NATURAL HISTORY

10/03

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American Museum of Natural History

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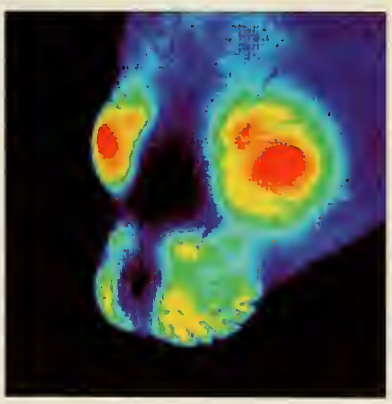
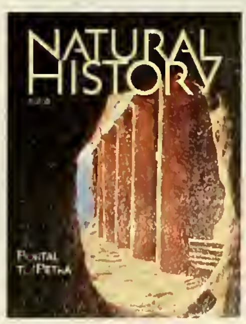
OCTOBER 2003 VOLUME 112 NUMBER 9

FEATURES





COVER
Petra: View from within the Urn Tomb.

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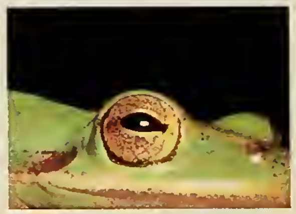
DEPARTMENTS



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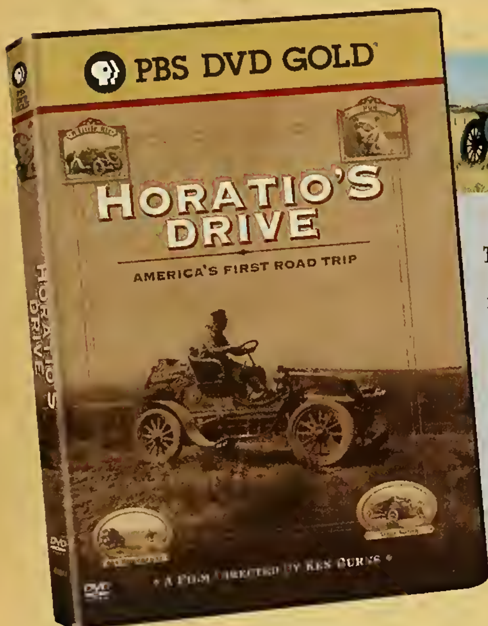

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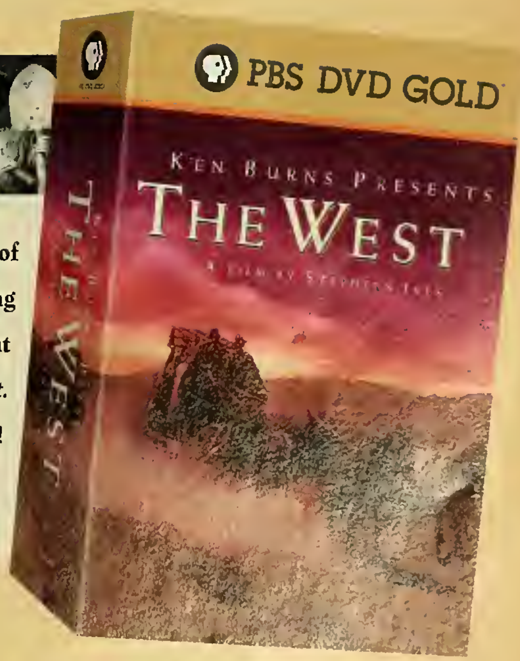

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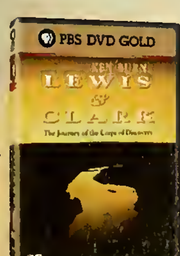

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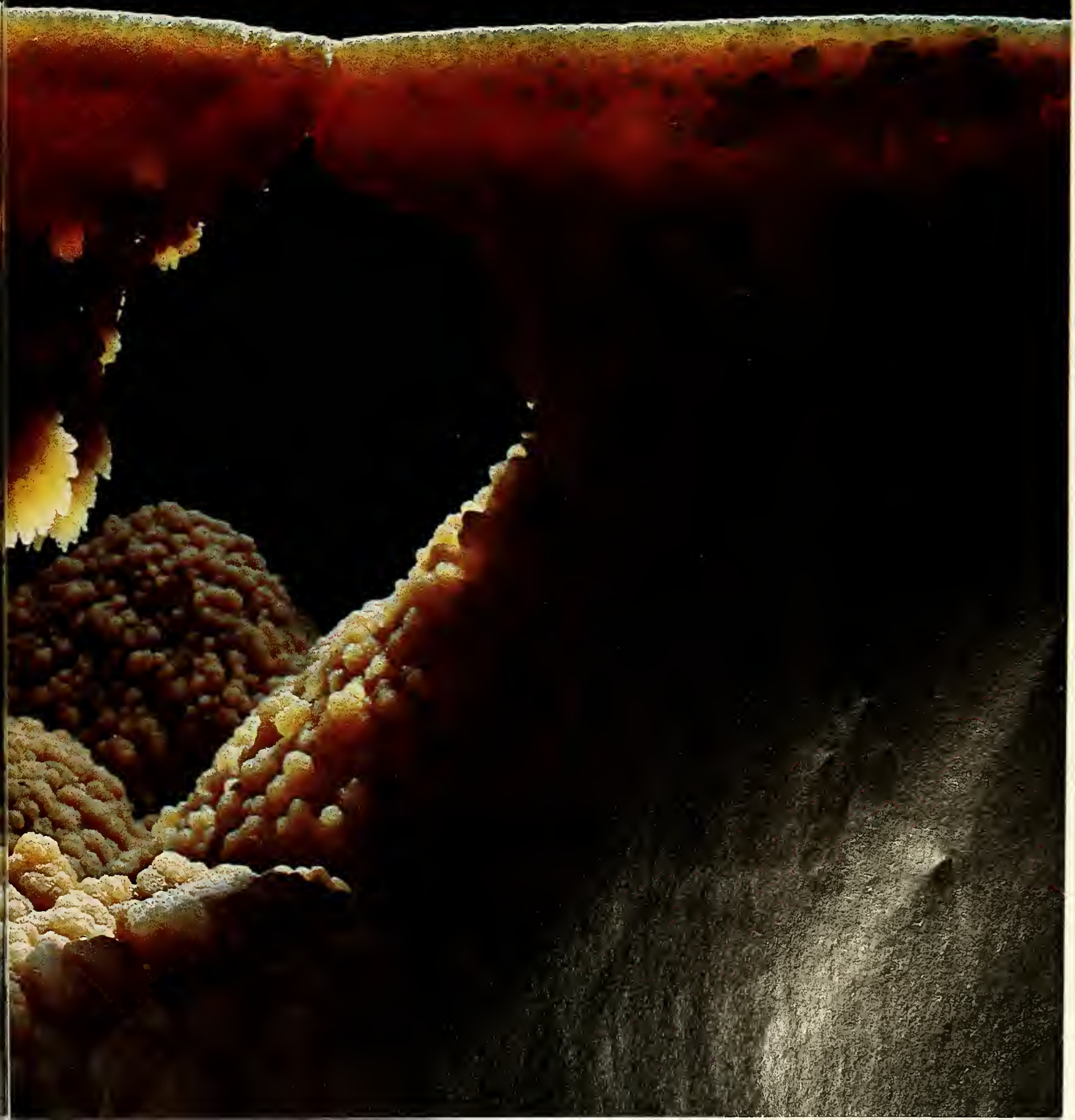
Photograph by Dave E. Bunnell



THE NATURAL MOMENT

◄ *See preceding pages*

A week of tramping for miles underground and sleeping in limestone catacombs tunneled out by sulfuric acid is not everyone's idea of happy camping. But Dave E. Bunnell—photographer and cave aficionado—is not everyone. He was thrilled to be among a small party of cavers allowed to map an arm of Lechuguilla Cave in southern New Mexico, the deepest cave in the continental United States. A few days in, after dozens of "squeezes" and lengthy rope climbs, Bunnell and his team stumbled across the area of orange calcite growths in the photograph, measuring several feet across.

This stunning cave is populated by a spectacular array of microorganisms. For despite the lack of light and nutrients, bacteria have adapted to Lechuguilla, some by absorbing metals such as manganese and iron. A number of investigators, among them Leslie Melim of Western Illinois University in Macomb and Diana Northup of the University of New Mexico in Albuquerque, are studying how the bacteria can build up calcified assemblages in caves—adding to the decor.

Melim and Northup believe that bacteria may have helped form the icicle-like extensions, known as "pool fingers," which point downward in Bunnell's picture. "Our working model is that bacterial slime is replaced or coated by calcite," says Melim. Such work in "extreme" environments is helping redefine where biologists search for life or its remains: think extraterrestrial.

—*Erin M. Espelie*

UP FRONT

Desert Secrets

It is impossible to conceive any thing more aweful or sublime than such an approach [to the ancient city]: the width [of the desert canyon] is not more than just sufficient for the passage of two horsemen abreast; the sides are in all parts perpendicular, varying from 400 to 700 feet in height; . . . and there is little more light than in a cavern. . . . We followed this half subterranean passage for the space of nearly two miles, the sides increasing in height as the path continually descended.

—Charles Leonard Irby and James Mangles, *Travels in Egypt and Nubia, Syria and the Holy Land* (London, 1868), quoted in *Petra: A Travellers' Guide,* by Rosalyn Maqsood

Once, 2,300 years ago, the ghost town at the end of the path—which you can still visit along the passage dramatically described above—was a bustling metropolis carved into the sandstone cliffs, its Broadway already excavated by a long-vanished stream. Petra, in what is now southern Jordan, was the Washington and New York City of the Nabataeans, the capital city and cultural center of a powerful nation built on the spice trade. When Steven Spielberg sought locations for his movie *Indiana Jones and the Last Crusade,* Petra was the site that shouted, "hidden treasure in the desert."

On October 18 a new exhibition, "Petra: Lost City of Stone," opens at the American Museum of Natural History in New York City. Some 200 objects will be on display through July 6, 2004. The exhibition then moves to the Cincinnati Art Museum, the co-organizer of the show, and thereafter to several other venues. "Portal to Petra," our gallery of pictures with text and captions by longtime Petra scholar Martha Sharp Joukowsky, begins on page 40.

• • •

Tectonic forces uplifted the sandstone in which Petra was carved, and those same forces created the deep, flattened depression, immediately to the west, known as the Dead Sea valley. Now investigators from a broad range of disciplines have made it clear that those geological events directly affected the course of human history. Between 2 million and 3 million years ago tectonic-plate movements opened a corridor linking northeastern Africa with the Near East. In those days, as Zvi Ben-Avraham and Susan Hough tell the story in "Promised Land" (page 44), the climate was much milder and wetter than it is today—so gentle and inviting, in fact, that it lured a rich flora and fauna, including early humans, out of Africa along the new land route. Stone tools discovered in the corridor, bearing a striking resemblance to tools unearthed in Africa, have been dated to 1.4 million years ago—a date that makes Petra's heyday seem as recent as yesterday's newspaper.

—Peter Brown

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CONTRIBUTORS

Since 1996, caver and photographer **DAVE E. BUNNELL** ("The Natural Moment," page 6) has been the editor of *NSS News*, the magazine of the National Speleological Society. His photograph of orange flowstone was made in the western branch of Lechuguilla Cave, near Carlsbad Caverns in New Mexico, during a mapping expedition at the site (see his Web site at www.goodearthgraphics.com/virtcave).

MARTHA SHARP JOUKOWSKY ("Portal to Petra," page 40) is a professor with a dual appointment at Brown University in Providence, Rhode Island: at the Center for Old World Archaeology and Art and in the department of anthropology. Since 1992 she has served as the director of the Brown University Petra Great Temple Excavations. She is the author of six books and more than fifty scholarly articles, and has served as president of the Archaeological Institute of America.

For the past twenty-five years geophysicist **ZVI BEN-AVRAHAM** ("Promised Land," page 44) has been investigating the geologic and cultural history of the fault zone around the world's lowest, saltiest lake, the Dead Sea. He is director of the Minerva Dead Sea Research Center at Tel Aviv University in Israel and a professor of marine geoscience at the University of Cape Town in South Africa. Ben-Avraham is the author or editor of more than 150 scientific papers, as well as eight monographs and books. **SUSAN HOUGH,** a seismologist with the U.S. Geological Survey in Pasadena, California, focuses her research on faults and earthquakes elsewhere in the world. Her article, written with Roger Bilham, on the earthquake zone in western India ("Shaken to the Core") appeared in the February 2003 issue of *Natural History.*

TERRIE M. WILLIAMS ("Sunbathing Seals of Antarctica," page 50) is a professor of biology at the University of California, Santa Cruz. In California she competes as a triathlete, but each year from September to December she trades in her running shoes, wetsuit, and bicycle for parka, insulated boots, and snowmobile to study Weddell seals in the Antarctic. *The Hunter's Breath,* a book for nonspecialists about her team's Antarctic exploits and their research into the icy life of Weddell seals, will be published early in 2004 by M. Evans and Co., Inc.

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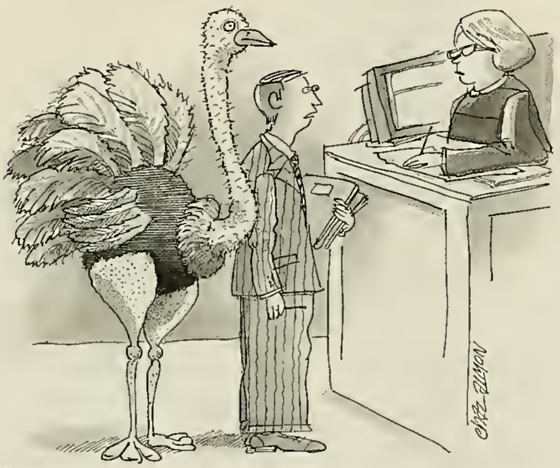
War of Words about War

R. Brian Ferguson ("The Birth of War," 7/03–8/03) has long believed the past was peaceful and has steadfastly ignored the archaeology refuting that myth. What he fails to realize is that most archaeologists have also fallen prey to the same myth and that, consequently, the research he relies on itself misreads the past as sublimely peaceful. Although he is now willing to see some warfare in the past—essentially only in the past 10,000 years—Mr. Ferguson continues to believe the myth that people have lived in ecological balance throughout most of human history, and as a result uses outdated interpretations in an attempt to salvage his own politically correct interpretations.

Why people engage in warfare is an important topic, and archaeology and ethnology provide essential information about it. Public policy derives ultimately from what we collectively think about this issue. Readers of *Natural History* who want to be usefully informed about the causes and history of warfare should also read newly formulated sources, such as Lawrence Keeley's book *War Before Civilization* and my own *Constant Battles: The Myth of the Peaceful, Noble Savage.*

My goal in my book *Constant Battles* was to synthesize the considerable body of information on past warfare and ecology.



"We request low bail, Your Honor. My client is no flight risk."

The evidence is overwhelming that warfare and ecological balance have been linked for millennia. Warfare in the past is patterned and explainable. Most important, warfare was just as intense and deadly in the deep past as it was in the more recent past.

Steven A. LeBlanc
Peabody Museum of Archaeology and Ethnology
Harvard University
Cambridge, Massachusetts

R. Brian Ferguson discusses prehistoric evidence as poorly as one might expect from a non-archaeologist. His omissions and errors are too numerous for this brief response—almost every generalization he makes about when and why warfare began is contradicted by archaeological facts.

Let one example suffice, the assertion that warfare began when people settled down and began farming. Wrong. The Natufians of the Near East, still as foragers, were the first people in the world to live in permanent villages—stone-walled houses, house mice, and so on. Yet they were quite peaceful, at least compared with recent tribal people. The equally sedentary Pre-Pottery Neolithic people who followed were the world's first farmers, and they, too, were peaceful. Meanwhile, their contemporaries, the mobile foragers of the Nile Valley, were very violent. Similarly, in the American Midwest, war deaths were common among Late Archaic foragers (3800–1500 B.C.); rare during the later semi-agricultural, sedentary Middle Woodland period (1500 B.C.–A.D. 900); and became common again among the later Mississippian farmers (900–1450).

Note too that during the three-day Civil War battle of Gettysburg, only 3 or 4 percent of those actively engaged were killed. Thus, many of the "peaceful" prehistoric people Mr. Ferguson mentions lived in circumstances, in many cases lasting for generations, that were as murderous, or more murderous, than one of the bloodiest modern battles.

As for the difference between human capabilities and what people actually do, all humans are capable of understanding archaeology, logic, and arithmetic. But, just as with making war, not all of them do so all of the time.

Lawrence H. Keeley
University of Illinois at Chicago

I suggest that the underlying motive for conflict is internal to societies and cultures, not external. War and the preparation for war enables people with certain abilities to acquire greater power and more resources, not primarily from their enemies, but in relation to others within their own society.

Suppose I am an engineer skilled at building walls. Because I will do well in times of war, my behavior will subtly favor a culture of war, thereby gaining me higher standing in my society and a larger share of its wealth. True, if there are warlike people in a nearby group, we ourselves must be warlike. But in a sense, those who stand to benefit from conflict within each group are partners in maintaining the dynamic.

Alan Silverman
Stone Ridge, New York

R. Brian Ferguson suggests that the scarcity of evidence is particularly telling in the case of prehistoric warfare. Yet I am sure that a survey of burials in the United States in the twentieth century would show that the vast majority of skeletal remains show no evidence of battle injuries, even though the U.S. has been at war for twenty-two out of the past hundred years and has been involved in militarized disputes off and on during most of the years of so-called peace. Indeed, most burials in U.S. military cemeteries in recent decades would indicate a death by natural causes. Fatalities in warfare are rare, even in an era when warfare is ubiquitous. If warfare is intended to test relative capability and resolve, and if prehistoric combat managed to do so with few casualties, then warfare could have been more common than the archaeological evidence suggests.

Mr. Ferguson writes that "the decision to wage war involves the pursuit of practical self-interest by those who actually make the decision." It is not clear how this observation squares with his argument that war is an innovation of human prehistory. If war is relatively recent, so too must be its causes. But surely the pursuit of practical self-interest is not a recent human innovation. In any case, wars are episodic, with beginnings and ends. Like a light switch, a cause of war must be switched on and then switched off as the conflict proceeds. Yet if wars are precipitated by ethnic hatred, scarcity, or the fact that leaders gain from them, it is unclear how they can end—unless we are also prepared to believe that Serbs stopped fighting Muslims because they stopped hating, that peace came to East Timor because Indonesia became richer in the late 1990s, or that the first Bush Administration's desire to gain political power from the Gulf War was satisfied only a hundred hours after the land invasion began.

One remarkable finding about warfare, now widely accepted by students of international relations, is that states with liberal political systems—democracies—are much less likely than are other political systems to engage each other through combat. If the first inklings of civilization led to warfare, it may be, paradoxically, that the most sophisticated political structures yet developed can offer the promise of less war in the future. This rumination is germane both to the cradle of civilization, and to warfare: in the contemporary Middle East, democracy is in short supply.

Erik Gartzke
Columbia University
New York City

R. Brian Ferguson cites a finding by the anthropologist Raymond C. Kelly that hunter-gatherers whose social organization only loosely extends beyond family are warless, whereas war is more common among those with larger and more defined groupings, such as clans. But simple numbers might explain that difference better than type of social organization. Larger numbers increase the chances that a grievance could spark a conflict, and that the conflict would involve group violence rather than, say, murder. Furthermore, the smaller the group, the less able it is to tolerate the loss of multiple individuals.

Ken Morgan
Williston Park, New York

My heartfelt thanks to R. Brian Ferguson for three sentences that express clearly why I have so much trouble believing the rhetoric that relentlessly bombards us: (1) "My view is that in most cases . . . the decision to wage war involves the pursuit of practical self-interest by those who actually make the decision." (2) "Those advocating war always define it in terms of the highest applicable values." And (3)

"Those who start wars usually seem to believe in the righteousness of their chosen course."

I agree emphatically, but unhappily, that our skill at rationalizing our choices confirms his ending statement: "It is that capability that makes human beings such a dangerous species."
LaVerne C. McGee
Anderson, South Carolina

R. Brian Ferguson replies: In spite of Steven A. LeBlanc's suggestion to the contrary, I have often written about prehistoric warfare. As early as twenty years ago I argued that the Pacific Northwest Coast potlatch was, in part, a response to a pattern of deadly warfare, which I asserted went back at least 3,000 years. For another instance, in a 1992 article in *Scientific American* I wrote: "Even in the absence of any state, archaeology provides unmistakable evidence of war among sedentary village peoples, sometimes going back thousands of years."

Nothing I have ever written suggests that prehistoric people lived in some Eden-like idyll of natural conservation, the myth that Mr. LeBlanc attacks. He appears to think that is the only alternative to warfare over food resources. But a variety of other processes—crashes in the food supply, low life expectancy, high infant mortality, migration—keep populations from overwhelming their available resources. Isn't that the way of life on Earth? I am hardly against ecological explanations of war, having offered a few myself. But having "been there, done that" with ecological anthropologists more than a dozen years ago, I am aware of the limitations of these kinds of explanations.

By all means, interested readers should read *War Before Civilization* and *Constant Battles.* When they do, they should keep a sharp eye out for how often the authors attack a position without providing any specific citation showing that someone has actually taken that position. Readers would also do well to note how few archaeological cases (as opposed to ethnographic cases) the authors actually describe in support of their sweeping conclusions about the prehistoric record. Even Mr. LeBlanc's crucial discussion of the European site Dolni Vestonice, I am prepared to argue, bears almost no resemblance to the actual findings there.

Where tribal warfare exists, combat may account for more than 25 percent of adult male deaths.

Lawrence H. Keeley maintains that just about everything I say is wrong, but the one example he bothers to cite is itself misguided: that I claim there was no war before people "settled down and began farming." I make no such claim. Agriculture is associated with a variety of developments that, over time, make war more likely, but it is neither necessary nor sufficient for war to develop. My article specifically discusses pre-agricultural people who made war and agriculturalists who did not. Some of the details Mr. Keeley mentions, such as the sequences in Eastern North America, I could not include because space was limited. While we're at it, the violent, at least partly sedentary foragers of the Nile Valley (Site 117, in Sudan, in my article) were not contemporary with the Pre-Pottery Neolithic people, but lived 2,000 to 4,000 years earlier.

I agree with Alan Silverman that motives for conflict should be sought within war-making societies, but not to the exclusion of external incentives.

Erik Gartzke raises several interesting points. On the paucity of skeletal trauma, one cannot compare tribal war to modern war without qualifications. Here I am in line with Mr. Keeley in *War Before Civilization*. In tribal combat, mobilization can exceed 40 percent of adult males, battles that are mere tests of resolve rather than an effort to kill are rare, and combat death not infrequently accounts for more than 25 percent of adult male deaths. Imagine our graveyard populations if such figures applied to us.

Yes, I believe humans have always pursued practical self-interest. But the conditions that make self-interest lead to war became common only in the past 10,000 years. I do not see war as switched off and on like a light. I agree that how wars end needs much more study, but I doubt that many of them end because the conditions that started them are somehow reversed. I also am interested, even encouraged, by findings in the literature on "democratic peace." More democracy may put a brake on the unbridled power of leaders—though as the past year shows, not always. But that issue was far beyond my topic.

I agree with Ken Morgan that numbers are important. As for Raymond C. Kelly's findings, which Mr. Morgan mentions, I would note that Kelly does not address what makes formal groupings such as clans and lineages emerge. There is a good deal of support for the idea that among the forces behind the emergence of clans are growing populations and the consequent competition for resources. It could be, as Mr. Morgan suggests, that small hunting bands place a higher value on individual lives, making war seem less of an option. Some investigators have also stressed that for small, scattered groups of big-game hunters, the logic of self-interest works against territorial conflict and encourages ramifying networks of information exchange and movement.

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

By Stéphan Reebs

Burning ground in northern Mali

Hot Rocks

For centuries the nomadic Tuaregs of the Sahara, warned off by legends of diabolical fumes and flames, have avoided camping in the dry lake beds around Timbuktu, Mali. Some geologists noted similarities between the lakes' steaming cracks and the fumaroles of volcano craters—and wondered if magma might be brewing there. Problem was, West Africa has no active volcanoes and is tectonically stable. Henrik Svensen, a geologist at the University of Oslo in Norway, and several colleagues went to investigate.

The team took a direct approach: they dug an eight-foot-deep trench into the leading edge of a smoking, migrating heat front. What they found wasn't fiery lava but a layer of smoldering peat—the result of microbial decomposition of the organic residue left in the sediment when a lake has dried out. The decomposition generates so much heat that the buried peat self-ignites, roasting the ground above it to temperatures as high as 1,400 degrees Fahrenheit. ("Subsurface combustion in Mali: Refutation of the active volcanism hypothesis in West Africa," *Geology* 31:581–84, July 2003)

Reading the Leaves

When soil is poor in phosphorus, plants put a lot more effort into growing hairy roots than they do into growing the parts people eat. So, to make sure crop yields are high, farmers tend to use a lot of fertilizer. But excess phosphorus leaches out and eventually triggers blooms of algae that choke lakes and rivers; besides, cheap natural sources of phosphorus will be exhausted in less than a century. Wouldn't it be great if a farmer could know, just by looking at a plant, when it needs a hit of the stuff?

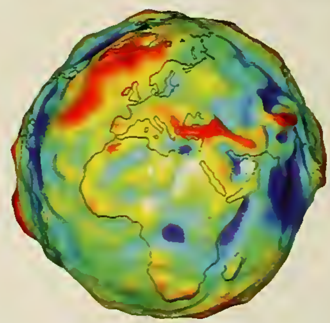
Biotechnology to the rescue. John P. Hammond of Horticulture Research International in Warwickshire, England, and his colleagues have pointed out that a gene known as *SQD1* could play a role in such signaling. *SQD1* gets activated when plants are starved of phosphorus but not when they're stressed by other problems. Moreover, that response takes place before the plant's growth has been compromised by a decline in phosphorus.

By welding *SQD1* to another gene—one that makes a substance visible in leaves—Hammond and his team have created a plant that signals its own needs. By checking its leaves regularly, a farmer could see at once whether the plant is hungry for phosphorus. ("Changes in gene expression in *Arabidopsis* shoots during phosphate starvation and the potential for developing smart plants," *Plant Physiology* 132:578–96, June 2003)

Serious Gravity

If the Earth were a uniform orb both inside and out, its gravity—and thus your weight—would be the same everywhere. But our planet is flattened at the Poles; it has deep seafloor trenches and towering mountain ranges; the density of the rock underfoot is far from uniform; and gradual processes such as the melting of polar ice and the flow of rock in the mantle redistribute its mass. That makes Earth's gravity field vary from place to place (and even from time to time): you'd weigh slightly more in Tokyo than you do in Tulsa.

A joint five-year U.S.-German space mission—the Gravity Recovery and Climate Experiment (GRACE)—is now bringing unprecedented precision to the measurement and mapping of Earth's gravity field. Since March 2002, two identical satellites have been following the same orbit around the globe, some 130 miles apart, and when they encounter minute variations in the strength of the gravity, the distance between them fluctuates. Because that fluctuation can be measured to within a tenth of a hair's breadth, geophysicists at NASA and the German Aerospace Center in Potsdam can now map changes in gravity with exquisite accuracy.



Model shows how gravity varies slightly around the Earth. Blue "valleys" represent relatively weak gravity fields, and red "peaks" relatively strong ones. The valleys and peaks are exaggerated for clarity.

Why should anyone trouble to measure the global gravity field? The average field ultimately reveals a lot about ocean circulation and the structure of the seafloor; the fluctuations provide early signs of shifts in weather patterns and long-term climate change. (www.csr.utexas.edu/grace)

Experiment of the Month

Question: How did the dung beetle cross the road? Answer: By moonlight.

This past March this column noted the first-ever evidence of an animal—the elephant hawkmoth—seeing color by night. Now another insect has joined the ranks of the perceptually advantaged.

When a dung beetle finds a pile of fresh manure, it selects the choicest, least-fibrous bits and crafts them into a large ball that will supply its own dinner for days to come or serve as both shelter and food for its developing young. Rolling the ball away from the raw dung heap as quickly and efficiently as it can (so that the ball won't be stolen and the work wasted), the nocturnal beetle heads off in a straight line—if the Moon is out. On moonless nights, though, it zigzags all over the place.

Orienting itself by the direct light of the Moon would not win the dung beetle any space here; many other animals do that. But when Marie Dacke, a biologist at Lund University in Sweden, and several colleagues shielded the rising Moon from the beetles' direct view, the insects still moved in a straight line. Could the beetles have been navigating by polarized moonlight—extremely feeble illumination that is scattered by minute particles in the atmosphere—rather than by the Moon itself?

African dung beetle (Scarabaeus zambesianus) *rolls its dinner home.*

To test the idea, the biologists placed a polarizing filter over moving beetles. If the filter was aligned along the sky's dominant axis of light transmission, the beetles kept moving in the same straight line. But if the filter was rotated ninety degrees, the beetles, too, suddenly veered off at right angles: an elegant demonstration of an amazing visual ability. ("Insect orientation to polarized moonlight," *Nature* 424:33, July 3, 2003)

A Matter of Taste

Every slab of cheese is an entire community of organisms, and, as with many human communities, its character may not be appreciated by everyone. Take Stilton. Made under license by only six dairies in the English Midlands, it's one of those cheeses whose strong aroma and intense flavor some find delightful and others find repellent. But just what makes a Stilton a Stilton? Danilo Ercolini, a microbiologist at Federico II University in Naples, Italy, and his colleagues at the University of Nottingham in England aimed to find out.

Using the latest techniques of DNA analysis, the microbiologists identified the panoply of bacteria that, along with yeast and the essential *Penicillium* mold, give Stilton its complex taste. They also discovered that distinct regions of the cheese—the blue veins (caused by piercing the ripening curd with needles to aerate it), the creamy ivory core, and the natural crust—vary in acidity and oxygen content and harbor different kinds of bacteria. Several unexpected micro-inhabitants are worth noting: two harmless species of *Staphylococcus*, the usually unwelcome intestinal microorganism *Enterococcus faecalis*, and several species of *Lactobacillus*. The investigators aren't certain whether they arrive on the scene by surviving the milk pasteurization process or by being introduced through equipment or other sources.

All the interlopers can serve as starter cultures in fermented products, such as yogurt and salami, in which they control the development of flavor, color, and texture. Their roles in Stilton are unknown, but their presence or absence may help explain why different batches of the cheese made at the same dairy can have highly different characteristics. Can custom-inoculated cheeses be far behind? ("Bacterial community structure and location in Stilton cheese," *Applied and Environmental Microbiology* 69:3540–48, June 2003)

Stéphan Reebs is a professor of biology at the University of Moncton in New Brunswick, Canada, and the author of Fish Behavior in the Aquarium and in the Wild *(Cornell University Press).*

Stilton, anyone?

Let There Be Light

Some 380,000 years after the big bang, the universal fog lifted and the cosmic background radiation was set free.

By Neil deGrasse Tyson

In the beginning of everything, when the universe was just a fraction of a second old, a ferocious trillion degrees hot, and glowing with an unimaginable brilliance, its main agenda was expansion. With every passing moment the universe got bigger. But it also got cooler and dimmer. And for millennia, matter and energy cohabited in a kind of thick soup, in which speedy electrons continually scattered photons of light to and fro.

Back then, if your mission had been to see across the universe, you couldn't have. Any photons entering your eye would, just nanoseconds or picoseconds earlier, have bounced off electrons right in front of your face. You would have seen only a glowing fog in all directions, and your entire surroundings—luminous, translucent, reddish white in color—would have been nearly as bright as the surface of the Sun.

Eventually, right around the time the young universe reached its 380,000th birthday, its temperature dropped below 3,000 degrees. Electrons began to slow down enough to be captured by protons, thus bringing atoms into the world. With fewer unattached electrons to gum up the works, the photons could finally race around without bumping into anything. That's when the universe became transparent, the fog lifted, and a cosmic background of visible light was set free.

That cosmic background persists to this day, the remnant of the light left over from a dazzling, sizzling early universe. It's a ubiquitous bath of photons—massless vehicles of energy, always moving at the speed of light, which act as much like waves as they do like particles. As the cosmos continued to cool, photons that had been born in the visible part of the spectrum lost energy to the expanding universe and eventually slid down the spectrum, morphing into infrared photons. As their wavelengths grew in size, they became cooler, that is, less energetic, but they never stopped being photons.

Some of the static you hear on a walkie-talkie comes from the microwave remnants of the early universe.

Today, some 13.7 billion years after the beginning, the photons that make up the cosmic background have cooled further still, shifting down the spectrum to become microwaves. That's how they got their modern moniker: "cosmic microwave background," or CMB for short. A hundred billion years from now, when the universe has expanded and cooled even more, astrophysicists will be writing about the cosmic radio wave background.

The temperature of the universe is directly related to the size of the universe. It's a physical thing. If the universe grows to twice its original size, all its free-traveling photons lose half their original energy. A growing universe forces a photon's wavelength to get longer, stretching along with the spandexlike fabric of space and time.

A photon's wavelength is simply the separation between one wave crest and the next—a distance you could measure if you had a small enough ruler. Because all photons move at the same speed, the shorter their wavelengths the more wave crests have to pass a given point in a given interval of time. Those are the higher-frequency photons. And a photon's frequency is a direct measure of its energy. That makes sense, too: the higher its frequency—that is, the faster it wiggles—the more energy it carries.

When an object glows from being heated, it emits radiation in all parts of the spectrum. But that radiation always peaks somewhere. The peak energy output of ordinary household lightbulbs lies in the infrared part of the spectrum, which people detect as warmth on the skin. But of course lightbulbs also emit plenty of visible light, or we wouldn't be buying them.

The peak output of the cosmic background has a wavelength of about a millimeter, which is smack-dab in the microwave part of the spectrum. The static you hear on a walkie-talkie comes from an ambient bath of microwaves, a few percent of which are from the CMB. (The rest of the noise comes from the Sun, cell phones, police radar guns, and so on.)

The existence of the CMB was predicted by the Ukrainian-born U.S. physicist George Gamow and his colleagues in the 1940s, culminating in a 1948 paper that extrapolated the known laws of physics into the early universe. The foundation of those ideas came from the 1927 work of Georges Édouard Lemaître, a Belgian astronomer and Jesuit priest who is generally recognized as the father of big bang cosmology. But it was two U.S. physicists, Ralph A. Alpher and Robert C. Herman, both of whom had worked with Gamow, who estimated what the temperature of the cosmic background ought to be.

In hindsight, theirs is a relatively simple argument, one that I've already made. The fabric of space-time was smaller yesterday than it is today, and if it was smaller, basic physics requires it to have been hotter. So the physicists turned back the clock and imagined an epoch when the universe was so hot that all its atoms were completely ionized—when all atomic nuclei were laid bare and all electrons roamed free. Under those conditions, they hypothesized, photons would not have sped uninterrupted across the universe, as they do today. The photons' free ride today would have required that the cosmos get cooler—cool enough for the electrons to combine with atomic nuclei, forming atoms and allowing light to move without obstruction.

Although it was Gamow who suggested that the universe was once hotter, and that you could know the physics of the early universe, it was Alpher and Herman who calculated its temperature: five degrees Kelvin (five degrees above absolute zero). Yes, they got it wrong—the CMB is actually 2.7 degrees Kelvin—but together, those guys made an extrapolation unlike any other in the history of science. To take some basic atomic physics from a slab in the lab, and then deduce the largest-scale phenomenon ever measured, was extraordinary. Discussing the feat in his book *Time Travel in Einstein's Universe*, J. Richard Gott III, an astrophysicist at Princeton University, writes:

> Predicting that the radiation existed and then getting its temperature correct to within a factor of 2 was a remarkable accomplishment—rather like predicting that a flying saucer 50 feet in width would land on the White House lawn and then watching one 27 feet in width actually show up.

When Gamow, Alpher, and Herman made their predictions, physicists were still undecided about the beginning of the universe. In 1948, the same year Alpher and Herman's paper appeared, a rival, "steady state" theory of the universe was proposed in two papers published in England, one by the mathematician Hermann Bondi and the astrophysicist Thomas Gold, the other by the cosmologist Fred Hoyle. The steady state theory required that the universe, though expanding, had always looked the same. And because a steady state universe could not have been any hotter or denser yesterday than it is today, the Bondi-Gold-Hoyle scenario maintained, matter was constantly popping into our universe, at just the right rate to leave the expanding cosmos with a constant average density. By contrast, big bang theory requires that all matter come into existence at one instant.

Predicting the CMB was a shot

(Continued on page 70)

Hiroshi Sugito, *The Drive*, 2002

Something to Howl About

To earn her spurs as a tropical biologist, the author decided to study a parasite that even her colleagues wanted to avoid.

By Katharine Milton

Juvenile howler monkey is heavily burdened with bot fly larvae on its neck. Each larva develops in a pocket of the monkey's skin, conspicuous for its open breathing hole. The parasites take a toll on their hosts and can lead to death, particularly in immature or weakened individuals. This juvenile is only half the size of an adult; it probably weighs between six and eight pounds.

In 1974, as a greenhorn to the tropics, I traveled to Panama to begin a study of the dietary behavior of wild howler monkeys on Barro Colorado Island. The island was separated from the mainland in 1912, during the construction of the Panama Canal: its six square miles of forest now serve as a field station managed by the Smithsonian Tropical Research Institute. In my first exhausting but exciting weeks settling into new quarters and venturing on my own into the forest, I noticed that many howler monkeys had peculiar lumps under their fur, usually around the neck and throat but sometimes on the chest or stomach, on the back, even on a cheek or above an eye. The lumps were large, and they often made the monkeys appear grotesque. Infants looked as if they had two heads or a massive goiter; many adults resembled something out of B-movie sci-fi.

Curious, I asked other biologists on the island about the lumps. They, too, were fairly new to the site, but their answer was immediate: "Bot fly larvae." Bot fly larvae? Eek! I'd never heard of them, but they sounded pretty alarming. I learned that *Dermatobia hominis,* the "human" bot fly, is well known to science because of the diabolically clever way it finds hosts for its offspring. A female ready to deposit her eggs seeks out a bloodsucking insect, generally a fly or mosquito. She grasps the insect—known in the trade as an egg porter—and holds it firmly in flight while she attaches rows of her eggs to its abdomen with a water-insoluble glue. She then releases the insect unharmed. Now, though, it is neatly decorated with twenty-odd bot fly eggs. There the bot fly embryos grow quietly until they're ready to hatch.

The trigger for hatching comes from a third animal species. When the egg porter makes a meal from the blood of a mammal—a meal required for the insect's own reproduction—the bot fly embryos, by now developed into tiny threadlike larvae, sense the heat from the mammal's body and burst from their eggs. The larvae burrow directly into the mammal's skin, where they make themselves at home.

Each larva lives in what is known as a warble, a pocket or chamber that forms in the host's skin. In its warble, which has a small breathing hole open to the air, the larva feeds on a rich soup of tissue fluids produced by the host. There the larva passes through three more "instars," or developmental stages, growing larger all the while. At the end of the third instar, the larva wriggles out of its warble, falls to the ground, and burrows into the soil to pupate. Some weeks later an adult fly emerges from the soil to seek a mate, and the cycle is repeated. Because most egg porters are not picky about whose blood they sip, the larvae of *Dermatobia hominis* can end up on almost any warm-blooded animal—from a squirrel to a monkey to (as the name implies) a human being. Double Eek!

My fellow scientists on the island regaled me with dramatic tales of intensely painful bot fly larvae growing in inaccessible places, in disgusting places, in very private places. According to these battle-scarred veterans, the best way to get rid of a larva is to plaster a thick piece of bacon on your skin above the breathing hole of a larva's warble. In desperation (since bot fly larvae have to breathe), the larva crawls out of its warble and up into the bacon. Then you whip off the bacon with the larva trapped inside. Poor howler monkeys, up in the trees with no bacon, nor even with the manual dexterity to force larvae out of the warbles by hand—my heart went out to them!

I went on with my field study, and months went by. Thankfully, I acquired no bot fly larvae, and neither did anyone else on the island. In fact, none of the other monkey species on the island—capuchins, spider monkeys, tamarins—were infested with bot fly larvae either, even though during some months virtually every howler monkey I saw bore multiple warbles. The other biologists noticed the same thing. As it turned out, none of these scientist-raconteurs had ever gotten a *Dermatobia* larva on Barro Colorado Island; all their exciting stories were based on experiences elsewhere in the neotropics. Perhaps these larvae were not that same notorious pest after all.

A veterinarian friend in Panama named Nathan B. Gale, the director of the Veterinary Public Health Laboratory, took an interest in the problem. Sick or wounded wild animals were occasionally brought to his clinic for treatment, and when a howler monkey arrived one day, he removed its bot fly larvae, put them in a preservative, and mailed them to an entomologist friend at Washington State University in Pullman, the late E. Paul Catts. Catts recognized that they were larvae of an entirely different species, *Alouattamyia baeri,* the howler-monkey bot fly. That was a big surprise, but also a big relief: the reason only howler monkeys were afflicted with the larvae was that the bot fly is host-specific.

Catts had written an extensive review describing the members of Cuterebridae, the New World family to which both *Dermatobia* and *Alouattamyia* belong. From Catts's review it was clear that *Dermatobia* is a maverick. Other species in the family tend to associate closely with just one mammalian host, typically a rodent or rabbit. In general, they also place their eggs not on egg porters but rather in areas of habitat likely to be visited by the host. A rodent bot fly, for instance, might leave its eggs on grass or twigs near the trail of its specific rodent host. When the rodent passes by, the heat from its body alerts the larvae, which emerge instantly from their eggs and attach themselves to the animal's whiskers or fur.

Howler-monkey bot fly larvae (upper photograph) are pictured at the third-instar stage, the last stage before pupation. Starting out cream colored (left), the third instar puts on additional weight and darkens (right). A fully developed larva is nearly an inch long and can weigh more than a tenth of an ounce. Male howler-monkey bot fly (lower photograph) has a distinguishing stripe on each eye. The insect is about seven-eighths of an inch long.

In most cases the larvae enter the host's body not by burrowing directly into the skin but by passing through the nostrils, eyes, or mouth. Larvae then spend several days migrating through internal organs and tissues, finally coming to rest at a preferred site on the host's body. The neck region is the most frequent target for the howler-monkey bot fly larva, but wherever it settles, it opens a breathing hole and ensconces itself in its warble to mature, a process that takes six or seven weeks.

So little was known about *Alouattamyia baeri,* however, that I decided I was in an ideal place to study its life cycle. My first task was to find out what the adult fly looked like. No one in Panama, including me, actually knew. The thing to do was to collect some larvae and wait for them to mature.

Collection was easy enough. The larvae were plentiful on recently dead howler monkeys in the forest or howler monkeys temporarily captured for marking or weighing. When fully developed, the larvae were black and heavily corrugated, resembling miniature hand grenades [*see upper photograph on this page*].

But getting the larvae to mature was less straightforward. I set up two screened enclosures where they could pupate, one in the forest and another in a well-aired room. All I had to do, I assumed, was check them each day and collect my adult

Howler monkey rests in a Cecropia tree, whose young leaves as well as flowers and fruits are an important source of food.

flies as they emerged from pupation. But day after day the enclosures remained empty. After nearly five weeks of waiting, I was almost positive that humidity and fungi had killed all the pupae. Then on the forty-eighth day, when I went to check the screened enclosure in the room, I found a large fly buzzing around inside. My captive was more than half an inch long, covered with short, dense, velvety black hair, and had transparent, amber-brown wings. My joyful cries alerted everyone within shouting distance to come and see this amazing fly. I named her Lucille.

The life of "Lucille, the Famous Fly," as she became known to everyone on Barro Colorado Island, may have been a happy one, but it was not long. Flies of the Cuterebridae family emerge from their pupal cases, mate, and die in just a few days. Just three and a half days after Lucille first appeared, I witnessed her death throes. The cause was old age. It was a sad moment. Her pinned remains still occupy a place of honor in my office in Berkeley.

About a year later I began a research collaboration with Douglas D. Colwell, a bot fly expert at the Lethbridge Research Centre in Alberta, Canada. In Panama Colwell and I collected more than fifty third-instar larvae, and he took them back with him to his lab in Canada. Colwell proved to be a deft hand at raising flies. Ultimately he was blessed with fifteen males and nine females. The female flies were noticeably larger, and their eyes spaced more widely apart. The live male bot flies had a red vertical stripe on each eye—a striking characteristic that fades and disappears after death [*see lower photograph on preceding page*]. (Lucille lacked this distinction, by the way, confirming that she was a female, and thus correctly named.)

Bot flies at Lethbridge were willing to mate, and each female deposited, on average, 1,400 black, ridged eggs, in rows of about 250 each. The females preferred to lay their eggs in the creases of moist paper towels. (For the laboratory bot flies that was the end; no monkeys were used in these experiments.) We have still not found the bot flies' site of choice for egg laying in the natural environment, though our prime suspects are tree leaves and branches.

No one has seen *Alouattamyia* mate in the wild, but males in the Cuterebridae family typically develop more quickly than females do, and then gather in trees or other high places. Again, no one knows why, but perhaps males in a group can attract more females per male, on average, than a single male could acting alone. That would improve each male's chances of mating, despite the competition. In any case, unmated females that fly near the group appear to have some way of advertising their virgin status, and the waiting males pursue them. When a male succeeds in clasping a virgin female, the pair alights to complete copulation.

Although the details of bot fly life history fascinated me, I particularly wanted to understand the interactions

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of howler-monkey bot flies and their hosts. Received entomological wisdom holds that a "prudent" parasite does not kill its host. Such restraint might seem particularly important for a host-specific parasite such as *Alouattamyia*. After all, if the parasite eliminates its natural host, it has nowhere to raise its larvae.

Yet many of the dead howler monkeys I found in the forest still bore a large number of bot fly larvae—ten or more. Because one third-instar larva can weigh more than a tenth of an ounce, ten larvae would be a heavy metabolic load, particularly for an immature monkey. My census of howler monkeys, about 1,200 individuals, also showed the proportion of juveniles was suspiciously low. Although about 300 infants were born each year, I estimated that there were only about 150 juveniles in the population. Perhaps, at times, "prudent" parasites weren't being quite prudent enough.

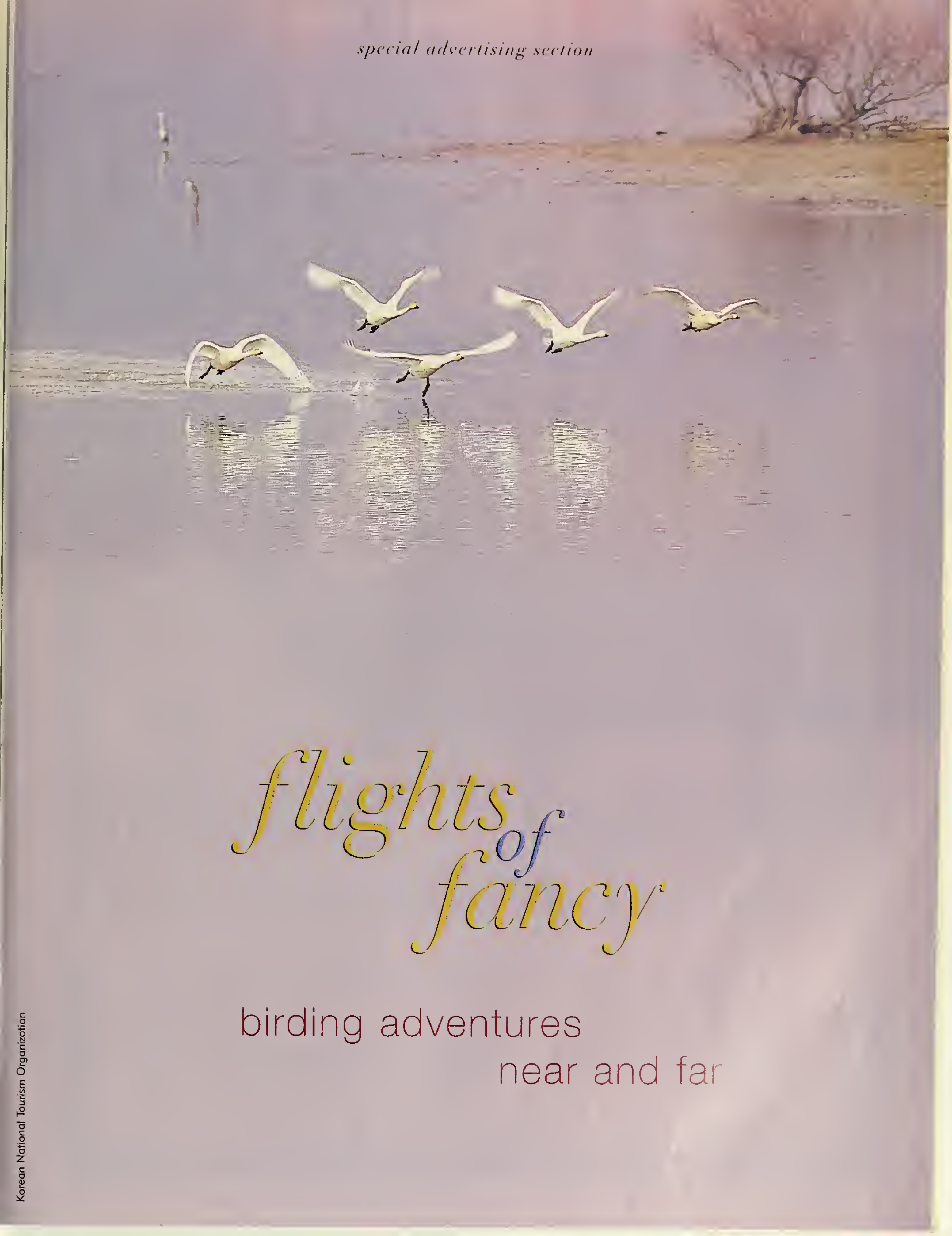
For the next five years I kept a monthly record of the number of bot fly larvae present in a representative sample of howler monkeys. I found a few afflicted monkeys in every month of the year, but the infestations seemed to peak two or three times a year, both in the number of monkeys afflicted and in the average number of bot fly larvae present on each monkey. The peaks came during the rainy season, which lasts from May through November, though the largest of them usually did not take place until July or later.

Throughout that same five-year period I also kept track of howler-monkey deaths. Scientists and visitors on the island alerted me or my assistants whenever a monkey was found dead, and we collected the remains. Although the procedure couldn't give us a complete tally of deaths, it did enable me to chart the pattern of annual mortality. The death rate was highest in July through November—the mid- to late-rainy season. At that time of year the energy-rich fruits and protein-rich young leaves the monkeys prefer to eat are in short supply. Were the high death rates caused by a food shortage, or by the cool, wet, cloudy weather? Perhaps those factors played a role, but, by themselves, they probably weren't sufficient: I found no overt signs of starvation or illness in the population. But I did note that bot fly larva infestations peaked at the same time.

A more complete account of the higher death rates probably goes something like this: The immune system of a howler monkey in good physical condition appears able to limit the number of larvae that can establish themselves at any one time. But howler monkeys in poor condition seem in jeopardy. Repeated attacks by bot fly larvae may exhaust the howler monkeys' fat reserves, which would normally carry them through the annual food shortages. Immature or fat-depleted hosts would be particularly at risk; combined with the stresses of cool, wet weather and low-quality food, many such monkeys would die.

Our data on infestation and mortality, as well as similar accounts of other bot fly–host interactions, suggest that populations of howler monkeys and their bot flies swing up and down like many other populations of predators and their prey. When the howler monkeys increase in number, all else being equal, the density of the howler-monkey bot flies increases as well. At times, though, the bot flies escalate their numbers out of proportion to their hosts. That leads to the deaths of so many howler monkeys that their population drops. But here the bot flies pay for their violation of the "prudent parasite" rule. They die off for lack of hosts. Hence the infestation rate drops, and the howler monkey population gradually recovers.

Katharine Milton is a professor in the Department of Environmental Science, Policy and Management, Division of Insect Biology, at the University of California, Berkeley. She has been studying the ecology and population dynamics of howler monkeys on Barro Colorado Island for thirty years.



flights of fancy

birding adventures near and far

Korean National Tourism Organization

Photos: Bermuda Tourist Board

BERMUDA

[illegible]

THE SUBTROPICAL ISLAND OF BERMUDA is a haven for birds and birders alike. Be prepared to spot a wide variety of birds—350 species have been recorded in this twenty-one-square mile paradise. The bright, lemon-yellow great kiskadee is both easy to spot and easy to hear. Listen for the loud, distinctive kis-ka-dee call that gave this raucous bird its name—it sounds uncannily like "*Qu'est-ce que dit*" in French. A member of the flycatcher family, the kiskadee was introduced into Bermuda in the 1950s and is now a year-round resident. Look for it in trees and shrubs or diving for fish.

Bermuda's most famous bird, the Bermuda petrel, or cahow, is a rare but rewarding sight. Considered extinct for 350 years, it was rediscovered in the 1950s. The petrel has a wingspan of thirty-six inches and nests in burrows on the East End islets from November through May. If you're lucky, you'll see this nocturnal bird soaring over the ocean at dusk.

Bermuda's native bluebirds can be seen in the many bluebird boxes lining the golf courses (every course on the island has a monitored bluebird trail). The island also has a population of white-tailed tropicbirds, known as the Bermuda longtails. With a three-foot wingspan and two long, streaming tail feathers, these birds are easy to recognize.

In the fall, Bermuda is a rest stop for birds migrating from Canada to South America. Thirty species of shorebirds regularly stop here. Look for them at Spittal Pond, Warwick Pond, and Seymour's Pond. Spittal, the best birding site in Bermuda, is also home to the greater flamingo. In autumn its mudflats host migrant shorebirds including plovers, yellowlegs, and sandpipers, and warblers are common in woodlands at both ends of the pond. You may also find cuckoos, kingbirds, flycatchers, swifts, swallows, orioles, and tanagers in the fall. Look for great blue herons among the reeds and shallow waters of Bermuda's marshes, or watch ruddy turnstones digging for food on the beaches.

With world-class resorts, sumptuous meals, turquoise waters, excellent snorkeling and scuba-diving, and a host of other attractions, it's not surprising that visitors return to Bermuda year after year!


TELEPHONE
TELEPHONE

Photos: Patricia Brodley

THE CAYMAN Islands

Birders in the know are finding their way to Cayman Brac, one of the three Cayman Islands.

CAYMAN BRAC, A SMALL ISLAND IN THE western Caribbean Sea, is one of the least explored birding destinations in the West Indies, but it is a birders' delight: miles of trails through tropical forests and coastal woodlands, good roadside viewing, and lots and lots of birds. In fact, 180 of the Cayman Islands' 224 bird species are found on the Brac.

One of the best times to visit the Brac is between August and May, when large numbers of migrants flock to the island, joining resident seabirds, wetland species, and an interesting combination of endemics. Don't miss *Amazona leucocephala hesterna*, the Brac parrot, the smallest member of the green Amazon parrot family. This parrot's size, coloring, call, and habits make it very different from its cousins on Grand Cayman, Cuba, and the Bahamas, so much so that if studies on its genetic makeup confirm that its genes are as distinctive as the rest of its attributes, it will become a new species. Look for this near-threatened parrot in the forests of the Parrot Reserve, established by the National Trust.

In the fall, parrots are seen everywhere on Cayman Brac. After months of child-rearing duties at the nest, the pairs emerge to teach their offspring the do's and don'ts of life in the forest. They fly from one fruiting tree to another; favorites include red birch, pepper cinnamon, wild fig, mangoes and papaya. Because they are creatures of habit, the parrots can be seen at regular sites as they fly to and from their breeding and roosting sites.

To see the five species of land birds that occur together on the Brac—Caribbean elaenia, vitelline warbler, thick-billed vireo, red-legged thrush, and Brac parrot—would otherwise require visits to the Swan Islands, coastal Central America, Cuba, and the Bahamas. The thrush is sartorially elegant in gray and black, with red legs and bill. It is usually noisy and bossy, but from November to January it becomes silent and disappears into the forest.

In between birding outings, try a little snorkeling or diving on the Russian wreck. You might go fly- and deep-sea fishing; photograph iguanas, orchids, and butterflies; or visit historic houses, caves, and the museum. And then there are the sunsets!

Korean National Tourism Organization

Korea

LOOKING FOR A BIRDING VACATION off the beaten path? Why not visit Korea, with some 400 bird species and fantastic opportunities to see some of East Asia's greatest birds?

Birdwatchers have discovered that Korea's extensive tidal flats, along with one of the world's steepest tidal ranges, make it a fantastic place to watch shorebirds. Add good roads with English signs, excellent public transportation, and a network of ecotourism groups, and you have a first-class birdwatching destination.

At the bird sanctuary on Bamseom Islet, high-powered binoculars allow glimpses of many species of ducks and raptors. Seosan Reclamation Lakes/ Cheonsuman Bay is probably Korea's best site for wildfowl. In winter, it's easy to see raptors, Oriental white stork, and white spoonbills. Large flocks of waterfowl—peaking at 300,000 birds in November—soar over the site's two main lakes. The Iron Triangle Battlefield, in Cheorwon, Gangwon-do, is a paradise for migratory birds. Located within the DMZ, and uninhabited by humans in the last 50 years, this site is a popular stopover for ash cranes and eagles.

For more information on birding in Korea, visit www.tour2korea.com.

Queen Anne's County

LOVELY AND HISTORIC QUEEN Anne's County, a gateway to Chesapeake Country, is also a fine site for birding. Start your visit in picturesque Kent Island, established in 1631. Across from the island, in Grasonville, you'll find the Horsehead Wetlands Center.

Operated by the Wildfowl Trust, this 500-acre sanctuary has trails around six waterfowl ponds, each representing a different wetland habitat. You're likely to come across red fox, river otter, geese, and swans. Native waterfowl include northern shovelers, redheads, wood ducks, and tundra swans. The ponds also attract black ducks, canvasbacks, American wigeons, lesser and greater scaups, green- and blue-winged teal, cinnamon teal, and herons. Migratory birds traveling north and south on the Atlantic Flyway also stop here.

Don't skip the visitor center, where a powerful scope overlooks a waterfowl pond. The center also boasts an aquarium with critters from the Chesapeake Bay. Other must-see sites include Terrapin Beach Nature Park, with a one-mile nature trail, a pond, and two observation blinds. Look for birds of prey, migratory birds, and breeding waterfowl.

Garrett County

GARRETT COUNTY, the westernmost county in Maryland, boasts extensive and exceptional birding hot spots. This frontier region's state parks and forests are ablaze with beautiful foliage, crashing waterfalls, and clear lakes.

Because of its geographical location and topography, Garrett attracts many birds not usually found at this latitude: Garrett is the only place south of the Mason-Dixon Line where you can see birds usually seen in Canada, the Great Lakes, and the Northeastern states. Discover the hermit thrush in shady maple and hemlock groves, bobolinks in golden hay fields, northern water thrush in swamplands, and hawks migrating in autumn.

Spring and fall bring swarms of migrant flocks. The seven local lakes are a stopover point for thousands of feeding, migrating waterfowl, while the forests are filled with migrant songbirds.

With more than 140 species of breeding birds, including 28 species of breeding warblers, Garrett County is indeed a birder's paradise. To get the *Birds of Garrett County* brochure, stop by the Garrett County Visitors Center. And ask about the many state parks that conduct birding programs.

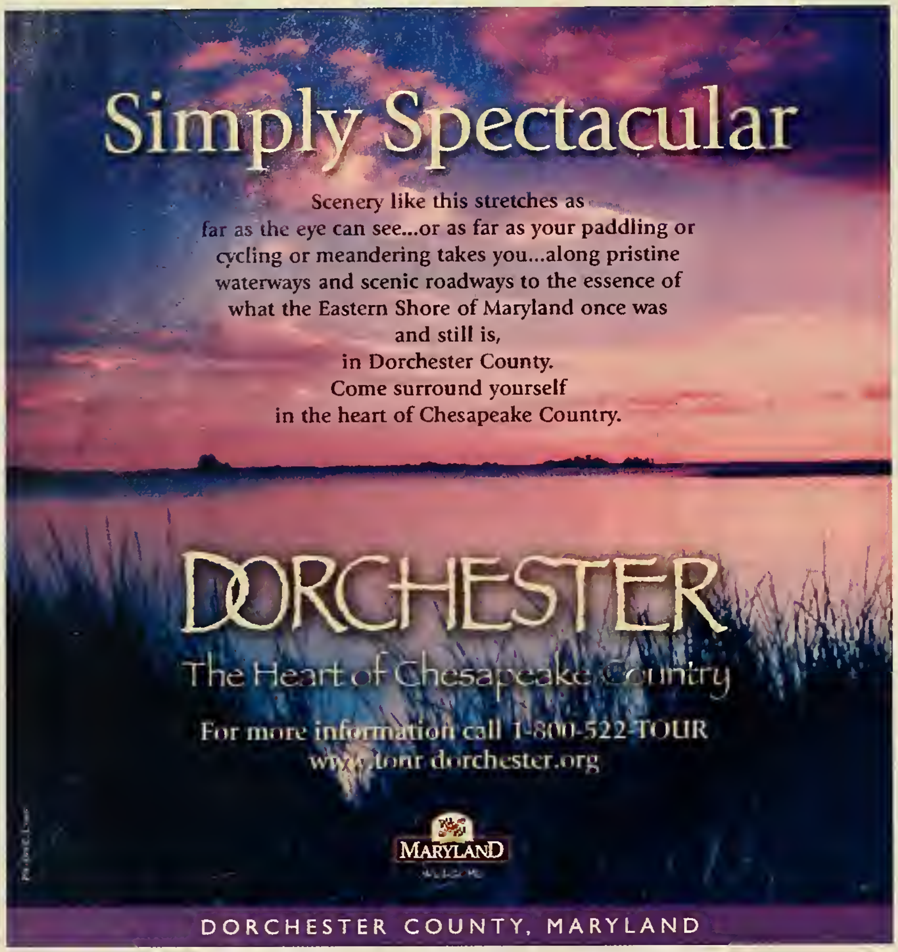
Worcester County

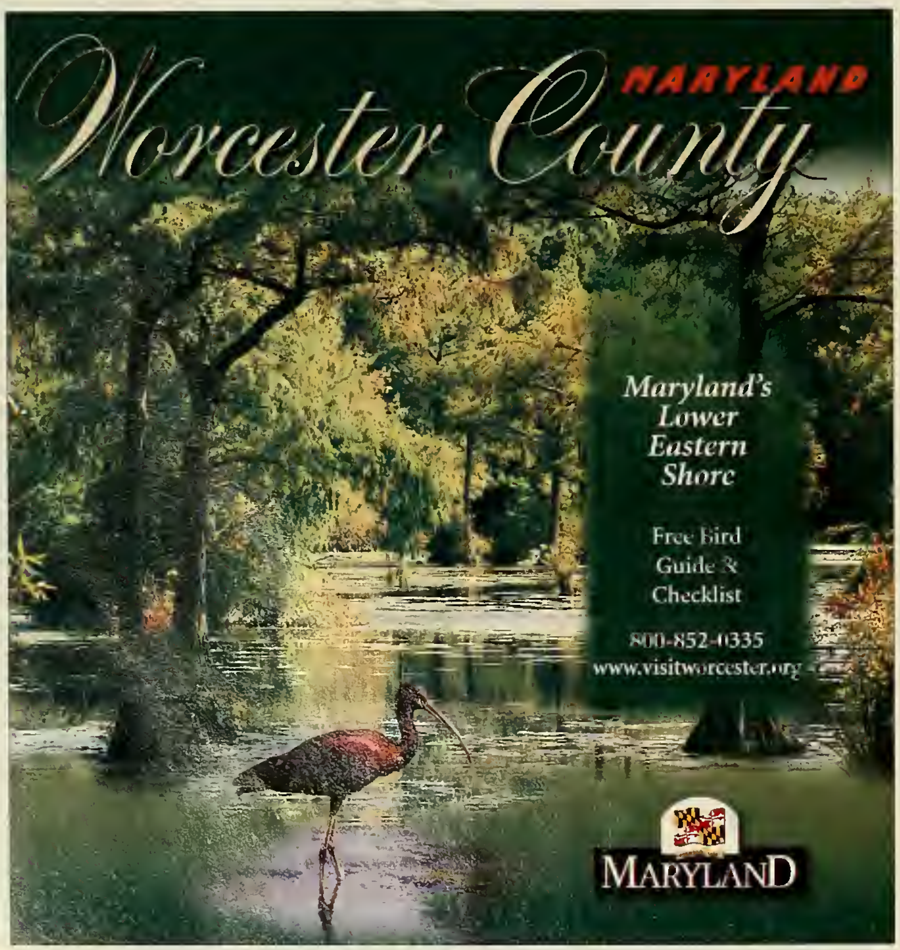
THE ONLY OCEAN-FRONT COUNTY in Maryland, Worcester County is especially known for the sandy beaches and boardwalk of Ocean City and the wild ponies that roam the dunes of Assateague Island. But Worcester is also a great place for birdwatching. With its great ecological diversity—the county is home to a barrier island, a cypress swamp, centuries-old forest, tidal wetlands, and secluded fields—Worcester hosts more than 350 species of birds.

Gerald Gerlitzki

In the fall, you'll spot myriad migratory species, including peregrine falcons, merlins, and flocks of tree swallows. If you are visiting Ocean City, take a birdwatching trip on a charter boat to see shearwaters, skuas, Wilson's storm-petrels, and Atlantic puffins. For those who prefer to stay on shore, Ocean City's bayside overlooks mudflats that harbor waterfowl, shorebirds, and gulls.

In the Pocomoke State Forest, the scenic Pocomoke River twists through stands of bald cypress. The best way to explore this spectacular river is by boat or canoe, which you can rent in Snow Hill. In addition to rare plants and wildflowers, you'll find hawks and ospreys lining the river and a host of waders along the shoreline. The Pocomoke Cypress Swamp is a major bald eagle roost; sometimes you'll find flocks of fifty eagles here.





Charles County

COME TO CHARLES COUNTY, THE gateway to historic Southern Maryland, and see the wild side of the Potomac! Visitors to this suburban county—less than an hour from Washington D.C. and historic Annapolis—are surprised to find it teeming with wildlife and natural beauty. Charles also offers first-class fishing, a dense population of nesting bald eagles, acres of beautiful forest land, 150 miles of spectacular shoreline, enough history to fill several books, sumptuous fresh seafood, and top-flight golf.

Charles County Office of Tourism

Among birders, Charles County is known for its large population of bald eagles, along with 321 other species. You can spot the eagles along winding Nanjemoy Creek, whose high banks protect their nesting sites. The creek also is home to ospreys and great blue herons. For 50 years, 2,500 herons have returned to the Nanjemoy Creek Great Blue Heron Sanctuary, operated by the Nature Conservancy, where they pair up, and lay and incubate a clutch of eggs. The mature forest along Mattawoman is home to the barred owl and vibrantly colored songbirds. A good time to visit is in the early evening, when you can hear the birds calling back and forth to one another. And the Chicamuxen Wildlife Management Area, near Mattawoman Creek, harbors rare species such as the Louisiana thrush.

Dorchester County

USFWS

FOR A TASTE OF CHESAPEAKE BAY tradition and the unique lifestyle of Maryland's Eastern Shore, come to Dorchester County. Bounded by the Choptank River and Chesapeake Bay, this gracious land welcomes you with the charm and simplicity of yesteryear.

Stop at the Visitor Center at Sailwinds Park to begin exploring the Heart of Chesapeake Country. Find the information you need, a waterfront boardwalk, a garden, a playground, and a spectacular view right on the banks of the Choptank.

Take in spectacular sunsets along 1,700 miles of shoreline. View many endangered species and hear the familiar calls of waterfowl at world-renown Blackwater National Wildlife Refuge, home to more than twenty species of ducks and eighty-five varieties of birds, including the American bald eagle.

Stroll along Cambridge's historic district, where stately eighteenth- and nineteenth-century homes grace brick-paved, tree-lined High Street. Let a historic tour—or even a ghost walk—take you back to this prosperous era. Visit the county's museums, which preserve its rich heritage. Explore the birthplace of Harriet Tubman and home of sharpshooter Annie Oakley.

At the end of the day, choose a retreat at a quiet inn or a luxurious resort in the Heart of Chesapeake Country.

special advertising section

BigPockets

BEFORE YOU EMBARK ON YOUR next birding or natural history trip, take some time to browse www.bigpockets.com or to request a catalog (877-247-3758). BigPockets is the first company to design and manufacture clothing specifically for birding.

To make shopping easy, the company arranges its catalog according to clothing, accessories, gear, and gifts. Going to Alaska in June? You'll find cozy jackets, sweaters, hats, gloves, foot warmers, and socks for your trip. Spending the summer at home? Check out the lightweight clothes that wick away moisture, sun block, sun hats, chigger repellent, and cool-cat collars. Going someplace wet? Big Pockets offers a waterproof field notebook and a pen that writes in the rain.

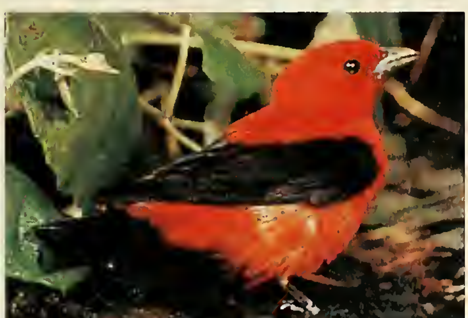
The company's most popular product, the BigPockets tropical vest, is virtually weightless, dries quickly, and takes up little space in a pack. The vest features ten big pockets to hold the largest tropical field guides plus binoculars, tickets, umbrella, repellent, and water bottles.

BigPockets sells great gifts for birdwatchers and other naturalists—from bird-friendly coffee and chocolate to stuffed toys for children. All products meet three criteria: functional for birding, best in their class, and compact enough to fit in a suitcase or daypack.

The Johns Hopkins University Press

FOUNDED IN 1878, Johns Hopkins is one of the largest and most reputable university presses in the country. Birders will be especially interested in the press' many books on Chesapeake natural history, including *Birds of the Mid-Atlantic and Where to Find Them*, by John Rappole, the only comprehensive field guide to bird life in the area that also directs readers to public sites where each species can be found. Rappole, a noted ornithologist, provides extensive information about every species: description, identification details for distinguishing similar species, habitat preference, vocalization, range, and Mid-Atlantic seasonal occurrence, abundance, and distribution. Each entry is accompanied by a color photograph, making identification easy for amateur bird watchers, and by a range of maps. A helpful guide to sites lists the best places to spot specific birds, from common species to rarities, and how to reach the sites by car.

For more information about the Johns Hopkins University Press, visit http://www.press.jhu.edu/press/index.html, where you can browse the catalog of 2,000 books in print.

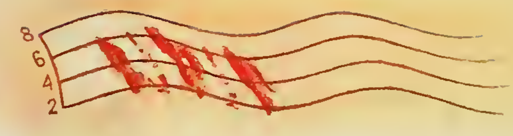


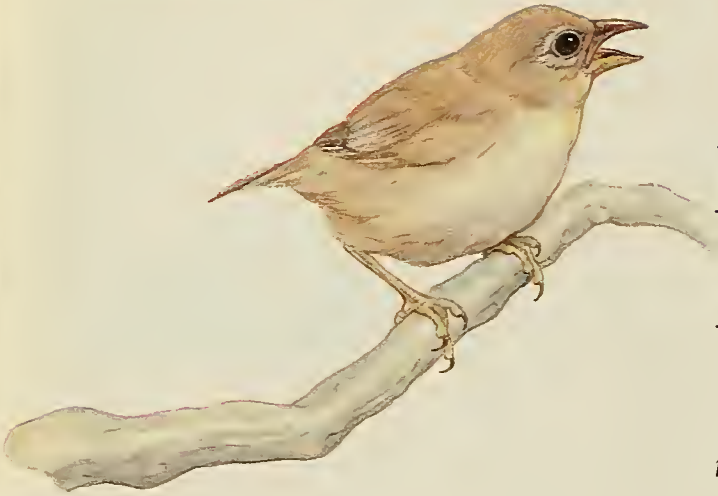
And Don't Miss...

ANNE ARUNDEL COUNTY—On the shores of the Chesapeake, this Maryland county is home to historic Annapolis, America's sailing capitol, and the Patuxent Research Refuge, which harbors over 200 bird species—including a pair of bald eagles that has been nesting here since 1989!

LITTLE ST. SIMONS—This private Georgian isle offers seven miles of pristine beaches and an unhurried pace. Located on the Atlantic Flyway, the island is a critical staging area for migratory birds. Flocks of shorebirds appear every fall.

TALBOT COUNTY—Discover the unspoiled beauty and maritime heritage of Maryland's Eastern Shore, and take the longest cable-free ferry in the U.S. to Oxford, once a major ship-building center.





Evolutionary Anthems

The songs of Darwin's finches might be responsible for the group's rapid speciation.

By Adam Summers ~ Illustration by Mick Ellison

On Santa Cruz Island, in the eastern Pacific Ocean, the morning sounds of songbirds foraging and courting are reassuringly familiar in the otherwise outlandish landscape of the Galápagos Islands. The dry washes here partly conceal tortoises the size of refrigerators; iguanas as long as your arm sprawl in the baking sun. Darwin's finches, one of the best-studied examples of rapid speciation, are the source of the early morning's whistles and trills. But the birds are far more than mere pleasant diversions that remind homesick biologists of their own territorial origins. Rather, already famous as the subjects of long-term studies on feeding adaptations and the origins of species, the birds are proving to biomechanists that their calls represent a mechanical link between foraging abilities and song production. The co-variation of song and beak size may have been the driving force behind the rapid evolutionary development of finch species in the small island chain, a process that took less than 3 million years.

Speciation—how one species gives rise to another—is easiest to grasp for populations that become isolated. Imagine that an earthquake upends enough rock to create rapids in a formerly sluggish stream (a common event in South America). The new stretch of rapids could keep fish upstream of the rocks from mating with their downstream counterparts. Inevitably, over the generations, the two groups will have to contend with differences between the two habitats—whether in dissolved oxygen levels, water temperature, food availability, or the presence of parasites. Those selection pressures—as well as the simple accumulation of diverse mutations—may be enough to genetically isolate the upstream from the downstream population.

Speciation without physical separation, however, is a trickier concept. Species arising by such a process are known as "sympatric," a term whose Greek roots mean "of the same country." The finches of the Galápagos present a textbook example of sympatric speciation. One common ancestor gave rise to fourteen distinct species, even though members of the ancestral population were within easy flight of one another—in other words, even though there was no geographical barrier to interbreeding.

Thirty years of fieldwork, molecular biology research, and morphological study have led to a good understanding of the evolutionary history of Darwin's finches, particularly the link between their food habits and the shapes of their beaks. Today's birds descend from a generalist ancestral finch that invaded the islands from mainland Ecuador. Galápagos species now inhabit a variety of ecological niches, and each species has a beak suited to finding food in its niche: insect-eating species, for example, have narrow, warbler-style beaks, useful for nabbing insects from leaves and bark; seedeaters have robust bills, tough enough and strong enough to crack the hard seeds they favor. Now the variations among Darwin's finches have enabled Jeffrey Podos, a behavioral ecologist at the University of Massachusetts in Amherst, and colleagues at Duke University to prove that a bird's beak is as vital to its song as to its supper.

The clear tones of birdsong emerge from internal air sacs that can inflate and deflate, much like a bagpipe's bladder. Muscles surrounding the sacs force air through a part of the bird's respiratory tract called the syrinx, a thin-walled region of muscle and cartilage roughly analogous to human vocal chords. As it passes through the syrinx, air vibrates at several dominant frequencies and many overtones, blatting as though it were blown through the mouthpiece of a trumpet. And, just as in a trumpet, the tone of the sound is profoundly affected by the length and shape of the resonating chamber "downstream" of the original vibrations. In the bird's case, the vocal tract acts as a long, fleshy resonating chamber, damping out many of the overtones. By rapidly opening and closing its beak a bird can alter the damping characteristics of the vocal tract.

Podos and his colleagues demonstrated in the laboratory that when sparrows sing, their beaks partly determine the tone of their call. The slower the beaks move, the simpler is the melody of the call, both in tonal range and rhythm. The next step was to study birdsong in the field, focusing on several species of closely related birds with varying beak shapes and sizes.

Mechanical systems usually have to sacrifice force for speed. That constraint is particularly telling in biological mechanical systems—where, for instance, jaws that can move rapidly cannot close with a lot of force. Podos realized that among Darwin's finches, the varieties of this trade-off and the natural variability of beak shape could enable him to test whether a bird's song could indicate the bird's ability to eat hard seeds. With Joel Southall, also at the University of Massachusetts, and Marcos R. Rossi-Santos of Projeto Baleia Jubarte in Caravelas, Brazil, Podos filmed the calls of seven species of Galápagos finches. The birds ranged from the warbler finch *(Certhidea olivacea),* with a pointy, narrow beak [*see illustration on opposite page*] to the large ground finch *(Geospiza magnirostris),* with a broad, heavy bill [*see illustration below*]. The results meshed well with the laboratory data. The heavy-billed birds had simpler calls, presumably because the bill, more suited for closing forcefully on a tough seed, was not able to move as rapidly as the more delicate beak of the insect eaters.

One of the chief roles of calls among songbirds is to find mates, and that takes me back to the topic of sympatric speciation. When that first population of generalist finches invaded the Galápagos, natural variation in beak size among individuals would have made the tougher seeds an accessible food item for some of the animals but not for others. Because song pitch and beak strength are interrelated, those birds would also have sung a slightly simpler, deeper song than their smaller-beaked brethren. Many female birds prefer males with a familiar call—their own—and so heavy-beaked females would have preferred the song of heavy-beaked males. The link between song and food could thereby lead to segregated mating within a population, even though all the individuals in the population could freely mix.

Ah, the sweet sound of evolution in action!

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

A bird's song is determined by the interplay of its vocal tract and its beak. The songs of Darwin's finches, whose vocal tracts are basically identical, differ mostly because of the birds' beaks. At the same time, the beaks largely determine the finches' diets. Jeffrey Podos demonstrated that a finch's song could predict the hardness of the seeds the bird could eat. The thin, fast-moving beak of the warbler finch (Certhidea olivacea) [see illustration on opposite page] *pitches the bird's song as high as nearly 8,000 hertz—almost three octaves above a soprano's high C—whereas the robust beak of the large ground finch* (Geospiza magnirostris) [see illustration at right] *limits the bird to a less variable melody that rarely breaches 2,000 hertz. The sound spectrograms next to the birds are not musical scores; rather, they portray, from left to right, how the frequencies of the birds' songs, in thousands of hertz, change with time.*

Portal to Petra

Hewn out of sandstone cliffs, the hidden capital of the ancient Nabataeans became a center for spice traders, artisans, and urbane sophisticates 2,300 years ago.

By Martha Sharp Joukowsky

Iridescent as a ribbon of silk fluttering in the air, the Silk Tomb (above) of the ancient city of Petra (see map at right), is named for the iron oxide striations in the sandstone monument. The Silk Tomb, which dates to the first century B.C., actually housed several burials and is one of the most distinctively colored rock-cut monuments of the Nabataean culture that made Petra its capital city.

Towering high above the Wadi al-'Arabah, a seasonal streambed that runs between the Dead Sea and the Gulf of 'Aqabah, in southwestern Jordan, majestic cliffs strike the eye with their patterns of russet and gold. Yet tucked inside the sandstone cliffs is a site even more thrilling to travelers, adventurers, and archaeologists: the "Rose-Red City," Petra.

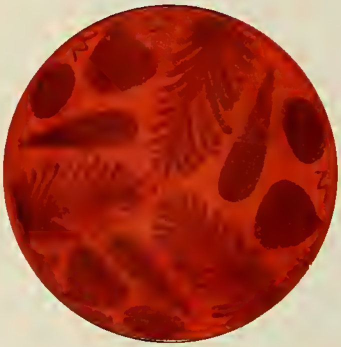
Beginning in perhaps the seventh or sixth century B.C., nomadic Arabs from as far away as the southern reaches of the Arabian Peninsula threw up temporary shelters against the mountain walls around the site of what would become the city. According to a fourth-century B.C. Greek account reported by the first-century B.C. historian Diodorus of Sicily, the earliest Petrans, or Nabataeans, as the people were then called, did not plant grain, fruit trees, or vines. But they did raise camels, which provided them with milk, cheese, and meat, as well as hides for tents. Sometime in the second century B.C. the Nabataeans and their camel caravans attained wide-ranging economic success through their control of the spice trade routes. The Nabataean dominance extended over the southern routes through the Arabian Peninsula, to Amman and Damascus to the northeast, and through the Negev desert and into the Sinai to the west, as far as the western edge of the Nile delta.

Petra was the capital of the Nabataeans' independent kingdom, and as Greek and Roman demand for such exotic goods as cassia, cinnamon, frankincense, and myrrh increased, so did the prosperity of the Nabataeans. They excavated the cliffs to build some 800 tombs as well as numerous extraordinary freestanding structures. Their hydraulic engineers dammed nearby water sources and built massive cisterns for retaining the infrequent rains. With a reliable water supply, they irrigated crops and sustained a growing population, estimated at its peak to have been between 20,000 and 30,000 people.

As their trade expanded, the Nabataeans borrowed artistic styles from Hellenistic, Parthian, and Roman cultures, adapting them to their own eclectic style. They so prized foreign goods that, according to the ancient Greek geographer Strabo, "they conferred honors on anyone who increased them" (though Strabo adds, in wonder, "they have only a few slaves").

An earthquake in A.D. 363, one of several that was to strike Petra, may have precipitated the city's demise. By that time, trade no longer centered on Petra, and its population had declined. Christianity flourished in the waning days of the city, which survived well into the sixth century. In the eighth century, another earthquake struck, but by that time the city had been abandoned. □

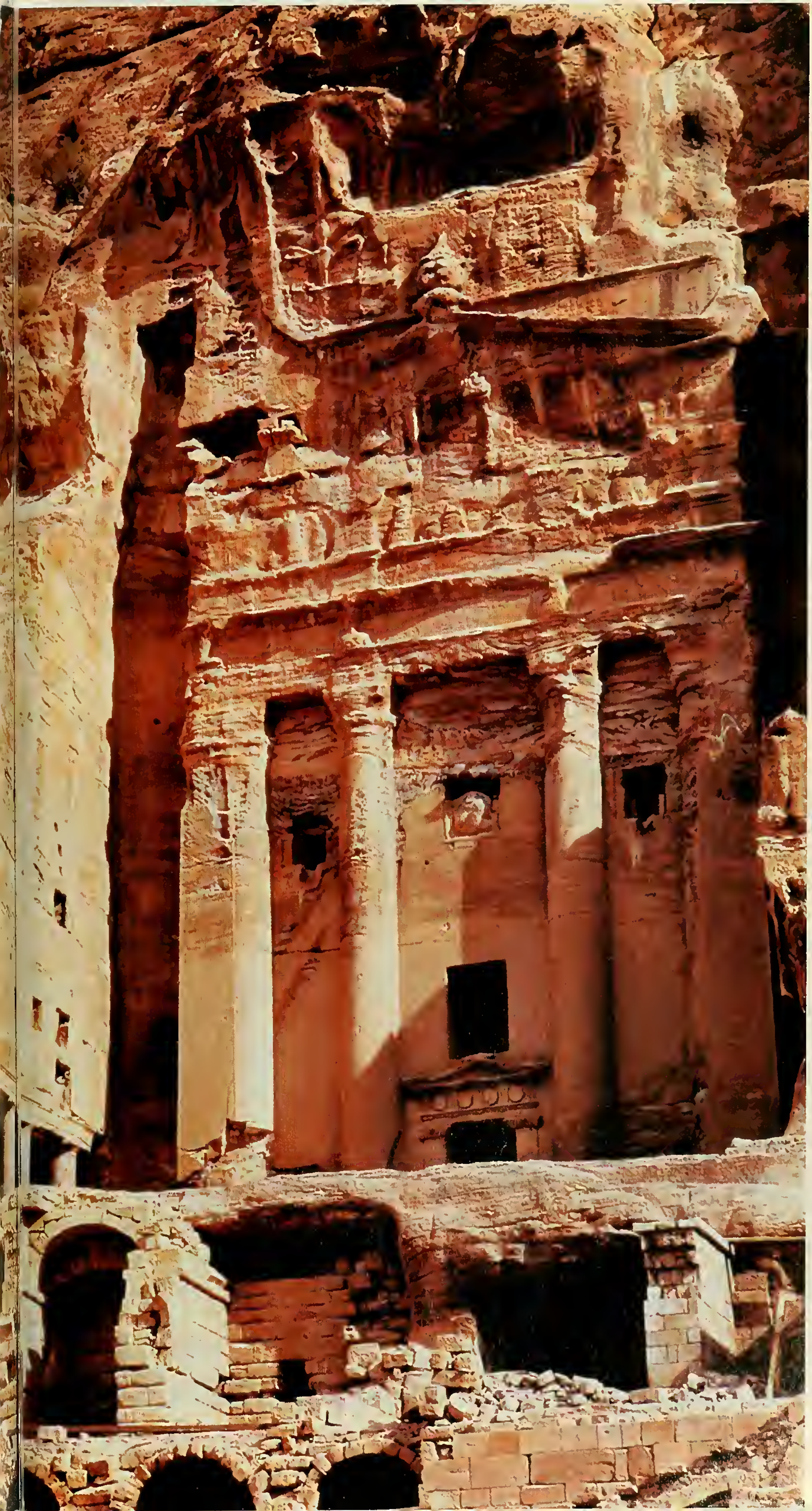
Urn carved out of the rock wall decorates the top of the Dayr, or "monastery," Petra's largest rock-cut monument. From this high perch, some 150 feet above the valley floor, visitors can take in the site of Petra and its vast surrounding landscape.



Nabataean plate displays typical decorative motifs of the culture, including figs, olives, and palm leaves. The Nabataeans were renowned for their extraordinary ultrafine pottery bowls and plates, decorated with designs unique to the Nabataean culture.

Betyl, or stone idol, dated to the first century B.C., depicts a stylized human face that may represent one of the great goddesses of Petra. A "house" for the god is indicated by the pediment and architectural details around the edge. The inscription reads: "Goddess of Hayyan, son of Nybat."

Terra-cotta plaque from the first century A.D. depicts a male pipe player accompanied by a pair of female musicians. The Nabataeans often had large gatherings at mealtime, and one ancient writer commented that it was common to have two female singers at each banquet.



Mosaic roundel, from the floor of the sixth-century Church of Petra, may depict a camel, the backbone of the Nabataeans' successful trade in exotic spices. Alternatively, it may depict a "camelopard," the name the Greeks and Romans gave to the giraffe, which they described as a camel with the spots of a leopard.

The Urn Tomb, so-called for the small vessel carved at the top of the facade (toward the center, near the top) is one of the largest of Nabataean rock-cut monuments. Architects first removed a large section of the hillside to create a seventy-foot courtyard in front of the tomb. The central niche, seen below the pediment, may have been the tomb of King Malik II, who ruled from A.D. 40 to 70.

Promised Land

Several million years ago tectonic forces began to create an edenic corridor that led early humans out of Africa and into the Near East.

By Zvi Ben-Avraham and Susan Hough

Straddling the border between Israel and Jordan, deep within a region torn by decades of political strife, is the stark, desolate, intensely saline Dead Sea. Virtually barren of life, and imbued with a stillness that bespeaks extreme antiquity, the Dead Sea, in geologic terms, is actually quite young—a mere several million years of age. Both the sea itself and the entire Dead Sea valley in which it lies are the result of north-south motion at the boundary between two tectonic plates—two parcels of the Earth's rocky crust.

Continents might appear to be indestructible, but when tectonic forces pull blocks of crust in different directions, eventually even a continent will break. Until 20 million to 30 million years ago the African and Arabian plates were a single massive block of our planet's lithosphere. But then the floor of what soon became the Red Sea began to spread—launching the Arabian plate to the north-northeast, toward Eurasia; breaking the small Sinai subplate away from the African plate; and tearing up Earth's crust along the way.

Nowadays the Arabian plate is diverging from the Sinai subplate at a rate of about four millimeters a year. That's slow even by geologic standards (and a dozen times slower than human fingernails grow), but given enough time, even a slight but continual movement of a tectonic plate can cause inexorable, prodigious changes. In the past 20 million years or so, the Red Sea has opened, the Arabian Peninsula has taken shape, and the eastern flank of the Dead Sea fault has shifted about sixty miles northward with respect to the western side—enough to sculpt the Dead Sea valley, a long, prominent path through the landscape of the Levantine Corridor [*see map on next page*]. From that distant time until what was, geologically speaking, yesterday, the Dead Sea valley became the main land route out of Africa for both flora and fauna. Among the fauna, of course, were some of our earliest hominid ancestors. And as the geologic story of the Levantine Corridor has come into focus, an intriguing plotline has emerged: for perhaps the first time, investigators have shown that large-scale geologic processes have helped shape the course of human history.

Like so much else in nature, the topography of the Earth eschews straight lines. When a markedly linear feature does emerge, say from a subtle topographic trend discernible only in a satellite photograph, the trained eye of a geologist invariably sees an active fault—a feature along which earthquakes persistently recur. But you don't have to be a geologist to see the Dead Sea fault zone. Viewed from high above, its linear morphology, running up the middle of the Levant, is a dramatic—and decidedly unsubtle—indicator of its geologic character [*see illustration at left on page 47*].

The tectonic forces on the Arabian plate and the Sinai subplate are pulling in slightly different directions, and at different rates, creating what geologists call a transform fault [*see diagram at right on page 47*]. From the Dead Sea the fault extends almost due south to the Red Sea, and almost due north along the Jordan River and up into Lebanon, eventually wending its way into southern Turkey. Flanked by margins as high as 7,000 feet above its floor, the rift valley created by the Dead Sea fault is one of the deepest and most abrupt depressions on Earth.

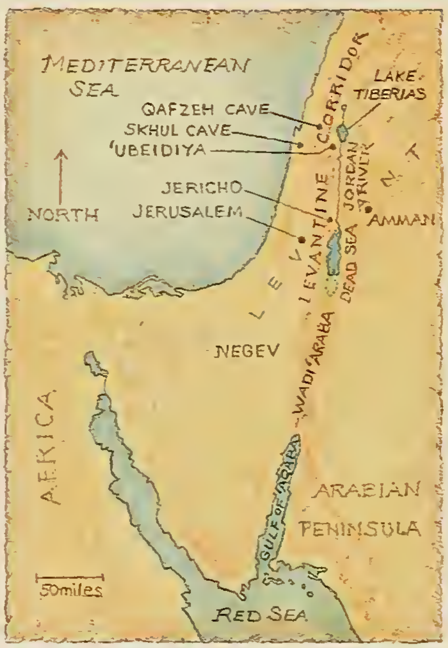
Investigators can point to compelling evidence for ancient, damaging earthquakes in the anthropologically and archaeologically crucial area bordering the Jordan River. The first-century A.D. Jewish historian Flavius Josephus, writing of the destructive earthquake of 31 B.C., describes "an earthquake in Judea, such as had not occurred before, which killed many cattle. . . . And about thirty thousand persons also perished in the ruins of their houses." Characteristically toppled and fractured blocks of limestone that were once columns are evident among the ruins of early Jericho and elsewhere. And the sediments in the Dead

Dead Sea valley, a once-verdant corridor that runs through the region just east of the Mediterranean Sea, was the land route taken by hominids emigrating from East Africa, beginning about 2 million years ago. Today the valley is arid and thinly populated, and the Dead Sea which lies at its heart, is inhospitable to most forms of life.

Sea basin incorporate evidence of a good deal of seismic upheaval during the past 70,000 years.

For now, however, the Dead Sea rift valley offers geologists a nearly unparalleled opportunity to see and investigate continental breakup in action. Natural processes can be studied here without impediment, because the area is both sparsely populated and largely free of vegetation. The shores of the Dead Sea itself are the lowest dry land on Earth, and among the Dead Sea valley's unique characteristics is that, even though it has sunk to hundreds of feet below sea level, much of it is not submerged. Rock formations are thus well exposed.

Tens of millions of years ago, before the Arabian plate set off on its Eurasian journey, the Mediterranean Sea was far bigger than it is today, and covered much of the Levant. Later activity at the boundary between the Sinai subplate and the Arabian plate caused major upheavals of the seabed; between the two plates a block of crust sank, forming a valley known as a graben. As the huge, salty Mediterranean evaporated and receded, that graben retained some of the water. Eventually the large body of salty water that occupied most of the Dead Sea valley shrank because of evaporation. Several lakes subsequently appeared and disappeared in the rift valley; the present Dead Sea, comprising two sub-basins, was left behind about 10,000 years ago. Its northern sub-basin was, and remains, by far the deeper: it now holds less than a thousand feet of water, and its bottom lies about 2,350 feet below sea level. The much shallower, southern sub-basin is now dry.



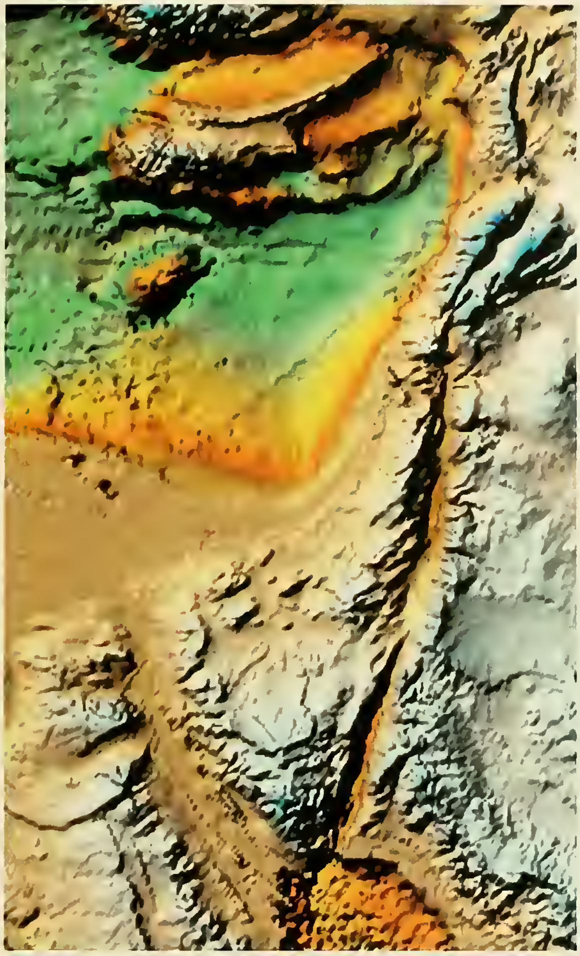
Geologists have devised a number of clever ways to reconstruct the past movements of tectonic plates. One important clue comes from estimating the rate at which sediments were deposited. Investigators have found that the upper, hence later, layers of sediment in the Dead Sea valley built up more quickly than the lower, earlier layers. Hence the water that carried the sediments from higher land to the flat valley floor must have flowed more quickly as the millennia passed. That implies the surrounding landscape was becoming increasingly mountainous. Accordingly, geologists have inferred that before about 5 million years ago the entire Dead Sea fault zone was relatively flat, but that in the past 2 million to 3 million years, accelerating tectonic processes have strongly uplifted its flanks.

There is further evidence of rapid change in the Wadi 'Araba, or Arava Valley, the southern part of the Dead Sea valley, which reaches from the southern end of the Dead Sea to the Gulf of 'Aqaba. In the past 2 million years the Wadi 'Araba subsided, as the neighboring Negev region to the west—as well as the Trans-Jordanian plateau to the east—was uplifted and tilted. Here, as elsewhere, seemingly gradual geologic motion has led to dramatic cumulative changes. In the blink of a geologic eye the Dead Sea transform fault carved up enough of the landscape to reconfigure the patterns of river drainage in the Negev desert. As a result, within just the past 2 to 3 million years sizable freshwater lakes formed in newly created depressions in the Wadi 'Araba.

The appearance of large bodies of freshwater in an otherwise arid zone invariably gives rise to a wetter, more temperate local climate. The air becomes more humid because of evaporation from the lakes, and large bodies of water also tend to buffer the extremes of hot and cold, making the region altogether more inviting and hospitable to terrestrial life.

In the southern Levant the new lakes would have beckoned to flora and fauna alike, just as in more recent times in North America, trailer parks have sprung up near new bodies of water such as southeastern California's Salton Sea (suddenly created as a result of an engineering gaffe combined with major flooding on the Colorado River in 1905). Of course Airstreams and RVs were hard to come by during the Pliocene and Pleistocene Epochs, but the migrating creatures of Africa, including early modern humans, gradually made their own kinds of living arrangements near the lakes that appeared in the rift valley. Thus did the Dead Sea fault carve the land route out of Africa: a navigable, habitable corridor flanked by raw, rugged rock.

We *Homo sapiens* are descended from bipedal primates—usually called hominids—that first appeared in Africa some 5 million years ago. The



Dead Sea transform fault, the nearly linear north-south boundary between the Arabian plate and the Sinai subplate, is clearly visible in the topographical relief model (above). For 20 million years the floor of the Red Sea has been spreading apart and the Arabian plate has been pivoting northward with respect to the Sinai subplate and its parent, the African plate (right). By 2 million to 3 million years ago the movement along the fault had created a deep, lush, navigable valley.

earliest hominid remains have been unearthed in East Africa—that is, in present-day Ethiopia, Kenya, and Tanzania. The earliest hominid tools that appear to be part of a standardized tool-making tradition were discovered in the same region: hand axes related to the Acheulean culture. Such axes were a Paleolithic invention—rounded at one end to fit in the palm, pointed at the other end, chipped and fractured to a cutting edge along the perimeter.

Early Acheulean axes, about 1.4 million years old, were found at Olduvai Gorge in Tanzania, the site made famous by the findings of the archaeologists Louis and Mary Leakey. Outside Africa the earliest hand axes whose dating is uncontested are also Acheulean and also about 1.4 million years old. They were unearthed in the Dead Sea valley about sixty miles north of the Dead Sea—at the extensive site of 'Ubeidiya, a vanished lake just south of what was once the biblical Sea of Galilee, now variously called Lake Tiberias or Lake Kinneret.

Excavations at 'Ubeidiya have uncovered the best available hard evidence for the migration of early hominids [*see "Down in the Valley," next page*]. Since 1960 some thirty archaeological layers, showing multiple distinct periods of occupation, have been exposed. On the basis of several kinds of converging evidence—magnetic characteristics of the rock layers, changes in sedimentation, ecological changes reflected in pollen grains, and deposits of bones, boulders, fossils, and tools—investigators have been able to date the occupations with confidence. Later sites elsewhere in the Dead Sea fault zone have yielded a wealth of additional evidence of hominid and human occupation, such as uncracked, hard-

shelled pistachios, acorns, and water chestnuts, accompanied by pitted stone hammers and anvils. The earliest known raisins and olives have been found in this region. And, tellingly, within natural oases are trees of Sudanese origin: emigrants from the southwest.

A million years ago, in Pleistocene times, when freshwater was far more abundant than it is today, the Dead Sea rift valley would have been lush, verdant, and full of things for the indigenous fauna to eat. And the paleontological record clearly shows that the splendid new corridor attracted a remarkable influx of species—birds, mammals, invertebrates, plants—between 2 million and 3 million years ago. Arriving in step with East African flora were the creatures of the East African savannas: gazelle, giant deer, hippopotamus, rhinoceros, wart hog. Life arrived and blossomed once tectonic movements had pried the region's blocks of crust apart and tilted them to form mountains, providing the water from which all else flowed.

Today, unfortunately, that land of milk and honey is no more. The freshwater lakes that once dotted the Wadi 'Araba are permanently dry. The Dead Sea itself is nearly lifeless. Almost 35 percent (by weight) of its "water" is made up of dissolved solids—not

Down in the Valley

By John J. Shea

On the outskirts of Jericho, beside the road to Jerusalem, is a sign welcoming visitors to "the world's oldest town." "Oldest" hardly begins to say it. At least 1.8 million years ago—long before 12,500-year-old Jericho became the continuous habitation on which the sign stakes its claim—some of the first hominids ever to venture out of Africa probably walked through Jericho and drank water from its spring. The lakes that filled the valley of the Jordan River between 2 million and 3 million years ago formed a biogeographic corridor connecting hominid habitats in East Africa with the southern foothills of the Alpine-Himalaya mountain belt.

The earliest evidence for a human presence in the Jordan valley comes from the site of 'Ubeidiya, just south of Lake Tiberias (the Sea of Galilee) in northern Israel. There, stone tools and the fossils of large mammals occur together in remnants of a muddy shoreline about 1.4 million years old. Hand axes similar to the ones discovered at 'Ubeidiya occur throughout southern Eurasia, suggesting that the site records the passage of one of Africa's earliest emigrants, *Homo erectus.* (Earlier hominids, such as *H. habilis,* may have passed through the region en route to sites such as Dmanisi, in today's Republic of Georgia, but they left no trace of their sojourn in the valley.)

Acheulean hand axes from 'Ubeidiya in Israel (left) and Olduvai Gorge in Tanzania (right)

Stone hand axes, fashioned according to African techniques and found at a site just north of Lake Tiberias, suggest another round of emigration out of Africa about 780,000 years ago. Remains discovered west of Lake Tiberias at Skhul Cave and Qafzeh Cave indicate that early modern humans—probably either descendants or near relatives of the recently discovered, 160,000-year-old *H. sapiens* fossils from Herto, Ethiopia—were present in the Jordan River valley between 80,000 and 130,000 years ago.

Some 70,000 years ago Neanderthals arrived in the area, perhaps driven southward by the abrupt onset of glacial conditions; they probably competed with modern humans for caves and other habitats. Within 40,000 years Neanderthals had become extinct throughout Europe. The Jordan valley is one of the first places where modern humans developed strategies for displacing rival species and establishing dominion.

With the waning of the Ice Age some 12,000 years ago, hunter-gatherers living in the Dead Sea rift zone made some crucial innovations in the collecting of plant foods. The earliest levels of excavation in Jericho show that they gathered the seeds of cereal grasses from the rocky crags flanking the valley and planted them in fertile alluvial soil. The result: domesticated plants, followed centuries later by domesticated cattle, goats, and sheep, and the expansion of human settlements.

John J. Shea, a specialist in stone-tool analysis and in the Paleolithic period of the Near East and Africa, is a professor of anthropology at Stony Brook University in New York State. During the 1990s he codirected excavations at 'Ubeidiya, Israel; he is now codirecting excavations at Omo Kibish, Ethiopia.

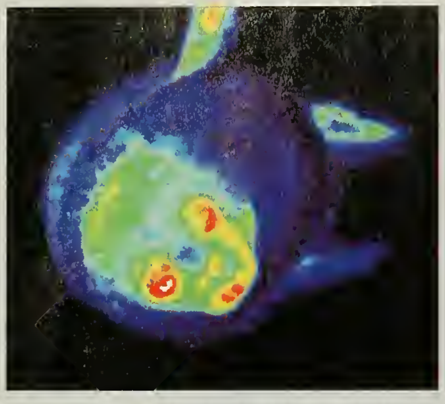
Dead Sea, the lowest, saltiest lake on Earth, was originally left behind in a deepening valley as the vast Mediterranean Sea retreated from the Levant between 5 million and 6 million years ago. The water level at the shoreline is about 1,360 feet below sea level, and it continues to fall because of evaporation, laying bare the saline, mineral-rich sediments visible in the photograph.

only sodium chloride but also potassium, bromine, and magnesium salts—giving it the highest salinity of any lake on Earth. With each passing year, evaporation further drops its level and raises the salinity of the remaining fluid. Since 1929, when hydrologists began keeping records, the Dead Sea has dropped by more than seventy feet. Only highly specialized communities of salt-tolerant microorganisms make their home in it today.

Scholars tend to seek meaning along sharply different timescales. A historian typically searches across decades or centuries for the written word. An evolutionary biologist may study a species across hundreds of thousands of years. A physical anthropologist considers the few million years that hominids have walked the Earth. The frame of reference for a terrestrial geologist may be longer still—as long as Earth's 4.6-billion-year history. The longest timescale of all is the cosmologist's 13.7-billion-year age of the universe.

Yet rarely, it seems, have the disciplines met. For the historian, the questions addressed by evolutionary biology, anthropology, geology, and cosmology have generally (except for the occasional natural catastrophe) fused with the unchanging background against which the real action takes place. Increasingly, though, physical scientists and historians are seeing connections. The physiologist and evolutionary biologist Jared Diamond of the University of California, Los Angeles, for instance, has advanced the thesis in his notable book *Guns, Germs, and Steel* that the exigencies of geography, if not geology, have played a critical role in shaping the development of cultures.

In the study of the Dead Sea fault zone, one can extend the connections further still. Creakingly slow geologic forces opened up the corridor for humanity's earliest ancestors to take their first steps out of Africa and into the world beyond. That exodus was probably inevitable, but the timing and direction of the migration were determined by plate tectonics. Perhaps it behooves our species, now poised to shape the planet in dramatic and potentially disastrous ways, to realize how fundamentally the planet has shaped us. □



Infrared image of a Weddell seal pup reveals the insulating efficiency of its lanugo, or baby fur. In the false-color image, shades of blue and green represent relatively low temperatures on the animal's surface; shades of yellow and red represent relatively high ones. The image shows that only the face and flippers radiate heat.

Sunbathing Seals of Antarctica

The puzzle is: How do they keep cool?

By Terrie M. Williams

Within an hour of the passing of a late October blizzard, there is little evidence of the storm on a vacant Antarctic beach. The bright Sun shines in a cloudless sky, and a light breeze riffles the clear waters of an open pool in the sea ice of McMurdo Sound. Weddell seals, spurred by the improved weather, haul themselves out of the water onto the icy edges of the pool. Each one, whether burly male, young female, or mother with youngsters in tow, claims an accustomed spot on the frozen shoreline. They settle on their backs into grooves in the ice that fit their bodies like familiar chairs. The adults soon doze soundly except for the occasional relaxed snore, while the energetic youngsters continue to play, popping in and out of the water. Finally exhausted, they crawl next to their mothers to sleep, their rounded bellies pointed directly toward the Sun.

For six years my colleagues and I have witnessed the spectacle of the sunbathing seals during the beginning of the austral summer, but never once have we considered joining them. After all, we are just 840 miles from the South Pole. As inviting as the pool appears, the "beach" where we are standing has been carved out of frozen sea ice by the constant summer sunlight and the movements of the Erebus Glacier ice tongue, near McMurdo Station. The Sun may never set, but air temperatures can plummet to −4 degrees Fahrenheit, and blinding snowstorms appear without warning. Sunbathing here can be risky business: even huddled in our parkas and boots, the members of our expedition live under the constant threat of frostbite and hypothermia.

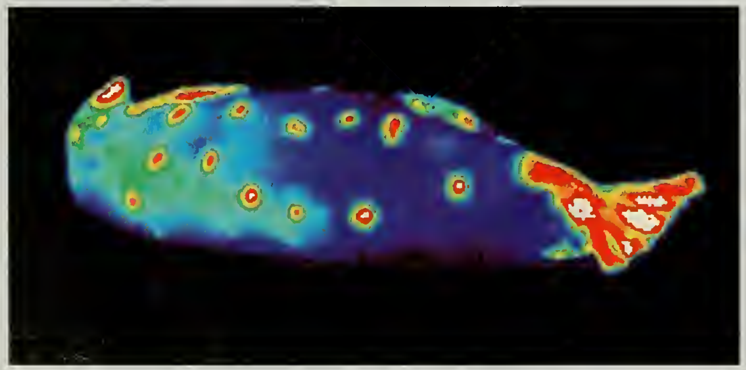
Remarkably, Weddell seals manage to thrive year-round on and under the sea ice, without shivering and without the long, thick fur characteristic of cold-adapted terrestrial mammals such as Arctic foxes and musk oxen. (The coarse, half-inch-long hairs of the Weddell seal pelt provide little in the way of insulation.) By any standard, that is an extraordinary thermal feat. Yet the very effectiveness of the insulation raises a puzzling question: How can a sunbathing seal in the Antarctic avoid overheating? The answer depends on an even more remarkable, if somewhat counterintuitive, physiological feat. Weddell seals have evolved a temperature-regulating system that enables them to keep warm in the coldest climate on Earth, yet remain cool enough to lollygag about in the summer air without even breaking into a sweat.

Our research team in Antarctica includes eight biologists who travel south every austral summer to study Weddell seals as they hunt beneath the sea ice. With the support of the National Science Foundation's Office of Polar Programs, we explore the seals' navigational abilities, predatory tactics, and diving capabilities. As the team's exercise physiologist, I am charged, among other things, with finding out how the seals maintain their relatively constant, hot internal temperature while they hunt and rest in water that would render a person hypothermic in minutes. As one might expect, the answer begins with fatty tissue: blubber.

In 2002 my graduate student Matthew R. Rutishauser and I arrived in Antarctica with several pieces of specialized equipment from my laboratory at the University of California, Santa Cruz. The first

Weddell seal pups such as the one in this photograph wear their fluffy lanugo fur coats for insulation until they reach about four weeks old. Thereafter they rely, as their parents do, on blubber to keep them warm in the water.

Adult seal, bleeding from the left foreflipper, may be sunbathing to recuperate from its wounds. The Sun's heat may stimulate an increased flow of blood, heat, and oxygen to wounded tissues, thereby promoting healing.



Numerous thermal "windows," which radiate excess heat, are apparent in this thermal image of a sunbathing seal. The animal can jettison excess heat though its face, foreflippers, and hind flippers. The hot spots along the body are bite wounds in the pelt.

was a portable ultrasound machine, originally designed for monitoring human pregnancies, that enabled us to view and measure the thickness of the blubber layer just below the skin of adult seals and their pups. The ultrasound scans showed a relatively uniform layer of blubber running virtually the entire length of the body, and ranging between 1.6 and 2.4 inches thick, in adults that weigh between 900 and 1,100 pounds. Even in one-month-old pups, which are the size of mature Saint Bernards, the blubber layer is between 1.2 and 1.6 inches thick.

Our second piece of equipment was an infrared thermal camera, which shows differences in temperature across the surface of an animal as a false-color image. We knew from earlier investigations that diving Weddell seals have a core body temperature that hovers around 97.7 degrees Fahrenheit. The camera would show us just how effective the fatty blubber was at keeping that heat from escaping into the ice and frigid Antarctic air.

The first seal I examined was a male that had recently emerged from a hole in the ice. At first the camera didn't even distinguish the wet animal from its frozen surroundings; the entire image was dark blue. Assuming the camera was working, the seal's skin temperature was the same as that of the ice—otherwise the batteries in the camera had failed in the cold.

Then the seal turned his head toward me and yawned; his hot open mouth glowed bright red in the image. Subtle surface temperatures soon became apparent. Hot nostrils intermittently popped into the picture each time he breathed. The skin around his eyes glowed as well, suggesting that surface blood vessels prevent the eyes from freezing as he hunts for fish in the chilly waters beneath the ice. The rest of the seal's thermal image was a ghostly blue, a testament to the quality of his blubber insulation.

In mid-October the Antarctic Sun sets for the last time for nearly four months. Throughout that period of uninterrupted daylight, Weddell seals haul their massive bodies through cracks in the sea ice or in the growing pools of meltwater, and onto frozen beds of ice. Too rotund to shake out the water quickly freezing onto their fur, the animals roll around in the soft snow, to "towel" themselves dry. Once settled, they lounge in the sunlight for hours, which sometimes dissolve into days. The Weddells often stay so long in one position that they melt into the ice, leaving telltale bathtub-size, seal-shaped imprints scattered across the frozen surface. Rather than avoid the intense solar radiation, the seals seem to revel in the sunlight. Only when temperatures dip below –4 degrees Fahrenheit, winds whip up above fifteen knots, or snowstorms blow across the ice, are the seals driven back into the water, where the environment is far more stable.

But if the blubber layer enables the seals to meet the thermal challenge of living in the frigid water under the ice, it also poses a double peril for their well-being. In the first place, we estimated it would take only a few hours of lying in the intense Antarctic Sun for Weddell seals to cook in their own skins. The second problem is that overheating would threaten reproduction, particularly the viability of sperm. So the seals must get rid of the excess heat, but how? After all, they cannot shed their blubber, the way Matt and I take off our parkas when we get too warm. As it turned out, the solution to the puzzle of keeping sperm cool was the first step in figuring out how blubbery Weddell seals can spend days soaking up sunlight.

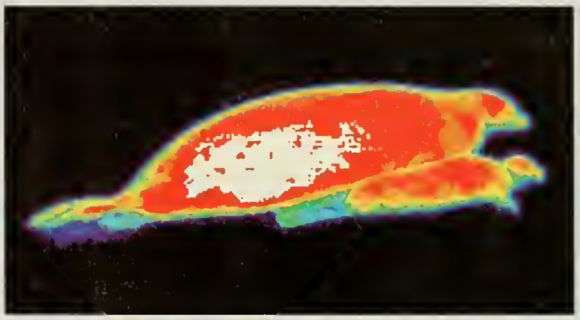
For a male mammal to produce viable sperm, the temperature of the testes must be precisely controlled; typically, it is several degrees cooler than the core body temperature. In land mammals, the testes remain cool because they reside in external scrotal sacs. For a mammal that lives in water, however—not to mention icy Antarctic waters—the same body plan would be a liability. A scrotal sac would expose the testes to extreme cold, and interfere with a sleek, hydrodynamic profile. Hence the testes of Weddell seals, like those of other seals and cetaceans, are internalized, lying between the abdominal muscles and the thick insulating blubber layer. Of course, that placement exposes sensitive organs to the risk of becoming too hot.

The problem is solved in seals with an elegant anatomical arrangement of blood vessels, first described by Sentiel A. Rommel, a comparative morphologist at the Marine Mammal Pathobiology Laboratory in St. Petersburg, Florida, and his colleagues. The investigators painstakingly mapped the seal's vasculature, and so discovered a dense network of veins enveloping the seal's testes. The network receives blood directly from the veins of the two hind flippers. Because the seal's layer of blubber does not extend to its flippers, veins in the flippers lie close to the surface of the skin, poorly insulated from the ice and cold water. Hence the blood in those vessels is cooled. On its return trip to the heart, the blood passes through the testicular net, cooling the testes.

The specialized arrangement of blood vessels gives the seals a thermal "window" through their insulating blubber, keeping temperature-sensitive reproductive organs cool. In the males, the window safeguards sperm production. In the females, an analogous vascular net helps regulate the temperature of developing fetuses.

Thermal windows—primarily through the hind flippers, but also through the mouth, eyes, and nose—seemed to us the most likely areas for dissipating the seals' excess heat. Rutishauser and I hoped to record those windows with our infrared camera, expecting to see dark blue insulated seal bodies punctuated with red-hot hind flippers. A dog in its winter coat displays a similar thermal pattern: seen with equipment similar to ours, a cool, insulated body fades into hot, thinly furred legs and paws.

To our astonishment, not only did the seals' flippers glow, but so did the rest of their bodies. And



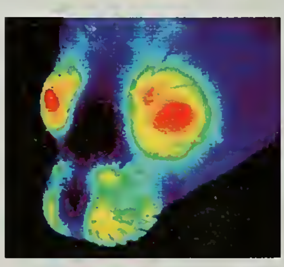
A mother and pup glow brightly in the infrared image. To sunbathe without becoming dangerously overheated, the animals cannot rely on thermal windows alone. Instead, their entire bodies act as radiators. Networks of arteries and veins close while the animals are underwater, but open to shed excess heat within an hour after a seal hauls itself out of the water.

Bathtub-shape grooves in the ice, in which seals lie during sunbathing, form from the intense heat of the seals' bodies. Their surface temperatures can rise by as much as fifteen degrees Fahrenheit in the first hour they spend out of the water.

the longer the seals were out of the water, the warmer their bodies became. We found that the stubby front flippers, the hind flippers, the nose, and the eyes glowed first. But then the back and belly warmed, too. Obviously, the entire body surface of a sunbathing Weddell seal was acting as a radiator—which explained the seal-shape tubs that had melted into the ice. By comparison, when I pointed our camera at Rutishauser, who was bundled in a parka and insulated wind pants, his thermal image was blue and nearly invisible against the blue backdrop of the ice.

Here again, in whole-body cooling, we found that specialized blood vessels were the mechanism for transporting heat and controlling temperature in the seals. Hair follicles throughout the pelt of a Weddell seal occur with a side-by-side array of highly branched arteries and veins known as arteriovenous anastomoses (AVAs). More than 6,000 AVAs are packed into every square inch of the seal's skin, where they act as thermal perforations along the pelt, enabling excess heat to escape when the seals lie in the Sun.

Poking its head through a hole in the ice, a Weddell seal (top) enjoys a long-awaited chance to breathe. While lying on the surface of the water, another seal (bottom) keeps the icy waters out by squeezing its muscular nose shut. A network of blood vessels surrounds the eyes to keep them from freezing, and so they glow with heat in the thermal image.



The distribution of the AVAs for Weddell seals was originally described in 1975 by G. S. Molyneux and M. M. Bryden of the University of Queensland in Brisbane, Australia. But seal AVAs differ in shape, complexity, density, and distribution from the AVAs in terrestrial mammals. The AVAs of sheep and rabbits, for instance, also regulate temperature, but they are densest in sparsely furred peripheral areas such as the forelimbs and ears. The density of AVAs in Weddell seal skin is several times greater than it is in such land-based mammals, and their distribution is bodywide. With the infrared camera we could observe the sequential opening of the AVAs along the body and the consequent warming of the sunbathing seals' skin. Slowly the seals turned from a cool blue to a bright warm orange, as blood flowed through the AVAs.

Weddell adults and pups alike have AVAs, but their function changes as the pups mature. Newborn Weddell seals lack a substantial blubber layer, and so they rely instead on a pajama-like coat of fluffy gray hair called lanugo to retain body heat. Because the ratio of the surface area to the volume of their small bodies is relatively high, they cool quickly. As a result, they have to be particularly careful to conserve body heat. In our infrared images the youngest seals resembled Matt in his parka, showing blue rather than the red of their parents. The AVAs hidden beneath the lanugo appeared to be closed.

As they grow fatter from nursing, the pups lose their lanugo, add blubber, and acquire the sleek spotted coats of the adults. But with a new coat and a thick blubber layer for insulation, the pups now face the same dilemma as the adults, how to get rid of excess heat. Soon the flippers of the pups are glowing warm, and by the time they are six weeks old, their entire body is as red-hot as their sunbathing mothers.

Even as young pups, then, Weddell seals have several anatomical adaptations that enable them to avoid overheating in the sunlight. But why did they ever need them in the first place? After all, wouldn't it be far simpler for them to stay in the water, where it is cool enough to let blubber take care of their thermal needs? Several behaviors we observed offered one explanation.

Anyone watching the sunbathing Weddells quickly notices that many of them have numerous skin wounds. Flippers, armpits, backs, and bellies are often covered with bites; some are large, open, and bleeding, but most are just small nicks and scrapes. With a submersible camera developed by Randall W. Davis, a physiologist at Texas A&M University in Galveston, our team was able to observe the underwater behavior of the seals, and soon discovered how the wounds come about.

After a dive in search of a meal, seals frequently

Breathing holes in the ice are small and scarce. When a seal returns to breathe after a long, deep dive, it may bite any other seal blocking the way to the air. Such bites have little chance to heal underwater, but the warm Sun may promote healing. Hence sunbathing may be the seals' indirect response to the scarcity of breathing holes.

battle each other for access to breathing holes in the ice. The fights become more intense as temperatures fall and ice holes and cracks freeze shut. It is not unusual for a seal returning from a prolonged dive to resort to a quick nip on the flippers or belly of another seal in order to gain access to a breathing hole. When the animals we observed hauled themselves up onto the ice, the infrared camera readily highlighted the battle scars. In one case a male seal was so badly bitten that he looked as spotted as a Dalmatian dog, with red, hot wounds covering his entire body [*see lower photograph on page 52*].

So perhaps the sunbathing behavior of the Weddell seals is not simply a recreational activity but, rather, integral to the healing of their many wounds. In mammals, tissue repair requires the development of a large number of blood vessels and subsequent heating of the injured area. That component of healing has recently been the focus of intense medical research. Heated bandages, radiant-heat dressings, and even laser therapy are all under investigation to promote tissue repair in human patients. It occurred to me, as I watched the battle-scarred seals lying in the Sun, that the sunbathing Weddells of the Antarctic had already discovered the benefits of radiant-heat therapy. By hauling out in the constant sunlight, blood—and so heat and oxygen—flows to the injured areas. That promotes healing. As the ghostly blue infrared images of submersed seals had shown, the alternative is poor blood flow to the cool skin, and presumably little chance for wounds to heal.

But whatever their reasons, Weddell seals young and old are drawn to one of the southernmost sunbathing beaches on Earth. During the long days of the Antarctic summer they sleep and yawn, scratching their heads and bellies, their idleness in stark contrast to the lively activity of the remarkable thermal mechanisms operating just below the skin.

By late April the Sun has sunk below the Royal Society mountain range for the last time, drawing the animals and their icy beach into total darkness for several months. It is hard to imagine how the Weddell seals stay warm and nurse their wounds during those long, cold, winter nights. The severity of the Antarctic winter will keep that secret hidden with the seals for now. □

Fern Relations

A patch of forest in Massachusetts harbors some shady characters.

By Robert H. Mohlenbrock

Bartholomew's Cobble, looking northward, with the Berkshires in the distance

Near the foot of the Berkshire Hills, alongside the scenic Housatonic River in southwestern Massachusetts, is a National Natural Landmark known as Bartholomew's Cobble. In its 329 acres more than 800 plant species flourish, including fifty-three species of ferns and so-called fern allies, one of the finest such concentrations in the United States. The "Cobble" part of the site's name refers to two large, adjacent outcroppings of bedrock (think "cobblestone"). Bartholomew is the name of a family that farmed the land from 1833 until 1901. The Trustees of Reservations, a Massachusetts land trust that now owns the property, acquired the main parcel in 1946 and added to it in subsequent years through purchases and donations.

About 70 percent of the landmark area is covered in forest dominated by hemlock. Where the shade is not too dense, the forest floor is brightened by a number of flowers, especially in springtime; in autumn, broadleaved trees such as northern red oak and sugar maple stand out amid the evergreens, adding splashes of blazing red and orange. Portions of the rock outcroppings are also forested with hemlocks or other trees, and many plants find a foothold in the crevices of the exposed bedrock. Only the west-facing areas of the limestone, marble, and quartz, which get the brunt of the afternoon sunshine, remain dry and nearly bare of vegetation.

Found in the shade throughout the growing season are numerous ferns and fern allies. All of them are vascular plants that do not form seeds as part of their reproductive cycle. Like many plants, their generations alternate between a spore-producing form, called the sporophyte, and a gamete-producing form, called the gametophyte. In vascular plants, the sporophyte is the plant people usually see and recognize. It gives rise to spores, which are haploid cells—cells that contain only one from each pair of chromosomes in the parent plant. The dispersed spores grow into gametophytes, small and obscure structures that give rise to gametes, or sex cells. When two gametes unite—restoring the double number of chromosomes—the resulting cell can give rise to a new sporophyte. (A seed is merely a dormant, embryonic sporophyte, protected by a covering and supplied with a store of food; dispersed in this form, the sporophyte can germinate and grow rapidly when conditions are right.)

Ferns, whose sporophytes usually have delicate-looking, much divided, broad, flat leaves, are common denizens of the forest. About forty-five species grow at Batholomew's Cobble. Fern allies tend to be less familiar. They often differ from ferns in the appearance of their sporophytes but are defined botanically according to various details of their gametophyte life cycle, which is more complicated than that in ferns.

Fern allies fall into five families, three of which are represented in the landmark area. One of these is the Equisetaceae, members of which are often referred to as living fossils: the group dominated terrestrial plant life when dinosaurs roamed the Earth. Their sporophyte has a jointed, leafless stem containing silica, which the plant takes up from the soil. If the stem is unbranched, the species is aptly (but not always) called a scouring rush (American pioneers would bind bunches of the stems together and use them to scour pots and pans). If whorls of very slender branches radiate from each joint, making for a bushy-looking plant, it is more appropriately referred to as a horsetail.

Two more families of fern allies found in Bartholomew's Cobble are the club mosses (Lycopodiaceae) and spike mosses (Selaginellaceae). Both tend to have small leaves that are flat or scalelike. Club mosses with stiff branches and scalelike leaves are often called ground pines.

HABITATS

Hemlock forest American beech, basswood, northern red oak, sugar maple, and white pine, along with the hemlock trees, create a deep shade. In it grow such ferns as adder's-tongue fern, bog fern, Christmas fern, crested fern, Goldie's fern, maidenhair fern, New York fern, ostrich fern, and spinulose woodfern. The delicately branched woodland horsetail and two ground pines (fan club moss and running club moss) also grow here. Where the woods border the Housatonic River appear colonies of large cinnamon fern, ostrich fern, and royal fern, along with the somewhat smaller sensitive fern. Joining these are three scouring rushes (common scouring rush, variegated scouring rush, and water horsetail) and the common, or field, horsetail.

Wildflowers that grow beneath the canopy include so-called spring ephemerals—plants that usually come up in early April, bloom no later than the end of May, set seeds in May or June, and disappear by July. Among them are Dutchman's-breeches, spring-beauty, and various species of toothwort, trillium, and violet. A few spring wildflowers persist, such as doll's-eyes, Solomon's seal, and false Solomon's seal. Nonephemerals that bloom during the summer or fall are Canada lily, false hellebore, and species of aster, goldenrod, and sunflower.

Moist rock Ferns that grow from very moist, moss-covered patches of soil on the rock outcroppings include berry bladder fern and brittle bladder fern (also called fragile fern), both of which, in addition to forming spores, create asexual "bladders"—small bits of tissue that can grow into a new plant if they land in a favorable place. Others are maidenhair spleenwort, two kinds of polypody, and walking fern. Walking fern is unfernlike in appearance because it has undivided, narrow, lance-shaped leaves that taper to a long, drawn-out tip. Where the point of the leaf touches the mossy substrate, the tip forms roots, anchoring the plant on the rock face. In this manner, the fern "walks" across the rocky surface. The delicate spring meadow spike moss, with nearly transparent leaves, lies flat on moist, mossy surfaces at the base of some of the rocks.

Exposed rock Crevices in drier bedrock harbor such ferns as purple cliff-brake and two species of *Woodsia*. Also found here is shining club moss, which has membrane-like leaves and spore cases hidden at the base of each leaf, and the spike moss northern selaginella, which has short, needlelike, evergreen leaves. Another cliff-dwelling plant is yellow honeysuckle, whose downward arching stems bear flowers from June through August. Wildflowers include bishop's-cap, blue-stem goldenrod, buffalo currant, hepatica, herb Robert, wild columbine, and zigzag goldenrod.

For visitor information, contact:
Sarah Robotham, Property Manager
Bartholomew's Cobble
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www.thetrustees.org

Running club moss, a "fern ally" and one of several club mosses also commonly known as ground pines, produces its spores in elongated cones.

Walking fern—which looks nothing like a typical fern—spreads by growing new plants at the tips of its long, slender leaves.

Robert H. Mohlenbrock is professor emeritus of plant biology at Southern Illinois University in Carbondale.

Dorothea Lange, *Tractored Out*, Childress County, Texas, 1938

Crop Circles

Spin notwithstanding, can GM food still save the world?

By Marc J. Cohen

What good is genetically modified food? Is GM food a savior, an essential ingredient in any program for ending world hunger? Or is it a villain, a Trojan horse that, if allowed into the food production and distribution system, will poison people and the environment? Few aspects of everyday life provoke such sharp disagreement as the emerging biotechnology of food.

Yet there is remarkably broad consensus that there is a crisis in world hunger and about the reasons for it. Almost everyone who has looked seriously at the causes of hunger agrees that the main factor is poverty. People go hungry because they lack money to buy food, or they lack the land, water, credit, and other resources they need to produce food on their own. Poverty, in its turn, is often linked to political powerlessness, gender discrimination, poor education, and the debilitation resulting from endemic, untreated disease. Each year malnutrition in developing countries contributes to the deaths of more than 5 million preschool-age children—a toll equivalent to the entire population of Denmark. The malnourished children who survive face a lifetime of impaired physical and mental development.

Food, Inc.: Mendel to Monsanto—The Promises and Perils of the Biotech Harvest
by Peter Pringle
Simon & Schuster, 2003; $24.00

Safe Food: Bacteria, Biotechnology, and Bioterrorism
by Marion Nestle
University of California Press, 2003; $27.50

Yet global food production is rife with paradox. Enough food is available today to provide every human being on Earth with more than the 2,350 calories needed daily for a healthy and active life. Even more paradoxical than the persistence of hunger amid plenty is that its center of gravity occurs in rural areas. Some 75 percent of those with inadequate access to food live in the countryside of the developing world. It is here, in such areas of rural poverty, that new agricultural technology, in particular biotechnology, may offer the greatest hope for improvement.

Unfortunately, that hope remains largely unrealized. Biotechnological developments have led, however, to a bumper crop of books aimed at popular audiences. Two of the latest additions are *Food, Inc.: Mendel to Monsanto—The Promises and Perils of the Biotech Harvest,* by the journalist Peter Pringle, and *Safe Food: Bacteria, Biotechnology, and Bioterrorism,* by the nutritionist Marion Nestle.

In many ways biotechnology would seem made-to-order to address part of the plight of small farmers in developing countries. Agricultural productivity there remains low, which implies both high unit costs of producing food and low farm incomes. Many factors contribute to the low productivity: losses to pests and the weather; low soil fertility and lack of access to fertilizers; acid, salinated, or waterlogged soils. The low yields that result lead in turn to poor nutrition and poverty on the farms, as well as among the people who depend on such farms for food. As the circle of poverty widens, demand for goods and services produced by poor nonagricultural rural households decreases, and urban areas suffer increased rates of unemployment and underemployment.

Agricultural technology alone cannot address all the complex economic, social, political, and ecological forces that contribute to world hunger. And technology cannot reach its potential unless it is part of a comprehensive strategy to reduce poverty, enfranchise low-income people, and protect the environment. Still, research that leads to increased productivity can play an important role in reducing hunger. For example, crops could be designed to resist drought, pests, and diseases; tolerate salty soil; absorb nitrogen from the air; and provide a broad range of added nutritional benefits.

But the potential of biotechnology for helping reduce hunger has barely been tapped. Virtually all the biotech crops currently on the market are limited to just two traits: herbicide tolerance and insect resistance. A big share of the global GM harvest for 2002—two-thirds of which was in the hands of U.S. farmers—went into animal feed or textile fibers. Commercial soybean farmers in Argentina, whose operations have much more in common with North American large-scale farms than with African subsistence plots, accounted for another big chunk of the GM harvest. Small farmers in China, India, and South Africa have begun to grow pest-resistant GM cotton.

Back before anyone had heard of GM foods, the great advance in food production technology was the introduction of high-yield seeds, the so-called Green Revolution, which reached its pinnacle in the the late 1970s and early 1980s. The new seeds boosted global cereal output, though their use was generally accompanied by increasing application of mineral fertilizers, synthetic pesticides, and irrigation water.

There are two big differences, though, between the Green Revolution and its modern counterpart. The research and development for the Green Revolution were carried out almost entirely by public-sector research institutions and philanthropic foundations. Public policies, moreover, played a central role in encouraging the adoption of the technology. The fruits of the research were placed in the public domain.

In contrast, the vast majority of the research in agricultural biotechnology that is the basis for the Gene Revolution (as many have come to call it) has been carried out in the laboratories of private multinational "life sciences" corporations, based in the industrialized nations. Having made huge investments, the corporations are eager for profits to recoup their costs. Accordingly, they seek patents or other forms of intellectual-property protection for both the products and the processes they develop.

The second big difference between the Green and Gene revolutions is that the former was based on conventional crossbreeding among different varieties of a single food-crop species, or, occasionally, a crossing with close relatives. But the Gene Revolution, with the development of recombinant DNA technology, made it possible to transfer genes between species, even between plants, animals, and microorganisms. Biotechnologists have inserted a gene from a soil bacterium into corn and cotton, enabling the plants to produce their own natural insecticide. Rice containing genes from daffodils and bacteria—labeled GoldenRice because of its yellow tint—may soon be available to farmers; it is high in beta carotene, which the body converts to vitamin A. In developing countries, inadequate vitamin A leads to infectious diseases, blindness, and death for hundreds of thousands of children each year.

The two volumes under review address food biotechnology from quite different points of view. Peter

Pringle stakes out a middle ground in a highly polarized debate, and explores how the technology might become more accessible to poor farmers in developing countries, particularly in Africa. Marion Nestle devotes only about half of her book to biotechnology (the rest deals with food safety in more traditional contexts), and she focuses her discussion of biotechnology on the resistance by the food industry to stronger, more coherent government safety regulations. In passing, she, too, addresses the potential relevance of food biotechnology to poor farmers and consumers in developing countries, but her focus is mainly on the United States.

Pringle's book is organized around the flash points of food biotechnology, the stories that have gotten major media attention in the past few years: the development of GoldenRice; reports that GM crops are harmful to monarch butterflies; laboratory experiments on mice that raised concerns about health risks; and the discovery of GM corn pollen in Mexico, leading to accusations that it could contaminate natural strains.

Pringle takes a balanced approach to his topic, criticizing both the extreme claims of biotech companies, which trumpet their seeds as the salvation of the starving, and the "environmental ideologues" who cry "Frankenfood!" and seek to ban biotechnology altogether. He rebukes the London-based environmental group Greenpeace for its willingness to seize on any evidence of environmental or health risk, however inconclusive, to support calls for a ban and to justify the destruction of test plots. At the same time, he condemns executives of the Monsanto Company, based in St. Louis, Missouri, the leading purveyor of biotech seeds, for their "arrogance." For example, he cites their unwillingness to concede that pollen from GM crops could cross-fertilize nearby conventional or organic varieties. (An organic grower whose crops become cross-pollinated could lose hard-won and lucrative organic certification.)

Pringle also notes a much more troubling effect that GM food is having on the tangled politics of world hunger. European consumers continue to voice fierce opposition to GM foods, and the European Union is seeking to impose strict labeling requirements on GM products. Consequently, the leaders of some developing countries are reluctant to adopt GM food technology, or even accept food aid that might contain biotech seeds. Either action, they fear, might compromise their nation's ability to export food products to Europe. An extreme case unfolded last year, when famine-stricken Zambia rejected U.S. food aid on just such grounds.


William H. Martin, *Riding a Giant Corncob to Market,* 1908

In Pringle's view, though, GM foods are here to stay. More caution will be needed in developing and deploying them; genuine risks will have to be properly managed. But, with those caveats, he thinks the technology may help reduce hunger. To do so, industry will have to be more willing to make patented technology available to developing countries. Governments of developing countries will need to devote a greater share of their expenditures to agricultural research. And seed banks must receive adequate funding for operations and maintenance to conserve plant genetic diversity.

Among the strengths of *Food, Inc.* are its clear explanations of the complex science of plant biotechnology, as well as the complex history of how U.S. patent law has evolved to cover novel plants and even genes. Unfortunately, though, Pringle ignores the important precedent set by India's 2001 seed law, which seeks to balance plant breeders' rights to profit from their innovations with farmers' rights to use the seed they harvest from the plants they grow. That model has great bearing on how biotechnology might benefit poor farmers.

Where Pringle is even-handed in showing how extremists have hijacked the debate over GM food, Nestle is an unapologetic partisan. As she writes in her introduction, a major theme of her book is "the food industry's promotion of economic self-interest at the expense of public health and safety." In the case of food biotechnology, she maintains, the industry invokes "science" as a cover for advancing its own interests.

As Nestle shows, U.S. government regulators who are supposed to ensure that foods do not threaten public health or the environment often bend over backward to accommodate industry. In part, that cozy relationship is a consequence of the "revolving door" that moves key people back and forth between industry and government. Another difficulty is that regulatory authority is fragmented across a bewildering spectrum of government agencies and limited by long-outdated statutes. As Nestle notes, Congress can change the laws, but generous campaign contributions from industry ensure a favorable legislative environment.

For Pringle, adequately funded public science would be a saving grace, but Nestle is skeptical. The department of

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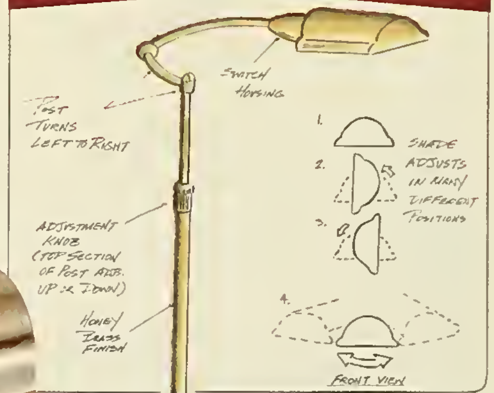

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plant and microbial biology at her alma mater, she writes, the public University of California, Berkeley, "auctioned itself" to the Swiss biotechnology firm Novartis International AG, headquartered in Basel. The arrangement, she states, allowed the company to review research prior to publication and to negotiate licenses.

The case of GoldenRice, engineered by Ingo Potrykus, a plant biologist at the Swiss Federal Institute of Technology in Zurich, highlights some of the pitfalls now faced even by scientists at public institutions, funded through philanthropic foundations, who get caught in the intricate web of corporate patents. Pringle shows how the development of GoldenRice, which at first seemed a triumph in the war against malnutrition, turned into a nightmare snarl of ownership claims covering dozens of processes and genes. He points out that the public-sector scientists were hardly to blame for their partnership with the private sector: the European Commission required them to partner with a European company in order to get public funds. The company then obtained the exclusive right to market GoldenRice in the industrialized world, in exchange for making it available free of charge to poor farmers in developing countries.

Nestle is much more sympathetic than Pringle is to the critics of food biotechnology. She argues that they have couched their criticisms in the language of food safety, particularly in the United States, because regulatory policy has limited debate strictly to scientific questions. Social and political issues—the concentrated corporate control over biotechnology, the lack of transparency in decision making, the corporate resistance to food labeling that could make consumers better-informed about their choices—are not on the scientific agenda. Thus, Nestle maintains, critics have no choice but to demonstrate, litigate, and, on occasion, engage in provocative rhetoric, often disseminated quite effectively via the Internet. (Despite her sympathies, however, Nestle, like Pringle, condemns acts of violence that opponents of biotech have sometimes directed against test plots and laboratories.)

Nestle devotes a lot of attention to the globalization of food safety and biotechnology. She rightly points out that food-safety standards in industrialized nations are often little more than tariff barriers by another name: they protect domestic growers by keeping out competing agricultural products from developing countries. She also explains how the debate about labeling has gone global: the European Union, for instance, is seeking to have biotech imports separated from conventional produce, and documented as to their source.

One department at UC Berkeley, Nestle writes, "auctioned itself" to a Swiss biotechnology firm.

But Nestle's presentation is marred by errors and omissions. She does not discuss the formal U.S. complaint to the World Trade Organization—which she repeatedly and incorrectly refers to as a UN agency—that the Europeans are violating global commercial rules by discriminating against GM products. She also writes that an international agreement called the Biosafety Protocol permits countries to ban GM food imports because of concerns about environmental safety, but she fails to mention that the U.S. government vociferously rejects that interpretation.

Like Pringle, however, Nestle does not reject food biotechnology outright. She, too, regards it as a tool for alleviating hunger—despite her criticism of corporate tactics. She calls upon the industry to "tithe," donating 10 percent of its profits to research into the food needs of developing countries.

One encouraging model may be the way a GM sweet potato was developed in Kenya. A crippling infection known as the feathery mottle virus can reduce sweet potato yields by 80 percent. In Kenya, sweet potatoes are grown mainly by poor farmers and eaten by poor consumers, so the economic implications of creating a disease-resistant GM sweet potato had little in common with, say, the adoption of herbicide-tolerant soybeans in North America. In particular, biotechnology corporations did not stand to profit significantly from such a project. Accordingly, Monsanto licensed its technology free of charge to a publicly funded institution, the Kenyan Agricultural Research Institute. That enabled Kenyan investigators to engineer a sweet potato that resists the feathery mottle virus. Critics have called Monsanto's contribution a public-relations move. But if such free licensing in developing countries were more the norm, such criticism would carry less weight, and more research relevant to hunger would be done.

Food production, of course, is just one piece in the hunger puzzle, and biotechnology is only one part of food production. For example, people must also have access to the food produced—yet more than 800 million people, one in seven worldwide, do not have ready access to all the food they need. According to the UN Office for Coordination of Humanitarian Affairs, that figure includes 56 million people (more than two-thirds of them living in sub-Saharan Africa) who need food and other emergency humanitarian assistance.

Those figures actually represent an improvement since 1970. Three decades ago more people went hungry, both in absolute terms (an estimated 959 million) and as a fraction of the world population (more than one in every four people). But the

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For fastest service, call toll-free 24 hours a day **800-859-2923** rate of progress in reducing hunger slowed in the 1990s, compared with the two preceding decades. Leaving aside China (where the number of the hungry was reduced by 74 million), the number of hungry people in the rest of the developing world actually rose by 50 million during the 1990s. Hunger is increasingly concentrated in South Asia and sub-Saharan Africa, and in the latter region the number of people lacking access to adequate food more than doubled between 1970 and 1999.

Access to food is hampered by poorly developed markets, environmental degradation, inadequate roads, isolationist regimes, theft, and any number of other factors. The social consequences of such failures to feed hungry populations include huge stresses on already overtaxed medical systems, reduced productivity, stunted economic growth (compounding the poverty), and malnourished mothers who give birth to more malnourished children. Vitamin and mineral deficiencies, which afflict more than 2 billion people, likewise lead to illness, lost productivity, premature death, and less prosperous economies. Political instability, violence, and hunger go hand-in-hand.

One common misconception is that many people still die from outright starvation, or "famine." In fact, famine per se directly kills perhaps no more than 200,000 people a year, on average. But the consequences of hunger, malnutrition, and related disease account for nearly 11 million deaths a year, a fifth of the deaths from all causes globally. The scope and complexity of the problem of hunger will unfortunately continue to call on the best minds and noblest hearts among us for a long time to come.

Marc J. Cohen is Special Assistant to the Director General of the International Food Policy Research Institute, a publicly funded international agricultural research center that identifies and analyzes strategies for improving the food situation in developing countries (www.ifpri.org).

BOOKSHELF

By Laurence A. Marschall

Space, the Final Frontier?
by Giancarlo Genta and Michael Rycroft
Cambridge University Press, 2003; $29.00

Edward H. White took the first U.S. spacewalk, June 3, 1965.

Rockets, like locomotives almost two centuries ago, are embodiments of progress, symbols of society's technical mastery over nature, and so they raise a host of questions about the ultimate destiny of the human race. Most people seem to take one of two general points of view on the quest that rockets represent: A vocal minority is certain that humanity will colonize space, just as Europeans colonized the New World. A less vociferous majority doesn't seem to have given the subject much thought. As a result, the debate, if it can be called that, tends to be rather lopsided.

Space enthusiasts, who write most of the science and science fiction on the subject, take it for granted that, given enough time, humanity will spread throughout the galaxy. To them, the outstanding questions are largely technical: Is it easier to mine metals from the asteroids on-site, or is it more economical to tow them first to the Moon? Can a nuclear-powered rocket carry enough fuel to make it to the nearest star and back again? How can the human body and psyche be prepared to survive long journeys in space?

Those questions, however, don't interest most people. Opponents of the space program have long pointed out that too many pressing problems remain on Earth to give serious attention to technologies so far away, both in space and time.

The question mark in the title of *Space, the Final Frontier?* might have signaled a third point of view—a critique of the very idea of a cosmic manifest destiny. But Giancarlo Genta and Michael Rycroft fail to deliver much beyond a few "on the other hand" comments. That's a shame, because their book serendipitously appears at a critical moment in the space debate, and their discussions might have informed the questions raised in the recent report on the breakup of the space shuttle *Columbia.* The authors of that report excoriated policy makers for the budget cuts and drift of purpose that, according to their investigation, were partly responsible for the deaths of seven astronauts this past February. In effect, they told the government, give NASA a compelling mission for sending people into space—and then fund it appropriately—or else get out of the manned space business.

For the most part Genta and Rycroft are strong on the mission but weak on the analysis of cost, writing optimistically about colonies on the Moon, manned expeditions to Mars, and eventual colonization of the stars. Sympathetic space enthusiasts will enjoy the compendious coverage of topics ranging from the prospect of "terraforming" other planets into carbon copies of Earth, to methods for traveling faster than the speed of light (well, maybe).

How much of what Genta and Rycroft describe is wishful thinking? They do offer an occasional cautionary remark about the physical, economic, and ethical limitations on placing people in outer space. And they hedge their bets by avoiding specific predictions for how long it will

take to colonize this or that planet, or to travel to this or that star. But they leave no doubt that human destiny lies in the heavens. The clear implication is that those with reservations about the enterprise are, alas, quixotically trying to hold back the tides.

Some of their argument is utilitarian: just as the Western frontier provided *lebensraum* for the surplus population of nineteenth-century America, so space will provide a safety valve for a planet threatened by pollution and overpopulation. And the arguments put forth by some for a "space imperative," the authors say, are even more important: "space exploration is a primary duty of humankind, who must not let themselves always be distracted by problems, even by the very serious ones."

Exhortations aside, what if there is a fundamental difference between the terrestrial frontiers of the fifteenth through the twentieth centuries and the frontier of space? Consider that undersea travel has been possible for more than a century. Yet though the ocean bottom is far closer than the Moon, it remains a place visited only temporarily, by expensive oceanographic and military vessels. How many permanent colonies will be established in the foothills of the mid-Atlantic ridge? How many undersea mines, mills, and Wal-Marts will be built there? Is it just a lack of will that keeps our feet on terra firma? Or are the barriers between the heavens and the Earth much higher than even a pair of rocket scientists can imagine?

Eating Apes
by Dale Peterson, with an afterword and photographs by Karl Ammann
University of California Press, 2003; $24.95

Karl Ammann, in love with Africa from an early age, is a Swiss citizen who has lived for the past quarter century in Kenya. He came to Nairobi as a hotel manager and gradually drifted into wildlife photography. But his experience aboard a huge trading and transport vessel during a business trip on the Zaire River more than a decade ago turned him abruptly from hotelier into environmental activist. The issue was the trade in wild game, or, as Africans call it, bushmeat.

Ammann had noshed on bits of python in the past, but he had never appreciated the enormous dimensions of the bushmeat market, or how many species find their way to African tables. As the vessel sailed upriver, hunters paddled out from shore, offering carcasses as well as live animals to the crew and to the professional meat merchants onboard. The boat's meat locker became crammed with freshly slaughtered lizards, monkeys, snakes, and turtles. Live crocodiles, hogtied to keep them fresh for market, began to pile up on the decks outside the merchants' cabins. Then one day a hunter carrying a cheap shoulder bag came on board with the smoked carcass of a mother chimpanzee; inside the bag was the chimpanzee's orphaned baby.


Chimpanzee, illustration from a 1686 volume by the Dutch geographer Olfert Dapper

Ammann bought the baby, and in the months that followed he searched among the various African primate refuges to find it a home. The experience transformed him into a fierce advocate for change in African hunting practice and diets. In the past decade he has gone "underground" in several countries to report on the illegal market in apes and other large mammals. His stark color photographs of slaughtered gorillas and chimpanzees (some of which are reproduced in this book), have energized a growing public awareness of the need for more effective regulation of the bushmeat trade.

Dale Peterson, who has written widely about primates in Africa, makes Ammann's story the centerpiece of his wide-ranging account of the bushmeat problem. Although he shares Ammann's partisan views, Peterson explains why conservationists cannot simply will the end of ape-eating through legislation. Selling ape meat is already illegal throughout most of Africa. But so many people rely on bushmeat for protein, and so many regard it as a delicacy that connects them with their past and their ethnic identity, that game wardens and police officers are more likely to buy bushmeat from a poacher than to arrest him.

Peterson shows, too, how European logging corporations in Central Africa are playing a key supporting role in the growth of the bushmeat trade. They cut roads deep into virgin forest, giving hunters ready access to once-remote habitats. They cut costs by feeding cheap bushmeat to the loggers. And the truck drivers they employ run a lucrative side business in the transport of contraband ape body parts, concealed in compartments under their engine hoods. The net effect is that hunting bonobos, chimpanzees, and gorillas has now become big business. And the targeted species, already endangered, may be driven to extinction.

With such strong economic and social forces in play, any argument that simply appeals to the repugnancy of eating our closest cousins is bound to be dismissed as ethnocentrism. If the French eat horses, or the Vietnamese eat poodles, who's to say the Africans can't eat apes? Peterson counters that eating apes endangers public health. He cites the work of Beatrice H. Hahn, a virologist at the University of Alabama in Birmingham, who in 1998 traced the AIDS virus to a virus known as SIV, common among chimpanzees. This past June, Hahn and her colleagues reported in the journal *Science* that the chimpanzees themselves may have contracted the virus by eating monkeys.

Unlike chimpanzees, though, people can clean up their act. If advocates like Peterson and Ammann prevail, apes may someday disappear from the market and the dinner table. With any luck, that will happen before they disappear from the rainforest as well.

The Silent Landscape: The Scientific Voyage of HMS Challenger
by Richard Corfield
Joseph Henry Press, 2003; $24.95

The nineteenth century, no less than the age of Columbus and Magellan, is notable for its voyages of exploration. A search of Amazon.com returned nearly thirty entries for books about Darwin's travels with the HMS *Beagle,* and more than twenty for books about John Franklin's ill-fated expedition to the Arctic. Yet only two entries (one for this book!) featured the HMS *Challenger,* which carried out the most remarkable and influential maritime mission of the Victorian era. The obscurity of *Challenger*'s voyage is understandable: no lands were claimed, no passage remained blocked by ice, no crews were decimated by frostbite, scurvy, or starvation. In fact, the voyage went pretty much as planned—which is to say it brought back scientific results of surpassing importance.

HMS *Challenger* left Portsmouth, England, in December 1872 with an itinerary that had been drawn up, not by commercial explorers or adventure-seekers, but by the academicians of the British Royal Society. Its objectives were scientific, pure and simple: to circumnavigate the globe, to take soundings at regular intervals along the way, and to measure the physical and biological characteristics of the ocean, from surface to bottom. Aboard were twenty naval officers, a crew of 200, and a scientific staff of five. John Murray, one of the scientists, spent the remaining decades of the century compiling a fifty-volume report on the expedition's results. *Challenger* was the first great oceanographic research vessel, and its findings were to set in motion revolutions in earth science and biology for the next hundred years.

When *Challenger* set sail, the prevailing wisdom was that ocean life could not exist below about 300 fathoms (1,800 feet). Yet virtually every time the dredge was hauled up from the deep, so many weird creatures came to light that scientists and crew alike quickly conceded that the ocean depths are a rich repository of primitive life-forms.

By the time the ship had reached the West Indies, the expedition scientists had come upon a great range of

HMS Challenger, *from the frontispiece of the 1878 volume* At Anchor

undersea mountains running down the middle of the Atlantic Ocean. Two years later, on the other side of the world, their sounding lines revealed a chasm in the western Pacific more than five miles deep. Both features, and many others first recorded by *Challenger*'s crew, are now recognized as part of the system of cracks and seams that connect the moving tectonic plates of our planet's crust.

Richard Corfield draws not only on the voluminous records of the expedi-

EXPLORER GUIDE

tion's scientists, but also on the personal memoirs of its naval officers—most memorably, the candid and previously unpublished diary of a young ship's steward named Joseph Matkin. The book's real excitement, though, lies in the many technical digressions that Corfield, an earth scientist himself, includes from the perspective of modern science. Climatology, evolutionary biology, oceanography, and plate tectonics all got a jump start from *Challenger*'s results. It's easy to understand why two great contemporary research vessels—the *Glomar Challenger*, the first oceanographic drilling vessel, and the late and much lamented space shuttle *Challenger*—both bore the name of a cramped and creaky sailing ship of a century gone by.

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

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Thought for Food

By Robert Anderson

Unless you don't eat, you probably already have strong personal opinions about genetically modified (GM) foods [*see "Crop Circles," by Marc J. Cohen, page 58*]. Rightly or wrongly, they call forth many of the same health anxieties people have about pesticides, hormones, and food irradiation.

A good place to begin sorting through the relevant information available on the Internet is the "GM Food" page at "Scope" (scope.educ.washington.edu/gmfood/). On the "Scope Forum" menu, at the upper left of the screen, "Positions" will lead you to incisive responses from eight experts to questions about the risks and benefits of GM foods. "Site Bites," in the same menu, gives brief reviews of sixteen other Web sites on GM food, "scoping out" the biases you're likely to run into at each one.

I began with the site run by the Union of Concerned Scientists. Their "Food" page (www.ucsusa.org/food_and_environment/index.cfm) offers a balanced examination of humanity's short experience with GM crops (click on "Biotechnology" under "In This Section"). Under "Contents," on the right, you can also click on two excellent "Special Features" that focus on the way new technologies can threaten the food supply. A good discussion of the risks of genetic engineering is available under "Backgrounders," and under "Guides" you'll find a list of altered foods currently allowed in U.S. markets.

To check out one of the principal players on the "upbeat" side of the debate, the "Site Bites" reviews suggest Monsanto, which has "created an unceasingly and completely positive picture of GMFs" (go to www.monsanto.com/ and search for "GM Food"). So has the U.S. Department of Agriculture (www.usda.gov/agencies/biotech/index.html): "Blue skies for agricultural biotechnology, here," says the Scope review.

But to see how a bastion of spirited scientific nay-sayers is saying nay, go to the "Genetic Modification" page of the London-based Independent Science Panel (indsp.org/gm.php). There you'll find the organization's recently issued report, "The Case for a GM-free Sustainable World."

If you're looking instead for some explanation of biotechnology that falls in between the Bad Guys and the Good Guys, Colorado State University offers an up-to-date guide to transgenic crops. Without taking sides, this excellent site (www.colostate.edu/programs/lifesciences/TransgenicCrops/index.html) presents the science underlying the issues in substantial detail. On the menu at the left, the entries on current and future transgenic products (toward the bottom of the list) give concise overviews of specific GM crops in use and in the pipeline.

Whether or not you think the trend toward GM foods is leading into dangerous waters, you do have the right to know which of your supermarket purchases have been genetically engineered. GM-food labeling is not required yet in the United States, but some of the more partisan Internet sites can help you out. For example, at Greenpeace's "True Food Network" site (www.truefoodnow.org/) you can click on the blue icon at the right for the "True Food Shopping List." There you'll see which companies have embraced the brave new world and which continue to make food the old-fashioned way.

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

(Continued from page 19)

across the bow at the steady state theorists. If it existed, the CMB would clearly indicate that the universe had once been different—smaller and hotter—from the way it is today. Thus the first direct observations of the CMB were nails in the coffin for the steady state theory. Those observations were made inadvertently in 1964, by Arno Penzias and Robert Wilson of Bell Telephone Laboratories—Bell Labs, for short—in Holmdel, New Jersey. Little more than a decade later, Penzias and Wilson won a Nobel Prize for their persistent work (and good luck).

By the early 1960s physicists all knew about microwaves, but almost no one had the technology to detect weak signals in that part of the spectrum. Back then most wireless communication was done with radio waves, which have longer wavelengths than microwaves, and so the existing receivers, detectors, and transmitters weren't suitable for the task. You needed a shorter-wavelength detector for microwaves and a sensitive antenna to capture them. And Bell Labs had one: a king-size, horn-shaped antenna that could focus and detect weak signals.

If you're going to send or receive a signal, you don't want other things contaminating it. Penzias and Wilson were looking at radio emissions from the Milky Way galaxy, and they wanted to pin down the sources of background interference—from the Sun, from the center of the galaxy, from terrestrial sources, from whatever. So they made an innocent measurement. They weren't cosmologists; they were radio astronomers, unaware of the predictions by Gamow, Alpher, and Herman. What they were decidedly *not* looking for was the cosmic microwave background.

So Penzias and Wilson made their observations, and corrected their data for all the sources of interference they knew about. But there was a background noise in the signal that just didn't go away, and they couldn't figure out how to get rid of it. It seemed to come from every direction, and it didn't change. Finally they looked inside the antenna, and what greeted them was a flock of nesting pigeons, surrounded by liberal deposits of a white dielectric substance: pigeon poop. Could the droppings, they wondered, be responsible for the background noise? The only thing that was all over their fancy horn-shaped antenna yet didn't change was the pigeon poop. So they cleaned it out, and sure enough, the noise dropped a bit. But it still wouldn't go away. The paper they published in 1965 in *The Astrophysical Journal* refers to the persistent puzzle as inexplicable "excess antenna temperature."

While Penzias and Wilson were scrubbing bird droppings off their antenna, a team of physicists at Princeton University, led by Robert H. Dicke, were building a detector specifically to find the CMB. The professors, however, didn't have the resources of Bell Labs, so their work went a little slower. The moment Dicke and his colleagues heard about Penzias and Wilson's work, they knew they'd been scooped. The Princeton team knew exactly what the "excess antenna temperature" was. Everything fit: the temperature, the fact that the signal came from every direction, and that it wasn't linked in time with Earth's rotation or position around the Sun.

Inside the antenna were liberal deposits of a white dielectric substance: pigeon poop.

Because light takes time to reach us from distant places in the universe, we are actually looking back in time when we look into space. So if, while we were watching, the intelligent inhabitants of a galaxy far, far away were measuring the temperature of the cosmic background radiation for themselves, they should get a temperature somewhat higher than 2.7 degrees Kelvin, because they are living in a younger, smaller, hotter universe.

Can such a mind-bending assertion be tested? Yup. Turns out that a molecule called the cyanogen radical gets excited by exposure to microwaves. If the microwaves are warmer than the ones in "our" CMB, they will excite cyanogen radicals a little more than our microwaves do. The cyanogen radicals in distant, and thus younger, galaxies ought to be exposed to a warmer cosmic background than the cyanogen radicals in our galaxy, the Milky Way. So their cyanogen radicals ought to live more excited lives than ours. And they do: the spectrum of cyanogen radicals in distant galaxies shows the microwaves to be just the temperature they should have been at the time the radiation left the galaxies on its journey to Earth.

You can't make this stuff up.

But why is the CMB interesting? The universe was opaque until 380,000 years after the big bang, so you couldn't have witnessed matter taking shape even if you'd been sitting front-row center. You couldn't have identified where the galaxy clusters and voids were starting to form. Before anybody could have seen anything worth seeing, photons had to travel, unimpeded, across the universe.

The spot where each photon began its cross-cosmos journey is where it smacked into the last electron that would ever stand in its way. As more and more photons escaped without being deflected by electrons, they created an expanding shell that astrophysicists call the "surface of last scattering." That shell, which formed over a period of some 120,000 years, is where and when the first atoms in the cosmos were born.

By then, matter in large regions of the universe had already begun to coalesce. Where matter accumulates, the strength of gravity grows, enabling more and more matter to gather—a snowball effect. Those matter-rich regions seeded the formation of planets, stars, and galaxies, while other regions were left relatively empty. The photons that last scattered off electrons in the coalescing regions developed a different, slightly cooler profile as they climbed out of the strengthening gravity field.

When we astrophysicists map the CMB in detail [*see "Sharper Focus," by Charles Liu, May 2003*], we find that it's not completely smooth. It has spots that are slightly hotter or slightly cooler than average, by one hundred-thousandth of a degree. We know what matter looks like today because we see galaxies, galaxy clusters, and galaxy superclusters. To figure out how those systems arose, we probe the cosmic microwave background, a remarkable relic of the remote past. Studying its patterns is like doing cosmic phrenology: feeling the bumps on the "skull" of a youthful universe to infer its behavior not only as an infant but also as a senior citizen.

The most detailed map of the CMB ever made is the survey unveiled this past February by the Wilkinson Microwave Anisotropy Probe (WMAP). WMAP data enable astrophysicists to compare, for instance, the distribution of sizes and temperatures of the warm and cool areas. From that comparison the strength of gravity in the early universe can be inferred, and thus how quickly matter accumulated. From that the relative amounts of ordinary matter, dark matter, and dark energy in the universe can be calculated (the percentages are 4, 23, and 73, respectively), and from those percentages it's easy to tell whether or not the universe will expand forever.

Ordinary matter is what everyone is made of. It exerts gravity and can absorb, emit, and otherwise interact with light. Dark matter, however, is a mysterious substance that exerts gravity but does not interact with light in any known way. Dark energy is a mysterious pressure that counteracts gravity, forcing the universe to expand faster than it otherwise would. The phrenology exam confirms that cosmologists understand how the early universe behaved, but it also demonstrates that most of the universe, then and now, is made of stuff they're clueless about.

Profound areas of ignorance notwithstanding, today, as never before, cosmology has an anchor. The CMB is the vestige of a portal through which everything we are made of once passed: the surface of last scattering. From the fascinating physical processes whose traces are imprinted on that surface, a great deal can be learned about the universe both before and after its light was set free.

The simple discovery of the cosmic microwave background turned cosmology into something more than mythology. But it was the detailed mapping of the CMB that secured cosmology's place at the table of experimental science.

Cosmologists have plenty of ego: how else could they have the audacity to deduce what brought the universe into being? But the new era of modern, observational cosmology ushered in by the WMAP data may call for a more modest, less freewheeling stance among its practitioners. For each new observation, each morsel of data, wields a double-edged sword: it continues to build the kind of foundation for cosmology that so many other sciences enjoy. But it will also dispatch some of the tall tales theorists dreamed up before there were enough data to declare them fantasies.

Yes, cosmology has come of age.

Astrophysicist Neil deGrasse Tyson is the Frederick P. Rose Director of the Hayden Planetarium in New York City. Videotapes of a dozen of his lectures, under the title "My Favorite Universe," were recently released by the Teaching Company (www.teachco.com). *All twelve are based on essays that have appeared in* Natural History.

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Petra: Lost City of Stone

October 18, 2003–July 6, 2004

Literally carved from the red sandstone cliffs in the Jordan Rift Valley is the ancient city of Petra, now mostly in ruins. *Petra: Lost City of Stone*, opening at the American Museum of Natural History on October 18, 2003, tells the story of this thriving metropolis at the crossroads of the ancient world's major trade routes and of the technological virtuosity that allowed its founders, the Nabataeans, to build and maintain a city in the harsh desert environment. Developed in collaboration with the Cincinnati Art Museum and presented under the patronage of Her Majesty Queen Rania of Jordan, *Petra* is the first major cultural collaboration between Jordan and the United States and the most complete portrait ever mounted on the amazing yet enigmatic city of Petra and its people.

"With its complex intermingling of nature and culture," said Museum President Ellen V. Futter, "the fascinating story of Petra mirrors the very work and mission of the Museum. For more than 130 years, our curators have studied relationships between nature and humanity. Understanding how the underpinnings of other cultures flourish, and how they grow and spread has perhaps never been more relevant than it is today, as we embrace the challenges and opportunities of living in a truly global community."

Petra: Lost City of Stone features approximately 200 exceptional objects on loan from collections in Jordan and Europe, many on view for the first time in the United States, and from collections in the United States. Stone sculptures and reliefs, ceramics, metalwork, stuccowork, ancient inscriptions, and a selection of some 25 19th-century paintings, drawings, and prints will be displayed alongside architectural sections from several of Petra's famous monuments.

This rare and delicate glass mosaic fragment of a man's head formed a part of the extraordinary wall mosaics that decorated Petra's Byzantine basilica.

First conceived by the Cincinnati Art Museum in 1994, *Petra: Lost City of Stone* has been organized by the American Museum of Natural History and the Cincinnati Art Museum. The American Museum of Natural History has been renowned for more than 130 years as a leader in archaeological fieldwork and research, and has a long tradition of presenting exhibitions that illuminate complex cultural and scientific issues. The Cincinnati Art Museum (CAM), one of the oldest and most important visual arts institutions in the United States, has an extraordinarily rich permanent collection representing many cultures and historical periods, including the most extensive and important collection of Nabataean artworks outside Jordan. CAM's Nabataean collection was excavated in 1937 at the site of Khirbet Tannur and was originally divided between American and Jordanian authorities. This exhibition will reunite the two collections, which contain some

For the first time since antiquity, the two original halves of this important Nabataean statue will be united for the exhibition *Petra*. This image, taken several years ago, shows the authentic upper half of the statue (in the collection of the Cincinnati Art Museum) together with a cast of the lower portion of the original, which resides in Amman, Jordan.

of the most important works of Nabataean art extant. The Jordanian Ministry of Tourism and the Department of Antiquities, as well as the American Center for Oriental Research in Amman, have assisted with the development of this project. After its pre-

This eagle, a Nabataean symbol of celestial power, sits atop a thunderbolt, an ancient symbol of the heavens and of the storms they produce.

miere at the American Museum of Natural History, *Petra* will travel to other venues throughout the United States including CAM.

Among the highlights of *Petra: Lost City of Stone* will be several important architectural pieces, such as a sculpted garland frieze from a major temple at Petra, a sculpted window frame from a private villa, a portion of a monumental temple façade featuring figures from the zodiac, and a limestone pulpit from a sixth-century Byzantine church. Key masterworks will include a monumental limestone head of a Nabataean male deity, a seated sandstone cult statue of a storm god, a life-size cast bronze statue of the goddess Artemis, and a marble head of a Roman emperor.

One notable display will unite two halves of a sculpture believed to have been broken during an earthquake and separated some 1,500 years ago. The top of the sculpture, which depicts the 12 signs of the zodiac surrounding a bust of Tyche, a Nabataean goddess, resides in CAM's collection, while the bottom is held at the National Archaeological Museum in Amman, Jordan. In *Petra,* the two halves of this intriguing piece will be reunited as a complete statue for the first time in 1,500 years.

From the second century B.C.. through the second century A.D., Petra prospered—it is estimated that at its height, the city was as large as lower Manhattan, with a population of more than 30,000. As the city grew to link far-flung regions of the ancient world, a cultural merging occurred that is expressed through the unique style of art and architecture found at the site, representing the heterogeneous nature of its society. A massive earthquake in A.D. 363, however, destroyed much of Petra. Although partially revived after that, Petra was no longer the economic powerhouse it had been. Much of the technological infrastructure that had made life in Petra possible fell into disuse, and political and religious changes in the ancient world led to the eventual abandonment of the city in the seventh century A.D.

The city was then "lost" to Westerners until a series of European explorers rediscovered it. In 1812, Swiss explorer Johann Ludwig Burckhardt reawakened European knowledge of the site's existence after more than 1,000 years. The theme of European rediscovery of the ancient site also will be explored through paintings, drawings, and prints by David Roberts, William Bartlett, Edward Lear, and Frederic Church, including Church's large-scale oil painting of the famous Treasury (1874).

Petra remains a source of deep fascination for Western visitors, with its savage beauty and natural grandeur, its desolate setting, the mystery and splendor of its rock-carved architectural ruins, and the variegated color of its cliff faces.

"Petra is one of the world's most spectacular archaeological sites, combining an extraordinary natural landscape and monumental buildings," said Craig Morris, Senior Vice President, Dean of Science, and Curator, Division of Anthropology at the Museum. "The exhibition re-creates many aspects of this impressive natural and human setting using artworks, photographs, and actual architectural elements to tell the fascinating story of life in this ancient city using the eloquent beauty of the work of its people."

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.

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.

COMPANION EXHIBITION

The Bedouin of Petra

October 18, 2003–July 6, 2004

Photojournalist Vivian Ronay's evocative color photographs taken between 1986 and 2003 document the Bdoul group of five sedentary Bedouin tribes living around the archaeological site of Petra in Jordan.

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

PANEL DISCUSSION

The Petra Siq

Sunday, 10/19, 2:00 p.m.

Petra's remarkable hydraulic system, designed over 2,000 years ago, transformed a semi-arid land into a lush environment. The same conditions that challenged the Nabataeans complicate conservation efforts at the Petra site today. In this panel discussion, Aysar Akrawi and Ma'an Huneidi of the Petra National Trust, and Douglas C. Comer of Cultural Site Research and Management, will illustrate how archaeology and satellite imagery have influenced conservation measures at Petra.

MUSEUM EVENTS

EXHIBITIONS

The Butterfly Conservatory
Opens October 11
The butterflies are back! Mingle with more than 500 live, free-flying tropical butterflies in an enclosed tropical habitat.

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

Vietnam: Journeys of Body, Mind & Spirit
Through January 4, 2004
This comprehensive exhibition presents Vietnamese culture in the early 21st century.

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.*


R. MICKENS/AMNH

Experience the sights and sounds of a bustling

Vietnamese Marketplace

and sample traditional foods at Café Pho.
Through January 4, 2004

77TH STREET LOBBY, FIRST FLOOR

LECTURES

Curators' Lecture: Milstein Family Hall of Ocean Life
Thursday, 10/9, 7:00 p.m.
Melanie Stiassny and Mark Siddall describe the spectacular renovation of the Milstein Family Hall of Ocean Life.

Sea Dragons: Predators of Prehistoric Seas
Wednesday, 10/22, 7:00 p.m.
Richard Ellis discusses the lives, deaths, reproductive habits, and hunting strategies of the giant marine reptiles of the Mesozoic era.


RICK EDWARDS

Richard Ellis

Curator's Lecture: Arthur Ross Hall of Meteorites
Thursday, 10/23, 7:00 p.m.
Denton S. Ebel will discuss 21st-century perspectives on the oldest rocks in the solar system.

The Extraordinary Sea Voyages of Captain James Cook
Tuesday, 10/28, 7:00 p.m.
Anthropologist Nicholas Thomas brings Captain James Cook to life.

WORKSHOP

Animal Drawing
8 Thursdays, 10/2–11/20, 7:00–9:00 p.m.
An intensive after-hours drawing course among the Museum's famed dioramas and dinosaurs.

FAMILY AND CHILDREN'S PROGRAMS

It's a Wild, Wild World
Live animal presentations and hands-on workshops.
Saturday, 10/11:
Raptors: Birds of Prey
Saturday, 10/18:
The World of Reptiles

Watch Out! Meteorites on the Big Screen
Sunday, 10/26, 2:00–3:30 p.m.
Clips from classic science fiction films illustrate the myths and realities of meteorite impacts.

HAYDEN PLANETARIUM Programs

Virtual Universe: Orion Nebula
Tuesday, 10/7, 6:30–7:30 p.m.
Redefine your sense of "home" on this monthly tour through charted space.

Celestial Highlights: Another Eclipse!
Tuesday, 10/28, 6:30–7:30 p.m.
Find out what's up in the November sky.

Celebration of Space: Far Out: Space Probes as Landscape Photographers
Monday, 10/20, 7:30 p.m.
A panel of scientists, photographers, philosophers, and poets will discuss the role of planetary images on the art and politics of the human condition.

A Weather Report from an Extrasolar Planet
Monday, 10/27, 7:30 p.m.
With Dimitar Sasselov, Harvard-Smithsonian Center for Astrophysics.

Courses

Stars, Constellations, and Legends
5 Wednesdays, 10/15–11/19, 6:30–8:00 p.m.
Learn to locate and identify the seasonal constellations.

Using a Telescope
4 Mondays, 10/20–11/10, 6:30–8:30 p.m.
Ideal for those who have a telescope but are not sure how to use it, this course covers the basic functioning of telescopes.

Introduction to Astronomy
6 Mondays, 10/20–11/24, 6:30–8:30 p.m.
Designed for those with no background in astronomy, mathematics, or physics.

Stars: Binaries and Clusters
6 Thursdays, 10/23–12/11, 6:30–8:30 p.m.
Explore single stars, binary stars, star clusters, and galaxies to find out what the study of these objects can tell us about the universe.

DONALD GARNETT (U. ARIZ.) ET AL. HUBBLE HERITAGE TEAM, NASA

Nebula N44C

Foundations of Science: Archaeo/Ethno-Astronomy
6 Thursdays, 10/16–11/20, 6:30–8:30 p.m.
Cosmologies from diverse societies and the symbolism associated with them.

The Rose Center: Envisioning the Virtual Universe
5 Tuesdays, 10/14–11/18, 6:30–8:30 p.m.
Tours and hands-on control of the Hayden Planetarium's computer-generated cosmos.

SPACE SHOWS

The Search for Life: Are We Alone?
Narrated by Harrison Ford

Passport to the Universe
Narrated by Tom Hanks

Look Up!
Saturday and Sunday, 10:15 a.m. (Recommended for children ages 5 and under)

LARGE-FORMAT FILMS

In the Samuel J. and Ethel LeFrak IMAX® Theater

Pulse: a STOMP Odyssey
Last chance! Closes October 10.

India: Kingdom of the Tiger
Opens 10/11
A glorious tribute to this magnificent land and its greatest ambassador—the mighty Bengal tiger.

Coral Reef Adventure
A fantastic underwater journey to document some of the world's most beautiful—and most threatened—reefs.

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.

Starry Nights:
Live Jazz

Friday, 10/3, 5:30 and 7:00 p.m.
Rose Center for Earth and Space

The Paquito D'Rivera Quintet

The 5:30 performance will be broadcast live on WBGO Jazz 88.

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

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

The Salt *Not* of the Earth

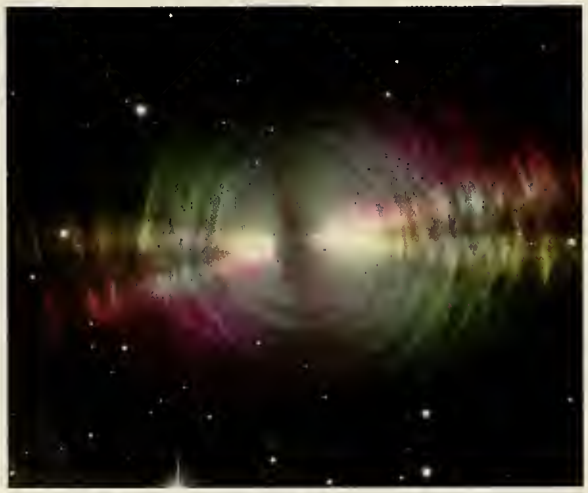
Throughout the Egg Nebula, astrochemists have detected—what else?—sodium chloride.

By Charles Liu

Chemistry, to most of us, means test tubes, Bunsen burners, and beakers filled with bubbly concoctions. A select group of chemists, however, rarely handle flasks of foul-smelling fluids. Instead, telescopes are their glassware, and the stars, their crucibles. They study astrochemistry—the creation and transformation of molecules and compounds in the universe.

The astrochemical laboratory is the hyperrarefied, mostly weightless, extreme-temperature environment people colloquially call outer space. In space, atoms can combine to form molecules one can't ordinarily find on Earth. Conversely, many compounds common on our planet practically never occur outside a rock-iron planet with a thick, gaseous atmosphere.

Take ordinary table salt. A union of a single sodium atom with a single chlorine atom, salt (or, as chemists call the compound, sodium chloride) is ubiquitous on Earth: it permeates our oceans, our food, and our blood, not to mention the massive veins of the stuff in the Earth. Beyond our solar system, though, it had, until recently, been detected in only one place: in the vicinity of a dying, carbon-heavy star known as IRC +10216, in the constellation Leo. Now, though, a team led by Jaime L. Highberger, an astrochemist at the University of Arizona in Tucson, has reported the discovery of a sprinkling of salt in a cloud of gas and dust named CRL 2688, in the constellation Cygnus, the swan. Because of its roughly oval shape and its position at the tail end of a constellation named for a bird, the cloud has long been known as the Egg Nebula.



Clouds of dust and gas that make up the Egg Nebula, visible here as roughly circular arcs, are sloughed off in a series of outward puffs from an aging, central star (positioned, but not visible, at the center of this image) that is transforming itself from a red giant into a white dwarf. The colors of the image are not true colors, but instead represent various angles of polarization that are imposed on the starlight as it passes through the dust. Astrochemists surveying the clouds' dust and complex molecules have found ordinary table salt, NaCl, among the gaseous compounds there.

Molecules are far more complicated than the sum of their parts. The bonds between the individual atoms aren't as rigid as the sticks and balls of chemistry models suggest. Underinflated beach balls held together by bedsprings make a better analogy; molecules are wobbly constructions, constantly flopping, spinning, and flexing. As a consequence, they can absorb and emit radiation, just as single atoms can—and it is their radiation-emitting property that enables astronomers to find them.

Their structural complexity, however—all that flopping, spinning, and flexing—ends up complicating their spectroscopic signatures, making them far harder to interpret than the spectra of solitary elements. On top of that, when molecules "glow" in open space, their glow is a cold one, generally in the microwave region of the electromagnetic spectrum, where wavelengths are thousands of times longer than they are for visible light. To see them, astrochemists must focus on them with specialized radio telescopes.

Figuring out how (and where) various kinds of molecules might form in space is even trickier than detecting their presence. Free-floating atoms in interstellar gas clouds can't just collide and stick together. In most cases, such concentrations of atoms are so rarefied that the chances of colliding are infinitesimal. Even if atoms do collide, they have too much kinetic energy to stick. The atoms just bounce off each other and keep going.

Instead, molecules have to form on the surfaces of dust grains. There the collisions are likely enough, and the environment is quiet enough, for chemical reactions to take place. Atoms need to land on a grain, meet, and create a molecular bond. Then, the newly formed molecule needs to float off the grain back into space.

It turns out that almost all the free-floating molecules in space are extremely simple ones: either hydrogen gas or carbon monoxide. For heavier and more complex molecules, though, aging stars, replete with larger atoms, are an ideal place to look. Stars of about the same mass as our Sun (but older) go through a red-giant phase before becoming white dwarfs. The outer layers of a red giant slough off in a series of outward puffs of gas, forming a planetary nebula—a system of rings and loops of glowing gas around the star. The planetary nebula around such a star is rich in dust grains as well as heavy elements, and its internal heat can provide enough energy to build compounds. But the nebula is not so hot that it breaks the delicate molecular bonds.

That's why Highberger and her colleagues looked at CRL 2688, a star in the last stages of red gianthood—and the planetary nebula forming around it. Observing with the twelve-meter radio telescope at Kitt Peak in Arizona, and with the thirty-meter IRAM radio telescope at Pico Veleta, Spain, they found unmistakable evidence that the Egg Nebula is salty.

Finding molecules in space has its own rewards, but the work is more than just a search for curiosities. The distribution of salt in the Egg Nebula gives important information about how stars recycle their contents, providing raw materials to make new stars. Highberger's observations show that the free-floating salt occurs in roughly spherical layers more than a trillion miles from the central star. At such distances the salt should be so cold it should all have condensed into solid grains, which are undetectable to astrochemists. Since the salt is clearly observed, a puzzle arises: How has all this vaporized salt survived?

One possibility is that astronomers simply don't understand gaseous salt well enough yet. Perhaps temperatures have to be much colder before solid salt can form.

Highberger and her colleagues suggest another scenario. As the central star sheds its outer layers, they drift outward at varying times and speeds. If a fast-moving layer puffs outward shortly after a slower-moving layer, the newer material would ultimately crash into the older stuff. The resulting shock wave would stir up cold gas and reheat it. The heat would trigger a new wave of molecule formation, and produce the glowing gaseous salt that is observed. If the model is correct, I'd say the Egg Nebula isn't just salted; it's scrambled and fried, too.

Charles Liu is an astrophysicist at the Hayden Planetarium and a research scientist at Barnard College in New York City.

THE SKY IN OCTOBER

By Joe Rao

Always hasty, Mercury makes a brief appearance before dawn early this month, rising just above the due-eastern horizon. It soon disappears into the glare of the Sun and reaches superior conjunction (on the other side of the Sun as seen from the Earth) on October 25th.

Venus, shining brilliantly at magnitude –3.9, chases the Sun across the sky throughout October. As seen from midnorthern latitudes, the planet sets thirty minutes after the Sun on the 1st; by the 31st, because of both shortening days and Venus' own movements, the planet sets about an hour after our star. On the evening of the 26th it appears just to the right of a very young crescent Moon.

Mars, shining in the constellation Aquarius, crosses its highest point in the sky about three to four hours after sunset. How it has dimmed in the past few weeks! As its distance from Earth increases from 42 to 58 million miles during October, Mars fades to less than half its early-month splendor, from magnitude –2.1 to –1.2.

The king of the heavens meets the king of the jungle: Jupiter is in the constellation Leo. It rises about two-and-a-half hours before the Sun at the beginning of the month and more than four-and-a-half hours before sunrise on Halloween. On the morning of the 22nd Jupiter is well to the right of the waning crescent Moon.

Saturn, in the constellation Gemini, rises out of the northeast about five hours after sunset at the beginning of the month; by the time the hobgoblins and ghouls are out and about on the 31st it is rising less than four hours after sunset. Saturn's rings continue to be a spectacular sight, even through a small telescope. On the night of the 16th Saturn appears to hover above the Moon in the east-northeastern sky; by the 17th the Moon shifts far east of the planet.

The Moon reaches first quarter on the 2nd at 3:09 P.M. and waxes full on the 10th at 3:27 A.M. Traditionally the full Moon following the Harvest Moon is known as the Hunter's Moon. The Moon wanes to last quarter on the 18th at 8:31 A.M., and the new Moon arrives on the 25th at 8:50 A.M.

"Fall back" in much of Canada and the United States, as daylight saving time ends on Sunday, the 26th: the hour between 1 A.M. and 2 A.M. is officially repeated.

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

Pees & Cues

By Ryan C. Taylor

An amphibian charmer, Hyla squirella

My academic life at the University of Louisiana in Lafayette came to a crossroads the day Bryant "Buck" Buchanan placed a squirrel treefrog *(Hyla squirella)* in my hand. In the blink of an eye, the small green frog slipped from my grip and rocketed across the lab, leaving a puddle in my palm. Somehow, in midflight, it latched onto some metal shelving with one foot and hung on for dear life. In my astonishment all I could do was wipe off what was left on my hand.

Until that moment I had been a gung ho fish guy, planning a research career in marine biology. But for some reason I found the treefrog experience so amusing that when Buck offered me the chance to study the creatures with him, I accepted on the spot. Our aim was to find out why treefrogs so frequently do just what my little guy had done to me: dump their bladder water when they feel threatened.

A few days later Buck brought me into the field to get me better acquainted with our research subjects. Wading through fronds of chest-high dwarf palmettos in the dense understory of a hardwood forest in St. Landry parish, we talked about the frogs and our approach to the project. I had already seen that they are no bigger than most car-alarm remotes: about an inch and a quarter, on average, from snout to cloaca. Daytime conditions in their native habitat in the southeastern United States are warm and often baking. Hence, by day, squirrel treefrogs nestle into dense vegetation, pressing themselves flat against a leaf and tucking their feet under the body, to expose as little skin as possible to the drying effects of the air. But, I learned, such a water-conserving posture is not always enough to prevent dehydration. That's why the frogs take the added precaution of storing water in their bladders, in the form of dilute urine. The bladder water is essential to their survival.

Yet even in the dry season, from September to November, treefrogs often dump their precious bladder water when potential predators approach—that much was evident from my first treefrog experience. Could dumping its bladder benefit a frog by lightening its load, thereby increasing the distance it could jump? Buck and I decided to find out.

Our first step was to measure how much bladder water squirrel treefrogs retain. By weighing adult males with full and then empty bladders, we found that bladder water makes up, on average, 14 percent of the animal's entire body weight. To our amazement, one treefrog was storing 59 percent of its total body weight as bladder water—the equivalent of a 175-pound man whose bladder is holding more than twelve gallons of water.

Our next step was to test the frogs' jumping. We weighed each frog as soon as it rehydrated, and then let the animals loose one by one inside a plastic-lined "arena." Some of the frogs—apparently those that were more skittish—dumped their bladders; others didn't. But they all jumped, either spontaneously or after a gentle prod. We then measured their jumps and weighed them again. Our data showed that the frogs with empty bladders jumped nearly 20 percent farther than the frogs with full ones.

By the end of our study I realized that, when danger threatens, treefrogs face a potentially life-altering decision: To pee, or not to pee. By jettisoning their bladder water, they gain an advantage in getting out of harm's way, but at the likely cost of dehydration. I also realized that, like the frogs, I, too, faced a life-altering choice. I could continue down the road to marine biology, or stick with my newfound amphibian friends. Let's just say I never really recovered from the treefrog experience.

Ryan Taylor is finishing his doctoral research at the University of Louisiana in Lafayette on the factors that influence mate choice in squirrel treefrogs.