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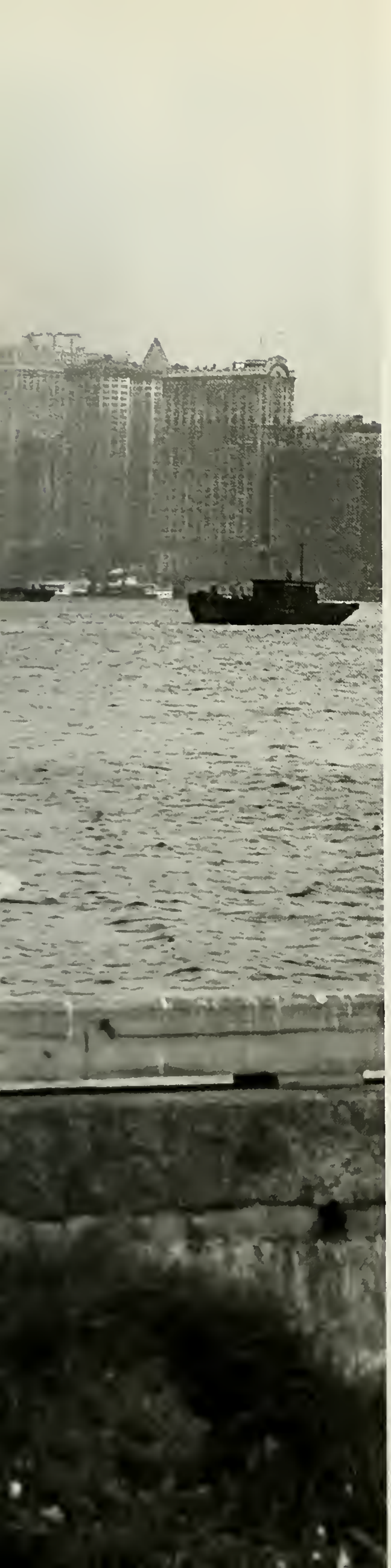

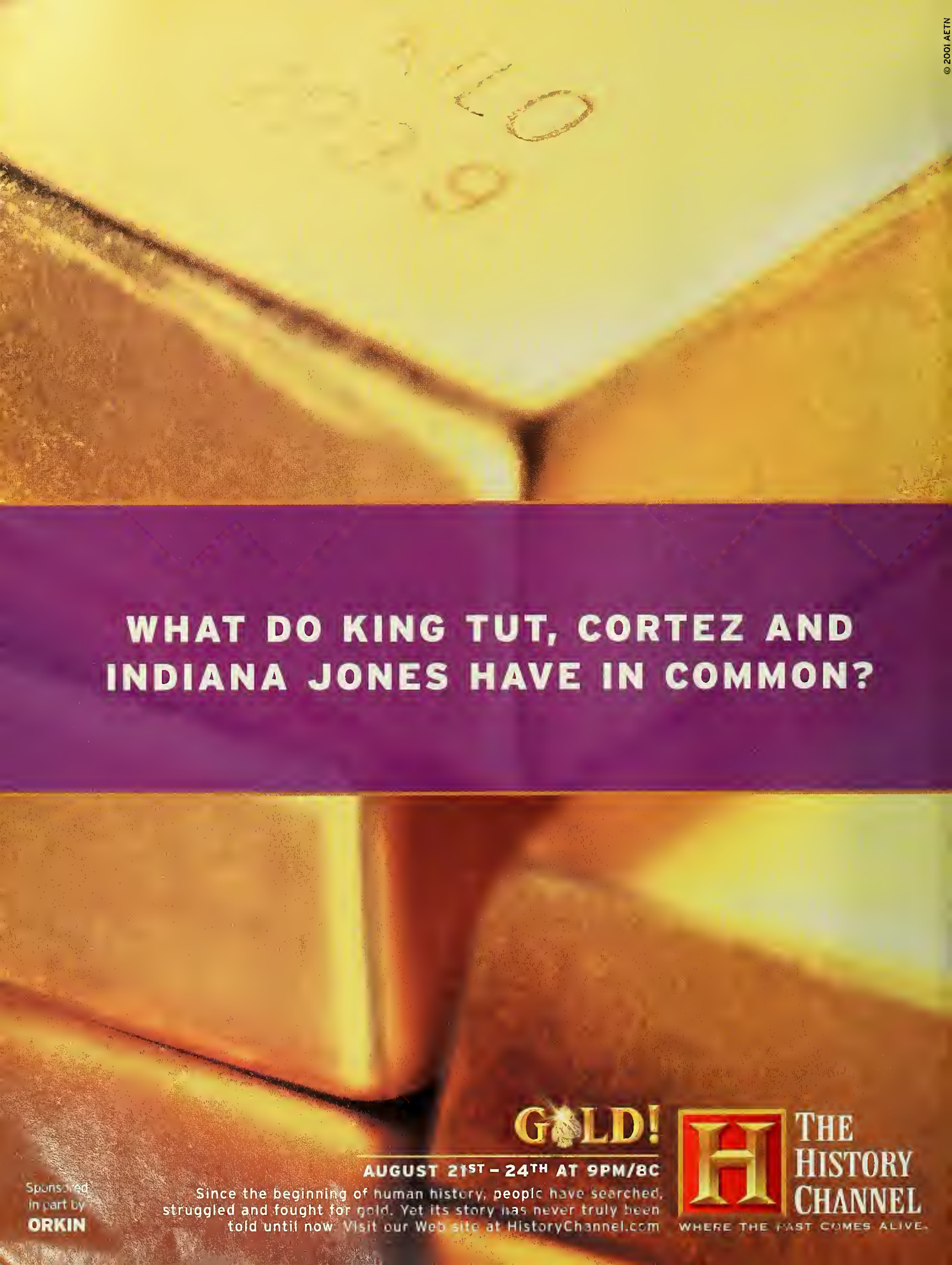
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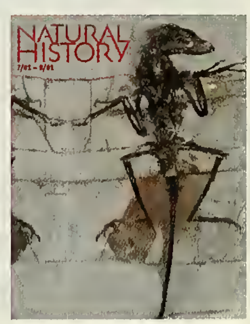
JULY – AUGUST 2001 VOLUME 110 NUMBER 6

FEATURES



DEPARTMENTS

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UP FRONT

The Dark Side of the Sun

At some point in the recent history of our species, people of European descent began to cultivate the suntanned look. (Notions of physical beauty are often tied to symbols of prosperity and leisure. A suntan—which once signaled long hours of working outdoors—became in the twentieth century a conspicuous advertisement that one had nothing more pressing to do than travel to a seacoast and lie about on a beach blanket.)

Biologically, suntans—and dark-pigmented skin in general—tell another, more objective story: that human beings have an ambivalent evolutionary relationship with the sun. Yes, our star is the source of all life and energy, yet we can never look straight at it, and overexposure to its radiation can be fatal. Other animals, as well as plants and protists and bacteria, have the same paradoxical involvement with the sun. That's why hammerhead sharks get suntans, why some sea urchins eat algae, and why certain grasses produce chemical sunscreens.

Ultraviolet image of an explosion on the sun

J. GURMAN, S. PLUNKETT, S. HILL, S. HAUGAN; SOHO/NASA

Back in 1985, the British Antarctic Survey announced that the ozone layer was thinning and that living things were being exposed to elevated levels of ultraviolet radiation—the form of sunlight with the greatest potential to cause biological harm. Getting a suntan, like cigarette smoking several decades earlier, dropped from the list of life's harmless pleasures.

Science writer Jay Withgott ("Feeling the Burn," page 38) reports on biological research that has followed the discovery of the ozone hole, relaying the sometimes reassuring, sometimes alarming findings. If you happen to read this article while vacationing at the beach, please move into the shade.—*Ellen Goldensohn*

NATURAL HISTORY

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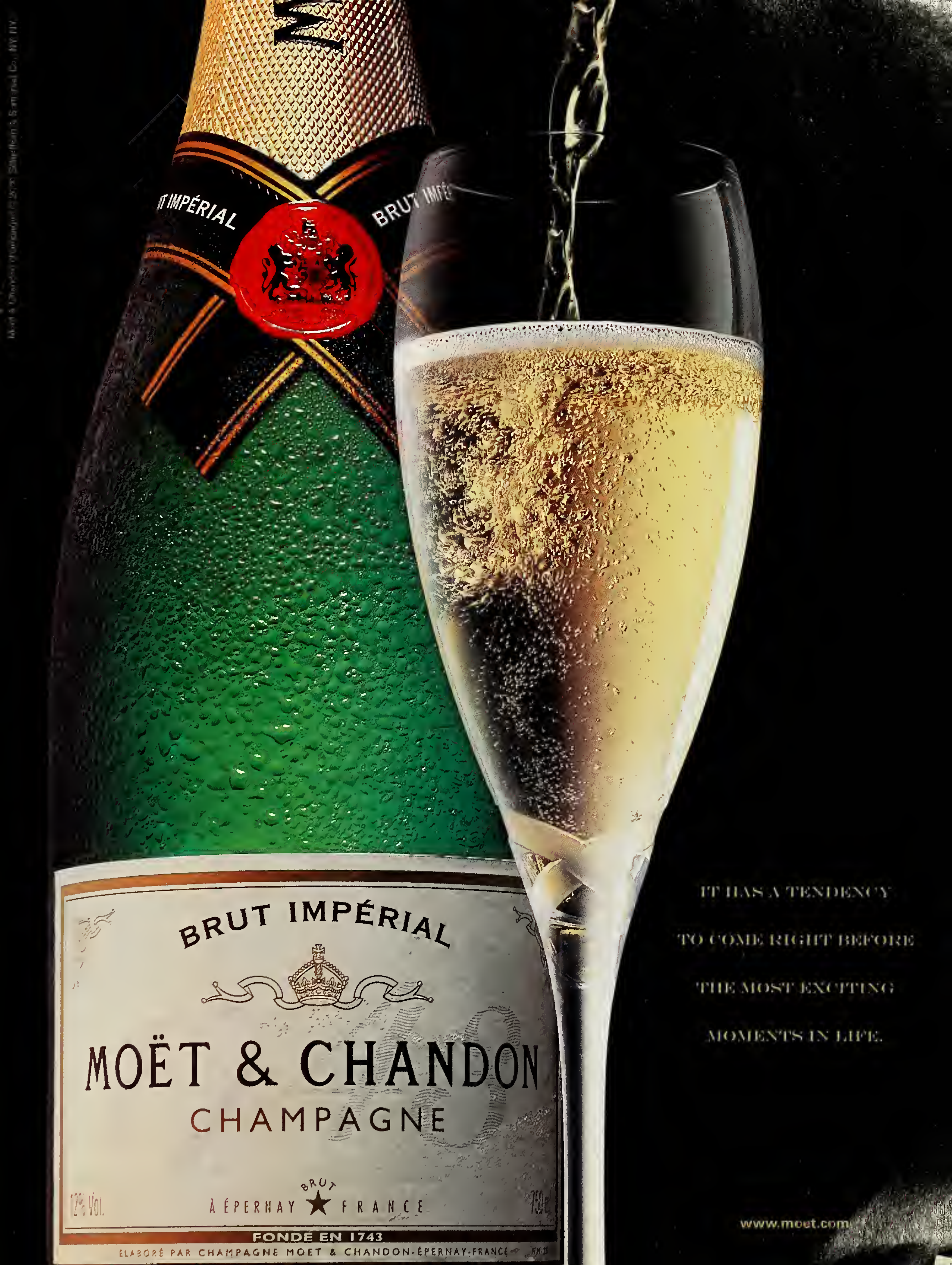
Natural History (ISSN 0028-0712) is published monthly, except for combined issues in July/August and December/January, by the American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024. E-mail: nhmag@amnh.org. Subscriptions: $30.00 a year; for Canada and all other countries: $40.00 a year. Periodicals postage paid at New York, N.Y., and at additional mailing offices. Send subscription orders and undeliverable copies to the address below. For subscription information, call (800) 234-5252 or, from outside U.S., (515) 247-7631. Postmaster: Send address changes to *Natural History*, P.O. Box 5000, Harlan, IA 51537-5000. Canadian GST Registration #128426574. Canadian Publications Agreement #1423274. Printed in the U.S.A.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LETTERS

Theories of Relativity

Regarding Jared Diamond's interesting article "Deaths of Languages" ("Nature's Infinite Book," 4/01): the Crimean word *marzus* (wedding) sounds Turkic to me. And indeed, a phrase for "wedding" in modern Turkish is *evlenme merasimi,* in which *merasim* carries the sense of "ceremony." You might find a cognate for *marzus* in old Tatar tongues.
Bill Shepherd
via e-mail

Might Crimean Gothic's *marzus* have had a Latin origin? I suggest the following cognates: Old French *mariage* (marriage); Latin *maritare* (to marry), from Latin *maritus* (husband); and English "marriage."
Kenneth L. Sanders
Fort Myers, Florida

The word *marzus* is recognizably related to the Indo-European origins of "marriage": Latin *maritus* (husband); Sanskrit *maryas* (lover); Lithuanian *marti* (bride); Welsh *merch* (girl); even French *mari* (husband).
Eric W. Knight
New York, New York

JARED DIAMOND REPLIES: Quite a few correspondents wrote to suggest that the Crimean Gothic word *marzus* might somehow be related to our English word "marriage," which entered English from French and ultimately from Latin *maritare* (to marry). This suggestion turns out to illustrate a fascinating general problem in linguistics.

While some linguists also derive *marzus* from *maritare,* others doubt the words are related, for two reasons. First, although both the Crimean and the Latin word share the syllable *mar-*, it's hard to trace the other syllable, *-zus,* to a Latin root. Hence some linguists have suggested similar-sounding Lithuanian, Greek, and even Arabic words as antecedents of *marzus*. Second, most recognizable Crimean Gothic words are Germanic, with a smattering of loan words from the languages of other people with whom the Goths had contact, particularly the Iranians, the Turks, and the Greeks. Little or no evidence exists for Latin influence on Crimean Gothic, making one wonder whether the resemblance of *marzus* and *maritare* is accidental. If one compares the vocabularies of undoubtedly unrelated languages—Navajo and Basque, for example—one can still find similarities of sounds in about 15 percent of all corresponding words, because human speech consists of only a finite number of sounds. This problem of distinguishing chance similarities from real relationships is the most difficult single problem for linguists trying to detect relationships between languages that might, at best, be only distantly related.

Mothers and Udders

Sarah Blaffer Hrdy ("Mothers and Others," 5/01) made no mention of a common baby-sitting custom here in Texas cattle country. One mother cow baby-sits a group of twelve to fifteen calves whose mothers are out grazing, usually nearby. Coyotes, and in some areas dog packs, would find easy pickings if it were not for the guarding cow. Every hour or so a grazer comes back, finds her own calf and nurses it, then lies down and relieves the caretaker, which gets up and goes out to graze. All the mothers take their turns, but the lower-status cows seem to have less free time and much more baby-sitting duty.
Elizabeth S. Roach
Eliasville, Texas

Expanding Space

In his informative article "Cosmic Plasma" ("Universe," 5/01), Neil deGrasse Tyson states that a few microseconds after the big bang, the size of the universe "was not much larger than our solar system." For that to be the case, the speed of expansion would have to have been several orders of magnitude greater than the speed of light, which would have violated the principles of relativity. Is there something I'm missing?
Ivan Stanko
via e-mail

NEIL deGRASSE TYSON REPLIES: Let there be no doubt, the speed of light is not just a good idea, it's the law. But this law applies only to objects that move through a preexisting space, not to the expansion of space itself. So the universe can expand as fast as it wishes, carrying the galaxies along for the ride at less than, the same speed as, or faster than the speed of light.

The Truth About Seahorses

I've been studying the pygmy seahorse *Hippocampus bargibanti* for several years and have spent more than 180 hours underwater observing them, in collaboration with Amanda Vincent and Project Seahorse. I wish to clarify some statements that appeared in "Coral Stables" ("The Natural Moment," (4/01). At present it is an assumption that the male broods the young as in other seahorses. We hope to have a definite answer later this year. Furthermore, I have witnessed a pygmy seahorse birth in which not just a few but thirty-four juveniles were released from one adult. The gestation period is less than the several weeks implied in the short article, and these seahorses' monogamy may be short-lived. Presently we do not know what pygmy seahorses feed on. We still have much to learn about these delightful creatures.
Denise Nielsen Tackett
Paden City, West Virginia

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

CONTRIBUTORS

A former electrical engineer, **Kathryn Rusch** ("Whispers in the Canyon," page 32) was working on a sound-transmission study in southeastern Arizona when she became fascinated by the hummingbirds fighting and vocalizing at a feeder in Ramsey Canyon. This led to her long-term studies of the songs of blue-throated hummingbirds and other canyon denizens. Rusch, seen here with her younger daughter, Michaela, is a research assistant at the University of Wisconsin-Milwaukee Field Station in Saukville. Her two daughters, now ages seven and four, help her with research on ruby-throated hummingbirds in their backyard.

Science writer **Jay Withgott** ("Feeling the Burn," page 38), whose story examines the biological impact of ultraviolet radiation, recently published an article in *California Wild* on whether microbes could survive UV exposure in outer space, as well as a piece in *BioScience* on the role of ultraviolet light in the vision of birds and other animals. Withgott has done graduate research on snake predation and on aphids and is an avid birder. He also accompanies his wife, Susan Masta, a biologist, in collecting toads and spiders. "She hopes that after doing this article, maybe I'll remember to use sunscreen," he says.

Butterfly specialist **Phil Schappert** ("Butterfly Buffet," page 46) is a lecturer at the University of Texas at Austin's School of Biological Sciences and manager of its Stengl "Lost Pines" Biological Station. About sixteen years ago, in Ontario's Lake Superior Provincial Park, Schappert chanced upon an unforgettable sight: hundreds of colorful nymphalid butterflies blanketing a black bear carcass. Later, he began to wonder why butterflies feed "on the most unappealing substances imaginable." Schappert has authored *A World for Butterflies: Their Lives, Behavior and Future* (Firefly Books, 2000).

While looking for an Andean topic for his master's thesis in ethnology, **André Affentranger** ("The Condor and the Bull," page 50) learned about the traditional condor bullfight in Cotabambas, Peru, and reasoned that there must be a significant interplay between the event itself and the attention lavished on it by the media. A native of Switzerland, Affentranger (left) is completing his doctoral thesis at the University of Basel and editing a video about the condor bullfights. Born in Italy, **Ernesto Bazan** is a travel and news photographer based in Havana. He was the photographer for two previous stories in *Natural History:* "The Season of *Las Parrandas*" (December 1997/ January 1998) and "Cuba's All-Stars" (April 1999).

Curator and chairman of the American Museum of Natural History's Division of Paleontology, **Mark Norell** ("The Proof Is in the Plumage," page 58) has been at the forefront of documenting the evolutionary relationship of theropod dinosaurs and birds. In Mongolia, he discovered the first embryo of a carnivorous dinosaur, the theropod *Shuvuuia*, and the strange Mongolian bird *Mononykus* (see "New Limb on the Avian Family Tree," September 1993). Norell (right) has also analyzed the new fossil birds and dinosaurs emerging from northeastern China. Illustrator and photographer **Mick Ellison**, who has visited the Chinese site five times, is principal artist in the Museum's Division of Paleontology. In addition to his work illustrating fossil creatures, he enjoys painting portraits of people.

After completing a master's thesis in geology, German-born **Theo Allofs** ("The Natural Moment," page 80) changed direction and launched a career in travel photography. A few years later, he decided to become a full-time nature photographer; his subjects have included orangutans in Borneo, capybaras in Brazil, and flying foxes in Australia. He and his wife, Sabine, live in a log home near Kluane National Park in Canada's Yukon Territory. To see more of Allof's award-winning work, visit www.theoallofs.com.

THIS LAND

Following the Silver Trail

Vestiges of mining towns line a route into the central Yukon.

By Robert H. Mohlenbrock

Canada's northwesternmost territory, the Yukon, has just two major highways—the Alaska Highway, which runs east to west across the southern part of the region, and the Klondike Highway, which starts south of Whitehorse (the territory's capital) and runs northwest through Stewart Crossing to Dawson City. The great Klondike gold rush, which followed the discovery of gold along Bonanza Creek in 1896, was responsible for making Dawson City a major town. Stewart Crossing is near Stewart Creek and Duncan Creek, where gold was discovered in 1895 and 1889, respectively. Silver-rich deposits of galena, a lead ore, were mined in an area northeast of Stewart Crossing. The road leading there, which strings together the three towns of Mayo, Elsa, and Keno City, is still known as the Silver Trail.

One cool August morning, my wife, Beverly, and I got an early start out of Whitehorse and followed the Klondike Highway for 120 miles, to the few buildings that remain of Stewart Crossing. We then turned onto the Silver Trail, which at first follows the Stewart River upstream. After about two miles, our view of the river was obscured by a white spruce forest. The forest grows atop permafrost, a layer of soil that remains frozen year-round. A dense ground cover of mosses provides insulation

during the summer, helping to preserve the permafrost below.

Another ten miles or so down the road, the landscape broadened into a floodplain, and twenty miles farther along, we saw a pair of low ridges. These are moraines—glacial deposits of sand and boulders—marking the western limit of glacial ice in the Stewart River Valley some 14,000 years ago, during the most recent ice age. East of here, geologist Christopher Burn has reported, the area was once covered by ice up to 1,500 feet thick.

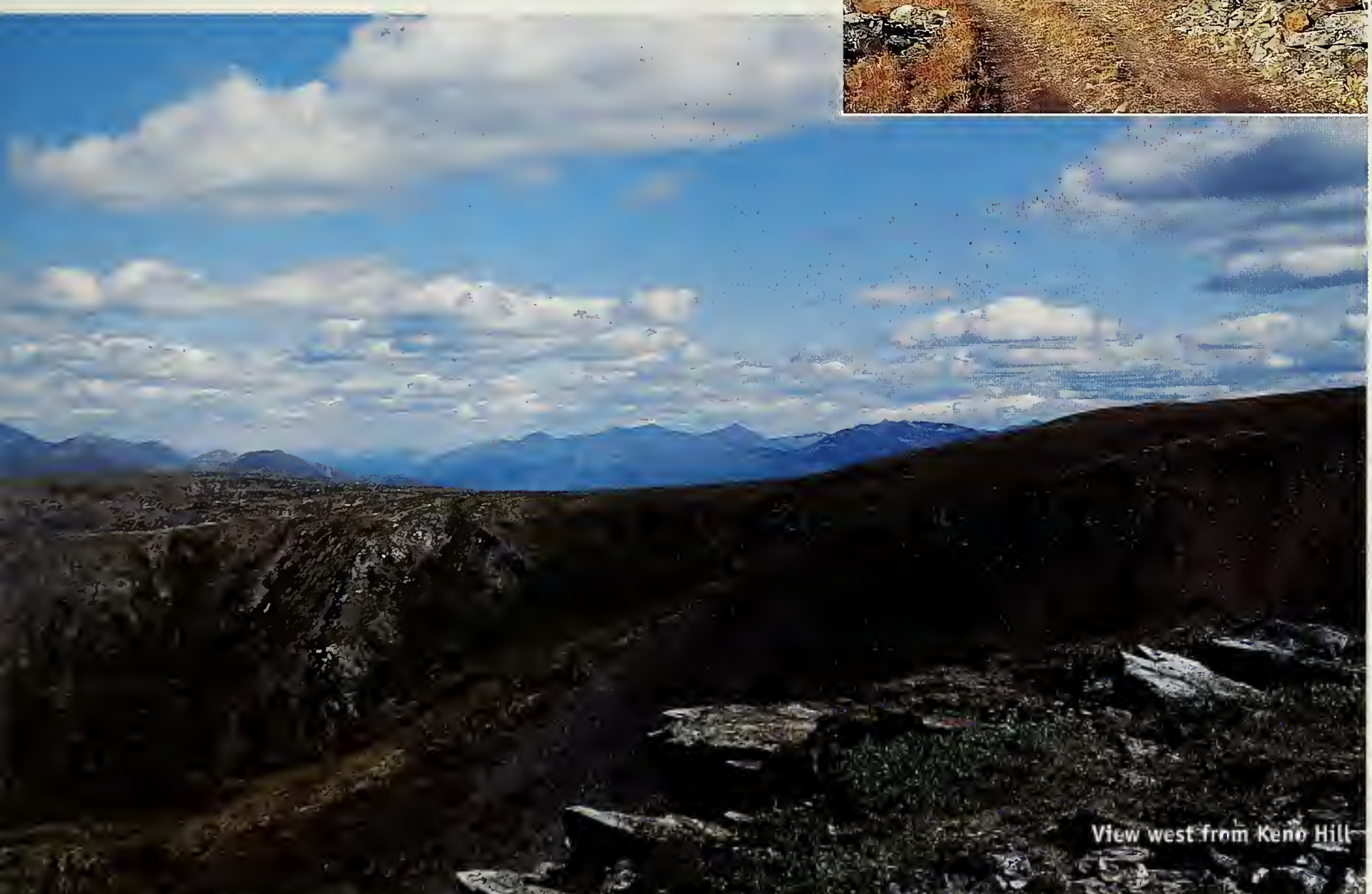
Just outside Mayo, thirty-six miles along the Silver Trail—about the halfway point—we reached a bed-and-breakfast where we had arranged to spend two nights. Mayo, which once boasted 30,000 inhabitants, now has about 500. Nevertheless, it is the region's center of activity. (Elsa is nearly a ghost town, with less than half a dozen residents, while Keno City has about twenty-five.) Coincidentally, Mayo holds the record for both the coldest and the hottest temperatures in the Yukon. In February 1949, a low of –80° F was recorded, while in June 1967, the temperature rose to 97° F.

After we had spent the night, the host of our bed-and-breakfast drove us to Keno City. On the way, near the former settlement of Minto Bridge, we stopped to see a "drunken" forest of spruce trees tilted at various angles. The forest owes its appearance to an adjacent lake, one of a number of thermokarst lakes in the region. Such lakes originate from the melting of ice in the upper layer of permafrost; in this case, according to Burn, the melting resulted from nineteenth-century forest fires. Because the lake does not freeze to the bottom in winter, deeper layers of permafrost beneath it, as well as the frozen soil around it, continue to thaw. As the banks of the lake collapse, the trees begin to topple.

The trip to Keno City gave me the opportunity to see Keno Hill, which rises several hundred feet above the

Miner's cabin

BOTH PHOTOGRAPHS BY RICHARD HARTMIER



View west from Keno Hill

town. Reaching 6,755 feet above sea level, the top of the hill is above the timberline, and several plants unusual for this part of Canada grow here. A rough road leads up to the summit, passing first through one of the northernmost stands of alpine fir in the world. On the way up, we stopped to examine the roadside vegetation in this forest and again, above the timberline, to see a wet meadow and a dry meadow. Finally we reached the rocky summit, which harbors tiny flowering plants. In most of these species, the leaves are crowded into a compact "cushion" that protects them from the harsh, drying winds.

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

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JOE LEMONNIER

HABITATS

White spruce forest also includes paper birch and balsam poplar. The shrub layer has western rose, buffaloberry, northern comandra, and shrubby cinquefoil, while the ground is carpeted with both soft mosses and crunchy reindeer moss (actually a lichen). Canada goldenrod and northern bedstraw are among the few wildflowers.

"Drunken" forest consists mainly of black spruce, although there are also a few small willows. Common shrubs are shrubby cinquefoil, mountain cranberry, western rose, northern black currant, northern comandra, buffaloberry, and a dwarf raspberry. Along with a heavy ground cover of soft mosses are horsetails and such wildflowers as Ross's avens, bluebells, sweet coltsfoot, a grass-of-Parnassus, a fleabane, and various sedges.

Keno Hill roadside vegetation includes native forest species such as white and black spruce, alpine fir, gray alder, trembling aspen, and Scouler's willow.


"Drunken" forest
FRED BRUEMMER

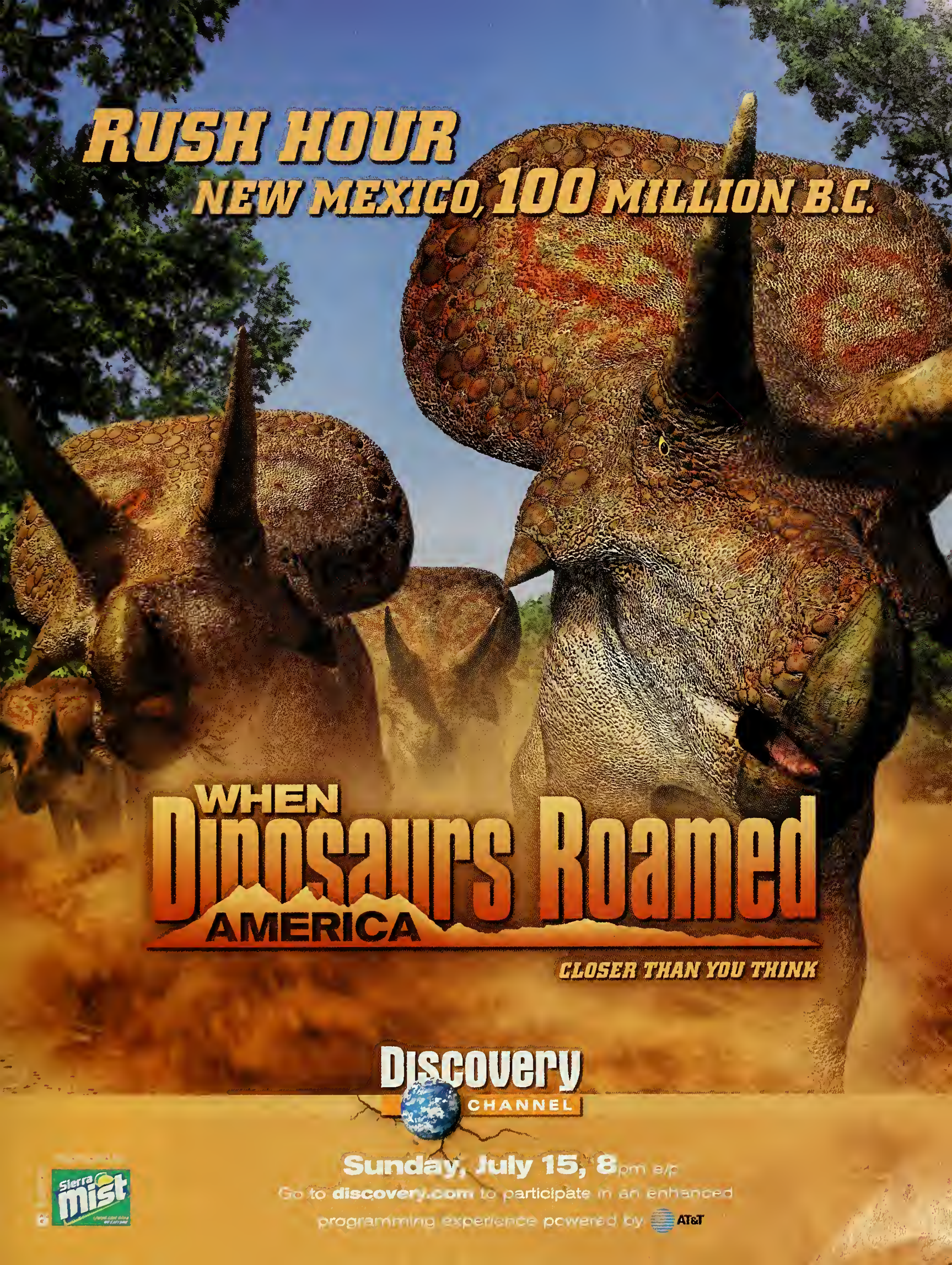
The creation of the road, however, has made an opening for other kinds of plants, including fescue, bent grasses, myriad leaf, a stinging nettle, western dock, and the colorful fireweed.

Wet meadows have abundant grasses, sedges, and rushes, while low-growing shrubs include black crowberry, mountain cranberry, shrubby cinquefoil, and three dwarf willows. Common wildflowers are a pink-flowered and a white-flowered bistort, Arctic shooting-star, three kinds of buttercups, *Parrya nudicaulis,* and Langsdorf's lousewort. Rare for the Yukon are the tiny moschatel, Sitka valerian, and *Epilobium lactiflorum* (a white-flowered, alpine willowherb).


Arctic shooting-star
MARK NEWMAN: PHOTO RESEARCHERS, INC.

Dry meadows have less species diversity than the wet meadows. Arctic willow and Labrador-tea make up the shrub population. There are three kinds of saxifrages, including the rare alpine saxifrage. The purple-headed Siberian aster is common.

Rocky summit species include the rather rare Huddleson's locoweed, a three- to four-inch-tall, hairy white plant that produces pink-to-purple flowers and oversize seed pods. Other rarities are the dwarf, shrubby *Diapensia lapponica,* whose solitary creamy white flowers are borne above a cushion of evergreen leaves, and Lapland poppy, whose yellow flowers appear on leafless stalks nearly ten inches above the basal leaves. Among the common wildflowers are one-flowered cinquefoil, woolly lousewort, alpine willowherb, three saxifrages, and an Indian paintbrush. A mat-forming shrub known as white mountain heather has minute leaves crowded into four rows. The delicate fragile fern and the larger fragrant wood fern nestle in the crevices of the sheer cliff off the northern side of the summit.



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NATURE'S INFINITE BOOK

Anatomy of a Ritual

In several New World cultures, the enema was the technique of choice for taking hallucinogenic drugs. The practice was based on sound physiological principles.

By Jared Diamond

Ritual intake of alcohol and hallucinogens by enema used to be widespread among Native American tribes and is still practiced today by some. It was performed both by hunter-gatherers in the Amazon jungle and by the Maya, the most advanced indigenous civilization in the New World. But the custom may seem puzzling or bizarre to many people today. After all, if you're disposed to mind-altering drugs, it's easy just to swallow, smoke, sniff, or lick them. Why go to the trouble of taking them by enema?

The answer does not have to do with the unique beliefs of exotic cultures but with basic principles of intestinal physiology, applicable to all of us. My own research specialty as a physiologist consists of trying to figure out how our intestine is adapted for doing what nature meant it to do. Rectal administration of drugs seems to be the reverse of what's natural. How could the outcome not be disastrous if we use an orifice specifically adapted for expelling chemicals to admit them instead? But recent advances in our understanding of digestive physiology lead me to conclude that Native American enema devotees knew what they were doing. Until the modern invention of hypodermic syringes for intravenous injection, the rectal route for hallucinogens offered special advantages.

Most *Natural History* readers, insofar as they think of enemas at all, doubtless associate them not with optional entertainment but with unpleasant medical necessity. Physicians routinely prescribe enemas to clean out a patient's lower intestine before an operation or a diagnostic procedure such as a colonoscopy. As far back as the time of the ancient Sumerians, medical enemas were used to relieve constipation by washing out intestinal contents, and to eliminate parasitic intestinal worms by instilling an antiworm drug, or vermifuge (same etymology as "centrifuge," from the Latin *fugere,* to flee, but in this case the flight is from the worms, Latin *vermis,* rather than from the center). For instance, rectally administered tobacco infusions—whether employed against pinworms, roundworms, tapeworms, or threadworms—proved an effective vermifuge in sixteenth-century Europe.

These two Old World uses of enemas are easy to understand. In both cases, substances were administered by rectum, rather than by mouth, because the aim was to reach the lower intestine. There was no intent for the substances to reach the brain, and every intent for them not to. That's where traditional New World practices differed. American Indians used enemas only to administer mind-altering drugs. The rectum served not as a dead-end street but as a highway to the broad meadows of the body and brain. The enema was elevated from an uncomfortable, cold-blooded, results-oriented medical procedure to a delicious, quasi-religious ritual.

New World na-

ALL PHOTOGRAPHS BY JUSTIN KERR

Self-administering a drug by enema; Maya clay figurine, A.D. 600–800

Hovering birds suggest the hallucinogenic possibilities of a ritual enema; Maya vase, A.D. 900–1200.

tives used many mind-altering drugs ranging from alcohol and nicotine to hallucinogens, and several of the latter were avidly embraced by drug users in the 1960s. Cocaine comes from the leaves of an Andean tree; mescaline, from the peyote cactus of Mexico and Texas; LSD analogues, from morning glory seeds; and psilocybin and psilocin, from Mexican mushrooms. With these or any other mind-altering drugs, the user's basic problem is how to get the drug to the brain. Today one can just use a needle and syringe to inject a drug into the bloodstream, but other means were needed in the days before hypodermics. While all such methods rest on the principle of getting the drug in contact with some body surface through which it will be absorbed into the blood, many choices of surface present themselves.

The most familiar choice is the small intestine, the upper stretch of our intestine just below the stomach. Coiling back and forth, the small intestine has a total length of about twenty-three feet. Its inner surface has innumerable microscopic and submicroscopic folds; smoothed out, it would cover about 5,000 square yards, comparable to the area of a football field. This enormous expanse makes the small intestine well adapted not only to its natural function of absorbing almost all the nutrients we ingest in food but also to the abnormal function of absorbing swallowed drugs.

Smoking is a popular route of drug intake for basically the same reason: microscopic folds also give our lungs a football-field-sized expanse through which to absorb oxygen and remove carbon dioxide. Still other absorptive surfaces are the tongue, the lining of the mouth, and the lining of the nose, reached through licking, chewing, and sniffing, respectively. Indians took drugs by all these still familiar routes plus two now unfamiliar ones: applying drugs to the skin and delivering them through the eyes, either by dripping them as liquids or blowing them as smoke.

The remaining absorptive surface discovered by Native Americans was the lower part of our intestine, known variously as the large intestine, colon, or rectum. To reach the other surfaces I have mentioned, all you have to do is swallow, inhale, lick, chew, or sniff (or simply expose an expanse of flesh or an eyeball). The rectal route, however, requires some mechanical props.

Perhaps the simplest prop is the suppository, a drug-impregnated plug designed for self-insertion into the anus, where the plug is melted by body heat, releasing the drug. While suppositories are a popular means of taking medicine in France, they have the disadvantage of exposing the drug to just a small fraction of the rectum's absorptive surface (the rectum is about six inches long, much longer than any suppository). Hence physicians must prescribe a considerably larger dose of any drug administered as a suppository than if the same drug is taken by mouth.

Indians devised two methods of rectal drug administration that are superior to the suppository. Both involve the insertion of a hollow bone or tube through which a drug-containing fluid is squirted deep into the rectum, thereby attaining rapid absorption across a large surface. In the first method, a helper simply fills his mouth with enema solution and blows it out through the tube. In the other, more sophisticated method, the protruding end of the tube is connected to a bulb made of an animal bladder, a leather bag, or rubber. The bulb, rather than the helper's mouth, is used to squirt the enema fluid. Thus, Indians invented the rubber-bulb syringe, now adopted worldwide for perfume atomizers and medicine droppers.

Evidence of Maya drug-taking technology comes from colorfully painted vases unearthed by archaeologists.

Between about A.D. 1 and 900, the Maya Indians of Central America developed a highly advanced civilization; their achievements included writing, beautiful artworks, astronomy books, and a notoriously complicated calendar. When archaeologists first began to find slender tubes of unknown function in Maya tombs, they did not immediately realize that Maya sophistication also extended to enema technology. The evidence came with the unearthing of beautiful, colorfully painted vases, some of which clearly depicted the purpose of the formerly mysterious tubes with an unmistakable clarity that made archaeologists blush. One of those vases (opposite page) shows a recumbent man with his legs spread, receiving an enema from a standing person (probably a woman) holding an enema bag. At the recumbent man's head stands a male helper ladling enema fluid out of a large jar. Another painted vase (see page 20) portrays a male god about to receive an enema from an attractive young goddess/woman standing behind him as she unties his loincloth, with an enema pot and bulb syringe ready in front of her. While we can only speculate about the ingredients, a clue is that some vases depicting enemas show containers of a foaming fluid resembling *balche,* the Maya beer that was popular at the time of the Spanish conquest and that may sometimes have been laced with hallucinogens.

But why on earth should anyone choose to administer mind-altering drugs by enema, which requires apparatus and often an assistant, instead of just swallowing the drug? Remembering that the purpose of the whole exercise is to get the drug to one's brain, I see three physiological advantages.

First, try to recall your nausea the first time you drank a lot of alcohol or inhaled smoke from a cigarette. And ask a few drug users how they felt when they first tried heroin, peyote, or psychedelic mushrooms. Most hallucinogens tend to cause nausea; even experienced Indian peyote-chewers are prone to feel sick to their stomach.

Thus, to consume mind-altering drugs by mouth can be self-defeating. If a drug stimulates vomiting, it may never reach the small intestine. In trying to take it by mouth, one may not only lose the drug but also turn what was intended as a pleasurable experience into a miserable one. By contrast, drugs taken by rectum can't produce

Ritual enemas for a god (far left) and a traveler (second from right); Maya vase, A.D. 750–950

nausea by irritating the stomach or the small intestine. Even if you do vomit, you retain the drug, because vomiting expels the contents of the stomach and upper small intestine but not of the large intestine.

The second advantage that enemas have over swallowing stems from the following facts of physiology: To get a "high" from a drug, you want to absorb it quickly so that it will reach a high concentration in the blood and brain. That's why intravenous injection is so effective—a needle-injected substance reaches the brain in less than half a minute. In the prehypodermic era, the fastest means of drug delivery was by enema.

From this perspective, swallowing is inefficient. Anything you swallow has to traverse your stomach before it can get absorbed through your small intestine. If your stomach already contains food, the drug that you swallow may sit in your stomach for hours until the food is ready for release into the intestine. This problem is compounded for the class of chemicals termed alkaloids, which includes most drugs of abuse: heroin, cocaine, nicotine, mescaline, LSD, and others. In chemical jargon, alkaloids are bases. What this means, in effect, is that when alkaloids reach the stomach, which secretes acid, they bind with a hydrogen ion and their absorption rate slows greatly. Hence, alkaloid absorption is negligible in the stomach and retarded in the small intestine. But this problem of retarded absorption doesn't arise in the rectum, because the rectum doesn't secrete acid. Rectal administration of alkaloids approaches the effect of mainlining them into a vein with a stroke of a hypodermic's plunger.

The remaining physiological virtue of delivering drugs by enema is that they bypass the small intestine's private line to the liver. While blood from the rectum goes straight into our general circulation and thence via the heart to the brain, blood from the small intestine goes first to the liver, which acts toward drugs as the bouncer at the nightclub door acts toward undesirable customers. One of the liver's functions is to admit absorbed nutritious foodstuffs into the general circulation but to weed out drugs and poisons that entered the small intestine accidentally or through our perverse intentions. The long list of drugs thus weeded out by the liver includes alcohol, cocaine, morphine, nicotine, and tetrahydrocannabinol (the active ingredient of marijuana).

In short, when you swallow a drug, it inevitably ends up in your liver, whose job is to prevent you from doing exactly what you are trying to do: get that drug to your brain. Circumventing that dilemma is the main reason for using any route of drug administration other than the stomach and small intestine—such as the lungs, nose, tongue, mouth, eyes, or rectum. But numerous drugs that you wouldn't want in your lungs or eyes are tolerated by the rectum.

At the risk of belaboring the obvious, I'll conclude by stressing why this piece shouldn't convince you to rush out and give yourself (or ask your beloved to give you) a hallucinogenic enema. Every argument against taking hallucinogenic drugs by any route applies with full force to the enema. Drugs destroy your body slowly if used carefully. They kill you quickly if used carelessly. They cut off your access to all the diverse and persistent pleasures of a normal life, in return for brief flashes of a single sickening pleasure. Added to all those general arguments, drug enemas pose other risks of their own. They are so tricky to administer correctly that they can easily cause severe poisoning or death. Native Americans knew that they had to leave enema administration to an expert elder.

It's ironic that some of the same drugs that Indians learned to handle safely are today causing terrible and widespread problems in our society. While the drug enema is an old tradition in the New World, the groups that indulged in the practice had the good sense to reserve it for rare ritual occasions. The extreme care and relative infrequency (compared with drinking and smoking) with which the custom was practiced by the very people who invented it testifies to their understanding of its dangers.

Jared Diamond is an intestinal physiologist and evolutionary biologist at UCLA. His book Guns, Germs, and Steel: The Fates of Human Societies *won a 1998 Pulitzer Prize.*

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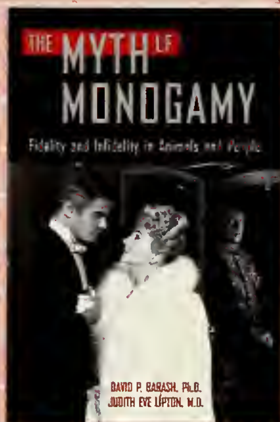

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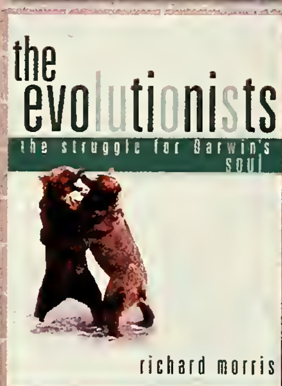

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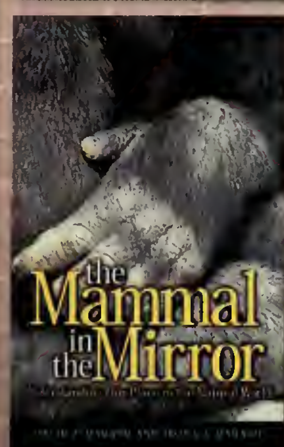

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UNIVERSE

By Any Other Name

When it comes to plain speaking, astrophysicists claim bragging rights.

By Neil deGrasse Tyson

The chief merit of language is clearness, and we know that nothing detracts so much from this as do unfamiliar terms.

—Galen (A.D. 129–ca. 216)

Do you know what term medical doctors have for one of the bones in your big toe? Ungual phalanx of the hallux. Do you know the official term that astrophysicists use for the beginning of the universe? Big bang. Why does it take nine syllables to name a bone in your toe but only two syllables to name the origin of all the space, time, matter, and energy in the cosmos? Something is wrong.

Doctors are not uniquely guilty of sesquipedalian transgressions, but they certainly lead the way. The community of astrophysicists, however, proudly wields simple words, even for our most complex concepts. Not only do our terms typically have few syllables, they also tend to be descriptive and, in some cases, just fun to say. Medicine and astrophysics are probably polar opposites in the name game, with other professions filling in the middle.

Despite the scowls of my geologist colleagues, I have not managed to remember what plagioclase feldspar looks like, and I am still wondering what's so friendly about migmatitic gneiss. Perhaps geologists should pass a law against words of more than eight syllables. That way, I would never have to pronounce "uniformitarianism," whether or not it's an important doctrine.

When ichthyologists go home at night, do they see *Carassius auratus* instead of goldfish swimming in their fishbowls? Can anyone get more obscure than biologists and paleontologists, who reflect for thirteen syllables on whether or not ontogeny recapitulates phylogeny? In such cases, you feel especially ignorant, because you trip over the words just trying to pronounce them. Should I confess to the authorities, here and now, that I have occasionally snorted oxymetazoline hydrochloride? Yes, I inhaled all ten syllables as the active ingredient in my nasal decongestant spray.

And how about those dozen roses I just gave my wife? Do botanists give each other a dozen *Rosa nutkana* instead? One of the best known lines in Shakespeare is the romantic utterance of Juliet, who declared that a rose by any other name would smell as sweet. True, but what she neglected to mention is that a rose by a five-syllable botanical classification scheme rarely makes its way into iambic pentameter.

The parade of extinct species, with names from *Archaeopteryx* to *Zalambdalestes,* would leave most heads spinning, although one of the great mysteries of the universe is how eight-year-old kids seem to have no trouble with the taxonomy of extinct ferocious beasts.

Sociologists, professional educators, and literary critics are just as bad (or perhaps worse) than scientists. Is there some tablet in the sky upon which is inscribed a commandment requiring sociologists to refer to your neighbor as a residential propinquitist? Accuse someone in New York City of being one, and you might suffer a bruised jaw—or would that be a mandibular contusion? When I was a schoolboy, the one-syllable word "test" did the job. Today you can hardly find the term in the discourse of professional educators. A test has become "an assessment instrument." And much as I have tried, I still cannot understand the following randomly chosen passage in the 1991 book *Deconstruction: Theory and Practice,* by Christopher Norris, a British professor of English:

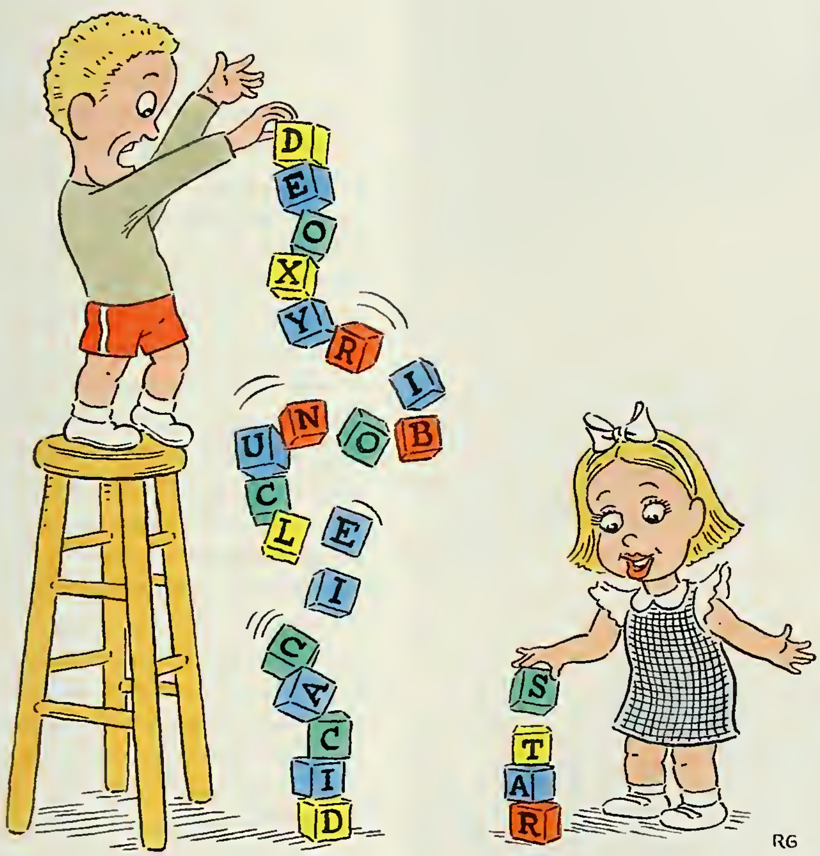
> *But the point of these metaphors is not to reinstate a thematics of presence or expression, as opposed to the* differance *of structural inscription. Rather, it is to demonstrate that structuralism itself arises from the break with an attitude (the phenomenological) it cannot reject but must perpetually put into question.*

Maybe it's not a beginners' book on deconstruction. Maybe beginners' books don't exist on the subject. Or maybe I'm just stupid, and all the people who speak this way are brilliant thinkers. If not, then their work is easier to understand than they let on, and their jargon erects a downright opaque psychological boundary between those who know and those who don't.

The renowned physicist Richard Feynman, in an essay entitled "What Is Science," written for a 1969 issue of *The Physics Teacher,* recalled a childhood conversation with a friend:

> *We were playing in the fields and this boy said to me, "See that bird standing on the stump there? What's the name of it?" I said, "I haven't got the*

slightest idea." He said, "It's a brown-throated thrush. Your father doesn't teach you much about science." I smiled to myself, because my father had already taught me that . . . "even if you know all [the] names for it, you still know nothing about the bird. . . . Now that thrush sings, and teaches its young to fly, and flies so many miles away during the summer across the country" . . . and so forth. There is a difference between the name of the thing and what goes on.



ROBERT GROSSMAN

Feynman's dad was basically right, but if we take his argument to the extreme, we would all stare at each other, mute in the forest. So we obviously need words for things before we can communicate ideas that relate to them. And in the sciences, words for things can be precise, historical, and even illuminating. But I remain intrigued that in social settings such as cocktail parties, you will impress people more with the obscurity of your vocabulary than with your actual command of a body of knowledge.

I submit that the widespread public interest in cosmic discovery, measured by frequency of headlines, may be fueled partly by the transparency of astrophysical jargon. When writing a newspaper article, a journalist can swiftly reach the substance without wasting precious column length introducing and defining terms. Our simple and occasionally fun jargon uncloaks what are truly complex concepts and grants the reporter and the public an opportunity to think about the ideas rather than puzzle over the names of things.

Astrophysicists eschew big words and the general latinization of terms—although I wonder if our vocabulary would be different if Latin were a living, vibrant language. In any case, we simply tell it like it is. We started with the big bang, but let's keep going: What do we officially call big red stars? Red giants. How about big blue stars? Blue giants. Or small white stars? White dwarfs.

How about that official term for spots on the Sun's surface? Sunspots. Or that persistent red spot in Jupiter's atmosphere? Jupiter's Great Red Spot.

Want dark mysteries? We call the early period in the universe—the time before the first stars were born—the dark ages. Ninety percent of all the gravity in the universe comes from a substance that neither emits nor absorbs light in any form. We call the offending stuff dark matter. And the universe is not only expanding but was recently discovered to be accelerating as well, by the action of an unknown energy that fills the vacuum of space. What else could we call it but dark energy?

While we are being dark, let's not forget that there are regions of the universe where the gravitational forces are so strong that if you fell in you would never get out. So strong is the gravity that space and time have curved back on themselves, preventing not only you, but even light, from escaping. I challenge you to invent a better term than black hole.

The way astrophysicists name gas clouds in our own Milky Way galaxy is not fundamentally different from what you did as a kid when you lay on the beach gazing at the puffy cumulus clouds that drifted by. Our list is rich in simple imagery. Want a sampling? We've got the Cat's Eye Nebula, the Crab Nebula, the Dumbbell Nebula, the Eagle Nebula, the Horsehead Nebula, the Lagoon Nebula, the North American Nebula, the Ring Nebula, the Tarantula Nebula, and the Veil Nebula. We even name entire galaxies this way, such as the Pinwheel Galaxy, the Sombrero Galaxy, and the Whirlpool Galaxy. Sure, each of these objects has an official numerical designation in a formally compiled catalog. But in professional research publications and in scientific parlance, the formal designation is not a substitute for the common, descriptive term (when one is available).

Whenever specialized vocabulary is simple and fun, the words can slide into the language of commerce and culture. This fact has placed the names of our most cherished objects and concepts within reach of everyone. The list is long and impressive. Who among you has not sipped Celestial Seasonings tea? Or taken a bath using Moon Glow bath beads? I have yet to taste Kentucky Fried Chicken's recently introduced Big Bang sandwich, but I can imagine that its flavor must be intense.

Even so, no matter how accurate Pulsar brand watches are advertised to be, their timekeeping precision pales in comparison with the original rapidly rotating neutron stars of the same name. Black holes are what people perceive as one-way phenomena, such as paying taxes or feeding the financial needs of teenagers. And no matter how quickly my Quasar brand microwave oven cooks food, the original quasars at the edge of the universe would cook it much, much faster.

Of course, stars twinkled in the sky long before the noun *star* and the verb *star* ever applied to movie actors.

I am too young to have driven Ford's Galaxie 500, a prototype of the land yacht, but my wife's first car was a Chevy Nova. I believe that if General Motors knew that a Nova was a star that had just exploded, they might have reconsidered the name.

Saturn automobiles remain as popular as the planet itself. We know the company is named after the planet and not the god because the company's logo is a tilted, stylized, ringed orb. The real Saturn is light enough for any scoop of it to float on water. I wonder (although don't really wish to test) whether the Saturn car will float, too.

Mercury is an entire division of the Ford Motor Company, while the Mitsubishi Corporation has a car called the Eclipse. And the peculiar connect-the-dots diagram on the back of all Subaru automobiles is a representation of the famous Pleiades star cluster in the constellation Taurus. Indeed, the Japanese call the Pleiades "Subaru."

No doubt the most famous molecule in biology is deoxyribonucleic acid—ten syllables. Even when abbreviated, it still has three syllables: D-N-A. Has anyone adopted this term for anything besides science writing? To sell products? To write a jingle? On hearing it, is anyone driven to compose verse? As of this printing, there are no cars named after latinized biological species or medicinal ingredients.

Of course, we in the astrophysics community are not totally without polysyllabic guilt. In the Germanic tradition of slapping words together to make an even bigger word, some of our terms can make strong men weep. My favorite in this category is magnetohydrodynamics, which is the study of plasmas and their interplay with electromagnetic fields. In this particular case, the subdiscipline happens to be as complicated as the word that describes it.

By the way, we also have some misleading terms—such as planetary nebula, which has nothing whatever to do with planets. William Herschel first observed and described these nebulae in the eighteenth century, with the help of the world's then-largest telescope. The circular fuzzy disks loosely resembled the little circular images of planets he had studied.

We also use the first word in the phrase "amateur astronomer" to mean something different from what you might expect. While you probably wouldn't be drawn to an advertisement for an amateur neurosurgeon or an amateur attorney, you are always in good hands with an amateur astronomer. It's a title worn proudly by those for whom the night sky is a playground of objects and phenomena. Amateur astronomers, as a group, monitor the sky more than anybody else, professionals included. In so doing, they discover and track comets, asteroids, supernovas, variable stars, and all manner of transient cosmic phenomena. They are indispensable to the health of the field.

Astrophysicists also use at least one term that makes chemists cry. We freely describe the thermonuclear fusion of hydrogen in the centers of stars as burning. Since the act of burning is a strictly chemical process, and since what goes on in the center of a star is strictly nuclear, we are guilty as charred.

And we do have one or two tongue twisters. In case you didn't know, Earth, the Moon, and the Sun are in syzygy every time they line up in space. And our official term for the angle between Earth's equator and the plane of Earth's orbit around the Sun is the obliquity of the ecliptic—but we are not proud of this fact.

Among its numerous duties, the International Astronomical Union (IAU), the professional society of the world's astrophysicists, makes the rules of nomenclature. In many cases, however, a naming scheme or term gets established only after it has enjoyed wide use by the profession. Consequently, rulings by the IAU are often the formal recognition of an already existent naming trend. This approach to the jargon of a discipline tends to preserve the history, spontaneity, and novelty in scientific discourse. For these reasons, cosmic discovery will likely remain forever attractive and accessible to the general public and to the creative energies of authors, artists, and producers.

We might therefore credit (in part) the public's vicarious joy in cosmic discovery to the astrophysicist's monosyllabic lexicon—an assortment of terms that by any other names would leave you stalled in the dictionary, more in awe of the words than of the concepts themselves.

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

CELESTIAL EVENTS

Blue Light Specials

Uranus and Neptune are ready for their close-ups—again.

By Richard Panek

IMKE DE PATER; UC BERKELEY

Uranus, as imaged by the Keck II telescope

In January 1986, *Voyager 2* flew near Uranus and found it to be big and blue and featureless. In August 1989, *Voyager 2* swept past Neptune and found it to be big and blue and featureful—roiling with brief, fierce storms. But that was then. Now astronomers are finding that these two planets aren't quite what they seemed at first glance.

Of course, they're both still big—almost identically so. The diameters of Uranus and Neptune at their equators are 31,763 and 30,775 miles, respectively, making them the third and fourth largest planets in the solar system. And they're both still blue, due to the absorption of red light by the methane in their atmospheres. But astronomers already knew that much about Uranus and Neptune before *Voyager 2* was launched in 1977.

Back then, even the most powerful telescopes on Earth couldn't resolve either planet into much more than a small bluish disk. Uranus's orbit takes it anywhere from 19 to 21 astronomical units (AUs) away from Earth, and Neptune's, from 29 to 31 AUs (one AU is equal to the average distance between Earth and the Sun, about 93 million miles). That means they are, respectively, twice and three times as far from Earth as the next farthest planet, Saturn.

Even in the aftermath of *Voyager 2*'s 1986 visit, Uranus still appeared to be a serene gaseous planet. Not until years later did computer enhancements of the data begin to reveal rapidly rotating bands of clouds in the planet's atmosphere—features that subsequent Hubble Space Telescope observations first confirmed and then amplified. Gone was the image of Uranus as a blank blue marble; in its place now churns a turbulent cauldron.

Perceptions of Neptune have recently been undergoing a similar metamorphosis. Just last year, a team of astronomers used the 10-meter Keck II telescope's new adaptive optics system (a technology that greatly compensates for the blurring effects of Earth's atmosphere) to study Neptune's highly volatile atmosphere. Hubble observations had already indicated that massive storms on Neptune might be popping into and out of existence, but this new information has added unprecedented detail. "This shows us how much structure there is in the planet's atmosphere, how dynamic it is—as dynamic as Jupiter's," said the project's lead astronomer. Gone is the initial image of Neptune as merely the more active twin of Uranus; in its place now seethes, well, another Jupiter.

But what's been changing since the *Voyager 2* flyby isn't only the quality of the data. In the case of Uranus, it's the planet itself. Both because Uranus orbits the Sun once every 84 Earth years and because relative to the plane of the solar system it rotates on its side (presumably due to an ancient collision with a massive object), the northern hemisphere of the planet, which is just now coming into view, has been in darkness since the 1960s. In terms of current observational technology, that's nearly forever. Astronomers studying the planet's newly emergent hemisphere have already detected stark distinctions between the clouds there and those in its southern hemisphere—differences in color, brightness, and altitude.

Are these variations seasonal or permanent? Are the clouds in Uranus's northern hemisphere a result of the Sun's warming of the atmospheric gases? Will those clouds, over time, come to resemble their southern hemisphere counterparts? Only a decade ago, the major question underlying all these considerations—just how *un*featureless Uranus really is—would have been nonsensical. Now, thanks to adaptive optics, astronomers will actually be able to observe the planet long enough to find the answer.

You, however, won't—unless you have access to Hubble or Keck II. But you will be able to take advantage of the year's best opportunity for amateurs to observe Uranus and Neptune, both of which will be rising throughout the summer soon after nightfall in the southeastern sky. On July 30, Neptune reaches opposition; at magnitude +7.8, it won't be visible without binoculars, at the very least. Then on August 15, Uranus also reaches opposition; at magnitude +5.7, it might be barely visible, under ideal viewing conditions, with the naked eye. To observe either planet, a good star chart is a must. What you'll see, at best, is the same bluish disk people have always seen—the planetary equivalent of "That was then." But for the first time, you'll also be able to begin filling in the details, and to know "This is now."

Richard Panek is the author of Seeing and Believing: How the Telescope Opened Our Eyes and Minds to the Heavens *(Penguin, 1999).*

THE SKY IN JULY AND AUGUST

By Joe Rao

Mercury is above the east-northeastern horizon at dawn during the first weeks in July. On the 9th, it will reach its greatest western elongation from the Sun, rising about one and a half hours before sunrise. Shining at magnitude +0.5, the innermost planet can be seen (with only slight difficulty) about 14° above the east-northeastern horizon. Mercury and a brighter Jupiter (emerging out of the solar glare) approach each other, with Mercury passing 1.9° below and to the right of the gaseous giant on the 13th. By late August, Mercury moves to the western evening sky and, in contrast with July, has a very poor apparition—its worst in 2001.

Venus rises an hour or more before morning twilight in early July, despite being many weeks past its greatest elongation. Although fading slightly, this lanternlike planet is still a spectacular sight as it lifts up early in the morning in the east-northeast. On the morning of July 13, binoculars trained on Venus will reveal the third-magnitude star Epsilon Tauri, or Ain, just 0.1° from Venus. The following morning, Venus passes 3° north of Aldebaran. On July 15 you'll be able to see both Venus and Saturn within the same field of a low-power telescope. As dawn arrives over North America on July 17, Venus and Saturn shine low in the east near the waning crescent Moon, which creeps closer to the planets as they fade from view in the brightening sky. If you follow the pair with a telescope, picking them up against a clear daytime sky, you'll see the Moon actually pass in front of Venus. The occultation is visible over the whole continent, occurring between 2:30 and 3:30 P.M. in the eastern and central regions, late morning to midday in the west, and midmorning in Hawaii. All during August, Venus hangs at about the same place above the dawn horizon. Early in the month, the planet attains the highest altitude of its current apparition. Jupiter passes nearest to Venus on the mornings of August 5 and 6, and the Moon skims past it on August 16. On the morning of August 26, Venus forms a striking line with Castor and Pollux (above and to the left of the planet).

Mars, although fading rapidly from its peak of brilliance in June, still shines at brighter than -2.0 magnitude through July 11 and remains brighter than Sirius through August 2. By the end of August it dims to -0.9 but still manages to outshine the brightest star of the summer sky—the similarly hued Arcturus—by half a magnitude. Throughout July and August, you'll find Mars glowing in the south-southeast at dusk. The Moon will be nearby on the evenings of July 2 and 30 and August 26 and 27.

Jupiter rises early in July during morning twilight on the east-northeastern horizon. On the morning of the 13th, Mercury is nearby, passing less than 2° to the south. Jupiter is plainly visible on July 18 below and to the left of a slender Moon. In August the planet rises at about 3 A.M. local time on the 1st and at about 1:00 A.M. local time by the 31st. Venus passes by Jupiter on the mornings of August 5 and 6. Next to Venus, Jupiter is the most brilliant predawn "star." If you're outside during morning twilight in August, look east to spot both Jupiter and Venus: the last pair of starry lights to fade before the coming of day. The Moon is not far from Jupiter on August 15.

Saturn is visible in the morning sky during both July and August. Between July 11 and 17, it rises a few hours before sunrise and joins dazzling Venus and the ruddy star Aldebaran to form a trio (all fitting within a 5° circle). On the morning of July 15, Venus can be found just 0.7° south of Saturn. Two mornings later, the waning crescent Moon joins the gathering. In August Saturn rises soon after midnight. The Moon forms a triangle with the planet and Aldebaran on the morning of August 14. The planet's rings are now tipped at 26.2°, and in sunlight they cast a noticeable shadow on the planet, rendering its appearance strikingly 3-D through a telescope.

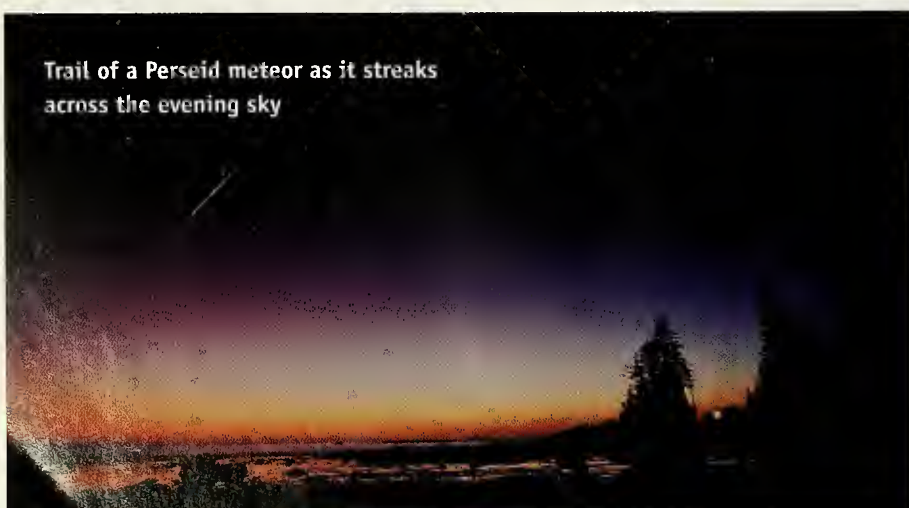
The Moon is full on July 5 at 11:04 A.M., and a partial lunar eclipse, visible in the United States only from the Aleutian Islands and Hawaii, occurs with this full Moon. It begins to enter Earth's umbra at 3:35 A.M. Hawaiian Standard Time (HST); deepest eclipse, with the upper half of the Moon's diameter in shadow, occurs at 4:55 A.M., HST. Last quarter comes on July 13 at 2:45 P.M., new Moon falls on July 20 at 3:44 P.M., and first quarter is on July 27 at 6:08 A.M. Full phase in August occurs on the 4th at 1:56 A.M., last quarter on the 12th at 3:53 A.M., new Moon on the 18th at 10:55 P.M., and first quarter on the 25th at 3:55 P.M.

A planetary lineup from mid-July to mid-August will make it worthwhile getting up about an hour or two before sunrise. Mercury, Jupiter, the Moon, Saturn, and Venus will be hanging low in the eastern sky, forming a striking line best viewed at about 5:00 A.M. on July 18.

Earth is at aphelion—its farthest point from the Sun—94,502,836 miles—at 10 A.M. on July 4.

The Perseid meteor shower will reach its peak on the night of August 11–12. These bright, swift streaks appear to emanate from the vicinity of the constellation Perseus (hence the name Perseid). Unfortunately, the bright Moon is at last quarter and not far from the "shooting stars" during their peak, but a fair number of Perseids may be seen for a few nights before and after the peak.

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


Trail of a Perseid meteor as it streaks across the evening sky

DAVID NUNUK/SPL; PHOTO RESEARCHERS, INC.

IN SUM

Chemical

BEE BOUQUET When a bumblebee finds a nectar-rich flower, it tags the blossom with a scent mark, identifying the flower as being worth a return visit. Since bumblebees are social insects that work for the good of the colony, researchers suspect that individual members of a hive leave marks that help their hivemates find the best blossoms.


MARTIN GARWOOD; NHPA

Solitary bee feeding on nectar

Solitary bees are a different story. Foraging only for her own young, each female is in direct competition with all others of the same species. But Francis Gilbert, of the University of Nottingham, and colleagues have shown that solitary bees also rely on scent markings to identify the best food sources.

Working for six years at study sites in Portugal, the researchers studied females of the solitary bee *Anthophora plumipes* as they foraged for the nectar of honeywort flowers. The team found that, like bumblebees, solitary bees rely on at least two separate components in their scent markings. One is a self-repellent that wears off within about thirty minutes, dissipating as the plant renews its stock of nectar. By the time the flower once again has a full supply, the scent has degraded to the point that the bee is no longer repelled by it. The other component is a short-term attractant, lasting less than three minutes. The scientists suggest that the bee might use this mark if it doesn't extract all the available nectar during an initial visit, facilitating a return within seconds to finish the job. So far, however, it is unclear why a bee doesn't—or can't—remove all

Talk New findings expand our understanding of communication in the animal kingdom.

the nectar the first time it feeds at a blossom.

A. plumipes females appeared to respond differently to different individuals' scent marks. The bee that made the most visits to blossoms in each flower patch—dubbed the major bee—ignored the marks made by others and laid her own mark on top of them. The other bees avoided the flowers she had marked. The researchers thus suspect that the scent marks may also be a way for the dominant female to remind her neighbors she's top bee. ("Individually Recognizable Scent Marks on Flowers Made by a Solitary Bee," *Animal Behaviour* 61:1, 2001)

SAVVY SPIDERS All animals—even predators—have to avoid being eaten. One way to dodge an untimely demise is to gather information about potential predators in advance of an attack.

The wolf spider *Pardosa milvina* does all it can to avoid being swallowed by *Hogna helluo*, a much larger wolf spider that occupies the same habitat. Zoologists at Miami University in Ohio and Susquehanna University in Pennsylvania have recently demonstrated that the smaller spider is able to decode chemical cues left by the larger one, and to change its behavior accordingly.

The researchers divided the larger spiders into two groups. One group was fed only *P. milvina*, the other only crickets. Both groups were then allowed to wander across sheets of filter paper. After removing the predators, the scientists lined one enclosed area with the exposed filter paper (which held traces of *H. helluo*'s silk and excrement) and another with clean paper. The smaller spiders were then released into both areas, and their activity levels were monitored. (The larger spiders usually prey on moving targets; inactivity is thought to be an important way for a prey species to avoid attack.)

Wolf spiders, large and small

ERIC STASHAK; SUSQUEHANNA UNIVERSITY

The spiders placed on the paper with chemical cues from *H. helluo* were much more likely than those placed on clean paper to stop moving altogether. In addition, they reacted more strongly to cues from spiders that had been fed *P. milvina* than to cues from those that had been fed crickets. Detecting such differences is key to assessing danger, since *H. helluo* consistently prefers to attack one type of prey in the wild. (In a previous study, the researchers found that *H. helluo* also reacted to chemical cues, preferring filter paper that had been exposed to whatever it was fed—either the smaller spiders or crickets.)

For the smaller spiders, holding still may be an important way to avoid being eaten, but there are, after all, some costs associated with inactivity—it doesn't allow the smaller spider to do much reproducing or eating of its own. Fortunately, *P. milvina*'s fine-tuned sensing system makes it possible for the species to resort to inactivity only when absolutely necessary. ("Wolf Spider Predator Avoidance Tactics and Survival in the Presence of Diet-Associated Predator Cues [Araneae: Lycosidae]," *Animal Behaviour* 61:1, 2001.)

REPULSIVE NEWTS Both vertebrates and invertebrates use chemical signals—pheromones—to communicate with others of the same species during the mating game. In most species, the pheromones act as attractants and sexual stimulants. Some invertebrates have also been shown to produce repellents that drive away competitors. Now biologists Daesik Park and Catherine Propper, of Northern Arizona University, have found evidence that in at least one vertebrate species—the red-spotted newt *(Notophthalmus viridescens)*—a pheromone produced by courting males repels rivals.

Placing different combinations of males and females in the arms of a Y-shaped maze, Park and Propper introduced a test male into the base of the maze and allowed him to choose, based only on the odor cues he received, which arm of the maze to enter.

The researchers found that the test male was influenced by the concentration of repellent pheromones he encountered and was more likely to approach a lone female than one in the company of males. Males that had been exposed to females were less often approached by the test newt, suggesting that males have to be in the presence of a female to effectively repel a rival.

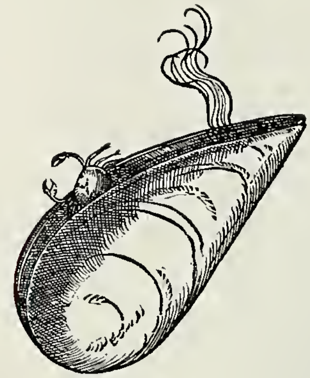
Red-spotted newts

MICHAEL LUSTBADER; PHOTO RESEARCHERS, INC.

The repellent function may benefit all males by allowing the initial suitor to continue his courtship without conflict, while potential rivals channel their energies into finding a solitary female, with whom the chances of success are likely to be greater. ("Repellent Function of Male Pheromones in the Red-Spotted Newt," *Journal of Experimental Zoology* 289, 2001) —*Kirsten L. Weir*

IN THE FIELD

Mussel-Bound Crab



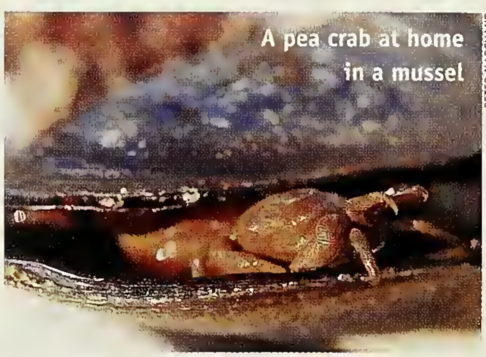
FROM *LIBRI DE PISCIBUS MARINIS*; PHOTO J. BECKETT, AMNH

A naturalist plays hide-and-seek with a tiny crustacean.

By Peter J. Marchand

My search for the elusive pea crab began almost a year ago on the rocky coast of northern California. It was a matter of simple curiosity at first—chasing down yet another fascinating story of animal diversity in the intertidal zone—but the longer it took to find the crab, the more obsessed I became. Before my quest ended, I had crisscrossed the United States twice, talked with fishermen on Cape Cod, recruited the assistance of a diver on Maui, engaged the services of oystermen and a marine biologist at Chesapeake Bay, and even had a few New England chefs looking on my behalf. I was in Rhode Island when I finally laid eyes on a pea crab—on the tailgate of my truck.

Not that the pea crab is rare. One species or another in the genus *Pinnotheres* can be found on both sides of the Atlantic and Pacific Oceans. And they've been the subject of study from the British Isles to Brazil and from California to Taiwan. My difficulty in finding them had to do with their unusual habits. The male, impossibly small and cryptically colored, is skittish; the female lives most of her life out of sight—inside the shells of live mussels, oysters, scallops, and clams and in the tubes of the marine worms known as polychaetes. And like many small animals in ever changing environments, their numbers rise and fall. You might find a crab in eight out of ten shellfish, or you might find none. Everywhere I went, there had been "plenty the week before," according to locals, but none at the moment I was inquiring. I just couldn't hit it right until David Beutel, of the University of Rhode Island's Fisheries Center, put on his boots to help. Wading into the submerged tide pools at Black Point on Rhode Island Sound, he probed among the rocks, plunging his arms into the chilly water to grope for dense clusters of mussels held together with intertwined strands of algae. Soon he emerged with a half-full bucket containing several dozen medium-sized mollusks. I carried the shells over to the back of my truck and went to work with a shucking knife. Within a few minutes I sighted my first pea crab, hunkering in the shadowy interior of a living mussel.



A pea crab at home in a mussel

PETER MARCHAND

Pea crabs are appropriately named, not just for their small size but for the female's resemblance in shape and texture to a slightly flattened pea or bean. Soft and succulent looking, this crab was a female with a caramel brown coloring that matched rather closely the shade of the mussel's flesh (females occupying other shellfish range from white to salmon pink, but whether this coloration is adaptive is unknown). Although the mussel I found it in was less than two inches long, the crab had grown to nearly half an inch, exclusive of its legs, and occupied almost a quarter of the mussel's mantle cavity—not bad, considering the crab's inauspicious start.

All pea crabs begin their lives as free-swimming larvae less than a millimeter long. Males remain mobile throughout their two- to three-year life span and, like most other crabs, eventually develop into hard-shelled adults with prominent eyes and relatively stout chelipeds, or claws. But the males grow to no more than about 3/16 inch wide. Bristles on their second and third pairs of legs serve as an aid in swimming, and their flattened body, considerably thinner than that of the female, enables them to slip freely in and out of the narrow gape of mollusk shells as they shuttle from one temporary home to another. Females, on the other hand, generally find their way into the mantle cavity of a bivalve long before development is complete. There they mature, eventually attaining two or three times the width and thickness of the male but without the male's hard shell or bulbous claws, and with their eyes nearly concealed by a soft carapace. Poor swimmers, they remain within an individual mollusk, picking food particles off the gills or mucus strands of their filter-feeding host.

The freeloading habits of pea crabs are not news. Guillaume Rondelet's 1554 work *Libri de Piscibus Marinis* includes an illustration of a tiny crab, with somewhat exaggerated chelipeds, emerging from a mussel. (This drawing is reproduced at the top of the opposite page.) For most of the four and a half centuries since the publication of this treatise (and even today in some literature), the relationship between crab and mollusk has been considered commensal, with the crab benefiting by the association but neither hurting nor helping its host. The validity of this assumption is being reevaluated, however, and newer evidence suggests a less benign relationship. Compared with its nine-inch, clam-crushing relative the blue crab, this diminutive scavenger would hardly appear threatening, but its constant picking at the host's gills can result in considerable wear and tear over the years, and studies now show that the gill lesions frequently observed in occupied mollusks result in less efficient water filtration by the host. This compromised filtration, coupled with the crab's interception of food, can add up to significant metabolic costs for the host: both lower respiration rates and slower growth. Thus, while the crabs cause no immediately life-threatening damage, the female pea crab—unable to survive outside its host once it becomes established—is by all other measures a true parasite.

A pea crab at large

E.R. DEGGINGER; COLOR PIC, INC.

There may be another reason I failed in my initial attempts to locate this diminutive crab. Pea crabs are not found just anywhere. Whether due to the larvae's deliberate selection of a host or to improved survival under more favorable circumstances, pea crabs are found more often in larger mollusks, which filter a greater volume of seawater. They are also found more commonly in mollusks living beyond the lower tidal zone—that is, in areas where continuous submergence allows the host to remain open and filtering longer. In both cases, the advantage conferred is more food coming through the door. Had I been thinking like *Pinnotheres*, I might have experienced considerably greater success in my search.

Peter Marchand is a visiting scientist at the Carnegie Museum of Natural History's Powdermill Biological Station in Rector, Pennsylvania. *He wishes to thank Susan Geller, Pauline and Mike Severns, Jacques van Montfrans, Tommy Leggett, and David Beutel for going the extra mile to help with his quest.*

Whispers *in the* Canyon

Singing softly, Arizona's blue-throated hummingbirds go on the record.

By Kathryn Rusch

In the mountains of southern Arizona, a creek bubbles down a wooded canyon, heading to the desert a mile below. Painted redstarts hop along the water's edge calling to one another, and acorn woodpeckers screech from high in a giant sycamore tree. Listening carefully to the riparian symphony of birdsong, wind, and water, I begin to pick out some faint, clicky sounds. Then I locate their source. Just ten feet away, perched on a juniper twig, is a blue-throated hummingbird. A male, as evidenced by his iridescent throat patch, is facing the creek but repeatedly turns his head to scan the area. I watch as he lifts his bill slightly and again utters a soft series of whirs and clicks. He never opens his bill, but movements of his throat correlate with the barely audible song. After vocalizing for four seconds, the bird rests momentarily and repeats the song, continuing on and off in this way for about a minute. Then, in typical hummingbird fashion, the blue-throat departs at one notch south of light speed up the creek bed and out of sight. Fortunately, I have managed to catch his "whisper song" on tape.

Since 1995 my fellow ornithologist Millicent (Penny) Ficken and I have roamed the canyons of this region in spring and summer to document the songs of blue-throated hummingbirds. We work at two sites: the American Museum of Natural History's Southwestern Research Station in the Chiricahua Mountains, and Ramsey Canyon in the Huachuca Mountains. The study of birdsong is a rich and growing field. Because of their complex songs and specialized neural pathways for learning them, songbirds, or oscines, have been favored subjects of study among scientists. Over the past decade, however, researchers have begun to focus on the vocalizations of hummingbirds and other nonoscines, which belong to lineages of the avian family tree completely separate from that of the songbirds. Many songbirds, such as American robins and song sparrows, must learn their songs; some ethologists have started to look at the possible role of learning in nonoscines. Other researchers are investigating birds' vocal apparatus and areas of the brain involved in learning, to discover how song learning evolved separately in different avian lineages (see "Findings," October 2000). While some species of hummingbirds are known to sing—and Anna's, green violet-ear, and sparkling violet-ear hummingbirds appear to learn—we found that very little had been written about the sounds of blue-throated hummingbirds. Penny and I wanted to record the blue-throats in their natural habitat, analyze their vocalizations, and determine when and how the males of the species use the sounds to communicate. Along the way, we found out that the males were not the only blue-throated hummingbirds with something to say.

DAVID MUENCH

A blue-throated hummingbird probes a penstemon flower for nectar, below. Populations of the birds spend summer along creeks and in wooded canyons of the Chiricahua Mountains of Arizona, opposite.

STEVE AULSTON

Blue-throated hummingbirds inhabit mountainous areas from southern Mexico to the southwestern United States. The blue-throats we study migrate relatively short distances from Mexico and begin to appear on their breeding grounds in southern Arizona in spring. Blue-throats hover at flowers such as bearded penstemon, mountain sage, and various types of agave to drink nectar, but their diet consists mainly of insects and spiders gleaned from vegetation and insects snatched midair while both birds and prey are on the wing. At times of the day when insects are less active, the birds will raid spider webs for ensnared arthropods. Like many other hummingbirds, male blue-throats defend a territory and fiercely repel intruders, particularly other males, by engaging in high-speed chases and physical combat that includes stabbing or "sword fighting" with their bills. In the populations we study, courtship may take place anytime from late April through early August. Males usually mate with more than one female and are totally uninvolved in the parental care of their offspring. Female blue-throats build their nests and care for the one or two young as a solo effort.

Small and speedy, hummingbirds do not lend themselves to easy observation, much less recording sessions. Although we follow color-coded birds marked with a small dot of nonpermanent paint, and we keep watch at feeders as well as creek sides, the blue-throats are often no more than beautiful colors in motion. But we do have advantages: blue-throats happen to be the biggest of the hummingbirds that breed in North America, and the males can often be found patrolling their linear territories along canyon creeks and singing from preferred perches.

Although it is a member of the largest hummingbird species to breed in the United States, a blue-throated hummingbird is dwarfed by the multiple blossoms of an agave flower cluster.


TOM VEZO

After recording our birds in the field, we head to the laboratory to begin the exacting task of turning our audio information into visual printouts. Because these vocalizations are mere whispers, many notes are emitted within seconds, and listening to the tapes does not enable us to discern all the components. We use a computer program to convert the tapes to a visual display called a sonogram, which, with a little practice, can easily be "read." The sonogram not only can reveal notes but can also show how groups of notes are repeated in a songlike pattern. After amassing a collection of sonograms, scientists can build a dictionary of sounds and search for patterns.

Our first step was to determine whether blue-throats do indeed produce a complex song. After generating many sonograms of our very first tape, we were surprised to find a high degree of complexity and variety in the notes of this particular male's vocalizations. Our second step was to collect and analyze enough songs to determine whether all our male blue-throats sang a stereotyped song or whether the songs of individual birds varied substantially. Some species of songbirds have a simple repertoire. White-crowned sparrows, for example, all sing one basic song; at the other extreme are northern mockingbirds, which have rich repertoires. Each mockingbird compiles its own songbook by mimicking sounds—from other birds' songs to sirens—in its particular environment.

Males often sing before or after aggressive displays, fights, and chases. Females approach only singing males, never silent ones.

Our subsequent recordings of other blue-throats confirmed that notes were grouped. The groups were consistent both within an individual's vocalizations and across the population. Male blue-throats, then, do not appear to have distinct individual repertoires but sing the same tune. However, within the groups of notes were many different single notes that clearly demonstrated a large and complex acoustic dictionary. The pitch of the notes ranges from two to fourteen kilohertz—a wide spread of frequencies compared with those of songbirds, whose notes typically vary from about two to seven kilohertz. In addition, we found that the males did not randomly combine these groups of notes into songs but consistently put them in a particular order, which we refer to as syntax. We labeled the five groups we identified A, B, C, D, and E.

The peaks of the Huachuca and Chiricahua ranges can be considered "sky islands" rising out of a sea of desert. This geographical isolation allowed us to compare the songs of blue-throats living in ranges about one hundred miles apart. We found that blue-throated hummingbirds in both mountain ranges share the A, B, C, D, and E groups as well as the same syntax. When we fine-tuned our analysis, however, we found consistent differences in the opening, or A, group of notes. Songs from the Chiricahua Mountains had a harsh tone absent in songs from the Huachucas. Other minor tonal idiosyncrasies appeared as well. So whisper songs do show slight geographical distinctions.

The songs we recorded during spring and early summer—the beginning of the breeding season—were more succinct and defined than the song of a male we recorded in August. That bird's song seemed to be less developed than the others. We believe this may have been due to his being a young bird. Could he have been "practicing" the song? Some birds, such as chickens, ducks, and gulls, are born knowing their vocalizations, while many songbirds and a few species of hummingbirds have a song that develops over time. The presence of poorly formed notes produced during a critical period when young birds practice singing may be a clue that learning is in progress. During this phase, vocalizations may become more distinct and timing may improve as the bird matures. Our taped song of the young male suggests that whisper songs may not be entirely preprogrammed and that learning may play a role in this species also.

Male songbirds may sing for four main reasons: to defend their territory, to attract a mate, to maintain the bond with the mate, and to induce egg laying in the female. To find out just when and why our non-songbirds were singing, we listened to and carefully watched blue-throats throughout their breeding cycles. We found that songs are sung in a variety of contexts—after foraging, before and after fights and chases, after preening, and after prolonged rest periods. Following spring migration, males arrive in the wooded canyons and begin staking out creek-side territories. Singing tends to be more frequent at this time and often precedes or follows fights, chases, and aggressive displays. One male, for example, would sing from a hidden perch in a dense juniper. If another male approached, the first would stop singing and chase the intruder, then promptly return to the perch and resume singing. One of our favorite singing males would perch on a laundry line at the midway point between the creek and a feeder. I recorded many of the great bouts of song he delivered in between his aggressive feeder patrols. We also noticed that females would approach only singing males, never silent ones. Perhaps the longer songs and longer bouts of singing

SID AND SHIRLEY RUCKER; DRK PHOTO

Blue-throated hummingbirds enjoy nectar, but their main course usually consists of insects and spiders.

we heard when sexual activity was at its peak give some indication to females that the singer is fit and healthy and will pass on quality genes.

Blue-throats also voice a second type of sound that is simple, loud, and given from an exposed perch at dawn and dusk. It sounds like a series of "chips" and may be delivered in a single continuous bout lasting ten minutes or longer. These high-amplitude vocalizations, so different from the whispered quality of the song, may function as a long-distance advertisement of territory, carrying quite well above the din at the water's edge. The "chips" may correspond to the loud advertisement calls of songbirds, while blue-throat songs, like those of songbirds, serve to attract females and warn other males to stay away.

So why whisper, rather than belt out, a song? The answer may relate to habitat and to typical hummingbird displays. Like other birds, hummingbirds communicate through both auditory and visual signals. Many North American species of hummingbirds engage in dynamic aerial displays that play a role in territoriality and courtship. Shuttle flights—close-range, back-and-forth flights—are common and usually directed at a perched bird. Allen's hummingbird performs dive displays from heights of well over a hundred feet and at speeds of up to sixty miles per hour, while black-chinned, broad-tailed, Costa's, and others perform their own signature dive displays. These species, which do not sing complex songs, live in more open and variable habitats than blue-throats. Our whispering blue-throats do not engage in dives and shuttle flights. They live and reproduce in specialized habitats—deciduous streamside mountain canyons. Similarly, the white-eared hummingbird, which sings a complex song and does not display aerially, lives in a specific habitat of scrubby undergrowth in mountain woodlands.

In the case of the blue-throat, the water's edge can be a thick, verdant mix of shrubs and trees. The whisper songs may serve for close-range communication in dense creek-side habitats, where aerial maneuvers would be difficult to perform or hard for other birds to see. The sound of running water is a constant in the blue-throat's breeding habitat. Water sound frequencies are concentrated below 1 kilohertz, whereas the whisper song of blue-throats is concentrated at higher frequencies. The song also includes elements that seem to help it stand out against the sound of a gurgling creek. Studies of birds living near torrents in the Himalaya have shown that high-pitched songs are common against such a background of steady sound.

A male blue-throated hummingbird shows off his iridescent blue gorget and bright white tail highlights, below. Opposite: During the breeding season, males often patrol a linear territory along mountain streams and creeks.

BOB AND CLARA CALHOUN/CALHO: BRUCE COLEMAN INC.

DAVID MUENCH

Female song is rare in songbirds from temperate regions of the world and has not been reported in other hummingbirds. We found that during a brief interlude in the breeding cycle, female blue-throated hummingbirds produce their own complex whisper song, different from that of males. The territorial males are combative, quick to chase one another to acquire or defend nectar and other food sources, such as a succulent patch of penstemon in full bloom. If a female intrudes on a male's flower patch he will chase her away, but with less intensity. During the courtship period, the urgency to mate overcomes aggressiveness. Both male and female blue-throats use an array of sounds and postures to solicit company. Typically, a male will sing and a female ready to mate will approach, perch next to him, and join him in vocalizing. Although their songs are different, they overlap completely, an unusual phenomenon in the realm of avian communication.

Typically, a male will sing and a female ready to mate will approach, perch next to him, and join him in vocalizing.

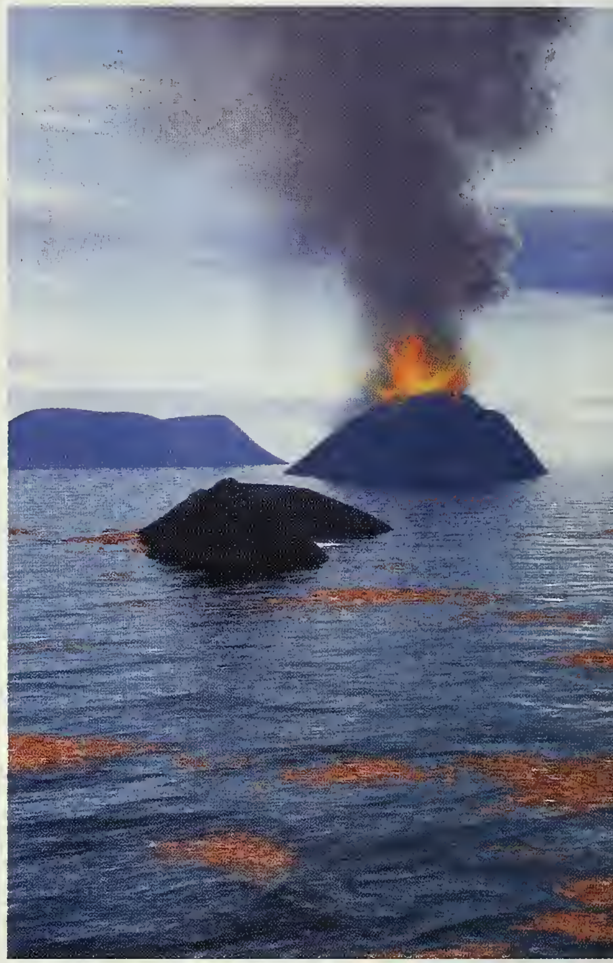
A female's song may indicate to a male that she is a potential mate and may help defuse his aggressiveness. Just prior to mating, the female constructs a tiny cup nest of moss, lichens, and the silk of spiders' webs. She then leaves the nest area in search of a male. During one to several days of whispering together, an unusually drawn out period of time for hummingbird sexual activity, the next generation is conceived. (In the few copulations we observed, the males also uttered a fragment of whisper song prior to copulation.) Our experiments have shown that the songs of female blue-throats do not travel very far through the environmental backdrop of thick vegetation, so these communications are up close and personal.

After about eighteen days' incubation, one or two chicks will hatch, fledge, and begin to whisper the blue-throat song. By late summer, the birds' breeding season, and our field season, will have wound down. The blue-throats, including the new generation, will head south to the mountains of Mexico, while Penny and I migrate back to Wisconsin. There, during the long winter, we will listen to our recordings of their song and plan for our rendezvous next spring. □

FEELING the *BURN*

Can plants and animals (including human beings) cope with increased exposure to the sun's ultraviolet rays?

By Jay Withgott

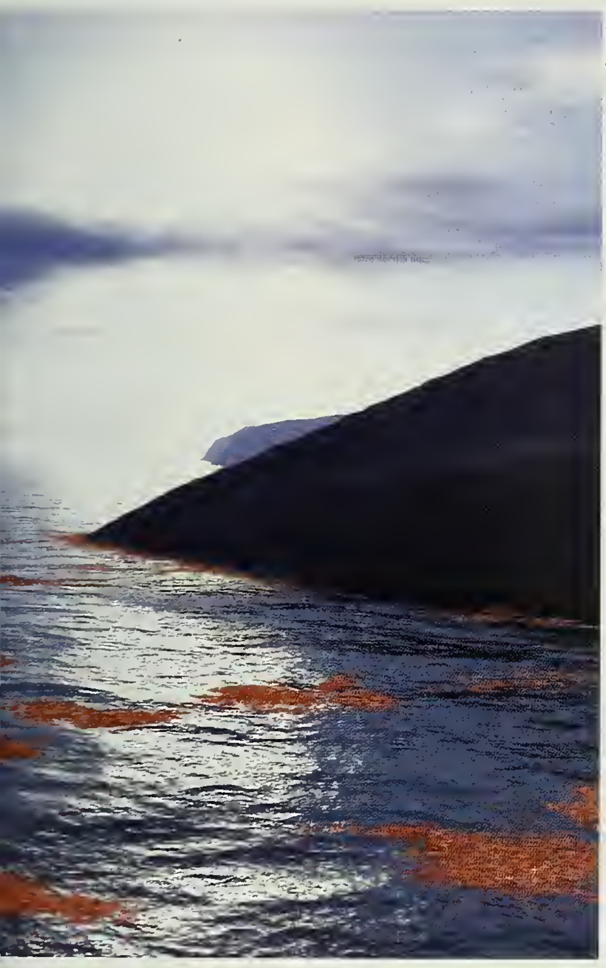


A shaft of sunlight is a double-edged sword. The sun powers life on earth, but its ultraviolet radiation—capable of bending DNA, RNA, and protein molecules into harmful shapes—poses a threat to life. We may love soaking up the rays, yet we also know enough to don hats, slather on sunscreen lotions, or head indoors to reduce the risk of skin cancer. Now that depletion of the ozone layer allows more ultraviolet light to reach us, we humans are learning to take extra precautions. But what about all the other organisms in the world, including plants, which can't retreat into the shade? Can they cope with increased exposure to ultraviolet light?

As it happens, this is not a new challenge. Two billion years ago, when life inhabited only the seas, relatively little oxygen and ozone circulated in the atmosphere. These gases began to accumulate only when organisms capable of photosynthesis evolved. The first such organisms were the one-celled cyanobacteria (and members of this group are still with us today). They churned out oxygen (O_2). Ozone (O_3) was created when ultraviolet light bombarded oxygen molecules and knocked some of them apart, allowing lone oxygen atoms to latch onto other oxygen molecules. Eventually a thin layer of ozone formed in the stratosphere.

The ozone layer resists penetration by ultraviolet light; hence the alarm generated by the ozone hole over Antarctica. This calamity is apparently the result of human pollution of the atmosphere. Such depletions may have been "geologically quite common," however, suggests Charles Cockell, of the British Antarctic Survey. He reasons that comet or meteorite impacts, intense volcanism, and nearby supernovas—catastrophic events capable of causing mass extinctions such as those evident in the fossil record—could have led to massive ozone loss. The climatic "winter" believed to have been triggered by such catastrophes, Cockell argues, would often have been followed by an "ultraviolet spring," which could have helped finish off organisms under stress that survived the initial event.

Extraordinary episodes apart, the ozone layer has never completely sheltered life-forms from ultraviolet light, so organisms have evolved ways to reduce the damaging effects of exposure. Lynn



RON MILLER

Earth two billion years ago, as envisioned in an artist's rendering: The land had yet to be colonized, and the oceans contained only microscopic organisms, among them the cyanobacteria, which formed mats both on the water's surface and in intertidal zones. Pioneers in photosynthesis, cyanobacteria were responsible for adding oxygen—and ultimately ozone—to the mix of atmospheric gases.

Rothschild, of NASA's Ames Research Center, suggests we may discover that ultraviolet radiation played a creative role in several evolutionary milestones. She speculates that it spurred the appearance of the first eukaryotes (organisms in which the cell has a defined nucleus), prompted organisms from the sea to colonize the land, and helped drive the evolution of DNA repair processes that may underlie the origin of sexual reproduction.

Ultraviolet light (UV) is part of the spectrum of electromagnetic radiation with wavelengths too short to be perceived by human vision (X rays and gamma rays have still shorter wavelengths). Biologists divide it into three types, based on the radiation's biological effects. A great deal of UV-A, with wave lengths of 400–315 nm (nanometers, or billionths of a meter), reaches the earth's surface, but it poses little danger to life. UV-B (315–280 nm) causes biological damage and reaches the surface in varying amounts (1 to 10 percent gets through the atmosphere). UV-C (280–100 nm) is the most damaging of all but fails to penetrate the upper atmosphere even where the ozone layer is weakened. Thus biologists, as well as knowledgeable sunbathers, focus their attention on UV-B.

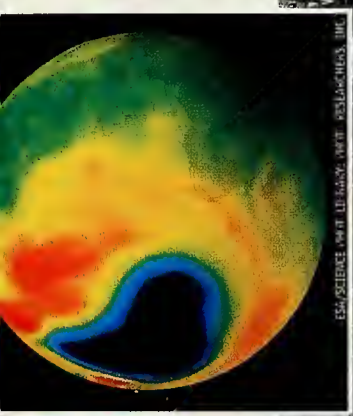
Three decades ago, research on the biological effects of ultraviolet light was stimulated by sugges-

Surges in ultraviolet radiation may have had a role in mass extinctions.

tions that supersonic transport aircraft might destroy the ozone layer. The discovery of the Antarctic ozone hole, however, was the real wake-up call. Many scientists warned that increased UV-B levels were not only a threat to species but might also disrupt ecosystems. One report on phytoplankton (algae and other drifting plant life) in Antarctic waters showed a 6 to 12 percent decrease in their productivity—that is, conversion of energy into biological mass through photosynthesis. This boded ill, because phytoplankton are considered the base of the marine food web, ultimately supporting such high-level consumers as fish, squid, and whales.

Fortunately, a few scientists had been laying the groundwork for studies on the biological impact of ultraviolet radiation. One was Martyn Caldwell, now at Utah State University, who as a graduate student back in the 1960s elected to study alpine plants and ultraviolet radiation. He and other early researchers investigated UV-B's potential consequences for plants and also how organisms were

Antarctica is home to only two flowering plants, pearlwort (inset, top right) and hairgrass (bottom right). Both species have had to compensate for the recent depletion—due to pollutants such as chlorofluorocarbons (CFCs)—of stratospheric ozone, which shields the earth from ultraviolet radiation.



Above: The ozone hole over Antarctica was mapped by satellite in October 1995; black indicates the lowest ozone concentration, blue to green indicates more, and red to yellow, the most.

coping with ultraviolet light. Come the ozone-hole scare, researchers hit the ground running, measuring ultraviolet light's effects on a range of species through laboratory and field experiments that either increased or filtered out UV-B.

In Antarctica, marine biologists measured productivity in the lush "meadows" of phytoplankton at sea, while other biologists, such as Thomas (Tad) Day, of Arizona State University, Tempe, examined plants on dry land. Botanical identification is child's play on the Antarctic continent, which has only two species of flowering plants—a tiny grass and a pincushion-shaped plant that in the harsh climate takes half a century to reach the size of a softball. Day has found that under increased UV exposure, these plants produce smaller, thicker leaves and stock them with extra photosynthetic pigments and other chemicals. For every unit of surface area, says Day, "your construction costs are higher," and these costs may accumulate over time. In a four-year experiment, Day found that the plants were more adversely affected each year.

At the other end of the world, in Sweden, researchers at the Abisko Scientific Research Station pioneered the study of UV effects near the Arctic Circle. Their field experiments have shown that UV exposure can reduce nitrogen fixation (the incorporation of atmospheric nitrogen into ammonia), a process that makes nitrogen organically accessible. They also found that such exposure can

GARY BRAASCH

GARY BRAASCH

GARY BRAASCH

make shrubs more vulnerable to early frosts and that it has mixed effects on plant-litter decomposition (UV-B breaks down litter photochemically, but it also kills bacteria and fungi that aid decomposition). Unlike the Antarctic researchers, however, the Abisko scientists found that some plants they observed did acclimatize to increased UV exposure.

Other scientists were finding that UV-B stimulates the movement of transposons (sequences of nucleotides that can change position on a chromosome) within plant genomes. For example, by irradiating maize pollen, Stanford University's Virginia Walbot induced rampant relocation of these "jumping genes." This type of genetic shuffling may have unpredictable, often deleterious effects.

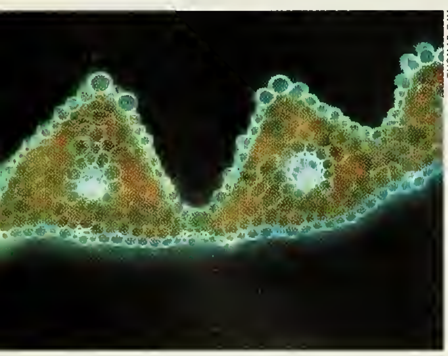
Meanwhile, researchers studying UV exposure in animals were learning that it causes everything from developmental problems in fish and retinal damage in frogs to outright death in zooplankton (drifting marine animals, usually of microscopic size). Ultraviolet light has been implicated as one cause of a global decline in amphibians and might also play a role in declines observed in many salmon populations around the world.

Plants have chemical sunscreens that intercept ultraviolet light.

As they tabulate the effects of UV exposure, scientists have also learned more about the defenses that organisms erect against ultraviolet light. Many have chemical compounds that intercept incoming radiation before it reaches cell nuclei. In plants, flavonoids and other phenolic compounds (pigments that in many cases color plant parts) absorb UV-B. In many animals, pigments such as melanin serve to block ultraviolet light; a number of amphibians, for instance, produce eggs equipped with melanin. And in many microorganisms as well as in larger creatures, chemicals called mycosporine-like amino acids (MAAs) also play a role as natural sunscreens.

Animals cannot synthesize MAAs but have found ways to obtain them from the plants, fungi, and microbes that can. J. Malcolm Shick, of the University of Maine, and his colleagues have found that corals acquire MAAs from the one-celled dinoflagellates that live inside them as mutualists, swapping food and sunscreens for a place to live. They've also shown that sea urchins and sea cucumbers obtain MAAs by eating algae and cyanobacteria. Deneb Karentz, of the University of San Francisco, has determined that the urchins concentrate these MAAs in their eggs; because the eggs are released into surface waters, they need the protection more than the bottom-hugging adults do, she says.

A cross section of an Antarctic hairgrass leaf—photographed with a technique that causes its normally colorless sunscreen compounds to fluoresce blue-green—shows that the compounds are concentrated in the outer layer of cells. These sunscreens protect inner tissue that performs photosynthesis; the chlorophyll in this tissue glows red.



THOMAS DAY

Often, exposure to sunlight stimulates production of these radiation-intercepting compounds. Extra melanin is deployed in human skin exposed to the sun; this protective response of tanning also occurs in some other mammals and even in some sharks. Production of MAAs and flavonoids may require exposure to UV-A light. But biologists don't know whether organisms evolved the capacity to produce these kinds of chemicals specifically in response to the hazards of ultraviolet radiation. Plant phenolic compounds, for example, play other roles, such as staving off insect attacks. MAAs, by contrast, are not known to serve any other function.

Some ultraviolet radiation is bound to sneak past even the best sunscreens, however. The task of repairing the DNA damage is the responsibility of enzymes—such as photolyase, which is found in nearly all organisms. The chemical armies within plants and animals have to fight on another front, too, for ultraviolet light also releases free radicals, which oxidize many biological molecules, including DNA. In plants, carotenoid pigments such as anthocyanins often help tackle these aggressors.

Organisms vary in their defensive strategies. The microscopic invertebrates known as rotifers, for instance, load up with sunscreens but do little repair, whereas fish eggs and larvae have very high repair rates. One mundane yet effective defense is physical protection: fur, feathers, shells, and scales. Tunicates (sea squirts and similar small marine chordates) add layers of extra cells around their eggs and embryos, Stanford's David Epel has found. Some amphibians and fish lay eggs in clusters, with the outer ones protecting the inner ones. Adolfo Marco, of Seville's Doñana Biological Station, and his colleagues have studied a salamander that wraps its eggs in leaves. And ancient cyanobacteria often built up layered structures known as stromatolites—as do their modern descendants—in which the individuals on top bear the brunt of solar radiation. Although some of these protective measures may have evolved in response to other environmental factors, they also serve as effective sun shields.

Of course, mobile organisms can simply move out of the way of ultraviolet light by seeking shady habitats or by becoming nocturnal. In the daytime, many planktonic organisms, including tiny aquatic crustaceans called *Daphnia*, move downward in the water to depths not reached by most ultraviolet light. They then move upward at night. Yellow perch, which normally lay their eggs in shallows, seek deeper water when exposure to ultraviolet light becomes intense. Many marine invertebrates spawn at night, when their delicate eggs and sperm will not be scorched by ultraviolet light. Again, it is difficult to determine whether or not these various kinds of behavior evolved primarily because they protect against ultraviolet light.

Given all this, one might expect to find a correlation between the amount of ultraviolet radiation to which a particular kind of organism is exposed and its defense capabilities. Most biologists hesitate to declare that such a tight pattern exists, but some findings are suggestive. Comparing various frog, toad, and salamander species, Oregon State University's Andrew Blaustein has found that those species whose eggs are normally subject to the highest UV exposure show the greatest photolyase activity. Martyn Caldwell, surveying across latitudinal and altitudinal gradients from Alaska to the equatorial Andes, discovered that plants tend to filter out ultraviolet light most in low latitudes and high altitudes, where it is most intense. Karentz has found that sea urchins living in intertidal zones have higher MAA levels than those inhabiting deeper water—a pattern that Shick and others have also detected with corals.

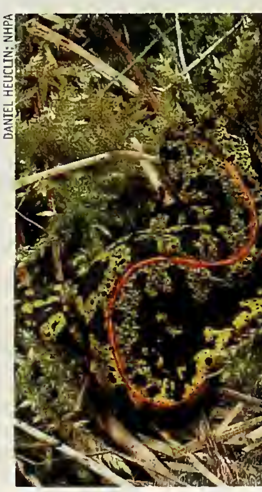
Many sea animals spawn at night, when eggs and sperm can't be scorched.

The correlation closest to home, though, concerns differences in human skin coloration, a phenomenon whose evolutionary significance has long been debated. Last year, anthropologists Nina Jablonski and George Chaplin, of the California Academy of Sciences, created a stir when they published an exhaustive account showing that indigenous human skin coloration varies across the globe in relation to UV-B intensity, as determined by NASA's measurements of the variation in ultraviolet radiation reaching different areas of the earth's surface. They also offered an explanation: in equatorial climes, the melanin in darkly pigmented skin protects against damage, while in regions closer to the Poles, which receive less sunlight, melanin has been reduced, assuring the penetration of sufficient light for vitamin D synthesis. They further maintain that equatorial peoples did not evolve dark skin because it affords protection against skin cancer, since cancer does not usually kill people during their reproductive years. Rather, they argue, the chief threat of ultraviolet radiation is destruction of folate, a metabolite essential for human embryonic development; another very serious threat is damage to sweat glands, which are so essential for thermoregulation in humans.

From melanin to photolyase, the same defense strategies are found in many different species, suggesting that these defenses originated in distant ancestors many millions—even billions—of years ago. Ancient cyanobacteria certainly succeeded in surviving UV exposure somehow; modern cyanobacteria show substantial levels of MAAs and other sunscreens. "The thing that is striking to me is the extent to which many organisms have already addressed the UV issue," comments Lehigh University's Craig Williamson.

GARY MESZAROS/MESZA; BRUCE COLEMAN, INC.

Left: Eggs of the American toad contain melanin, which helps protect them from overexposure to ultraviolet light. Southern Europe's marbled newt, below, wraps its eggs in leaves. Experiments have shown that this practice helps the eggs survive UV exposure; it may also protect them from other hazards, such as predators.



DANIEL HEUCLIN; NHPA

Does that mean we humans should worry only about our own exposure and let the rest of nature take care of itself? Well, not exactly. We must also be concerned about the possible loss of other species and the condition of the biosphere on which we depend. Thankfully, the worst-case scenarios envisioned a decade ago—such as the collapse of the Antarctic food web—have not come to pass. But a slew of studies have shown how the impact of ultraviolet light extends beyond individual organisms, altering the balance of species in habitats and ecosystems.

Much of this work was inspired by a 1994 study by Max Bothwell and his students Darren Sherbot and Colleen Pollock, of Environment Canada. They demonstrated that, unexpectedly, stream algae benefited overall from ultraviolet light; the radiation hurt insect larvae that fed on the algae more than it hurt the algae themselves. In ecology, the enemy of your enemy can be your friend.

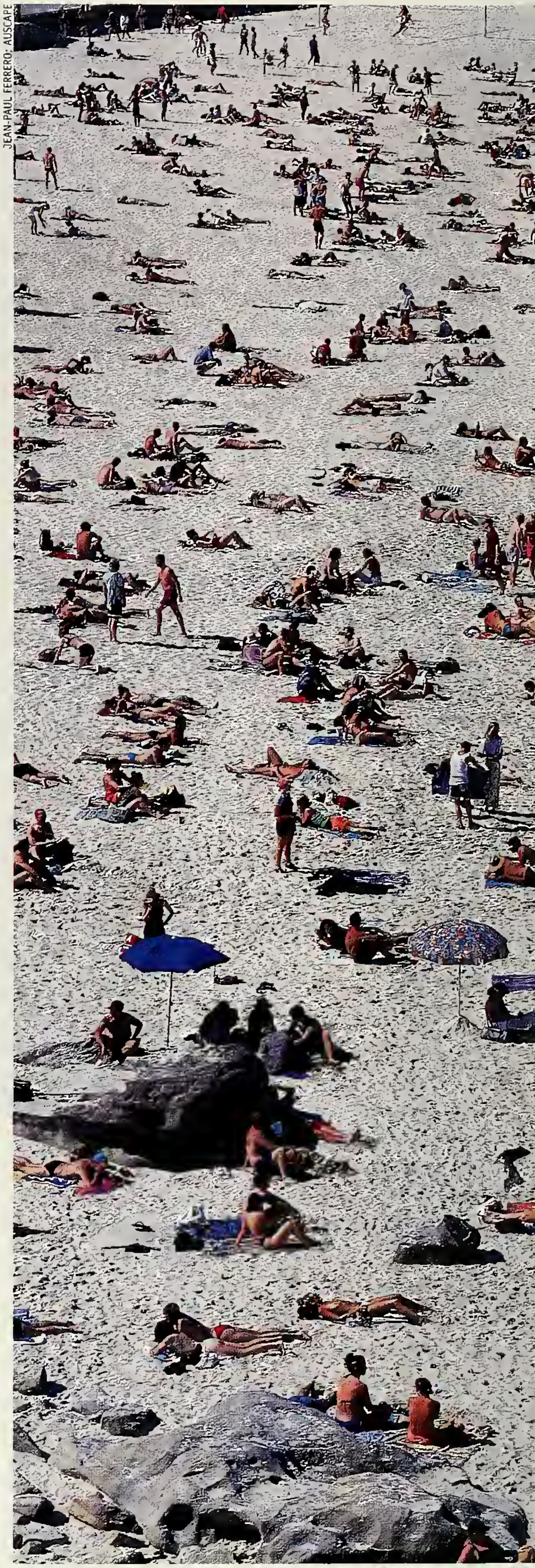
"When you get into the ecosystem-level responses, things get interesting," says Nigel Paul, of Lancaster University. "They're more complex and less predictable." Paul has found that with increased UV exposure, pea plants become more resistant to insect pests—because the leaves suffer a decrease in nitrogen content, making them less nutritious and less attractive, and because production of phenolic compounds increases, also discouraging insect appetites. Similarly, Caldwell's group, working in southern Argentina, has determined that ultraviolet light reduces insects' taste for plants, perhaps by causing an increase in phenolic compounds.

In contrast, researchers at Sweden's Abisko station have found that increased UV exposure appears to threaten trees in northern forests. While mountain birch produced sunscreens that made its foliage hard to digest for caterpillars of the autumn moth, the caterpillars simply ate more leaves to compensate for their lowered nutrition. In addition, ultraviolet light seemed to make the caterpillars better able to fight off harm from the larvae of parasitic wasps, which normally help keep the caterpillar population in check.

Folate, crucial to a human embryo's development, is destroyed by UV-B.

Large-scale ecological effects are hard to predict not only because they involve multiple species but also because ultraviolet light may interact with other factors. Global warming and acid rain, for instance, reduce the amounts of organic matter in Canadian lakes, allowing ultraviolet light to penetrate the water more deeply. Joseph Kiesecker, of Pennsylvania State University, Blaustein, and Lisa Belden, of Oregon State University, have shown that intensified El Niño cycles periodically lower water levels in lakes and ponds, exposing amphibian eggs to more ultraviolet light and thereby promoting their fatal infection by fungal pathogens. The likelihood of such unanticipated synergistic effects is one reason researchers urge us to remain concerned about ozone depletion.

And although the impacts detected so far do not seem drastic, we may be unaware that profound changes have already occurred. Karentz points out that Antarctic phytoplankton are generally single-celled organisms with life spans of hours to days. "Anything that could not have survived those first few ozone-hole events is gone now," she says. Caldwell echoes her concern: "Maybe we're looking at a system that's already been altered, and no one studied it previously to have a before-and-after comparison. Perhaps we're just too late." □



JEAN-PAUL FERRERO; AUSCAPE

GWEN GOODMAN-LOWE

On Bondi Beach in Sydney, Australia, right, sunbathers cultivate their melanin, whose distribution and quantity in the skin changes with exposure to ultraviolet light. Variations in human skin color and in the tanning response probably result from the evolution of ancestral populations at different latitudes and under different climatic conditions. Below: Baby hammerhead sharks raised in a shallow seawater pond in Hawaii exhibit tanning. The shark at left was sheltered from ultraviolet rays.

Besides sipping flower nectar, these flighty insects dine on sweat, tears, and slug slime.

Most people associate butterflies with flowers. Flight requires a great expenditure of energy, and these insects get most of the calories they need to control their wing muscles from the sugar in flower nectar. The best flowers for butterflies produce nectar with a 20 to 25 percent sugar content and store it in chambers that can be easily penetrated by the insect's uncoiled proboscis. Suitable blossoms also present a "landing pad" on which the butterfly can alight. Among the favorites are asters and daisies, milkweeds, mustards, mints, peas, and vervains.

While flower nectar forms the bulk of most butterflies' diets, these insects actively pursue many other kinds of food (some species do not utilize nectar at all). In addition to finding the sugars, salts, nitrogen, and amino acids they need to survive, they must also consume certain chemicals used for making sex attractants. Tree sap, wet soil, flower pollen, and dead plants are part of the motley assortment of foods commonly sought by butterflies, but the full list is far longer. Butterflies are supreme opportunists, and their expanded menu may also include rotting fruits, vegetables, and mushrooms, as well as carrion, owl pellets, mammal dung, urine, bird droppings, slug slime, tears, sweat, and other animal secretions. These items do not readily come to mind when we think of colorful, frolicking butterflies, yet they are common alternatives to flower nectar.

Butterflies seek out such fare to obtain additional compounds they need to function as adults; the plants they ate when they were caterpillars had low levels of some crucial compounds. For example, plant tissues have relatively little salt, which is essential for all animals. Like deer and other creatures that eat only plants, butterflies must find salt in other places, such as natural mineral deposits. Similarly, most plants contain little nitrogen, so the caterpillars that feed on them—and the adult butterflies those larvae become—operate on a nitrogen deficit. Male and female butterflies, however, use different sources to correct these deficits.

Butterflies, like many other animals, have evolved the practice of providing "nuptial gifts." During copulation, the male transfers a spermatophore—a packet of nutrients, salts, and sperm—to the female. This is no small gift. A spermatophore can weigh as much as half the male butterfly's own weight, and the female may depend on it for the materials necessary to provision her eggs. Consequently, she can save the time she would otherwise spend searching for these compounds and concentrate her efforts on locating host plants for her eggs.

The male, on the other hand, must seek out sources of the chemical compounds essential to the nuptial gift, so he directs his activities in different ways and to different places than the female does. This partly explains why males constitute the vast majority of butterflies clustering at salty or urine-soaked ground, colloquially known as puddle clubs. Urine is easy to find by its strong odor—and it's a veritable cocktail of nitrogenous waste, amino acids, salts, and excreted sugars. To an unmated male butterfly, puddle clubs are the equivalent of fine dining. And if a puddle gets a four-star rating, feces garner twice that, and carrion even more. □

BUTTERFLY BUFFET

By Phil Schappert

Male queen butterflies (*Danaus gilippus*) compete for access to the dry head of a flossflower in southern Texas. Having moistened the flower's surface with regurgitated fluids, they can imbibe dissolved chemicals, which they use for making sex pheromones.

DURRELL D. KAPAN

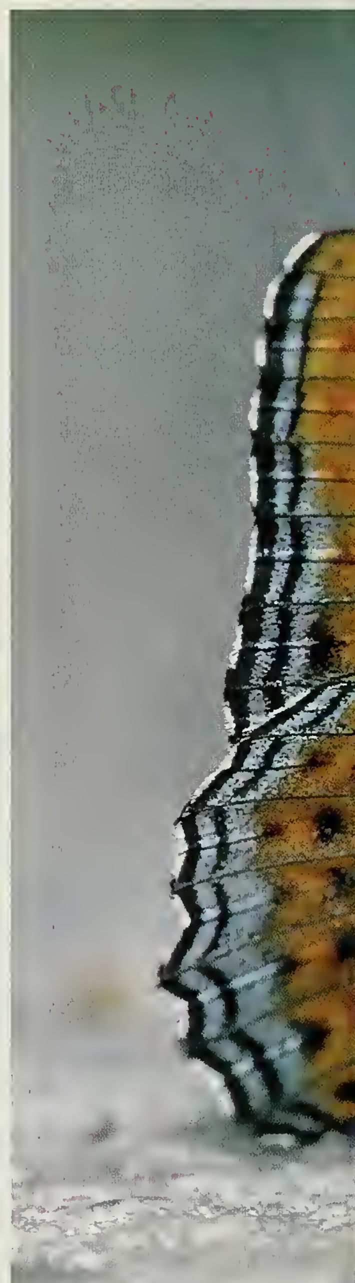
The salts and nitrogenous compounds in bird droppings provide nourishment for many insects, including a tropical skipper (Hesperiidae) at Tinalandia Reserve in Ecuador.

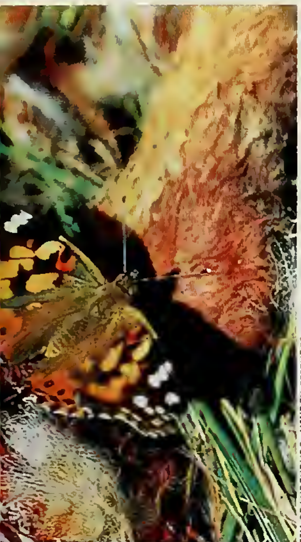
FRANS LANTING; MINDEN PICTURES

In Peru, a congregation of various pierid and other butterflies sip mineral salts from damp sand.

PATTI MURRAY

In Kenya, a gold-banded forester butterfly *(Euphaedra neophron)* feeds on a slime trail that a slug has left on a leaf.





JIM BRANDENBURG; MINDEN PICTURES

A painted lady *(Vanessa cardui)* feeds on the nutrient-rich carcass of a swift fox in western South Dakota.

RICHARD TANNER

Two *Morpho peleides* dine on fallen fruit in Costa Rica. Natural fermentation provides an alternative source of the energy-rich sugars they require.

MARIO MAIER; GERMANY

A poplar admiral *(Limenitis populi)*, left, shares a piece of fox dung with a scarce fritillary *(Euphydryas maturna)* in the countryside of southern Germany.

The CONDOR and the

An Andean spectacle i

"We did not get the pay we were promised," complains José Quispe. He and twenty other men endured two weeks without shelter in the cold, arid Peruvian plateau, subsisting on meager rations, in order to capture a condor for the big fiesta in the village of Cotabambas. Hired by the district governor and district mayor, Quispe (a pseudonym) and his companions—all of whom are Indians who speak more Quechua than Spanish—fulfilled their end of the bargain. The job required hiking 3,000 feet up from their Andean village (elevation 11,000 feet), killing an old horse brought as bait, and waiting until the rotting carcass finally attracted the scavenging bird.

The capture itself required considerable exertion. The bait was placed at the bottom of a hollow, and the men spaced themselves around the rim. After the condor landed to feed, a signal was given and the men swooped down from all sides, shouting and swinging their lassos and ponchos. A condor cannot easily take flight from the ground without a running start and thus rarely escapes if its hunters are quick. After wrapping their quarry in a poncho, the men carried it down to Cotabambas in time for the village's national Independence Day festivities, held during the last five days of July.

As farmers who subsist by growing corn, potatoes, and wheat and by breeding a few sheep and cows, the men welcome odd jobs. A dollar a day is average pay when a man works in the village for one of the more affluent mestizos, bilingual residents of mixed European and indigenous ancestry. Three dollars a day was promised for catching the condor, so the job sounded very attractive. But the men have been told that, at least for now, there isn't enough money to go around. Quispe says some of them have received two dollars, others one dollar, and a few nothing at all.

Cotabambas (population 1,300) lies about thirty-five miles (as the condor flies) west of Cuzco, which in former times was the capital city of the

Schoolboys prepare for the national Independence Day parade in Cotabambas, Peru. Behind them, a statue of a condor riding a bull portrays what will be the highlight of the festivities.

BULL

Story by **André Affentranger** ~ Photographs by **Ernesto Bazan;** GETTY IMAGES

ess—and more—than meets the eye.

Quechua-speaking Inca. Cuzco is five to nine hours away by bus or truck, and most of the villages near Cotabambas can be reached only on foot or horseback. The community's one telephone, in Ludmila Ortiz de Zevallos's grocery and variety store, has been there just a couple of years. Yet at the end of July, movie teams, photographers, and journalists from all over the world, together with students and professors from the anthropology and

At the rim of a hollow high in the Andes, above left, men lie in wait for a condor to take the bait. Above right, the captured bird is carried down to the village. Right: The man in charge of the expedition (center, wearing a poncho) presents the animal to the authorities responsible for organizing the village festivities.

The hunters had to wait until a horse carcass attracted the scavenging bird.

tourism departments of Cuzco's National University of San Antonio Abad, converge on the village for the events marking Peru's independence from Spain. "These are the only days when Cotabambas wakes up from its lethargy," comments middle-school principal Julian Baez.

The crush is the result of the *toro pujllay* (bull games), the bullfights that take place during the two days following Independence Day, July 28. The setting is a grassy village square that is turned into an arena by blocking off the entrances with tree trunks. No bulls are killed during the bullfights; instead, toreros show their bravery by closely engaging the animals with their ponchos, jackets, or homemade capes. These bulls can be quite wild, since they usually range free in the mountains. Prizes such as sheep

and beer encourage the toreros to take risks. The climactic event, however, consists of tying the captive condor by its feet onto the back of a bull. Crazed by the flutter of wings and the bird's attempts (even though its beak is tied shut) to bite his back, the bull rages for two or three minutes, jumping impressively around the arena to enthusiastic applause. The following day, the condor is released.

Movies and news reports generally represent the spectacle as a metaphor for the struggle between the indigenous population (the condor) and the Spanish conquerors (the bull) or, in the same vein, as symbolic revenge on the part of the Indians for the injustices they had to suffer under Spanish domination. This is the explanation offered by the mestizos, the people most apt to be interviewed by journalists, who stay in the village just a few days. And this interpretation, which so appeals to readers and viewers in the United States, Europe, and Japan, may have acquired some validity. But it isn't the one given by the Quechua farmers, who enrich the fiesta by singing and dancing until the last drop of alcohol is consumed.

Although not a native animal, the bull has, after five centuries, become fully integrated into the indigenous world. The *toro pujllay*—with or without the condor—is a fixture of most celebrations in the Andes of southern Peru, and to most Indians, the blood shed by toreros injured in the event is in part an offering to Mama Pacha, or Mother Earth. As far as the region's farmers are concerned, the inclusion of the condor is simply another tradition, an added feature that makes the celebration all the more exciting and attractive for the audience.

Above: Drinking is integral to the celebration, which continues for five days. Right: A bull corners a torero, whose goal is to closely engage the animal, not to kill it. Prizes are offered to encourage bravery.

"Even before me, my uncle and great-uncle caught condors," says Lucio Mantilla (a pseudonym), a Quechua farmer who has led condor-catching expeditions since 1956. "From time to time, the authorities in Cotabambas would ask them to bring a condor for either Independence Day or the day of the patron saint, so that the bull would become wilder and the bullfight more interesting, earning more prestige for the sponsors." But the custom may not be terribly old: there seems to have been no indigenous tradition of capturing live condors for ceremonial purposes, and the earliest account of a condor bullfight anywhere in the Andes appears to date from the second half of the eighteenth century.

"These are the only days when Cotabambas wakes up from its lethargy."

Nowadays the condor bullfight in Cotabambas occurs almost exclusively during the July festivities, but at one time it took place around December 8, the day of the Virgin of the Immaculate Conception, the village's patron saint. Organization and funding of the fiestas was undertaken by one or two sponsors, known as *dueños del cargo* ("masters of the obligation"). Normally these were great landholders who underwrote the expenses to enhance their own prestige and to show piety toward the saint.

Such sponsorship is no longer possible. "After the agrarian reform of 1969," explains Wilbert Chaco (a pseudonym), a teacher in the district, "nobody had the funds needed to organize such celebrations anymore. On top of this came the resistance of the Augustine monks, who did all they could to discourage such excessive occasions." In the 1960s, after an absence of 150 years, the Augustines had returned to the village and restored the local church, reestablishing a Catholic priestly presence. On religious grounds, they opposed the association of the bullfights and other spectacles with the patron saint. The switch to July occurred more for economic and political reasons, however, and during the past few years, in fact, a condor bullfight has been reintroduced in December.

Most of the responsibility for organizing the event now lies with the district governor and the district mayor, but the financial burden is borne chiefly by their political representatives in each of the eight participating villages—the deputy governor and the mayor's agent. Both posts are held by indigenous people chosen locally. Each representa-

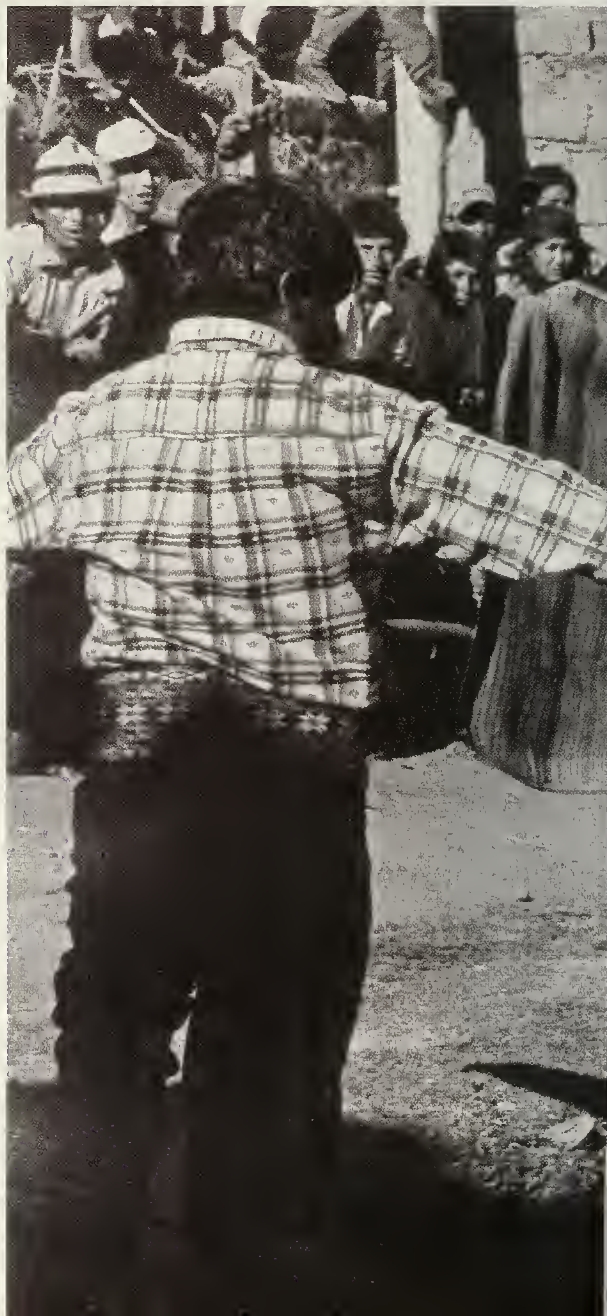
Below: Young musicians rehearse for the July 28 parade commemorating Peru's independence from Spain.

tive is obliged to provide a band, abundant supplies of maize beer and alcohol, food, two bulls for the bullfight, and prizes for the best toreros.

While those in the region who hold important political and educational positions come from the former landholding families, the indigenous officials are not nearly so well off. A representative's Independence Day expenditures (about $600) are so high that nowadays hardly anybody willingly shoulders the office. "The duties for July 28 are very hard on us, as we are already poor and this fiesta makes us even poorer," says the deputy governor in one of the participating communities. "But the mayor and the governor tell us that we are responsible for carrying on these old traditions from the time of the Inca and that we have to fulfill our obligation, as our fathers did before us."

The condor bullfight is so extraordinary an event that a number of people have been capitalizing on it for quite a while. According to Wilbert Chaco, the commercialization of the condor catch was started in the 1960s by an important local landowner and politician. "At the beginning," says Chaco, "it was by exacting a consideration for the bird from those obligated to sponsor the fiesta, then later by selling permission to witness the condor capture to film teams and journalists."

Now it is almost impossible for outsiders—including Ernesto Bazan, whose photographs accompany this story—to document the condor-catching expedition without making informal payments to some of the principals. These include the man (typically a politically well connected mestizo) who organizes the expedition and who usually accompanies it on horseback. And because journalists from outside the area interact most frequently and readily with this individual, he ends up figuring prominently in their documentaries and news videos.



The condor is presented to the public, left, on the first of two days of bullfighting. Above and right: Tied to a bull by its feet, the condor excites its mount, which bounds around the arena for several electrifying minutes. To ensure that the custom will be allowed to continue, as well as out of respect for the mountain spirits, the villagers protect the condor from harm during its days of captivity.

While regrettable from some points of view, this commercialization is one of the principal reasons the tradition has been able to survive. Since 1970, Peru's Ministry of Agriculture has forbidden the capturing of condors except for "scientific or cultural purposes." The fame that the village has achieved through films and press coverage has made Cotabambas one of the few communities that can probably count on getting an informal cultural exemption. Some other villages have given up the tradition, substituting something more like a Spanish *corrida;* others now tie a dog or a duck instead of a condor onto the bull. While in Cotabambas the bulls are never killed and the condor is carefully protected and well fed with meat, beer, and wine, the animals used in these other villages are not likely to be treated with the same care.

Solicitude for the condor has a practical motivation, because if the bird were to be accidentally killed or injured, it might mean an end to a popular and, for some, lucrative event. For José Quispe and the other Quechua farmers whose job it is to capture the bird, however, the sentiments run deeper. To them, the huge Andean condor is a messenger of the Apus, the sacred mountains. According to a widespread belief, anyone who harms a condor in any way may be struck by lightning.

The men of the condor-catching party follow certain ritual procedures as they pursue their goal. The old horse brought as bait is killed by strangling it with ropes as it faces the sunrise. And during their mission, the hunters carry out ceremonies directed to the holy mountains and to Mother Earth so that a condor will be attracted to the carcass. Among the indispensable offerings for these rituals are mussels, snail shells, corn husks and kernels, incense, coca leaves, and llama fat.

On July 31, the last day of the festivities, the condor is carried to a steep hillside where it can be safely released. Offerings are made once again to the mountains and Mother Earth, thanking them for the condor and asking them to protect it on its way home. If many film teams and journalists are present, the mestizos make the ceremony more elaborate. Then the condor is liberated, and the people wait until it takes flight. Commercialized or not, it is always a very emotional moment. □

The Proof Is in the Plum

A new fossil from northeastern China's Liaoning Province offers the best evidence yet of feathered dinosaurs.

Over the past ten years, discoveries from China's Liaoning Province have been giving us rare glimpses of a fossil community near the boundary of the Jurassic and Cretaceous periods. These glimpses just keep getting better. Known as the Jehol biota, these ancient plants and animals are embedded in fine-grained sediments that preserve details: the veins of leaves and insect wings, the patterning of skin, and the filaments of feathers. Some of the fossils are proving pivotal in testing the hypothesis that birds are the living descendants of dinosaurs.

Liaoning's farmers have been collecting fossil fish and insects in the area for decades. The Chinese government now regulates fossil collection and while paleontological excavation has taken place sporadically for years, most specimens are still unearthed by local people. The Jehol fossils are enclosed in gray volcanic ash that was deposited on the bottom of shallow lakes. They are the remains of a varied community of plants and animals that perished in or near the lakes and were quickly buried. The most abundant fossils are arthropods, but plants and fishes are also common. Rarer fossils include dinosaurs, turtles, pterosaurs, lizards, and early mammals. Some specimens reveal fossilized stomach contents and skin shaded in patterns. We cannot tell what colors the patterns represent, but we do know that some Jehol animals, including insects, fish, and small dinosaurs, were spotted or striped, like their living relatives.

Among the first of the remarkable fossils of land-dwelling vertebrates to emerge at Liaoning in the 1990s were creatures called protobirds. They are more closely related to modern birds than is *Archaeopteryx* from southern Bavaria, but more primitive than birds alive today. Protobirds such as *Confuciusornis* had the same kind of feathers as modern birds; some specimens even display long tail feathers reminiscent of tropic birds and birds of paradise.

In 1996 the fossil of a small theropod—a bipedal, birdlike dinosaur—came to light and made news in the popular press as well as the scientific community. Named *Sinosauropteryx*, this creature was the first nonbird whose fossil included featherlike structures. The subsequent discovery of other small dinosaurs with feathery appendages—*Caudipteryx, Protarchaeopteryx, Beipaosaurus,* and *Sinornithosaurus*—was seen by most paleontologists as evidence supporting several hypotheses: birds are the living descendants of theropod dinosaurs; birds are not the sole feather-bearing creatures; featherlike structures preceded flight and hence did not evolve in connection with it. Some scientists accept the presence of feathers on *Confuciusornis* but reject the idea that other Jehol theropods were feathered. They suggest that these creatures are actually primitive birds, or that the featherlike impressions are from a bird that became mixed in with the skeleton during burial, or that they are internal structures related to tail or body musculature. To clinch the argument, we needed a fossil that unambiguously showed a nonavian dinosaur with a feathery body covering.

A new specimen—for now known as NGMC 91—is that kind of fossil. I examined this specimen with colleagues from the Chinese Academy of Sciences. We know that it is a dromaeosaur, a theropod and relative of *Velociraptor*. We are confident about this assignment because NGMC 91 has several features present only in dromaeosaurs, notably the second toe modified into a sickle claw and the series of elongated connections between tail segments, which serve as stiffening rods. The head, tail, and much of the body are covered with single small fibers. Other parts of the body are covered with tufts or sprays of filaments. On the back of the "arms," branched structures lie parallel to one another, just like the barbs of a modern bird feather.

Discovered by a farmer in the winter of 2000, the fossil was acquired by the National Geological Museum of China shortly thereafter. It is now on

age

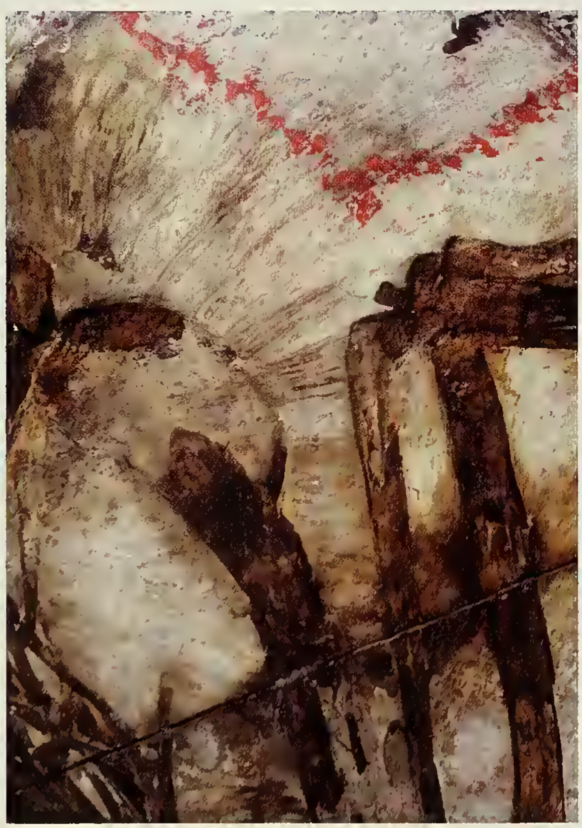
Story by Mark Norell
Images by Mick Ellison

Not a bird: The juvenile dromaeosaur from Liaoning Province, China, is covered with feathery filaments from head to ankle (only the feet are bare). Like many other theropod dinosaurs, it was equipped for life as a predator. The relatively large head indicates that it was a young animal when it perished about 130 million years ago.

Entombed in fine-grained sediments of volcanic ash that preserve minute details, the skeleton of the still-nameless dromaeosaur is haloed with fibers and filaments. It measures about two feet long from head to tail tip. A small fish is visible near one foot.

Crowning glory: Featherlike structures on the top of the head (detail, left) are not the impressions of a crest or head plume, because within the fossil, several layers of the filaments are present and separated by sediments. The entire head is covered by a thick mat of the short filaments.

The head, tail, and much of the body are covered with featherlike filaments. Other parts bear long feathery tufts, or sprays.



On the "arms" and tail, the featherlike structures are bunched, originating and radiating from a single point. Except at the tip, the long tail has short filaments (far left). The longest featherlike structures are the spray of filaments on the shoulder and "arms" (the detail at left shows the shoulder, folded arm, and bent wrist.)

The wings of a flying insect, below, reveal subtle shading indicative of color patterns. Bottom: Halves of a single fossil hold a cycad influorescence.

loan to the American Museum of Natural History and will be on display until the end of August 2001. The skeleton, including the tail, is only about twenty-four inches long and is preserved on a slab and counterslab, two halves of one sheet of rock. The size of the head—large in relation to the rest of the body—indicates that this was a young animal. The serrated teeth and sharp claws show that it was a predator, and the long hind limbs suggest that it was a fast, nimble runner.

The shallow lakes that once dotted northern China were repeatedly filled in with ash from erupting volcanos.

Despite the specimen's fine preservation, we are not sure to what species it belongs. A similar dromaeosaur found in the same general area and first described in 1999 was given the scientific name *Sinornithosaurus*. A few characteristics seem to indicate that NGMC 91 is a different species, yet until further research is done, we will wait to name it. (In the meantime, we call it Dave, a name from an old Cheech and Chong routine.) We know that if measurements of the bones of *Sinornithosaurus* and NGMC 91 are placed in a mathematical model that describes the growth pattern of *Archaeopteryx* (the most primitive of the protobirds), both animals deviate from the *Archaeopteryx* trajectory in the same way. So while neither grew like the protobird, they seem to have grown like each other.

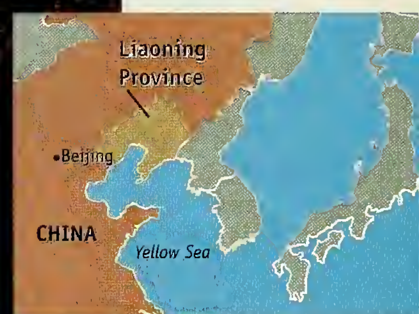
Determining the age of the Jehol fossils is problematic. Groups of researchers using various techniques have come up with conflicting results. The kinds of mammals and pterosaurs found in the Jehol fossils appear to be Late Jurassic, roughly the age of *Archaeopteryx*. However, measurements of radioactive decay give dates of both 147 and 124 million years, a period that straddles the boundary between Jurassic and Cretaceous. This may not reflect error; the samples taken for analysis are from the same area but not the same quarry. The shallow lakes that once dotted northern China (and are now the fossil beds) were repeatedly and over long periods of time filled in with debris from erupting volcanos. Sets of plant and animal communities of several ages may be represented.

The issue of time is important. Vocal critics of the theropod theory of bird origins often point to the lack of dromaeosaurs in sediments the same age or older than those that contained *Archaeopteryx*. They argue that if dromaeosaurs are birds' closest, albeit more primitive, relatives, they should have lived at an earlier time. This argument confuses the hierarchical branching pattern of the tree of life with a direct, linear process of ancestry and descent. Taken to an extreme, this line of thought would leave one unable to explain the existence of so-called primitive mammals alive today, for example platypuses and opossums, which split off from the branch that led to placental mammals, including us, nearly 100 million years ago.

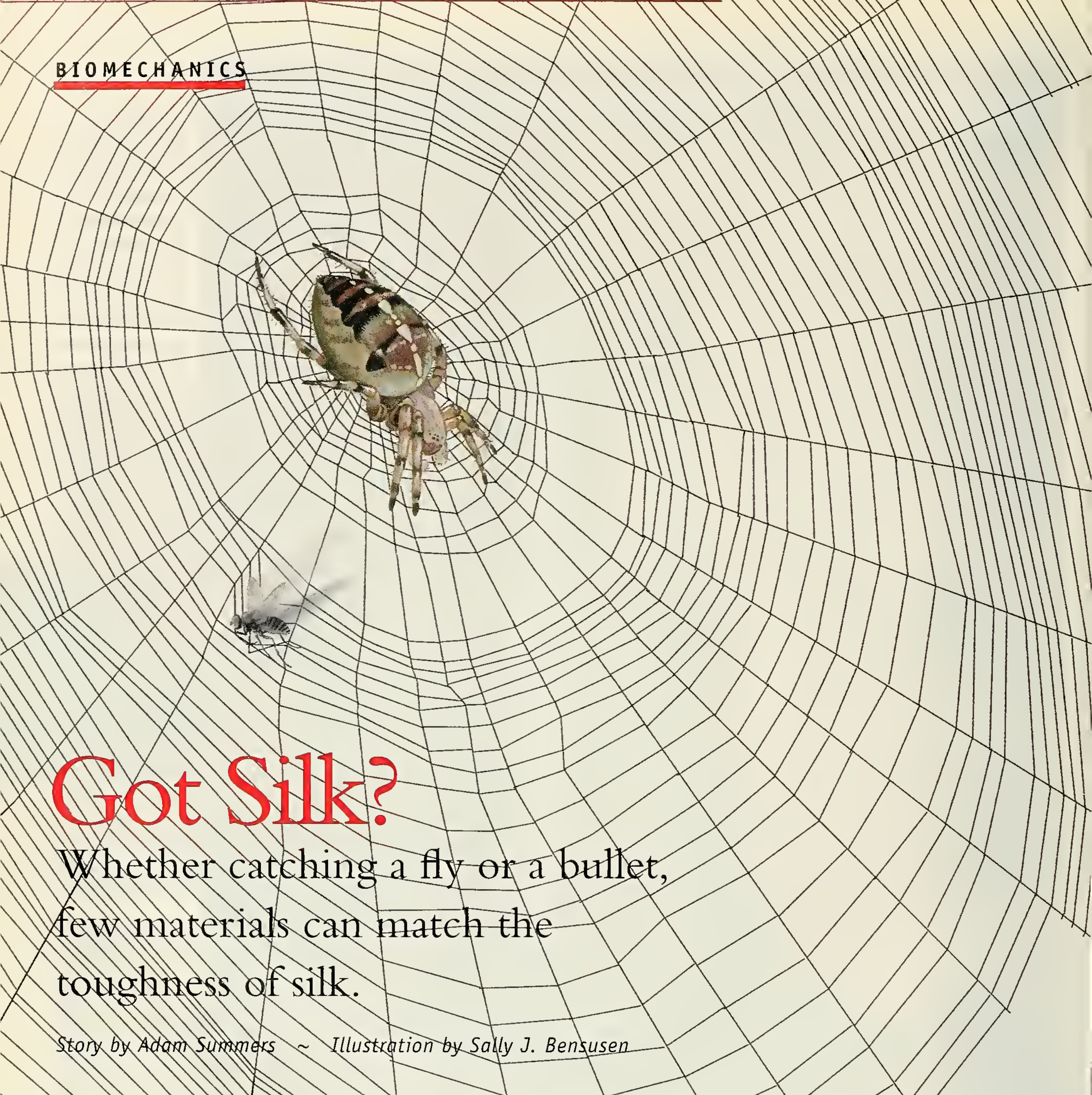
The new fossil tells us that a body covering similar to feathers was present in nonbirds. If not connected with the ability to fly, could feathers have evolved to keep animals warm? (See "First Came Feathers," September 1998.) Modern birds are warm-blooded, and feathers play an integral role in maintaining body heat. A reasonable idea, although difficult to verify, is that theropods developed featherlike structures in tandem with warm-bloodedness. Only later were the structures co-opted for flight and display.

As more evidence of ancient life comes to light, we can refine our vision of dinosaurs and birds-as-dinosaurs. If we could see the juvenile dromaeosaur that hunted along the lakes of Liaoning, the best way we could describe it would be: Like a bird. Strange, but like a bird. □

Beneath the green farm country of Liaoning, northeast of Beijing, layers of sediment preserve communities of organisms that lived in and near ancient lakes: plants, insects, small dinosaurs, birds, fish, various reptiles, and mammals.



BIOMECHANICS



Got Silk?

Whether catching a fly or a bullet, few materials can match the toughness of silk.

Story by Adam Summers ~ Illustration by Sally J. Bensusen

In 1887 an obscure California medical journal published a frontier physician's observations on the remarkable properties of silk. The doctor, George Goodfellow, noted that silk scarves and handkerchiefs were impenetrable to the bullets with which the ne'er-do-wells of Tombstone, Arizona, were shooting one another. Since then, a good many engineers, biologists, biochemists, and physicists have spent time trying to unravel the mystery of silk's resilience. Much of the early research focused on the silk spun by silkworms for their cocoons (and used in the making of parachutes and pantaloons, as well as scarves and hankies) because these caterpillars can be easily farmed. Spider silk, however, turned out to be an even better material for warding off projectiles. Recent research has revealed the molecular as well as the genetic basis for the way different types of spider silk behave under stress.

Examine an orb weaver's web early in the morning, when it is still covered with dew. Radiating from the center are strands of frame silk, which form a grid that supports the network of capture-silk threads. Right away, you'll notice that the capture threads sag under the weight of the dewdrops, while the strands framing the web shrug off the added burden. The frame, or dragline, silk is stiff and strong but not at all sticky. By contrast, the fly-catching capture threads in the spiral of the web are made of viscid silk—a strong, stretchy thread covered with droplets of glue. Spiders produce other types of silk (to wrap prey, for example), but these two types have been the main focus of biomechanical research.

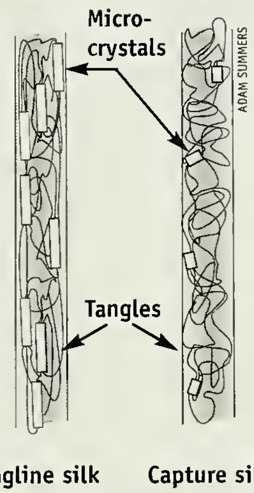
John Gosline and colleagues at the University of British Columbia have been investigating the differences between dragline and capture silk. In particular, they are interested in three properties: stiffness, strength, and toughness. Stiffness refers to how much the silk resists when pulled, while strength is a measure of how much force it takes to break a strand of a given diameter. Dragline silk is about as stiff as nylon thread and, pound for pound, stronger than steel cable. Capture thread, which stretches like rubber, is not stiff at all, but it still has nearly one-third the strength of steel. Though these qualities are impressive, some man-made materials can match silks in both stiffness and strength. The toughness of spider silk—its ability to withstand a sudden impact without breaking—is quite another matter, however, and one of special interest to the military and to industry.

Some materials fracture when struck or yanked on; others give ground but don't break unless more energy is used. Kevlar, the fiber found in bulletproof vests and bicycle helmets, has less energy-absorbing capability than does either dragline or capture silk. Dragline silk is especially remarkable in this regard: when weights are dropped on this type of silk, it can absorb up to ten times more energy than Kevlar can. On impact, most of the kinetic energy dissipates as heat. From the point of view of a hungry spider, this is much better than storing it as elastic energy—which might simply catapult a prey item right back out of the web.

Industrial interest in producing artificial spider silk has led to the cloning of certain spider genes that specify the proteins, called fibroins, that make up the silk. Some of these cloned genes have been inserted into goats, whose milk now contains "harvestable" fibroins. Ultimately, many researchers hope to create synthetic, enhanced genes and to produce commercially viable quantities of fibroins to be spun into miracle fibers for everything from brake pads to surgical sutures.

Genetic research has shown that the dragline fibroin molecule has two, quite different components: highly organized microcrystals (20–25 percent of each molecule) and amorphous, spaghetti-like tangles. The microcrystals form linkages between fibroin molecules. The amorphous tangles are dry, rigid, and glassy, giving the fiber its stiffness. Unlike glass, however, this material is not brittle. As the silk is pushed and pulled, the tangles straighten out, allowing the material to stretch without breaking. Dragline silk can be stretched by about 5 percent and still bounce back. Stretching it more than this permanently changes the configuration of the fibroins (primarily in the amorphous tangles), and the silk is unable to regain its shape. However, the thread doesn't actually rupture until it has been stretched by 30 percent of its resting length; Kevlar fibers snap when extended just 3 percent.

A molecule of capture fibroin is made of the same two components but in very different proportions: it consists almost entirely of tangles, with very few microcrystals. In addition, hydrated glue on the surface of capture silk keeps the strands moist, thus rendering them even less brittle than dragline silk. Rubbery and viscid, this silk stretches up to about three times its length when pulled on and takes a good deal of abuse before breaking—an important quality in a material responsible for entangling prey.



The protein molecules of dry dragline silk are made up of spaghetti-like tangles and many tiny crystals (all oriented the same way). In sticky, stretchy capture silk, the molecules consist almost entirely of tangles, with very few crystals (pointing every which way).

A simple change in the relative amounts of the two fibroin components, and the addition of a gluey coating, thus results in very different behavior. If fibroin can be engineered with just the right proportion of crystalline regions, manufacturers might be able to produce garments that are stretchy enough to be comfortable and fashionable, yet stiff enough to protect the underlying skin. Bulletproof T-shirts anyone?

Adam Summers is an assistant professor at the University of California at Irvine.

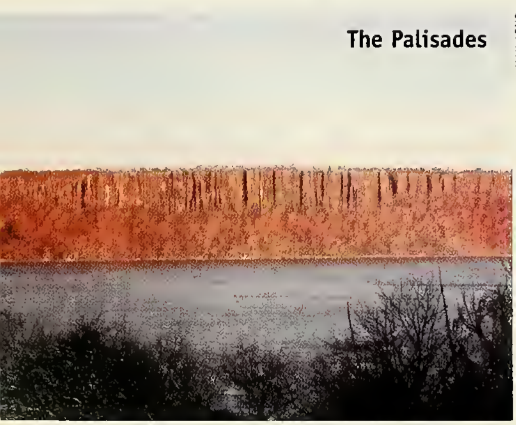
AT THE MUSEUM


MADELINE KUNSBERG

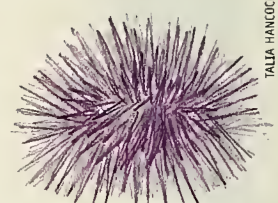
Young Naturalist Awards 2001

For the American Museum of Natural History's fourth annual Young Naturalist Awards, students in grades 7 through 12 were invited to embark on an expedition that focused on a topic in biology, earth science, or astronomy and to document their observations and analyses of the natural world. The winning entries (selected from nearly a thousand) are summarized below. Full-length versions are available in a catalog published by the Museum's National Center for Science Literacy, Education, and Technology and online at www.amnh.org/nationalcenter/youngnaturalistawards/.

Shaped by Nature and Man: The Geological History of the Palisades, *by Max Arno (Hastings High School, Hastings-on-Hudson, NY; Grade 10)*
Along the lower Hudson River rises a series of sheer cliffs known as the Palisades—400 feet high and 200 million years old. Max Arno describes their majesty this way: "My eyes trace the ancient sill of lava curving around the land like a gigantic fortress. Glancing down, I can see the jagged wall of rock plunging straight down. I am fascinated by the thought that continental plates once collided and then pulled apart, and huge glaciers swept across the very spot on which I stand." Not only does Max delineate the cracking, compression, grinding, and polishing that formed these "stark vertical cliffs," but he also explores the Palisades' commercial history—how the rocks were quarried to build Manhattan's brownstones and to pave its streets (in the late 1800s, one firm alone took out 12,000 cubic yards of traprock a day).


The Palisades
MAX ARNO

Tide Pools and the Life Within Them, *by Talia Hancock (Aliso Viejo Middle School, Aliso Viejo, CA; Grade 7)*
Talia Hancock, who has always lived near the Pacific Ocean, and who visits the seashore most days, is intrigued by the array of creatures living in tide pools. She dedicated four autumn study sessions to pools at Doheny State Beach in southern California, taking care to visit at different times of the day and to focus on different animals. She writes, for example, that chitons are "about half an inch long and use raspy files on their feet to scrape off algae from the rocks to eat. They have eight sections that let them cling to uneven rocks. Chitons usually eat at night, so I wasn't able to observe them eating." Talia plans to further her research by "learning about how to protect tide pools and the endangered animals in them."


Sea urchin
TALIA HANCOCK

Birding Sector 7, *by Daniel Hinnebusch (Upper St. Clair High School, Pittsburgh, PA; Grade 11)*
"Normal teenagers do not wake up at two in the morning and drive south for half an hour to look for owls," confesses Daniel Hinnebusch, describing an owling expedition. "Normal teenagers have not even heard of the Christmas Bird Count, an international citizen science bird count that takes place within two weeks of the 25th of December." This bird count (his fourth) and owling expedition (his second) took Daniel to seven sites in the Pittsburgh area within fourteen hours. He logged seventy-six miles by car, eleven miles on foot, and thirty-eight species.

Daniel concludes that the Christmas Bird Count is important because it "collects a massive amount of data on the abundance of bird species throughout the United States and other parts of the world."

Tardigrades As Environmental Bio-Indicators, *by Amber Hohl (Central Lee High School, Donnellson, IA; Grade 12)*
In sixth grade, Amber Hohl fell in love with tardigrades, microscopic invertebrates that inhabit mosses and lichens. Since their hosts "sponge up everything the air brings their way—carbon dioxide, sulfur dioxide, heavy metals, radiation, and dust," Amber wondered if tardigrades did, too. She soon demonstrated that living downwind of the coal-fired James River Power Plant in Springfield, Missouri, adversely affected their population. To her amazement, her interest in tardigrades led to recent summer fieldwork in Greenland, with fifteen tardigradologists from around the world. There, from a radioactive spring, or "hot zone," Amber collected several moss samples; in one, she observed a rare occurrence: tardigrade carnivory. She looks forward to the prospect of making a "contribution to the discovery of scientific truth."

Nesting Habits of the Barn Swallow *(Hirundo rustica)*, *by Elspeth Iralu (Home School Program, Gallup, NM; Grade 8)*
Barn swallows nearly always keep the same mate all their lives and migrate every year back to their nesting places in North America from as far south as Argentina. The more Elspeth Iralu watched two pairs nesting on opposite corners of her front porch in New Mexico last year, the more engrossed she became, especially in examining their nests and learning how she could facilitate the birds' nest building and repair. This past summer, each swallow couple raised three sets of young. Elspeth had the opportunity to

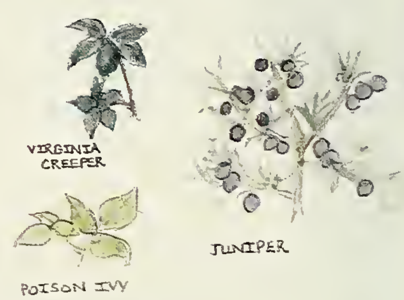
REBECCA KANE

Pitcher plant

observe all kinds of behavior; perhaps the quirkiest occurred when she played *The Best of World Music* on her family's CD player "just to see the barn swallows 'dance.' "

Bog Trotting, *by Rebecca Kane (Home School Program, Lee, NH; Grade 8)*
Lee Hill Bog in New Hampshire has a history that goes back about 10,000 years—when glaciers from the Ice Age retreated, leaving a poorly drained pond in which dying vegetation decomposed and turned to peat. Rebecca Kane analyzed three stages of bog formation as represented by Lee Hill Bog and two nearby ponds, observing that "bogs are so acidic that for plants it is as if they are trying to live in a pond full of orange juice." After visiting the bog one day last September, she recorded her amazement at its variety of life: "The leaves have all turned and the cotton grass has gone to seed. I can hear the songs of migrating birds: phoebes, white-throated sparrows, towhees, catbirds, chipping sparrows. I push through the underbrush, looking for pitcher plants. I find some. Each clump is a different color: some are a deep, shiny red; some are a bright green; and others are bright green but with a network of veins that look as if they are carrying blood. I split one open and find at the bottom all the plant's recent victims."

A Day at the (Barrier) Beach: My Expedition to Sandy Hook, *by Madeline Kunsberg (Home School Program, Maplewood, NJ; Grade 9)*
"A barrier island has a natural defense against erosion: it moves," writes Madeline Kunsberg, describing the "littoral drift" that continually changes the formation of New Jersey's Sandy Hook. This long, narrow area of dunes and forestland looks "like a curved, brown finger protruding from the northeast coast of New Jersey." Madeline discovered that "over the last 250 years, Sandy Hook has been two



MADELINE KUNSBERG

and three separate islands, and now it is technically a 'barrier spit,' not an island, with a sandy bridge created by the refraction of incoming waves." The vegetation varies, from beach grass and Virginia creeper stabilizing the dunes to eastern red cedar and even prickly pear. Joining an organized science outing, she collected both ocean and bay water samples to test their pH, ammonia, nitrite, and dissolved oxygen content. Madeline spent part of her day, however, scrambling out of poison ivy and the cold undertow. "Perhaps the most memorable lesson of the day was that expeditions never go as planned," she comments.

How Do Humans and Plants Interact in Tidal Wetlands? *by Bianca Male (Thomas Jefferson High School for Science & Technology, Alexandria, VA; Grade 9)* "Stepping off of our noisy bus into the frigid morning air, I am immediately astounded by the primal beauty of the marsh," writes Bianca Male at the beginning of her field journal devoted to a tidal wetland area at the Prime Hook Wildlife Refuge in Delaware. "The golden and magenta sunrise highlights the background, silhouetting the graceful cordgrass as it dances in the biting wind, and reflecting shards of sparkling light on the glassy water." Although the area appears pristine, Bianca soon sees that invasive *Phragmites australis* is beginning to choke areas of native *Spartina alterniflora* (salt marsh cordgrass), which "plays a major role in the detritus-based food web that supports the marsh ecosystem." Plastic wrappers, cigarettes, soda cans, and a discarded shoe further mar the "glittering, wind-whipped water." Bianca ends her journal "pondering not what the marsh will look like in coming years, but whether it will even exist at all."

An Essential Mineral, *by Frieda Shmuel (Woodland Middle School, East Meadow, NY; Grade 7)* At 1,300 feet below sea level, Israel's Dead Sea is the lowest point on earth. "Stepping into the Dead Sea was like stepping into a hot cup of tea," observes Frieda Shmuel, who visited it with her family. But what really fascinated her was the sea's exceptionally high salinity. After returning home, Frieda decided to investigate the properties of salt and to conduct an experiment comparing salt crystals from the Atlantic Ocean with those from the Dead Sea. She writes,

MAX SHMUEL

Comparing various salt crystals

"I have never thought of salt as valuable. It just has always been there." But without salt, she continues, "we wouldn't be able to survive. Human blood has salt, tears have salt, and body cells cannot function without salt."

First Flights: Fledgling Bald Eagles in Southeast Alaska, *by Caitlin Stern (Home School Program, Haines, AL; Grade 12)* Alaska's Chilkat Valley is "the site of the largest bald eagle congregation in the world," which happens each fall, while the salmon are running. For the past three years, Caitlin Stern has participated in a bald eagle ecology study there. Last summer, Caitlin observed bald eaglets fledging from nests at two sites. Spending lengthy hours patiently watching the eagles (and avoiding the many brown bears at one site) allowed her not only to forget herself but also "to discover the wonders of the wide array of other organisms that are part of the environment here. The environment of any one place is vastly complex. By studying one organism, you can begin to see the many ways it is related to and dependent on its environment. Through these eagles, I have come to better understand the place in which I live."

Investigating Vegetation and Small Mammals, *by Jennifer Vrentas (State College Area High School, State College, PA; Grade 11)* On a three-week expedition to the Cloud Peak Wilderness Area of Wyoming's Bighorn Mountains, Jennifer Vrentas focused on the biology of three habitats around one stream, Oliver Creek. She examined changes in vegetation at increasing distances from the creek, the types and diversity of small mammals, differences in soil samples and air conditions, and

JENNIFER VRENTAS

Identifying macroinvertebrates in Oliver Creek

various types of macroinvertebrates. Joining her high school group were seventeen students from a high school in Edinburgh, Scotland. Not only did Jennifer get to camp for the first time in her life, but she also "marveled over how the Scots supposedly spoke the same language as we did yet used so many foreign words. Their use of 'trainers' for sneakers, 'minging' for disgusting, and 'Philadelphia' for any type of cream cheese prompted us to put together a Scottish-American dictionary."

Exploring a Woodlot's Ecosystem, *by Susan Wiedmeyer (Mukwonago High School, Mukwonago, WI; Grade 10)* "I never originally thought of my backyard as an 'ecosystem,' but this expedition has helped me see how all living and nonliving things are connected through intricate relationships," writes Susan Wiedmeyer, who has enjoyed exploring this "wooded sanctuary" since she was a toddler. House wrens and chickadees compete for

SUSAN WIEDMEYER

Woodlot creatures

cankerworms and caterpillars; wood ducks, gray squirrels, flickers, and screech owls fight for the same nesting sites. She notices the intricate food webs that connect everything in the woodlot to the nitrogen cycle, and, echoing her relatives' comment "My, how you have grown" (delivered at family reunions), she says, "In the same way that I am always changing, so is the ecosystem in my backyard." □

MUSEUM EVENTS

DURING JULY AND AUGUST

Photographs of primates collected during the American Museum Congo Expedition (1909–1915) are now on display in the Museum's library. (You can also view them at library.amnh.org/staging/diglib/primates.html.) This coming fall, the Museum's Digital Library Program will offer comprehensive on-line access to the expedition's photographs, field notes, scientific publications, and artifact and speci-

Chimpanzee

HERBERT LANG: AMNH

men data—all compiled by Museum scientists Herbert Lang and James Chapin during their six years in Africa. Generous support for this project has come from the Andrew W. Mellon Foundation.

IMAX Theater: *Lost Worlds: Life in the Balance* (biodiversity and the need for conservation); *Shackleton's Antarctic Adventure* (the dramatic story of the 1914–17 British Imperial Trans-Antarctic Expedition); Opening July 14—*Bears* (natural history of the grizzly, polar bear, and various other species).

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

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REVIEW


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A Down-Under Look at North America

What if we returned not just mustangs and burros but also elephants and lions to our continent's wilds?

By David A. Burney

In the movie *Crocodile Dundee,* Paul Hogan's tough but endearing Outback character eventually winds up in New York City and treats Americans to a refreshingly topsy-turvy view of themselves. The same approach works fabulously in Aussie mammalogist Tim Flannery's bold new book on the ecological history of North America, *The Eternal Frontier.*

Flannery opens the book with a bang—the bang at the end of the Cretaceous, 65 million years ago, when North American conifers and dinosaurs were erased in the wake of an asteroid impact in Mexico. The result was the complete reordering of the continent's life forms—mixing diminutive survivors with new arrivals. Land bridges formed and dissolved, letting in immigrants from eastern Asia, Europe (via Greenland), and South America.

The evolution of North American flora and fauna has been affected by the continent's pronounced sensitivity to climate change. This landmass, writes Flannery, is "a great thermal trumpet," an "inverted wedge with a 6,500-kilometer-wide base deep in the sub-Arctic [that] narrows until it is reduced to a peninsula just sixty kilometers wide" in the Central American isthmus. Unlike Eurasia, a continent at similar latitudes but with mountain ranges that run predominantly east to west, our great Rocky and Appalachian mountain chains run north to south, funneling superchilled arctic air south in winter and warm air from the Gulf of Mexico north in summer. The continent has thus been hit hard by the drastic climate shifts that have contributed to biotic turnovers every 10 million years or so since the dinosaurs bowed out. Flannery's chronicle of evolutionary triumphs and setbacks, foreign invasions, and the rise of some continental specialities—such as horses, camels, dogs, and even cheetahs—would alone make the book worth reading. But the author really warms to his subject as he begins to discuss ice ages.

The Eternal Frontier: An Ecological History of North America and Its Peoples, *by Tim Flannery (Atlantic Monthly Press, 2001; $27.50)*

For instance, how many North Americans, before reading this book, would have reflected that during the glacial phases of the Pleistocene Epoch (from 1.6 million to 10,000 years ago), the earth's largest ice mass was located not on Antarctica but on the northern half of our own continent? How many would have considered the array of now vanished megafauna, including elephants and lions, that roamed North America before the troublemaker *Homo sapiens* arrived here just at the end of the Ice Age?

Flannery speaks with all the bravado of Dundee himself on various human-related controversies that have preoccupied many of his North American colleagues. On the "pre-Clovis" debate, Flannery argues against humans having arrived in North America before 13,000 years ago, drawing parallels to the archaeological records of Australia's Aborigines. He likewise casts doubt on prevailing climatic explanations for the extinction of such animals as mammoths and sabertooths at the end of the Pleistocene, arguing that climatic changes at the end of ice ages elsewhere did not result in megafaunal collapse.

Another theory receiving attention these days—promoted by American Museum of Natural History mammalogist Ross MacPhee and others—is

that an as-yet-unidentified disease introduced by humans killed three-quarters of the North American large-bodied genera. This idea rates a single sentence from Flannery. He does, however, hold with a theory first championed in the 1960s by Paul S. Martin, who argued that the earliest Americans were extraordinarily effective big-game hunters. Because the animals had never known threats from humans and had no innate or learned escape routines for eluding spear-wielding carnivores, they were extinguished across the Americas about 13,000 years ago by the so-called Clovis people.

Continuing his bold romp through the maze of North American paleotheories, Flannery contends that Clovis culture collapsed with the disappearance of the big animals, that Native American cultures found ways to adapt to the altered environment, and that Eurasian immigrants such as bison and elk replaced the extirpated mammoths, horses, and short-faced bears. Some of these species may have come across the land bridge at about the same time as the first humans and thus were preadapted to human predation. Others—contemporary wilderness symbols such as the wolf, moose, and grizzly bear—probably reached the Lower 48 somewhat later than humans.

With uniquely Australian panache, Flannery describes Europe at the time of its discovery of the New World as a "backwater." He draws on the ideas of historian Frederick Jackson Turner to explain the emerging and distinctive North American form of the frontier mentality. As in his other books (such as *The Future Eaters: An Ecological History of the Australasian Lands and People*), Flannery shows genuine empathy for the plight of the aboriginal peoples who lost their land to the greed of white settlers and their lives to the settlers' diseases and guns.

As the United States became the world's greatest technological and economic force, the pioneer spirit found itself for the first time without a frontier. "By the 1950s North Americans had eliminated about four-fifths of the continent's wildlife, cut more than half its timber, all but destroyed its native cultures, dammed most of its rivers," and done other damage as well, he writes, adding that they had "created one of the most affluent and self-contented societies ever seen, yet still the pillage of their natural resources was not finished."

Some who study the past propose, as does Flannery, nothing less than reestablishing evolutionary trends that were snuffed out by humans on this continent within recent millennia. Going well beyond the usual pleas for conservation and ecological restoration, Flannery looks deeply into his crystal ball: "I believe that the great question faced by park managers in North America today is whether, where suitable, they should introduce elephant, camel, Chacoan peccary, llama, panther, and lion into their reserves." In 1999, while Flannery's book was being written, Paul Martin and I published an article in *Wild Earth* entitled "Bring Back the Elephants!" We suggested that Americans should at least consider the evolutionary and ecological arguments in favor of careful experimentation along these same lines, so Flannery is a welcome ally. "Given the fact that the continent has never supported a more impoverished mammal fauna in the last 50 million years than it does at present and that the existing fauna is unbalanced," he suggests, "appropriate introductions are more likely to be beneficial rather than deleterious."

Watch out, fellow North Americans. This gutsy Aussie may have read our landscape and ecological history with greater clarity than any native son.

David A. Burney, of Fordham University, has conducted field studies on extinctions and environmental change in Africa, Madagascar, Hawaii, the West Indies, and his native North America.

nature.net

Bad Astronomy

By Robert Anderson

It's a sobering experience to examine common myths that are perpetuated as scientific fact by supposedly educated people. With so much bad science floating about, how is the average person to know what's true and what's not? A few crusaders have taken it upon themselves to set the rest of us straight. Sonoma State University astronomer Philip Plait is one of them, and everyone is fair game in the humorous (and educational) critiques at his web site, www.badastronomy.com.

According to Plait, it's the everyday misconceptions that are "the heart and soul of Bad Astronomy." One of his favorites to debunk is that you can stand raw eggs on end only on the vernal equinox, since in reality this feat is possible any day of the year. Apparently, this myth originated with a U.S. reporter in China who happened to observe the custom of egg balancing on *Li Chun*—which for the Chinese is the first day of spring, celebrated in early February (some six weeks before the vernal equinox). Her article appeared in the March 19, 1945, issue of *Life;* United Press picked up the story; and we have been saddled with the egg myth ever since.

A stickler for truth and accuracy, Plait also takes on the bad astronomy spread by the movies and television—particularly NBC's error-ridden made-for-TV movie *Asteroid* and Fox Television's "Conspiracy Theory: Did We Land on the Moon?"

"I may be bucking the odds," Plait writes, "but I can dream that someday this virus will be stamped out, and Good Astronomy will prevail."

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

BOOKSHELF

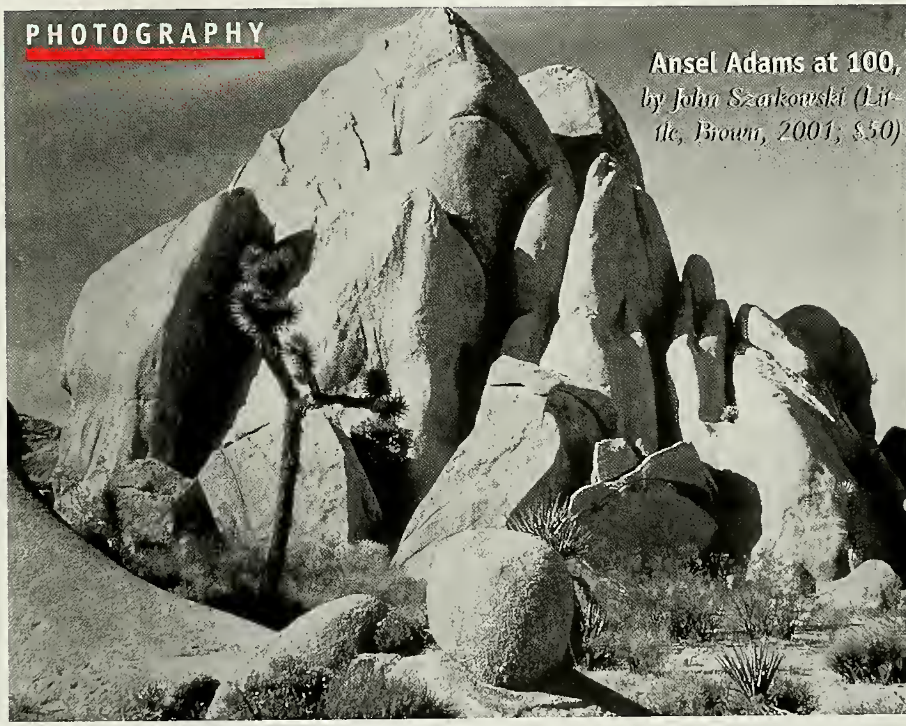
Encyclopedia of Astronomy and Astrophysics, *edited by Paul Murdin (Nature Publishing Group/Institute of Physics Publishing, 4 vols., 2001; $650)*
A single entry in this encyclopedia concentrates more physics into a few paragraphs than the average layperson encounters in a lifetime, yet the style is clear and direct, and the curious reader will be able to grasp many of the concepts even without a hard-core physics background. This comprehensive, nearly 4,000-page work contains more than 2,700 entries, including 650 in-depth subject articles (each with references and bibliography), 780 definitions of astronomical terms and objects, 650 biographies, and various lists and catalogs, as well as 3,500 illustrations and much more. The searchable online version, www.ency-astro.com, includes extensive links and quarterly updates.

Handbook of the Birds of the World, vol. 6: Mousebirds to Hornbills, *edited by Josep del Hoyo, Andrew Elliott, and Jordi Sargatal (Lynx Edicions/BirdLife International, 2001; $185)*
This gorgeous sixth volume in a projected twelve-volume, folio-sized series (intended to be the definitive handbook of the world's 9,000-plus living species of birds) became, according to the editors, so massive that they decided to limit its scope to three orders of classification, encompassing twelve families: mousebirds, trogons, kingfishers, todies, motmots, bee-eaters, rollers, ground-rollers, cuckoo-roller, hoopoe, woodhoopoes, and hornbills. Each family is discussed in terms of morphology, habitat, voice, breeding, and many other aspects, and each species merits an extremely detailed entry. The photographs and paintings are spectacular. A multifaceted foreword on avian vocalization, drafted by the late Luis F. Baptista and completed by Donald E. Kroodsma, runs more than thirty pages. Already published in this splendid series are *Ostrich to Ducks* (vol. 1), *New World Vultures to Guineafowl* (vol. 2), *Hoatzin to Auks* (vol. 3), *Sandgrouse to Cuckoos* (vol. 4), and *Barn Owls to Hummingbirds* (vol. 5).

Encyclopedia of Biodiversity, *edited by Simon Asher Levin (Academic Press, 5 vols., 2001; $695)*
The "story of a complex, self-organizing system—the biosphere—whose pieces can be examined individually, but cannot be understood outside the context of the whole" is told in 313 lengthy articles, each with a glossary, a bibliography, and cross references. "Fungi," for instance, has seven sections covering aspects from how fungi grow and the environmental niches they occupy to their industrial uses and the implications for species endangerment. The encyclopedia has a second story to tell, writes the project's editor in chief: "The coevolution of the biosphere and *Homo sapiens,* the first species whose own activities can feed back to influence the evolution of the biosphere on time scales that could lead to its own demise." For the online version, go to www.apnet.com/idealreferenceworks/.

The Oxford Companion to the Earth, *edited by Paul L. Hancock and Brian J. Skinner (Oxford University Press, 2000; $60)*
Concise discussions of our planet's myriad habitats—from deserts and wetlands to mountains, caves, glaciers, and coral reefs—make up only a fraction of the more than 900 entries written by 250 contributors. Entries range from natural phenomena (tornadoes, tsunamis, volcanoes, earthquakes, jet streams, weather fronts) and key figures in earth sciences (Agassiz, Cuvier, Darwin, Lamarck) to ecological concerns (acid rain, the ozone layer, waste disposal, the enhanced greenhouse effect) and land formations (sinkholes, fiords, yardangs, deltas). This volume, although weighty, could conceivably be a field companion.

PHOTOGRAPHY



Ansel Adams at 100, *by John Szarkowski (Little, Brown, 2001; $50)*

ANSEL ADAMS

The books mentioned are usually available in the Museum Shop, (212) 769-5150, or via the Museum's Web site, www.amnh.org.

THE NATURAL MOMENT

Spray It Again!

Photograph by **Theo Allofs**

Pelicans are well known for the elastic pouches in their lower jaws that sometimes serve as scoops for capturing fish and at other times become three-gallon buckets from which their young feed on regurgitated chowder. Despite this massive foldaway equipment, pelicans are graceful fliers that soar together in flock formations.

The world's eight species of pelicans are found near lakes, seashores, and lagoons in the Americas, Africa, Asia, Europe, and Australia. The Australian pelican, *Pelecanus conspicillatus*, is found all along the coast of the island continent. Like most other kinds of pelicans (but unlike American brown pelicans), this Australian species participates in cooperative hunts for fish. Many birds, beaks open, swim in lines toward the shore, some beating their large wings against the water's surface to drive their prey into the shallows.

Although pelicans normally obtain freshwater from the fish they eat, this individual, which lives near Shark Bay Marine Park in the state of Western Australia, makes daily visits to a local resident's garden to drink from a lawn sprinkler. According to park rangers, it is a descendant of a female that lived beside the Indian Ocean some years ago. Having injured her wing, she was captured and cared for by the rangers and, while incapacitated, learned to gulp freshwater at a sprinkler. After healing, she was released, but eventually returned with her offspring to the same sprinkler, where they also picked up the habit of taking a refreshing afternoon drink. The pelican shown here may be a member of the third generation of sprinkler drinkers.—*Richard Milner*

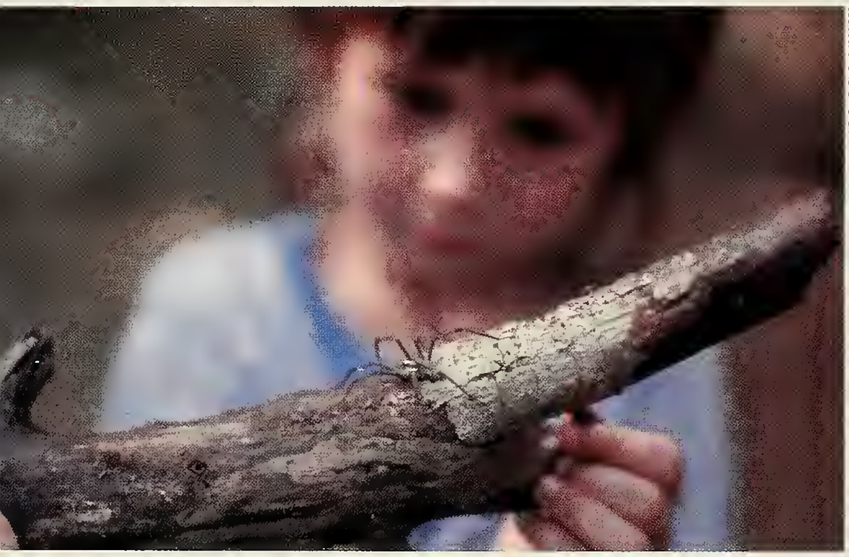
ENDPAPER

Slow & Barefoot

How to walk on the wild side

By Robb White

My mother was the slowest kind of person. When my two sisters got divorced (both at about the same time), they got into the habit of walking for miles around our old home place in Georgia for exercise. Momma went too, for company and commiseration, but it didn't work out. Every afternoon, those fast-walking women would do two or three laps to Momma's one. My sisters told me that one time, when they passed her after their first lap, Momma was bending over in the middle of the little dirt road with her head down, and they were worried she'd had some kind of heatstroke, but she was just watching the doings in an ant bed. Miles later, when they passed her the second time, she was still in the same place doing the same thing. She showed them the winged bodies of all the male ants of the colony scattered around the little mound where their wingless sisters had dragged them. "They killed them, and now they're hauling off the bodies," said Momma. "Good idea," growled my oldest sister.



KEVIN FLEMING/CORBIS

When I was a little boy, I was like my mother in one way. I was so fascinated by ants, wasps, and doodlebugs that I would have squatted in the road all day too, but unfortunately I did not inherit the slow gene. I was so twitchy that when I found something interesting, I would stomp all the grass around it to death during my observations. When Momma went walking, she would always come back with stories about how she had watched a whole nest of newly hatched baby lizards dig themselves out of the ground, or seen a snake swallow another snake, or caught the mating of a pair of pileated woodpeckers. I would squirm with envy and head straight out to see what I could find too, but all I came home with were scratches on my legs and tater-rows of dirt on my neck. My mother was not one to volunteer advice, even to her children, but I finally slowed down enough to ask her why she saw so much and I saw so little. "You walk too fast," was all she had to say about it.

She was right. I guess if those days had been these days, the school would have diagnosed some kind of ailment and doped me down with some pills. My mother dealt with my wigglesomeness in another way. She wouldn't let me in the house except when I was so hungry I had to sit still to eat or so sleepy I couldn't wiggle another wag. I'm still like that. When my good young doctor (also an animal watcher) tried to regulate my calorie intake to modify my blood chemistry a bit, I lost so much weight the first week that he was astonished. "You must have a metabolic rate about like an insectivore," he said. What I'm saying is that my own nature made it very hard for me to get close to nature when I was a little boy. That is, until I started going barefoot.

There is another errant gene in the family—this one causes serious inflammation of the Achilles tendon in some of us when we wear shoes. It first happens when we are about half grown, and the only thing to do is to leave those shoes off for the rest of our lives.

Having to go shoeless was the best thing that ever happened to me. It is impossible to walk too fast through brier woods when you don't have any shoes on. I started seeing box turtles copulating; baby birds hatching out; gopher tortoises laying eggs; grasshoppers, millipedes, and all kinds of other arthropods mating; baby quail and turkeys hiding; and hawks standing on the ground and eating doves, squirrels, and cotton rats. Deer were everywhere.

So what happened to the slow gene? I have a very slow four-year-old grandson, and just the other day I saw him squatting in the yard looking at something.

"What you see there, Will?"

"Look at what these ants are doing, Pop-Pop. The little ones that don't have any wings are killing the big ones that do have wings and dragging them off."

Robb White builds wooden boats in Thomasville, Georgia.