistic will be the stories of how it happened in the past.

Unfortunately, only the choir—people such as Gould, Lewontin, or Lloyd—seems to hear the preaching by critics of sociobiology and evolutionary psychology. It is hard to explain why—in spite of so much intellectual energy devoted to demonstrating the mistakes of sociobiology and evolutionary psychology—the scientific rebuttals have had so little effect. Simplistic evolutionary explanations seem to crop up like a pernicious fungus around every new discovery in behavioral science. Does the persistence of adaptive accounts of human behavior merely reflect a collective fondness for explanations that are easy to understand, and comfortable because they justify the status quo?

Francis offers a different reason for the current addiction to adaptive explanations. He suggests that the need for "why" answers is analogous to paranoia, to a delusional belief in the operation of an external force. Just as the paranoid thinks someone is always out there, trying to hurt him, so evolutionary psychologists think something is out there, making everything happen for a reason. That belief comes close to religious faith, and in biology Francis traces this belief back to William Paley, the nineteenth-century theologian who argued, against Darwin, that God, rather than evolution, creates species. Perhaps, Francis suggests, evolutionary psychology is best understood as religious faith dressed up as science.

DEBORAH M. GORDON *is a professor of biological sciences at Stanford University and the author of* Ants at Work: How an Insect Society Is Organized *(Norton & Company, October 2000).*

PICTURE CREDITS Cover: SCALA/Art Resource, NY; p.4–5: ©Kevin Schafer/Peter Arnold Inc.; p.8: photo of author W. Orent by Dougherty Photographicsp.10: ©Bud Grace; p.12: ©Galen Rowell/Peter Arnold Inc.; p.13(top): ©Peter Frischmuth/Peter Arnold Inc.; p.13(bottom): ©Jon Pelletier, University of Arizona; p.13(right): ©Sara Östlund-Nilsson, University of Oslo; p.14(top): ©Patti Murray/Animals Animals/Earth Scenes; p.14(bottom): ©A. Riedmuller/Peter Arnold; pp.16–18: courtesy JPL/NASA; pp.24–29: Erich Lessing/Art Resource, NY; p.26(bottom): map by Patricia J. Wynne; p.30: The Art Archive/Kanellopoulos Museum Athens/Dagli Orti; p.29: Réunion des Musées Nationaux/Art Resource, NY; pp.32–37: ©Thomas Wiewandt/Wild Horizons; pp.38–43: ©Lynn Johnson/Aurora Photos; p.44. courtesy Mary-Anne Martin/Fine Art, NY; pp.46–47: Photothèque R. Magritte–ADAGP Art Resource NY; ©2004 C. Herscovici, Brussels/Artists Rights Society(ARS)NY; p.49: ©The Museum of Modern Art/Licensed by SCALA Art Resource NY, ©2004 Artists Rights Society(ARS), NY/SIAE, Rome; p. 50(top): ©2004 Jim Wark/AlaskaStock.com; p.50(bottom): map by Joe LeMonnier; p.51: ©Michael Quinton/Minden Pictures; p.53: ©Arthur Tress/ClampArt, NY; p.56: courtesy Lyndon Irwin, Southwest Missouri State University; p.57: ©Nguyen Dong/UNEP/Peter Arnold Inc.; p.58: courtesy Concord Free Public Library; p.60: AKG-images; p.62: ©The Museum of Modern Art/Licensed by SCALA/Art Resource, NY, ©2004 Artists Rights Society(ARS),NY/ADAGP, Paris/Succession Marcel Duchamp; p. 71: (A)©Frans Lanting, (D)©Mitsuaki Iwago, (I)©Jim Brandenburg, (M)©Thomas Mangelsen/Minden Pictures; (B)©John Cancalosi; (C)©Luiz C. Marigo, (J)©Ed Reschke, (N)©Klein/Peter Arnold Inc.; (E)©William Osborn, (G)©Peter Blackwell, (K)©Bengt Lundberg, (L)©Jurgen Freund/Nature Picture Library; (F)©OSF R. Jackman, (H)©McDonald Wildlife Photography/Animals Animals/Earth Scenes. Errata: credit for April 2004 cover should read: watercolor of *Pachyrhizus erosus*(detail), courtesy of Hunt Institute for Botanical Documentation, Carnegie Mellon University, Pittsburg, PA. Torner Collection of Sessé and Mociño Biological Illustrations.

By Laurence A. Marschall

Locust: The Devastating Rise and Mysterious Disappearance of the Insect that Shaped the American Frontier
by Jeffrey A. Lockwood
Basic Books, 2004; $25.00

Among the more than 30 million items in the National Collections of Insects and Mites of the Smithsonian Institution is a pair of nondescript specimens: two dark grasshoppers of the species *Melanoplus spretus*, commonly known as the Rocky Mountain locust. In the 1800s vast armies of these creatures rose up every few years, rolling across the Great Plains and leaving nothing but ruin in their wake. Their approach was heralded only by an eerie grayness. Then the horizon disappeared beneath an advancing cloud of blackness, while a deafening buzz swelled out of the gloom. Frontier farmers ran for cover, choking and flailing at the air. The locusts shredded fields of ripening wheat, stripped the wood from the handles of farm tools, ate the very clothes off of farmers who ventured outdoors to drive them away. There were reports of trains unable to move, because the rails were greased for miles by the bodies of crushed locusts.

Grasshopper plague, exaggeration postcard, early 1900s

The devastation was biblical. A trained observer measured one swarm in Nebraska to be at least 110 miles wide. The swarm included an estimated 3.5 trillion insects. No wonder, then, that the homesteaders viewed the locusts as the wrath of an angry God.

More pragmatic souls devised ways to fight back, patenting devices like the King Suction-Machine, a horse-drawn contraption that vacuumed locusts into a chamber where they were hurled to their deaths against a wire screen and blown into bags for disposal. But nothing proved effective. It is no exaggeration to say that locusts were a critical factor in limiting growth on the American frontier, as well as in allocating public resources—as important to consider as climate, railways, and the struggle with Native Americans.

Yet the two insects in the Smithsonian collection are notable for another reason: they were the last living specimens of the Rocky Mountain locust. Because major infestations were sporadic and unpredictable, no one in the 1890s had noticed that the locust populations were in decline. Norman Criddle, a Canadian naturalist who collected the two museum specimens in 1902, had no way of knowing that the little dark grasshoppers would never be seen again. Yet, as if the prayers of the pious had been answered, the Rocky Mountain locust disappeared from the face of the Earth.

To the admittedly small company of grasshopper lovers (doubtless more numerous now, however, than in the 1800s), the disappearance of the Rocky Mountain locust remained one of the great biological puzzles of all time. Had some inadvertent environmental insult made it impossible for the locusts to survive? Had the settlers' infernal contraptions and pesticides accomplished their intended task after all? Had the locusts transformed (as some insects have been known to do) into an alternate form—a different-looking, more benign grasshopper?

The mystery was finally solved by Jeffrey A. Lockwood, an entomologist at the University of Wyoming in Laramie, who, after considerable searching, found frozen remains of locust swarms in remote glaciers in the Rockies. With modern techniques, Lockwood and his collaborators could rule out many of the old theories. Finally, over the decade of the 1990s, a satisfying picture of the fate of the insect emerged. Lockwood deserves credit, not only for his scientific acumen but for being a first-rate writer of natural history, and I will not spoil a great story by giving away his best lines. Suffice it to say that he has brought the Rocky Mountain locust to life, thankfully only on the pages of this lucid and eminently entertaining book.

Our Affair with El Niño
by S. George Philander
Princeton University Press, 2004; $26.95

For centuries, residents of Peru's arid coast have welcomed a warming of the normally frigid offshore waters, which comes every few years at Christmastime. They called it El Niño, Spanish for the baby Jesus. Fishermen still look to El Niño's arrival as a temporary respite from their work; most of their edible catch thrives best in colder waters. But when the waters of El Niño are particularly warm and linger longer than usual, the effects on local climate can be memorable. "The desert becomes a garden," recalled a visitor in 1891. "The soil is soaked by the heavy downpour, and within a few weeks the whole country is covered by abundant pasture." Residents have reported armies of yellow-and-black water snakes floating in balmy swells, along with bobbing armadas of bananas and coconuts.

These mysterious effects hinted that El Niño was somehow connected with events far from the shores of Peru, and that, indeed, turned out to be the case. During the International Geophysical Year (actually an eighteen-month period from July 1957 until December 1958), a worldwide collaboration to collect data on the state of the planet, oceanographers first

Farmer walking on cracked earth, a consequence of El Niño, in Vietnam

recognized the phenomenon for what it was: Peru's El Niño was just the easternmost edge of a strip of unusually warm water that periodically overspread the equatorial Pacific. What's more, they discovered, El Niño has a sister phenomenon, La Niña, a period of unusually cold waters that seemed to alternate with El Niño.

At the same time, meteorologists recognized characteristic shifts in the patterns of prevailing winds accompanying the seasonal temperature changes. Within a few decades El Niño's influence had been linked to a wide variety of weather and climate changes thousands of miles from its origin: the arrival of monsoons in India, the severity of winters in the United States, the intensity of droughts in southern Africa. Today scores of buoys continuously monitor wind and water conditions across the Pacific, updating El Niño's vital signs (check out www.pmel.noaa.gov/toga-tao).

There's a danger, though, warns S. George Philander, a geoscientist at Princeton University: all the supposed linkages can get pushed too far. In the popular mind El Niño has become the whipping boy for any change in climate that seems out of the ordinary.

The real phenomena, Philander explains, are far more complex. As elaborate as computer models of climate are today, they can only begin to approximate how water temperatures affect winds, how winds affect ocean currents, how increasing carbon dioxide alters baseline ocean temperatures, and how a host of other factors combine. Climatologists are only beginning to turn today's weather data into a reliable guide to the climate of the future.

El Niño is not just an oceanographic and meteorological curiosity. It has also come to prominence at the right time for focusing attention on the complexities of global climate. Environmental science and policy will turn to El Niño both as a starting point for research and as an object lesson on the connectedness of nature.

> ***Walden Pond: A History***
> *by W. Barksdale Maynard*
> *Oxford University Press, 2004; $35.00*

Asked to name the most important bodies of water in the U.S., an Australian schoolboy in the 1940s listed the Great Lakes, the Mississippi River—and Walden Pond. That's mighty impressive company for Walden, a freshwater lake outside Concord, Massachusetts, that is popular with residents of the western Boston suburbs as a picnic area, fishing hole, and bathing site. Measured by its area (barely sixty acres, depending on seasonal rainfall) or commercial value, Walden Pond surely isn't worth much more than any similar plot of real estate in New England. Yet the schoolboy was right: it is hard to think of a place of greater importance to the intellectual and spiritual development of the U.S.

A century and a half has passed since Henry David Thoreau wrote *Walden; or, Life in the Woods,* a chronicle of the author's two years of "deliberate living" in a small cabin on the lake's northeast shore. But that brief historical connection has made Walden Pond a holy shrine of the environmental movement. W. Barksdale Maynard, an architectural historian, begins his exhaustively researched narrative with Thoreau's first visit to the shores of the pond, at age four, in 1821. Maynard's real story, though, is the sometimes rocky history of the pond's "beatification," which he brings up to the present day.

Even before Thoreau's essay, Walden Pond exerted a magnetic appeal on writers such as Ralph Waldo Emerson, who saw the pond and its surrounding territory as an American counterpart to England's Lake District. There, William Wordsworth and other English Romantic poets advocated rusticity, in the form of rough-hewn cottages and quiet country lanes, as an antidote to the corruption of industrial civilization. Concord, even wilder and more rough-hewn than the English countryside, was a natural pulpit from which Emerson could preach the "Transcendentalist" gospel of nature, urging his contemporaries to leave the bustle of city life and seek peace and spiritual renewal among the pines.

Maynard puts Thoreau's great work squarely in the context of the Concord Transcendentalists, and shows how the modern conservation movement took root along the shores of Walden Pond. *Walden Pond* was not written as an environmental tract. But it is easy to see the pond as a microcosm of the struggle between conservation and development anywhere on the planet.

Even in the 1840s the pond was visited frequently by fishermen and woodcutters, and Thoreau could hear the rumble of the Boston-to-Fitchburg railroad as it passed along the western shore. After Thoreau left, his humble house was moved, and later torn down. Local memory of the site began to fade. In the late 1800s developers established a commercial picnic grove and amusement park along the railway at one end of the lake, and Walden Pond and its surrounding woods faced continuing threats from local developers right through the twentieth century.

Yet in those same years Thoreau's essays were becoming part of the canon of American arts and letters. As the country grew and development advanced, a largely successful effort to preserve and protect Walden Pond was carried on by the heirs of the Transcendentalists. Early on the preservationists included such Concord landowners as the Emersons, but, eventually, a host of people, inspired by Thoreau's writings were moved to


Walden Pond

help: from the ant expert, Edward O. Wilson of Harvard University, to Don Henley, a singer and drummer with the Eagles.

Books about the history of famous places seem destined for souvenir shops, where they may be purchased to sit on living-room bookshelves, unread. It would be a shame if Maynard's book were to share this fate, for it is important, illuminating, and of great narrative appeal. So read this *Walden*, perhaps after you've reread Thoreau's, at the shores of the pond or ocean of your choice.

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

EXPLORER GUIDE

Olympian Sites

By Robert Anderson

The Olympic Games are rooted in something far more ancient than the first footraces held at Olympia in the eighth century B.C. Many people, it seems, are naturally drawn to physical superlatives—strongest, fastest, fittest. Independently, ancient cultures evolved formal competitions to show off these attributes. A thousand years earlier, Egyptian athletes swam in the Nile and played tug of war and gymnastics (see www.touregypt.net/historicalessays/ancsportsindex.htm). In the New World, Mesoamericans competed in ballgames—often to the death—as early as 1500 B.C. (see www.ballgame.org).

Yet it is the Greek tradition of competition we celebrate. To search the Internet for information about the first Olympic Games, start at Rodney Polasky's site (www.archaeolink.com). Click on "Ancient Civilizations" and search the list of specialized topics for "Ancient Olympic Games." Polasky, an archaeologist and Web publisher, presents an impressive register of Olympic-related links.

First on the list is a link to a page from a special exhibit posted at "The Perseus Digital Library," at Tufts University. Among other things, the page describes all the ancient sports in detail, including chariot racing and the *pancration* (a combination of boxing and wrestling, spelled *pankration* on the Web site). [*See "With Hands and Swift Feet," by David C. Young, page 24*]

When you're tired of tuning in to the remote past, you can fast-forward to the 2004 games (www.athens2004.com) and preview this summer's events and venues in and around Athens.

Since the revival of the games in 1896, science has played an ever-larger role in helping athletes gain a critical competitive edge. In 1996, when the summer games were held in Atlanta, a site known as "The Why Files," maintained by the University of Wisconsin–Madison, addressed the subject with what is still the best general introduction to the topic. On the site is a special fourteen-page section called "Sport science meets the Olympics" (whyfiles.org/019olympic).

Today's professional athletes can combine the latest innovations in science and technology to scrutinize their own performances and find out what it takes to win. To see one example of how it's done, go to the site of the pioneering sports biomechanist Gideon B. Ariel (www.sportsci.com). A former discus thrower and member of the Israeli Olympics team, Ariel owns a company specializing in computerized performance-enhancement products. Take a look at the site's collection of video segments (www.sportsci.com/media). They include "The Perfect Jump," a glimpse of Bob Beamon's world-record-shattering long jump in 1968, and Carl Lewis's quest to beat it in the 1984 Olympics. (Lewis never did, but Mike Powell outjumped Beamon by two inches in 1991.)

Title page of official report for the first Olympic Games, Athens, Greece, 1896

How do athletes—even the ones with access to the latest techniques and technology—stack up against the rest of the animal kingdom? You can find world and Olympic records for people on a page of the official Olympics site (www.olympic.org); just enter "Olympic records" or "world records" on the site's search engine. And Petra H. Lenz, a neurobiologist at the University of Hawai'i in Honolulu, has tracked animal Olympians (www.pbrc.hawaii.edu/~Epetra/animal_olympians.html). On her site I learned that human beings don't even hold the record for being the fastest primates; that title belongs to the patas monkeys, which can sustain running speeds as fast as thirty-four miles an hour. (Compare that with the speeds of the fastest human runners: sprinters have reached a speed—albeit for only an instant—of just over 26.5 miles an hour; the fastest average speed clocks in at a little more than twenty-three miles an hour.)

"OceanLink" (oceanlink.island.net/records.html), maintained by the Bamfield Marine Sciences Centre in Bamfield, British Columbia, has data for many marine-animal record breakers, in a number of categories: the fastest fish, the Indo-Pacific sailfish, has been clocked at 68.18 miles an hour, whereas the sea horse ambles along at about one foot per minute (0.01 miles an hour).

At "The University of Florida Book of Insect Records 2003" (ufbir.ifas.ufl.edu), investigators have tracked the medal winners in the six-legged category—from the fastest flyers and runners to the insect with the shortest reproductive life. A species of Australian tiger beetle wins the gold for running speed, at 5.6 miles an hour.

If any of these sites pique your interest for the latest experiments in animal locomotion, check out a site maintained by Robert J. Full, a biologist at the University of California, Berkeley (polypedal.berkeley.edu). To hear Full's lecture on his experiments with giant cockroaches and centipedes, and to watch the insects running on a treadmill, click on "Intro to Bob Full's Projects" and then on the "locomotion" icon.

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

 (Continued from page 11)

prisoners in American custody, are favorably impressed with the "honesty, openness, unfettered access" manifest in our treatment of this incident. Some may even quote polls indicating that the great majority of Americans support our present war effort rather than our being "deeply divided," as Mr. Brown suggests. I do not claim to know that there is merit in these comments, only that there is much room for discussion and public debate.
Charles Zimmerman
Annapolis, Maryland

Bravo to Peter Brown for his editorial. Democracy, sharing, and truthful deduction are the very processes thanks to which good science happens. They are being debased and compromised in tandem as each new attack on the environment, for example, is disguised by monikers that suggest just the opposite of what will be the result.
Mark Sealey
Valencia, California

Animal Magnetism

Robert Zimmerman's article "Deep Impressions" (3/04), regarding the interior of the Earth, got me wondering: How would a reversal of the Earth's magnetic field affect the behavior of birds and other animals with "natural compasses" in their heads and bodies? The geologic record indicates that reversals in magnetic polarity happen quickly and frequently, relative to the pace of organic evolution.
Paul D. Neuwald
Martinez, California

Answers to "Birds of a Feather . . ." puzzle (page 71):

- *F – Swarm of eels*
- *D – Crash of rhinoceroses*
- *N – Kindle of kittens*
- *B – Knot of toads*
- *I – Unkindness of ravens*
- *H – Parliament of owls*
- *C – Army of caterpillars*
- *M – Convocation of eagles*
- *L – Smack of jellyfish*
- *K – Singular of boars*
- *J – Pod of sea lions*
- *A – Romp of otters*
- *E – Gaggle of geese*
- *G – Pride of lions*

ROBERT ZIMMERMAN REPLIES: No one can predict the exact consequences. But according to James L. Gould, an ethologist at Princeton University, if the polarity reversal is slow, there should be little effect on migrating birds. But if the transition is fast—a few years or less—many birds would have trouble remaining oriented. That birds have continued to thrive through any number of reversals, Gould suggests, is probably the best reason to think that magnetic-pole flips are not rapid.

Andromeda Strain?

As Charles Liu reported in his "Out There" column ("Gas Guzzlers," 4/04), the discovery of low-mass gas clouds around the Andromeda galaxy is truly groundbreaking work. Because Andromeda is so close to the Milky Way, however, it is exceedingly difficult to determine the distance to the gas clouds. Instead of orbiting Andromeda, they may be on the outskirts of the Milky Way or associated with the stream of gas being pulled from the Magellanic Clouds. Only when analogous gas clouds are found around more distant galaxies will astronomers be certain that such clouds are associated with the formation of galaxies. Such observations are extremely difficult, and may have to await the development of more sophisticated instruments.
Daniel J. Pisano III
Australia Telescope National Facility
Epping, New South Wales, Australia

AMENDMENT: Because of an editing error, the distance from the pitcher to home plate was misstated in Adam Summers's column "A Fly in the Curveball" (4/04). The prescribed distance—measured to the rear point of the plate—is sixty feet, six inches.

Natural History *welcomes correspondence from readers. Please send e-mail to* nhmag@naturalhistorymag.com *All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

Twinkle, Twinkle, Microlens

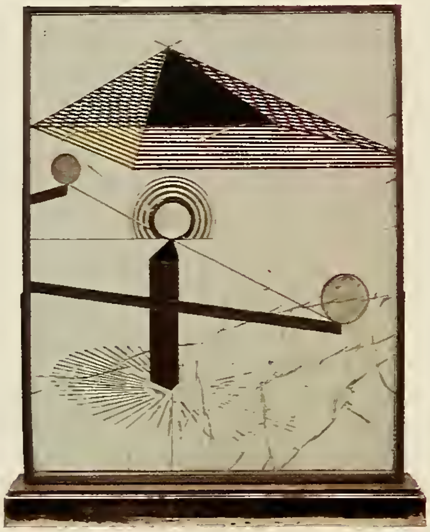
In trying to probe the dark matter surrounding the Milky Way, astronomers have confirmed the identity of a nearby gravitational lens.

By Charles Liu

In the early 1990s a team of astronomers led by Charles Alcock at the Lawrence Livermore National Laboratory began a pioneering, multiyear study of unseen matter in our Milky Way. They scanned millions of stars in the sky night after night, watching and waiting for signs of "microlensing"—gravity-induced magnification of background stars by small, massive objects passing in front of them. No one knew for sure how many such events the team would see. Some predicted that the search might not yield even a single microlensing event (including one young graduate student who now writes this column).

Now, older and hopefully wiser, I and my fellow naysayers cheerfully admit we were wrong; the experiment was a grand success. After eight years of painstaking observations, Alcock and his collaborators recorded several dozen microlensing events, all caused by planet- or star-size bodies within the "dark halo" of unseen matter that envelops our galaxy. A few dozen microlensing events may not sound like a lot, but it was a large enough sample to help open a new frontier of astronomical research, and in the process coin a spiffy new acronym: MACHO, which stands for "massive compact halo object."

Since those early days, more than a thousand microlensing events have been recorded by research groups around the world. Recently, astronomers reached another milestone in the study of microlensing. One of the earliest MACHOs detected, which caused an event dubbed LMC-5, has now been positively identified—lifting an anonymous, faint red star into the limelight of astronomical fame.



Marcel Duchamp, *To Be Looked at (from the Other Side of the Glass) with One Eye, Close to, for Almost an Hour*, 1918

The Milky Way has an ellipsoidal "bulge" of stars at its center, about 15,000 light-years long and 5,000 light-years high, which is bisected by a flat disk of stars and gas 100,000 light-years across and about 1,000 light-years thick. (You'll get the idea if you imagine a pizza with a plum stuck through the center of the crust.) The Sun, with Earth orbiting around it, resides in the disk, about midway between the bulge and the disk's edge.

The bright, familiar shape of the disk and bulge is enveloped by a spherical cloud of sparsely scattered stars called the stellar halo, which extends some 50,000 to 100,000 light-years from the center of the galaxy. The disk, bulge, and stellar halo in turn are all embedded in the center of a structure called the dark-matter halo (or dark halo), whose extent is still not definitively known; what is known, though, is that the dark halo dwarfs the galaxy's other components in both size and mass.

As its name suggests, the dark halo emits no light. Astronomers know of its existence from its gravity alone: without the dark halo, our galaxy's disk would not be stable. The structure and composition of the dark halo is one of the outstanding puzzles in astronomy—though astronomers suspect that about a fifth of its mass is comprised of small, massive bodies. But if no one can see it, how can astronomers figure out what it's made of?

Since gravity is the one measurable feature of the dark halo, Alcock and his colleagues decided to probe it with gravitational lensing [*see "The Quest for the Golden Lens," by Charles Liu, September 2003*]. The random orbital motions of its small, massive bodies, the investigators reasoned, would occasionally put those dark bodies directly in front of a distant star. As a body moved into, then out of, the line of sight between the star and Earth, its gravity would temporarily act like a telescope lens. As seen from Earth, the background star would brighten, then fade away, over a period of days or weeks, in a pattern predicted by Einstein's general theory of relativity.

In principle, gravitational lensing is simple: a massive object bends space much the way a heavy bowling ball would bend a trampoline if it were rolled around on the springy surface. Light beams passing through bent space bend too, almost as if they were focused by a magnifying glass. The devil, of course, is in the details. Solving the equations of general relativity can lead to a morass of difficult mathematics—and the natural "magnifying glass" created by an intervening dark object may act more like the thick glass at the base of a bottle of soda pop than like a carefully polished lens. To understand exactly what happens in a microlensing event, theoretical models are compared with the observed data to see which initial mathematical conditions lead to the best match with the magnification pattern. Rarely, alas, is enough information available—either theoretically or observationally—to afford an unambiguous interpretation.

Fortunately, the observational data on LMC-5, a microlensing event recorded in the direction of the Large Magellanic Cloud, were exquisitely detailed. In January 1993, an unremarkable bluish star in the cloud, nearly 200,000 light-years from Earth, began to grow noticeably brighter, and reached its peak on February 5, at nearly fifty times its usual brightness. Then it slowly faded, returning to its normal, unremarkable brightness by mid-March. Unmistakably, the event was caused by microlensing.

The next step was to find the mass and distance of the intervening dark object. On May 13, 1999, Alcock and his team made a color-composite image of the location of the LMC-5 event with the Hubble Space Telescope, and discovered a faint, red star almost right on top of a bright, blue star. Their angular separation was less than one-seventh of an arc-second—the equivalent of viewing a penny from almost twenty miles away. The faint, red star, the team concluded, was the likely lensing object, because it would not have moved far in the intervening six years, though, of course, it was no longer in the line of sight of the blue background star.

That conclusion, however, led to another problem. The luminosity and spectral characteristics of the red star showed that it is about 11 percent the mass of the Sun, at a distance of about 2,000 light-years from Earth. The mathematical models of the microlensing event, however, told an entirely different story: the estimated lens mass would be only 4 percent the mass of the Sun—smaller than any known star—and it would lie only 600 light-years from Earth. The nature of the LMC-5 lens remained indeterminate.

Now, theory and observation have finally converged. Andrew Gould, an astronomer at Ohio State University in Columbus, reworked the gravitational-lens equations and showed that a second, previously unrecognized solution to the equations exists, which places the lensing object at a distance of 2,000 light-years rather than 600. A few weeks after Gould's result was published, Andrew Drake at Princeton University, Kem Cook of Lawrence Livermore National Laboratory in California, and Stefan C. Keller at the Australian National University in Canberra published new measurements of the LMC-5 object, again made with the Hubble telescope. The new measurements confirmed that the red star was moving in a way consistent with Gould's calculations.

What those findings mean is that the MACHO that caused the LMC-5 lensing event is indeed this unnamed red star. It's the first definitively confirmed identity of a MACHO lens.

Ironically, the first confirmed "massive compact halo object" isn't a galactic halo object at all. At a distance of 2,000 light-years, in the direction of the Large Magellanic Cloud, this faint little red star actually lies in the outskirts of the Milky Way disk—one among billions of other nondescript dwarf stars, traveling in an unremarkable orbit within the galaxy. As so often happens in life, it owes its fame to chance: for 75.6 days in 1993, it was in the right place at the right time.

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

READER SERVICE

For free information from the advertisers listed below, circle the corresponding numbers on the attached postage-paid card. Mail card, fax it to 856-380-4101, or visit us at **www.naturalhistorymag.com.** If the card is missing, mail your request to: P.O. Box 9000, Maple Shade, NJ 08052.

1 **ADVENTURE LIFE JOURNEYS**
Small group travel in the Andes, Amazon, Galapagos, Patagonia, Antarctica, and Central America. Expert local guides lead our cultural and ecological explorations and naturalist cruises.

2 **ADVENTURES ABROAD**
Adventures Abroad offers small group tours to 110 countries. Our tours are part education, part exploration and a complete holiday.

3 **ALABAMA GULF COAST**
Spectacular beaches. Outstanding accommodations. And warmed by sunshine, history, culture and unspoiled natural beauty.

4 **AMAZONIA EXPEDITIONS**
Award-winning Jungle Lodge in the Tamshiyacu-Tahuayo Reserve, shown to have the greatest diversity of mammals in all of the Amazon.

5 **AMERICAN CRUISE LINES**
Enjoy scenic and culturally enriching 7 night cruises through the smooth waters of the inland passages along the eastern U.S. seaboard.

6 **ATHENA PUBLICATIONS, INC.**
Athena Review, journal of archaeology, history and exploration, invites you to send for more information on a free issue.

7 **BELIZE TOURIST BOARD**
Catch the Adventure! From rainforest resort to Barrier Reef. Belize is only 2 hours from the USA. Belize. Mother Nature's best kept secret.

8 **BERMUDA TOURISM**
Bermuda. It's not just a pretty island. It's a paradise served on fine bone china.

9 **CALVERT COUNTY, MD**
Discover a place where there are still places to discover...just an hour from Washington, DC. Catch a glimpse of Southern Maryland's heritage and history and experience fabulous festivals and extraordinary events.

10 **CANON USA**
Canon USA offers a full line of consumer imaging products from 35mm, APS and Digital Still cameras, Analog and mini DV camcorders, Image Stabilization Binoculars and Direct Photo Printers.

11 **CAPE MAY**
Come and relax on our pristine beaches, stroll the promenade, take a tour of Cape May, its hundreds of Victorian homes, and learn our history.

12 **CHARLES COUNTY, MD**
It's for the birds! Take a hike! Hunt for fossils, golf, fish, shop. Experience the wild side of the Potomac where eagles soar.

13 **COLONIAL WILLIAMSBURG**
Step back in time and experience Colonial Williamsburg, Virginia's 18th century restored colonial capital, where visitors of all ages can revel in activities. Including Historic Area walking tours, character reenactments, museum exhibits and first-class resort amenities.

14 **DORCHESTER COUNTY, MD**
Destination Dorchester - Home to world-renowned Blackwater National Wildlife Refuge, excellent paddling, cycling, fishing and hunting; explore the heart of Chesapeake Country on Maryland's Eastern Shore.

15 **FREDERICK COUNTY, MD**
Maryland's Crossroads of History. Antiques, Battlefields, Covered Bridges, Parks, Wineries and more close to Gettysburg and DC.

16 **GALAPAGOS TRAVEL**
Specializing in comprehensive, educationally-oriented, professionally-led natural history tours of the Galapagos Islands. Spend 11 or 15 days touring all the significant outer islands.

17 **GARRETT COUNTY, MD**
Experience the hushed quiet of western Maryland's mountains - hike forest trails, paddle rivers and seven lakes, 90,000 acres of parkland. Over 600 rental homes plus inns, hotels.

18 **GEVALIA KAFFEE**
Experience the pleasure of Gevalia Kaffee. Order a Trial Shipment for just $16.95 and receive a free coffeemaker.

19 **INCLINATOR CO. OF AMERICA**
Inclinator's Elevette® residential elevators provide convenience for people and add value to homes. They can be designed into new construction or added to existing homes.

20 **JOHNS HOPKINS UNIV. PRESS**
Celebrating 150 years of publishing for the world. Books about nature and science.

21 **KOLIBRI EXPEDITIONS**
Birding Peru and South America. Birdwatching and culture. Special tours to see hummingbirds and parrots. Endemic and threatened species. Budget or comfort trips. More birds!

22 **LAUREL HILL PRESS**
Get the full story on "The Greatest Show on Earth" - nature's dazzling display of fall color across our

eastern deciduous forests - books, videos, and now DVD.

23 L.L. BEAN
Setting the standard for quality outdoor gear and apparel since 1912.

24 LINDBLAD EXPEDITIONS
Expedition travel by the family that pioneered expedition travel.

25 LITTLE ST. SIMONS ISLAND
Exclusive 10,000 acre Georgia island paradise, private 7-mi. pristine beach, natural history tours, birding and recreational activities galore, gourmet regional cuisine and gracious accommodations await just 30 guests.

26 MILA TOURS TO LATIN AMERICA
Deluxe private tours: Machu Picchu, Lake Titicaca, Nazca Lines Amazon Jungle, Colca Canyon! Extensions: Galapagos & Easter Islands. Info sent via email only. Please include your email address.

27 MONTGOMERY COUNTY, MD
Experience transportation history along the C & O Canal and the National Capital Trolley Museum. So many things to do with easy access to the nation's capital.

28 NEW BRUNSWICK, CANADA
Leave your footprints on the ocean floor, next door in New Brunswick, Canada! Send for your free information today.

29 NEW YORK STATE
A New York State vacation is everything you want it to be . . . and more! Call for a FREE travel guide.

30 NORTH CAROLINA OUTER BANKS
Pristine Beaches. Fishing. History. For FREE Travel Guide & Getaway Card good for seasonal values.

31 NORWAY
Norway is nature at its most spectacular. A land of cosmopolitan cities, charming towns, ancient Viking ships and breathtaking coastal voyages.

32 NOVA SCOTIA
Yes, please send me my FREE 400 page Nova Scotia Doer's & Dreamer's Travel Guide - packed with everything I need to plan and book my vacation.

33 ORIENT LINES
Explore Scandinavia and Russia. Cruise to the Mediterranean's most glamorous playgrounds. Enjoy luxury at sea, aboard the elegant mid-sized ships sophisticated travelers prefer.

34 PACIFIC DELIGHT TOURS
Discover China and the majestic Yangtze River on a deluxe escorted vacation featuring the ships of Victoria Cruises.

35 PETER DEILMANN CRUISES
Enchanting 7 to 11-night luxury cruises on Europe's most majestic rivers. Magnificent scenery. Pre-Post cruise stays. All-inclusive tours also available.

36 POCONO MOUNTAINS
Free Official Vacation Guide. Info on natural areas, state parks, places to stay, attractions and events. Enjoy bird watching, river trips, hiking and more.

37 PRINCE GEORGE'S COUNTY, MD
Wonderful museums and historic sites, the National Wildlife Sanctuary, affordable accommodations and much more. All just minutes from Washington D.C.

38 PROMPERU
Peru has it all. Fascinating history, as the land of the Incas, incredible nature with more than 1,800 species of birds and colorful traditional culture. Come to Peru.

39 QUEBEC MARITIME
Nature destination par excellence, Le Quebec maritime is a vast land whose shores are washed by the Gulf St. Lawrence and the St. Lawrence River.

40 S&S TOURS
S&S Tours specializes in Copper Canyon with other Mexico trips focusing on whale watching, butterflies and colonial history. Costa Rica and Peru.

41 ST. LAWRENCE CRUISE LINES
Canadian River Cruise Vacations. Spend 5 or 6 nights aboard a classically designed riverboat cruising the calm waters of the St. Lawrence and Ottawa rivers.

42 TALBOT COUNTY, MD
Talbot County's five beautiful rivers, 602 miles of shoreline, unique charming hamlets St. Michaels, Oxford, Tilghman Island and Historic Easton offer a timeless treasury of natural beauty and history.

43 TARA TOURS
Tara Tours specialize in travel to Central and South America since 1980. Free brochures and quotes.

44 TIAA-CREF
For over 80 years, TIAA-CREF has helped the world's sharpest minds look forward to a secure and rewarding future. Find out how TIAA-CREF can help you achieve your financial goals. Log on for ideas, advice and results.

45 TOURISM NEWFOUNDLAND & LABRADOR
Newfoundland and Labrador. We offer our visitors the natural wonders of whales, icebergs and seabirds framed by our dramatic seascape and landscape and unique culture.

46 TOYOTA
For more information on Toyota innovations and technologies that positively impact the world in which we live.

47 VISIT BRITAIN
Visit Britain in 2004. Architectural masterpieces, gardens, vibrant cities, treasure and timeless traditions await you. Also enter for your chance to win a free trip.

48 WEST VIRGINIA
Get away to relaxing surroundings, fascinating history and unforget-table adventures. Escape to Wild and Wonderful West Virginia.

49 WILDLAND ADVENTURES
Authentic worldwide cultural and natural history explorations for active and inquisitive travelers. Free travel planners.

50 WORCESTER COUNTY, MD
Maryland's only seaside county. Visit Assateague Island National Seashore. Kayak, canoe, bird watch or golf. Stay in one of our many Bed & Breakfast Inns.

51 ZEGRAHM EXPEDITIONS
Offers small-group expeditions to remote locations around the world. Expertly led and staffed, our programs provide the finest adventure travel experience imaginable.

Young Naturalist Awards 2004

A RESEARCH-BASED ESSAY CONTEST FOR STUDENTS IN GRADES 7–12 TO PROMOTE PARTICIPATION AND COMMUNICATION IN SCIENCE

Each year American Museum of Natural History scientists endeavor to gain more knowledge about genetics, the accelerating expansion of the universe, plate tectonics that shapes Earth's surface, and the biodiversity of Earth's living things. They travel across the planet to places as far away as the Falkland Islands and as close as Central Park in New York City, observing, collecting, and documenting what they find. Their observations are recorded in field journals that they refer to again and again, long after the expeditions are over.

The Young Naturalist Awards program challenges students to embark on their own scientific expeditions. For this year's contest, students were invited to choose a topic in the area of biology, Earth science, or astronomy. First, students planned an expedition that would provide original observations, or data, to help them address their questions and formulate new questions about their topic. Then they shared their questions, experiences, data, and analysis through narrative essays that included drawings, maps, and/or photographs that illustrated their research. Included here are descriptions of and excerpts from the winning essays. Full-length versions of the winning essays and information on how to enter the contest are published on the Museum's Web site (www.amnh.org/youngnaturalistawards).

The Young Naturalist Awards are made possible by a generous grant from The J.P. Morgan Chase Foundation.

R. MICKENS/AMNH

Gopher Tortoises: My Endangered Fellow Floridians, by Dawn Edwards (Altamonte Springs, Florida; Grade 7)

COURTESY DAWN EDWARDS

Curious about the burrows she saw on a trail ride, Dawn Edwards investigated the habitat of a Florida neighbor—the gopher tortoise.

"Through my travels around Florida, I have seen rapid construction and population growth. The impact of our actions on our animal neighbors must be considered. It is important to raise awareness by educating the public. In order for future generations to enjoy animals like our fellow Floridian, the gopher tortoise, we must keep them safe now. We have the technology to learn and share information if only we all work together."

A Comparison of the Bisbee and Morenci, Arizona, Copper Ore Deposits, by Amanda Duron (Tucson, Arizona; Grade 7)

Intrigued by mineral samples from her home state of Arizona, Amanda Duron explored the geology of two local copper ore deposits.

"I found that the geology of the Morenci and Bisbee areas was very similar in certain respects. Although both areas contained various rock formations within various time zones, I was able to simplify these formations and group them into: base rock, older sediments, porphyritic intrusion, younger sediments, and recent sediments. I found these five major classes in both areas. I now understand many of the natural processes that took place over millions of years."

The Growth Patterns of Aspens, by Elsie Baum (Littleton, Colorado; Grade 8)

Admiring the beauty of aspen groves led Elsie Baum to wonder whether the diameter of the trees became smaller the further they were from the grove's center. She examined several groves to find out.

"Knowing that a grove is all one organism and that it spreads using 'shoots' from its root system, I believed that it would spread outward, with


COURTESY OLIVIA GRUGAN


COURTESY LAUREN FERRIGNI

the oldest and thickest trees nearer to the center and the younger, skinnier trees closer to the perimeter. So now, when I go up into the mountains and see the aspen trees gently swaying to some unheard melody written by the wind, I will see beyond the soil to the mass of compact roots and beyond the present grove to the grove as it grows and expands into the future."

Afpectus Lunae: ***Does the Moon Rotate on Its Axis?,*** *by Olivia Grugan (Alexandria, Pennsylvania; Grade 8)*

Gazing at the night sky, Olivia Grugan wondered if the Moon, like the Earth, rotates on its axis. She made nightly observations and conducted an experiment to find out.

"I have learned much in the past few months about the Moon, from its countless myths to its countless facts. I have also learned how to use a telescope and have gotten hands-on experience with the scientific method. I have been introduced to a new field, astrophysics. And, best of all, I have an unbeatable excuse to stay up late."

Life in a Vernal Pool, *by Yan Hui Lye (Houston, Texas; Grade 9)*

When a sudden rainfall turned a patch of muddy earth into a vernal pool, Yan Hui Lye explored the characteristics of the pool and the animals that depend on it.

"I found a lot of mosquitoes flying on the surface of the pool on the first day. As the days progressed, more and more mosquito larvae were seen. Later, the larvae metamorphosed into pupae. On the eighth and ninth days, mosquitoes were again seen flying on the surface of the pool. I realized I had just witnessed the complete life cycle of the mosquito."


COURTESY ALEXANDRA HOEFT

The Mystery of a Lifeless Creek: Investigating Dissolved Oxygen and Fecal-Coliform Bacteria, *by Anna Taylor (Melrose Park, Pennsylvania; Grade 9)*

Anna Taylor has lived near the creek her whole life, yet she has never seen any animals in or near it. She investigated the health of the creek to find out why.

"I have many memories of the creek. When I was younger, my friend and I would eagerly pull on rubber boots and splash into the creek and follow it downstream. However, for all the years I have lived by it, I cannot remember a time when it contained aquatic life. All the signs of a healthy aquatic environment were and are nonexistent. I desired to find out how polluted the creek really was."

Explaining the Divergence of the Marine Iguana Subspecies on Española Island in the Galápagos Archipelago, *by Alexandra Hoeft (Burke, Virginia; Grade 10)*

When she learned she would be participating in a once-in-a-lifetime trip to the Galápagos, Alexandra Hoeft began exploring how the unique marine iguana of Española Island evolved.

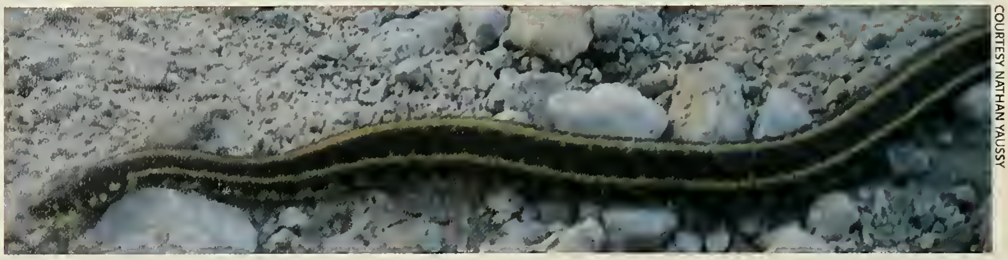
"As the gentle spray of slow waves misted my *panga* boat, I scanned the low coast of Española Island, attempting to see beyond the wall of the surf. I was looking for the red and turquoise backs of the Española race of marine iguanas. With a curtain of mist hanging over the lava-rock shore, however, the marine iguanas were impossible to spot, making my excitement mount in anticipation."

The Impact of Plant Density and Diversity on Animal Populations in a Sonoran Desert Environment, *by Lauren*

Ferrigni (Paradise Valley, Arizona; Grade 10)

Lauren Ferrigni wondered what impact the removal of dry vegetation would have on desert fauna. She conducted a study of plant and animal density and diversity to find out.

"Adjacent to my home is an acre of undisturbed desert flora and fauna. Because of the abundant wildfires that have plagued Arizona during the last two years, our neighborhood association required that all dry vegetation be removed from residential properties. The purpose of my study was to determine whether Sonoran desert flora densities and diversities would have any impact on the densities and diversities of desert fauna."


COURTESY NATHAN YAUSSY

Effects of Nitrate, Phosphate, and Hydrogen Ion Concentration on **Synedra ulna**: *Diatoms as Indicators of Water Composition, by Robyn Strumpf (Northridge, California; Grade 11)*

Robyn Strumpf investigated whether *Synedra ulna* could be used as an index to measure the effects of nitrate, phosphate, and hydrogen ion concentrations in her area's water supply.

"Though my data was inconclusive as to specific effects of changed chemical levels on the ratio of *Synedra ulna*, I found myself fulfilled after the completion of my experimentation. Perhaps someday, through persistent curiosity, questioning, and investigation, I will be able to make a noteworthy contribution to the field of science. My research has motivated me to continue working toward my goal of becoming a scientist."

Morphologic Variation in the Common Periwinkle, by Emily Tupper (Harpswell, Maine; Grade 11)

Her avid interest in marine environments led Emily Tupper on a quest to determine whether the form and size of periwinkles is affected by their shoreline location.

"With seals and orcas off the list, I became needy for a research fix. I took a walk to my little cove. I bent low and picked up a periwinkle. I hummed to it as I filled my lungs with fresh air. Then the circuit was completed. The electricity ran as excitement through my veins. I scrambled to ask my mom. After some careful rounds of negotiation, the proposed periwinkle laboratory was approved for immediate construction in my basement."

¡Que Vivan las Serpientes Muertas!, by Nathan Yaussy (Sunbury, Ohio; Grade 12)

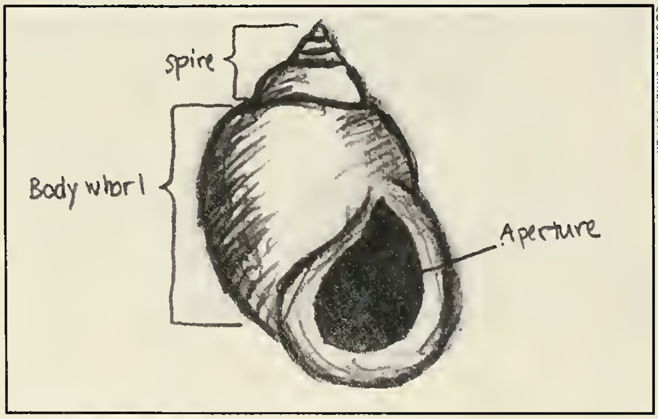
It began as a simple science fair project. Nathan Yaussy would conduct a road mortality survey of snakes in a local wildlife area to see if new locations of endangered snakes could be found. Four years later, he is still at it.

"In the first year, I had my first encounter with the eastern Massasauga rattlesnake. I was not ready for it when it came. My dad and I came upon it cautiously. When it started rattling at us, there was no mistaking what it was. We recorded the necessary data, but there was one problem: I also had to move the snakes off the road to save them from cars."

The Mysterious Peregrine Falcon, by Jessica Haines (St. John, New Brunswick, Canada; Grade 12)

While hiking along the Bay of Fundy, Jessica Haines encountered a peregrine falcon, a bird that had all but disappeared from the New Brunswick area. Was a nesting site close by? Jessica investigated to find out.

"When we reached the expected location of the nest site, we were greeted by the distinct cry of a peregrine falcon. We found an area with a nearly clear view of the cliff face. I had to balance on the edge of the cliff with one or both hands firmly grasping the branch or trunk of a tree. From this precarious position, it was possible to see that the peregrine falcons indeed had a nest."



COURTESY EMILY TUPPER


COURTESY JESSICA HAINES

Museum Events

AMERICAN MUSEUM ō NATURAL HISTORY

EXHIBITIONS

Frogs: A Chorus of Colors
Through October 3
This delightful exhibition of more than 200 live frogs from around the world explores the biology of these popular amphibians, their importance to ecosystems, and the threats they face in the world's changing environments.
With appreciation to Clyde Peeling's Reptiland.

Exploratorium/AMNH
Closed August 15–21
Fun, hands-on displays clustered around four natural science themes—Earth processes, rotation, mirrors and illusion, and pendulums—encourage audiences of all ages and all levels to investigate and play.
Exploratorium/AMNH is funded in part by a grant from the Small Business Administration. For information on accessibility, call 212-769-5100.

Seasons of Life and Land: Arctic National Wildlife Refuge
Through September 6
Stunning large-format color photographs by conservationist Subhankar Banerjee focus on the interdependence of land, water, wildlife, and humanity in Alaska's Arctic Refuge.

Art for Heart
Through September 26
Paintings by children who lost loved ones in the attacks on New York City's World Trade Center on February 26, 1993, and September 11, 2001, create a powerful and poignant memorial.
Made possible by/thanks to: Lower Manhattan Development Corporation; White & Case LLP; Toys'R'Us; 92nd Street Y; Jewish Community Center Metro West; Sid Jacobson Jewish Community Center; Family and Children's Agency, Inc.; Stamford Jewish Community Center.

Point Lobos
Through January 2005
John Daido Loori, scientist, photographer, and Zen master, explores notions of scale in the dramatic land- and seascape of Point Lobos State Reserve in California with these striking abstract photographs.
This exhibition is made possible by the generosity of the Arthur Ross Foundation.

Vital Variety: A Visual Celebration of Invertebrate Biodiversity
Through Spring 2005
Invertebrates, which constitute more than 80 percent of Earth's known species and play a critical role in the survival of humankind, are the subject of these beautiful close-up photographs.

GLOBAL WEEKENDS

Indigenous Peoples Day
Sunday, 8/8, 1:00–5:30 p.m.
Films, discussions, and performances celebrate the indigenous peoples of Australia, New Zealand, the Philippines, and other Pacific islands.

FAMILY AND CHILDREN'S PROGRAMS

Signed Tour of *Exploratorium/AMNH*
Saturday, 7/17, 1:45–2:45 p.m.

Signed Tour of *Frogs: A Chorus of Colors*
Saturday, 8/21, 1:45–2:45 p.m.

Dr. Nebula's Laboratory: Wind and Water
Saturday, 8/7, 1:00–2:00 or 3:00–4:00 p.m.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

***Virtual Universe:* Structure of the Milky Way**
Tuesday, 7/6, 6:30–7:30 p.m.
Clustering in the Universe
Tuesday, 8/3, 6:30–7:30 p.m.

This Just In. . .
July's Hot Topics
Tuesday, 7/20, 6:30–7:30 p.m.
August's Hot Topics
Tuesday, 8/17, 6:30–7:30 p.m.

Celestial Highlights:
August Is Meteor Month
Tuesday, 7/27, 6:30–7:30 p.m.
The Triangle and the Square
Tuesday, 8/31, 6:30–7:30 p.m.

PLANETARIUM SHOWS

SonicVision
Fridays and Saturdays, 7:30, 8:30, and 9:30 p.m.
Hypnotic visuals and rhythms take viewers on an unforgettable ride through fantastical dreamspace.
SonicVision is made possible by generous sponsorship and technology support from Sun Microsystems, Inc.

The Search for Life: Are We Alone?
Narrated by Harrison Ford
Made possible through the generous support of Swiss Re.

Passport to the Universe
Narrated by Tom Hanks

LARGE-FORMAT FILMS

LeFrak Theater
Lewis & Clark: Great Journey West
Opens July 17

Volcanoes of the Deep Sea
Through July 16

Bugs! A Rainforest Adventure

STARRY NIGHTS *Live Jazz*

Norman Hedman's Tropique

Friday, 7/2
5:30 and 7:00 p.m.
Rose Center for Earth and Space

Geri Allen Trio

Friday, 8/6
5:30 and 7:00 p.m.
Rose Center for Earth and Space

Tune in to the 5:30 set live on WBGO Jazz 88.

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

INFORMATION

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

TICKETS AND REGISTRATION

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

All programs are subject to change.

By Joe Rao

Mercury is tough to see in July. The period from the 6th until the 22nd offers observers the best chance to see the planet; binoculars make it much easier. On those evenings the planet shines above the west-northwestern horizon and sets about seventy-five minutes after the Sun. At the same time, though, it fades by half, from magnitude −0.6 to 0.2. Mercury passes just 0.2 degrees north of Mars on the evening of the 10th and glows more than six times brighter than the Red Planet, which is likely to be visible only through binoculars, if at all. On the 26th Mercury reaches its greatest apparent angular distance from the Sun for the year, 27 degrees to the east of our star. Nevertheless, for northern observers the elongation is unfavorable, because Mercury is well to the south of the Sun and not far above the horizon at sunset.

Throughout August, Mercury is approaching inferior conjunction: it passes between our planet and the Sun on August 26. Hence the planet cannot be seen all month.

Venus, the brightest of all planets, is quite spectacular as July begins: it rises in the east-northeast just as dawn breaks. It is still rather low in the east-northeast when it fades away in the growing light of day. As the month progresses, it rapidly leaps upward into high dawn brilliance. By the 14th Venus is rising in total darkness while shining at its greatest brilliancy (magnitude −4.5). A telescope shows it as a thick crescent. Venus shines so radiantly that in clear air it remains easily visible to the naked eye even after sunrise, if you carefully note where to look before dawn.

During August, Venus rises one and a half to two hours before the start of morning twilight, mounting a little higher in the eastern sky with each passing day. Those watching for Perseid meteors [*see below*] can enjoy the sight of Venus and the nearby crescent Moon on the mornings of the 11th and 12th. Venus reaches greatest western elongation from the Sun, 46 degrees, on the 17th.

Mars shines in stark contrast to its appearance last summer, when everybody was watching it as it made its historically close approach to Earth. This summer the Red Planet is pretty much on hiatus. Although still an evening object, it's much too close to the Sun to be readily visible. Nevertheless, you might look for it on the evening of July 10, when it passes within less than half a full Moon's diameter of Mercury.

Jupiter is the brightest of the evening planets in early July. Anyone with a clear view to the west can't miss it in the fading twilight. But Jupiter is heading down toward the horizon, finishing a yearlong apparition that peaked late last winter. By the end of July the planet is wrapped in the haze of the western horizon while evening twilight is still bright. Jupiter stands well to the lower right of the crescent Moon on the evening of the 21st.

In August, Jupiter continues its fast departure into the west after sundown. As the planet fades, you may need binoculars to pick it out of the bright twilight glare; in the end, though, the glare wins out. The planet is invisible throughout the final week of the month.

As July begins, Saturn, too, is lost in solar glare, and it reaches conjunction with the Sun on the 8th. It re-emerges above the east-northeastern horizon about one and a half hours before sunrise by the end of the month.

During August, Saturn becomes easier to see. By midmonth it rises in the constellation Gemini, the twins, about two and a half hours before the Sun, so the planet is well above the eastern horizon as dawn breaks. On the morning of the 13th it seems to hover about five degrees to the right of a crescent Moon.

In July the Moon waxes full on the 2nd at 7:09 A.M. It wanes to last quarter on the 9th at 3:34 A.M. and becomes new on the 17th at 7:24 A.M. It waxes to first quarter on the 24th at 11:37 P.M., and becomes full for a second time in July on the 31st at 2:05 P.M. The second full Moon in a calendar month is sometimes called a blue Moon—as in "once in . . . ."

In August the Moon wanes to last quarter on the 7th at 6:01 P.M. and becomes new on the 15th at 8:24 P.M. It waxes to first quarter on the 23rd at 6:12 A.M. Our satellite waxes full on the 29th at 9:22 P.M.

The most famous of all meteor showers, the Perseid meteor shower, is expected to peak on the night of August 11–12. It never fails to provide an impressive display and, because of its summertime appearance, most meteors seen by those who are not astronomy buffs are Perseids. The Perseids are fast and bright and often leave persistent trails. Unfortunately for people who go to bed early, the best views are from midnight until the first light of dawn. If the skies are clear, find a place free of bright lights and tall obstructions, look overhead and toward the northeast, and you could see as many as fifty to a hundred shooting stars an hour.

The meteors are known as Perseids because they appear to shoot outward from the constellation Perseus. The Finnish astronomer Esko Lyytinen suggests that a short-lived burst—lasting perhaps forty minutes—of high Perseid activity might take place on August 11 at 4:50 P.M., as the Earth passes very close to a trail of dust that was shed by Comet Swift-Tuttle—the source of the Perseids—in 1862. If anything unusual takes place, observers from eastern Europe to western China are in the best position to see it.

The Earth reaches aphelion, its farthest point from the Sun, on July 5 at 7 A.M. Our star is 94,507,582 miles away.

All exact times are expressed as eastern daylight time.

A

Birds of a Feather . . .

B

Right: they flock together. No question, animals live in groups, and people have been naming the groups for nearly as long as they've been naming the animals themselves: *herd* of elephants, *pack* of dogs, *school* of fish.

That suggests a word-matching puzzle. But forget *herd, pack,* or *school*—no challenge there. We've assembled some names below for groups of animals that, unless you've been training for crossword tournaments recently, will seem decidedly odd. Yet most of them can claim an ancient pedigree, having captured the fancy of list makers as far back as the fifteenth century. Other names have a basis in the animals' behavior.

So here's a twist on the usual matching game: instead of pairing a collective noun with an animals' name, match the group name to the photograph of the animals to which the name corresponds.

Answers are on page 61.

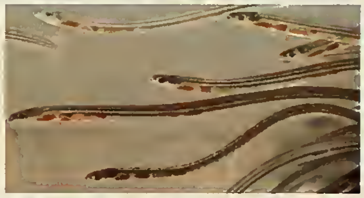
Swarm ____
Crash ____
Kindle ____
Knot ____
Unkindness ____
Parliament ____
Army ____
Convocation ____
Smack ____
Singular ____
Pod ____
Romp ____
Gaggle ____
Pride ____

C

D

E

F



G

H

I

J

K

L

M

N