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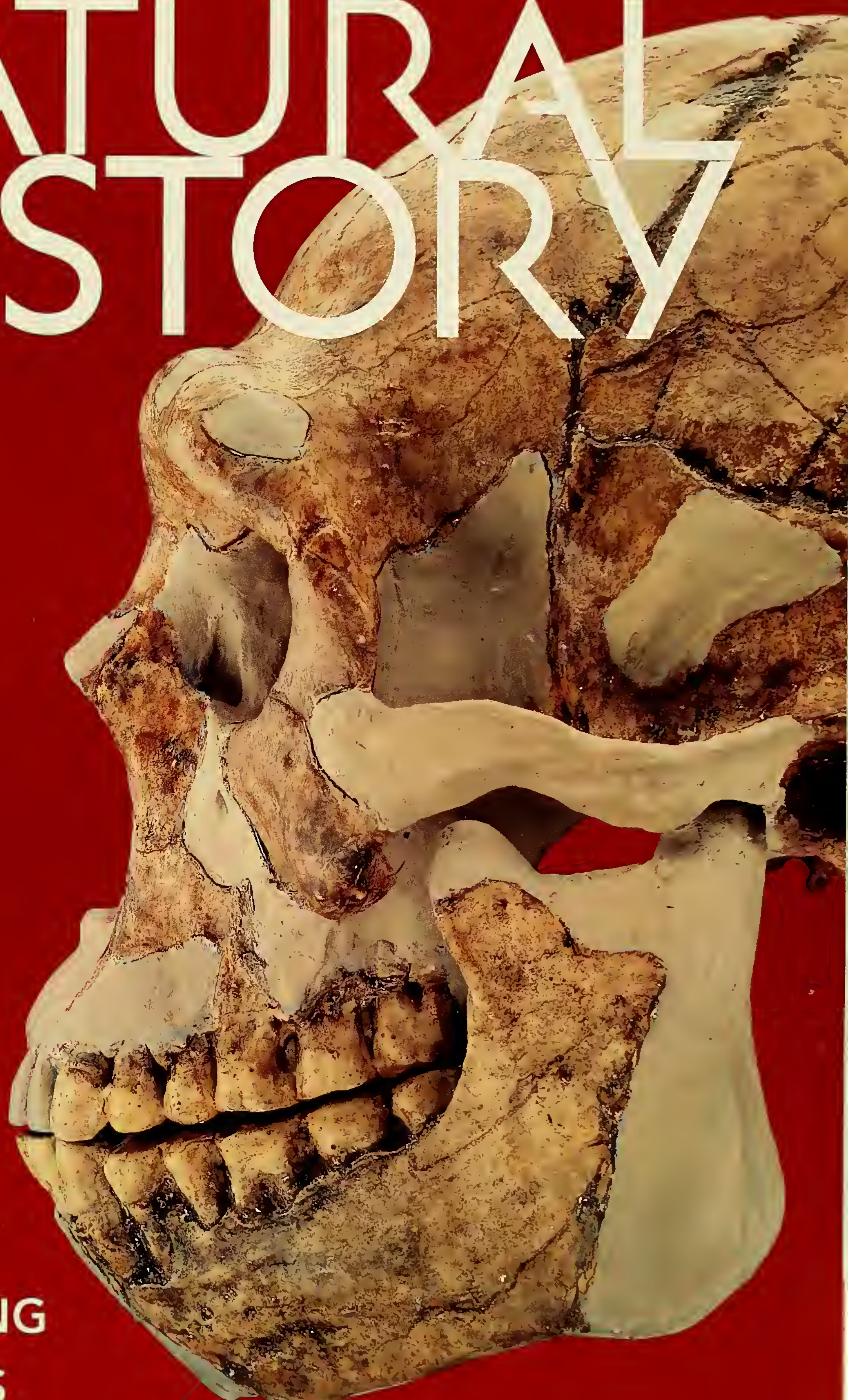

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NATURAL HISTORY

FEBRUARY 2004 VOLUME 113 NUMBER 1

FEATURES

COVER: *Homo erectus,* skull of Peking man reconstructed by G. J. Sawyer and Ian Tattersall
Photograph by David L. Brill

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NATURAL HISTORY

DEPARTMENTS

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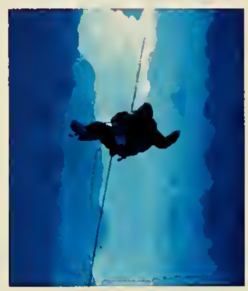

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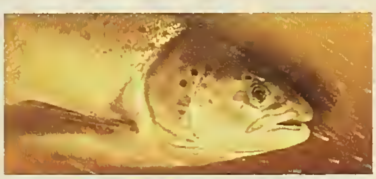

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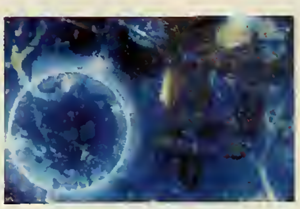

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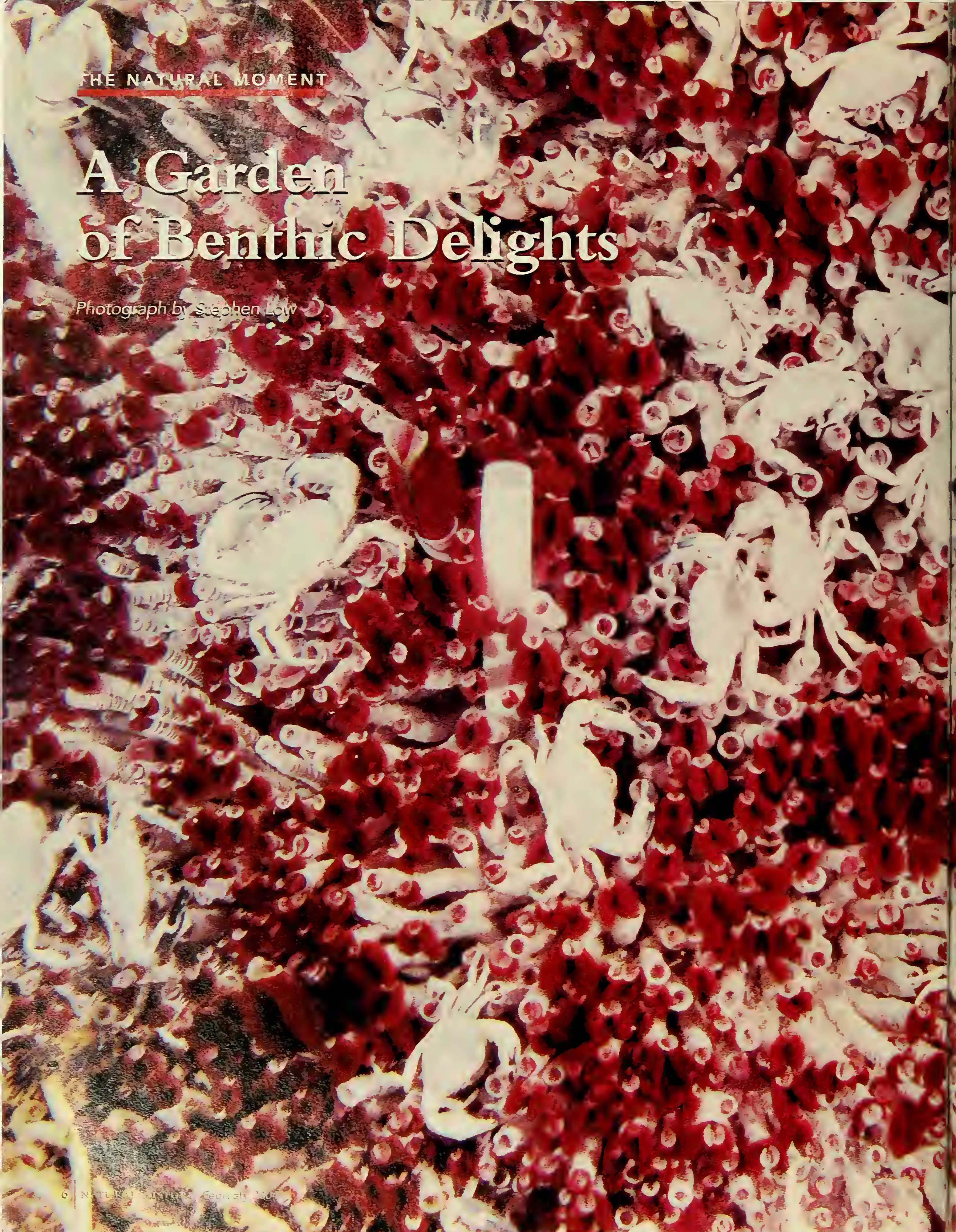
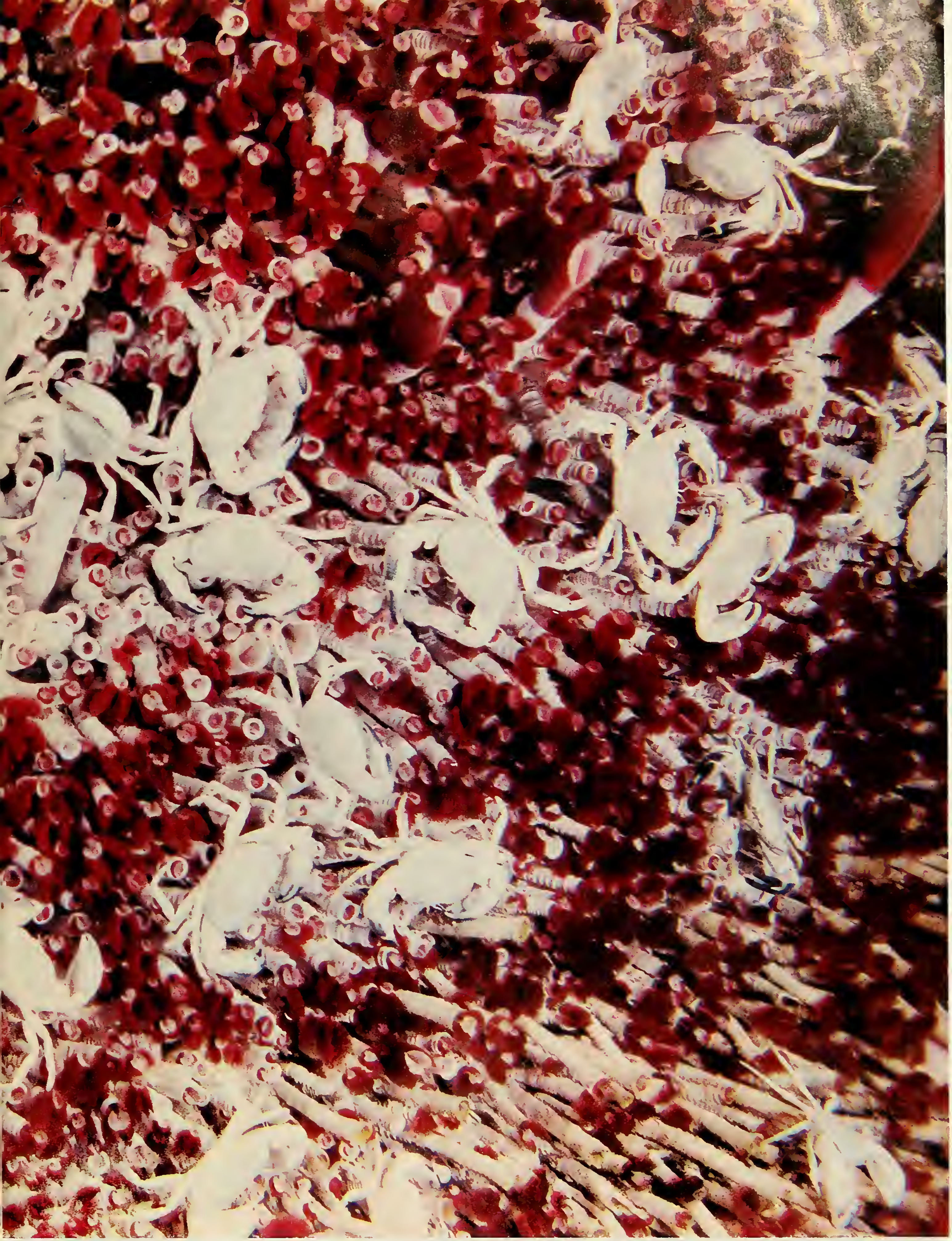
A Garden of Benthic Delights

Photograph by Stephen Low





THE NATURAL MOMENT

◄ *See preceding pages*

An underwater rumble strip of volcanic vents, continually repaved with fresh magma, winds around the Earth for some 40,000 miles, creating a rough roadway along the boundaries of the planet-wide system of oceanic plates. Among the vents, collectively known as the mid-ocean ridge, move strange assortments of benthic wayfarers. Two of them, the vent crab *(Bythograea thermydron)* and the giant tubeworm *(Riftia pachyptila),* are pictured here on the Pacific Ocean floor. Larvae of both the crab and the tubeworm can hitch rides—not entirely passively, some marine biologists say—on currents while traveling between hot spots.

For film director Stephen Low and his colleagues, visiting such a hot spot a hundred-plus miles off the coast of Mexico took more than hitching a ride. After a two-hour descent in a two-man submarine, with a pilot whose priority was to keep the sub from getting cooked, Low assembled his camera and turned on 4,400 watts of exterior lighting. Apparently the deep-sea creatures didn't bat an eye—even the ones that had eyes.

At the nutrient base of this hardy ecosystem live chemical-converting bacteria—some of which the giant tubeworms have adopted. Hydrogen sulfide diffuses across the tubeworms' crimson "lips" and is conveyed by hemoglobin in the worms' blood to the resident microbial colonies. For their part, the symbiotic bacteria—whose genome is just now being sequenced—churn out carbohydrates that keep the worms puckering up for more. —*Erin Espelie*

UP FRONT

Nasty, Brutish, and Short

Those who dig into the human past are finding hard knocks and dirty little secrets that give new substance to Thomas Hobbes's famous description of life (quoted in my title, from *Leviathan*). Fossils of Java man and Peking man (a.k.a. *Homo erectus*) suggest these close evolutionary relatives were frequent victims of physical violence (see "Headstrong Hominids," by Noel T. Boaz and Russell L. Ciochon, page 28). Some of the thick skulls and beetle brows of *H. erectus* show signs of head trauma that would have crushed the skull of any modern person. To Boaz and Ciochon, those skulls portray a group of protohumans whose survival depended on withstanding terrible blows to the head—lovingly delivered, in all probability, by their fellows. To these hulks, a punch landed in a barroom brawl would have seemed like a pat on the head.

The human genome, too, points to hard times in our past. Our own DNA is interspersed with bits of DNA from ancient viruses, suggesting that long ago our forebears were attacked by viruses that inserted their own genetic material into our genome. Such attackers, known as retroviruses, are still very much with us; the most infamous example is HIV, the virus that causes AIDS. T.V. Rajan, who recounts this human-virus history in "Fighting HIV with HIV" (page 38), takes heart from the finding. Our ancient viral DNA may once have been lethal, but its benign presence today in healthy human beings might well be a tactical clue to the eventual defeat of AIDS.

Hobbes's aphorism is just part of a longer string of qualities that the great seventeenth-century pessimist attributed to "the life of man": "solitary, poor, nasty, brutish, and short." What, then, can modern research say about the history of the solitary, poor man who must contend with group dynamics? In "Field Notes: The Wild Man of Samoa" (page 22), Joseph Kennedy offers the case history of a man who lived for nearly forty years on the fringes of an island community. The man turned out to be harmless, but as long as he remained in the bush, he was feared as a mysterious, near-mythic figure of untamed nature, and vilified for nearly every petty crime that befell the community.

• • •

Life is tough, but it needn't be altogether Hobbesian. As Jeffrey D. Sachs points out in his review ("Why Must the Poor Be Sick?" page 54) of Paul Farmer's latest book, Farmer's work has convincingly demonstrated that even the poorest people can have access to decent, affordable medical care. And that demonstration has a momentous implication: rich countries can no longer hide behind the specious assertion that poverty itself must be eliminated before the diseases of the poor can be cured.

• • •

Retroreaders who begin with the last page of the magazine are in for a treat this month. Our art director, Elizabeth Meryman, has assembled a Valentine's Day portrait of animal couples. She calls it "Will You Be Mine?" (page 72). —PETER BROWN

CONTRIBUTORS

An accomplished diver who has visited dozens of wrecks, IMAX filmmaker **Stephen Low** ("The Natural Moment," page 6) has directed the superlarge-format movies in the air *(Skyward)*, on land *(Super Speedway)*, and under the sea *(Titanica* and his most recent IMAX film, *Volcanoes of the Deep Sea)*. Low captured tube worms and scavenging crabs on film recently while on location for *Volcanoes*.

Noel T. Boaz (left) and **Russell L. Ciochon** ("Headstrong Hominids," page 28) met thirty years ago, when they were both graduate students in paleoanthropology at the University of California, Berkeley. Their interests in *Homo erectus* fossils from the Chinese site of Longgushan have brought them back together. Their new book, *Dragon Bone Hill: An Ice-Age Saga of* Homo erectus, is being published this month by Oxford University Press. Boaz is a professor of anatomy at the Ross University School of Medicine, on Dominica. Ciochon is a professor of anthropology at the University of Iowa in Iowa City.

Director of the nonprofit Coastal Plains Institute in Tallahassee, Florida, since 1984, **D. Bruce Means** ("Blossoms of Ice," page 36) began his career as a research biologist at the Tall Timbers Research Station, near Tallahassee. Means has appeared in a number of television documentaries, including the *National Geographic* series *Snake Wranglers*.

After medical training at the All India Institute of Medical Sciences in New Delhi, **T.V. Rajan** ("Fighting HIV with HIV," page 38) came to the United States in 1969. He is now a professor of pathology at the University of Connecticut Health Center in Farmington. Rajan's major current research interests are in tropical medicine.

For **Bryan D. Neff** ("Something Fishy in the Nest," page 46), the study of evolutionary development in a freshwater fish species was a natural segue from a childhood interest in aquarium fishes. Summers spent at a cottage on a lake led to snorkeling and diving around Ontario's Lake Opinicon, where he continues to document the lives of bluegill sunfish. Neff is an assistant professor of biology at the University of Western Ontario in London.

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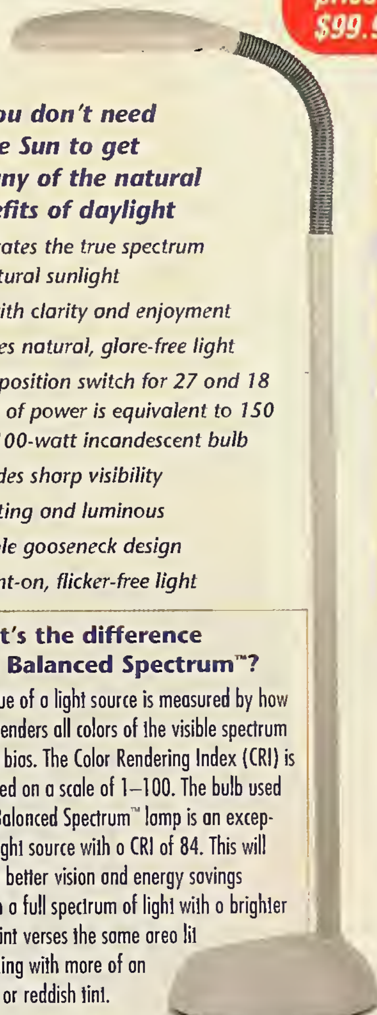

Ever since the first human went into a dark cave and built a fire, people have realized the importance of proper indoor lighting. Unfortunately, since Edison invented the light bulb, lighting technology has remained relatively prehistoric. Modern light fixtures do little to combat many symptoms of improper lighting, such as eyestrain, dryness or burning. As more and more of us spend longer hours in front of a computer monitor, the results are compounded. And the effects of indoor lighting are not necessarily limited to physical well being. Many people believe that the quantity and quality of light can play a part in one's mood and work performance. Now, there's a better way to bring the positive benefits of natural sunlight indoors.

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As a commercial photographer, I probably give more attention to lighting than most people and therefore was impressed with the smooth, soft daylight quality of your lamp.

Dennis M.
Richmond, VA

I sit in my comfortable chair after my husband has gone to bed, and I turn that lamp on. It makes it so nice because it's like daylight over my chair...I don't get sore eyes like I used to.

Grace A.
Margate, FL

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Talking Trash

The picture of the dead albatross in Charles Moore's article ["Trashed," 11/03] has affected me beyond description. If there ever was a need to do something about our wasteful lifestyles, now is the time. We have given lip service to recycling, but it is time that we did something to cut down and eliminate packaging and excess wrapping of products so that we can leave a planet to our children and grandchildren where they can live in harmony with nature.

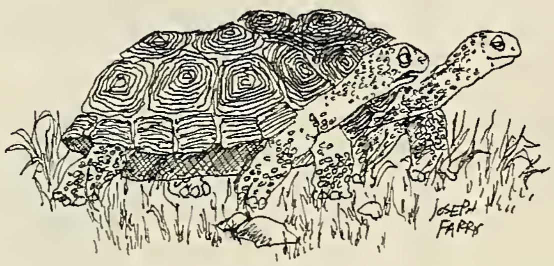
Susan A. Schiller
Denver, Colorado

The swill of bottle caps, baby toys, and countless plastic objects Charles Moore found throughout the eastern North Pacific gyre is both an aesthetic blight and a biological menace. Nearly half the world's marine mammal and seabird species and all of its sea turtles are known to either eat plastic debris or become entangled in it.

But gyres are not the only places where debris accumulates. Thousands, perhaps tens of thousands of nets and net scraps discarded or lost by North Pacific fishermen end up snagged on reefs in the northwestern Hawaiian Islands. There they abrade coral and entangle endangered monk seals and sea turtles. The National Marine Fisheries Service has organized annual cleanups and removed more than a hundred tons of netting from those reefs since 1996. Unfortunately, such efforts are all too rare, because the attitude toward marine debris is "out of sight, out of mind."

Mr. Moore and *Natural History* do a great service by spotlighting this issue, for only with broader awareness can the will and resources be found to address it.

David W. Laist
Marine Mammal Commission
Bethesda, Maryland



"Life is too long not to worry."

A Better Mouse Trap?

I was astounded to read in "Desert Dreams" [11/03] that the author, Michael A. Mares, used kill traps to find rare and elusive salt-pan mammals. He would do well to add his name to the list of reasons that these mammals may soon become extinct.

Cynthia Fleischer
Sonoma, California

Those of us searching for rare and elusive mammals in Africa in order to save them from extinction are facing the same problems Michael Mares describes. In 1890 locals in Togo brought two mice to one H. Buettner, a German colonial officer at Bismarkburg. Buettner sent the two mice, preserved in rum, to Berlin, where a specialist in African mammals, W. Peters, described them as a unique new genus and species—the Togo mouse *(Leimacomys buettneri).*

Since that time numerous teams have searched western Togo for more than a century for further examples of the mouse, but to no avail. Apparently, like the elusive African dormouse *(Graphiurus)* and the African fat mouse *(Steatomys),* the Togo mouse is trap shy, refusing to enter live traps, kill traps, or any other collecting equipment. So no one knows whether the Togo mouse is extinct or simply waiting for a Michael Mares to appear on the scene. When he or she does, I only hope an account of the search as interesting and entertaining as Mr. Mares's appears in your magazine.

Duane A. Schlitter
Texas A&M University
College Station, Texas

MICHAEL A. MARES REPLIES: Small mammals are hard to collect and even harder to identify without establishing voucher specimens that can be studied and compared with other specimens in a museum. Cynthia Fleischer raises a common concern, but species do not go extinct because of scientific collecting. They go extinct because of habitat destruction, uncontrolled hunting, and other massive assaults on their populations. By discovering that a new species exists, by defining its habitat, and by gauging its environmental threats, ecologists can develop better methods for its protection and conservation.

Duane A. Schlitter's letter underscores the fact that rare mammals are scattered throughout the world, many on the brink of extinction. Scientific collectors are often the last, best hope for a species' preservation. The scientific basis for collecting animals is detailed in my book *A Desert Calling: Life in a Forbidding Landscape,* and I would recommend the pertinent sections of the book to anyone concerned about the possible negative effects of these procedures. Alas, though, if such objections are made on moral grounds, scientific arguments will prove fruitless.

Nursing Wounds

As Terrie M. Williams reports in her article "Sunbathing Seals of Antarctica" [10/03], Antarctic seals apparently appreciate the causal connection between warmth and healing. That same connection has taken centuries to be applied systematically to the clinical care of human wounds, but recent studies are documenting how warming modifies tissue responses needed for healing. The benefits include increased blood and oxygen flow to the wound, improvement in local immune responses to control bacteria, increased proliferation of the cells necessary for healing, and the reduction of enzymes and other factors that inhibit repair in chronic wounds. Other principles of wound treatment include cleansing with a solution that does not harm cells (in most cases, normal saline solution) and the use of moist dressings. So the seals also benefit from their saline environment.

JoAnne D. Whitney
School of Nursing, University of Washington
Seattle, Washington

TERRIE M. WILLIAMS REPLIES: JoAnne D. Whitney is quite right that flushing with seawater is critical for wound healing in marine mammals. Indeed, as marine mammal veterinarians are well aware, the wounds most prone to infection are punctures that heal from the outside in. For that reason, veterinarians often leave small skin wounds open rather than suturing them closed and risking infection. In Antarctica, cold-induced vasoconstriction also makes healing inordinately slow—a fact that was not lost on those of us in the research team, as we nursed our own small nicks and cuts for months.

Ties That Bind

In his "Biomechanics" column on the mutable collagenous tissue (MCT) of sea cucumbers and other echinoderms ["Catch and Release," 11/03], Adam Summers remarks that the molecules thought to be responsible for rapidly changing the mechanical properties of MCT "have not been well characterized." But that is only partly true. Jennifer P. Tipper and colleagues recently published the peptide sequence of a stiffening factor called tensilin, obtained from sea cucumber dermis (*Matrix Biology* 21:625–35, 2002). This protein resembles the molecules in a group known as tissue inhibitors of metalloproteinases, or TIMPs. Metalloproteinases are enzymes that break down connective tissue, and TIMPs play an important role in counteracting their activities.

It is fascinating that a TIMP-like molecule should act as a stiffener in echinoderm MCT. In mammals, too, a TIMP known as TIMP-3 binds strongly to connective tissue components. The properties of tensilin suggest that the mechanism underpinning the mutability of echinoderms evolved from a biochemical system whose original role was to degrade connective tissue. It is also noteworthy that MCT may not be unique to echinoderms. My research collaborators and I have found that the stiffness of the connective tissue in a marine sponge may also be under physiological control.

Iain C. Wilkie
Glasgow Caledonian University
Glasgow, Scotland

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

Cramped Quarters

Anyone who visits a zoo has witnessed the sad sight of animals pacing back and forth. According to Ros E. Clubb and Georgia J. Mason, animal behaviorists at the University of Oxford, this effect is linked to an animal's propensity to roam widely in the wild.

Polar bears: unhappy captives

Clubb and Mason compared thirty-five species of carnivorous mammals and discovered that the larger an animal's home range in nature (think tigers and polar bears), the more pacing the species does in the zoo—and the more likely the young are to die soon after birth in captivity.

Tell that to the guy in New York City who claimed that the 425-pound tiger he kept in his apartment until last October was content with its quarters. ("Captivity effects on wide-ranging carnivores," *Nature* 425:473–74, October 2, 2003)—*Stéphan Reebs*

Deep Down Under

Hydrologists have recently discovered that immense reservoirs of nitrogen have been accumulating for millennia beneath the western deserts of the United States. Michelle A. Walvoord of the U.S. Geological Survey in Lakewood, Colorado, and her colleagues now estimate that as much as 16 percent more nitrogen lurks in subsoil reservoirs worldwide than had previously been thought. It occurs as nitrate (NO_3^-), the same stuff that's used in making fertilizers and in curing ham and bacon. During infrequent heavy rains it has been washed out of the sparsely vegetated soil and has become increasingly concentrated as the rainwater evaporates or is drawn up into the roots of plants.

Walvoord and her colleagues warn that several scenarios—irrigation, the more frequent heavy rains that climate change may bring, and the construction of reservoirs—could push the nitrate ever deeper into the earth, where it would eventually contaminate groundwater. ("A reservoir of nitrate beneath desert soils," *Science* 302:1021–24, November 7, 2003)

—*Avis Lang*

Death by Gluttony

Next time you spot a mosquito flying away engorged with blood from your arm, cheer up: she may soon pay the ultimate price for her ill-gotten gains. New research by Bernard D. Roitberg, a behavioral ecologist, and his colleagues at Simon Fraser University in Burnaby, British Columbia, shows that satiated skeeters, which had tripled their initial weight, flew at only two-thirds the speed of their unfed sisters. That made them easy targets for hungry predators or angry people. ("Pouncing spider, flying mosquito: Blood acquisition increases predation risk in mosquitoes," *Behavioral Ecology* 14:736–40, September/October 2003)

—*S.R.*

Save a Wolf, Save a Tree

Something is amiss in the cottonwood groves of Yellowstone National Park. Seedlings grow in abundance on the riverbanks, along with a fair number of old trees. But young trees are nowhere in sight. Robert L. Beschta, a forester at Oregon State University in Corvallis, decided to investigate what's been killing off the seedlings.

By comparing the trunk diameters of the park's old cottonwoods with the diameters and visible growth rings of cores extracted a decade ago from other cottonwoods in the area, Beschta found that none of the large cottonwoods in Yellowstone's Lamar Valley were younger than age sixty. But what could have happened back then that could explain why young cottonwoods stopped maturing? Well, in the mid-1920s wolves were eliminated from Yellowstone, as they were across much of the West.

In the following years, Beschta points out, elk started venturing into the once-dangerous habitats where cottonwood seedlings grew, and the animals began to devour the seedlings—that is, until wolves were reintroduced in the park in 1995. Now that the balance among carnivores, herbivores, and plants has been restored, aging cottonwood communities should finally be getting some young recruits. ("Cottonwoods, elk, and wolves in the Lamar Valley of Yellowstone National Park," *Ecological Applications* 13:1295–1309, October 2003)

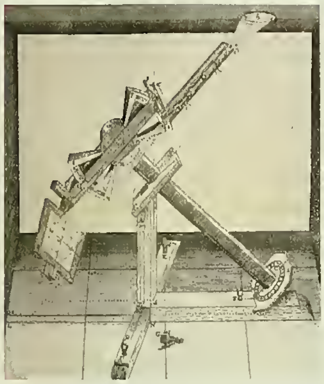
—*S.R.*

Stand of mature cottonwoods in northeastern Yellowstone

The Sunspot Chronicles

All those splendid auroras streaking across the sky at mid to high latitudes lately signal that the Sun has been magnetically hyperactive, breaking out in a bad case of sunspots [see "Our Stormy Sun," by Charles Liu, page 64]. But how often does the Sun's magnetism get in an uproar?

Now Ilya G. Usoskin, a geophysicist at the University of Oulu in Finland, and colleagues from the Max Planck Institute for Aeronomy in Katlenburg-Lindau, Germany, have discovered that the past sixty years have been the Sun's most magnetically active period in more than a millennium. Almost as intriguing as the discovery itself is the method that led to it: constructing a sunspot record by examining the amounts of a radioactive isotope of beryllium measured in ice cores from Greenland and Antarctica. The isotope, beryllium-10 (Be-10), is produced when cosmic rays—predominantly



Christoph Scheiner's "helioscopium" (sunspot viewer), 17th century

protons—collide with nitrogen and oxygen nuclei in the Earth's atmosphere. When the Sun is magnetically active, the "wind" of charged particles emanating from it (and dragging along its magnetic field) increases, deflecting cosmic rays and so cutting down on the production of Be-10. The concentration of Be-10 at a given, independently dated level in an ice core reflects the intensity of magnetic activity in the Sun.

Before the team's analysis, the only reliable records of solar magnetic activity were direct counts of sunspots, and those weren't made until 1610, soon after the invention of the telescope. The Be-10 data extend the "fossil record" of the Sun's past activities back to A.D. 850, enabling solar physicists to draw more reliable conclusions about long-term solar cycles. ("Millennium-scale sunspot number reconstruction: Evidence for an unusually active Sun since the 1940s," *Physical Review Letters* 91:1–4, November 21, 2003) —*Joomi Kim*

Frog Find

Nasikabatrachus sahyadrensis is one weird-looking frog. Known from a single female collected in 2000 near a cardamom plantation in India, the species has a round body nearly three inches long, unusually short limbs, very small eyes, and a small head ending in a pointed snout. S.D. Biju of the Tropical Botanic Garden and Research Institute in Trivandrum, India, and Franky Bossuyt of Vrije University in Brussels, Belgium, have examined the specimen

Yes, it's a frog!

inside and out, and analyzed its DNA to boot. Their conclusion is that the critter represents a brand-new family (not merely a new genus or species) of frog, the first such discovery since 1926.

Its closest relatives appear to be frogs from another family that occurs on just two islands of the Seychelles. Genetically, the two amphibian groups separated 130 million years ago. But physically, they parted ways 65 million years ago, when the Seychelles broke away from the Indian subcontinent as the latter (itself a fragment of the supercontinent Gondwana) migrated northward toward Asia. ("New frog family from India reveals an ancient biogeographical link with the Seychelles," *Nature* 425: 711–14, October 16, 2003) —*S.R.*

Watered-Down Fish

Aquaculture has brought down the price of salmon considerably, but it's also raised concerns. An estimated 2 million farm-raised salmon escape each year in the North Atlantic alone. The worry has been that farm fish strains may have lost certain genes that enhance survival in the wild; if the farm fish mate with wild fish their progeny may turn out to be poor survivors in the wild, ultimately undermining the genetic fitness of the wild population.

Recent experimental evidence suggests such fears are justified. Philip McGinnity, an ichthyologist at the Marine Institute in Newport, Ireland, and his coworkers recorded the ancestry and then tracked the success of wild, farm, and wild-farm hybrid Atlantic salmon at multiple stages of their life history.

At every stage, the wild fish were the fittest. Wild juveniles were the most likely young to survive, and wild adults were the most likely adults to return and breed. Having even one

Wild Atlantic salmon are losing their wildness—and their future.

farm salmon as a parent or grandparent hobbled a fish's chances; having two farm ancestors reduced the chances even further. The pure farm salmon fared the worst: very few returned to lay eggs. ("Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farm salmon," *Proceedings of the Royal Society of London B* 270:2443–50, December 7, 2003) —*S.R.*

"You Gotta Have Skin"

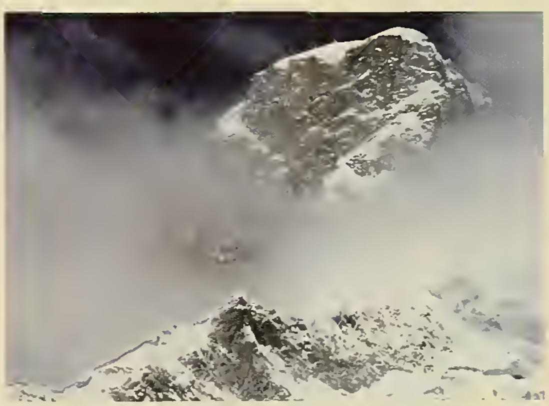
For life to develop on Earth, two components had to get together: chains of nucleic acids (RNA), and membranes that could form a protective cell boundary around the nucleic acids. There needed to be a kind of skin—"the thing that if you've got it outside," as the songwriter Allan Sherman once put it, "it helps keep your insides in." Problem was, no one had identified a situation in which both the genetic material and the would-be cell membranes were likely to form spontaneously at the same time. But now experiments by Martin M. Hanczyc, Shelly M. Fujikawa, and Jack W. Szostak, all molecular biologists at the Howard Hughes Medical Institute in Boston, suggest that the right conditions are present in simple minerals.

The three investigators found that a porous clay called montmorillonite, already known to encourage the linking of nucleic acids, also has an effect on fatty acids, the building blocks of cell membranes. When fatty acids meet up with particles of the clay, they rapidly form vesicles—bubblelike "skins"—that can encapsulate the nucleic acids. Made up of a double layer of fatty acids, the vesicles have the same kind of structure as the membranes of living cells. Moreover, when more fatty acids are slowly added to the system, the vesicles grow. They even divide by budding.

The study shows that the first cells on Earth could have arisen as a result of simple chemical processes, even in the absence of enzymes or other substances previously thought essential to early life. ("Experimental models of primitive cellular compartments: Encapsulation, growth, and division," *Science* 302:618–22, October 24, 2003)

—*S.R.*

Swift Lift



Mount Huascarán in the Peruvian Andes, 22,200 feet high

Why are the central Andes so high, and how did they get that way so quickly? Geologists Simon Lamb of the University of Oxford and Paul Davis of the University of California, Los Angeles, think they have the explanation. It's the lack of lubrication, caused by an arid climate.

About 14 million years ago, when ice sheets around Antarctica expanded drastically, the west coast of South America between ten degrees and thirty-three degrees south latitude—the belt that today comprises the most dramatic peaks and valleys—became much cooler and drier. In the relative absence of rain, the erosion of rock and soil decreased drastically. As a consequence, little sediment was washed into the mammoth trench in the Pacific seafloor where the Nazca tectonic plate has been sliding under the South American plate and pushing up the Andes.

Ordinarily, sediment acts like oil, lubricating the boundary between colliding tectonic plates. When there's little or no sediment, though, the friction between the two plates can exert a lot of force. In the central Andes that force is so strong and focused that it helps support the mountains, much as strong, deep foundations hold up a skyscraper. Lamb and Davis estimate that, had the climate not become "hyperarid," the region's mountains would be no higher than 6,500 feet. ("Cenozoic climate change as a possible cause for the rise of the Andes," *Nature* 425:792–97, October 23, 2003)

—*Caitlin E. Cox*

Cornshine

Here's a conundrum for you: The bone chemistry of Amerindian remains makes clear that maize (the vegetable most Americans call corn) became a dietary staple in the New World no earlier than 3,000 years ago in some areas and as recently as 500 years ago in others. Yet archaeological evidence indicates that people were cultivating teosinte, the ancestor of domesticated maize, more than 7,000 years ago. Back then the plant had small cobs and small, hard kernels of little nutritional value. So why grow it?

Peruvian corn deity, A.D. 200–600

John Smalley, an independent researcher, and Michael Blake, an archaeologist at the University of British Columbia in Vancouver, suggest that sugar from the stalk, not starch from the grain, was the big draw. The stalks of early maize—like those of sugarcane, its close Old World relative—probably yielded a sweet juice (a modern maize stalk contains as much as 16 percent sugar by weight). Smalley and Blake go even further: booze, they think, fermented from the sugary liquid, may have been the ultimate goal. After all, accounts dating from the time of the Spanish conquest (and thus before the introduction of sugarcane) mention maize-stalk beer. And judging by the similarity of historical names for it in otherwise distinct indigenous languages, the drink had already been popular for quite some time. ("Sweet beginnings: Stalk sugar and the domestication of maize," *Current Anthropology* 44:675–703, December 2003)

—*Graciela Flores*

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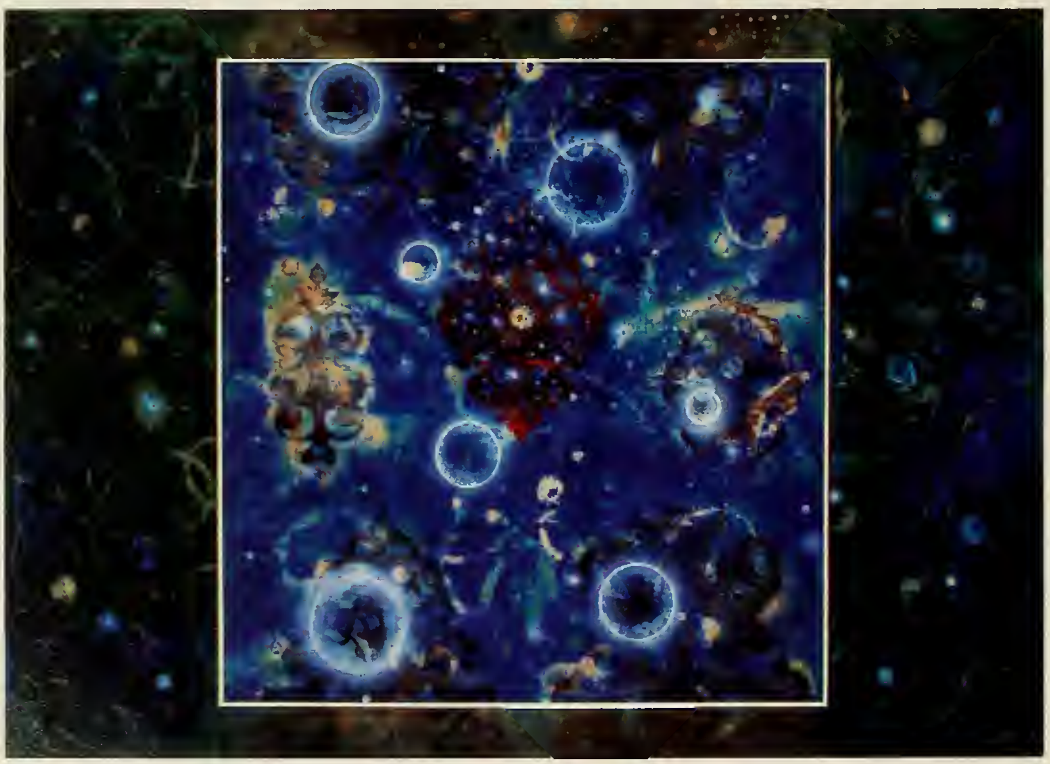
Replica of the Viking longhouse, erected beside the original site.

Great Masses from Little Ripples Grew

The organization of matter into superclusters and voids began with subatomic variations in density during the earliest moments after the big bang.

By Neil deGrasse Tyson



Gregory Gioiosa, *Conscious Field Light*, 1997

Of the many unknowns that perturb the modern cosmologist, the absence of a theory that seamlessly blends quantum mechanics and general relativity nags the most. Those two streams of thought—the study of the very small and of the very large—remain immiscible in physics, even though they readily coexist in the same physical universe. Part of the reason they can coexist is that they apply at such different scales. A galaxy of 100 billion stars can pretty much ignore the physics of the atoms and molecules that make up its star systems and gas clouds; still larger agglomerations of matter—superclusters that typically comprise many thousands of galaxies—are even more indifferent to the molecules in their midst.

Yet galaxy superclusters owe their very existence to what physicists call "quantum fluctuations"—very slight non-uniformities that generally pertain only to things as small as atoms and molecules. Quantum fluctuations first appeared in the primeval cosmos soon after the big bang, when the entire universe was still immeasurably smaller than today's atoms and molecules. Within such a volume, it's not surprising that the laws of the very small would dominate. And recent satellite observations have given cosmologists hard evidence that the quantum fluctuations of matter and energy in that early universe were just the right size to have given rise to the superclusters visible today.

Superclusters are probably the largest material structures in the universe—which makes whatever distribution they assume in space a central observational fact for cosmology to explain. For much of the twentieth century the distribution of matter in the universe was presumed to be both homogeneous (evenly sprinkled with galaxies in every location) and isotropic (appearing the same no matter which direction you look).

Homogeneity and isotropy may sound equivalent, but they're not. In a homogeneous universe, every position is similar to every other one, like the contents of a glass of homogenized milk. In an isotropic universe there is some vantage point from which the cosmos presents the same appearance in every direction.

To picture the difference, start with the way geographers mark longitude and latitude on Earth's surface. As you move away from the equator and toward the poles, the longitude lines get closer together, creating a nonhomogeneous globe. From the exact North Pole, however, where all the longitude lines converge, Santa Claus's view of the world is isotropic. Same holds for the South Pole. The grid of longitude and latitude looks the same from either the "top" or the "bottom" of the world.

Or imagine sitting atop a perfectly cone-shaped mountain, and suppose the mountain is the only topographical feature in the world. From your perch, every view would be identical to every other. The same thing holds if you happen to live at the center of an archery target, or if you're a spider sitting at the center of your web, waiting for lunch to drop in. In each case the scene is isotropic but decidedly not homogeneous. Only if space is isotropic everywhere—creating the same view for every possible observer—will it also be homogeneous. (Actually, mathematicians have demonstrated that if space is isotropic in just three places, it must be isotropic everywhere.)

It's also possible for a pattern to be homogeneous but *non*isotropic. One example is a wall of identical rectangular bricks, laid according to the bricklayer's traditional craft. On the scale of several adjoining bricks and their mortar, the wall is the same everywhere—bricks, bricks, and more bricks, all framed in mortar. Yet if you're an observer turning your head as you look at the wall, the changing sight lines will intersect the bricks and mortar at varying angles, creating a different view every time you alter the angle of your head.

The visible matter in the cosmos looks rather like the holes and fibers in a loofah sponge.

After telling you more than you ever wanted to know about homogeneity and isotropy, I hope you'll forgive me now for telling you that large-scale surveys of space have revealed a different picture than what astrophysicists originally expected. The observed universe has big empty gaps, bounded by galaxies arranged in intersecting sheets and filaments. In fact, the distribution of visible matter in the cosmos looks rather like the arrangement of holes and fibers in a loofah sponge: perfect loofahneity.

In retrospect, it seems the craving among cosmologists for a homogeneous and isotropic universe may have been mostly a matter of aesthetic preference. There were important dissenters: in the mid-twentieth century the astronomer Harlow Shapley and the obstreperous astrophysicist Fritz Zwicky presented extensive observational evidence to the contrary. Nevertheless, homogeneity and isotropy came to be jointly codified as the "cosmological principle." If you're feeling perverse, though, you could call it the "mediocrity principle," because it asserts that no part of the universe is any more interesting or eventful than any other.

On small scales of size and distance the cosmological principle clearly does not apply. Earthlings, for instance, live on a solid planet whose average density exceeds 5.5 grams per cubic centimeter. (In Americanese that's about 340 pounds per cubic foot.) But in intergalactic space, which accounts for most of the volume of the universe, there is less than one atom for every ten cubic meters. On what scale, then, if at all, could the cosmological principle apply? The region would have to be big enough to include more than one lonely example of any identifiable structural component: more than one galaxy, more than one supercluster, more than one void. If you selected such a cosmic region at random and scooped it out as a perfect sphere, like a giant melon ball, you would want its average properties to be similar in every way to the average properties of any other scoop the same size.

So how big would the scoop have to be? Earth is 0.04 light-second across. Neptune's orbit spans eight light-hours. The stars of the Milky Way delineate a broad disk about 100,000 light-years across. And the Virgo Supercluster (often called the Local Supercluster), to which the Milky Way belongs, extends some 100 million light-years. Therefore, a volume that, on average, might offer both homogeneity and isotropy would have to be bigger than the Virgo Supercluster.

It turns out that the contents of a spherical scoop 300 million light-years across—about one hundred-thousandth the volume of the visible universe—does indeed resemble other scoops the same size, thus fulfilling the hopes, dreams, and aesthetic predilections of the advocates of the cosmological principle.

Sir Isaac Newton, too, thought about this problem, three centuries ago, but he had a different set of worries. How can anything form in the universe, he wondered, without being joined by all the rest of the matter in the cosmos? What keeps their mutual gravity from creating one gigantic mass in the center of everything? Newton argued that the absence of such a mass implies the universe must be infinite. In a prescient letter he wrote in 1692 to the English theologian and classical scholar Richard Bentley, Newton reasoned as follows:

> If . . . all the matter in the universe were evenly scattered throughout all the heavens, . . . and the whole space throughout which this matter was scattered was but finite, the matter on the outside of the space would, by its gravity, tend toward all the matter on the inside, and by consequence, fall down into the middle of the whole space and there compose one great spherical mass. But if the matter was evenly disposed throughout an infinite space, it could never convene into one mass; but some of it would convene into one mass and some into another, so as to make an infinite number of great masses, scattered at great distances from one to another throughout all that infinite space.

Newton presumed that his infinite universe was static, neither expanding nor contracting. Whenever the cosmic need arose for a star or a planet, gravity would take care of the task. The modern astrophysicist, however, must grapple with the question of just how gravity could "convene" matter in numerous far-flung places at the same time as the infant universe was undergoing stupendously rapid expansion. In those early moments, if the cosmos had been strictly homogeneous and isotropic on all scales, the acceleration of gravity (the weakest force in the universe) could never have overcome the opposite urge for matter to separate as part of the expanding fabric of space. The result of a thoroughly uniform universe would have been consummately dull and boring, nothing more than endless vistas of widely scattered atoms: no galaxies, no stars, no astrophysicists.

We live in an exciting universe precisely because of the minuscule *in*homogeneities and *an*isotropies that arose during its earliest moments. They served as a kind of cosmic soup starter, a leg up for all the subsequent accumulations of matter and energy. On its own, when confronted with the expanding universe, gravity could never have gathered matter together swiftly enough to build the cosmic structures we now take for granted.

13.7 billion years ago, the fabric of the observable universe expanded faster than the speed of light.

To gain insight into cosmic inhomogeneity and anisotropy, you need to imagine traveling back in time, back some 13.7 billion years, to about 380,000 years after the big bang. That's when the cosmic background radiation formed. (The universe has expanded a thousandfold since then.) Today, having lost 99.9 percent of the energy they possessed at that time, the photons that make up the cosmic background manifest themselves as a nearly isotropic bath of microwave radiation. Hence the moniker "cosmic microwave background," or CMB. [*See "Let There Be Light," by Neil deGrasse Tyson, October 2003.*]

To cosmologists, the CMB serves as a proscenium that separates, yet connects, modern times with the first moments of the neonate universe. At

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the very beginning, 13.7 billion years ago, the fabric of the observable universe expanded faster than the speed of light, growing in one hundred-billionth of a trillionth of a trillionth of a second from a size far smaller than that of a proton to the size of a baseball or perhaps a grapefruit. That brief yet furious growth spurt was dubbed "inflation" by the physicist Alan H. Guth of the Massachusetts Institute of Technology, who proposed the idea in 1979—back when the American economy was undergoing something similar.

The inflationary universe came about because of a very early cosmic "phase transition." Such changes are not uniquely cosmological; some call for kitchen ingredients. Freeze water, and you get ice. Boil water, and you get steam. Expose glue to the air, and it hardens. Expose a pan full of wet, gooey batter to the heat of an oven, and it turns into a cake.

Inflation theory predicts that when the universe was smaller than a proton, its prevailing energy state underwent a phase transition that triggered the super-rapid expansion (liquid water expands, too, when it turns to ice, though that expansion is not quite so dramatic!). And it was at this moment, cosmologists believe, that the quantum laws governing the world of the very small left their imprints on the very largest structures in the universe.

Among the many strange but repeatedly confirmed predictions of the quantum laws is that events are forbidden from taking place at perfectly precise moments in time. In fact, the shorter the duration of an event, the more its energy (or its Einsteinian equivalent, mass-energy) fluctuates as the event unfolds. Since the inflation of the universe was an extremely short-lived event, those quantum fluctuations in the density of universal mass and energy became embedded in the ballooning fabric of space. The pattern of higher and lower densities of matter and energy went on to become the blueprint for the location and formation of galaxies.

So far, no one has figured out how to see back to the first hundred-billionth of a trillionth of a trillionth of a second. So astrophysicists do the next best thing: they look at the remnants of those early quantum fluctuations in density by looking closely at the CMB.

Until the CMB formed, photons continually scattered back and forth as they bounced off free electrons swimming in the cosmic soup. Looking at those photons would have been like looking through a dense fog with a searchlight on a dark night: you would have seen nothing but a glowing sea of light. Not until some 380,000 years after the big bang, by which time everything had cooled down to a few thousand degrees, did the fog disperse. The free electrons attached themselves to available protons and formed atoms. With the free electrons finally out of the way, the photons could move unimpeded through the universe; one by one, each freely moving photon became part of the CMB.

Each photon in the cosmic background, though, retained some clues about the time and place of its last scattering. Those photons that last scattered from relatively high concentrations of matter and energy would have been relatively warm. And those that last scattered from relatively empty regions of space would have been relatively cold. If the ideas of inflation are correct, the sea of photons should, through its patterns of warmer and cooler temperatures, "remember" where the matter and energy were just as the universal fog cleared. The temperature of the cosmic background radiation should vary slightly from one direction to another, depending on how the density of matter and energy varied from place to place when the fog first cleared. Hot spots would one day become hotbeds of galaxy formation; cold spots would one day become great, empty voids.

(Continued on page 63)

FIELD NOTES

The Wild Man of Samoa

A tale from the graveyard of strangers

By Joseph Kennedy

This past summer an e-mail message reached my office in Honolulu from a friend in Pago Pago, on Tutuila Island, American Samoa. A relentless rainstorm, he informed me, had washed out the pile of stones that marked Malua's grave. He thought I'd want to know.

The story of Malua and his unusual life had only recently come down to me. I had been conducting an archaeological survey not far from Pago Pago when I stumbled onto his grave in a neglected cemetery. Samoans traditionally inter their loved ones close to their homes, rather than in a communal area, so I knew at the outset that the overgrown gravestones I was examining marked the lonely bones of people from somewhere else, a graveyard of strangers. Buried there were sailors from the days when the U.S. Navy administered Samoa, between 1900 and 1951. There were civilian sea captains, killed far from home when their ships ran aground on the reef. There was a blacksmith from New England, a former postmaster of Pago Pago who had been a veteran of the American Civil War, a murdered merchant marine, a woman who died en route to San Francisco, and various beachcombers and adventurers. Most of the markers I saw were concrete slabs, with the occasional cut-stone monument mixed in with the lot.

Malua, the "wild man" of Tutuila Island, American Samoa, is pictured here in a 1923 photograph, shortly after his emergence from the mountains. A shadowy figure for nearly forty years, he had awakened primordial fears among the local inhabitants.

But tucked into one corner was an anonymous grave that looked quite different from all the rest. It was a simple rectangle of crudely mounded basalt rocks, a distinctive arrangement reminiscent of the way Samoans and other Polynesians marked their dead in the late nineteenth and early twentieth centuries. I wanted to know who occupied such a singular grave, and, if the person was indeed a Polynesian, why a South Sea Islander was lying among strangers.

All research involves a bit of luck, and I can hardly deny that good fortune came into play when I entered the American Samoa Archives with thoughts of the nearly impossible and emerged two hours later with a 1942 map of that very cemetery in hand. Six decades before, someone not only had taken the time to record all the grave locations and the names of the occupants but, whenever possible, had also thoughtfully added a brief narrative about the life or death of the deceased.

I took the map back to the cemetery and matched it with the mystery grave. It was plot number 5, occupied by one "Malua, Solomon Islander, the last of a boat crew that landed in Tutuila in 1884."

The Solomon Islands lie in Melanesia, some 2,000 miles west of Tutuila. How had Malua and his fellow crewmen made their voyage? Did they take a native vessel from their homeland and make a purposeful trip to the Samoan islands? Or were they fishermen blown off course, the survivors of an extraordinary ordeal at sea? What happened after they arrived? And what became of Malua's shipmates? With a date and a name, there was a chance that further investigation could yield some answers.

As it turned out, the story of Malua was so remarkable that it had been recorded in a now defunct local newspaper, *O le Fa'atonu* (Samoan for "to make correct"). Various contemporaries of Malua also chronicled his life: a commander in the U.S. Navy, a chap who took a "jaunt" through the South Seas in the early 1920s, a Mormon missionary, even the master storyteller (and intrepid Pacific traveler) Robert Louis Stevenson. Their accounts were far from complete or consistent, but with them I was able to piece together the basic elements of the story.

Politically, the Samoan archipelago is divided in two. The eastern islands make up the territory of American Samoa; the western islands constitute the independent nation of Samoa. In the 1880s a German firm controlled the production of copra (the dried flesh of the coconut) in the western islands, and was bringing in laborers for the plantations. Some were indentured workers, men who had signed up for a specified period. Others were "blackbirds," South Sea Islanders essentially kidnapped from their homes and forced to do the work.

More than a few of the men, both blackbirds and indentured laborers, came from the Melanesian islands. Among them was Malua. Whether he had been kidnapped or simply became dissatisfied with his lot, Malua, along with three or four companions, secretly built a crude raft and set sail from the island of Upolu, in the western Samoan islands, across a treacherous forty-mile-wide channel to Tutuila. Stevenson, who was a resident of Upolu at the time, described what followed in his book *A Footnote to History: Eight Years of Trouble in Samoa* (1892):

There are still three runaways in the woods of Tutuila, whither they escaped upon a raft. And the Samoans regard these dark-skinned rangers with extreme alarm; the fourth refugee in Tutuila was shot down (as I was told in the island) while carrying off the virgin of a village; and tales of cannibalism run round the country, and the natives shudder about the evening fire.


Horseman fighting a hairy opponent is depicted in a fifteenth-century Romanesque painted wood panel in Valladolid, Spain. Capturing or killing a wild man is a common theme in European folklore, often figuring in ritual enactments intended to renew the vigor of animal and plant

Edwin Taylor Pollock, the governor of American Samoa in the early 1920s, provided a somewhat different summary of the adventurers' fate: "One was drowned or killed by a shark when trying to land, one died or was killed after trying to abduct a Samoan girl, another died presumably about 1910, and one remained in the hills."

But whatever became of the other escapees, Malua and one companion did retreat to the hills, where they began to take on legendary status. Some months later, Malua's companion either came down to the village of Aua on his own or else was captured and brought before the naval governor, Commander Benjamin Franklin Tilley. A later report, apparently based on Tilley's account, describes the man, never named, as "a complete savage" about forty-five years of age and in fear for his life. In a smattering of his own language mixed with German and English, he said he was terrified of the Samoans—yet he refused passage back home to the Solomon Islands. By this account, he feared he had long since been forgotten by his people and, as a stranger, would be killed and eaten.

What ultimately happened to this apprehensive fellow is unknown, but before he slipped into the darkness of history, he did tell everyone in the village that Malua was still alive and living somewhere in the deep recesses of the mountains. Malua became the "Wild Man" of Samoa, and along with that moniker came all the trappings and fears associated with the mysterious and sometimes dangerous men who "take to the hills."

The wild man, as a character type of one form or another, is so common in folklore and literature that he seems ingrained in human consciousness. Stories about a wild man—often envisioned as an unclothed man, hairy and incorrigible as a beast—were widespread in medieval Europe. He was known as Wodewose to the Anglo-Saxons, Schrat in Old High German literature, Salvan to the Lombards, Orken to the Romanians. In earlier incarnations he was Leshiy to the Russians, Enkidu in the Gilgamesh epic of Babylonia, the satyr figure in Greek mythology, and Grendel in *Beowulf*, the epic English poem from the eighth century. Such figures as the leaf-covered Green Man of the early Britons played essentially the same cultural role: though seemingly more vegetable than animal, they nonetheless embodied the wild.

Similar legends abound elsewhere in the world. In *Tono Monogatari*, a collection of folk tales from Japan's Iwate Prefecture, a wild man with golden eyes struck terror in the hearts of the local people. He was Nguoi Rung to the Vietnamese, Xueren to the Filipinos, Yeh-ren to the Chinese, and Yeti to the peoples of the Himalaya. In North America he became Sasquatch.

In nearly all his forms, the wild man is said to steal livestock, abduct children, or otherwise threaten the citizenry. So it is hardly surprising that, as a scapegoat for a host of human misfortunes, the wild man has been the object of organized, or at least ritualized, hunts and executions. Various rural communities in Germany, for instance, held traditional enactments in which a local inhabitant was dressed to represent a wild man, sometimes in moss and leaves. He was then chased down and captured. In one region the man even wore a bladder filled with animal blood, which other townspeople stabbed to signify his execution.

The ritualistic hunt for a wild man typically came at the end of winter, and his "death" proclaimed the renewal and resurrection of spring. Anthropologists have often proposed that in folk beliefs, the wild man represented tree and forest spirits. The seasonal decay of the wild man's realm in the fall, then, was a sign that the regenerative powers of those spirits had weakened. When, at winter's end, a community finally took matters into its own hands and destroyed the wild man, his demise enabled a more robust wild nature to emerge. The Scottish anthropologist James George Frazer (1854–1941), who compiled mythic themes from around the world, offered a different, albeit related, interpretation. He compared the killing of a wild man known as the King of the Wood to the slaying of a ruler regarded as a god incarnate. In some traditional societies in Africa and elsewhere, he reported, such a ruler had to be killed at the first glimmer of weakness, so that his powerful spirit could be inherited, undiminished, by a younger successor.

Wild man imagined by an artist in this 1572 Flemish woodcut is depicted as naked and hairy, carrying a club and a shield.

Folklore aside, stories of people gone off to subsist alone in the wild are hardly uncommon. For about thirty years, until his death in 1889, one such wanderer hiked a regular circuit around Connecticut and southeastern New York State, begging housewives for food and finding shelter in nearby caves. Called the Leather Man because he dressed in patches of leather, he was believed to be a Frenchman who had fled to America when his spirit was broken by failures in business and love. Only a few years after the Leather Man was laid to rest, even as Malua was hiding in the hills of Samoa, another wild man was allegedly sighted in Winsted, Connecticut. A heavily armed mob of more than a hundred men and boys gathered on a street corner and then set off to hunt him down. (The mob succeeded only in catching up with some pigs running through the wood.)

One especially resonant form of wild man is the so-called wolf child, or wild child, the lost or abandoned child purportedly saved and then raised by wolves. Even if the nurturing role of the wolves may be doubted, the story of a child raised in nature, isolated from normal human socialization, is an endless source of fascination.

Contemporary explorers seem obsessed with similarly "wild" figures, such as the elusive Sasquatch and Yeti. Both creatures, at least by reputation, share much in common with the wild men of other legends. As is

A citizen costumed as a wild man performs a Schembart (German for "bearded mask") dance on behalf of the butchers' guild of Nuremberg at carnival time. The illustration, from a sixteenth-century manuscript, shows that wildness was evoked by leafiness as well as by hairiness.

often the case, the boundary between legend and concrete evidence (and whether the preponderance of the evidence suggests a "cryptic" animal or an outright fraud) is, at best, a disputed one.

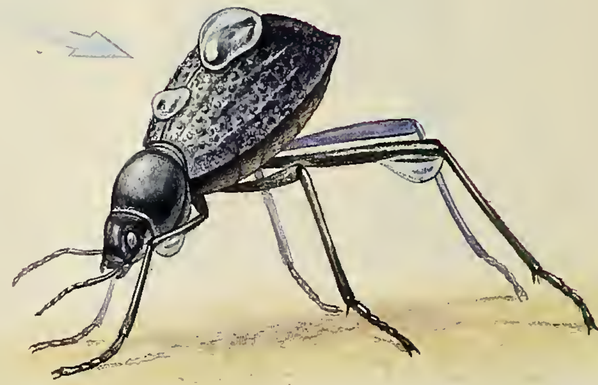
Whatever the reasons, the idea of a wild man has become fixed in the minds of people throughout history and around the world. Late-nineteenth-century Samoa was certainly no exception. When the news spread that a strange man was living somewhere in the hills of Tutuila Island, the responses would undoubtedly have been much like the responses to wild men in other places at other times. Parents would have warned their straying children to come home lest the wild man take them away. Malua would have been blamed for every pig or chicken missing from a farmer's pen. Governor Pollock noted in his account that reports of wild-man sightings "were

(Continued on page 66)

Like Water Off a Beetle's Back

An African insect could show how to wring moisture from the fog—and let the sun shine on cloudy airports.

By Adam Summers ~ Illustration by Roberto Osti



Follow the southwestern coast of Africa north from Cape Horn toward Namibia's gemstone-rich Skeleton Coast, and you come to the Namib Desert. Home to the world's highest sand dunes, the Namib is also a cornucopia of biomechanical marvels: a spider that rolls like a wheel; a gecko that dances on the hot sand; and the bizarre, two-leafed *Welwitschia mirabilis,* which looks like a wrecked airplane planted in the sand and can live more than a thousand years. The environment is a harsh one. Annual rainfall in the Namib typically measures less than an inch, and on most days the only source of moisture is the early morning fog that rolls off the chilly Atlantic, tantalizing the denizens of the parched sands.

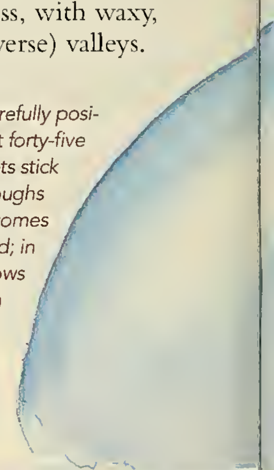
In the slaty light of one such foggy dawn, a long-legged Namib beetle (genus *Stenocara*) stands on a small ridge of sand. Its head faces upwind, and its stiff, bumpy outer wings are spread against the damp breeze. Minute water droplets from the fog gather on its wings; there the droplets coalesce, until they finally grow big enough to release their electrostatic grip on the wing surfaces and roll down to the beetle's mouth parts, giving the animal an early morning drink. In such an arid environment that drink is vital, for once the Sun burns off the fog, there is little the insect can soak up except blistering heat. Besides being helpful to the beetle, the water-gathering mechanism—only recently understood by investigators—might someday become the basis for large-scale, artificial schemes to gather water from the air.

There's plenty of water in a fog bank; the hard part is getting hold of it. The water droplets in fog are, on average, just one one-thousandth of an inch across, and the largest ones are only twice that size. The droplets are so small, in fact, that they often don't fall downward; instead they get carried sideways or even upward by currents of wind.

The trick to drinking fog is getting the droplets to aggregate, so that wind and electrostatic forces no longer overwhelm gravity. When a wind-blown fog droplet lands on a hydrophilic (water-loving) surface, such as clean glass or stone, the drop flattens out because of the electrostatic attraction between the molecules of water and those of the surface. The cross section of the flat drop is too small for the wind to pick it back up. And, because water molecules so strongly attract each other, the flat drop also presents a highly hydrophilic surface to which other droplets can attach.

Andrew R. Parker, a zoologist at the University of Oxford, and Chris R. Lawrence, an investigator at the defense research firm QinetiQ, headquartered in Farnborough, England, discovered that *Stenocara* beetles take advantage of those basic properties of water. On the beetle's elytra—its hardened, outer pair of wings—there is a pattern that alternates hydrophilic bumps, just one-fiftieth of an inch across, with waxy, hydrophobic (water-averse) valleys.

Windblown water (blue arrow in illustration above) becomes a drink for a carefully positioned Namib Desert beetle. Facing into the breeze, with its body angled at forty-five degrees, the beetle catches fog droplets on its hardened wings. The droplets stick there to hydrophilic bumps, which are surrounded by waxy, hydrophobic troughs (right). Droplets accumulate and coalesce until their combined weight overcomes the water's attraction to the bumps as well as any opposing force of the wind; in a ten-mile-an-hour breeze, such a droplet would stick to the wing until it grows to roughly two-tenths of an inch in diameter; at that point it would roll down the beetle's back to its mouth parts, quenching a desert thirst.



A fog droplet collects on each little bump, and further droplets attach to the first. The droplets coalesce and grow until they reach about two-tenths of an inch in diameter. At that size, because the insect's back slopes at roughly forty-five degrees to the horizontal, the drops are heavy enough to unstick from the bumps and buck the wind. Each drop slides down the wings toward the beetle's mouth like a bead of rain on the hood of a freshly waxed car.

It's a neat trick, but it hardly seems practical to have teeming hoards of beetles harvesting fog for water. What would you do with them for the fog-less rest of the day? And how would you keep them from drinking the water themselves, rather than donating it to crops, livestock, or people? Fortunately, Parker and Lawrence have a solution. They developed a surface to mimic the beetle's elytra that seems to work as well as the beetle's wings do. The two investigators partly embedded dozens of glass spheres, each about the diameter of a poppy seed, in a thin layer of wax. After de-waxing the top of each glass sphere with alcohol, they had an array of hydrophilic bumps in a hydrophobic field. In tests, they found that neatly ordered arrays of beads caught more mist than random, disordered ones did. But both kinds of array caught more than did smooth, waxy surfaces; most water drops just bounced off the latter. Water landing on bare glass drained in unpredictable directions.

Many techniques that imitate nature—collectively known as biomimetic technologies—are prohibitively expensive. This one might well be a commercially viable exception. There are a number of ways to create either flexible or rigid surfaces with hydrophilic-hydrophobic patterns. Perhaps the simplest would be to print hydrophilic dots onto sheets of such hydrophobic materials as polyethylene. On a camping tent, for instance, such a printed pattern, combined with suitable guttering, could gather the day's water supply from the early morning mist.

Parker and Lawrence's effort isn't the first time people have tried to harvest water from fog. People in remote areas of South America have already relied on fog for their water. According to the government of Canada (which collaborated, with an organization called FogQuest, on a plan to develop technologies to harvest fog), collectors near the village of Chungungo, Chile, gathered an average of 4,000 gallons of fog-borne water a day for several years in the past decade. The fog would collect on the threads of fine nets before it dripped into gutters leading to cisterns.

In other, windier areas, droplets could blow through the nets or get blown off again after landing. Parker and Lawrence's work shows that those drawbacks could be minimized by substituting solid panels for the nets. I even hold out the hope that solid panels could become so efficient that they could act as highly localized fog busters. For those of us who are routinely delayed as we pass through such perennially fogbound airports as San Francisco's, fog-busting itself might be the technology's "killer app." But my biggest hope for this discovery is that it will spur new efforts to preserve biodiversity. After all, you never know where you'll find your next drink.

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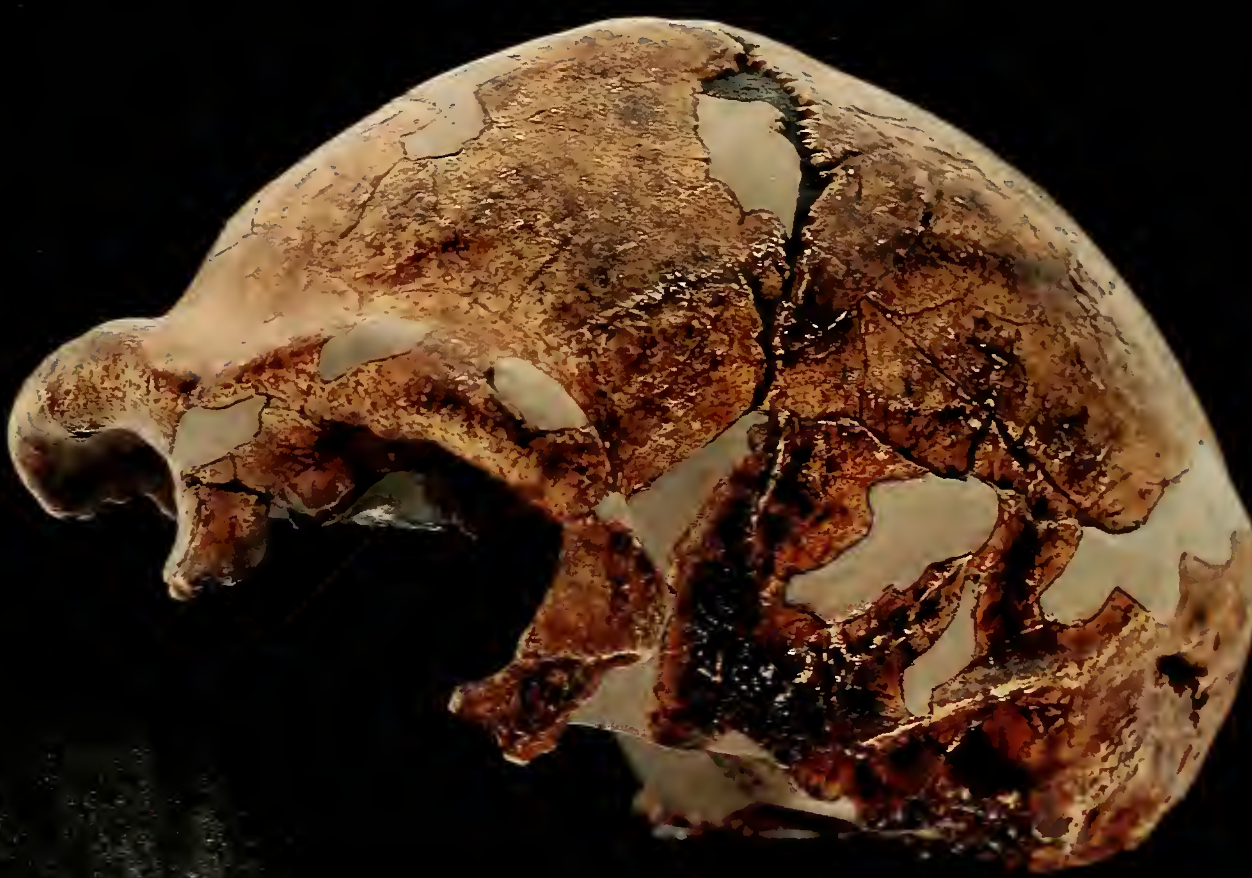
Headstrong Hominids

The mysterious skulls of Java man and Peking man may have evolved because males were clubbing each other in fights.

By Noel T. Boaz and Russell L. Ciochon



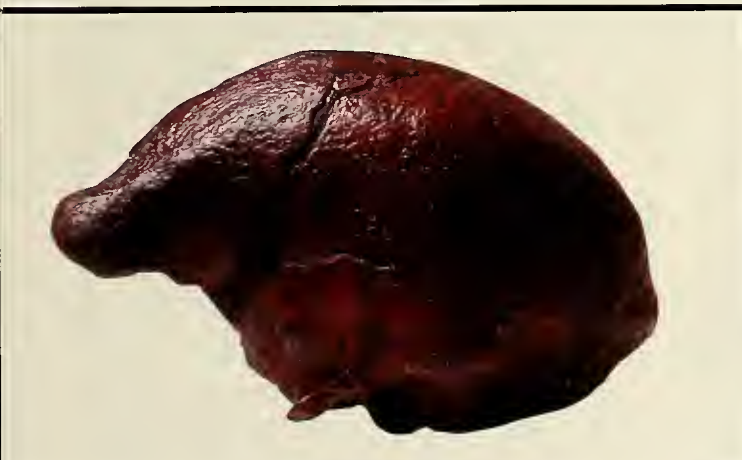
Heavy brow ridges are prominent in this cast of a reconstructed skull of Peking man (designated skull XII). Such robust features are typical of this and other *Homo erectus* specimens discovered in China. The cast was made under the direction of the paleoanthropologist Franz Weidenreich. The original fossil, dating from between 670,000 and 410,000 years ago, was lost during the Second World War.

Ever since the 1890s, when the Dutch anatomist Eugene Dubois unearthed the first-recorded cranium of the early, small-brained human relative now known as *Homo erectus*, scholars have been struck by the unusual anatomy of its skull. The top and sides of the cranium have thick, bony walls and a low, wide profile. To the modern eye, this part of its skull, known as the calotte, or skullcap, looks a lot like a cyclist's helmet—low and streamlined, designed to protect the brain, ears, and eyes from impact. In contrast, we modern humans hold our enormous, easily injured, semiliquid brains in relatively thin-walled bony globes. We have to buy our bicycle helmets.

Because Dubois discovered his fossils in Java, it and other specimens later found in that region became popularly known as "Java man." In the 1920s similar fossils were discovered in China's Longgushan Cave, about thirty miles from Beijing (then transliterated in the West as "Peking"), and were dubbed "Peking man." At the time, no other hominid fossils of comparable antiquity were known, so Dubois and everyone else initially regarded the skull's robustness—its strength and thickness—as typical of early human ancestors. Even as late as the 1940s, Franz Weidenreich, an eminent German paleoanthropologist then working at the American Museum of Natural History, proposed that *H. erectus* had descended from a line of massive, indeed gigantic ancestors, and that modern *H. sapiens* was the end result of a down-scaling trend. But as more hominid fossils have come to light, it has become clear that the ancestors of *H. erectus* did not have massive bones, and neither did *H. erectus*. In fact, except for its strange skull, the skeleton of *H. erectus* resembled our own.

H. erectus arose in Africa more than 2 million years ago, and soon thereafter some populations of this early human migrated out of the continent. Descendants of the migrants reached eastern Asia at least 1.9 million years ago. The stone tools they manufactured have been discovered at various sites, but the earliest fossils in eastern Asia have been found only in Java and China. Java man comprises both the earliest and the most recent specimens of *H. erectus;* the fossils span a period that lasted from 1.8 million years ago until just 50,000 years ago. Peking man dates more narrowly, from between 670,000 and 410,000 years ago.

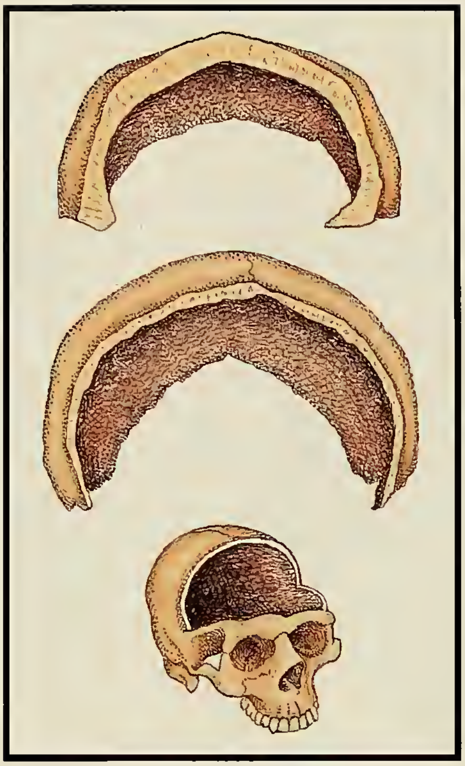
The skullcaps discovered in eastern Asia tend to be more robust than the ones in Africa. Hence some paleoanthropologists have regarded the African fossils as a distinct species, which they call *H. ergaster.* But one African skullcap just as robust as any Asian specimen was discovered by Louis Leakey in Olduvai Gorge, Tanzania. It dates from about 1.4 million years ago [*see photograph at right above*]. And even the strapping youth known as Turkana boy, the most complete *H. erectus* skeleton discovered so far [*see photograph on page 57*], probably would have had a thick skull when fully grown. In any case, there is little doubt that *H. erectus* was on the line that ultimately led to the first modern humans. Whether



Homo erectus cranium known as Sangiran 2 (above left), discovered in Java, is evidence that an early, small-brained hominid lived in Asia. This particular fossil may be as old as 1.6 million years, yet it belonged to the same species as the later Peking man (opposite page) and displays similar features. African fossil cranium of Homo erectus known as OH 9 (above right) was discovered by Louis Leakey in Olduvai Gorge, Tanzania; it dates from 1.4 million years ago. More robust than other examples known from African, it is comparable to the Asian specimens.

that further evolution took place in Africa or was a more widespread phenomenon is a matter of debate, but one way or another we got bigger brains and thinner skulls.

Many differences in hominid skulls can be accounted for by the evolution of the brain and the chewing apparatus. Large skulls are needed to contain large brains, and large jaws and teeth for processing tough foods need heavy-duty skull bones to anchor massive chewing muscles. Unfortunately, neither of these tried-and-true explanations can entirely account for the unique attributes of the *H. erectus* skull. What seems more likely is that the species badly needed some protective headgear. Functionally, the *H. erectus* skullcap is similar to the defensive carapace of a turtle—indeed, some excavators have mistaken cranial fragments of *H. erectus* for fossil turtle shell. But what special sources of traumatic injury did hominids face that might have encouraged the evolution of such a robust skull? We don't think it was exposure to predators (which can readily attack other, more vulnerable parts of the body), or a habit of venturing into slippery or precarious territory where the hazards of falling were increased. In examining the protection afforded by the *H. erectus* skull, we think the evidence points to some kind of violence perpetrated within the species itself.



Contrast between the cranium of Homo erectus *(top) and that of a modern human (middle and bottom) is clear in cross section.* Homo erectus *had by far the thicker skull, with a prominent keel along the midline and extra bracing along the lower sides.*

When a person is injured in the head today, whether or not the skull is fractured often makes the difference between life and death. What might seem like a relatively minor break in the skull can tear blood vessels that adhere tightly to its inside surface. The buildup of blood under the skull, known as a hematoma, pushes on the brain. Coma and, eventually, death can result.

In modern skulls one of the commonest kinds of fracture is the so-called eggshell. The concussion caused by a fall or by a blow from a blunt object can crack and push a section of cranial vault inward without disjointing the bone. The bone may remain depressed, but in an eggshell fracture, the bone—pulled by skin, muscle, and other tissues attached to the scalp—springs back to nearly its original shape. In either case, though, the damage is done. Branches of the blood vessels serving the meninges, or fibrous coverings of the brain, begin to bleed. As the hematoma expands and begins to compress the brain, sometimes hours after the injury, neurological symptoms become progressively severe.

In the days before emergency rooms, X rays, and intracranial surgery, people suffering from intracranial bleeding managed the best they could. Usually that meant not very well. Even if a person regained consciousness and survived the hematoma, profound neurological deficits often continued. Partial paralysis, gait problems, lack of hand-eye coordination, difficulties in speaking, or any number of disruptions in cognitive functioning were the result. For active early humans, it is hard to imagine a more debilitating condition. Any traits that reduced the chances of cranial fracture would have given a substantial evolutionary advantage to the individuals who possessed them.

As one might expect, the thicker the bone, the less likely it is to break on impact. In our most recent work we have been experimentally testing and quantifying the advantages of thick bones. With a nine-foot-high, guillotinelike bone-testing apparatus, we administer calibrated impacts on one-inch circular pieces of bone from human cadavers. Certainly thick bone does confer a competitive advantage. But minimizing weight and optimizing protective value at the same time is a problem that we continue to study.

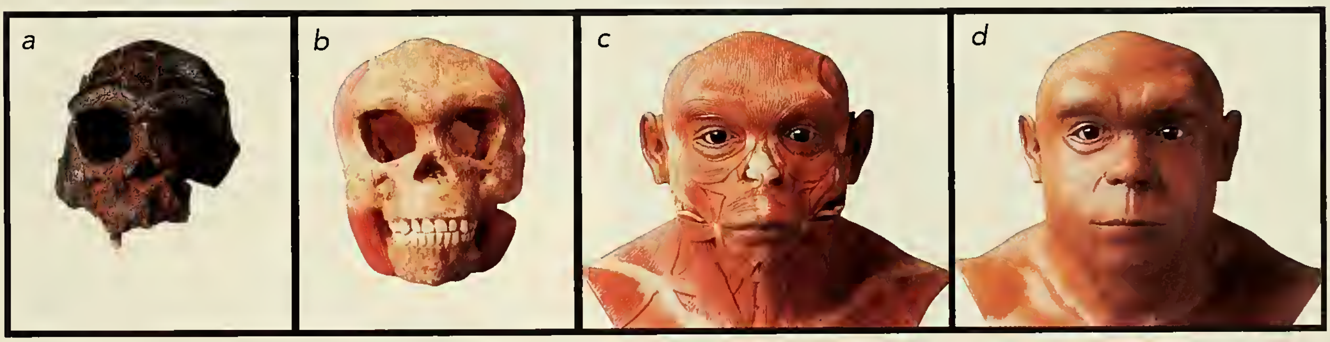
The *H. erectus* skullcap is described technically as pachyostotic ("thick-boned"): thick, solid layers of bone make up both its inner and outer surfaces. Sandwiched between them is a less strong, latticelike layer of bone, whose intervening spaces, in life, would have been filled with marrow and blood. The *H. erectus* skull also has a number of unique bony structures. Three of them, namely a beetling brow ridge and bony thickenings on the sides and rear of the cranium, form a bony ring starting above the eyes, extending back around the head above the ears, and meeting on the back of the head. The top of the skull resembles the inverted bottom of a boat, with a thickened bony mound that looks like the boat's keel extending along the midline of the skull [*see illustration on opposite page*].

In the 1920s an American surgeon named E.R. LeCount classified skull fractures by type. A heavy blow falling directly on top of the head tends to cave in the bone overlying the so-called superior sagittal sinus, a channel within the meninges for venous blood draining along the midline of the brain. LeCount hypothesized that the strongly constructed midline of the skull is an adaptation that protects against such damage. In most *H. erectus* skulls the same adaptation appears in exaggerated form as the so-called sagittal keel.

Blows delivered in a fight, however, are more likely to land at eye level than to rain down on top of the head. LeCount regarded the eye-level armor of the modern skull as the main protection against blunt trauma to the head. Again, the *H. erectus* skull, with its even thicker ring of bone, would have afforded even more protection. The bony ridge above the eyes protected the orbits, or eye sockets. The bony bulge on either side of the skull overlay the sinus that conducts blood into the internal jugular vein, and helped protect the ear region from blows to the side of the head. And the bony ridge on the rear of the cranium shielded the confluence of sinuses carrying venous blood inside the back of the skull, the rearmost lobe of the cerebrum, and the cerebellum.

In addition to the skullcap, other features of the *H. erectus* skull and jaws seem well adapted for defense against trauma. René Le Fort, a French surgeon working at the turn of the twentieth century, studied and classified the pattern of facial fractures in modern people. A Le Fort type I fracture is one that results from a blow to the upper face that breaks the bone forming an eye socket. *H. erectus* not only had a heavy brow ridge but also a remarkably flat and horizontal roof to the eye socket. That eye-socket covering would have been particularly hard to break because any impact there would have been transmitted straight back to the base of the skull.

Le Fort type II and type III fractures are highly debilitating breaks in which the facial skeleton is separated from the brain case. In *H. erectus* the face evolved to become tucked under the protecting brow ridges, making it less likely that a fracture would cause such a separation. A strong blow to the face would have resulted in soft-tissue damage, and perhaps in a fracture of the forward part of the upper jaw and damage to the incisors. But more serious fractures, such as breaks of the cheek bones, would have been reduced. *H. erectus* incisors were also reinforced by a thick layer of enamel on their inner sides and, often, by their "shovel shape."



Visualizing Java man: The fossil (a), designated Sangiran 17, is the most complete Homo erectus *skull discovered on Java. Under the supervision of Hisao Baba, Curator of Anthropology at the National Science Museum in Tokyo, sculptor Yoichi Yazawa reconstructed the individual's appearance in life. First, a cast of the fossil was rounded out with teeth, lower jaw, and chewing muscles (b). Other soft tissues were built up (c), and finally the outer skin was added (d). Because this fossil had relatively robust features compared with some others, it was presumed to be that of a male.*

An old boxing adage warns would-be fighters to avoid the ring if they have "a glass jaw." A broken mandible makes chewing painful and difficult, if not impossible, and even today the injury requires that the broken sections be surgically wired together. For *H. erectus*, such a fracture would have been life-threatening. Weidenreich was the first to point out, in a monograph on Peking man, that the *H. erectus* jawbone thickens on the inside of each mandible.

just behind the chin. That is exactly where the jaw most commonly breaks from trauma in modern people. The thickening makes the most anatomical sense as a defense against trauma to the lower face.

Another vulnerable part of the anatomy protected by the skull is the middle meningeal artery. In modern humans the main branch of the vessel runs beneath the temple, in a region of intersecting bone sutures known as the pterion. The bone here is particularly thin, though the overlying chewing muscle provides some protection. But a good blow to the temple is still likely to break the bone and tear the artery—a dangerous injury because arterial blood can bleed out so rapidly. Damage at the pterion usually results in a large hematoma and rapid loss of consciousness or coma. The little flange on baseball batting helmets, extending down the side of the helmet that faces the pitcher, is specifically designed to protect the batter against this injury from a hard-pitched ball.

Contrary to what one might predict, the *H. erectus* skull is not particularly thick at the pterion. But other details of its anatomy are just as revealing. In modern humans the middle meningeal artery divides into two branches, a large branch that runs forward on the inside of the skull, under the pterion, and a smaller branch that runs toward the back of the skull. In *H. erectus* the middle meningeal artery divides as well, but the forward branch is minuscule compared to the large rearward branch. Weidenreich, who discovered the anomaly, devoted a paper to it, considering it a reflection of the primitive quality of the *H. erectus* skull and brain.

We think this flow network, like the thick cranium, evolved in response to interpersonal violence. Moving the main blood supply to the meningeal coverings of the brain away from this vulnerable area of the skull helped mitigate the effects of arterial breakage. But why rearrange arteries when evolutionary change had so readily thickened other parts of the skull? Perhaps skull sutures created developmental or structural problems for such thickening, particularly while the cranial vault was expanding through evolution to house a larger brain.

Depressed fracture is evident at the top of this fossil skull of Peking man (designated skull X), perhaps the result of a blow from a blunt instrument wielded by another Homo erectus. *Such a wound is dangerous; it causes bleeding beneath the bone, which can put pressure on the brain. The fossil shows that this individual survived long enough for the fracture to heal.*

Franz Weidenreich was trained as a medical doctor, and worked most of his career in medical institutions in Germany. He even served briefly as a medic in the German army during the First World War. Doubtless, then, he had more than a passing familiarity with the devastating effects of head trauma—a familiarity that became invaluable when he began to analyze the skulls of Peking man.

In those fossil specimens he identified a number of depressed fractures that had subsequently healed. In other words, half a million years or so after these hominids had sustained massive blows to the head, Weidenreich had suddenly stumbled on evidence that could still reveal not only the kind of trauma that resulted, but also, because the trauma victims had survived, the protective value of their skulls. Tragically, the original fossils of Peking man were lost during the Japanese invasion of China in the Second World War. Fortunately, careful casts of the excavated remains had been made before the war, and so we were still able to reexamine the head trauma systematically.

Some of the damage Weidenreich first attributed to hominids he later ascribed to carnivores. Other damage was clearly geological: some bones have been crushed by overlying sediment, others bear the impressions of rocks pushed into them as they themselves turned to stone. But in the end, Weidenreich classified some ten depressions or defects in the skulls as having been caused by blows from other hominids. We agree. The damage closely matches in size, form, and even location the healed depressed fractures seen in human skulls today.

But what was the source of these injuries? To understand how and why pachyostosis and other features may have evolved in *H. erectus*, comparative anatomists look to other animal species in which similar protective armor has evolved. Among terrestrial animals, extremely thick skull bones occur in species as diverse as modern bighorn sheep and the Cretaceous dinosaur *Pachycephalosaurus*. One of the most striking forms of behavior in bighorn sheep is the way males butt heads. They each run at speeds of twenty miles an hour, colliding with an impact that sounds like an explosion. What could possibly lead these animals to engage in such potentially lethal behavior?

Females. Darwin long ago explained that such behavior is the result of sexual selection. Among many species, the male's ability to procreate depends to a substantial degree on attracting members of the opposite sex, or to winning access to females through competitions with other males. In the evolution of bighorn sheep, for instance, males that defeated their rivals in butting contests got to mate more often. The mating passed on whatever attributes had given the victor an edge—and one of those attributes was apparently a reinforced skull. Paleontologists speculate, by analogy, that *Pachycephalosaurus* engaged in similar behavior, but no one knows for sure.

We aren't suggesting that early hominids charged at one another and banged their heads together like rutting sheep (although if you think about football and some martial arts, the idea is not as bizarre as it might seem at first). Pachyostotic species that use the head as a weapon also have bony cranial outgrowths that evolved along with their behavior. Sheep have sharp horns rising out of their thick skulls, and *Pachycephalosaurus* had nasty-looking knobs projecting from the back of its domed head. *H. erectus* had none of these offensive adaptations. Modern human beings tend to fight with their hands, and (leaving out gunshots) almost all cases of serious or lethal trauma inflicted during nonsexual assaults are to the face and head.

When animals compete over mates or rank (which often amounts to the same thing), their combat tends to fall within certain instinctively understood limits. Nowadays, of course, violence among modern humans can be unrestrained, both in intergroup conflict (warfare) and between members of the same group. But some forms of human violence remain culturally circumscribed. In Western society, duels were historically carried out with matched weapons, and boxers (even fistfighters) follow the dictates of "clean" fighting. Among the Yanomami of Venezuela and Brazil, violence is traditionally limited, despite their reputation as "the fierce people." As the anthropologist Kenneth Good and the writer David Chanoff re-

The most complete H. erectus *skeleton found so far is designated WT 15000 ("Turkana boy"), from Nariokotome, Kenya. Like most African specimens, this one does not have particularly robust skull features, and some paleoanthropologists prefer to classify it as a different species,* H. ergaster. *But this boy was a young adolescent; more robust features would have developed with further maturation.*

port in their book *Into the Heart: One Man's Pursuit of Love and Knowledge Among the Yanomami:*

> When a situation really got heated, the men of two lineages or two villages might get involved in chest-pounding matches, where individuals took turns giving and receiving punches, either open-handed or with closed fists—depending on the level of anger. . . . A step up the scale were club fights, where antagonists traded blows to the top of the head with eight-foot-long staves. Often they carried the scars of these duels for life. But this too was ritualized violence, a substitute for deadly bloodshed.

A particularly instructive example comes from nineteenth-century ethnographic reports of Australian Aboriginal groups, particularly for central and southeastern Australia. Men or women who "had a bone to pick" with another group member followed a code for resolving the conflict. They challenged their adversary to a duel with a combination club and throwing stick called a *nulla-nulla.* Once the bout began, it continued until one of the combatants won by knock-out or TKO—that is, until the adversary was disabled and could not continue.

If Homo sapiens *evolved from* H. erectus, *why don't we, too, have thickened cranial bones?*

Peter Brown, a paleoanthropologist at the University of New England in Armidale, Australia, has investigated skull thickness in modern and historical Australian Aboriginal populations, whose cranial bones are the thickest of any living *H. sapiens.* In a sample of 430 Aboriginal crania, Brown found evidence of healed depressed fractures on the frontal or parietal bones in 59 percent of the female crania and in 37 percent of male crania. Depressed fractures occurred in these people and they survived; undoubtedly, many others did not. His findings led Brown to hypothesize that the thick skull vaults of the Aboriginals may have evolved as a consequence of the traditional method for settling conflicts.

A similar explanation may account for the evolution of pachyostosis and other unique features that strengthened the *H. erectus* skull. We are reasonably confident that the distinct anatomical features, as well as the healed fractures that have been preserved in the fossil record, are primarily a response to violence within the species. We can only speculate about whether the violence involved ritualized fights with clubs or rocks among hot-headed young males competing over females, or instead revolved around other kinds of conflict. But we would lay bets that, as in many other species, we are detecting the results of sexual selection.

If *H. sapiens* evolved from *H. erectus,* why don't we, too, have thickened cranial bones? If modern children had thicker skulls, for instance, significantly smaller numbers of them would suffer serious head injuries when they crash on bicycles, skateboards, and snowboards. Theoretically, a species could have both a commodious skull to house an enlarged brain and a thick, heavily armored skull for protection. But reality steps in when the weight of such a structure has to be supported and balanced atop the spine. Cranial bone may have become thinner in modern humans simply to reduce skull weight.

Another possible explanation comes out of the work of Dean Falk, an anthropologist at Florida State University, in Tallahassee. Falk argues that the heat generated by the enlarged human brain became an important factor in evolution. She hypothesizes that the pattern of venous blood drainage in the head became reorganized in order to cool the brain. Many small holes known as emissary foramina pierce the skull, enabling veins to transport blood from the scalp into the venous sinuses. This blood, cooled at the surface by sweat evaporating from the scalp, then enters the skull to help cool the brain.

Falk discovered that emissary foramina are much more common in large-brained *Homo* species than they are in the earlier, small-brained hominids known as australopithecines [See "A Good Brain Is Hard to Cool," by Dean Falk, August 1993]. Falk's hypothesis is still debated, but we think it could explain why skulls became thinner as modern humans evolved: a thick skull would have presented a far greater obstacle to penetration by the delicate, low-pressure emissary veins.

Thus was defensive armor reduced, as *H. sapiens* evolved a larger, more globular, thin-walled skull. Human violence by no means ended, but other means of protection from trauma or avoidance of attack, or both, were evolved by the descendants of *H. erectus.* Almost certainly, those adaptations were no longer primarily biological but cultural. Culture was to become the hallmark of our species. □

This article was adapted from Noel T. Boaz and Russell L. Ciochon's forthcoming book, Dragon Bone Hill: An Ice-Age Saga of *Homo erectus, which is being published by Oxford University Press in February.*

Blossoms of Ice

These delicate "flowers" sprout only in winter, but you won't find them catalogued in any herbal.

By D. Bruce Means

Scientific discoveries don't always burst into bloom overnight, accompanied by shouts of "eureka!" Some take years to crystallize in one's slumbering consciousness, before they finally flower. Passing through a rich hardwood bottomland one cold winter's morning in 1976, I noticed white reflections from icy formations on the forest floor, but my quest was for an eastern diamondback rattlesnake that I was radio-tracking, and so I paid them no further mind. A couple of winters later, when I chanced to see them again, their unique shape—like a taffy of ice, pulled into swirling loops and bows—seemed worth a photograph or two. By the time I returned with a camera, though, all had melted.

At the time, I was director of the Tall Timbers Research Station, nestled in the rolling red hills of north Florida, near Tallahassee. Other field biologists who worked and lived on the 2,800-acre site were just as puzzled by these icy wonders. None of us knew whether they were biological, geological, or meteorological phenomena, let alone when to expect them or where to look for them. And any chance to study them would be as fleeting as catching a whisper on the wind. I decided to plan ahead, but the next several winters came and went without any sightings.

Finally, on the night before Christmas, 1983, the stage was set. After an unusually warm autumn, without a single frost, the forecast warned of the overnight arrival of what (for Florida) would be a blustery cold front. Before sunup, I stole out of the house, camera in hand, determined to capture my elusive quarry.

About a mile from the house, in the same bottomland where I had seen them before, I panned my flashlight over the leaf litter. Each leaf sparkled with the fine frost crystals that blanketed the whole world that morning, but sadly . . . nothing out of the ordinary.

The ground crunched as I walked. I began to lose heart for the search, recalling fruitless winters past. Then my light played across something white, glistening on the distant ground. There, at last, were my "ice flowers," though they are not flowers at all. (Some call them "frost flowers," though they are not true frost, either.)

I lost no time investigating them before they vanished, shortly after sunup. Ice flowers can be as small as a Ping-Pong ball or as large as a grapefruit. They grow out of the fibrous bases of the perennial known as white crownbeard *(Verbesina virginica)*. During the growing season the plant is undistinguished, looking rather like its relatives ragweed and dogfennel. In winter, its stems are merely dried-out sticks, which mark where its roots will put forth new shoots in the spring. Curiously, early botanists called the plant frostweed. Related plants, such as yellow ironweed, as well as an unrelated frostweed, *Helianthemum canadense,* also bear

ice flowers. Why all plants do not yield such "blooms" is not known.

On close inspection, I saw that the "petals" of my ice flowers push their way through the vascular bundles of the dead stems: Water from the roots is drawn up the stems (either as part of the plant's natural transportation system or through capillary action) and expands as it freezes, breaking the stem walls and creating a flow of ice. The leading edge of the ice freezes to the stem's papery bark, and as the ice grows it is lifted upward by the attached bark, forming delicately curved, lacy ribbons.

Ice flowers are most common during the first frosts of late fall or early winter, depending on latitude; in Florida we have also seen them as late as February. They occur particularly after a wet autumn, when the roots have become saturated with water.

Ice flowers "grown" by the same plants during later freezes in the same winter take on entirely different shapes, often becoming more compact, like true flowers. The bark of the woody stems has already been peeled upward by the first freeze, and so it is no longer available to shape the growth of new ice flowers. □

Fighting HIV with HIV

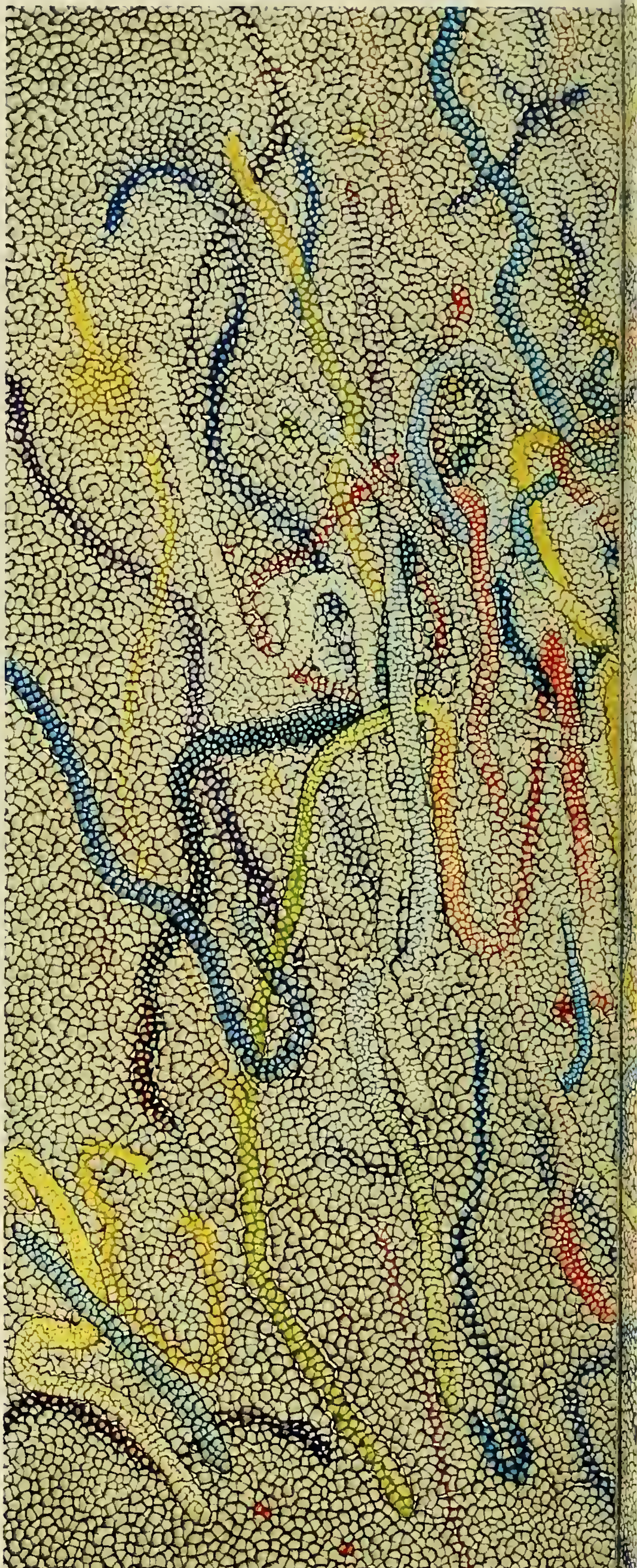
In its zeal to keep competing viruses out of a cell it controls, the AIDS virus may have exposed its own vulnerability.

By T.V. Rajan

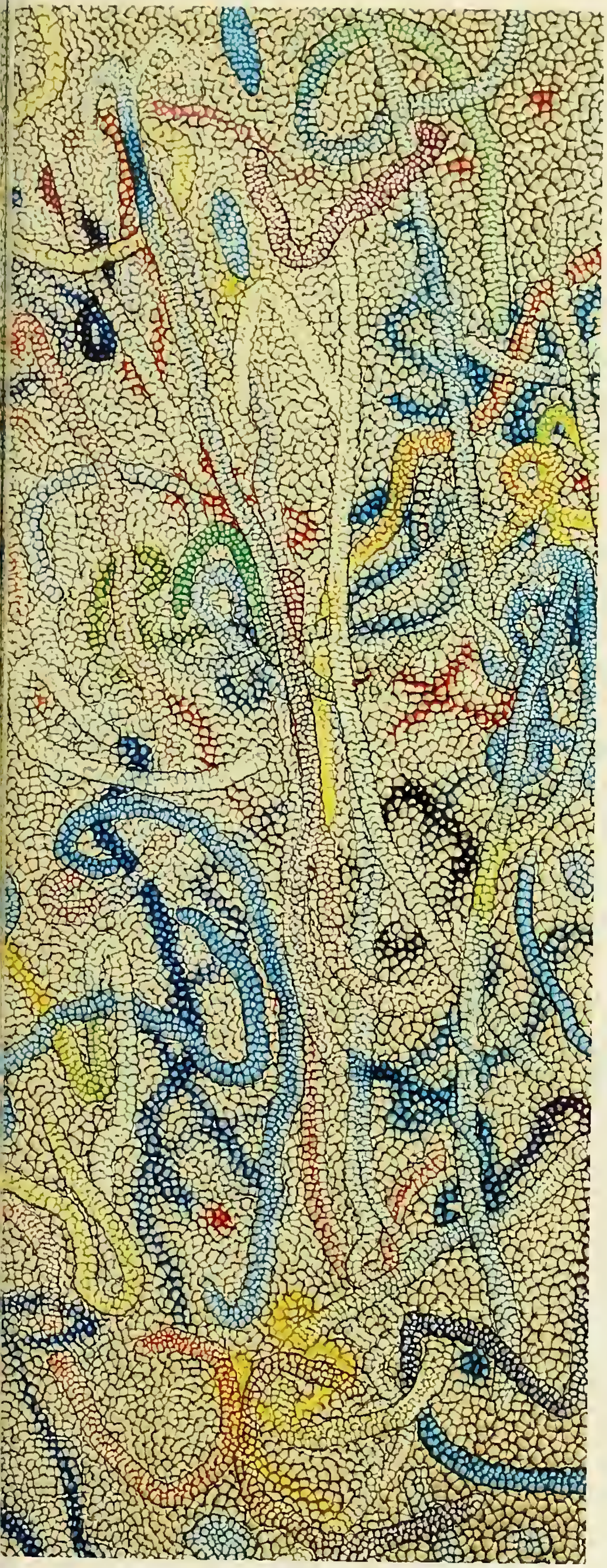
The acquired immunodeficiency syndrome, AIDS, has proved a challenging foe for medicine since it first became widely known almost a quarter century ago. Unlike most viral diseases, AIDS attacks more by stealth and by subverting the human immune system than by frontal assault. The virus that causes the disease enters a cell with the grace of an expert thief picking a complicated lock, using an array of the cell's sensors to its own advantage. Then the virus hijacks the machinery of the cell to reproduce—not in some violent orgy that leads to quick cell death, but patiently, quietly, spreading itself without raising much of an alarm.

Some of the world's best minds in biology have been working hard since the 1980s to define, design, and deploy a vaccine to prevent infection by the AIDS virus, and perhaps even to defeat the virus in established cases. Unfortunately, after the first rush of enthusiasm for such a strategy, many investigators have wondered whether a preventative vaccine is likely to appear in the next several decades, much less the next few years. The original model, or basic design idea, for such a vaccine, which goes back to the late eighteenth-century tactic the English surgeon Edward Jenner used to make the first smallpox vaccine, has proved unsuccessful so far.

But there are other options. One approach is summed up in an aphorism quoted by the first-century A.D. Greek writer Plutarch: "Knavery is the best defense against a knave." The knavery of the AIDS virus is twofold: its cunning method of infection—a large protein, which dangles from the virus



Ross Bleckner, *In Replication*, 1998



like a hair, tricks a cell into fusing with it—and its insidious practice, once it gets inside the cell membrane, of adding its own genetic material to that of its host. (The latter action is what gives the AIDS virus and a number of other similarly acting viruses their name: retroviruses.) Those two behaviors are what have made the disease so difficult to combat.

The best defensive knavery against the AIDS virus may be to exploit one or both these tricks. Virologists now realize that the ongoing AIDS pandemic is not the first time a species of mammal has come under attack by a retrovirus. For example, investigators recently discovered a group of mice that is immune to a highly virulent retrovirus that infects the genomes of almost all other mice living in the area, and that does so via much the same mechanism as the AIDS virus uses to infect the human genome. Furthermore, it is now clear that about 8 percent of the human genome derives from other viruses that long ago spliced their genetic material into human DNA. Understanding the effects of those earlier viral encounters holds out the possibility that we can end AIDS's reign of terror.

Thinking about the reign of AIDS, I still harken back to a day in 1982, when I was a young assistant professor of surgical pathology at the Albert Einstein College of Medicine, in New York City. The AIDS epidemic was just surfacing, and microscope slides prepared from fluid rinsed through a patient's air passages had just come in to the hospital's department of pathology. Almost every member of the unit gathered to look at the slides.

Reviewing specimens with the pathologist is an important learning experience for every young physician. Most doctors, though, loaded with heavy clinical burdens, seldom have the time for such reviews. Most material a pathologist examines, after all, is fairly commonplace. But the occasional rare specimen is of great interest, and on that day in 1982, the specimen in the pathology lab was highly unusual and still so rare that most of us had never seen it before.

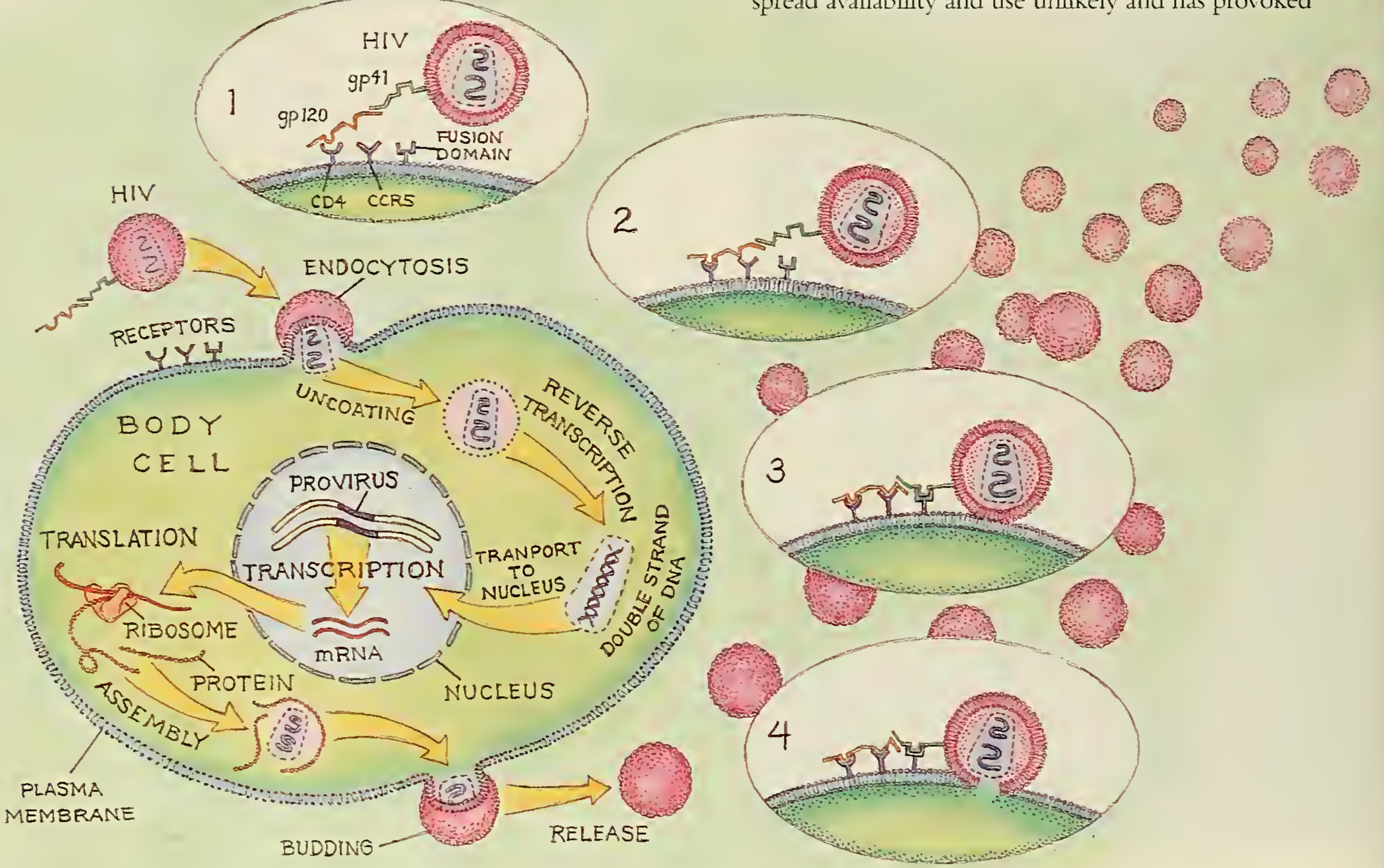
The *Morbidity and Mortality Weekly Report*, published by the Centers for Disease Control and Prevention (CDC) in Atlanta, had recently alerted the medical community that, in the preceding several weeks, a number of patients with similar case histories had been arriving at hospitals in large urban centers, particularly Los Angeles, New York City, and San Francisco. The CDC report went on to say that many of the patients were suffering from pneumonia, but that the pneumonia was caused by an uncommon agent, a fungus known as *Pneumocystis carinii*.

In the case at hand, a previously healthy, homosexual young man had been admitted to the hospital after suddenly developing fever, cough, and acute respiratory distress. The tentative clinical diagnosis had been *Pn. carinii* pneumonia, or PCP. But the definitive diagnosis rested with us pathologists. The attending physician had sent us a bronchial lavage—fluid used to rinse the patient's lower airways, including the lungs—to inspect.

Sure enough, the fluid had the telltale signs of *Pn. carinii* infection: dark, boat-shaped organisms, blackened by the silver stain used for their identification, were suspended in the fluid. We excitedly discussed the new disease that was apparently sweeping across the country—what it might signify, and why these young homosexual men, who had never had any symptoms before, were deteriorating so rapidly, suffering from such an extraordinarily rare disease. We wondered about lifestyles, and speculated about whether the use of recreational drugs by the men was responsible for the outbreak. But we had no data, just conjectures.

Now, of course, more than two decades later, virtually everyone is well aware that the complex of acquired immunodeficiency, along with opportunistic infections and rare tumors such as Kaposi's sarcoma, together comprise the syndrome known as AIDS. As early as 1983, a vast intellectual and scientific effort had revealed the ultimate causative agent for the syndrome: the sexually transmitted human immunodeficiency virus, or HIV-1. (A second, possibly independently evolved strain, known as HIV-2, exists; it typically occurs in western Africa.)

Yet despite the identification of the causal agent, the best method for combating the global threat of AIDS remains a topic of debate and a source of confusion. The ravages of AIDS in Africa, particularly in East Africa, are horrific. In countries such as Uganda and Kenya, AIDS has severely reduced the population of reproductively active adults, leaving their children without parental guidance or care. By 2010, according to the United Nations Children's Fund, 20 million youths in sub-Saharan Africa will have been orphaned by AIDS. In South Africa 5 million people are infected, and India and Thailand are projected to experience similar disasters in years to come. Although highly effective AIDS drugs have been discovered in the past decade (often administered as a drug cocktail called HAART, or highly active antiretroviral therapy), their cost has made widespread availability and use unlikely and has provoked



a vitriolic debate over who should pay for them. So finding a way to prevent new cases would lift a great dark cloud that continues to hover over humankind.

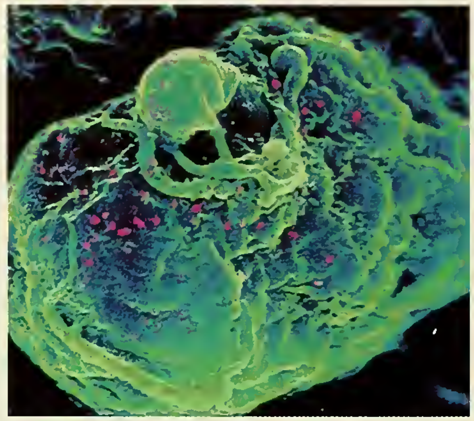
The best models for vaccines remain the ones given to counter the acute viral infections of childhood. Most of these infections are caused by lytic viruses, so called because they rupture cell membranes through a process known as lysis. Such viruses enter the host cell and then rapidly multiply inside the cell before killing it. A vaccine can block the process by introducing a weakened form of the infectious virus to the immune system. That induces an immune reaction—that is, the production of antibodies that can recognize and destroy normal forms of the virus—before an infection takes place.

Unfortunately, that strategy has not worked so far against HIV. There could be several reasons for the failure. For one thing, retroviruses such as HIV-1 are far stealthier than are lytic viruses. They can hide from immunological defenses for years inside their host cells. Furthermore, among the targets of the HIV-1 virus is the helper *T* cell, whose ordinary function is to orchestrate the response of the attack cells of the immune system. Such a wily subversion of the immune system may pose technical and conceptual problems that have yet to be faced.

David Baltimore, a molecular biologist who is now president of the California Institute of Technology in Pasadena, has posited another approach to the problem. Baltimore was the co-discoverer, with Howard M. Temin of the University of Wisconsin–Madison, of reverse transcriptase, the enzyme that enables retroviruses such as HIV to make a DNA version of their own RNA. (For their discovery, Baltimore and Temin shared the 1975 Nobel prize in physiology or medicine.) Baltimore's suggestion is to develop a method he calls intracellular immunization, to combat HIV. To understand the strategy, it may be useful to review some of the basic properties of viruses, and of the AIDS virus itself.

Entry and infection of helper T cell by HIV, the AIDS virus, is diagrammed schematically. An extracellular particle of HIV displays two linked proteins, gp120 (orange) and gp41 (green), on its surface (1). The first protein, gp120, fuses with two kinds of receptor on the outer membrane of the target cell (2): the so-called CD4 receptor and CCR5, which normally binds to a protein secreted by white blood cells. The second viral protein, gp41, attaches to a site on the target cell known as the fusion domain (3). The attachment causes the cell's membrane to fuse with the virus's, and lets the virus inside (4). There the virus releases its genetic material, in the form of RNA, as well as the enzyme reverse transcriptase (body cell, central part of diagram). With the help of the enzyme, the viral RNA is transcribed into DNA, which then integrates with the DNA in the target cell's nucleus. The cell, whose resources and machinery for making RNA and proteins are thereafter co-opted by the virus, begins releasing new HIV particles through its membrane to surrounding tissues.

All viruses, lytic viruses as well as retroviruses, lie in a gray area between things that are truly alive and things that are not. A truly living organism must be able to reproduce, and that implies it must carry two essential components: enough genetic information to specify how to make copies of itself, and appropriate machinery for making them. Viruses possess the first, in the form of either DNA or RNA, but they lack the second. More specifically, viruses have no systems to generate the energy needed to build long chains of nucleic acids; they have no way to synthesize the proteins that serve as protective coating for new viruses; and they carry none of the small precursors—sugars, phosphates, amino acids, and nucleotides—that are needed to assemble any of those larger molecules. In short, viruses travel light.



HIV particles, shown in false color (pink) in this electron micrograph, bud off an infected T cell.

Viruses therefore are known technically as obligate intracellular parasites. To replicate, they are obliged to hijack the cell's collected raw materials as well as its protein-making machinery. And to do that, they must be able to recognize the appropriate kinds of cell, and then enter such a cell to take advantage of its machinery.

HIV gains entry to its target cell with a pair of protein molecules called gp120 and gp41, which are attached like a hair to the virus's outer membrane, or "skin" [*see illustration on opposite page*]. Part of this molecular strand of "hair" is attracted to three other kinds of molecules attached to the surfaces of HIV's target cells, which the strand fits like a key in a lock. One of the target-cell molecules is a protein called CD4, which occurs on two cells of the immune system: helper *T* cells and macrophages. (Helper *T* cells recognize foreign substances and regulate the immune response to them. Macrophages ingest foreign particles and eliminate them from the body.)

The second target-cell molecule for HIV is a receptor known as CCR5, which normally binds to a small protein secreted by white blood cells when they encounter foreign materials. The third receptor, known as the fusion domain, is the target of gp41. When the viral protein gp120 binds to both a CD4 molecule and a chemokine receptor, and gp41 binds to the fusion domain, a "door" to the target cell swings open. The viral membrane fuses with the cell membrane, and the virus enters the cell.

Wasting no time, the virus deploys the reverse transcriptase it has brought along. The enzyme converts HIV's single-stranded genome, which is made of RNA, into double-stranded DNA. The newly minted DNA enters the cell's nucleus, where it splices itself into the DNA of the host cell. Once integrated with the host's genetic material, the DNA version of the retroviral RNA is called a provirus. The provirus now uses host resources to copy the DNA back into RNA molecules. The new RNA then plays a double role: it forms the genome for new virus particles, and it serves as the messenger RNA that instructs the cell to synthesize HIV's protein envelope. New viruses then bud off the host (rather than simply bursting it open, as the lytic viruses do). As one would expect, all this activity severely compromises the immune system of an infected individual: after all, the immune-system cells are working overtime to produce viruses rather than to fight them—or any other infectious agent.

The remnants of viruses that infected primate DNA 30 million years ago now make up 8 percent of the human genome.

Central to Baltimore's idea of intracellular immunization is a phenomenon known as viral interference. After one virus invades a host, any other virus becomes its competitor. The established virus best serves its own interests by excluding any would-be newcomers. Retroviruses such as HIV could minimize competition essentially by locking the door behind them, once they enter the host cell. To do that, their proviral DNA could direct the host cell to make enough receptor-binding protein to fill, say, all the CD4 receptor sites on the surface of the host cell. Blocking those sites would prevent the proteins of other HIV particles from attaching to the binding sites [*see illustration on page 44*].

Baltimore's idea is that an intentionally damaged or incomplete HIV provirus might be engineered that can produce receptor-blocking proteins without doing anything else to affect the host cell. The virus that gave rise to such a provirus could serve as a vaccine: like a dog in a manger, it would occupy a cell it could not use, but it would still keep out other viruses—in particular, undamaged, lethal HIV.

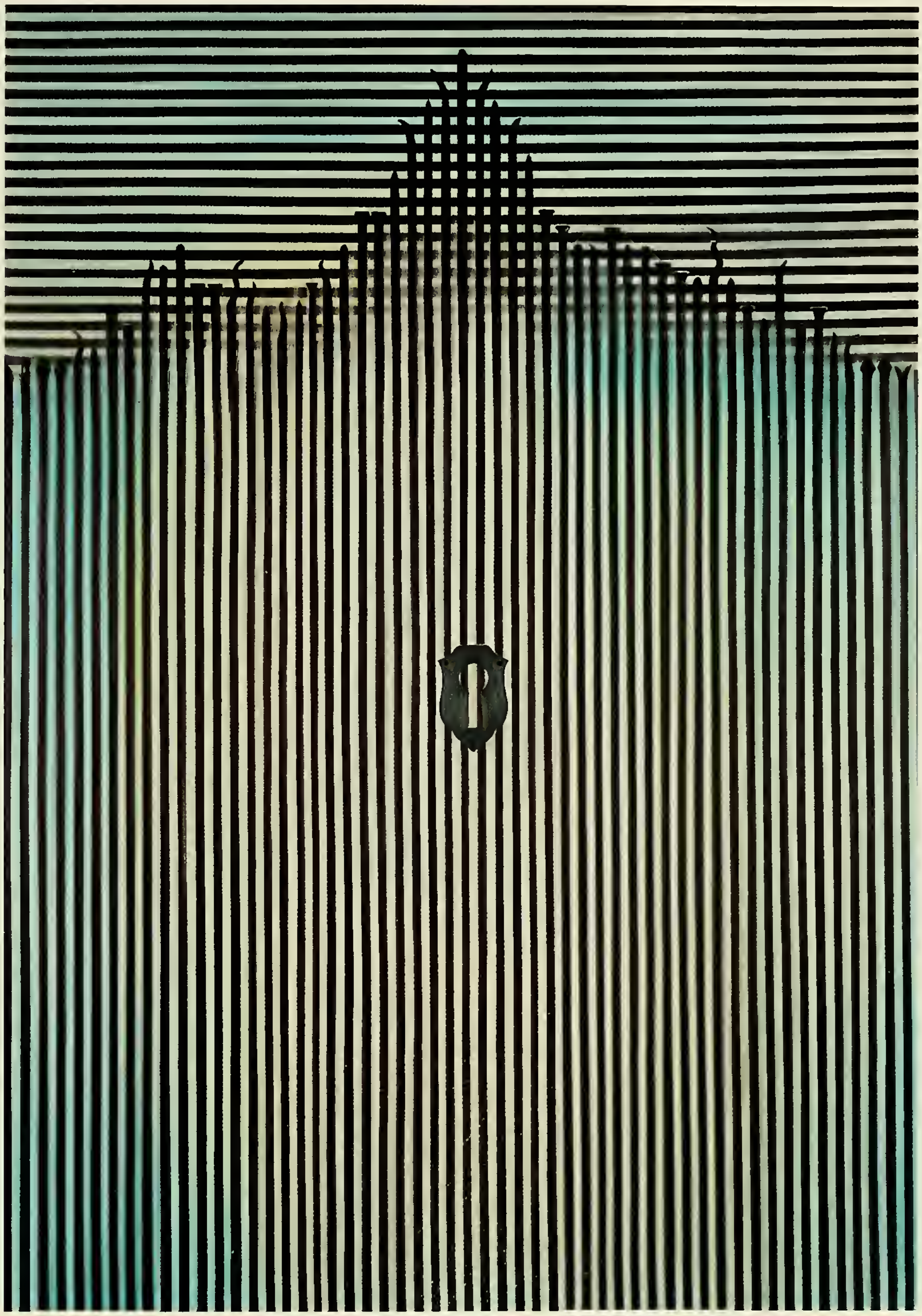
The strategy is not as far-fetched as it might seem. As I suggested earlier, proviral DNA from several different retroviruses comprises roughly 8 percent of the human genome. Fortunately, large chunks of the genetic material from the original retroviruses are missing from those proviral copies, and so the proviruses cannot make infectious viruses. Comparative genetic methods suggest these proviruses entered our primate lineage during a burst of retroviral infections about 30 million years ago, about the time the old and new world monkeys were diverging. What led to the infections then, or accounts for the relative lack of such activity ever since, is not known.

Nevertheless, these legacy chunks of proviral DNA are still partly functional within the human genome. Although they are too crippled to instruct human cells to make new retrovirus, they may block other retroviruses—at least retroviruses from the same family as the one that originally gave rise to the proviral DNA—from reinfecting our cells. Unfortunately, none of the proviral DNA is closely enough related to HIV to interfere with the HIV binding site, and so we as a species remain susceptible to the AIDS virus.

As with almost every evolutionary story, this one, too, has elements of conjecture and plausibility, but no definitive proof. It is clearly impossible for anyone to go back 30 million years and ask exactly what molecular events led these defective viral genomes to be incorporated inside our own. Yet in the late 1980s a team of pathologists led by Murray B. Gardner of the University of California, Davis, discovered that a group of mice had recently developed immunity to a retroviral infection in a way that probably mirrors what happened to our primate ancestors. The mice were undergoing what primates underwent 30 million years ago—and were showing, incidentally, that not every problem of human medicine can be answered by studying human beings.

Gardner and his colleagues became interested in retroviral infections among feral mice. In a barn on a squab farm near the town of Lake Casitas, California, they found a colony of mice in the throes of an epidemic. A particularly virulent retrovirus was spreading to young mice as they nursed. Yet within the closed population, some of the mice were clearly resistant to infection. Investigators analyzed the genomes of both the resistant and susceptible populations and quickly identified a stable, heritable genetic locus in the former group that was not present in the latter.

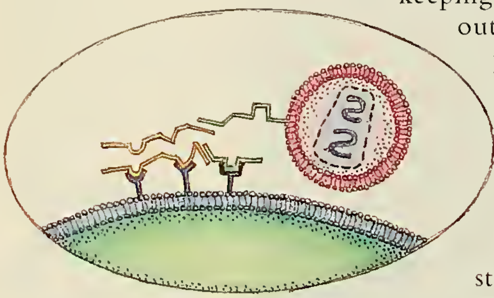
Molecular cloning of the locus showed that it carried a highly mutated form of the DNA copy of the retroviral genome infecting the colony. The data implied that within the group of virus-resistant mice, at least one founder had carried so many viruses in its bloodstream that the viruses were infecting other tissues, including germ cells. By the time the virus had become stably integrated with the germ-cell DNA, however, the virus had mutated, and so the mutated form was being passed



Ross Bleckner, *Gate #2*, 1986

along to the mouse progeny, just like the rest of the mouse genome.

The cells of these virus-resistant mice produced no viral particles. Instead, the cells produced just the viral proteins that would block the receptor molecules used by the viruses on the mouse cells, preventing complete, infectious viruses from entering. Even though the mice were presumably heavily exposed to the virus present in the barn, the defective copy of the virus they inherited was keeping new, lethal viruses out of their cells and protecting the lucky mice from the ravages of the disease.



Blocking the receptors to which the AIDS virus normally binds when it invades a cell should prevent HIV infection. To set up the blockage, virologists hope to add some viral genetic material to stem cells that generate white blood cells. The idea is that the white blood cells infected with the partial virus would produce the viral proteins gp120 (orange) and gp41 (green), but not complete virus particles. The viral proteins would then occupy the receptors on the white-blood-cell membrane that extracellular particles of HIV normally seek, essentially jamming the lock that HIV usually picks.

The Lake Casitas mouse colony offers an outstanding example of how evolutionary forces might deal with viral infections. Given the efficacy of the process, a number of investigators have begun to wonder whether a similar approach might work against HIV.

Donald B. Kohn and his collaborators at the Children's Hospital Los Angeles have been investigating the possibility of inoculating white blood cells such as *T* cells against HIV. White blood cells, red blood cells, and platelets are generated by a kind of stem cell in the bone marrow that displays a molecule called CD34 on its cell surface (the molecule lends its name to the stem cell as well). Infecting CD34 cells with defective HIV might offer an elegant way to treat people already infected with HIV.

Many leukemia patients and others have survived a medical procedure known as a bone-marrow transplant. In that procedure, the patient's marrow is irradiated to kill cancerous cells, and then non-cancerous stem cells from a donor are restored to repopulate the bone marrow. A similar treatment could help AIDS patients. If some of the CD34 cells were removed before irradiation and infected with defective copies of HIV, they could then be replaced after irradiation. As the replaced cells repopulated the bone marrow, they would give rise to *T* cells that also carried the genetic instructions for making defective HIV.

Such an "endogenous" copy of the retrovirus would then start making the viral protein, but not complete viral particles. The viral protein would block receptors used by complete HIV, protecting the *T* cells from infection by undamaged HIV, despite its presence elsewhere in the patient's body. In other words, what Kohn and his colleagues envision is to re-create the Lake Casitas scenario within the AIDS patient. And because the new *T* cells would not be consumed with making complete HIV, they could endow the AIDS patient with a functional immune system and increase the patient's life span.

Tampering with people's genomes can clearly lead to difficult ethical dilemmas, but Kohn's approach at least minimizes those dilemmas. For one thing, somatic, or body, cells, not germ cells, would be altered. Although the patient would acquire bone-marrow cells with defective provirus in their genomes, the reproduction of a complete retrovirus or its transmission to the next generation of people would be impossible.

Even if it turned out that such "defective" viruses, like the others I mentioned earlier, could reassemble themselves into intact viruses, such a treatment would not violate the physician's credo: "First, do no harm." After all, if the virus reverted to its fully functional form in a patient who was already infected with HIV, it would merely return the patient to the status quo ante. Without an effective technique to eliminate viral regeneration, however, using such treatment as a vaccine and providing it to an uninfected individual would constitute a serious moral blunder.

After more than twenty years of war against AIDS, it is intriguing that a colony of mice in an obscure barn might one day show the way to combating the disease. That is not to say the tactic is ready for the clinic. Present technical limitations make it unlikely that the therapy will become widely available in the near future. In principle, bone-marrow stem cells can give rise to every white and red blood cell circulating in the body, but in practice, so far, it has been hard to get transplanted stem cells to repopulate in large numbers. (Getting good repopulation is probably a surmountable technical problem.) And stem-cell inoculation would likely prove to be quite an expensive technique.

Yet there may come a time when patients in the poorest countries will be saved from dying of AIDS by the arcane pursuits of retroviral biologists. The lessons learned from models that seem so far removed from "real life" could make all the difference that matters in real situations to real patients in real countries. □

The Story of the British Museum, The Roman Empire and a UFO?

Not long ago, Thomas Cook was examining the strange and mysterious crop circles that had been cut into his farm in Lincolnshire England. While trying to define the origination of these "extraterrestrial" aberrations, he made a discovery that was much more down to Earth. He discovered a hoard of Roman Empire coins in a buried earthenware pot that dated to 270 AD! It was a find of a lifetime. He didn't find any evidence of a UFO but he did find an amazing archaeological site.

According to English antiquities law, these coins were quickly taken into possession by the British Museum where they were studied and cataloged in the archives. The coins received a full "treasure trove inquest" by the museum.

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The British Museum has allowed this offering to be made available to collectors since it has carefully studied and catalogued this amazing treasure. The First Federal Mint was fortunate to secure the last 4,993 of these rare Roman antiquities and is now releasing these ancient museum pieces to the public. Each is an original antiquity minted when the Roman Coliseum was still used by gladiators so this is a rare opportunity to own a true piece of ancient history.

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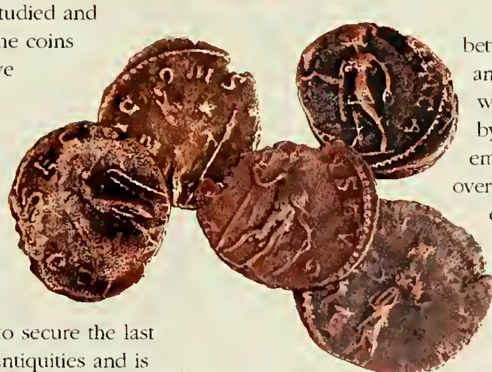

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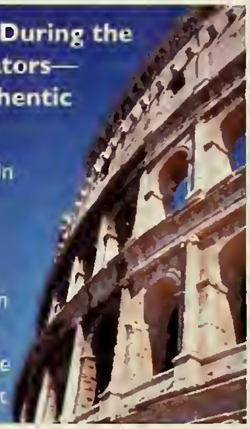

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Bluegill sunfish are social and spend much of their time in schools with other individuals of roughly the same age, foraging or, as shown here, just hanging out. Common in North American rivers and lakes, bluegills thrive in relatively shallow bodies of water with abundant weedy vegetation, such the emergent water lilies in this scene.

Something Fishy in the Nest

In many fish species, dad does the caregiving. But some sneaky bluegill males have ways of avoiding the responsibilities of fatherhood.

By Bryan D. Neff

Questions of fatherhood are a staple of dramatic conflict, whether in Greek tragedy, soap opera, or divorce court. In the natural world, too, conflicts brought on by uncertain paternity have opened up rich veins of phenomena for scientific investigation. Behavioral ecologists, who study how natural selection shapes animal behavior in light of ecological and social conditions, have long grappled with the role that parentage—genetic relatedness—plays in how much care fathers provide their young.

A fundamental principle of adaptation, growing out of Darwin's theory and elaborated in recent times by several prominent evolutionary biologists, is that individuals promote the spread of their own genes over the genes of competitors. The degree to which a male is sure he has sired offspring, then, should influence how much time and energy he invests in caring for them. To what extent that prediction might apply to human beings is a matter of debate; even for other animals, confirming it proves to be tricky.

Parental male bluegill defends his nest and young against perceived danger by facing the intruder (in this case the photographer) and flaring his pectoral fins. During such displays the dark "chest" of the male takes on a deep reddish hue (not visible in photograph).

DNA testing can determine who sired whom, but does the outcome of a DNA test really overwhelm other factors, such as parental age or number of offspring, that affect the time and energy an adult animal devotes to caretaking? Geneticists can determine family relationships via DNA fingerprinting, but can the males of animal species identify their young, and if so, how? And how much does care of the young by the biological parent matter anyway, so long as the genes of the parent survive? Those questions have intrigued me for more than a decade. Recently some answers have been emerging from work with a common freshwater fish I've found to be a finned exemplar of Shakespeare's line from *The Merchant of Venice:* "It is a wise father that knows his own child."

The bluegill sunfish *(Lepomis macrochirus),* a social, schooling species popular with anglers, is endemic to the freshwater lakes, ponds, and rivers of North America. The fish are particularly prolific in lakes with relatively shallow, warm water and plenty of weedy vegetation. Males, which are about 25 percent larger than females, range from eight inches long in southern Canada to fourteen inches in the southern United States. Young bluegills eat mainly zooplankton, but as they grow older, they become opportunistic and devour almost anything that fits into their mouths.

In bluegills, as in many other fish species, only the male cares for the offspring. During the summer breeding season, adult males called parentals venture near the shore of a lake, where they collect in colonies that may have hundreds of members, all ready to reproduce. The parental males fight fiercely for nesting sites in the center of the colony—in part because those locations provide the best available protection against such egg-feeding predators as catfish. Not surpris-

Each parental male in a large spawning colony makes his nest by sweeping his tail fin in the bed of a lake or river. The resulting bowl-shaped depression is about the size of a dinner plate.

ingly, the largest males usually secure the most central positions.

After staking out a spot, parental males construct nests by sweeping a bowl-shaped depression in the lake bed with their tail fins. Nests are about the size of large dinner plates and are positioned right next to one another in the crowded colony site. It takes a few days for the colonies to form. Once all the males have selected sites and built their nests, the general commotion subsides and the parentals await the females.

Then they arrive. A school of females that can number in the hundreds swims in, above the colony. What they look for in a mate is not yet known. But they do seem choosy, passing up numerous nests and potential mates before accepting one. Evolutionarily, of course, selecting a mate is critical: the offspring will not survive without proper care from a parental male. Yet once spawning begins, it lasts just a day—though it can recur several times in a season. During the day of spawning a female tilts her body and releases a spurt of about thirty eggs into a male's nest, a behavior known as a "dip." The male showers the eggs with his sperm. A female may dip many times into one male's nest, eventually leaving hundreds or even thousands of eggs. Then the females depart for deeper water and leave the males in charge.

I do much of my research in southeastern Ontario's Lake Opinicon, where the temperature-dependent spawning season is short. Colonies of bluegills typically spawn on eight distinct days, between five and seven days apart, from late May until early July. For the first two or three days after spawning, a parental male must oxygenate the eggs by fanning freshwater across them with his pectoral fins; any slacking off and the eggs will fail to hatch. By the fourth day the young fry emerge, and the male's main duty becomes protecting them from predators: bass, catfish, perch, and other sunfish. By the tenth day the fry leave the nesting area and fend for themselves. Tending the young takes a toll; males do not forage while caretaking, and so they lose about 15 percent of their body weight.

The sacrifices of parenting are not for all bluegill males, however. About 20 percent of them follow an entirely different reproductive course. Aptly called cuckolders (a term coined by Mart R. Gross, a conservation biologist at the University of Toronto), the bluegill males of this minority group mature at two years of age, several years earlier than the parentals. In the first phase of their sexual lives the cuckolders are referred to as "sneakers." After locating a spawning colony, they lurk behind rocks or debris near a nest until a female enters the nest depression. Just as she releases her eggs, the sneaker darts into the nest, discharges his sperm, and then hightails it out before the parental male can catch him. The tactic is risky, because the parental male has the edge in size: if he does manage to nab the intruder, he can easily kill him.

As a sneaker ages, he morphs into the very image of a female bluegill. By now he has grown too large to hide out near a nest, but mimicking a female allows him to brazenly enter the parental's nest in drag. Once there, he also adopts the behavior of a female bluegill. The mimic dips on his side and quivers just as the female does when she discharges her eggs. The deceit is effective: parental males cannot distinguish between the true female and the look-alike, and parentals appear all too happy to have both in the nest. Sometimes a parental will even court a mimic.

My colleagues and I have examined the sperm of mimics in the laboratory and found it to be highly similar to the sperm of parentals. Furthermore, DNA analysis demonstrates that in the 20 percent of spawnings in which cuckolders take part, their highly specialized tactics work: after invading a parental's nest, the cuckolder fertilizes nearly 80 percent of the thirty eggs released per female dip. Thus many offspring left in the care of the parental male are not his own.

Natural selection has not left parental males at the complete mercy of cuckolders—the mimics are simply not present at all dips, or are driven away in the sneaker stage by parental males. In the end it is the parental that fertilizes most of the hundreds or thousands of eggs in his nest. But the parental's devices to combat cuckoldry do not stop at spawning.

My research also has shown that parental males have evolved complex kin-recognition systems whose accuracy and sophistication rival our own. A parental bluegill has two distinct ways—one visual, one olfactory—of "judging" the kinship of the eggs and fry in his care. Because of the two methods of detection, and also because of the bluegills' stable lake environment, I was able to devise experiments that reliably tested predictions about caregiving and paternity.

First, my field assistants and I placed sneaker males in clear plastic containers, then showed them to some of the spawning parentals in our experimental group. The parentals could see the competition, but the sneakers could not actually release their sperm into the lake. We also put empty plastic containers within eyeshot of a control group of parental males. We found that parental males keep track of how many sneaker males they see loitering near their nests during spawning time. On the basis of that information, the parentals decide how much care to give the young. More precisely, compared with our controls, which saw no sneaker males, parental males that saw multiple sneakers nearby during spawning subsequently provided less care to the eggs: they fanned them less, or ate some of them, or even abandoned the nest altogether.

We then turned to smell, the second way bluegills can distinguish their own offspring. The odor, a chemical cue, may be emitted by the urine of newly hatched fry; it is not present in the eggs. Parentals that had already seen our sneaker males through a plastic container—and were thus informed that they had a good chance of being cuckolded—now "realized," via odor, that the fry were, after all, probably their own. Those parentals now reversed themselves and stepped up the level of care.

In the next experiment, I switched parts of egg clutches from one nest to another and then measured the degree of caregiving before and after the eggs hatched. Since eggs have no identifying odors, my actions could isolate smell as a means of detection. In the absence of cuckolders, experimental and control parental males showed no difference in caregiving before the fertilized eggs

A female and the larger parental male spawn amid sand and grass in only about two feet of water. Tilting and dipping to the side, the female releases about thirty eggs at a time; she will continue to dip and release until hundreds or even thousands of eggs are deposited in the nest depression.

Parental male (large bluegill sunfish at left) courts a female (center), as another male—a nonparental impersonating a female—sidles up at right. The parental male, unaware that the nonparental is a rival male, tolerates him. In about 20 percent of spawnings, a nonparental male, or so-called cuckolder, visits the nest of a parental male, fertilizes some of the eggs, and swims off.

were hatched. But after the eggs hatched, males whose nests had received alien eggs in bulk slackened off on nest defense. The smell of the fry also indicates the extent of cuckoldry: the more foreign fry placed in the nest , the more intense the cue. The nests most heavily parasitized by cuckolders were the ones most often abandoned.

Precisely how fishes and other animals recognize kin is hotly debated in the scientific community. In my view, the bluegill's ability to discern kinship depends on a process known as "self-referent phenotype matching." The idea is that an individual animal learns some salient aspect of its own phenotype—say, appearance or odor. Then, on the basis of that appearance or odor, the animal forms a template of what its kin should look or smell like. Potential kin are compared with the template, and if they match closely enough, they are accepted. Richard Dawkins, an evolutionary biologist at the University of Oxford, coined a pungent term for the mechanism: the "armpit effect."

But if the armpit effect holds, why don't the offspring of cuckolders take the next evolutionary step and learn to conceal their smell or otherwise blend in with legitimate fry? Such an "arms race" is common in biological systems. Here a three-way escalation would pit the offspring of the cuckolders (that would try not to be found out) against the surrogate parental males (that would not want to be fooled) against the genetic offspring (whose best bet would be to look and smell like their parents). Why has no such conflict come to pass?

The answer, I think, is that for the young of cuckolders, olfactory concealment is not the issue. Emitting no smell at all might not help much if a parental male is looking for a match to his own odor. Alternatively, how would the offspring of cuckolders be able to mimic the odor of a previously unknown and unrelated nest-tending parental male?

Perhaps, then, getting olfactorily lost in the crowd is the way to go. Given that thousands of fry occupy each nest, and that typically most of them are offspring of the parental male, a cuckolder's young could intersperse themselves with the parental's genetic offspring in order to mask their own alien odor.

That tactic, however, could lead to intense sibling rivalry. In some birds, for instance, siblings gang up on an unwanted brother or sister and may even physically push the victim out of the nest. Such seemingly mean-spirited behavior can be evolutionarily adaptive even when all the siblings are genuine. The remaining siblings will surely benefit from their increased share of the parent's resources, and that benefit will lead to the spread of the evictors' genes. And when the evicted occupant is unrelated to the other siblings in the nest, the parental investment in caretaking is more cleanly allocated to the parent's own genetic legacy.

Or is it? That brings me back once more to the further need to test the fundamental prediction of behavioral ecology: that individuals act to promote the spread of their own genes.

What happens among bluegill siblings? Is there any rivalry between the parental's and the cuckolder's fry? I plan to spend my next few summers back in Lake Opinicon, taking a close look at just-hatched bluegills. These fish have proved to be excellent subjects for testing some of the major theories of behavioral ecology. The bluegill nest may be the next arena for discovering other strategies that species find useful in playing the paternity game. □

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Why Must the Poor Be Sick?

Paul Farmer's exhortations sound familiar, and hopelessly idealistic, until you realize they are backed up by evidence and practical action.

By Jeffrey D. Sachs

Paul Farmer is a superb physician, a penetrating anthropologist, and a prophet of social justice. He combines an unflinching moral stance—that the poor deserve health care just as much as the rich do—with scientific expertise and boundless dedication. He has saved the lives of countless destitute patients in Haiti, Peru, and Russia, and he has shown that effective health services, even complex medical regimens, can be put in place in impoverished communities. His accomplishments have forcefully undercut the flimsy excuses that the rich countries have routinely offered for their inaction, as millions of people die unnecessarily each year in the poor countries. Farmer's moral philosophy, anthropological insights, and medical successes are described in his trenchant and timely new book, *Pathologies of Power.*

Pathologies of Power: Health, Human Rights, and the New War on the Poor
by Paul Farmer
University of California Press, 2003; $27.50

The case studies Farmer presents have three main themes. First, the poor are not the victims of their sins but of their circumstances; instead of sitting in judgment on the sick and dying, the rich countries should be helping to save them. Second, the poor can be successfully treated and cured of disease, even in the most unlikely and impoverished circumstances. Third, the human rights community should be defending the rights of the poor to health, for without the right to health, all other human rights are likely to prove empty. Nothing, Farmer argues, except practical, physical resources—in ample supply throughout the rich world—is keeping the poor world from undergoing a revolution in health.

These arguments are highly persuasive. Even though, at a couple of points, Farmer's emphasis is flawed, his overall arguments are so compelling, in fact, that they are having a significant effect on international health policy.

Farmer's moral stance is grounded in what the liberation theology movement calls a "preferential option for the poor," a principle of Roman Catholic social teaching that enjoins the rich to offer dignity and material support to the poor. Farmer's key epidemiological insight is a powerful, if ironic, twist on this moral dictum: pathogens such as the ones that cause tuberculosis and AIDS also show a preferential option for the poor. What Farmer is saying is that disease, too, follows class lines, tracking down and killing the poor with particular ferocity. Not only do the poor lack access to effective health services, he points out, but they are also systematically forced to live in circumstances that undermine their health and all too frequently claim their lives.

Farmer's many elaborations of this central anthropological insight come into excruciating focus as he tells the

personal stories of the indigent. He listens carefully to his patients and thereby uncovers the grim logic that led to their tragic conditions.

A young Haitian woman arrives at his clinic, already near death's door with AIDS. Her short life has been harrowing. For generations her family had farmed a fertile Haitian valley. Then one day they became refugees in their own country, displaced by a major dam project. Like other refugee families in their settlement, they fell into extreme poverty.

Because she was a young woman, she was harassed by the soldiers who prey on the vulnerable refugee community. In desperation, she entered warily into a sexual liaison with an army captain, who offered some promise of economic stability. But the captain had AIDS, a disease about which she had no knowledge; he died of the disease soon thereafter. The woman tried to save herself and her family by moving to Port-au-Prince and working, for minimal wages, as a housekeeper. Soon enough, she, too, was dying of AIDS.

It is Farmer's deep humanity that draws him beyond what could be just another hopeless clinical case of AIDS, a mere statistic, to the woman's life story and the stories of countless others like her. Such people, as Farmer dramatically illustrates in one example

Displaced Rwandans in a refugee camp at Benako, Tanzania, 1984

Washing clothes in a muddy pool in the slums of Port-au-Prince, Haiti

after another, have been caught in the grip of AIDS, not because of sins or misbehavior, but because of poverty—not by accident, but because of the structural fabric of their societies. That realization is filled with far-reaching implications for controlling the transmission of infectious diseases and treating them successfully within a community.

I do have one quibble with Farmer's account, however, that I believe leads his analysis astray, though not his conclusions. His Haitian patients have clearly suffered from what he calls "structural violence." Poverty indeed leaves people vulnerable to violence, not only to the violence of terrible disease but also to the more literal violence perpetrated by other people, who take cruel advantage of the desperate circumstances of the poor. That structural violence, in turn, traps the poor in their predicament, closing the avenues of escape. Farmer claims his term is apt "because such suffering is 'structured' by historically given (and often economically driven) processes and forces that conspire . . . to constrain agency."

But he goes on to suggest, often implicitly and sometimes explicitly, that structural violence is the key barrier to the escape from poverty. In essence, he occasionally comes close to espousing a neo-Marxist theory, according to which extreme poverty persists mainly because of exploitation by the rich and powerful. For example, he favorably quotes two liberation theologians who argue that poverty today "is mainly the result of a contradictory development, in which the rich become steadily richer, and the poor become steadily poorer."

That is not correct for two reasons. First, Haiti aside, the rich are not, in general, getting richer and the poor, poorer. The Haitian experience does not shed much light on the massive reduction of poverty in Asia in the past quarter century, particularly in China and India. Nor does it properly apply even to Haiti's next-door neighbor, the Dominican Republic, which underwent notable declines in child mortality and illiteracy in the past generation, and a similar decline in the proportion of households with incomes too low to meet basic needs.

Second, and just as important, there are many structural causes of extreme poverty that are not related to "contradictory development" or to "structural violence." A number of other factors can present steep barriers to economic development: an ecology that readily spreads disease (for example, the presence of particular mosquito vectors

and climate conditions conducive to high rates of malaria transmission); physical isolation (communities living in mountains or rainforests); adverse biophysical conditions for food production (such as vulnerability to drought and poor soils). But Farmer's overriding message—that the poor are not to blame for their poverty—is emphatically correct, even though his specific diagnosis of "structural violence" appears too limited to offer a truly global perspective on poverty.

Farmer's second major theme, that the poor can be treated—that they need not be left to die as a result of their structural conditions—is also right on target. In fact, his work is best known worldwide for the successful treatment of patients under what seem extraordinarily adverse conditions. He has shown—in his clinic in impoverished Haiti, treating tuberculosis and AIDS; and in the shantytowns of Peru and the prisons of Russia, treating multidrug-resistant tuberculosis (MDR-TB)—that high-quality medical care can be delivered successfully in what would seem to be the least propitious of settings.

Contrary to stereotypes prevalent within the bureaucracies of rich countries and international development agencies, the destitute and vulnerable patients that Farmer comes into contact with are smart, resourceful, and absolutely intent on staying alive. They adhere even to complicated drug regimens, provided those regimens are properly explained. And Farmer has raised the level of adherence through clever innovations attuned to the needs of diverse communities. For example, he applied the TB procedure known as "directly observed therapy" to AIDS treatment, sending out trained but often illiterate Haitian community-health workers every day from the clinic to patients in outlying villages.

Farmer's genius was to treat his HIV/AIDS and MDR-TB patients without asking permission from the official aid agencies. They would surely have said no. He was one of the first to introduce antiretroviral combination therapy for low-income AIDS patients, mainly with donated drugs. And his clinical results were extremely positive. His pioneering work with MDR-TB patients led to intense squabbles in the international health community, which felt that MDR-TB would be too hard and too expensive to tackle in places lacking substantial economic resources. Yet through persistence and vision (and with the help of a few pilfered supplies along the way), Farmer and his colleague Jim Kim, of the Harvard Medical School, not only demonstrated clinical efficacy in treating MDR-TB and HIV/AIDS, but also showed that drug prices could be sharply reduced through aggressive negotiations.

Pavement dweller, Delhi, India

As their successes have become apparent, Farmer, Kim, and their colleagues have increasingly focused on persuading policy makers to make a bold commitment to improved health care among the world's poor. Hence, the third theme of Farmer's collected essays is his message for the human rights community: that human rights are indivisible, that so-called social and economic rights must accompany civil and political rights. Making such a shift of emphasis would be a sea change for a community that has traditionally been organized around the defense of civil and political rights alone.

Once more Farmer is an acute observer and a compelling advocate. Again and again he shows that when poor people are abandoned to their economic fate, merely defending their civil rights will not keep them alive—much less give them a chance for a dignified and prosperous life. Farmer is surely being strategically wise to reach out to the civil rights community: the codifications of human rights that have emerged from the UN (both the 1948 Universal Declaration of Human Rights and the 1976 International Covenant on Economic, Social and Cultural Rights) are potent tools that can bolster Farmer's case for greater global attention to the health needs of the poor.

An alliance of public health and human rights will not be enough, however. Farmer's arguments will need to prevail in the capitals and international institutions of the rich world as well. Billions of dollars of rich-world income will have to be channeled to the poorest countries to fight the multiple challenges of AIDS, malaria, TB, and other disease killers that hold poor societies in thrall. And funding on such a scale is not the impossibility it might seem. On the contrary, I have direct and personal evidence that Farmer's successes, properly explained, can help move mountains.

At the end of 1999, the presiding director general of the World Health Organization (WHO), Gro Harlem Brundtland, asked me to chair a Commission on Macroeconomics and Health. The commission was designed explicitly to bridge the worlds of high finance and global health. I advocated large increases in development assistance for health in the poorest countries, and I recommended, in mid-2000, that a global fund be established to fight AIDS.

Later that year Farmer invited me to visit his clinic in central Haiti. The experience was pivotal. There is nothing like proof by example to motivate potential donors. Many AIDS clinicians already knew that AIDS could be treated in low-resource settings. But Farmer and his colleagues proved it. (An article describing their methods and results in Haiti was published in the journal *Lancet* in 2001.)

I returned again and again to Farmer's proof of concept in my subsequent work, both with UN Secretary-General Kofi Annan in helping to design and launch the Global Fund to Fight AIDS, Tuberculosis and Malaria, and with George W. Bush's White House in initiating a large-scale, U.S.-funded effort to control AIDS. So, too, did a growing flood of politicians and health-policy makers from around the world. The word truly did go forth from Haiti's Central Plateau.

A huge effort still awaits. Although a global effort to fight these diseases now exists, it is grossly underfunded (happily, Farmer did receive a large grant from the fund to expand his operations in Haiti). And though a $15 billion, five-year U.S. program to control AIDS in Africa and the Caribbean has been authorized, it has not yet gotten off the ground. The overall level of donor assistance for improving health in the poorest countries is growing, but it is still only a small fraction of what is needed. The WHO Commission on Macroeconomics and Health has calculated that about $25 billion a year from the rich world, directed at low-income countries, might avert as many as 8 million deaths a year. Yet $25 billion is about eight times the current level of rich-country financial assistance for health to low-income countries, and a small fraction of the cost of the war in Iraq. Fortunately, Jim Kim has now joined the WHO leadership team, and he is pushing hard for global efforts to scale up health investments in poor countries.

"We need to be untrammeled by obligations to powerful states and international bureaucracies," Farmer urges. It's an understandable sentiment from a bold and visionary iconoclast who has proved that the assessments of those at the centers of power are wrong, that they are stingy and shortsighted. Yet the real fight ahead is not the struggle of the poor to free themselves of obligations to the powerful. Rather, the battle is to instill a deep sense of mutual obligation between rich and poor. The rich have an obligation to the poor, to help the poor stay alive in the face of structural impediments of lethal dimensions. The poor have an obligation to work together with the rich, to ensure that assistance is well used and delivered to those who most urgently need it. And all of us have an obligation to heed Farmer's deep witness of our common humanity.

Jeffrey D. Sachs is Director of the Earth Institute at Columbia University and Special Advisor to UN Secretary-General Kofi Annan on the Millennium Development Goals.

By Laurence A. Marschall

A Brand-New Bird: How Two Amateur Scientists Created the First Genetically Engineered Animal
by Tim Birkhead
Basic Books, 2003; $26.00

Canary yellow, strange to relate, is not the natural color of canaries. In its native habitat, the Canary Islands, the bird is a nondescript greenish songster with a melodious warble. First brought to Europe in the fifteenth century, canaries became the prize possessions of royalty, who treasured them for the beauty of their song, not the color of their plumage. In an age before radio and CDs, songbirds were a welcome source of background music, brightening idle hours and relieving the boredom of repetitive work.

Over the centuries, though, songbirds became the hobby of bird fanciers, who selectively bred them for particular characteristics. Bird aficionados in Germany selected canaries for the strength and complexity of their song. Elsewhere in Europe, canary collectors emphasized unusual size, posture, or color, creating a remarkable variety of breeds that included the now-familiar yellow canary, but also others that were pure white, or mixtures of black, green, orange, and yellow.


Crimson canary, the modern realization of Hans Duncker's vision

According to Tim Birkhead, a professor of evolutionary biology at the University of Sheffield in England, the idea of creating a crimson canary came to Hans Duncker, a German high school teacher, in the mid-1920s. An ardent Darwinist trained in Mendelian genetics, Duncker was collaborating with an amateur canary fancier named Karl Reich on several breeding projects.

Reich had the bird breeder's equivalent of a green thumb, and was known among bird hobbyists for training canaries to sing the song of the nightingale. Duncker brought to the collaboration a trained scientific mind and an impressive command of the latest ideas in genetics. Their goal was to cross a yellow canary with a now-rare South American bird, the red siskin, creating a hybrid that would combine the fiery plumage of the siskin with the vocal talent of the canary. Duncker's breeding plan was based on a state-of-the-art genetic analysis, and though he and Reich never got the brilliant red plumage they were seeking, their work brought them fame and led to a better understanding of how both genetic and environmental factors affect variation in individuals.

Although the Duncker-Reich collaboration provides a unifying theme, it is a story only an obsessive bird lover would celebrate. Fortunately, only a small part of the narrative is taken up by it, and the real delight of the book is its frequent sidetracks into the biology, culture, lore, and politics of birds. Birkhead devotes several pages, for instance, to a description of musical instruments designed to teach songbirds how to sing.

He also includes several enlightening passages on the importance of canaries as gas detectors in coal mines, and a section on the sexual symbolism of birds (we learn that *uccello*, Italian for "bird," is slang for "penis," just as "cock" is in English). And there is a lengthy digression on catching and cooking songbirds.

Readers will search the body of the book in vain, however, for details about the "genetically engineered animal" of the subtitle. Taken in the modern sense, genetic engineering implies artificially implanting foreign DNA into the cells of a host animal.

Duncker and Reich, of course, as Birkhead remarks in his preface, knew nothing of molecular biology. They merely applied the familiar techniques of hybridization, augmented with the insights of Mendel's genetics. Charges of false advertising might be in order (probably against an overzealous editor looking to hook readers), but the author cannot be faulted for producing a thoroughly enjoyable book.

Surviving the Extremes: A Doctor's Journey to the Limits of Human Endurance
by Kenneth Kamler
Saint Martin's Press, 2004; $24.95

For me, and I imagine for most readers of this magazine, just about the only circumstances that require survival skills are those awful weeks in the year when public radio stations hold their fund-raising marathons. The physician Kenneth Kamler, however, knows the real meaning of endurance. A specialist in microsurgery of the hand, he's also an officer of the Explorers Club and has made a second career providing medical care to scientific expeditions and adventure travelers.

Kamler has seen a lot of people at the razor's edge of danger and heard a lot of harrowing stories, both about people who cheated death and about others who didn't but tried. His accounts of how it's possible to stay alive in exceptionally threatening conditions cover six extreme environments—the depths of the ocean, the high seas, deserts, tropical rainforests, the high mountains, and outer space. The book is too anecdotal to serve as an all-purpose survival manual, yet it is filled with tidbits of highly entertaining and—you never know!—useful information about the dangers to life and limb that people face when they push into territories that punish the body in ways even medieval torturers could admire.

Maybe someday, sticky and sweaty, I'll be tempted to skinny-dip in some meandering tributary of the Amazon River. Although I'm no prude, I will make it a point not to undress completely, remembering Kamler's description of the indigenous candiru:

> [It is] a kind of catfish, about the size and shape of a toothpick. Attracted to salt, such as that contained in the urine within a human bladder, it is small enough to swim through a male or female's genital opening and get lodged in the urethral tube. The fish's stiff pectoral fins angle backward; there is no way to pull it out. It has to be removed surgically.

Even with a generous health plan, that sounds like surgery to be avoided at all costs.

Nor is it beyond the range of possibility that one day I may find myself out of gas in the desert. Looking woefully at the unmoving dashboard gauge, I will surely recall Kamler's story of a mother and her two sons who lost their way in the Tunisian Sahara and died after trying to return to their car, which was only an hour's walk away. Thus fortified, I'll husband the gallons I've providentially brought along for emergencies, hunker down in the shade, and—if necessary—travel in the cool of night.

Rappelling a crevasse in Antarctica

Kamler is at his best, however, when he writes of places most people have no intention of visiting. He was on Mount Everest in 1996, when eight climbers died in a raging storm.

Already on his way to the top, and alerted to the situation, Kamler set up a high-mountain emergency first-aid tent. And during the stormy night Beck Weathers, a climber-physician himself, who had been left for dead by rescue crews, stumbled into it and, to everyone's disbelief, re-entered the world of the living.

The most detailed yarns, of course, focus on the fortunate few who, faced with an impossible situation, beat the odds and came back to tell about it. Kamler tries to explain how they did it. He makes a strong case that survivors are often the ones able to assess their plight rationally and find inventive ways to improve a bad situation. Even with those skills, he concludes, survival requires a strong will—not a surprising conclusion, but one that may lead some readers to be overly optimistic. Willpower, even when coupled with the finest gear and the best training and conditioning, won't keep a climber alive on Everest in a blinding blizzard, or bring a diver trapped in an undersea cave back to the surface.

Fortunately, the point is pretty academic. Very few of us will ever have to face a cerebral edema at 26,000 feet, or a nest of squirming bot fly larvae that must be dug out of an arm with a makeshift knife. And so these accounts of people who endure extreme physical trials can be recommended primarily as hints for surviving the ordeals of everyday life. In short, Kamler's book is a terrific diversion when you can't take the blather on the tube, and all the good radio stations are asking for donations.

The Land That Never Was: Sir Gregor MacGregor and the Most Audacious Fraud in History
by David Sinclair
Da Capo Press, 2004; $23.00

Before there was a bridge for sale in Brooklyn, there was land for the gullible in Poyais. Poyais? Ah . . . yes, that new republic on the Caribbean coast of Central America, the talk of the town. The year was 1822, a bull market was raging in London and Edinburgh, and the banking houses were abuzz with the news that Sir Gregor MacGregor was offering acreage in the New World at bargain prices.

If either Poyais or Sir Gregor's impressive credentials were unfamiliar, the potential settlers might have picked up Thomas Strangeways's *Sketch of the Mosquito Shore* (a reference, according to accounts of the day, to a cluster of small nearshore islands and rock formations—not to bugs), published that same year. The aptly named, but otherwise unknown, author described Poyais as a veritable Garden of Eden, with plenty of rich soil for growing idle money. Sugar, cocoa, and coffee were readily cultivated, and cotton grew wild. Saint Joseph, the capital city, was a model of European efficiency, its government and financial institutions ready and waiting for the inevitable flood of developers. Investors were impressed not only by the promise of easy wealth but by the romance of a tropical paradise where they could plant the flag of Anglo-Saxon culture in the heart of Spanish territory.

Two boatloads of settlers left the British Isles for Poyais in 1822 and 1823. It was only after the sea-weary travelers from the two voyages had been summarily dumped on the beach, and the chartered ships had disappeared over the horizon, that the luckless immigrants turned around and saw what they had bought.

Poyais was pure fiction. There were the rotting remains of an abandoned stockade, but no cities, no plantations, no mines or quarries, no docks or warehouses or public buildings. There was, undoubtedly, plenty of tangled forest, plenty of swampland, and more than enough mosquito-borne malaria and yellow fever to go around. Confusion turned to chagrin, then to anger, as most of the colonists beat a hasty retreat to the nearby British enclave of Belize. But before they could find passage out of the region, some 180 of the original 250 or so settlers died of tropical diseases. The survivors who straggled back to England found themselves without the resources to seek equitable restitution.

The bond issues, land sales, and trumped-up currency of the imaginary Territory of Poyais were all part of an old-fashioned scam. The monumental fraud had enlisted the credulity not only of starry-eyed adventurers but also of earnest bankers, profit-hungry land agents, and an old-boy network of tin-medal aristocrats. So convincing was Sir Gregor that he had duped them all.

Paul Nash, *Landscape from a Dream*, 1936–38

Journalist David Sinclair has drawn on a wealth of contemporary sources to create a deliciously detailed account of the great deception, as fantastic as a novel of magic realism by Gabriel García Márquez. According to Sinclair, everything that MacGregor claimed turned out to be a lie, or at best a shading of the truth. Humbug to the end, MacGregor parlayed his dubious record as a compadre of Bolívar into a pension from the Venezuelan government, and even managed to have the last laugh: he was interred in the cathedral in Caracas, with full military honors, in 1845.

Laurence A. Marschall, author of The Supernova Story, *is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.*

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Clicks Are for Kids

By Robert Anderson

Hundreds of interactive science Web sites for young people are just a click away via the Internet, in disciplines from astronomy to zoology. Finding good ones, though, on topics that really interest children, isn't easy. I wasted a lot of time until I stumbled on Science NetLinks (sciencenetlinks.com), an educational project conceived and operated by the American Association for the Advancement of Science (AAAS). A visit to this site beats scrolling through the hits from a Google or Yahoo search, hands down.

Science NetLinks is a virtual Grand Central Station for kids (and for parents and teachers) trying to reach Web sites that are both instructive and fun. On the home page, choose "Tools" from the menu bar at the top ("tools" is Science NetLink-speak for subject matter). Tools include such topics as "Exploring Caves," "Heat," "Simple Machines," and "The Water Cycle at Work." When you click on such an item, you jump to a Web-site link, a short description of the site, and some grade-appropriate activities relevant to the site's resources.

For example, the tool called "Monster Bugs," for children in kindergarten through second grade, features a Web site that helps teach about systems and their parts. When you click on the Web link, you're transported to a page of the "Magic School Bus" site, where you can build your own insects from a selection of bug body parts. (It's one of my kids' favorite Web pages.)

Helpful hints for bug construction are available at another tool, "Bug Bios," which advertises "shameless promotion of insect appreciation" through macrophotography—150 spectacular color enlargements. "Nowhere to Hide" focuses on evolution, with a simple, amusing demonstration of natural selection, and "Lunar Cycle 2: The Challenge" tests young astronomy fans on what they know about the phases of the Moon.

For grades three through five, try the tool "MARE's Build a Fish." The game at this site challenges children to put together a fish with the right characteristics to thrive in one of six ocean habitats—an engaging way to learn about species adaptation. A similar game, for grades six through eight, can be found at the tool "Walking With Beasts."

"Powers of Ten," for grades nine through twelve, directs you to a simple but highly effective scale-of-the-universe site at Florida State University. Based on a film originally conceived by designers Charles and Ray Eames, the visuals here are enhanced by a brief mathematical explanation of exponential notation.

Among the "Resources" listed at Science NetLinks (also available from the main menu bar), I found a long-time favorite, San Francisco's Exploratorium (www.exploratorium.edu), which includes some 15,000 pages. For games, click on "explore" on the menu bar at the top, then on "online activities" in the small green menu at the right. Also listed is NASA's "Quest" site (quest.arc.nasa.gov), which I found to be a great place for kids to learn why our planet is so special. Click on "Astro-Venture" (astroventure.arc.nasa.gov), which appears on the illustrated menu below the title. Here a child can play the role of astronomer, biologist, or geologist, practicing scientific inquiry to search the heavens for a planet and build it into a place suitable for human habitation.

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

(Continued from page 21)

And so the cosmological quest for homogeneity and isotropy comes to an end. First astrophysicists sought those characteristics, primarily on aesthetic grounds; then we found them, on very large scales. Then all the big-bang theorists wanted homogeneity and isotropy to go away—because ever since Newton, it has been clear that the existence of everything familiar requires the seeds of matter to have been planted by small-scale anisotropies.

Fortunately, the NASA satellite known as the Wilkinson Microwave Anisotropy Probe, or WMAP (note that its name makes no bones about the object of its search), found anisotropy aplenty in the CMB, manifested in minute differences in temperature. The typical difference is no more than a hundred-thousandth of a degree hotter or cooler than the average background temperature, and so the CMB is as smooth as a mile-wide pond with half-inch waves. Small as they were, however, those temperature variations were enough to get the show on the road.

In the WMAP portrait of the cosmic background [*see "Sharper Focus," by Charles Liu, May 2003*], the larger the hot spot, the denser the agglomeration of atoms. Billions of years later (albeit still billions of years in our past—remember, what WMAP sees is light that is roughly 13.7 billion years old), those hot spots would give rise to superclusters. In other words, in those regions gravity would beat out the expansion of the universe and gather enough matter so that superclusters would eventually be created. Excluding the dark matter, those regions would accumulate the mass-equivalent of 10^{14} Suns—or about a thousand galaxies, each with 100 billion stars. Conversely, the larger cool spots, having had no head start against the cosmic expansion, would remain devoid of massive structures.

Whenever I think about the diverse and elaborate architecture of the universe, I cannot help but stand in awe of certain facts. Quantum fluctuations in the distribution of matter and energy—heterogeneities billions of times smaller than the size of a proton—spawned superclusters of galaxies 100 million light-years across. From chaos to cosmos, that chain of cause and effect crosses more than thirty-eight powers of ten in size and fifty-two powers of ten in time. As with the microscopic strands of DNA that shape the identity of a species and the uniqueness of an individual, the modern look and feel of the cosmos was writ in the fabric of its earliest moments, and carried relentlessly through time and space. I not only know this intellectually, I feel it emotionally. I feel it when I look up. I feel it when I look down. I feel it when I look within.

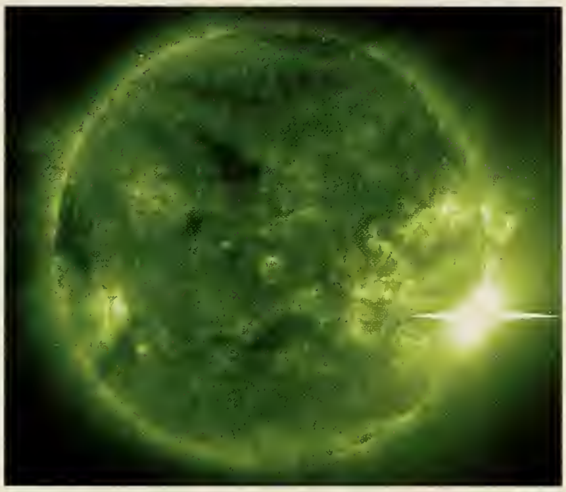
Astrophysicist Neil deGrasse Tyson is the Frederick P. Rose Director of the Hayden Planetarium in New York City.

Our Stormy Sun

What do refrigerator magnets, northern lights, and solar flares have in common?

By Charles Liu

Late last year a huge solar flare erupted from a massive sunspot, with a blast of X rays so intense that detectors aboard the Earth-orbiting Geostationary Operational Environmental Satellite (GOES) went off scale for more than eleven minutes. A day later, astronomers confirmed that the flare was by far the most powerful ever recorded, obliterating the previous record set in 1989 and matched in 2001.



False-color photograph of the solar flare of November 4, 2003, shows its record-setting X-ray burst. Solar flares are to solar storms (sunspots) what lightning strikes are to thunderstorms on Earth. Huge ejections of matter emanating from solar storms may herald a reversal of the Sun's magnetic poles.

The flare put an exclamation point on a fortnight of unprecedented storminess on the Sun. It also drew unprecedented media attention to the Sun, just 93 million miles away, and to the electromagnetic disruptions its violent surface can cause on Earth: power outages, disrupted communications, satellites lost through damaged electronics. But dire warnings of potential solar disaster, though good news copy, are at best unreliable.

Although the understanding of solar activity—including the origins and life histories of solar storms—remains poor, solar scientists are making steady progress in unraveling the mysteries of the Sun. A recent example is a study led by Natchimuthuk Gopalswamy, a solar astronomer at NASA's Goddard Space Flight Center in Greenbelt, Maryland, which makes a new connection between two great solar puzzles: what gives rise to coronal mass ejections—vast clouds of ionized gas thrown outward during solar storms—and why the Sun's vast magnetic field periodically flips polarity.

Most everyone who has used a compass knows that our planet has a magnetic field; at Earth's surface, it is slightly weaker than that of a typical refrigerator magnet. Our star's magnetic field is just a bit stronger than Earth's, but like any other magnet, its strength and direction can be represented as the density and direction of field lines that run between its north and south magnetic poles. The difference is that those field lines are enmeshed within the electrically charged, superheated plasma that comprises the body of the Sun.

Unlike a solid refrigerator magnet, the Sun has a restless interior. Heat gets transferred from deep inside the Sun to its surface as hot gas swells outward, cools off, and then plunges inward again, back and forth in a cycle. The Sun also spins unevenly: a "day" on its surface lasts about thirty-one Earth days near the Sun's poles, but only about twenty-seven Earth days at its equator. Huge gobs of Sun-stuff are pushed in and out, then pulled round and round in the chaotic turbulence. The magnetic field lines get dragged around as well, stretching, twisting, and tangling within the plasma into dense, messy knots.

When the knots emerge at the surface, they appear as sunspots; when too many field lines get tangled up in one spot, conditions become highly unstable. The tangled field lines act like a coiled steel spring too tightly wound, which can suddenly snap and realign. All the energy built up by the twisting of the plasma is suddenly released, as if millions of atomic bombs exploded in just a few seconds. Such an eruption of energy manifests itself as a solar flare. Often such magnetic realignments cause billions of tons of solar matter to be ejected outward through the solar corona—an event called, unsurprisingly, a coronal mass ejection (CME). The cloud of magnetized gas typically gets launched into space at several million miles an hour, fast enough to reach Earth in a day or so.

Huge amounts of charged matter swarming over our planet can damage delicate satellite electronics and overload unprotected power grids. Usually, though, the solar particles released by a CME only produce a harmless light show; deflected by Earth's magnetic field, they crash into gas particles in the upper atmosphere and set them aglow, creating auroras—the northern and southern lights.

Sunspots and coronal mass ejections are localized phenomena. Although often large enough to swallow several Earths, they still erupt across just a small fraction of the Sun's surface. But the Sun's internal motions cause another, larger-scale magnetic effect: the reversal of the Sun's magnetic poles. Over a roughly eleven-year period, coinciding with the solar sunspot cycle, the Sun's north magnetic pole gradually diminishes in its "north-ness." Then, after a period of seeming indecision, it becomes the south magnetic pole, increasing its "south-ness" to maximum strength. During the next eleven years, the now-south pole switches back again into the north pole. The same process happens in reverse at the Sun's south magnetic pole. (The process is not really as bizarre as it sounds—the Earth's magnetic poles flip too, albeit on much longer timescales; the planet's most recent polar reversal took place 780,000 years ago.)

Since both coronal mass ejections and polarity reversals are aspects of solar magnetism, astronomers have long suspected that the two phenomena are somehow fundamentally connected. Now Gopalswamy and his colleagues have uncovered some hard evidence to support that idea. Analyzing data gathered by Sun-watching satellites in the past quarter century, they found that the number of CMEs generated near the solar poles increases dramatically just before the polarity reverses. Then, after the reversal is completed, the CME rate drops to near zero. Gopalswamy's group hypothesizes that CMEs are how the Sun expels the last bits of the old "north-ness" or "south-ness" from a magnetic pole, making way for the new, opposite magnetic orientation. For those who like comparisons, think of the Sun as a cosmic kitty, throwing up CME hairballs to regulate its internal magnetic balance.

As you've probably noticed by now, the solar storms of 2003 didn't amount to much here on Earth. Only one of the many CMEs launched toward our planet caused significant disruption to anyone's routine—leaving 50,000 people without power in southern Sweden for about an hour. The other CMEs last year did nothing more than generate colorful auroras. But what about a future barrage of record-setting CMEs? Will their effects be just as benign, and if not, how should we prepare?

Not too long ago, forecasting violent storms on Earth was more art than science. But decades of patient research have helped meteorologists understand, and then predict, their behavior. Similarly, the work of Gopalswamy, his collaborators, and other solar astronomers may one day lead to a deeper understanding of solar storms—and, maybe, what to expect the next time the Sun sends a blob of itself hurtling toward our planet.

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

THE SKY IN FEBRUARY

By Joe Rao

Mercury is unfavorably placed this month for observers in midnorthern latitudes. It is a "morning star" in February, rising in the southeastern part of the sky an hour before the Sun as the month begins. By the 13th, though, it rises only half an hour before sunrise. Farther south, the planet will be higher—and your odds of seeing it, better. Binoculars will certainly help.

The "star" of the evening is Venus, which, as February passes, grows ever brighter. It is readily visible at sunset, if not before, and becomes ever higher in the sky at sundown as the month goes on—reaching 41 degrees above the horizon in the twilit west-southwest by month's end. At that point, Venus sets three and a half hours after the Sun. Seen through a telescope, Venus gradually swells in apparent size. A beautiful early-evening configuration in the western sky awaits you on February 23, when a crescent Moon approaches to within less than 3 degrees south of Venus.

Fading Mars speeds eastward into the constellation Aries, the Ram, at the beginning of February. On the 1st the planet is roughly 130 million miles from Earth, and it shines at magnitude 0.7. By the 29th it has receded to 154 million miles and dimmed to magnitude 1.1. Through a telescope this month, Mars appears rather small. Throughout most of the month Mars sets between 11:30 P.M. and midnight local time. It hovers just above a fat crescent Moon on the evening of the 25th.

Jupiter, centered in Leo, the Lion, shines well to the east of Regulus, the constellation's brightest star. The planet rises several hours after dark at the beginning of February, but by month's end it is shining very low in the east as twilight fades to night. Jupiter stands high in the south in the middle of the night, and low in the west at dawn. Good binoculars are all it takes to reveal Jupiter as a disk; a small telescope shows Jupiter's most prominent cloud belts.

Saturn, in the western part of the constellation Gemini, the Twins, is well up in the east-southeast during the early evening hours. At the beginning of February it sets after 5 A.M., but by month's end it sets two hours earlier. Shining at magnitude –0.2 at midmonth, Saturn continues to put on a grand show in a telescope; the great ring system is still broadly tilted toward Earth.

The Moon is full on February 6 at 3:47 A.M. It wanes to last quarter on the 13th at 8:40 A.M., and becomes new on the 20th at 4:18 A.M. The Moon waxes to first quarter on the 27th at 10:24 P.M.

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

(Continued from page 25)

generally received with smiles." But he adds that "there have also been harrowing tales about one or two people disappearing, the assumption being that they were stolen and eaten by the 'tamauli,' as this black man is called by the Samoans" (*tamauli* means "black man" in Samoan).

Then, in the spring of 1923, events took an unexpected turn. A renowned Samoan climber named Ielu left his young wife and family on Upolu Island and, like Malua, traveled to Pago Pago to seek his fortune. Before he could find a job in American Samoa, however, he was convicted of theft and locked up in jail. Part of his punishment was to work with a prisoner road crew during the daytime hours. He quickly became despondent about his fate and so resolved to commit suicide by scaling the nearest mountaintop and jumping to his death. Bolting from the road crew, he soon outclimbed his pursuers and escaped into the mountains.

On reaching a remote precipice where he contemplated ending his life, Ielu heard, in the stillness of his surroundings, coconuts dropping one by one to the ground. The rhythm of the sounds suggested someone was up in a tree, harvesting. When Ielu turned to address this unlikely possibility, he found himself face to face with the naked wild man. Something, perhaps the primordial impulse to "capture the wild man," propelled him to struggle with his fellow fugitive. And, as so often happens, the younger man won the day. Ielu bound Malua, covered his nakedness with a piece of cloth torn from his lavalava (the characteristic Samoan skirt), and after a long hike reported with his captive to the steps of the courthouse. It must have been quite a sight.

Yet here, too, the story takes a surprising turn. Instead of being killed, displayed, or otherwise roughly treated by the local population, Malua, who by now had white hair and was probably in his sixties, was welcomed by his captors. He was groomed, fed, given sweets (which he is said to have loved), and made to feel like a long-lost member of the family.

The reason for this unusual civility was that the Samoans had created a society in which no one was allowed to remain orphaned, hungry, or homeless. Polite behavior and friendly hospitality were almost a religion. Of course, Samoans were still perfectly capable of defining some people as outsiders, and they shared with the rest of the world an almost morbid fear of a wild man. Yet, once confronted with the mysterious backwoods creature in the flesh, the Polynesians embraced him as one of their own. Any stigma he might once have borne was quickly dispelled by their own overwhelming sense of humanity.

In the weeks following his arrival, Malua formed a particularly strong bond with the man who had captured him: Ielu became both his savior and brother. For his part, Ielu was sent directly back to jail and the road crew. But Malua, the former wild man, slept on the floor of Ielu's jail cell and helped him on the road crew. They were inseparable.

Unfortunately, the tale of the Wild Man of Samoa does not have a happy ending. After nearly forty years of robust, naked existence in a remote wilderness, Malua survived only three months before falling gravely ill with civilized man's pneumonia. He died on September 5, 1923, at the Naval Hospital in Pago Pago, and was buried in the cemetery of strangers, Polynesian style.

Ielu (left), who lived as a young man on Tutuila Island in the 1920s, was an accomplished mountain climber whose skills enabled him to capture Malua, the "wild man" (right). On his return to the human fold, Malua regarded his captor as a savior and brother.

Joseph Kennedy is the senior archaeologist with Archaeological Consultants of the Pacific, Inc., with offices in Hale'iwa and Kailua-Kona, Hawai'i. He recently completed writing a book on the American colonial involvement in Samoa.

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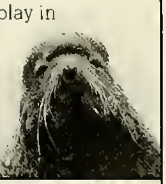

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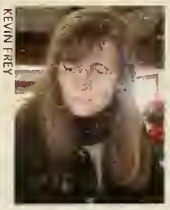
Living with Nature

EVERYDAY ACTIONS TO SUSTAIN OUR PLANET


KEVIN FREY

Eleanor Sterling

We spoke with Dr. Eleanor Sterling, Director of the American Museum of Natural History's Center for Biodiversity and Conservation (CBC), about Living with Nature, *the upcoming special program celebrating the CBC's tenth anniversary.*

Why is the CBC presenting this program, and why now?
We feel that it's very important to complement our research and education efforts with programs that reach out to the general public. The CBC has just marked its tenth anniversary, and we are celebrating the occasion with a special event that looks at the impact of our everyday actions on the natural world, and what that means for the future. The goal of the *Living with Nature* event on February 11 is to convey the message that *everyone* has a role to play in meeting the challenges of the biodiversity crisis—the accelerating loss of animals, plants, and habitats that is caused primarily by human activities.

What type of "everyday actions" will this event cover? Some people may feel that they have absorbed the "reduce, reuse, recycle" message, and want to hear more.
Certainly the "three Rs" are a central tenet of sustainability, but it's also important to recognize that many, many things we do and buy every day affect biodiversity. For example, the production and transport involved in simply a cup of coffee impacts myriad species—from invertebrates to birds to fish. And it will likely come as no surprise that we in the United States are the biggest consumers globally—it is estimated that if everyone in the world lived like we do it would take at least two additional planets to produce the resources, absorb the wastes, and otherwise maintain life.

Does living "more sustainably" mean making major lifestyle changes?
Absolutely not! I teach conservation biology, and I always tell my students that they should go ahead and indulge in those things they feel are necessary to live happy, fulfilling lives. However, I also suggest that if they take a reflective look at their everyday choices, they may find areas in which they can make changes that will not turn their lives upside down. For example, if you drink coffee, you might choose to purchase shade-grown, organic coffee. Biolo-


JAMES LUI

Living with Nature:
Everyday Actions to Sustain Our Planet
Wednesday, February 11, 7:30 p.m.
LeFrak Theater

Free and open to the public. **Reservations are strongly recommended:** visit http://research.amnh.org/biodiversity/ or call 212-496-4323.

Roundtable participants **Tundi Agardy,** renowned conservation biologist; **Eric Chivian,** founder and director of the Center for Health and the Global Environment at Harvard Medical School; and **Betsy Taylor,** founder and president of the Center for a New American Dream, gather to discuss ways we can sustain biodiversity while still benefiting from and enjoying it. Moderated by **Brian Lehrer** of WNYC Radio.

A **Resource Fair** will begin at 6:30 p.m. in the Hall of Northwest Coast Indians.

Living with Nature marks the occasion of the CBC's tenth anniversary and will continue with a series of in-depth public programs—the first, in fall 2004, will focus on sustainable (and delicious!) food choices.

gists report finding significantly more bird species in traditional shaded coffee plantations than in the newer, sunny coffee fields. Coffee grown in the shade also requires few or no chemical inputs—the leaf litter replenishes the soil nutrients and birds discourage pests.

What do you think is the most important lifestyle change you've made?

Buying organic, locally grown food is a great way to help sustain biodiversity—it reduces the pollution and energy associated with transporting food and avoids chemical pesticides. My husband and I participate in community-supported agriculture, or CSA. CSA links local farmers with local communities, strengthening the economy and providing people with a wide variety of foods harvested at the peak of ripeness and flavor. It's very affordable as well, and growing in popularity in New York City. Of course, there are other things that I do that are not as sustainable; for example, I'm writing a book on the natural history of Vietnam, and I seem to be filling several rooms with paper in the process (though it is double-sided).

I am very optimistic about the power of consumer choices as an effective tool to stem the tide of the biodiversity crisis, and I'm looking forward to February 11 when we will delve more deeply into this issue. If everyone committed to just one lifestyle change that was more sustainable, over time this would have a cumulative and positive impact on Earth.

Support for the Living with Nature *program series and publications is provided by a generous anonymous donor.*

Exploratorium/AMNH

Play and Learn

Exploratorium/AMNH
January 31–August 15
Gallery 3

EXPLORATORIUM

Turntable: The physics of rotation provides a challenge as visitors try to keep rings upright on their edges on top of a spinning disk.

The American Museum of Natural History is pleased to announce a special exhibition that will add an exciting and creative dimension to the way visitors learn science at the Museum.

Opening January 31, 2004, *Exploratorium/AMNH* will feature a collection of engaging interactive displays, on loan from the renowned Exploratorium science center in San Francisco, that invites visitors to explore concepts and phenomena in the natural sciences. Hands-on displays clustered around themes such as motion, light, pendulums, and rotation encourage audiences of all ages and all levels to investigate and play.

Myles Gordon, Vice President for Education, explains, "*Exploratorium/AMNH* brings scientific principles and phenomena to life. Museum visitors can literally get their hands on abstract fundamentals that underpin our world and the universe. *Exploratorium/AMNH* is a captivating experience that extends our mission of education, amplifies the impact of our exhibitions, and provides a springboard to discovery for school groups, families, and the curious of all ages."

> "Exploratorium/AMNH *brings scientific principles and phenomena to life.*"

Almost 40 exhibit elements and a cadre of well-trained explainers will beckon children and adults alike to engage their minds, bodies, and senses in learning. For example, at the Aeolian Landscape exhibit, you will be able to create miniature dunescapes with a simple adjustment of a fan, demonstrating how sand dunes and snow drifts are shaped by wind and the landscape. At the Everyone Is You and Me exhibit, a "mirror/window," experience how light is reflected and transmitted as your face merges into a composite with that of the person on the opposite side. At the Pendulum Snake, set in motion a line of pendulums of different lengths, and observe how the underlying mathematics cause patterns to appear and disappear.

Emphasizing the presentation of authentic experiences and working demonstrations of observable phenomena, *Exploratorium/AMNH* promises to be a popular exhibition that will spark curiosity, encourage inquiry, and extend and enhance the level of experiential learning at the American Museum of Natural History. Come explore for yourself—you'll be amazed by what you'll learn!

Museum Events

AMERICAN MUSEUM of NATURAL HISTORY

C. CHESEK/AMNH

The *Butterfly Conservatory*'s tropical habitat

EXHIBITIONS

Seasons of Life and Land: Arctic National Wildlife Refuge
Through March 7, 2004
Over 40 large-format color photographs by conservationist Subhankar Banerjee focus on the interdependent relationship of land, water, wildlife, and humanity in Alaska's Arctic Refuge.

Petra: Lost City of Stone
Through July 6, 2004
This exhibition tells the story of a thriving metropolis at the crossroads of the ancient world's major trade routes.

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

The Bedouin of Petra
Through July 6, 2004
Photojournalist Vivian Ronay's evocative color photographs document the Bedoul group of Bedouin tribes living near the archaeological site of Petra in Jordan.

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

The Butterfly Conservatory: Tropical Butterflies Alive in Winter
Through May 31, 2004
The butterflies are back! This popular exhibition includes more than 500 live, free-flying tropical butterflies in an enclosed tropical habitat where visitors can mingle with them.

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

Vietnam: Journeys of Body, Mind & Spirit
Through March 7, 2004
Gallery 77, first floor
This comprehensive exhibition presents Vietnamese culture in the early 21st century. The visitor is invited to "walk in Vietnamese shoes" and explore daily life among Vietnam's more than 50 ethnic groups.

Organized by the American Museum of Natural History, New York, and the Vietnam Museum of Ethnology, Hanoi. This exhibition and related programs are made possible by the philanthropic leadership of the **Freeman Foundation.** Additional generous funding provided by the Ford Foundation for the collaboration between the American Museum of Natural History and the Vietnam Museum of Ethnology. Also supported by the Asian Cultural Council. Planning grant provided by the National Endowment for the Humanities.

FAMILY AND CHILDREN'S PROGRAMS

It's a Wild, Wild, World: Snakes
Sunday, 2/8, 12:00 noon–1:00 p.m.
Live snakes from Texas, Madagascar, and elsewhere. Snake-related workshops are at 10:30 a.m. and 1:30 p.m.

Petra: Puzzles of the Past
Saturday, 2/14, 11:00 a.m.–12:30 p.m. (Ages 9–12)
Discover the ancient culture of Petra through archaeology.

Don't Know Much About Space® Quiz
Sunday, 2/15, 2:00–3:30 p.m.
(Ages 6 and up)
Kenneth C. Davis hosts a fun interactive game in which panelists chosen from the audience match wits.

CHILDREN'S ASTRONOMY PROGRAMS

Stories of the Native American Sky
Saturday, 2/7, 12:30–2:00 p.m.
(Ages 4–5, each child with one adult)

Space Explorers: Telescope Star Party
Tuesday, 2/10, 4:30–5:45 p.m.
(Ages 10 and up)

Life on Mars?
Saturday, 2/28, 12:30–2:00 p.m.
(Ages 11–13)

GLOBAL WEEKENDS

Black History Month: South Africa: Freedom, Liberation, and Democracy
Saturdays, 2/14, 21, and 28, 1:00–5:00 p.m.
Celebrate the tenth anniversary of the official end of apartheid and the election of Nelson Mandela, the first black president of South Africa, through films, discussions, spoken word, poetry, dance, and live musical performances.

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

R. MICKENS/AMNH

Experience the sights and sounds of a bustling

Vietnamese Marketplace

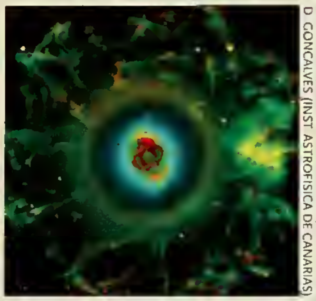
and sample traditional foods at **Café Pho.**
Through March 7, 2004
77TH STREET LOBBY, FIRST FLOOR

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe: Tale of Two Clusters
Tuesday, 2/3, 6:30–7:30 p.m.

This Just In...February's Hot Topics
Tuesday, 2/17, 6:30–7:30 p.m.



R. CORRADI (ISAAC NEWTON GROUP), D. GONÇALVES (INST. ASTROFISICA DE CANARIAS)

The Cat's Eye Nebula (NGC 6543)

Celestial Highlights: Spring Arrives
Tuesday, 2/24, 6:30–7:30 p.m.

COURSES

Astronomy, Art, and Physics
Saturday, 2/7, 10:00 a.m.–3:00 p.m.
Historical correlations between artistic revolutions and the insights of astronomers.

Using a Telescope
Four Mondays, 2/23–3/15, 6:30–8:30 p.m.
An introduction to the basics of amateur observing.

LECTURES

SIRTF: The Last of the Great Observatories
Monday, 2/9, 7:30 p.m.
With Jim Houck, Professor of Astronomy, Cornell University.

Biocosm: The New Scientific Theory of Evolution
Monday, 2/23, 7:30 p.m.
With complexity theorist James Gardner.

PLANETARIUM SHOWS

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

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

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

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

AMNH

SonicVision

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.

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As a Museum Member you will be among the first to embark on new journeys to explore the natural world and the cultures of humanity. You'll enjoy:

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- Free subscription to Natural History magazine and to Rotunda, our newsletter
- Invitations to Members-only special events, parties, and exhibition previews

For further information, call 212-769-5606 or visit www.amnh.org.

STARRY NIGHTS
Live Jazz

Friday, 2/6, 5:30 and 7:00 p.m.
Rose Center for Earth and Space

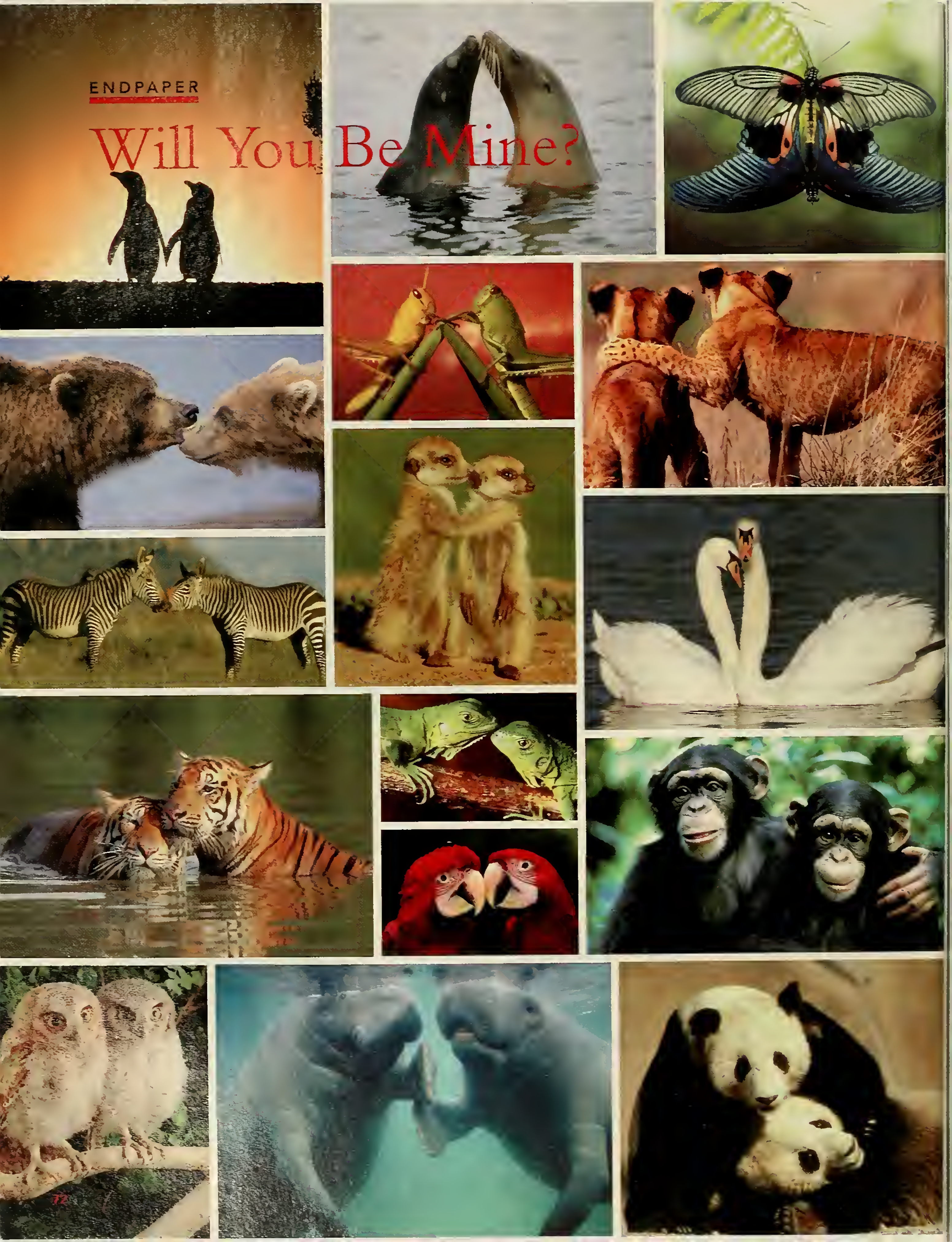
Onaje Allen Gumbs Quintet

Tune in to the 5:30 set live on WBGO Jazz 88, hosted by *Morning Jazz*'s Gary Walker.

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

ENDPAPER

Will You Be Mine?



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Are you tired of lugging around bulky binoculars on hikes or to sports events? Are your current binoculars too big to fit in your purse for the theater? Have you just skipped on buying binoculars because they are too expensive?

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