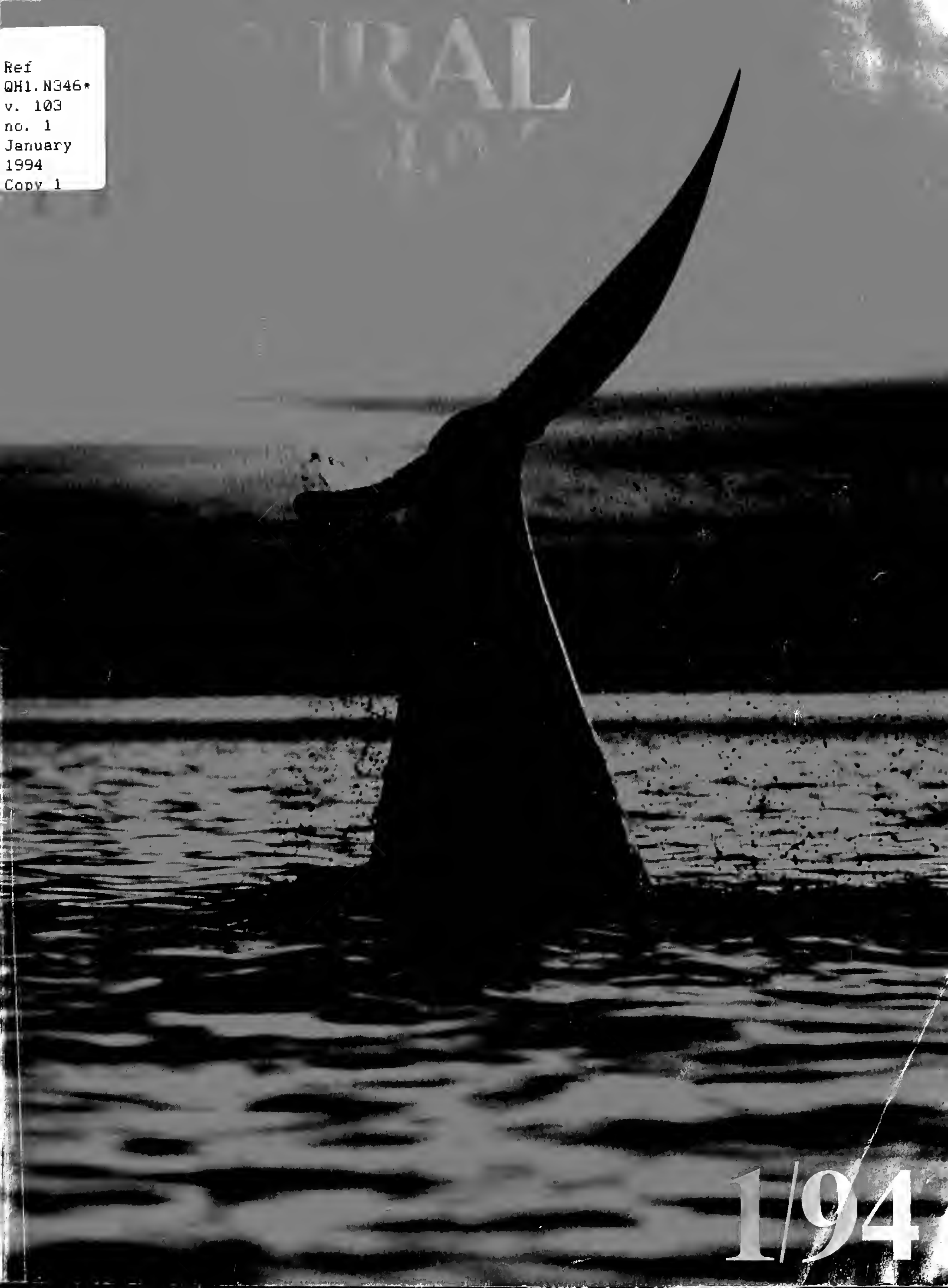
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NATURAL HISTORY

Vol. 103, No. 1, January 1994

COVER: *With flukes raised, a right whale sails across the bay—whales often do this repeatedly—at its wintering grounds near Argentina's Peninsula Valdés. Story on page 40. Photograph by Iain Kerr.*

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NATURAL HISTORY
A monthly magazine of the American Museum of Natural History

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LETTERS

BREADFRUIT—PUERTO RICAN STYLE

In "A Fruit Freely Chosen" ("A Matter of Taste," September 1993), Raymond Sokolov explores the ways breadfruit is prepared and eaten in the British and French islands of the Caribbean. He does not mention, however, the use of this fruit in Spanish-speaking islands.

Breadfruit trees can be found all over Puerto Rico. *Panapen,* or *pana,* as we Puerto Ricans call breadfruit, is usually cooked while still green. The skin is removed and the flesh cut into trapezoid-shaped pieces and boiled until tender. The taste is slightly sweeter than a potato's. The boiled *pana* can also be mashed and a little flour added to make *pasteles*—pies filled with stewed beef, pork, or chicken.

Puerto Ricans also love *tostones de pana*—fried breadfruit sticks, but my personal high point in breadfruit came while I was camping on a beach on the island of Culebra, off the "main island" of Puerto Rico. As the sun set on the horizon, a fisherman brought to my tent some baked balls of breadfruit stuffed with lobster meat. Every bite was heaven.

MIGUEL BUXEDA
Miami, Florida

DEFENSIVE SNORING DEFENDED

Although Roger L. Welsch does not mention me by name, I am the paleoanthropologist whose hypothesis on human snoring is the butt of his September 1993 column, "For Immediate Release." As a rancher in northwest Wyoming for the past eighteen years, I appreciate the barnyard humor. One correction needs to be made, however: Welsch got the wrong idea when the American Anthropological Association indicated in their press release that I was affiliated with the Institute of Human Origins. In fact, I have only been connected via friendship, fieldwork, conference attendance, and contributions.

Maybe the fellas at Slick's tavern would like to know that snoring (not to be confused with sleep apnea, which is pathological in nature) is brought on by hormones (predominantly male). And although many people do laugh when they hear my hypothesis—that snoring protected our forebears by warning away predators—they usually come around to my way of thinking when they see how the medical facts fit with the paleoanthropological, anthropological, and primatological data I have collected. As to flatulence in mammals, they all do it and all are capable of being audible. Unlike snoring, flatulence is equally a malady of the young. (If a child snores, this indicates a pathology; one must reach physical maturity with an age-softened palate in order to snore properly and keep the beasties at bay.)

CAROL ANDERSEN TRAVIS
Jackson, Wyoming

CAMOUFLAGE IS RELATIVE

I do believe that Simon D. Pollard ("Little Murders," October 1993) has fallen prey to an old, untested assumption about cryptic arthropods. He states that the ability of a female crab spider to match flower color "makes her a formidable predator of pollinating insects and affords her some protection from becoming a victim herself." Vertebrate predators such as birds probably see flower colors as we do, so a color-matched spider may be missed. But bees, one of the largest pools of prey for the spider, see best on the ultraviolet end of the spectrum. They are therefore drawn to many otherwise plain-looking flowers, whose "hidden" patterns, called nectar guides, are visible only to ultraviolet-sensitive eyes. (We humans can see them only with the help of an ultraviolet lamp or with special lenses.) Tom Eisner and colleagues observed in 1969 (*Science,* vol. 166, pp. 1172–74) that crab spiders, cryptic to us in "normal" light, are conspicuous to creatures with ultraviolet vision.

Thus, crab spiders and similar flower-dwelling arthropods may be invisible to predators such as birds and lizards, but they are easily seen by many prey. The most likely evolutionary explanation for this (if there is one) is that visual predators, and not improved hunting success, have selected for crypsis. We need to remember that safety, like beauty, resides in the eye of the beholder.

JACK C. SCHULTZ
Julian, Pennsylvania

A New President's Vision of Science and Society

In November, after her first week on the job, the new president of the American Museum of Natural History, Ellen V. Futter, discussed with the editor of Natural History *her vision of the future of the Museum and its role in society. Excerpts from the interview follow:*

This Museum has a unique capacity to help each of us answer the underlying question: Where do I fit in? When you look at what's shown here or think about what goes on here, you begin to get, not answers, but clues or pathways to thinking about where you fit in, both biologically and culturally. And that relates to how we all get along.

We have an attitude problem about science in this country. But we can't concede because of that. I think that this Museum can play a unique role in informing the public about science because we can do it in a way that no other type of institution can. The minute you come through our portals, your sense of wonder, your imagination are piqued. That's the beginning of interest, the beginning of learning. We can build on that spark both here and—in cooperation with teachers—in the schools. By putting together effective software and other educational materials, we can have a great impact. I am very committed to making that happen. The class visit is the beginning of a process: first, to get the students to come back and, second, to reinforce the visit and develop ways of helping them learn on their own by using our materials. This applies to adults, too. The technology revolution opens a new world for museums. We can put together primers and programs that speak to everyone. I think lifelong learning about science is important for children and adults. I know it is important for society.

At an exhibit under construction, Museum President Ellen V. Futter stands in front of a Diprotodon, *the largest-known marsupial. The fossil will be on display when the Halls of Mammals and Their Extinct Relatives open at the end of April 1994.*
Peter Goldberg

Of course, fund raising is an important part of this job. It's necessary to keep the Museum active and at the forefront. How we maintain what we do superbly and step up to new obligations—as a partner with the city, as a partner with the schools, as a major voice in national and global discussions of social and scientific issues—is one of the great challenges, one that will require funding to do well.

I have a great personal interest in human rights, in social justice, in helping all of us to get along. I suppose this reflects in some measure my legal training. The anthropological side of the Museum, with its studies of the meaning and values of cultural diversity, gives us a special role in this city. Even as we take on a broader role nationally and internationally in scientific issues, we won't for one moment fail to be a solid, contributing institutional citizen of New York City.

We have a national shortage of scientists, and among the communities that are least represented in science are women and minorities. I come from an institution (Barnard College) that has a strong track record of producing women scientists, including many who have become leaders in their fields. This Museum is an important research institution—with scientists at the laboratory bench and in the field. The Museum can help by speaking out nationally about the importance of training more scientists and by offering internships for women and minorities, as well as for other students. That would be a nice linkage with my background and with my strong concerns about women's issues and social justice.

The Museum is at an important intersection for social change, for education, as well as for pure research and scientific literacy. This institution is a mediator of understanding. Our role should be to facilitate and to help. We should not be afraid to raise questions, even controversial ones. A contemporary museum has to be brave enough to raise questions.

From 1981 to 1993, Ms. Futter, 44, was president of Barnard College, where she led curricular reforms, major building projects, and fund-raising campaigns. A former associate of the New York law firm of Milbank, Tweed, Hadley & McCloy, she now serves on the boards of numerous organizations and is chairman of the Federal Reserve Bank of New York. Her husband, John A. Shutkin, is a lawyer, and her two daughters, Anne, 12, and Elizabeth, 8, are regular visitors to the Museum their mother now heads.

Losing Game

Coaxed out of Bolivia's vanishing wilderness, the last Yuquí are reluctant to give up the hunt

by Allyn MacLean Stearman

I first heard of the people I later came to know as the Yuquí in the early 1960s, when I was a Peace Corps volunteer working in agricultural development in lowland Bolivia. I was assigned to the old Franciscan mission town of San Carlos, which sits on a bluff overlooking a wide expanse of lowland forest to the west; in the distance, the first ranges of the Andes rise abruptly from the blue-green haze. The villagers, I found, were fond of recounting what I suspected were apocryphal tales about isolated groups of native Amazonians still living in inaccessible corners of this wilderness. About forty-five miles northwest of the city of Santa Cruz, San Carlos was a jumping-off point for hunters, loggers, and the occasional settler, who stopped to buy supplies at our local stores. From time to time, we would hear unconfirmed reports of shooting incidents involving these adventurers and the shadowy people of the forest.

One memorable day, four men carried a wounded settler into San Carlos; a large, bamboo-tipped arrow had pierced his thigh. Old Ignacio León, at the center of the crowd that gathered around the man, looked at the arrow and solemnly pronounced, "It is from the people we call *chori,* the ones who live in the forest." We talked about this incident for weeks afterward as the villagers pondered this close encounter.

With large game scarce, a Yuquí hunter killed a macaw for food.
Kent H. Redford

Such confrontations have had a place in lowland Bolivian folklore since early colonial times. Just prior to the European conquest, according to tales recorded in the early Spanish chronicles, the warlike Itatín, inhabiting what is now northern Paraguay, sent raiding parties north into the plains and forests of eastern Bolivia, primarily to take land from the indigenous people and capture individuals for use as slaves. The Yuquí, Sirionó, and other present-day Guaraní-speaking peoples in Bolivia are most likely the descendants of Itatín warriors who chose to remain in this territory.

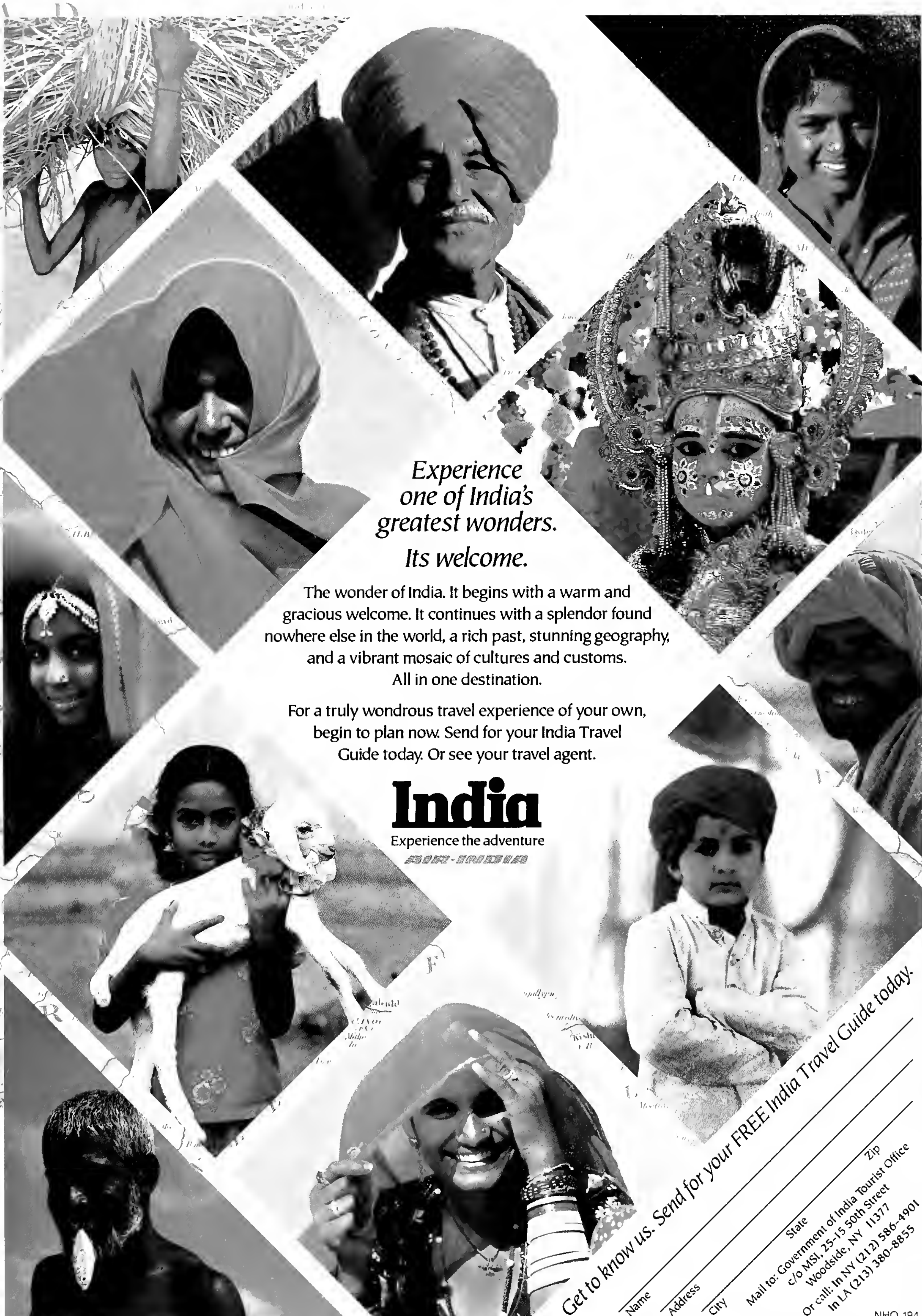
During the early years of Spanish expansion into lowland Bolivia, these groups fought the European advance but were ultimately defeated. Most of the survivors ended up near missions such as San Carlos, where they, and other indigenous peoples, interbred with Europeans to form the present-day mestizo, or mixed, population. Only some, like the Yuquí, found refuge in the forests beyond the reach of their enemies.

In their infrequent encounters with outsiders over the years, the Yuquí were invariably hostile. Well aware of the group's fierce reputation, Bolivians entering the wilderness went well armed and prepared for conflict. Even with firearms, however, they were often no match for the elusive Yuquí, waiting in ambush with seven-foot-long bows and arrows. Often, only a glimpse of an armed Yuquí was enough to keep people out of an area for years.

Then, in the 1950s, the Bolivian government decided to make the development of the lowlands a priority and began promoting pioneering by the highland peasantry. As far as the Bolivian government was concerned, much of this region was vacant land. With colonization projects expanding to the north and south of their territory, the Yuquí found themselves trapped in a vise of settlement.

Violence escalated as more colonists moved into the region. To put an end to the Yuquí threat, as well as occasional pilferage of crops, the settlers began to plan organized manhunts. Learning of the increased sightings and hostilities, the New Tribes Mission, a group of North American Protestant missionaries, set up camp near the Chimoré River, about ninety miles west of San Carlos, to try to make peaceful contact with the Yuquí. After several public debates, the missionaries convinced the settlers that the better strategy would be to "pacify" the Yuquí rather than to risk more lives in efforts to exterminate them.

From 1955 to 1965, the missionaries engaged in a tedious campaign to earn the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trust of one nearby group of Yuquí. This was often a nerve-racking endeavor. The Yuquí men were fond of wrestling and applying choke holds, an often serious game of dominance. They also enjoyed pretending to shoot arrows at the missionaries at close range, catching the arrow at the last moment as it slid across the bow. One missionary was wounded in the hand when he reached up to protect himself and caught the tip of an arrow.

Finally, in 1965, friendly contact was achieved, and after another four years of gradually lengthened periods of residence at the missionary camp on the river, the small Yuquí band made the decision to give up their nomadic existence. Decimated by skirmishes with settlers, they numbered only forty-three.

In the late 1970s, another band was sighted as colonists began spreading farther into Yuquí territory. Again, hostilities resulted and unknown numbers of Yuquí were killed. As before, the missionaries set out to befriend this new group, and with the assistance of the Yuquí who had previously been pacified, the process moved somewhat more quickly. On December 28, 1986, the new group, numbering twenty-three people, was brought to the Chimoré River camp. Nineteen more, probably the last surviving in the wilderness, were coaxed to follow in late September 1989. With the addition of the new bands, as well as the natural increase assisted by modern health care, in 1990 the Yuquí population reached about 130.

I met the first of the now sedentary Yuquí in 1982, having become an anthropologist following my stint in the Peace Corps. I had recently begun fieldwork with members of another lowland indigenous people known as the Sirionó. The group I was studying, first contacted in the mid-1930s, were settled in Ibiato, a community about 250 miles northeast of the Chimoré River camp (*see* "Territory Folks," *Natural History*, March 1986). At the time, no one knew much about the Yuquí, but they were thought to be an isolated contingent of Sirionó. Curious about this possibility, I spent enough time with them to learn that they indeed came from the same ancestral group. But the Yuquí and Sirionó languages and cultures had diverged significantly during their years of separation.

Even for foragers, the Yuquí, like the Sirionó, had an unusually simple material culture. As forest dwellers before contact, they had no means of making fire, wore no clothes, built no structures, and did not use watercraft. Their household goods consisted of a hammock and a baby sling, both made from twined tree fiber, and a few hastily made baskets that could readily be discarded. The Yuquí did not adorn their bodies with bright feathers or elaborate painting. Their one concession to style was for the women to pluck their eyebrows and brow hair, giving them a startling resemblance (from the perspective of outsiders) to aging, balding men.

The Yuquí depended on palmwood bows and two types of arrows to provide most of their meat protein. Wild game was supplemented by fish, which were taken from forest ponds by hand or with bow and arrow. Unlike other Amazonian peoples, who, in addition to hunting and gathering, practiced slash-and-burn agriculture, the Yuquí planted no crops.

By 1982 the Yuquí at the Chimoré River camp had been settled there for a dozen years, but they continued to forage for most of their food. Their farming efforts were still rudimentary, consisting of exploiting a few stands of plantains established by the missionaries, and they preferred meat and fish to the supplies of flour and dried milk provided by the mission. Unlike many other Amazonian groups, their dietary taboos excluded little, except snakes and insects. Even here an exception was made for bee larvae, which the Yuquí harvested along with honey. On honey-gathering trips with the Yuquí into the forest, I was always offered a slab of comb containing not only honey and pollen but also several cells of immature bees, which the Yuquí called milk. (Despite all my intentions to experience Yuquí life to the fullest, I could never develop a taste for this treat: no matter how much the Yuquí touted their delicate flavor, the larvae reminded me of blackboard chalk.)

Honey was an important part of the Yuquí diet, even though they had access to refined sugar at the mission store. I was always amazed at the amount of effort the Yuquí were willing to put into a honey hunt, felling tree after tree until a good supply was found. They would consume enormous amounts of this sought-after food in a single sitting, laughing at my inability to tolerate so much of a good thing.

Going after honey was only one aspect of Yuquí foraging, which often combined the search for animals, fruit, and honey into a single expedition. While the men did the hunting, women were far from tagalongs: they were constantly on the lookout for edible items and sometimes spotted game before the hunters did. They were expert trackers, capable of mimicking animal calls to bring prey within shooting range.

One morning during my second visit to the Yuquí in 1983, the young headman, Leonardo, and his wife, Loida, came by my house to invite me to go on a monkey hunt and to fish for *sábalo,* a large bony fish found in oxbow lakes. Loida told me that they had located several promising bee trees along the trail we would follow. Even if we didn't get any fish or game, Loida assured me, we were certain to come back with honey. Leonardo had his .22 rifle, Loida carried his bow and several arrows, and I took the ax. Most Yuquí men now possess firearms, but ammunition is expensive, making bow hunting, particularly for fish, still a useful technology.

After walking for almost two hours through the forest, we heard a commotion in the trees overhead. Leonardo stopped abruptly, holding up his hand. Loida put down the bow and arrows and motioned for me to do the same with the ax. Then she showed me how to cup my hand and press my mouth against the palm, making a sharp sound with my lips. It sounded just

A missionary tows a Yuquí-built canoe to the river for launching.
Allyn MacLean Stearman

like a monkey screech. Smiling at my beginner's efforts at animal calling, Loida motioned for me to move in a wide circle under the trees. While Leonardo stood still, she moved in the opposite direction.

We continued calling the monkeys, which began to move closer, answering with their own sharp cries. Out of the corner of my eye, I saw Leonardo raise his rifle and get off two quick shots. A moment later I heard a third shot, and a yellow squirrel monkey fell from the trees. Loida picked it up by the tail and struck the wounded animal sharply against a tree, killing it instantly. Two others, apparently dead, remained caught in the tangle above. We cut long poles from arrow cane and, after several attempts, finally dislodged the remainder of our prey. After tying the monkeys together with a vine, Leonardo tossed them over his shoulder and we continued our trek.

Our next stop was a small pond in the forest. Leonardo said we could rest there and make camp while he fished. As Loida and I gathered wood for a fire to roast the ripe plantains we had brought along, Leonardo tried his luck with his bow. Within an hour he had shot three good-sized *sábalo,* which Loida threw whole on the green-stick grill. She also took advantage of the stop to singe the hair off the monkeys—a foul-smelling chore that I quickly moved away from, using as an excuse my curiosity about Leonardo's fishing techniques.

He pointed to a place in the pond where there was an almost imperceptible ripple. Instantly, an arrow flew into the water. The long shaft shuddered a moment before the fish splashed to the surface, the arrow embedded in its side. After several misses but many more successes, Leonardo had caught another ten *sábalo* by late afternoon. These were strung whole on a vine for transporting.

Following our meal of fish and plantains, we started back toward camp. The sun was low in the sky, and the light was coming through the trees at right angles. Darkness falls quickly here. I asked Loida if we would go after the honey as well, now that we had fish and game to bring back. She smiled and said, "Of course. If we don't take it, our relatives will." The bee tree had been spotted by Leonardo some days before and was just off the trail we were following. Leonardo cut through the tree quickly while I waited with Loida at its base, trying to adopt her nonchalant attitude as to which way the tree might fall. Within a half hour, we had our honey safely wrapped in palm flower sheaths and were on our way home.

In 1983, a Yuquí returning home from a hunt laden with fish, game, fruit, and honey was a common sight. Animals were plentiful, and people seldom had to venture more than a day's walk from camp on foraging expeditions. For a period of fifty-six days, I kept track of all the fish and game brought back by the Yuquí men. Most of the fish came from the Chimoré River, which the Yuquí had learned to exploit by using hook and line and the gill net supplied by the mission. At the time, there were seventy-three Yuquí at the Chimoré camp, and according to my figures, each consumed an average of three ounces of animal protein per day. This was well above minimum nutritional standards set by the United Nations and similar agencies and compared favorably with the consumption rate of other Amazonian people on whom similar studies have been done.

I returned to the Chimoré River five years later, in 1988, excited about meeting the new Yuquí who had arrived in 1986. I expected the intervening years of permanent settlement to have had some effect on game animal densities and, therefore, on Yuquí hunting strategies and success rates. But I was unprepared for the degree of change that had occurred. In 1983, the Yuquí were still isolated from the major settlements of colonists in the Chapare colonization zone. Other than the few Yuracaré families who had always lived in the area, the banks of the Chimoré River were undisturbed. The Yuquí hunted this area without fear of competition or of encounters with Bolivian settlers—occasions still fraught with uncertainty.

Now, as I traveled upriver with my fieldwork supplies, the area looked like a suburb of the pioneer settlements in the Chapare: house after house lined the southern bank. Most of the settlers were growing coca for the drug trade. With the booming international market in cocaine, lands that normally would have been ignored as settlement areas were now being cleared for this lucrative crop. As a result, in just five years the Yuquí camped on the river found themselves hemmed in on three sides by colonists. This not only affected their access to the forest but also had an impact on fish and game supplies.

Colonists were now competing for these resources, particularly since current patterns of coca production do not encourage subsistence farming. Typically, land is cleared and burned, and coca bushes are set out. Once the plants are established, the grower remains in the region only long enough to pick, dry, and pack the leaves for sale, returning to the highlands between harvests. A coca farmer does not take the time or make an effort to grow food crops or keep domestic animals, both requiring a great deal more attention than the hardy coca bushes, which continue to produce even in the midst of weeds. Hunting and fishing thus provide a convenient substitute for conventional provisions.

The game species most affected by the presence of colonists was the white-lipped peccary, which runs in large herds and is a significant and preferred source of meat for the Yuquí. Unfortunately, peccaries are also the preferred food of the colonists, because the animal is large and the meat has a mild flavor similar to that of many domestic animals. The Yuquí claimed that they had not seen a peccary herd pass through their hunting territory for three years, attributing this to overhunting by colonists and the disturbance to the habitat created by increased settlement.

Of greater consequence to Yuquí subsistence was the recent depletion of fish in the Chimoré River. While interviewing missionaries, Yuquí, and settlers who lived along the river, I learned that colonists, unwilling to invest the money and time needed to catch fish with nets and other fishing gear, were illegally using dynamite to kill fish. Many of the coca farmers colonizing the area were ex-miners (ironically, laid off from their jobs to trim the national debt and free funds to fight the drug war). Most of these ex-miners were experts at using explosives, which they casually tossed into the river to supply a few days' meals.

The practice devastated spawning areas. Adding to the problem, the remaining fish were being taken by commercial fishers, who stretched nets across the entire width of the river. These entrepreneurs, whose motorized launches were outfitted with large ice chests, had fished out the Chimoré to supply the markets of the cities of La Paz, Cochabamba, and Santa Cruz. Primarily as a result of the decline in their fishing productivity, the Yuquí were consuming on average slightly under an ounce and a half of animal protein a day, far below recommended nutritional requirements.

Hunting success also could not keep pace with population growth, despite modifications in hunting strategies. In the past, there were certain animals the Yuquí seldom killed because they considered the meat inferior. In particular, coatis and kinkajous, both members of the raccoon family, were said to "taste bad and make you sick." In 1983, only four coatis and one kinkajou were captured in an eight-week period. In 1988, this number had increased to forty-three coatis and fifteen kinkajous for a similar period. The Yuquí were now actively hunting these animals for food but complaining all the while that if hunting weren't so bad, they would have tastier animals to choose from. The older people talked constantly about the lack of white-lipped peccaries, wistfully remembering the days when these and other preferred game animals such as capybara accounted for most of the meat in camp.

The Yuquí were also venturing farther away from the mission and for longer periods of time, although this meant giving up the security and comfort of mission life (the Yuquí had come to depend on the store and clinic, as well as the presence of missionaries, who acted as a buffer against the real and perceived threats of the outside world). They often hunted on the other side of the river, where settlement was still sparse and game animals relatively plentiful. Having to cross the Chimoré brought with it the risk of drowning, for although the Yuquí were now making and using dugout canoes, few could swim, except for those raised in the Chimoré settlement. In recent years, two Yuquí men have been lost in canoe accidents.

Loida (with whom I had shared many successful foraging trips in the past), Leonardo, and two other families left the mission for ten days, camping about six miles away on the other side of the river. There they killed and ate howler monkeys, fish, and other animals that were plentiful in this remote area. Loida delighted in telling me about all the food they consumed during the trip. But she also complained that she had to spend nights away from her house (she had not done so for more than three years), and that she suffered greatly from the mosquitoes, rain, chilly mornings, and the threat of predators lurking in the forest.

Living at the mission station on the Chimoré has undermined the Yuquí's ability to survive under precontact conditions. Although they are not yet full participants in the new world around them, they are dependent upon it for many of their needs. At the same time, they continue to look to the forest to supply much of their food. As more of this wilderness becomes the property of others, the Yuquí will confront even greater stresses on their traditional foraging patterns. At present, the mission supplements their diet with surplus food provided by the U.S. government, but this does not offer a long-term solution.

The Yuquí will probably be forced to become better farmers, an activity they dislike and avoid when possible. Farming also takes away time the Yuquí would rather spend searching for game. For the present, they prefer growing plantains, a perennial crop that is ideally suited to their often haphazard attempts at cultivation. Other, more demanding crops, such as rice and corn, have frequently failed, either from a lack of agricultural expertise or from neglect. By their own definition, the Yuquí are not farmers but "people of the forest."

Alejandro and his family stopped by my house to say goodbye when I had to leave. I noticed that they were heavily laden with household items for an extended trip. "Where are you off to?" I asked the family. Resting his shotgun easily on his shoulder, Alejandro answered, "Across the river to the place where the howler monkeys are eating wild papaya. There is no longer any meat here, and I am a hunter."

Allyn MacLean Stearman is a professor of anthropology at the University of Central Florida and Senior Fellow in the Tropical Conservation and Development Program at the University of Florida.

Cabinet Museums Revisited

Jam-packed Victorian displays still contain up-to-date messages

by Stephen Jay Gould

In Dublin's fair city, at the heart of Georgian elegance near Trinity College and the Old Parliament House, stands an anatomically correct statue of Molly Malone. I do not speak of Molly herself, who may or may not be properly rendered (I didn't particularly notice), but of her legendary wares. She holds two baskets, one full of cockles and the other of mussels—not quite "alive, alive, o!" in their bronzed condition, but clearly sculpted as accurate representatives of the appropriate species. The artist has respected zoological diversity by representing the song's complete natural history. (To comment on diversity of another valued kind, I never understood why the song's third verse included the only nonrhyming couplet in such a consistent and admirable ditty: "She died of a fever; and no one could save her." But then I learned that these words do rhyme in Ireland—just as "thought" and "note" rhyme in Yorkshire, and therefore in Wordsworth.)

Just a few blocks from Molly and right next to the Dail (the modern Parliament of the Irish Republic), stands the Dublin Museum of Natural History. This museum traces its origin to a private association of fourteen citizens, founded in 1731 as the Dublin Society. The first public exhibit (largely of agricultural implements) opened in 1733 in the basement of the Old Parliament House. George II provided a royal charter in 1749, and parliamentary grants began in 1761. Growing collections required a new building, and a government grant of five thousand pounds, made in 1853, largely financed the present structure. Lord Carlisle, the lord lieutenant of Ireland, laid the foundation stone in March 1856. His lordship, speaking in orotund tones suited both to Victorian practice and to the dignity of his official title, expressed a hope

> that the building about to arise on this spot...may, with its kindred departments, furnish ever-increasing accommodation for the pursuits of useful knowledge and humanizing accomplishments, and open for the coming generations worthy temples of science, art, and learning, at whose shrine they may be taught how most to reverence their creator, and how best to benefit their fellow creatures.

I learned these details of the museum's history in a fine pamphlet, *The Natural History Museum Dublin,* by C. E. O'Riordan. (You may buy your copy of this government document at the museum itself, as I did, or you may pick one up at the Government Publications Sales Office at the memorable address of Molesworth Street, Dublin.) The museum building, although harmonizing with its earlier Georgian surroundings in exterior design, could not be more quintessentially Victorian within. Two fully mounted, magnificently antlered skeletons of the fossil deer *Megaceros giganteus*—informally, if incorrectly, called the Irish elk—greet visitors at the entrance to the ground floor (while a third skeleton of an unantlered female stands just beyond). The rest of the ground floor mostly houses representative collections of Irish zoology, phylum by phylum and family by family (a case of the "roundworms of Ireland" or on "Irish crabs" certainly conveys an impression of admirable thoroughness in coverage).

The remainder of the museum, a first floor and two galleries above, seems even more frozen into its older style of full and systematic presentation. Cast ironwork and dark wood cabinets, the mainstays of Victorian exhibition, abound. Copious light enters through the glass ceiling and streams around the shadows made by cabinets and their contents. Heads and horns adorn the walls in profusion, and we wonder for a moment whether we are visiting a museum or a lord's trophy room.

The ensemble seems so coherent that we might view the entire display as an embodiment of a blueprint in the head of some Victorian museum worthy under the spell of John Ruskin. In fact, as with any living entity, the exhibits were melded, fused, reordered, and cobbled together over many decades—although these particular decades did end quite some time ago. The horns were not installed until the 1930s, but most of the other exhibits have changed little since Victoria and, later, her son Edward VII ruled this land—or at least since the locals demoted Edward's son George V to establish the Irish Free State in 1921.

O'Riordan, who provides a meticulous account of every change in venue for any stuffed bird or seashell, also acknowledges twentieth-century stability. He discusses a massive rearrangement, begun in 1895, to establish the current scheme of Irish specimens on the ground floor, with a run-through of worldwide Linnaean order on the first floor and galleries above. He writes: "The recruitment of extra staff in 1906 enabled work on the invertebrates on the top gallery to proceed quickly and this was completed by 1907. The exhibition on the upper floor and galleries has not radically changed since." He then mentions the addition of several Irish elk skulls to the ground floor exhibit in 1910 and comments: "Apart from relatively minor alterations in the content and disposition of the exhibits, the overall theme and plan of the exhibition has since remained the same."

We tend—falsely I shall soon argue—to view such stability as a sure sign of stagnation, if not decrepitude and ruin. Our basic concept of "Victorian" includes images of soot-blackened buildings, cold interior spaces lined with dark wood, chipping paint, peeling wallpaper, and shelves of bric-a-brac. In many towns, the classic late-Victorian (Queen Anne) mansions are now either funeral homes or lawyer's offices—and neither enterprise seems much beloved of late.

I confess that my first visit to the Dublin Museum of Natural History did nothing to dent this stereotype. I spent a good part of 1971, yardstick in hand, measuring the skulls and antlers of Irish elks. I visited the manors of the Marquess of Bath and the Earl of Dunraven, and I measured the mistreated male of commercialized Bunratty Castle (near Shannon Airport), where besotted revelers at the nightly medieval banquet had left the poor fellow with a fat cigar in his jaws and coffee cups on the tines of his antlers. But the best stash of specimens belongs to the museum in Dublin, where the two skeletons can be supplemented with another fifteen heads and horns, mounted high on the walls of the ground floor, one head above each major cabinet.

The same Dr. O'Riordan greeted me warmly and treated me well; his specimens formed the centerpiece of my study (published in the professional journal *Evolution* in 1974, but initially, in a more general version, as my very first article for this magazine in 1973). The specimens were fine, but, oh my, the museum was a dingy place back then. Little light, less comfort, and dust absolutely everywhere. I had to sit on top of the tall cabinets to measure the heads mounted above. There the dust, undisturbed for so many years, had congealed into thick layers of grime. I doubt that any living being had been up there with any sort of cleaning device since Leopold Bloom met Stephen Dedalus in Nighttown (or since Molly Malone last sold the sort of stuff labeled in the ground floor exhibits as "Mollusca of Ireland").

With such memories, I approached my visit in September 1993 with some trepidation—for the extrapolated curve of deterioration did not lead to happy expectations. I could not have been more joyously surprised. Not one jot or tittle of any exhibit has been altered, but all the surroundings have been restored to their original condition—not just accurately, but lovingly as well. An army of brooms has been through the premises (I think of the enormous clone constructed by Mickey Mouse in the *Sorcerer's Apprentice* of *Fantasia*)—and, as my grandmother would surely have said, "you could eat off the floor" (although I never understood why all my older relatives invoked this expression, as I couldn't imagine why anyone would want to try the experiment, however thorough the scrubbing). The glass ceiling has been cleaned, and the light floods through. The dark wood of the cabinets has been repaired and polished, and the glass now shines. The elaborate cast ironwork has been scraped and decorated in colorful patterns reminiscent of the "painted lady" Victorian houses of San Francisco. The ensemble now exudes pride in its own countenance—and I finally understood, viscerally, the coherent and admirable theory behind a classical Victorian "cabinet" museum of natural history.

"My only ambition in life is to become part of the fossil record."

Two factors—one a prejudice, the other a condition—generally debar us from appreciating the Victorian aesthetic. First, our smugness about progress leads us to view any contrary vision from the past as barbarous. Thus, when modernism espoused simple geometries, with unornamented and functional spaces, the Victorian love of busy exuberance became a focus of pity and derision. (We might praise an old Japanese house for anticipating modern simplicity, but what could we do with a shelf of curios?) In a sense, this dismissal might be viewed as payback, for the Victorians aggressively depicted their own times as the pinnacle of progress and they often treated the past with condescension. In any case, our knee-jerk dismissal of things Victorian is now fading as the preservationist movement wins more converts and as postmodernism brings eclecticism and ornament back into architecture and design.

Second, and more important, our image of Victorian has not been set by the objects themselves, as constructed for their own time, but by their present appearance, usually after a century of neglect and deterioration. The situation is almost perverse. I would not, after all, allow my image of "grandfather" to be set by the present state of my Papa Joe's remains at his gravesite. Why, then, do we conceptualize "Victorian" as a ramshackle building with broken steps, creaking floors, and peeling paint—fit only for the Addams family or as the Halloween haunted house set up by the local Jaycees?

My first, and keenly revealing, experience with Victorian as Victorians knew the style, divested of a century's overlay in deterioration, occurred in 1976 when, to celebrate our nation's 200th birthday, the Smithsonian Institution opened a replica of the Philadelphia centennial exposition of 1876. This wonderful exhibition included plows, pharmaceuticals, implements for house and farm, and, above all, machines and engines, all spanking new, freshly painted, and entirely in working order, with all their wheels, whistles, and hisses. I particularly remember a case of

Fiona McDougall, NYT

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ax blades—all shiny and sharp. And I realized that I had always pictured Victorian tools as rusted and dull—without ever articulating to myself the obvious point that they must have been gleaming and functional when first made. I am always amazed at the power of a prejudiced assumption (however absurd, and especially when backed by a mental picture, for primates are visual animals) to derail the logical thinking of basically competent people like myself.

I remember Glasgow as the planet's ugliest city upon my first visit in 1961, and as one of the loveliest places I had ever seen upon my return in 1991. The difference: Glasgow is the world's greatest Victorian city in public and commercial architecture. All the major downtown buildings, horribly soot-blackened and decrepit in many other ways in 1961, have now been cleaned and showcased, often by converting traffic orgies into pedestrian malls. I was stunned by the exuberance of these buildings, each different in its curves, ornaments, and filigrees; each vying with all the others, yet somehow forming an integrated cacophony (you have to see them to know why my chosen description is not oxymoronic). I was revolted at my first sight of the Natural History Museum in London—each archway of its elaborate Romanesque entranceway blacker and grimier than the one within—and uplifted by the subtle colors and arching forms of the cleaned building. The Victorian secular glass of Harvard's churchlike Memorial Hall passed beneath my notice for twenty-five years. Now I force these wonderful windows, designed by John La Farge and other great American glassmakers, and resplendent in their newly cleaned state, upon the notice of every visitor, for Memorial Hall is stop number one on my personal tour of Harvard's architecture.

I now add the Dublin museum to this list of Victorian buildings uplifted from squalor to glory by the simple expedient of restoring them to the original intentions of their architects and designers. Most of all, this splendid restoration taught me something that I had never appreciated about Victorian museum design.

The display of organisms in these museums rests upon concepts strikingly different from modern practice, but fully consonant with Victorian concerns. Today, we tend to exhibit one or a few key specimens, surrounded by an odd mixture of extraneous glitz and more useful explanation, all in an effort to teach (if the intent be maximally honorable) or simply to dazzle (nothing wrong with this goal either). The Victorians, who viewed their museums as microcosms for national goals of territorial expansion and faith in progress fueled by increasing knowledge, tried to stuff every last specimen into their gloriously crowded cabinets—in order to show the full range and wonder of global diversity. (In my favorite example, Lord Rothschild, richest and most prolific of all great collectors, displayed zebras and antelopes in kneeling position or even supine, so that one or two extra rows could be inserted to include all specimens in floor-to-ceiling displays at his museum in Tring.) The standard Victorian cabinet (including many in the Dublin museum) provides several rows of locked wooden drawers beneath the creatures on display under glass—to house all the museum's additional specimens, which can then be shown to professionals and others with specialized interests.

I realize that this tactic of displaying every last specimen includes a dubious side in recording the spoils of aggressive and militaristic imperialism, with all the attendant racism and ecological disregard. But do honor and acknowledge the countervailing virtue of exhibiting such plenitude—as best expressed in the words of Psalm 104: "O Lord, how manifold are thy works!... the earth is full of thy riches." You can put one beetle in a cabinet (usually an enlarged model and not a real specimen), surround it with fancy computer graphics and push-button whatsits, and then state that no other group maintains such diversity. Or you can fill the same cabinet with real beetles representing a thousand species—of differing colors, shapes, and sizes—and then state that you have tried to display each kind in the county.

The Victorians preferred this second approach—and I am with them, for nothing thrills me more than the raw diversity of nature. Moreover, the Victorian cabinet museum thrives upon an exquisite tension in commingling (not always comfortably, for they truly conflict) two differing traditions from still earlier times: the seventeenth-century baroque passion for displaying odd, deformed, peculiar, and "prize" (largest, smallest, brightest, ugliest) specimens—the *Wunderkammer* (or cabinet of curiosities) of older collectors; and the eighteenth-century preference of Linnaeus and the Enlightenment for a systematic display of the regular order of nature within a coherent and comprehensive scheme of taxonomy. (Pardon a little toot on the personal horn, but my recent book with photographer Rosamond Purcell, *Finders Keepers,* illustrates these different components in notable collectors from Peter the Great to Lord Rothschild.)

I have long recognized the theory and aesthetic of such comprehensive display: show everything and incite wonder by sheer variety. But I had never realized how powerfully the decor of a cabinet museum can promote this goal until I saw the Dublin fixtures redone right. Light floods through the glass ceiling, creating a fascinating interplay of brightness and shadow reflecting off both specimens *and* architec-

tural elements of iron struts, wooden railings, and the dark wood and clear glass of the cabinets themselves. The busy arrangement of cabinets mirrors the crowding of organisms, while the contrast between dark wood and clear glass reinforces the variegated diversity of the creatures within. The regular elements of cast iron and cabinetry echo the order of taxonomic schemes for the allocation of specimens. The exuberance is all of one piece—organic *and* architectural.

I write this essay to offer my warmest congratulations to the Dublin museum for choosing preservation—a decision that was not only scientifically right but also ethically sound and decidedly courageous. The avant-garde is not the only place of courage; a principled stand within a reconstituted rear unit may call down just as much ridicule and demand equal fortitude. Crowds do not always rush off in admirable or defendable directions.

In choosing to construct a dynamic museum of museums, in asserting the old ideal of focusing display on nature's full diversity, in restoring their interior space to Victorian intent by harmonizing architecture with organism, the Dublin museum's curators have stood against most modern trends in museums of science—where fewer specimens, more emphasis on overt pedagogy, and increasing focus on "interactive" display (meaning good and thoughtful rapport of visitor and object when done well, and glitzy, noisy, push-button-activated nonsense when done poorly) have become the norm.

Much as I love the cabinet of full variety, I could not defend Dublin's decision if this exhibit in the old style usurped all available space for displaying natural history. After all, we have learned something in the last century, and many of the newer techniques work well, particularly in getting children excited about science. But Dublin has found a lovely solution. They have restored their original housing to one of the world's finest and fullest exhibits in the old and still-stunning cabinet style—not just a room to showcase the past, but an entire building in full integrity. And they have opened a new building on the next street for needed exhibits in a more modern vein (now featuring the great inevitability of this year of *Jurassic Park*—a display about dinosaurs).

I would not be defending the cabinet style if such museums only honored a worthy past. I support this ideal of fullest possible display because it remains so vital and exciting, as capable as ever of inspiring interest (as well as awe) in any curious person. I agitate for these old-style museums because they are wonderful today. They provide, first of all, a richness in variety not available elsewhere. When I visited the Dublin museum, for example, a college course in drawing had convened on the premises—and each student sat in front of a different mammal, sketching at leisure.

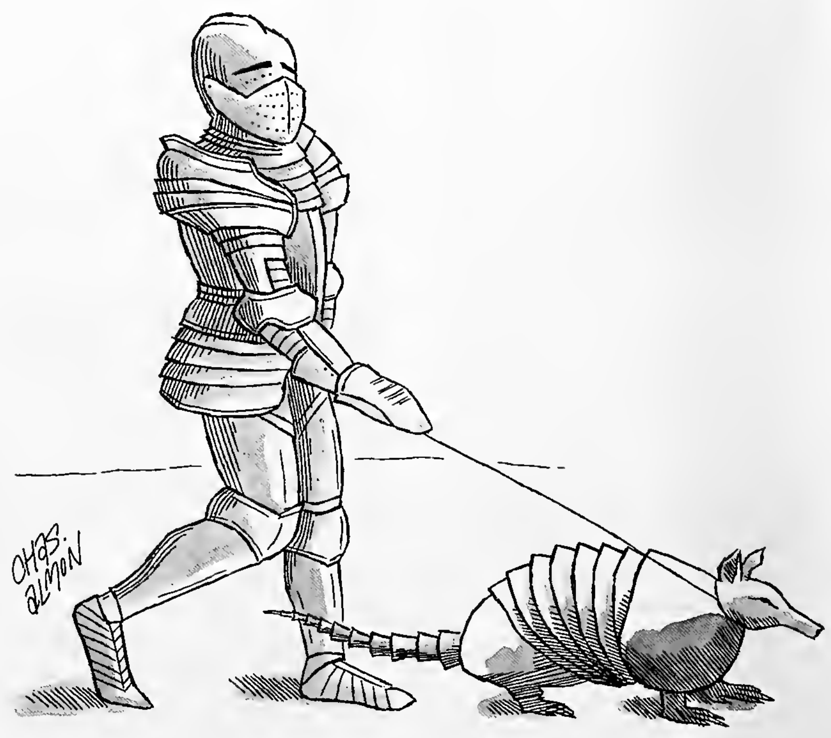
But a second reason beyond immediate, practical utility must be embraced if my argument has any power to persuade. This more subtle, and controversial, point was beautifully expressed by Oliver Sacks in two letters written to me:

> My own first love was biology. I spent a great part of my adolescence in the Natural History Museum in London (and I still go to the Botanic Garden almost every day, and to the Zoo every Monday). The sense of diversity—of the wonder of innumerable forms of life—has always thrilled me beyond anything else. [December 1990]

> Love of museums was an intense passion for me, for many of us, in adolescence. Erik Korn, Jonathan Miller, and I spent virtually all our spare time in the Natural History Museum, each of us adopting (or being adopted by) different groups—holothuria (Erik), polychaetes (Jonathan), cephalopods (myself). I can still see, with eidetic vividness, the dusty case containing a *Sthenoteuthis carolii* washed up on the Yorkshire coast in 1925. I have no idea whether that case, or any of the dusty cases we were so in love with, still exist—the old museum, the old museum *idea,* has been so swept away. I am all for interactive exhibits, like the San Francisco Exploratorium, but not at the expense of the old cabinet type of museum. [September 1992]

None of these three teen-agers grew into a professional zoologist (although others of the same clone and cohort, including me at the New York museum that publishes this magazine, did)—but all became men of great accomplishment, at least partly because they maintained (and transferred to their chosen profession) a museum-inspired love of detail and diversity. My friend Erik Korn is England's finest antiquarian book dealer in natural history; Miller's work in medicine and theater, and Sacks's in neurology and psychology, are well known. Sacks, in particular, has based the passionate humanism of his unique insight into individual personalities—his revival of the old "case study" method in medicine—upon his earlier love for zoological taxonomy. In his letter to me, he continued, "I partly see my patients (some of them, at least) as 'forms of life,' and not just as 'damaged,' or 'defective,' or 'abnormal.' " These "old-fashioned" museum displays had a profound effect upon the lives of three supremely talented, yet remarkably different, men.

I must therefore end with a point that may seem outstandingly "politically incorrect," but worthy of strong defense nonetheless. We too often, and tragically, confuse our legitimate dislike of elitism as imposed limitation with an argument for leveling all concentrated excellence to some least common denominator of maxi-

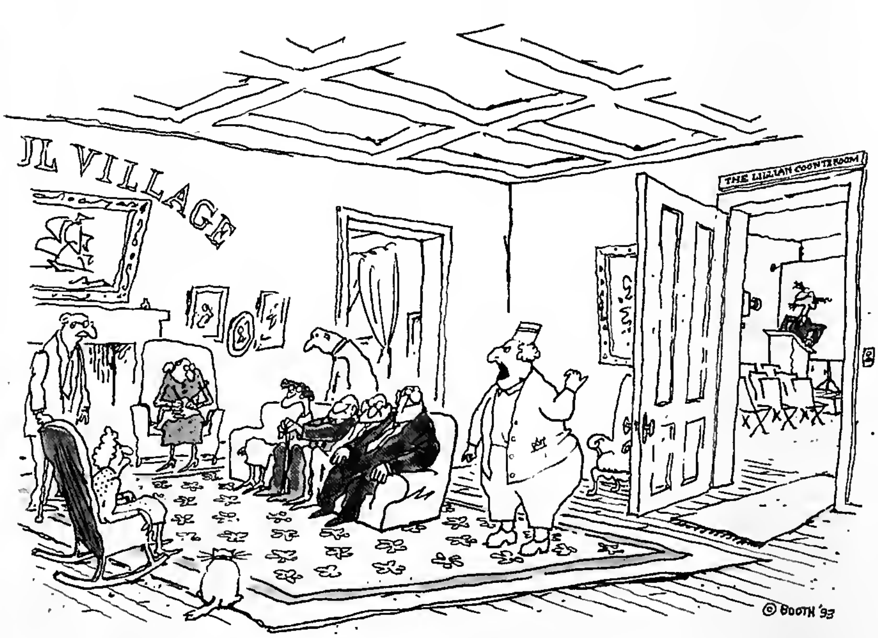


mal accessibility. A cabinet museum may never "play" to a majority of children. True majorities, in a TV-dominated and anti-intellectual age, may need sound bites and flashing lights—and I am not against supplying such lures if they draw children into even a transient concern with science. But every classroom has one Sacks, one Korn, or one Miller, usually a lonely child with a passionate curiosity about nature and a zeal that overcomes pressures for conformity. Does not the one in fifty deserve an institution as well—a magic place, like a cabinet museum, that can spark the rare flames of genius?

Elitism is repulsive when based upon external and artificial limitations like race, gender, or social class. Repulsive and utterly false—for that spark of genius is randomly distributed across all the cruel barriers of our social prejudice. We therefore must grant access—and encouragement—to everyone; and we must be unceasingly vigilant, and tirelessly attentive, in providing such opportunities to all children. We will have no justice until this kind of equality is attained. But if only a small minority respond, the true enthusiasts of all races, classes, and genders, shall we deny them the pinnacle of their soul's striving because all their colleagues prefer passivity and flashing lights? Let them lift their eyes to hills of books and at least a few museums that display the full magic of nature's variety. What is wrong with this truly democratic form of elitism?

While in Dublin, I also visited Saint Michan's church, with its beautifully carved organ, which Handel played (although some dispute the claim) at the premiere of *Messiah,* first performed in Dublin in 1742. Handel, who wrote four great odes for the coronation of George II; the same King George who then granted a royal charter that eventually led to the Dublin Museum of Natural History. And I thought of my favorite chorus (not "Hallelujah!") in part two of *Messiah,* set by Handel with a richly polyphonic beginning and a strong homophonic ending—a lovely analogy, I thought, to the interplay of nature's wondrously variegated diversity with the unity of taxonomic order and evolutionary explanation, the themes so well displayed and intertwined in the Dublin museum. And I thought of the words, expressing the most noble mission of teachers: to expand out to the ends of knowledge, and then to gather in—by song, by writing, by instruction, by display. "Great was the company of the preachers.... Their sound is gone out into all lands, and their words unto the ends of the world."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



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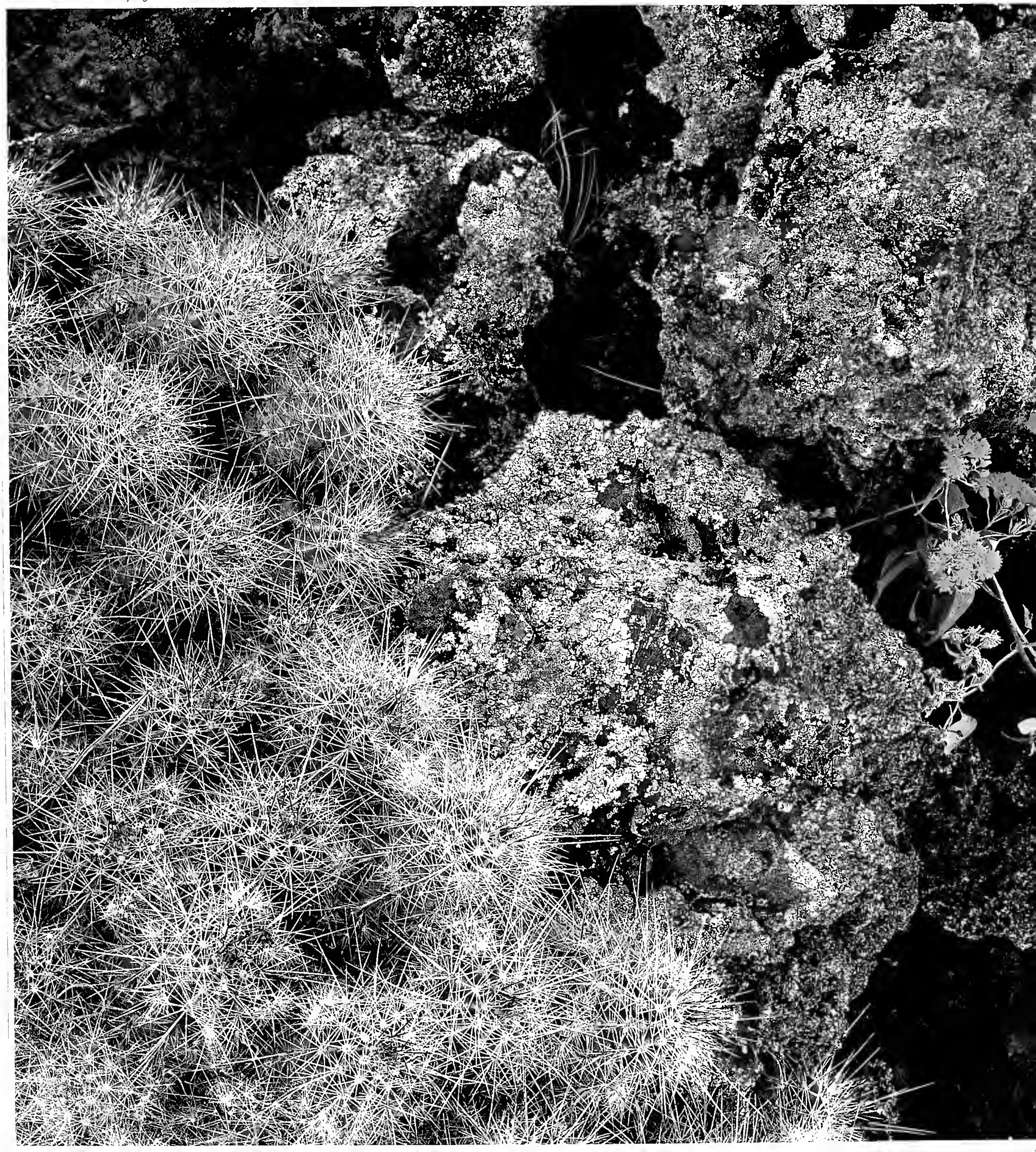

Paxton Cone, New Mexico

by Robert H. Mohlenbrock

Volcanoes have been an active force in northwestern New Mexico for the past four million years, beginning with the first violent eruption of Mount Taylor. Some 590 square miles of lava between the Zuni Mountains and Acoma now provide a museum of volcanic phenomena. This arid, inhospitable area is known as El Malpais, "the badlands." Part of the land is private, part is managed by the National Park Service, and part is managed by the Bureau of Land Management. A small area falls within Cibola National Forest.

Paxton Cone, on the National Forest land, was created between 10,000 and 40,000 years ago, when an eruption sent a river of lava northeastward down Zuni Canyon. Lying about thirty miles southwest of the present-day community of Grants, the cone built up from cinders that fell around the eruption orifice. The lava that flowed northeast was thick and tarlike; it solidified leaving very rough, sharp surfaces and an intricate network of fissures. This type of lava is called aa (the word is Hawaiian).

Cinder cones are only one of four volcano types found in the Malpais area. The most violent, exemplified by long-extinct Mount Taylor, is the stratovolcano, which ejects material into the upper atmosphere. When it last erupted, Mount Taylor sent tons of lava, cinders, ash, and steam into the air as its crater walls fell inward to form a caldera. Less violent are shield volcanoes, broad, flat volcanoes that often release their energy through several orifices. Shield volcanoes usually can be recognized by multiple craters at the top. Finally, basalt cones, with wide, steep-sided craters, erupt rapidly and send out a rather thin-textured lava that cools to a smooth or somewhat ropy surface. This type of lava, referred to as pahoehoe, is the most common in El Malpais.

At higher elevations, where conditions are relatively cool and moist, the Malpais area is forested with well-developed coniferous trees. Douglas firs and ponderosa pines are found at elevations between 7,000 and 8,900 feet, along with a lower layer composed primarily of Rocky Mountain juniper. Douglas firs, which require more moisture, are found mainly on northern slopes and on rough lava where rainwater tends to accumulate in the fis-

Douglas firs and ponderosa pines grow on Paxton Cone, above, which erupted between 10,000 and 40,000 years ago. Left: Claret cup cactus and yellow-flowered pericome cling to the volcanic rock.
Don Kurz

A dead juniper stands among the living on a lichen-covered lava flow.
George H. H Huey

sures. Quaking aspens, which also need a lot of water, can also be found in these locations.

Douglas firs germinate poorly in the lava because of the heated surface of the rock. Botanist Alton Lindsay has found that during the summer, the surface temperature of the lava rises as high as 129° F. According to Lindsay, the roots of Douglas firs get under the surface crust of the lava and grow along small tunnels that are warm and moist, but contain no soil. As the roots get older, they may break through the thin lava crust and be partly exposed. The growth of many of these trees is stunted by lack of nutrients and water, and they are often bent eastward in response to the strong prevailing winds. Lindsay, who has studied the vegetation patterns on El Malpais for years, found one mature, cone-bearing Douglas fir that was only sixteen inches high.

At about 7,000 feet and below, Douglas firs drop out and the plant community is dominated by ponderosa pines, with a variety of shrubs, wildflowers, and grasses often creating an understory. Ponderosa pines have thicker needles than the Douglas firs, and their roots penetrate more deeply, keeping them well supplied with water. And because their very large seeds produce sturdy seedlings that send out roots promptly and deeply, they can germinate in spite of the hot lava surface.

The Douglas fir zone and the ponderosa pine zone extend to lower altitudes in El Malpais than in nearby areas free of lava. As a possible explanation for this, Lindsay suggests that the dark lava becomes hotter than nonlava rock, stimulating an upward convection of heated air that causes an extra measure of rain to fall on the lava. Rainwater accumulates in the fractured lava long enough for plants growing there to replenish their supply.

Here and there in El Malpais are sinkholes in which water accumulates, draining down from the Zuni Mountains or emerging from natural springs. These oases are home to duckweeds, sago pondweed, and watercress, surrounded by a border of cattails, soft-stem and three-square bulrush, reed grass, and swamp milkweed. But at the lowest altitudes, between 6,200 and 7,000 feet, water is usually scarce. Plants that can make it here include piñons, one-seeded juniper, banana yucca, and cactuses. Broad-leaved shrubs, such as Apache plume, skunkbush sumac, New Mexico privet, and a couple of gnarly oaks, grow in lava-free zones or where shallow soil has slowly built up in lava fissures. The broad-leaved plants often have some mechanisms to prevent desiccation, such as leaves that are extremely small, succulent, or covered with hairs.

In many places, the aa supports only gray, yellow, or orange lichens, which cement themselves to the black, craggy surface of the lava. Requiring few nutrients for their minimal growth and effectively conserving the moisture in their tissues, the lichens may remain glued to the lava for hundreds of years. Lava does not cover all of the the Malpais area, however. Islands of deeper soil with richer vegetation, called kipukas, dot the landscape. Today's kipukas probably resemble the region as it was prior to volcanic activity.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Paxton Cone

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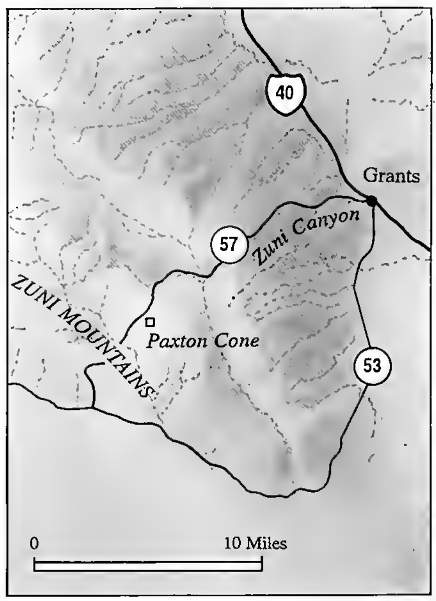


Joe LeMonnier

Edward S. Ross

Sex, Drugs, and Butterflies

For male milkweed butterflies, a dead, withered leaf may have a chemical allure no pretty flower can match

by Michael Boppré

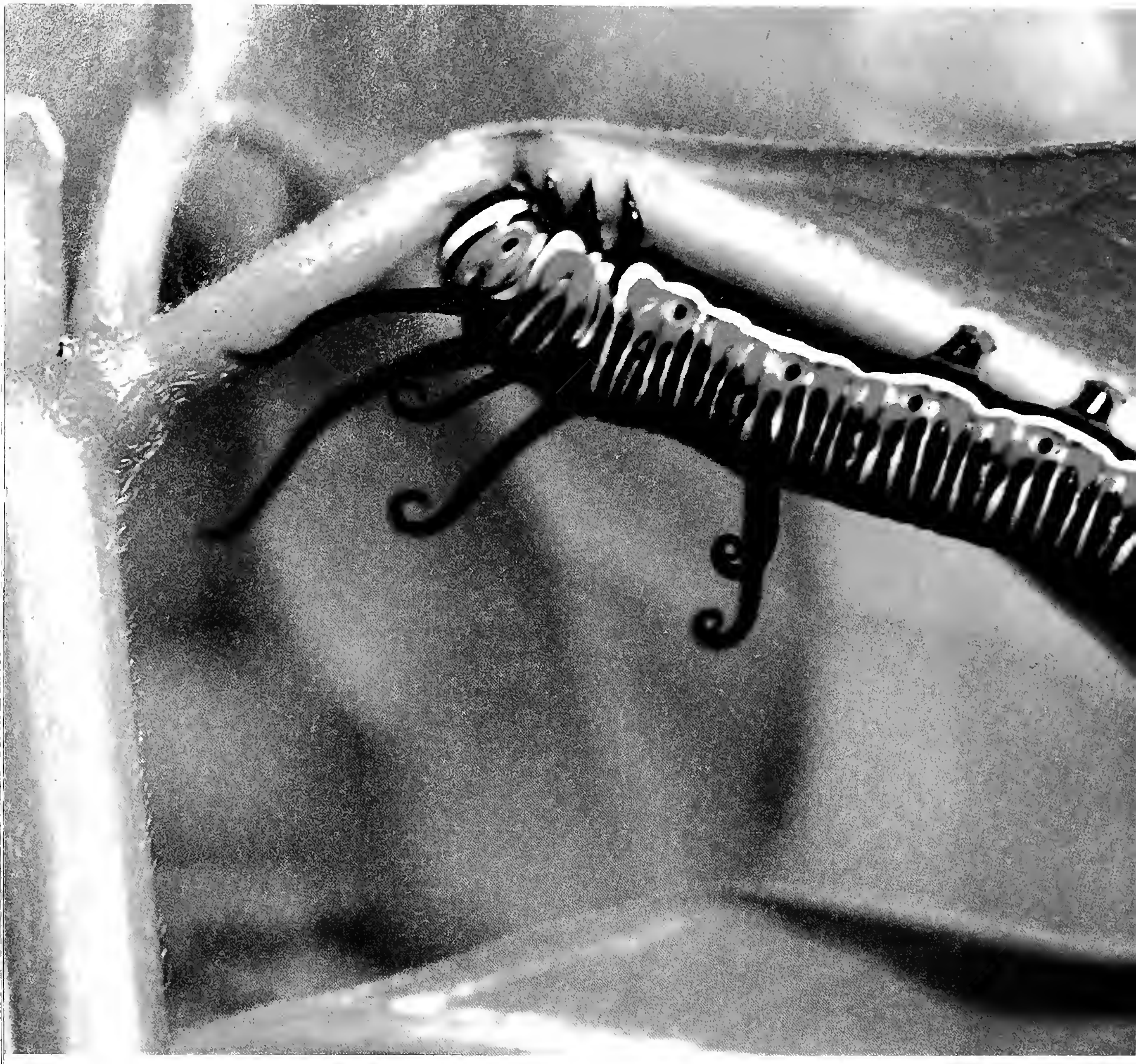
Observe the butterflies, sombre black fellows…flying in a crowd round a shrub with thick silvery-looking leaves. It is the *Tournefortia Argentifolia,* a tree that I see on almost every seashore that I have visited throughout the Pacific.… A branch is broken, and the leaves are hanging dry and wilted. The butterflies settle on the dead leaves in swarms, almost pushing and jostling one another to get a good place. Notice that it is the withered leaves and flowers that they prefer, and seem to become half-stupid in their eagerness to extract the peculiar sweetness, or whatever it is, that the leaves contain.

Since these observations were published in 1890 by C. M. Woodford, in *A Naturalist Among Headhunters,* other reports in the scientific literature have described butterflies apparently sucking at dead parts of *Tournefortia* trees and a number of other, unrelated plants. For nearly a century, these reports were a great puzzle to naturalists and scientists: first, because dead plants are dry and butterfly mouthparts are designed to suck up liquids, and second, because only male butterflies were seen at the dead leaves. Only in the last few decades have scientists in Australia, Europe, and the United States pieced together an explanation involving complex interactions of sexual communication and chemical protection.

The butterflies Woodford watched were members of the genus *Euploea* (commonly known as crows) in the milkweed butterfly subfamily, Danainae. Other family members include the tiger, queen, and monarch butterflies. Males of all danaines possess hairy glandular organs. Nineteenth-century naturalist Fritz Müller proposed that all these "pencils, tufts or manes of hair," which he found in a variety of forms in the males of many butterfly species, were odoriferous organs serving "as an excitement to the opposite sex." The proof came nearly one hundred years later. In the mid-1960s, studies by Lincoln Brower (now at the University of Florida, but then at Amherst College) and his coworkers showed that male Florida queen butterflies locate females visually and, once they are within close range, emit chemicals from these glandular organs, or hairpencils, to seduce them. Such chemical sexual stimulation is widespread in butterflies and moths, but the danaines exhibit one of the most elaborate chemical communication systems known among the Lepidoptera. (The American monarch, *Danaus plexippus,* is an exception. In the mating strategy of this species, chemical communication plays a minor role. Male scent organs are much reduced and rarely employed in sexual interactions, which appear to the human eye more like rape than seduction.)

Left: Male crow and blue tiger butterflies congregate on a bundle of dried Heliotropium *plants, in search not of food but of pyrrolizidine alkaloids. Numerous other insects, such as the snouted tiger moth, above, are attracted to the dried parts of plants containing these protective compounds.*
Michael Boppré

During courtship, a danaine male hovers above a female. He extrudes his hairpencils (usually hidden inside his abdomen) close to her antennae and then expands them, often for just fractions of a second. In many species, the sudden protrusion and expansion of the hairpencils delivers tiny, pheromone-laden particles to the female's antennae, which are lined with olfactory receptors. Without ade-



quate pheromonal stimulation, the female would reject her suitor.

Not all danaine pheromones smell alike, and the human nose can detect some differences in the male perfumes of milkweed butterfly species. Mostly they smell strong but pleasant to us: some, sweet like chocolate; others, more like pineapple. However, for a more precise identification of the pheromone composition, sophisticated technical equipment is needed. Jerrold Meinwald, of Cornell University, and Stefan Schulz and Wittko Francke, of the University of Hamburg, have analyzed the chemistry of hairpencil extracts taken from many species and found that the pheromones are species-specific bouquets made up of twelve to fifty volatile components, most of which are "unsmellable" by the human nose.

What is the male telling the female with this fanfare of pheromones? Danaine butterflies locate one another by sight, so the pheromones cannot be long-range attractants. However, mimicry is very common among these butterflies, so something more than just visual inspection may be necessary to allow members of a species to recognize one another. At close range, the female may use the male's perfume to determine which species her suitor belongs to: "Let me smell you so I can know who you are."

But there appears to be more than species recognition to the story. Certain chemical compounds are common components in the pheromone bouquets of many danaine species and thus are unlikely to contribute to species specificity. Called dihydropyrrolizines, these chemicals often make up the largest proportion of the hairpencil volatiles, with up to 500 μg (a half thousandth of a gram) in a single pair of hairpencils, an enormous amount compared with that of pheromones in other insects. These chemicals must serve a different purpose.

Studies with field-caught male danaines revealed that the amount of dihydropyrrolizines varies greatly from individual to individual. Freshly hatched males possess various other pheromone components but lack dihydropyrrolizines entirely, and as Thomas Pliske and Thomas Eisner, of

The crow caterpillar, left, may gather and store certain noxious plant compounds, such as cardenolides, while feeding on its host plant. Below: The chrysalis of a friar butterfly has a strong metallic luster, the effect of light reflecting off many thin layers in the cuticle.
Photographs by Michael Boppré

Cornell University, discovered, male queen butterflies lacking this type of compound are much less successful in getting accepted by a mate. These findings suggested that the chemicals played an important role in the lives of the butterflies, but no one knew just what that role was or where the dihydropyrrolizines were coming from.

The answers to these questions began to come in the mid-1970s, from scientists working independently (John Edgar, with the Commonwealth Scientific and Industrial Research Organization in Australia) and collaboratively (Jerrold Meinwald and others at Cornell, and Dietrich Schneider and me at the Max Planck Institute for Behavioral Physiology). We now know that adult male milkweed butterflies utilize certain secondary plant compounds, known as pyrrolizidine alkaloids (PAs), as chemical precursors for synthesizing dihydropyrrolizines. (Secondary plant compounds are chemicals that are not part of the plant's essential molecular makeup but that frequently have a defensive function and lead to better survival.)

The butterflies use their sense of smell to locate the dry, withered, or damaged parts of certain plants that contain pyrrolizidine alkaloids. After landing on an appropriate plant, the butterflies walk about, probing the surface here and there with their proboscises. Eventually they settle down at one spot and release drops of fluid on the plant. They then reimbibe the fluid mixture and, with it, some of the plant's PAs. Butterflies often congregate in small groups and fight over spots previously wetted by others. What Woodford saw a century ago was undoubtedly such an incident, for *Tournefortia* trees contain pyrrolizidine alkaloids. (Other PA plants include *Crotalaria*, or rattlebox, in the pea family; *Senecio*, or groundsel, in the aster family, and *Heliotropium* in the borage, or forget-me-not, family.)

These alkaloids occur in living as well as dead plants, but in live tissue, the compounds are sealed within cell vacuoles, where the butterflies cannot detect them. If, however, a leaf has been damaged by, say, leaf-feeding beetles, it may attract male milkweed butterflies, which, chickenlike, scratch at it with their legs, creating fresh tears in the plant tissue and thus gaining access to the alkaloids within.

Using pyrrolizidine alkaloids purified from plant extracts, we have demonstrated that the butterflies are after the PAs and not any other plant compounds. And their interest in these chemicals is independent of any nutritional requirements: their sole reason for visiting PA-containing plants is to gather the alkaloids. These butterflies, then, visit two groups of plants: those they

Tim Laman; The Wildlife Collection

After scratching at a beetle-damaged Heliotropium *leaf, two blue tiger males, below, gain access to the pyrrolizidine alkaloids within. These butterflies must also continue the regular business of feeding on nectar, right.*

Michael Boppré

feed on, which could be thought of as grocery stores, and those they gather secondary chemicals from, which could be considered pharmacies.

Why do males engage in these efforts? Some twenty years ago, biologist Miriam Rothschild studied moth larvae feeding on fresh PA plants and proposed that insects are capable of stockpiling the alkaloids to protect themselves from predators. In the years since her suggestion, chemical analyses conducted by several separate research groups have revealed that pyrrolizidine alkaloids gathered by adult butterflies from dry plants are used for the same purpose. The insects' storage capacity is impressive: up to 15 percent of a butterfly's dry weight may be made up of unconverted pyrrolizidine alkaloids extracted from dry plants.

Behavioral tests of butterfly predators have shown that the stockpiled PAs can provide the insects with protection from many enemies. These chemicals, which become toxic once ingested, taste bad and have been found to be repellent, to varying degrees, to some mice, bats, lizards, spiders, birds, and all unadapted insects.

Some members of the milkweed butterfly family — monarchs and queens — are protected by other chemicals unpalatable to predators. Unlike PAs, these chemicals, known as cardenolides, have an immediate effect on heart rate and blood pressure. Neither egg-laying females nor larvae specifically seek out cardenolides, but if the larval host plant contains them, they are ingested along with food. Stored in the larval body and retained into adulthood, these cardenolides deter several predators, as has been well documented during the last twenty-five years. Film footage based on Lincoln Brower's studies with blue jays provided the most memorable proof: blue jays eating with gusto and then immediately vomiting up monarch butterflies that had been reared as larvae on cardenolide-containing plants.

For certain milkweed butterfly species or individuals, then, pyrrolizidine alkaloids add another dimension to their unpalatability, while for others, the alkaloids may be the only defensive compounds. In all cases, however, these plant chemicals play a dual role in the lives of danaines: they help males seduce females, and they act as potential lifesavers. Thus, males have good reason to pursue pyrrolizidine alkaloids. But why is a female so interested in whether or not a suitor smells of the PA-derived dihydropyrrolizines? And

why does she seem to use them in selecting a mate?

As the research teams of Thomas Eisner and Keith S. Brown, Jr., have demonstrated, male milkweed butterflies transfer more than just sperm to the female during copulation: included in the ejaculate is a mass of pyrrolizidine alkaloids, previously collected by the adult male from plants. This nuptial gift varies from male to male: the more of the alkaloids a male has taken in, the more his personal perfume will smell of dihydropyrrolizines and the more PAs he has to offer a female. Thus, if a male's aroma is an indication of the size of the nuptial gift he is likely to present, the female may have a meaningful basis for choosing a mate: the more alkaloids she can get from the male, the more she will possess to protect herself and to incorporate into her eggs for their protection, too.

Studies of the chemical ecology of milkweed butterflies led to a better understanding of other insects that utilize PA-containing plants as grocery stores and pharmacies at the same time. The larvae of several tiger moth species (family Arctiidae) store PAs for their protection, and some also use them as pheromone precursors. Although many are specialized to feed on PA plants exclusively, not all are capable of detecting PAs directly. Among the most interesting of the PA moths are those such as *Creatonotos* species, which respond to PAs behaviorally, as danaines do. The larvae of these moths can feed and develop perfectly well on a variety of shrubs, including some that contain PAs and others that do not. Under experimental conditions, however, these caterpillars show a definite interest in the alkaloids, feeding eagerly on almost any material, including fiberglass disks, as long as the material has been first impregnated with the chemicals. As with the milkweed butterflies, their enthusiasm for these chemicals is independent of their nutritional requirements.

Creatonotos moths exhibit some striking similarities to danaine butterflies. Males possess eversible scent organs, called coremata, that emit a dihydropyrrolizine derived from pyrrolizidine alkaloids, and they, too, stockpile unconverted PAs for protection and transfer them to females. However, there are some basic differences. Both male and female *Creatonotos* feed on PA plants, gathering the protective compounds together with food, and they do so only as larvae (the short-lived adults do not feed at all). So while milkweed butterflies accumulate PAs as adults only, *Creatonotos* moths hatch with a fixed amount of pheromone and protective chemicals. In both groups, the degree of protection varies from individual to individual, as does the amount of male pheromone.

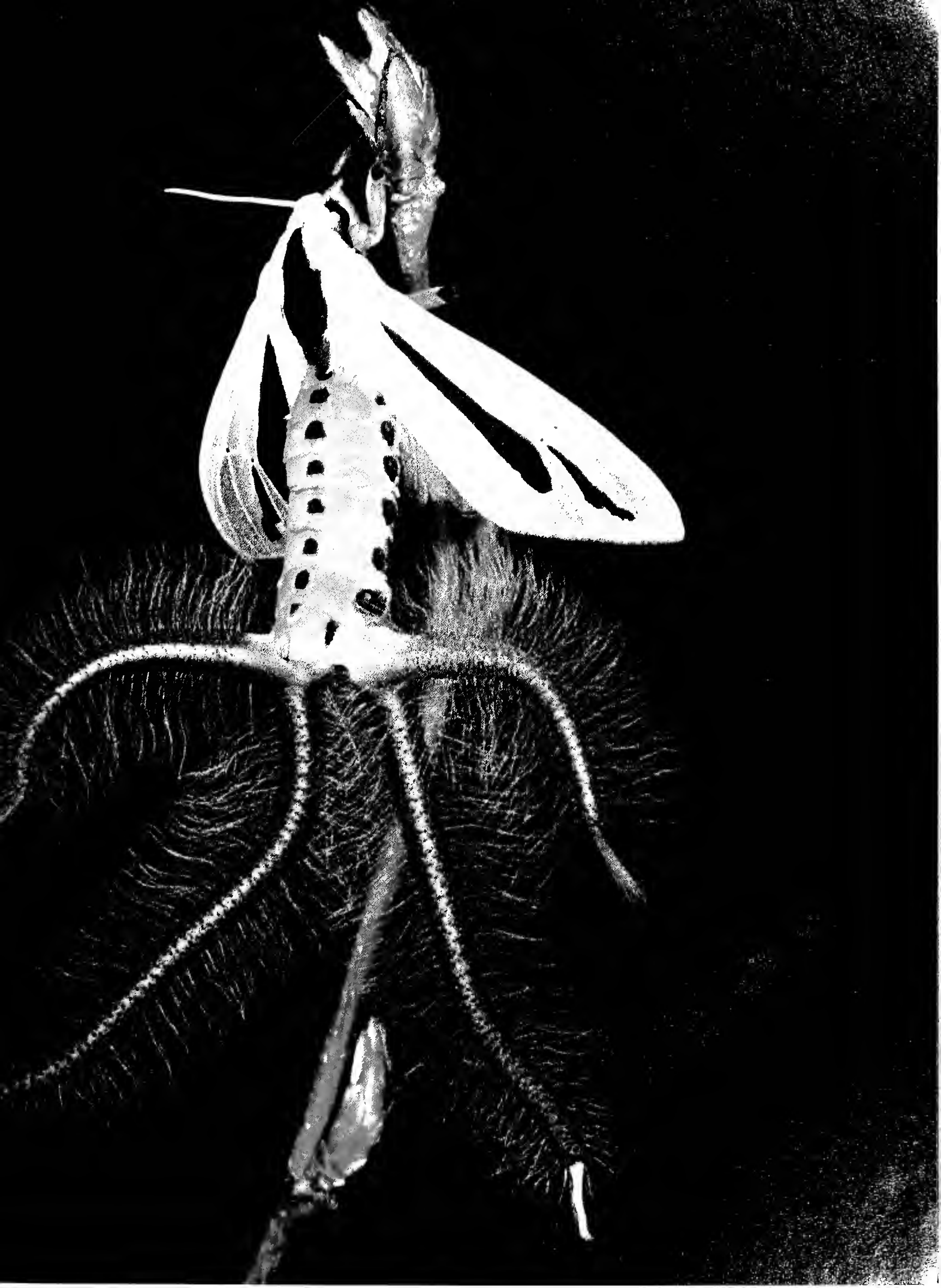
The dihydropyrrolizines of many danaines and *Creatonotos* are structurally identical, but their roles in influencing the behavior of conspecifics are quite different. In most butterflies and moths, males expand their scent organs only in the final phase of courtship, after the sexes have come together through sight (butterflies) or smell (moths). *Creatonotos* males, in contrast, display their organs for hours, starting at dawn, whether any females are around or not. The pheromones the males release appear to lure both females and males, leading to the establishment of mating aggregations, or leks. Since *Creatonotos* females also produce pheromones to lure males (as is typical among moths), the genus appears to use two markedly different means of bringing the sexes together.

We have not yet been able to conduct a detailed field study of these rare, nocturnal, and quite small moths, but one aspect of their biology has already added a fascinating element to the complex story of plant alkaloids and insects. In the field, some *Creatonotos* individuals have gigantic coremata, exceeding the insects' wingspan; others of the same species have

Male milkweed butterflies and male Creatonotos *moths use pyrrolizidine alkaloids for protection and in the synthesis of sex pheromones. The butterflies emit pheromones from glandular organs known as hairpencils, below. The size of a moth's scent organs, or coremata, right, depends on the amount of PAs it gathered as a larva.*
Photographs by Michael Boppré

coremata so tiny they are almost invisible; and yet others exhibit intermediate sizes. In the laboratory we have experimented with feeding *Creatonotos* larvae different amounts of pure PAs and have demonstrated a direct correlation: the more PAs a moth took up while it was a larva, the larger its coremata and the more PA-derived pheromone it produces. (No other part of the moth is affected by these dietary changes.)

Available phylogenetic evidence indicates that adaptations to utilize pyrrolizidine alkaloids evolved several times in various insect groups. Certain leaf beetles, grasshoppers, and chloropid flies, for instance, as well as numerous other species of butterflies and moths, seek out these chemicals independent of feeding. Experiments have demonstrated that these insects are attracted to the alkaloids, whether they are presented in the form of dry plants or laboratory dishes impregnated with the chemicals. Not all these insects possess male scent organs, so the chemicals' role as a pheromone precursor is limited, and not all insects that need them to produce pheromones use them in the same way in sexual communication. By improving their chances of survival and perhaps by increasing their reproductive success, however, all do better with PAs. For these insects at least, purloining plant poisons pays off. □



Young Lizards Can Be Bearable

In Australia, live-bearing skinks have evolved from egg layers. Why?

by Richard Shine

One of the reasons I was attracted to the study of lizards and snakes, rather than other kinds of animals, is that they generally like to stay in bed on cold mornings, just as I do. I thought that I wouldn't have to rise at dawn (like the bird watchers) or muck through muddy swamps at night (like the frog catchers) because Australian skinks come out into the woods and fields on sunny afternoons.

Unfortunately, as I discovered in the field, these common little lizards are so elusive after they have warmed up by midmorning that they are almost impossible to catch. Chilly mornings are the best time to pick them up as they lie, rigid with cold, under their nighttime logs. In the Brindabella Range of southeastern Australia, where I study and collect skinks, I imagined the kookaburra birds were mocking me with their annoying "laughter" as I turned over logs from first light until the sun's rays dispersed the morning fog. Each morning a few hours after dawn, I returned to my tent, with dew-soaked socks and chattering teeth, to boil the billy (kettle), change into dry clothes, and sit by the campfire gloating over the fruits of my morning's labors.

My prizes wouldn't have impressed most people. Every day I caught about twenty small, drab skinks, most of them less than six inches long. Why endure so many bone-numbing morns to collect these little creatures? Because to me they were objects of intrigue: I hoped that they might help me solve one of the great mysteries of reptilian reproduction.

All these unspectacular skinks may look very similar, but they include several species that are biologically very different. About half the Brindabella lizard species reproduce by laying eggs (oviparity); the other half, by giving birth to fully formed babies (viviparity). Those that lay eggs range from the elegant little elf skink, which lives under cool, moist logs, to the larger, three-lined skink, which basks in the open and rapidly sprints between snow grass tussocks when approached. The live bearers are all active in the daytime and are generally larger than the egg layers. Among them are two varieties of heavyset water skinks, confident lizards that are undisputed owners of large logs on the forest floor. As I approached, they would fix me with a baleful glare; but reluctant to move out of the warm sunlight, they were easily caught with a noose of fishing line at the end of a rod.

In all skinks, egg layers as well as live bearers, the females ovulate their large, yolky follicles in late springtime (November in Australia). These are immediately fertilized internally by sperm that they have stored either for a week or two (in spring-mating species) or throughout the entire winter (in autumn-mating species). Eggs are laid in a moist, protected site under a log or rock. In live-bearing species, the females retain membranous eggs without shells inside their oviducts.

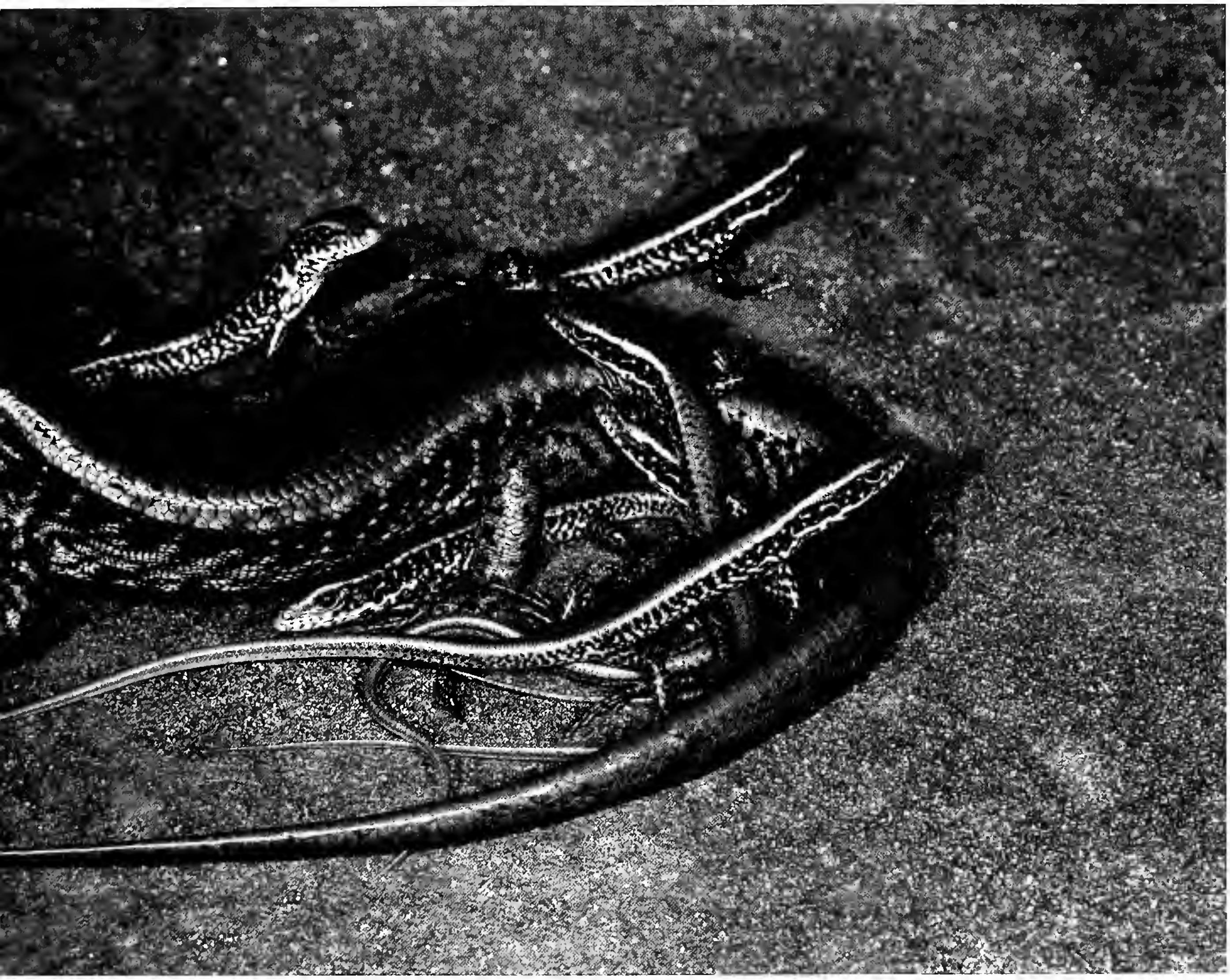
The soft, leathery shells of lizard eggs are much more permeable to water than are the brittle eggs of birds; thus, egg layers need to deposit their eggs in moist environments. Because of this water uptake, lizard eggs swell to twice their initial size as they develop. Since both types of eggs absorb water as the embryos grow, pregnant females of live-bearing species are grossly distended by the end of the gestation period.

By getting several pregnant females to run along miniature "lizard racetracks" in the laboratory, I was able to show that they are much slower runners than their nonpregnant counterparts, especially when close to birthing time. In laboratory trials, small, venomous white-lipped snakes—a common predator of the Brindabella skinks—were much better at catching pregnant lizards than nonpregnant ones. While these tests appear to confirm the self-evident (ask any pregnant woman how the last few weeks of pregnancy affect her mobility), they were the first of their kind. (Charles Darwin said he "loved a fool's experiment," because it is remarkable how often the "obvious truth" turns out to be wrong.)

I am continually amazed that lizards so similar in other ways—size, shape, color, diet, and general behavior—can differ so profoundly in the way they bring forth their young. When viviparous species omit an external egg stage, they also substantially increase the length of time during which a female must carry her developing young.

She pays a heavy price for this burden. Not only is she slower in outrunning predators and capturing prey, but her store of fat may be so reduced as to impair her reproductive ability the following year. Why should both egg laying and live bearing occur in otherwise similar species? My curiosity was piqued about the possible adaptive advantages of live bearing.

Ken Griffiths NHPA



An Australian lowland water skink, above, is surrounded by her brood of live-born babies. This species strongly asserts territorial claims to logs or basking spots. Left: A female western skink broods her eggs at Gardner Ridge, east of Brooking, Oregon.
Alan D. St. John

Australian blacksnake babies emerge fully formed from membranous "eggs," above, almost immediately after the female extrudes them. Common in the cool Brindabella Range, these venomous snakes prey on skinks. Collet's snake, right, a member of the same genus from a warmer habitat, lays shelled eggs that take two months to hatch.
Peter Harlow

Peter Harlow

A *pregnant female agama lizard from Africa is an egg layer. She carefully regulates her temperature by pushing her body away from the hot rock while she basks.*

Don W. Fawcett

What gains could justify the costs?

Both egg laying and live bearing can occur even within a single species, as in Bougaineville's skink, an almost limbless burrowing lizard from southeastern Australia. While mainland populations are egg layers, those on isolated southern islands produce their young alive. In some cases these islands are only a few miles off the coast, and the egg layers and live bearers live in very similar habitats. Studies have shown that the difference in reproductive modes is genetically determined and not subject to short-term change. Since egg laying in reptiles is believed to be the primitive, or ancestral, condition, the island populations must have evolved viviparity in fairly recent times—certainly since the last Ice Age.

When I combed the literature to find out how many times viviparity had been known to evolve within lizards and snakes, I found many more examples than I had expected: about a hundred separate origins of this characteristic. Furthermore, they occurred in a definite pattern.

In almost every part of the world where there are lizards and snakes, live bearers are the dominant type only in colder parts of their ranges. In the tropical rain forests of northern Australia, less than one-third of the lizard and snake species are live bearers, while the vast majority lay eggs. But in the cold and windy mountains of southern Australia, the proportion of live bearers rises to almost 100 percent of the indigenous reptiles. Among the few species that brave even colder habitats, including European adders inside the Arctic Circle, Canadian garter snakes in the frigid fields of Manitoba, or the small lizards that scurry across snowdrifts at 12,000-foot elevations in the Andes, all are viviparous. Almost *all* of the live bearers that are closely related to egg layers—presumably those that most recently evolved from them—are found in colder habitats.

Although viviparous species have evolved in many other animal groups besides reptiles, any correlation between their reproductive pattern and cold climates isn't apparent. In some cases, the reverse trend appears. Viviparous sharks and rays, for instance, tend to inhabit tropical or subtropical oceans, while egg-laying species live in cooler waters. Among amphibians, there are no clear correlations. Some European salamanders that live at low elevations are egg layers, while their high-elevation relatives produce well-developed offspring.

Viviparity has also evolved at least twice in tropical amphibians, where protection of the eggs against drying out may be the most important advantage for these animals. Oddly enough, cold climates have not led to viviparity in any species of birds, although such cold-adapted flightless birds as penguins would seem likely candidates. Mammals evolved viviparity only once—early among their egg-laying ancestry—and it eventually spread throughout almost the entire group. (Platypuses and echidnas are the only surviving egg-laying mammals.)

Reptiles aside, the number of times viviparity has evolved in living vertebrates is small—about ten instances in sharks and rays, a dozen in bony fishes, four in amphibians, one in mammals, and none in birds. Because the trait spread throughout mammalian lineages so long ago, we have lost any basis for a comparative study within that group.

With a hundred origins of viviparity in reptiles, however, we have at least some hope of finding a plausible explanation as to why this characteristic has evolved so often. Correlation with climate may provide a starting point. Why should reptiles show so many striking examples of evolving viviparity in colder habitats? Under cooler conditions, what factors could enable live-bearing reptiles to become more successful than their egg-laying cousins?

One answer was proposed more than fifty years ago by three scientists (Rudolf

Mell, Claire Weekes, and A. M. Sergeev) who had studied reptiles in three different countries (China, Australia, Russia) and published their results independently in three different languages (German, English, French). All had noticed that viviparity was more common in cold-climate reptiles, and each suggested that embryos developed inside the female would have better odds of surviving the cold.

Their explanation was that the pregnant female's warmth insures that the young develop not only more safely but also much more quickly. Whereas cold soil exposes eggs to dangerously low temperatures and the embryos develop slowly, eggs kept inside the female's body are warmed whenever she basks in the sunlight. Even when air and soil temperatures are close to freezing, many reptiles can keep their own body temperatures at about 85° F by judicious basking.

This idea is supported by the timing of lizard embryo development. In the Brindabellas, embryos of egg layers may spend as much as 50 percent of their development time in the mother's oviducts—about a third longer than in warmer habitats. After fertilization, oviparous females deposit a thick, calcareous shell around their eggs, and lay them from forty to sixty days later. Eggs laid during the Australian midsummer (December–January) in the mountains, where soil temperatures are low, develop slowly, and may hatch late in autumn (March-April). By contrast, viviparous females can keep their babies much warmer, so they develop more quickly. Live-bearing females usually give birth to living young in late summer (February) or early autumn (March), at least a month before the eggs of their oviparous cousins will hatch.

This head start for the young may be the most important advantage of viviparity. Babies born early have more time to grow before the onset of winter and more time to locate safe hibernation sites where they are less likely to freeze. Young lizards that emerge earlier can set up and defend territories against later arrivals. Also, being kept warm during incubation may result in the young being somehow "better"—perhaps larger or smaller or fatter or thinner or quicker or smarter. Fitness may involve all of these attributes at various times or at different stages of the life cycle—and it is always relative to the environment. Many aspects of an individual reptile's life are determined by the temperatures it experiences while still in the egg. Incubation temperatures can affect the animal's size, shape, color, basking behavior, agility, and strength. In all crocodilians, many turtles, and some lizards, incubation temperatures even determine the sex of the individual.

The oviparous skink Saproscincus mustelinum *with her eggs, right, and the viviparous species* Pseudemoia entrecasteauxii, *below, are abundant in many parts of the Australian high country.*

The lizards that I found during those frosty Brindabella mornings helped to confirm some of the earlier investigators' ideas. Pregnant females were slowed down by their babies, making them easier for predatory snakes to capture. Embryos that remained inside viviparous females were kept warmer, and did develop much faster than did eggs laid in natural nests under rocks and logs. Overall, this warming reduces the total incubation period by about one month. Without this accelerated development, eggs of most of the oviparous species would not have enough time to hatch before the onset of winters (at least in cooler years), and thus would be killed by freezing. Short summers may be the reason that so few species of oviparous reptiles reproduce successfully in very cold areas, where soil temperatures are favorable for only a brief period each year.

The data from the Brindabella skinks also supported my hunch that retaining eggs inside the female's body might directly influence the quality of the hatchlings. I checked this possibility by testing the development of eggs laid in captivity by oviparous skinks. I incubated some at normal (soil) temperatures, and others from the same clutch at hotter temperatures—simulating the warmth of a basking mother's oviducts. Compared with their siblings from cool-temperature incubation, the artificial viviparous babies were shorter, fatter, and generally less active, but were much faster runners when tested on my lizard racetracks. They also developed more quickly and hatched earlier. I carried out a similar experiment with one of the live-bearing species by giving some pregnant females access to more basking time, and again found that the higher temperatures affected the shape and behavior of the newborn lizard.

I still don't know if these characteristics of artificially warmed babies would help them survive any better or grow any faster in the wild. By marking and releasing lab-incubated young of both types and then recapturing them later, I hope to learn more. Meanwhile, my hopes of sleeping until midmorning have faded away, and I am resigned to enduring more dawn laughter from the Brindabella kookaburras. □

Among Whales

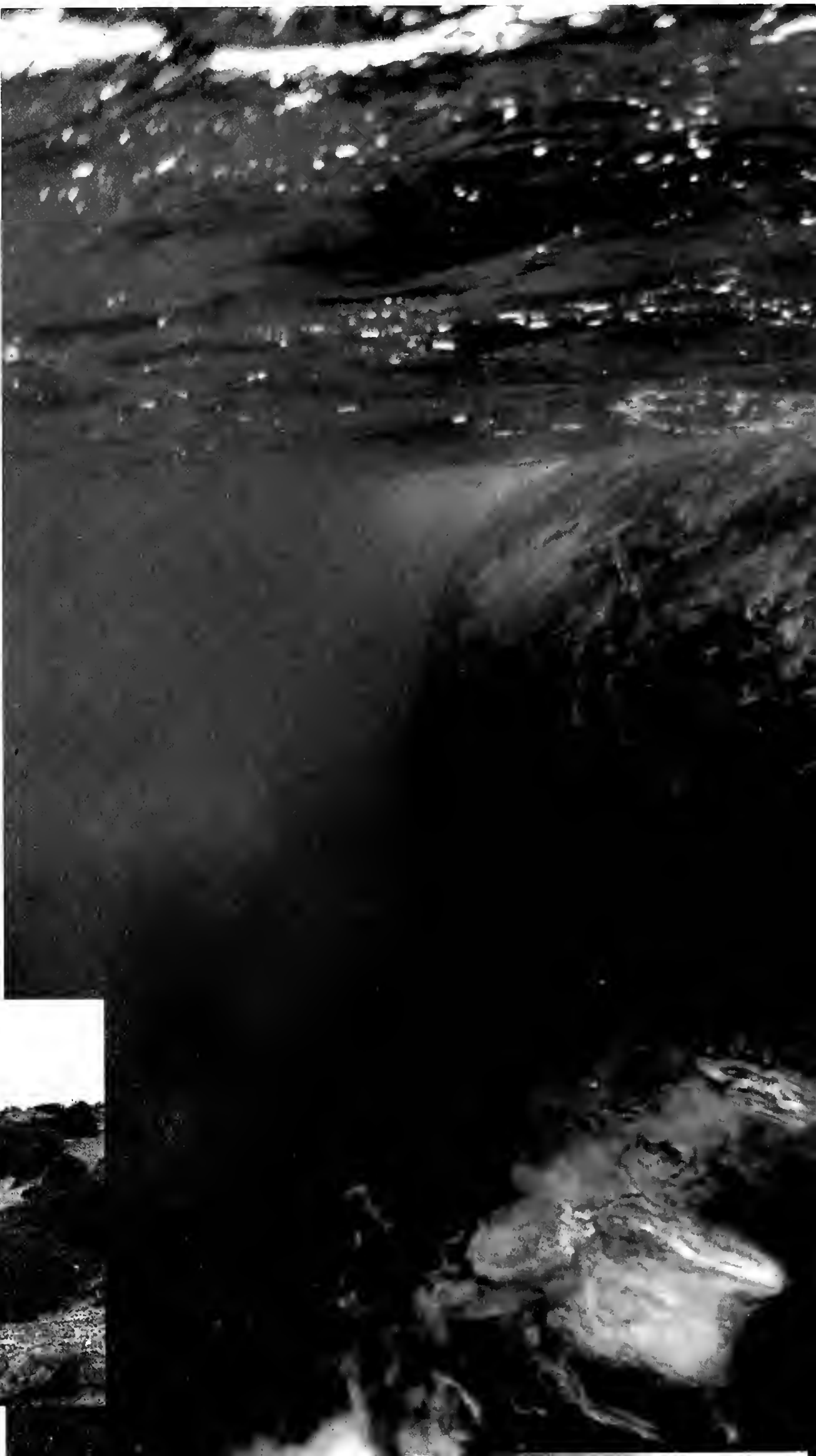
In the fall, southern right whales return to the waters off Patagonia to mate and raise their young

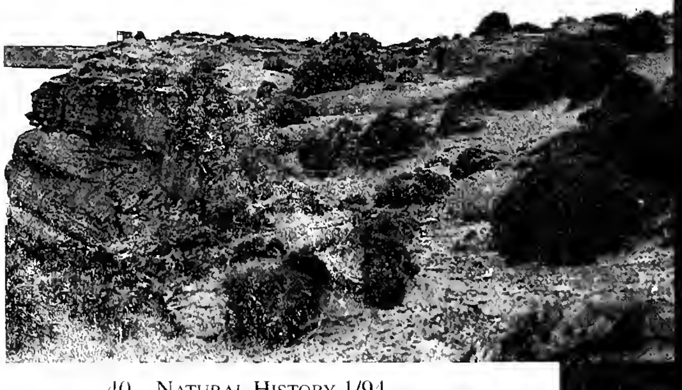
by Roger Payne

In 1970 I read about a sighting of twenty right whales along a little-traveled section of Argentine coastline called Peninsula Valdés (about halfway between Buenos Aires and Cape Horn). Because right whales were almost extinct before receiving protection in 1937, seeing several at once was a rare event.

I had never heard of Peninsula Valdés but noticed it was at the same latitude south of the equator that Cape Cod is in the north. I knew that right whales came to Cape Cod every year, even though they are rare. Peninsula Valdés's two nearly landlocked bays, Golfo San José on the north and Golfo Nuevo on the south, bear a striking similarity to Cape Cod Bay and Nantucket Sound; and the combined landforms of Cape Cod, Martha's Vineyard, and Nantucket are so like Peninsula Valdés that I wondered whether right whales might also be coming there each year. The New York Zoological Society, where I then worked, provided the funds to go investigate, and so, in late September 1970, I went to Argentina with an old friend, Oliver Brazier, and my then wife, Katharine Payne.

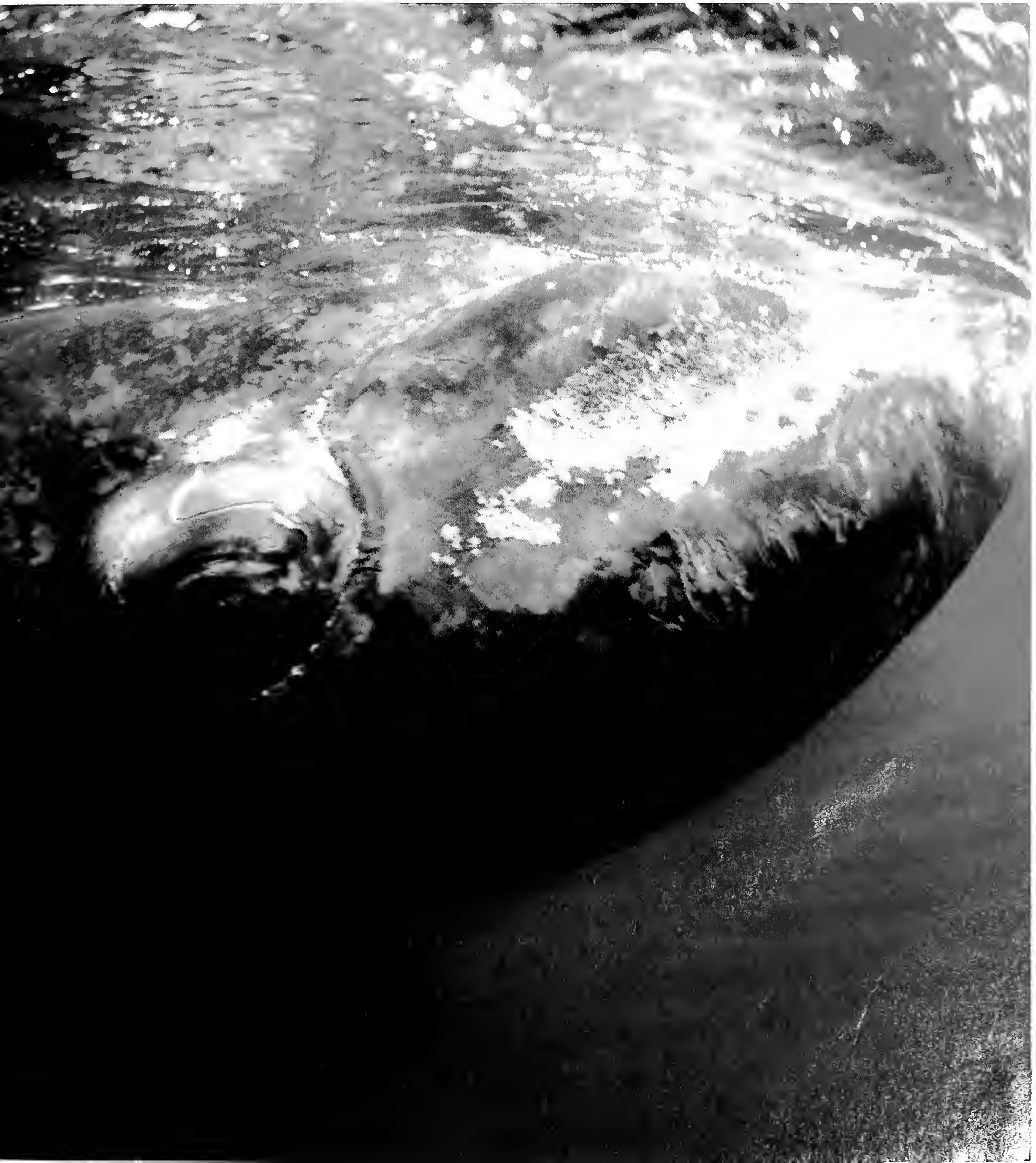
We drove from Buenos Aires to Rio Negro, the northern boundary of Patagonia, on what is now a paved highway (at the time it was a dirt track in places). Four days later we stood on the beach at Punta Norte, the northeast point of Peninsula Valdés. Three right whales were playing in the surf less than fifty feet offshore.





Lysa Leland

A subadult right whale, below, about twelve feet long, swims in the bay off Peninsula Valdés. Adult southern right whales can grow to fifty feet in length. Inset: The cliff hut observation point.
Flip Nicklin, Minden Pictures



In the days that followed, we found the peninsula to be one of the world's greatest comings-together of land, sea, and wildlife. The currents in the bays, which can reach six knots, are generated by tides that rise and fall as much as thirty feet—a tidal amplitude, the locals claim, second only to that in the Bay of Fundy. Albatrosses, petrels, shearwaters, fulmars, terns, and gulls ride the winds of the roaring forties, while penguins shuffle up beaches. We saw sea lion rookeries and elephant seal harems that stretched for thirty miles along the shore to where they dissolved in the distant heat shimmer. Elephant seals reared up as we approached, making loud, intimidating belches—an after-dinner noise of such exquisite vulgarity that even the most jaded eight-year-old boy could not have failed to be stunned with delight by them.

One morning one of our hosts—we were guests of the local tourist office—showed Katy a deserted beach in Golfo San José from which he had often seen whales. Later that afternoon we all visited the place. It was less than a mile long and flanked by tall cliffs that stretched along the coast to the north and west. I climbed the western cliffs and walked to a nearby headland, where we later established an observation hut. The wind had died, and the sun was setting in a spectacular display of colors. As the peace and stillness seeped into me, a whale started breaching far out in the bay, followed in the next few minutes by two others closer to shore. In all I counted thirty-two right whales.

I realized that we had discovered the ultimate place from which to study whales, a place where they came so close to shore that we could work from land and not disturb them. Neither would we have to raise enormous funds to support the costs of operating seagoing boats. Here we could even bring our four young children, and they would be safe, safe among whales.

The next year, with funds from the New York Zoological Society, we established a camp on the beach and later a permanent research station. Katy and I lived there for almost four years with our children, the most formative of their lives and our happiest as a family. It was the longest I have ever lived continuously in the wild, and this stretch of Patagonian coast became my heart's home.

Since we founded Whale Camp twenty-three years ago, I have returned to Peninsula Valdés every year between August and mid-November (with the exception of three seasons when others were present to do the work)—the longest continuous study of a whale species based on recog-

The right whale's baleen, left, allows it to filter copepods and krill from the sea. Here the whale is probably not feeding but skimming along the surface to cool off in the warm winter waters.
James D. Watt; Planet Earth Pictures

nized individuals. We can now identify more than 1,200 individuals. Some we have seen hundreds of times; others we have never seen again because they were either passing through or have subsequently died.

Nothing is more exciting than seeing the first whales arrive at Peninsula Valdés for the winter. Each year these whales make the long migration from the cold, subpolar waters of Antarctica to winter in Patagonia's warmer waters. Their enormous size and thick blubber are adaptations enabling them to keep warm enough and swim far enough to gain access to the most enormous blooms of food on the planet—the annual swarms of krill in the icy Antarctic Ocean—as well as to return to their warmer wintering grounds to mate and give birth to young.

The pregnant females in our Argentine population probably make the 1,400-mile swim without eating. They linger in the bays of Peninsula Valdés for up to four months, during which time they give birth to a calf. Although a mother may get an occasional snack, she is basically fasting. (Normally, right whales catch their prey by skim feeding; we've recently discovered, however, that the whales of Peninsula Valdés are not feeding when they swim along with their mouths open but are probably cooling off in the warm waters through a heat-exchange mechanism along the roof of the mouth.)

For months after her calf is born, a mother pumps massive quantities of rich, creamy milk into the calf, which may gain as much as 125 pounds a day—at least in the first few weeks—while also putting on a thick blubber coat. At the end of this period, the mother—still fasting—leaves the wintering grounds with her calf and swims all 1,400 miles back to the feeding grounds. We are still not certain that we have found the main summer copepod and krill basket for Peninsula Valdés's right whales (although South Georgia does look like a good bet, as do the waters around Tristan da Cunha).

We can watch the mothers and calves closely from our observation hut (called the cliff hut), located above the only place for miles where the cliffs plunge straight into the water. When the tide is halfway up the cliff or higher, the water is just deep enough for whales to swim directly below the hut. Mothers with calves faithfully follow the 16.5-foot-depth contour at Peninsula Valdés, (just deep enough for a large mother to be clear of the bottom but not enough to allow attacks on her calf from below by killer whales and sharks). They are creatures of habit and will swim to exactly the same area—even the same rock—year after year. Once they start having calves, they return to the bays of Peninsula Valdés once every three years. So while following the 16.5-foot contour, they swim along almost touching the cliffs. Hundreds of whale-sized underwater niches in the eroded hardpan along the shore provide shelter.

Satellite photographs of Cape Cod, top, and Peninsula Valdés show striking similarities in landforms.
Roger Payne

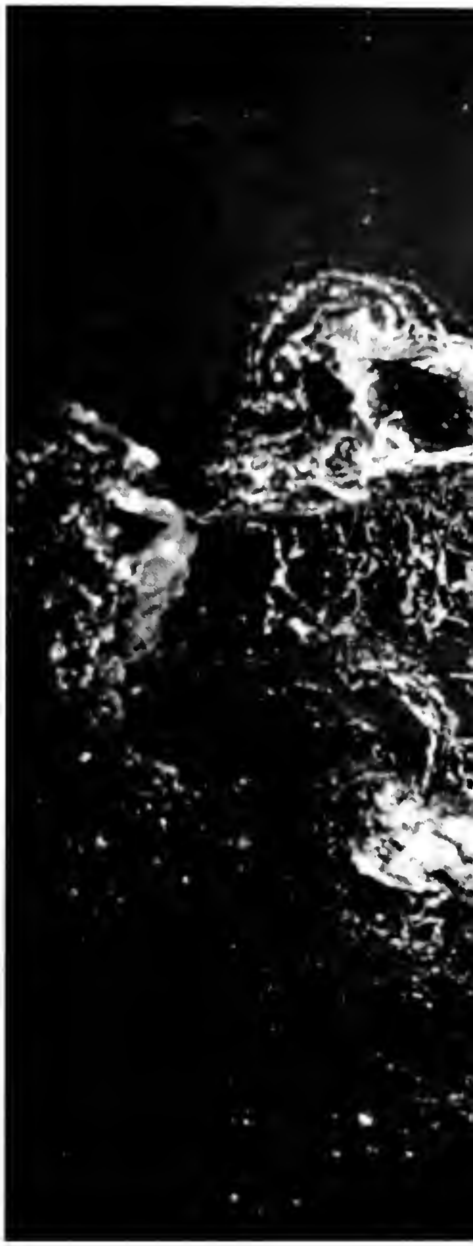
The places chosen by mother whales to defend their calves, unlike the niches where they hide, are open areas with soft, sandy bottoms and plenty of room on every side from which to launch cataclysmic haymakers. Right whales defend themselves with their tails, which they sweep sideways with stunning effect. (In this sense they are like the "undefended" apatosaurus now believed to have fought off attackers by sweeping them off their feet with its massive tail, perhaps even breaking or disjointing limbs in the process.) I suspect that if a person were struck by a right whale's tail, the blow might well be deadly.

I once watched a pack of killer whales move along a line of female right whales and their calves. As the orcas approached a mother and calf, the mother would flex her body, cocking her tail for a blow toward the closest killer whale. They never attacked. From the cliff hut, Katy observed a nearby group of mothers form a ring around the calves as killer whales passed nearby. With their heads directed toward the center of the circle, they thrashed the water frantically with their flukes. Had

Roger Payne

Old-time whalers referred to the callosities on the right whale's snout as the "bonnet," below. The unique patterns of these callosities identify individual whales. Right: Usually most of the individuals in a mating group, like the one here, are males in pursuit of a single female that is the center of attention.

Iain Kerr



any orca tried to get at the calves in the middle of the ring, it would probably have been killed outright.

Females with calves appear to form the center of the herd in our corner of the bay, but over the years—through observations from the cliffs, boats, and the air—we have been able to piece together other information about the herd's overall structure and movements. Joining the primary mother-calf unit are subadult males and females, whose mothers have given birth to new calves. After a few years of traveling with this group, however, young males disappear, perhaps going off to live with other males, while the females remain with the group until the year they give birth to their first calf, when they are between five and nine years of age. We don't know where the females go between calving years; we only know that they subsequently reappear every three years on average with a new calf.

Covering up to twelve miles in a day, the herd doesn't take up a station at just any point along the shore, but moves back and forth along a fixed and relatively small stretch of the coastline. Once established, the beat remains the same for years, usually between headlands projecting out from the general contour of the coast. This behavior makes sense given the underlying acoustics, as points of land cast underwater acoustic shadows, and we suspect that right whales use sound as a means of staying together in herds.

Along the most extensive sandy beaches of the peninsula, the mothers stretch out across the water each day like beads on a chain. Look at them in the morning, and the whole group appears stationary, a mother every half-mile or so. Look again at lunch time, and sometimes the entire herd has moved as much as six miles, but their spacing is still more or less intact. Females appear to help themselves to the best areas—a long beach, protected from the full force of wind and storm waves, with a gently sloping sand bottom—and to push everyone else out, which is just what seems to happen.

We have learned to identify individuals by callosities—patches of thickened skin distributed on the top, front, and sides of a whale's head—which make a whale recognizable from all directions except from below. Callosities tend to be more developed in males than females, and males seem to use their callosities for fighting, the way bulls use their horns—only not for gouging but for scraping opponents. Thousands of external parasites, called cyamids, or whale lice, cover the naturally gray callous tissue so thoroughly they make it look white. As the cyamids feed on the thickened, dead skin of the callosities, they sculpt the tissue into distinctive forms. Another way to identify individual whales is by their distinctive white belly markings. If we are diving in murky water, these bright white markings look almost luminous and are clearly visible long before the rest of the whale looms into view. Callosities and belly patches probably also enable the whales to identify and recognize one another.

Although the whales of Peninsula Valdés appear to be active day and night, mornings are their favored time for sleeping, and when the morning is especially calm and sunny, they are scattered throughout the bay like drifting logs, with the sounds of their snores filling the air. When their nostrils don't open and close cleanly, the snores sound like deep growls,

which, when heard at night, may sound scary to the uninitiated.

When a mother falls asleep in the shallows, the falling tide lowers her slowly toward the sea bed. Often her flippers dig deep into the sand before she wakes up and moves. This leaves obvious flipper impressions, which, if the day is calm, survive the falling tides so we often can walk out to where the whale was sleeping and admire her flipper prints. As we stand between them on the vast, draining tide flats, the scale of these marks is an eloquent statement of just how big the whales are.

Aside from these tranquil activities, the whales are engaged in courtship and mating when in residence at Peninsula Valdés. Surrounding the central core of mothers are groups of adult males, scattered widely about in the middle of the bay. They appear to be doing nothing except for engaging in occasional bouts of furious breaching—possible challenges to the group of males that has taken up a position closest to the coast and with the greatest access to the females. We do not yet know exactly what is going on, but perhaps the males nearest the shore help reduce the pressure from other males on the mothers with calves (thus increasing the chances that calves will not be injured).

There is no pair bonding, and on any given day a male may mate with several females. But since a female is slightly larger than a male, she can easily avoid unwanted mating attempts. Whales mate belly-to-belly, so one of the female's strategies is to swim into shallow water and scrape the male off on the bottom. Once, when a male managed to squeeze himself under a female in shallow water, I saw her flex her back dramatically so that her head and tail lifted out of the water into the air, bringing many tons of weight bearing down on top of him. He left.

Another strategy: Instead of lying belly up, the female puts her tail in the air, holding it there for minutes at a time. If the male is to mate with her in this position, he must put his tail into the air alongside hers. But without his tail to act as a propeller, he can't swim. He has to use his flippers to drag his whole body, held in a vertical, head-down position, around her as he tries to achieve proper alignment with her. Meanwhile, she simply revolves slowly about her own long axis, keeping her ventral slit just out of reach, and when she needs to breathe, she slips off to one side and grabs a few breaths. Whenever a persistent male tries to get beneath her, she rolls forward and raises her tail into the air once again.

A male's testes weigh 2,200 pounds, making them the largest on earth (and particularly impressive when compared with the 150-pound testes of the blue whale, the largest animal in the world). Presumably such large testicles have evolved because

Flip Nicklin; Minden Pictures

A mother and large calf rest in shallow water, below. A right whale, opposite, breaches off Peninsula Valdés.

Roger Payne

of the right whale's mating system, in which multiple males compete to inseminate the female. The one who gets the most sperm into the female will have the best chance of being the father of a calf.

Yet by cooperating rather than competing, males gain at least some chance of mating with a female. In our bay, we have seen groups of males stay together for periods of at least six weeks. We are not sure yet how they are related or how they got together in the first place, but we have watched such groups try to push a female, who was lying belly up and inaccessible, under the water so one of them could mate with her.

We suspect that many of the groups are made up of related males. In a group of brothers, even if one whale gets less than his rightful share of successful matings, he still shares roughly half the genes that his more successful brother passed along to the next generation. If groups of related males are thus favored, this would explain why every year, for three years, some young males return to the same breeding areas to gather with their brothers.

We've also noticed that while a mother discourages her calf from playing (because the mother has to provide all of the calf's caloric intake at a time when she is fasting), she will allow her calf to play with subadults, at least some of which are her calves from previous years. In this way, two related males can get to know each other so that later, when both are sexually mature, they may become members of the same mating group.

The sense of tranquillity, of life without urgency, power without aggression, has won my heart to whales. One time I watched a mother frustrate her calf's attempts at nursing by moving into shallow water where the calf could not get underneath her to nurse—just the way she would lead a male into water too shallow for him to fit beneath her. The calf still pestered her, so she rolled on her back, easing herself under the calf and cradling it in her flippers. She then came up from below, stranding the calf high and dry on her chest, and patting it slowly.

As the season at Peninsula Valdés nears its end, the right whales ease themselves out through the entrance to Golfo San José, perhaps to rendezvous briefly with companions and acquaintances at Punta Norte and then set out across the vast South Atlantic toward either South Georgia or Tristan da Cunha. I always wonder if I will see them again and what revelations I will be privileged to witness. □

Thousands of Mexican free-tailed bats emerge at dusk from a cave entrance at Carlsbad Caverns National Park, New Mexico.
John Cancalosi

Wings on Their Fingers

Despite 50 million years of evolution, bats don't become expert fliers overnight

by Rick A. Adams and Scott C. Pedersen

As the sun sets, we approach the exit hole of a maternity colony of little brown bats (*Myotis lucifugus*) that has taken up residence in the historic armory at Fort Laramie, Wyoming. This colony contains only females and young; the males gather in bachelor colonies several miles away. A few feet from the hole in the building's wall, we block the bats' exit path with our harp trap, a large metal frame vertically strung with more than two hundred wires spaced an inch apart.

At dusk, several adult bats leave the colony to begin their nightly insect hunt. The first flies toward the trap, stops in midair, hovers, deftly backs away, and escapes capture. A second adult quickly folds up into a cannonball, barrels forcefully between the wires, then flies away on the wind. Another slips through sideways, its wings perpendicular to the ground. Barely tapping the wires, it leaves us amazed at its split-second timing and acrobatic skills.

Moments later, a juvenile exiting the colony awkwardly attempts an evasive maneuver, but hits the trap and drops gently into a capture sack below. In quick succession, several other juveniles tumble out of the exit hole, only to join their clumsy comrade in the sack. Within a few minutes, we have bagged a dozen surprised, but unharmed, juvenile little brown bats.

Bats, the only true flying mammals, are thought to have evolved more than 50 million years ago, during the Eocene period, from an insectivorous ancestor related to moles and shrews. Anatomists have known for at least three hundred years that a bat's wing contains finger bones of the same form, number, and relative position as those of the human hand. The scientific name for this mammalian order is Chiroptera (hand-wing), implying that the bat's wing differs from other mammals' forelimbs only in shape and proportion. Indeed, each wing is composed of an elongated forearm and, except for the thumb, extremely long fingers sandwiched between two thin sheets of skin. The diminutive thumb is left free. Elastic webbing connects the fingers to one another and

Bill Beatty

Not yet able to fly, a juvenile little brown bat, left, clings head-up to a tree trunk. When landing, older bats execute a flip that allows them to hang from their feet. Magnified ten times, a stained embryo of a little brown bat, below, about thirty-five days old, shows early bone development. Cartilage appears in blue and bone in red. Fingers have begun to elongate for their eventual function as wing struts.
Rick A. Adams and Scott C. Pedersen

then to the body, forming a broad wing surface. A similar membrane spreads between the legs and tail, completing an air foil that surrounds the entire body. Most insect-eating bat species strike the insects with their wings, then grasp the stunned prey with their feet.

Juveniles are not as agile or maneuverable as adult bats. One reason, of course, is simply inexperience, but restrictions associated with growth and development also handicap young fliers. Bats first attempt to fly when they are about four weeks old, but their wings are still underdeveloped. In some species, including most insectivorous bats, youngsters have only about 20 percent of the adult wingspan. Yet in four weeks, the rest of the juvenile's body may have reached 60 percent of the adult size. This imbalanced development leaves the young in a precarious situation, for their early flights are awkward at best. In fact, it is not uncommon at our maternity site to observe what appear to be very disgruntled young bats *walking* back to the roost after having apparently, for whatever reason, given up on flying for that night. Their wings reach full size about forty to fifty days after birth.

A bat's ability to fly is preceded by a long process that begins well before it is born. Although some researchers have studied the development of flight in bats, little work had been done on bone formation in their wings. By focusing on the growth studies, we hope to shed light on the diversity and plasticity of the ancestral vertebrate body plan: four limbs, each ending in five digits. We are interested in the unique developmental events that allow bats to transform an otherwise "standard issue" mammalian embryo into an airborne acro-*bat*.

To observe growth rates and the differentiation of anatomical structures in preserved embryos, we used special chemical stains that migrate to different kinds of tissues, a technique that had not previously been applied to the little brown bat. Alcian blue combines with certain sugars (mucopolysaccharides) in the developing cartilage, while alizarine red lodges in the calcium found in developing bone. After staining, the embryo is "cleared" using an enzyme (usually trypsin) that digests much of the remaining skin, muscle, and connective tissue. Now the embryo specimen becomes translucent, allowing a clear view of the stained bones and cartilages. The final preparation is rather like a three-dimensional, color version of an X-ray image.

In mammals, most skeletal elements begin as cartilage "models," or precursors of adult structures. As each bone develops, the cartilage becomes infused with calcium salts that will eventually form a hard, hollow matrix. As more salts are deposited, the cartilage is eventually replaced by ossified calcium, at which point the bone stops growing.

Most bats develop in utero for about fifty to sixty days, but we began to see significant developments in the skeleton

Stephen Dalton, NHPA

A roosting little brown bat, below, exposes its daggerlike teeth, evolved for crunching the exoskeletons of insects. Right: A mouse flees from a dive-bombing false vampire bat, a Southeast Asian species. Bats that feed on small mammals have stronger wings than do insect-eating bats but are less versatile aerial acrobats.

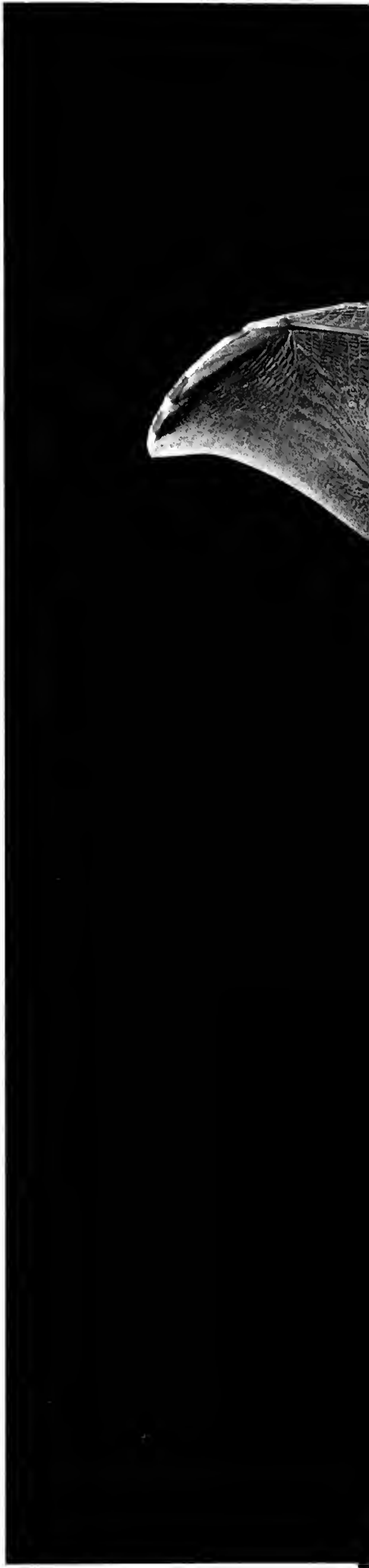
Wayne Lankinen; Bruce Coleman, Inc.

about thirty-five days after fertilization. At this stage, the cartilaginous model for the entire skeletal system had already formed. In fact, some calcification had begun in the lower jaw (dentary) and collar bone (clavicle), as indicated by their absorption of red stain. The embryo's eyes, which had long been apparent as small black dots, now appeared as larger, hollow spheres. Its mitten-shaped, cartilaginous hands with incipient models of each finger were also visible. The hand was about one-third the size of the head, which is about average for many mammalian species at this stage. No features indicated that this embryo was to become a flying mammal.

Only near the beginning of the third trimester, about forty days into gestation, did the fetus begin to appear distinctly "batlike." As development continued, the fingers grew at an accelerated rate that outpaced that of the body—the first indication of the formation of wings. We could now see bone at the centers of the limbs; it would continue to be deposited outward toward both ends, which is typical for mammals. At this stage, we also saw calcification of the cartilaginous ribs, scapula, and the spine.

Dramatic changes now took place in the fingers, which continued their accelerated growth until, just before birth, they exceeded the length of the forearm. At the end of the third trimester, the feet were almost fully developed; the toes and thumbs had grown claws. These little hooks will allow the juvenile bat to cling to its mother's fur immediately after birth. In a few more days, a newborn can hang from its feet in the roost while its mother leaves the colony to feed.

Although the most striking feature of bats is certainly their wings, other anatomical features show a unique pattern of growth. The timing of their dental development, for instance, is different from that of most other mammals. Their highly recurved milk teeth, which are apparent prenatally, are probably adapted for grasping the mother's nipple while suckling. Whereas most mammals retain their milk teeth for months, some bat species lose these teeth soon after birth and have adult dentition even before they are weaned. In other species, the process begins before birth. The molars that really grind the food, and do not have milk teeth precursors, typically begin erupting in utero. This early start may mean the difference between life and death for young bats by



A moth attempts an evasive movement as an echolocating greater horseshoe bat approaches. The bone development of these bats, which are native to Europe, Asia, and North Africa, is adapted for maneuverability in flight.
Stephen Dalton NHPA

allowing them to ingest an adult diet almost as soon as they begin flying. By contrast, young mice must eat a soft diet for some time until their adult teeth come in.

As the juveniles begin to be weaned, both their teeth and wings develop enough to allow attempts at hunting insects in flight. About a week after they begin flying, they shift to the adult diet of moths, flies, and beetles. Now their teeth are capable of masticating food, but young bats' ability to capture prey remains limited by underdeveloped wings and inexperience.

During the three weeks after birth and just before its first flight, a juvenile bat's wings develop faster than they did in the prepartum period. At the time of their first flight, the wingspan of a little brown bat may be only 20 percent of an average adult's.

Because they receive elaborate parental care in the maternal roost, most newborn bats survive the first few weeks of life. After juveniles begin to take flight, however, the mortality rate soars, and most do not make it through the first year. Because a growing bat's wings change somewhat in size and shape practically every time it attempts to fly, there are subtle but noticeable changes in wing performance.

If someone were continually changing your car's power and cornering ability while you were learning to drive, you can imagine how difficult it would be to avoid disaster. An analogous situation exists for young, newly flying bats.

Among insectivorous species, the young must quickly become capable of capturing enough insects to fuel a heart rate that exceeds 1,100 beats per minute in flight. When grounded because of exhaustion or poor flight skills, the young are soon gobbled up by raccoons, skunks, snakes, or coyotes. But even though "development on the wing" is a highly precarious adventure, more than nine hundred different species of bats have evolved throughout the world—about 25 percent of all living mammalian species. With all its perils and improbabilities, "batness" has been a tremendously successful endeavor for these mammals. □

Microdon piperi *flies develop within small chambers called puparia, below, formed from the skin of the flies' last larval stage. A scanning electron micrograph, right, reveals the intricately sculptured surface of the larval skin.*
Photographs by Gregory Paulson

A Fly in Ant's Clothing

Beware of larval imposters

by Gregory Paulson and Roger D. Akre

As the sun rises, the dull thud of an ax echoes through a valley in northern Idaho. A group of elk, startled by the sound, begin to move purposefully toward the forest, when the sudden roar of a chain saw sends them headlong toward the shelter of the trees. The cause of this commotion is not another logging operation; rather, it is our research team in search of *Microdon*—the subject of our long-term study. *Microdon* are syrphid flies, also known as flower or hover flies, and they live most of their lives in the nests of social insects. Although some tropical *Microdon* live with wasps, the North American species we study are associated only with ants. We have gathered them from colonies of carpenter ants and from the nests of *Formica* ants in stumps and logs. Hence the need for our sophisticated collection equipment: an ax, a pry bar, and a chain saw.

Most of our collecting expeditions have been carried out in the northwestern United States, particularly in northern Idaho. We have also "stalked" *Microdon* in the Midwest, from the Black Hills of South Dakota to the forests of northern Minnesota. While *Microdon* are fairly easy to find once you know exactly where to look, they are not common. This probably holds true for most inquilines, insects that reside in the nests of other insects. Most have a parasitic or predatory symbiotic relationship with their hosts. Their strategy is to live in the midst of their hosts—and subtly live off them—without being detected.

Each year we begin our studies as soon as the snow melts. Mature *Microdon* larvae overwinter deep within the ant nest. In spring, they move to the surface of the nest to pupate. This is when they are easiest to find and extract. If the ant colony is within a decayed stump or log, as is frequently the case, the larvae and pupae will be readily visible when the wood is split open with an ax or pry bar. *Microdon*, like all "higher" flies, pupate within a chamber, or puparium, formed from the skin of the final larval stage. The larvae secrete a glue that tightly bonds with the wood and holds the puparium in place as the pupa develops and, later, as the adult emerges. Adult *Microdon* are quite hairy and range from gray to orange depending on the species. *Microdon piperi* adults are a striking metallic green and are strong and agile fliers. They live only long enough to mate and lay eggs, often in the same nest from which they themselves emerged. We are most intrigued, however, not by the beautiful adults, but by the biology, morphology, and behavior of the immature forms of *Microdon*.

Perhaps because of their sluglike appearance, *Microdon* larvae were at first misidentified as mollusks and later as scale insects; their true identity as flies was not revealed until the 1880s. How they survive was long debated, but since the 1970s, scientists have known that some species prey on ant larvae. The extent and the exact mode of predation were unknown until 1985, when one of the larval strategies came to light.

In an experiment, William Garnett, of the University of Cincinnati, placed many first instars (the first of three larval stages) in a glass-sided observation nest complete with host ants and their brood. Previously, most entomologists had thought that the first instars dispersed immediately upon hatching, settling deep within the ant nest. In this experiment, most of the larvae under observation had disappeared and were thought to be dead. One remained, however, and at about 1/32 inch long was visible only through a dissecting microscope. It was clinging to the outer surface of an ant cocoon. The magnification revealed the larva becoming rounder and rounder, as if it were exerting pressure to distort its shape. Suddenly, it was simply gone. A little time and deductive reasoning led to the conclusion that the larva had inserted its mouth hooks into the silken cocoon and created a hole large enough to allow it to enter. When the instar had exerted enough pressure and the hole was large enough, the larva quickly popped inside (and a new term, "pupa popping," was coined). The disappearing larvae were simply inside the cocoons, feeding on the

A larval Microdon, *mimicking an ant larva, is grasped by an adult* Formica *ant, to be carried away for safekeeping. The papery cocoon just under the* Microdon *holds an ant pupa.*
Roger D. Akre

ant pupae and molting into the next larval stage. The discovery of pupa popping proved invaluable to our work. It explained why newly hatched *Microdon* had rarely been found before in the field and provided us with an efficient method of locating them. Now, instead of searching for the fly larvae as we had in the past, we concentrate on collecting ant cocoons, which can be carefully opened in the lab to see if they contain *Microdon.*

Microdon larvae, especially later stages, also feed on ant larvae, moving freely about the ant brood chamber as they do so. One day, some of the *Microdon* larvae that we had exposed in a tree stump provided us with another surprise. We saw these instars fold themselves lengthwise until they were practically indistinguishable from ant cocoons. After this transformation, agitated worker ants arrived, seized the impostor young, and carried them to the safe depths of the nest. We had discovered a most unusual case of aggressive mimicry. The ants perceived the fly larvae to be ant cocoons. The prey was tricked into protecting the predator.

How were the *Microdon* able to accomplish this feat? Chemical communication is important in ants, so we thought that this deception might be chemically based. Tests carried out by U. S. Department of Agriculture entomologist Ralph Howard showed that the chemistry of the outer, hard cuticle of the larval flies and that of the larval ants matched almost perfectly. On the outside, the flies were chemical mimics of the ant larvae. The ants merely mistook the folded *Microdon* for their own developing offspring and transported them to safety. Subsequently, we watched for and observed this subterfuge many times. We also saw ants carrying aggregates—whole clumps—of *Microdon* larvae, just as they often grasp and transport aggregates rather than single larvae of their own species.

We wanted to find out if *Microdon* acquired these recognition chemicals from eating ant larvae or if they synthesized the chemicals within their own bodies. To answer this question, we studied *Microdon albicomatus* and one of its host ants, *Myrmica incompleta.* In the spring of 1989, we collected 235 fly larvae; we washed some in a solvent to extract the chemicals for analysis and kept more than a hundred others alive for radioisotope testing. The chemical analyses confirmed that the chemicals on the surface of the *Microdon* matched those of its host, and radioisotope labeling revealed that a larva did indeed synthesize the chemicals to match those of its host—a case of true chemical mimicry. This chemical defense is employed only by *Microdon* larvae; adult flies are readily attacked and killed by the ants. The adults' defense is solely behavioral. They pupate near the nest surface so that they can make a quick getaway, and they tend to emerge early in the morning when worker ants—especially carpenter ants, which are largely nocturnal—are least active.

We know that many species of *Microdon* are host specific, that is, they reside with just one type of ant, but some can be found with two or even three different hosts. *Microdon albicomatus,* for example, has turned up in nests of several species of *Formica* ants, as well as in colonies of the unrelated genus *Myrmica.* We are still trying to unravel the relationships that occur with multihost *Microdon* and to determine if these insects can change their recognition chemicals in response to a change in host.

Microdon larvae have a topography of odd structures covering the back of their sluglike bodies. Most highly developed and visible on mature, third-larval instars, some of these structures look like toadstools, others like flowers, and still others are beyond analogy. On the underside of the larvae are other elaborate protuberances, some of which remind us of the "Schmoos" created by Al Capp in his comic strip Li'l Abner. Although these structures have long been known, their function has not. We now suspect that they contain glands or glandular openings for secreting the chemicals that the larvae use to mimic their hosts. Since the surface is so convoluted, it would also present an enormous area for the dispersion of these chemicals. The reticulations may also physically deter attacks from the host ants. Yet another possible function is as a receptor system for chemical signals from the ant larvae or from the adult ants.

For all our educated guesses as to the secrets of these structures, perhaps just as appealing is the suggestion made by the European entomologist E. Heckt in 1912 that they are "a result of an exuberance of forms, which overrides with élan the borders of the purely necessary forms." That exuberance and élan can be perceived in a larva is hardly more surprising than the recently discovered chemical and behavioral ploys displayed by *Microdon.*

Gregory Paulson is an instructor in the Program in Biology and Roger D. Akre is a professor in the Department of Entomology at Washington State University in Pullman, Washington.

Spring in the Air

Sooner or later, scientists will get the message

by Roger L. Welsch

As I understand it, scientists watch for natural patterns and then try to determine exactly how they work and what they mean. Not that scientists are the only people capable of spotting bits and pieces of these patterns, which are often widespread. Take gravity, for example. Not easy to miss gravity. After all, it's not as if Newton invented gravity. Cave dwellers had to deal with gravity. Trilobites had to deal with gravity.

Recently I've had to deal with springs (boing-boing springs, not trickle-trickle springs). Springs have suddenly and dramatically inserted themselves in my life. Like the troglodyte or trilobite contemplating gravity, I have had the uncomfortable problem, therefore, of sensing a pattern without being able to pin it down. See what you can do with my raw data and maybe someday they'll name a syndrome after you.

It all started one morning when I was in my shop working on a tractor transmission. I studied the technical manual in detail; I looked at the housing, levers, gears, and rods carefully and from every angle; I proceeded slowly and cautiously. The problem is, when it comes right down to it, I don't know anything about mechanical things, so in my case all of these precautions are bottom-line necessities.

Whoever wrote the technical manual must have taken his degree in the works of Jean-Paul Sartre. Nothing was obvious, even when it appeared to be obvious. My suspicions were aroused by the line in the manual that said, "Be careful not to lose the detente spring and ball." Maybe I was tipped off because the statement seemed clear and straightforward. Right—don't lose the detente spring and ball. Made sense to me. But hey, wait a minute. In the chapter on engines, the book doesn't say, "Don't lose the pistons," even though pistons are fairly important components of an engine. I know *that* much about mechanical things. So why go to the trouble of mentioning that I shouldn't lose the detente spring and ball? For that matter, what is a detente spring and ball?

I looked at the accompanying diagram. An arrow numbered 46 pointed in the general direction of precisely where I was working in the transmission. Number 46 in the list said "detente spring and ball." I checked the book's index; nothing about detente springs or balls. Gently I eased out the shaft that obscured the location, insofar as I could tell, of the detente spring and ball. So far, so good. I used a little mirror on a flexible handle to see if I could find anything resembling a spring and ball. Nothing. It had to be inside something else, maybe behind the shaft. I eased the shaft out a little farther. Still nothing. I slid the shaft another quarter of an inch.

And then it happened. I heard an ever-so-tiny ping and just out of the corner of my eye sensed—I didn't actually *see* it, only sensed it—something very small flying at great speed out of the transmission case, straight out the open window six feet to my right, and into the two-foot-high grass. I didn't need the manual to tell me what it was.

I had no more than sputtered, "Well, I'll be dipped in..." when my astonishment was enhanced by the roar of my daughter Antonia riding by my shop window on our riding mower, throwing mangled grass—and presumably one detente spring and one detente ball—in every direction.

I suppose a skeptical spirit would consider all that a coincidence: "Big deal, you lost a spring and ball, it flew out the window, and your daughter ran over it with a mower. You're not going to get a law of physics out of that, Welsch." Well, I'm not done with the story.

The next day I went to Kerry's grocery store after picking up the mail, but to my surprise, Kerry hadn't opened yet. I sat on his doorstep waiting almost a quarter of an hour before he finally came rushing up. Here, verbatim, is what he told me:

"Sorry I'm late, Rog. I can't believe my bad luck. I borrowed a lawn sprinkler from Dad yesterday. Of course he asked me if I knew how to use it, and of course I told him I'd have to be an idiot not to. You know, it's one of the 'chuck-chuck-chuck-chuck...sizzle-sizzle-sizzle' ones." Pivoting on his right foot, his right arm extended, Kerry imitated a sprinkler jerking step-by-step in one direction and then quickly sweeping back.

"Well," Kerry continued, "I wanted to adjust it so it would cover the yard but not hit the house, so I was prying away at this little lever thing under the sprinkler head and all at once, PING..." and Kerry's forefinger described an arc I knew all too well. "This spring-thing flew about thirty feet out into the weeds. I just came back from Maurie Flembeck's place, because I heard he has a metal detector. If I don't find that blasted spring before tonight, my dad is going to kill me."

Right. "Just another coincidence." Still not convinced? Later that same day I was talking with my brother-in-law Gary and I told him what had happened to Kerry and me. And he told me about the time he was sitting out in a boat blind with Mick the Brick(layer) waiting for some ducks to come within range. Mick was showing him how you have to depress a little pin inside the chamber of certain shotguns before you can slide the bolt out, and.... See? You've spotted the pattern too. That's right: a ping, a flash of light, and a little plunk in the water about thirty feet from the boat.

I called up Mick to see what he had to say about the events Gary had described, and to verify my impression of an immutable pattern and potential law of physics. Mick confirmed Gary's account, but even more to the point, he told me about the time in Marine boot camp when the drill instructor was in the middle of a lecture on how to dismantle some weapon or another and said, "Whatever you do, ladies"—that's the way DIs talk—"*whatever you do,* be sure you keep your thumb on that little slot right in front of the set screw, because if you don't..." and at that point a spring leaped from beneath the thumb of the poor unfortunate sitting next to Mick.

Mick used the very same word Kerry, Gary, and I had used—"ping"—and with his hand he described the lightning arc. Except in this case, since there were no weeds, grass, or water for it to land in, the spring found its way to the ceiling, directly to a twelve-foot-long fluorescent light bulb immediately over the drill instructor's head. Mick says that even before some of the little pieces of glass had stopped rocking on the concrete floor, the DI hoisted the miserable miscreant by his collar and dragged him from the building, never to be seen again. "He's probably still carrying buckets of sand from one end of the camp to the other, even these twenty years later," Mick said.

I think it is pretty clear: springs are not simply coils of metal capable of storing small amounts of energy for later release. There is substantial reason to believe, in my opinion, that springs can think. They do think. And their thoughts are consistent and malevolent.

Scientists continue to turn their giant telescopes, antennas, and radiotelescope dishes toward space, waiting for a sign, a message, a clue that intelligent life exists "out there." I predict that sooner or later one of them will be adjusting the digital calibration retainer or, for that matter, trying to fix a cheap ball-point pen, and will see the sign, hear the message, or sense the clue he or she had looked for in the inky blackness of outer space: "Ping!"

In fact, didn't I read somewhere that the last message from the *Mars Observer* was "Ping"?

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

At the American Museum of Natural History

The Accelerating Global Crisis

Environmental and demographic issues in the next century will be the subject of a free talk by Paul M. Kennedy, the J. Richardson Dilworth Professor of History at Yale University and author of *Preparing for the Twenty-First Century*. The lecture, the first of a four-part, Tuesday-evening series, will take place on January 18, at 7:30 P.M., in the Main Auditorium of the Museum. Other topics in this series include the rise of global cities on January 25; the role of ethnicity, religion, and nationalism on February 15; and the prospects for global renewal on February 22.

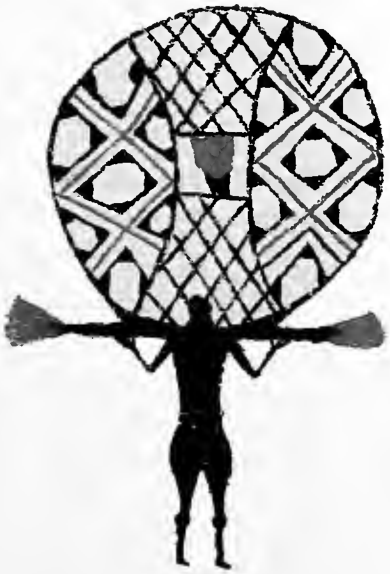
In "Undesirable Elements," the eight members of Ping Chong and Company will dramatize their experiences of having been born in one culture and now finding themselves in another. The program will be presented on Sunday, January 23, at 2:00 and 4:00 P.M., in the Kaufmann Theater. Call (212) 769-5315 for information about this and other free events that are part of the Museum's year-long program, "Global Cultures in a Changing World."

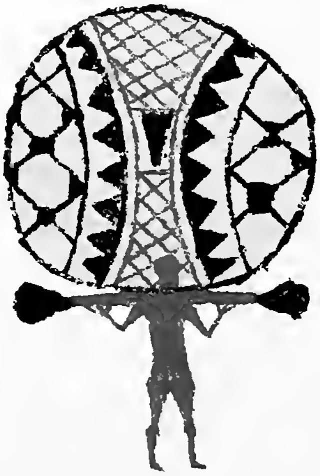
Supernovas and Star Formations

The life cycles of stars and the links between stellar death and the creation of life in the universe will be discussed by Catherine Garmany, of the University of Colorado's Joint Institute for Laboratory Astrophysics. The lecture, part of the "Frontiers in Astronomy and Astrophysics" series, will be held on Monday, January 10, at 7:30 P.M. Tickets are $8 ($6 for members). For information about this and other Planetarium events, call (212) 769-5900.

Sea Monsters During the Age of Dinosaurs

Gigantic aquatic reptiles that lived 245 million years ago and were the world's largest predators will be the subject of a talk on Thursday, January 27, by paleontologist Judy Massare, professor of earth science at SUNY Brockport. This lecture will be held at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for information.





Drawings by Waurá Indians of two masks, a toucan, and a young tapir are on display in the Museum's Akeley Gallery.
Bob L. Nugent

The Coral Reef at Night

The undersea transformations of a coral reef at night will be the subject of a talk by Joseph Levine, an associate in the ichthyology department at Harvard University's Museum of Comparative Zoology and author, with photographer Jeffrey Rotman, of *The Coral Reef at Night*. Levine's talk will be presented in the Kaufmann Theater at 7:00 P.M., on Tuesday, January 11.

Ancient Egyptian Jewelry

Colored breast ornaments found in the tomb of Tutankhamen had particular symbolic properties for ancient Egyptians. Robert Steven Bianchi, curator of the Egyptian department at the Brooklyn Museum for fifteen years and author of *Inside the Tomb of Nefertiti*, will give a slide-illustrated talk about ancient Egyptian jewelry on Thursday, January 6, at 7:00 P.M., in the Kaufmann Theater.

The Shoestring Players

The tale of a prince journeying far and wide to find a cure for his ailing father will be performed, with three other folktales from around the world, by the Shoestring Players on Saturday, January 29. Using only minimal costumes and no sets, the Shoestring Players call upon the audience's imagination to envision the props and scenery. The program, for children ages 5 through 12, takes place at 1:30 and 3:30 P.M. in the Kaufmann Theater. Call (212) 769-5606 for ticket availability.

Designs of the Waurá

Since 1986, anthropologist Vera P. Coelho and artist Bob L. Nugent have encouraged the Waurá Indians of the Mato Grosso area of Brazil to reproduce in drawings the motifs of the ornamental art portrayed in their body painting, pottery, basketry, and woodcraft. An exhibition of their geometric designs, anthropomorphic figures, mythological or supernatural beings, zoomorphic figures, and landscapes will be displayed in the Akeley Gallery, beginning on Friday, January 14, and running through Thursday, March 24.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

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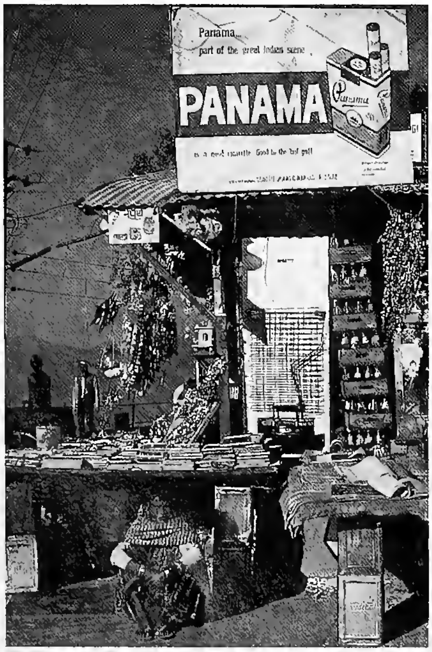


Waiting for customers in northern India.
Dawn Starin

Vanished Greatness

by Paul D. Spudis

Between 1961 and 1969, the United States chose to compete with the Soviet Union in the initial exploration of another world in the solar system, the moon. This epoch saw the emerging infant technology of space flight boldly pressed into the service of scientific exploration. Don Wilhelms relates this inspiring story from the perspective of both an observer and a participant.

Wilhelms's long career as a geologist for the U. S. Geological Survey (USGS) has been devoted mainly to reconstructing the history of the moon by studying photographs of its surface. He was involved in the geological training of the Apollo astronauts and in the selection of sites on the moon, both for the initial demonstration landings and for the later, more sophisticated scientific expeditions. But his principal scientific contributions are in the area of historical geology, or the natural history of the moon preserved in its layered rocks. Like that of the earth and other rocky planets, the moon's record may be read and reconstructed from photographs of its surface.

The episodic story of how we came to understand the history and processes that have shaped the moon begins with the pioneering work of Grove Karl Gilbert, first chief geologist of the USGS, who marshaled evidence in 1893 that craters on the moon were formed by the collision of asteroidal bodies. The largest of these impacts formed a prominent feature on the front side of the moon, the Imbrium Basin, a crater more than 600 miles across.

Fast-forwarding to 1949, Wilhelms highlights the work of astronomer Ralph Baldwin, whose book *The Face of the Moon* got nearly everything right: that the moon's craters were formed by impact; that the dark maria were volcanic lavas; and that the surface of the moon was old—very old.

After reading this book, Nobel Prize-winning chemist Harold Urey became obsessed with finding out more about the moon, which he believed was a piece of primeval nebular matter, unheated and unmodified since the creation of the solar system, 4.5 billion years ago. Urey campaigned for the scientific exploration of the moon, using the up-and-coming technique of rocketry, which had been salvaged from the ruins of a smoldering and prostrate Germany. Aiding him in this task was Gerard Kuiper, a heretic astronomer who was interested in the planets and who treasured photographs as a source of data.

TO A ROCKY MOON: A GEOLOGIST'S HISTORY OF LUNAR EXPLORATION, by Don E. Wilhelms. *University of Arizona Press, $29.95, 477 pp., illus.*

Meanwhile, beginning in 1948, a young, energetic geologist was mapping the uranium deposits of the Colorado Plateau and dreaming of exploring the moon. From that point on, Eugene Shoemaker devoted his career to making geology a part of the burgeoning and nascent lunar exploration program. Such an exploration strategy was far from self-evident: to Shoemaker, more than any other person, Wilhelms gives credit as the founder of an entirely new discipline, planetary geology. Shoemaker went on to establish a branch at the USGS, created specifically to study the geology of other planets in the solar system and charged with mapping the geology of the moon to support the Apollo effort.

The addition of geology into the mix of scientific subdisciplines involved in the exploration of space created an amusing and intriguing conflict of goals and techniques—a conflict that continues to the present day. Wilhelms carefully (and I believe, objectively) recounts the fundamental differences in the thought patterns and methods of those scientists who specialize in the "quantitative" sciences (such as physics and chemistry) and those who work in the "descriptive" sciences (such as geology and biology). Unraveling the complex history of a planet requires both approaches, but it is Wilhelms's thesis (and one that I completely agree with) that our fundamental understanding of the moon came more from the "descriptive" geological approach than from the highly mathematical conjectures of certain physicists and astronomers—Nobel Prizewinners notwithstanding.

Once President Kennedy articulated the goal of a manned lunar landing, a spacefaring infrastructure had to be created almost literally from scratch. The story of the engineering involved in this heroic feat is recounted in several recent books (most enjoyably in *Apollo: The Race to the Moon,* by Charles Murray and Catherine Bly Cox, published in 1989 by Simon & Schuster). Wilhelms' great accomplishment is to complement these narratives by adding a perspective of science and scientific planning, including insider accounts of the fights, arguments, exhortations, and contributions of the scientists who were charged with the task of helping men land safely on the moon and then explore it productively.

Although the idea of safely landing on the moon seems obvious to us today, in 1962 perspectives were primitive, to say the least. Like medieval cartographers, some alarmists raised specters of dragons in "bottomless pits of dust" and of lunar soil so chemically reduced that it would explode when it made contact with the pure oxygen of the *Apollo* lunar module.

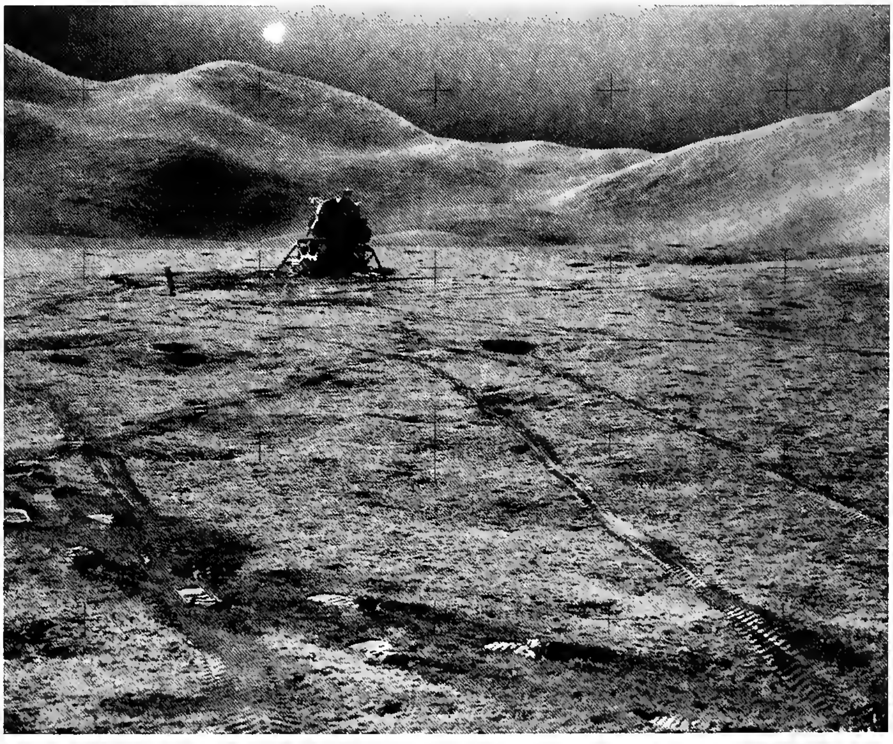
Project Apollo was not merely a program to land men on the moon, it was a strategy for lunar exploration. Wilhelms first describes how we prepared scientifically to go to the moon. This preparation involved mapping the moon (because all good explorers need maps), training the astronauts to be precise scientific observers, and sending a variety of unmanned precursor probes to tell us about the nature, composition, and state of the lunar surface. These robotic probes were a boon to lunar science: they mapped, surveyed, tasted, and examined the moon on a variety of scales. They produced data that are still being analyzed as we continue to unravel the moon's secrets. But most importantly, they paved the way for the coming of *Apollo* and proved that the things people had to fear on this epic journey were largely illusory; the moon benignly and patiently awaited them.

Wilhelms next recounts each *Apollo* lunar mission in detail, including that of the hard-luck *Apollo 13,* which exploded on the way to the moon in 1970, nearly costing the lives of its crew. For each mission, he describes the scientific preparations (including the oft-contentious selection of a landing site), the mission itself, what we learned from the mission, and how that information fit into our emerging picture of the history and evolution of the moon.

Each chapter is expertly and carefully drawn, and the scientific controversies are told at a level that makes them easily understood by the general reader. We see through these pages how the Apollo system developed from a minimalist engineering test-bed into a robust and astonishingly capable exploration tool. This emergence was neither a foregone conclusion nor a fortuitous happening, but came about through the determined efforts of a dedicated group of talented engineers and scientists who, in my opinion, gave the American taxpayers the best value for their money that they have ever gotten, before or since.

Wilhelms sprinkles his text with many anecdotes. He has a fine eye for the character sketch and a dry, understated wit; both tools serve him well in his description of the myriad characters, eccentrics, and occasional genius that this business seems to attract. We meet, for example, Dan Milton, a geologist who applied for astronaut training, although colleagues who rode in a car with him as driver feared for their lives; Gordon Swann, raconteur and good-ole-boy, who nimbly jumped political minefields and ably led the field geology team for the *Apollo 14* and *15* missions (which greatly increased the scientific capability and productivity of the Apollo system); and the inimitable Hal Masursky, a geologist who ran through obscure airports to yet another meeting (where some momentous decisions occurred) to look after the interests of the geologists.

Some of the sharply drawn portraits are of the men who went to the moon: Neil



In 1971, Apollo's lunar-lander Falcon set down near the moon's Apennine Mountains. Vehicle tracks and footprints are visible in the foreground.
NASA photo AS15-92-12430

Armstrong, first man on the moon and one of the best and brightest of the "galvanized geologists," according to Wilhelms; Dave Scott, a test pilot who went bonkers for geology and turned in a stellar scientific performance as commander of the first of the complex "J-missions," the enhanced *Apollo* science missions; and Harrison "Jack" Schmitt, the only professional geologist to go to the moon, who got the chance that Gene Shoemaker missed—to swing his rock hammer on the boulders of the Taurus-Littrow Valley.

The story concludes with Wilhelms's chapter describing what we have learned in the years separating us from the *Apollo* missions. That this can be adequately done in 20 pages (out of nearly 500 for the whole book) is no testament to laziness on Wilhelms's part, but rather a reflection of the pitiable state of lunar exploration during the last twenty years. America has not sent a mission to the moon since *Apollo 17* in December 1972, and the Russians have not done so since August of 1976.

If all goes well, we may see some new lunar data in our lifetimes as the joint Defense Department-NASA mission called *Clementine,* scheduled to be launched in January 1994, will map the distribution of minerals over the entire moon during the course of a two-month period. But this new robotic mission will not be followed by a manned mission—or even any additional robotic probes—in the foreseeable future. In 1989, then president George Bush's attempt to reestablish direction and purpose for our space program by calling for a return to the moon floundered, and then sank, in a sea of media carping, congressional blundering, and parochial whining from the scientific community.

Don Wilhelms has written the definitive history of the scientific exploration of the moon. Its lively and entertaining text informs and stimulates, but there are some slight flaws. The illustrations are not reproduced very well, and the place map of lunar localities used as the frontispiece is quite useless as the guide to craters and maria that it was meant to be. However, don't let these minor problems dissuade you from reading this book; from enjoying and savoring a distant time when America was confident, looked forward to the future, and did not shrink from challenge.

Paul D. Spudis, a staff scientist at the Lunar and Planetary Institute, Houston, Texas, is deputy leader of the science team for the Clementine *moon mission, to be launched in January 1994.*

Lost but Not Forgotten

by Gail S. Cleere

As the new year begins, Mars is hidden in the solar glare, along with Mercury, Venus, Neptune, and Uranus. The *Mars Observer* is hiding, too. All contact with the spacecraft was lost last August 21, after it had journeyed 450 million miles to reach the red planet. For several weeks, technicians tried everything they could think of to reestablish contact, but no response was picked up on NASA's Deep Space Network of antennas. Without contact, scientists have no way of telling where the spacecraft is or even if it still exists. It may be uselessly orbiting Mars, or it may have sped past its destination on a path that will eventually take it out of the solar system.

The silence began just as flight controllers at California's Jet Propulsion Laboratory sent signals to pressurize the spacecraft's propellant tanks in preparation for maneuvers that would place it in orbit around Mars. Pressurizing the tanks required opening valves, which are operated by firing small explosive charges. The resultant jolts may have caused the spacecraft's main and backup clocks to fail simultaneously when faulty transistors or wiring welds were jarred, crippling the craft's central computers and communications systems. Transistors of the type used in the *Mars Observer* have failed on other spacecraft, such as the NOAA-1 weather satellite. A NASA committee has been set up to investigate the failure and to insure that no other spacecraft contains the suspect transistors.

The loss of the *Mars Observer* has been a major setback for planetary scientists. The first spacecraft to visit Mars since the *Viking* landers touched down in 1976, the *Mars Observer* was to have mapped the planet from an altitude of 250 miles for one Martian year (687 Earth days). Its instruments were designed to provide a wealth of data on the red planet's topography, atmosphere, climate, and geology. More than a hundred scientists were poised to begin analyzing the flow of data beamed to Earth—more data on the red planet than had been obtained from all the previous Mars missions combined.

Some of the information was crucial to planning future Mars missions that are already scheduled. Another NASA spacecraft, named *Pathfinder*, is due to land on Mars in July 1997 to carry out the Mars Environmental Survey Mission. *Pathfinder* will include a lander and a rover carrying instruments and cameras for gathering information from the planet's surface. Scientists were hoping for more detailed images of the Martian terrain from *Mars Observer* to help them select *Pathfinder* landing sites.

Last September, in the wake of the *Mars Observer* disaster, Daniel Goldin, NASA's chief administrator, challenged his agency to find a way to build and launch another Mars spacecraft by October 1994, when the earth and Mars come into proper alignment (which happens only once every twenty-six months). A team of scientists was quickly put together to review the options. Their recommendation was to use spare *Mars Observer* electronic and instrument components, which were built as test models and backups and are now stored in New Jersey, and assemble them on a lightweight military satellite frame. The craft could have been carried aloft by the space shuttle and boosted out of the earth's orbit by rocket, or it could have been launched on a foreign rocket. Despite NASA's efforts, however, a new Mars spacecraft will not be ready on time.

The Russians plan to take advantage of next October's window of opportunity to launch landers that will reach Mars in late 1995. This mission will feature not only landers but also rovers that will traverse the terrain analyzing samples, as well as a balloon that will drift along dragging sensors across the Martian surface. NASA will have to wait until 1996 to launch a mission to Mars.

The Planets in January

Mercury is close to the sun at the beginning of the month. During the final week of January, however, Mercury moves far enough away to be spotted on the western horizon just after sundown. It will make a close approach to Saturn at the end of the month.

Venus reaches superior conjunction with the sun on the 16th. It is then behind the sun.

Mars is a morning object, but much too close to the sun to be seen.

Jupiter rises a couple of hours after midnight and shines brightly in the southern sky by dawn. The planet, now residing in the constellation Libra, continues its retrograde (western) motion across the sky and approaches Zubenelgenubi, the third-magnitude star that marks the right claw of Scorpius. On the morning of the 6th, the waning crescent moon stands well below and to the right (west) of Jupiter, and on the 7th it will be well below and to the left (east) of Jupiter.

Saturn is in Aquarius this month, rising in midmorning to the east of the sun. It sets in the west a few hours after sunset. This gives us a chance for one last look at the ringed planet before the sun's glare overpowers it. On the evening of the 14th, Saturn will be the bright, yellowish white "star" well off to the left (east) and slightly below the waxing crescent moon. The brighter planet Mercury will be near Saturn by month's end.

Uranus and **Neptune** are in conjunction with the sun on the 11th and 12th.

Pluto is hidden near the tail star of the faint constellation Serpens, not far from Jupiter. Pluto will remain in this position throughout 1994, making its way slowly eastward toward the constellation Ophiuchus, and will remain closer to us than Neptune.

The **Moon** reaches last quarter on the 4th at 7:00 P.M., EST; is new on the 11th at 6:10 P.M., EST; reaches first quarter at 3:27 P.M., EST, on the 19th, and is full on the 27th at 8:23 A.M., EST.

The Quadrantid meteor shower is one of the year's most potent. This shower appears to emanate from a point between the constellations Boötes, Draco, and Hercules. The name of the shower is from Quadrans Muralis (the wall quadrant), an eighteenth-century constellation created in a failed attempt to rename the classical constellations. The Quandrantid meteors are characteristically blue in color and leave long silver trails. The shower has been known to reach rates of 100 meteors per hour, but usually for only a few hours during the peak of the shower. This year the Quadrantids will peak on January 3 at 12:00 noon, EST. Before sunrise on this date, the Quadrantids are likely to be only about a quarter as numerous as during the peak. The bright, waning gibbous moon in the sky will not help. Parent comets have been identified as the source of meteors in other showers, but not for this one.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

Pyramid Power

The USDA has abandoned the four basic food groups, and confusion reigns

by Raymond Sokolov

More nonsense has been written about nutrition than any other topic so important to the survival of the human race. Fad diets promoted by doctors have cost worried people billions of dollars and millions of hours...for nothing. Meanwhile, even the medical-nutritional establishment (MNE, pronounced mo-ney) has flip-flopped enough on this vital topic to erode the confidence of panicked laypeople.

As a child, I watched apparently sensible adults go on weight-reduction diets heavily canted toward protein and shunning carbohydrates. My parents' friends would gorge on steak and other red meats loaded with fat and turn their noses up at potatoes and rice and bread. Then the bad news came in about cholesterol, so they dropped all that red meat and began peeling the skin off chicken. They dropped butter altogether, along with eggs, whole milk, and cheese.

By and by, the news thundered through from the East that Asians, with very little fat of any kind in their diets, are less vulnerable to many chronic diseases than we Westerners are. They also had lower rates of colon cancer because they were happy to eat foods high in fiber.

These dire facts led more or less directly to the boom for oat bran, which some studies showed provided an obvious source of fiber. (The phrase *high fiber* always makes me think of *high five,* that exuberant greeting popularized by some African-Americans. After eating an oat bran muffin, I often suppress the impulse to give my wife a high five across the table to celebrate my dietary shrewdness.) No sooner had American cereal producers adjusted to the demand for oat bran than the flighty world of official nutritional dogma came forth with an awesome and all-encompassing ukase. In 1992 the U. S. Department of Agriculture made headlines and waves with the Food Guide Pyramid.

Intended as a simplifying, graphic device for representing modern thinking about healthful eating, the pyramid confused laypeople and infuriated professionals in both industry and science. Leaving aside that the new symbol was not a (three-dimensional) pyramid but a (two-dimensional) triangle, the "pyramid"—with its four "tiers" and six "groups" subdivided into eighteen categories of foods—was not a simplifying substitute for the old-fashioned system of four food groups that it was meant to replace.

The old four groups (originally seven, but don't try to keep track; no nondietitian ever really succeeded) were all created equal, just like people. In a "balanced" diet, educated consumers divided their meals equitably between each group: (1) milk and dairy products; (2) meat, chicken, and fish; (3) grains and breads; (4) fruits and vegetables.

From the modern point of view, this is not only a crude system but also a dangerous one. It seems to recommend that we devote half our consumption to foods rich in fat and low in fiber (groups 1 and 2). The pyramid abandons this innocent policy of apparent nutritional egalitarianism in favor of a frank elitism favoring carbohydrate sources over protein sources and demoting fat to pariah status. At the pyramid's broad base, the bread, cereal, rice, and pasta group is approved for six to eleven daily servings. The next tier up, narrower and by implication less worthwhile, contains both the vegetable group (three to five servings) and the fruit group (two to four servings). Still higher up, tier three is divided between the milk, yogurt, and cheese group (two to three servings) and the meat, poultry, fish, dry beans, eggs, and nuts group (two to three servings). At the apex of the triangle are fats, oils, and sweets, which we are admonished by the USDA to "Use Sparingly."

Brief reflection should make it obvious why almost no one liked this new dietary polygon. Those who took it on its own terms wanted to know why foods of such different nutritional content as navy beans and porterhouse steak were put in the same group. The dairy industry wondered, with justice, why skim milk and nonfat yogurt should be lumped together with whole milk and cheese. Olive oil producers didn't think their product should be tarred with the same brush as lard and chocolate fudge.

These were not just sectarian concerns. They raised real questions, but they did not go to the heart of the pyramid's prob-

lem. The pyramid, by itself, did not directly answer the most fundamental question it raised with its own jargon: What is a "serving," and how many servings from each group should be combined to make a dish or a meal? The poor consumer, already bludgeoned by health statistics and doctors into supposing that cheese kills, was now confronted with an ostensible answer to the life-or-death question of what to eat, but the answer could not be understood and did not ever speak to the problem of the well-meaning cook in a real-life kitchen. Just imagine the quandary of someone about to cook, say, spaghetti *alla carbonara,* trying to calculate how many servings of pasta or unsmoked bacon or sparingly grated Parmesan were in the total recipe and how many forkfuls equaling how many "servings" were consumed by each family member. And did the cook have to ask each one at the table what he or she had eaten at lunch so as to make the amount of noodles on the plate tally with that person's pyramidal goals for the day?

Underlying all of this inevitable confusion was the fundamental question, what is a serving?

This is not easy to find out. But if you can find a USDA publication of August 1992 called *The Food Guide Pyramid,* it is clear enough, in its way. "What counts as a serving?" it asks rhetorically. Well, it goes on, a serving of bread is one slice (thin? whole-wheat? egg challah? Don't ask). A serving of ready-to-eat cereal is one ounce, so get out your scale and don't be surprised if the amount seems mingy. A serving of raw, leafy vegetables is one cup (compressed or not? Who knows?), but a serving of fruit is only a half cup, while a serving of fruit juice is three-quarters of a cup, even though fruit juice is usually more concentrated than whole fruit.

Logic evaporates altogether in the dairy tier. A serving of milk is the same as a serving of yogurt: one cup, no matter what the actual fat content of either. Utterly absurd is the cheese-serving guideline: one and one-half ounces of so-called natural cheese but two ounces of processed cheese (up with Velveeta, down with cheddar). And in the high-protein tier, the USDA wants you to believe that two to three ounces of cooked lean meat, poultry, or fish, one cup of cooked dry beans, two eggs, or four tablespoons of peanut butter are fungible quantities—each is equivalent to one serving.

Perhaps I have convinced you that the food guide pyramid is a snare and a delusion. If so, I'm not particularly happy about it. In fact, the pyramid makes me sad, in the way that every well-meant failure to do good lowers one's spirits. The pyramid, to mix a metaphor, had its heart in the right place. Its bottom line (bottom tier?) was clear and valid: fat is bad; plant-derived foods, especially those made from grain, are good.

Unfortunately, that message was lost in the pseudogeometry and semantic tangle of tiers and groups and servings. But the basic message is, in fact, the nutritional orthodoxy of our day. Most people now accept as common sense that densely caloric, easily storable fats are undesirable for people who typically live long enough in a sedentary manner to acquire cardiovascular and other diseases associated with obesity and the accumulation of cholesterol. "Common sense" also dictates that grains

Karen Karp's Banana Bread

Three flours combine to give this perfect tea cake its serious flavor. Karp is a restaurant consultant in New York. She recommends substituting six small finger bananas for the three regular ones whenever possible. Remember that finger bananas must be very ripe, almost mushy in the hand; otherwise they will be fibrous and unappealing.

8 tablespoons (1 stick) unsalted butter, at room temperature
¼ cup sugar
2 large eggs
3 ripe bananas or 6 finger bananas
1 tablespoon milk
1 cup flour
½ cup rye flour
½ cup whole-wheat flour
1 teaspoon salt
1 teaspoon baking soda
1 teaspoon baking powder
Sesame seeds

1. Preheat oven to 325 degrees. Grease a 9 x 5 x 3-inch loaf pan and set aside.
2. Use a whisk or a hand mixer to cream the butter and sugar in a large mixing bowl until light and fluffy. Beat in the eggs one at a time and continue beating until the color of the mixture is pale yellow.
3. In a small bowl, mash the bananas with a fork. Then mix in the milk and chopped nuts.
4. In another bowl, mix together flour, salt, baking soda, and baking powder.
5. Add banana mixture to the butter-sugar-egg mixture and stir until well combined. Add dry ingredients from step 4 and continue stirring until the flour disappears.
6. Pour the batter into the prepared loaf pan. Smooth and level the top. Sprinkle with sesame seeds and bake for an hour or until a toothpick inserted in the center comes out clean. Set aside to cool on a rack for 15 minutes. Then slide a knife around the edges of the banana bread to make sure it doesn't stick to the pan.
7. Place a platter over the open side of the pan, invert, and unmold. Invert the bread onto a rack (so the top—the convex side that was exposed in the oven—is up) and let cool completely before slicing.

Yield: One loaf

All-Rye Banana Bread

This is a somewhat less fiercely healthful version of a recipe printed on the Arrowhead Mills rye flour bag. It has much less molasses and uses real milk instead of powdered. If you want the full-bore molasses taste, simply eliminate the sugar and use ⅓ cup molasses. The original recipe also suggested honey as a sweetener, another attractive option.

4 tablespoons (½ stick) unsalted butter
⅓ cup sugar
1 tablespoon molasses
3 eggs
2 bananas, mashed
1 teaspoon vanilla
¼ cup milk
2½ cups rye flour
1 teaspoon salt
2 teaspoons baking powder.

1. Preheat oven to 325 degrees. Oil a 9 x 5 x 3-inch loaf pan and set aside.
2. With a whisk or a hand mixer, cream the butter, sugar, and molasses. Then mix in the eggs, banana, vanilla, milk, and ⅓ cup water.
3. In another bowl, stir together the flour, salt, and baking powder. Stir this mixture into the banana mixture until the flour disappears.
4. Pour batter into the prepared loaf pan and bake for 1 hour or until a toothpick inserted into the center comes out clean. Let cool for 15 minutes. Then slide a knife around the edges of the banana bread to make sure it doesn't stick to the pan. Place a platter over the open side of the pan, invert, and unmold. Invert the bread onto a rack (so the top—the convex side that was exposed in the oven—is up) and let cool completely before slicing.

Yield: One loaf

and their derivatives offer a desirable alternative source of nutrition: cholesterol- and fat-free calories easily put to use and dissipated, and much fiber.

This was not at all the common sense of yesteryear. In 1968, that *annus mirabilis* of revolutionary thought and action, if I had suggested that a grain-based diet extremely low in animal fat was the way to go, almost everyone (including the most radical) would have dismissed the idea as unhealthful and dangerous macrobiotic extremism. Now most of us have swung in that direction, at least in our minds. Why? How did it happen?

In traditional societies, new ideas percolated downward from elites to a wider public. In our world, where novelty ricochets from all sides at high velocity carried by the mass media, the rate of communication is almost instantaneous, but there is still a vestige of the old top-down dynamic. Serious medical and nutritional research has gradually convinced those capable of rational thought that the low-fat/high-fiber theory is correct.

Why didn't science reach this conclusion sooner? The reason is simple. To discover the nature of optimal diet is not the same as learning to cure a disease. Disease kills dramatically, one person at a time, and it can be studied with efficiency in individuals. Optimal diet reveals itself through statistics and must be studied in many people over long periods of time. The data are notoriously unreliable because people are quick to lie about what they put in their mouths. But these obstacles have been laboriously and tediously overcome. First came the evidence about obesity and cholesterol in the Framingham Heart Study in Massachusetts. Then, decisively, comparative data arrived from China, and the discussion was, in a major sense, over.

Since 1983, a joint Chinese-American project (by the Academy for Preventive Medicine in Beijing and Cornell University) has investigated the diet of 6,500 rural Chinese. The results show with devastating clarity the superiority of a plant-based diet. The average Chinese diet was only 10 percent animal based. Less than 15 percent of the calories were derived from fat. Chinese ate a third less protein than Americans, and only about a tenth of that protein was animal. Americans got about 70 percent of their protein from animals. Chinese fiber consumption was huge compared to American. Chinese, moreover, typically have about half the blood cholesterol that Americans have. And the incidence of heart disease and cancer is much lower in China than here.

The most impressive—and depressing—statistics are those that show the disastrous effect of modest increases in animal-based food consumption on the Chinese sampling. Heart disease and cancer rates climbed.

All of this confirms the theory that animal fat and animal-based foods in general produce the diseases rife in affluent Western societies. This is a negative result and leads to a negative course of action: reduce consumption of animal-based foods. But there is also a positive conclusion to be drawn and a positive course of action to be taken: Increase the intake of plant-based foods, not just as a desperate alternative but as a constructive remedy, a restoration of balance in what we eat.

I am not advocating a rigorous vegetarian regimen. But I do believe that all evidence points to a need for radical renovation of the way we plan meals, that we must find ways of de-emphasizing meat and of tilting the scales toward plant-based foods. Unwavering, true vegetarianism requires a moral commitment that only a minority will embrace.

Instead, we should be revamping our menus by choosing dishes rich in vegetables and, especially, grains. Grains supply the food energy and the fiber we must have to survive. They are versatile, and they are major ingredients in thousands of recipes people already love. The trick is to put these grain-centered dishes at the center of our diet, rather than the periphery.

Something like this has already been happening. The vogue of pasta is a key example. So is the trend toward Asian stir fries (despite insidiously high amounts of fat from the oil used in frying) and other dishes in which the central ingredient is rice and in which meat, when there is any, is a superaddition, almost a condiment. As this kind of eating becomes more common, it will be less normal or mandatory to plan a meal around a cut of meat, such as a roast or a steak. This readjustment of attitude, moderate and gradual, will have the revolutionary goal of returning our meals to a pattern that has been the historical norm for most human beings at all times everywhere. The battle will be won if ordinary Americans ask themselves: Should we have risotto tonight? Or barley with chicken?

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Ghost in a Snowstorm

Gliding silently through the chilly night, a flying squirrel navigates a forest in Hokkaido, Japan's northernmost island. Although this species (*Pteromys volans*) is known as the European flying squirrel, it ranges throughout the coniferous forests of Eurasia, from Finland to eastern Siberia and the northern tip of Japan. Brown with white underparts in summer, its entire coat turns silver gray and silky smooth in winter.

A versatile climber that is awkward on the ground (and avoids walking on it), a flying squirrel can glide as far as 130 feet from tree to tree. A furry flightskin on the sides of its body, joined to the front legs and rear ankle joints, acts as an airfoil, while the bushy tail serves as a rudder. Active mainly in the evening and at night, flying squirrels eat birch bark and leaves, buds of coniferous and deciduous trees, insects, pine seeds, alder catkins, berries, and mushrooms. In winter, the northern populations feed almost exclusively on larch bark and buds.

Photographer Seiichi Meguro has dedicated himself to photographing the squirrels, foxes, and other shy forest creatures near his Hokkaido home. Since flying squirrels habitually traverse the same routes on their feeding rounds, Meguro positioned himself near the sites of their regular flights. Focusing his camera on the area in which he expected a squirrel to leap, he clicked away when one appeared. Because the squirrels' movements are very rapid, Meguro finds it useless to follow them through the camera's viewfinder. Working at night, when his subjects are most active, the photographer kept after the squirrels for five years before he was able to create this eerie winter nocturne.—*R. M.*

Photographs by Seiichi Meguro
Nature Production

AUTHORS

Richard Shine (page 34), shown here with a black-headed python, was born in Brisbane, Australia, and has been fascinated by snakes and lizards since an early age. He used to keep several at home, but says "I now have enough of them to look at when I'm at work." The forty-three-year-old herpetologist has earned two doctorates: a Ph.D. from Australia's University of New England in 1975, and a D.Sc. from the University of Sydney in 1988. He now teaches in the biology department at the University of Sydney. Shine's fieldwork has taken him from the chilly Brindabella Range in southern Australia to northern Australia's wet-dry tropics. Shine says, "My skink studies combine two of my greatest interests: the biology of reptiles, and the ways that evolutionary processes operate. I'll admit to choosing the Brindabellas as a study area partly because it has good trout streams (and I'm an avid fly fisherman), but the sad reality is that I've been so busy working on the lizards that I've never managed to even unpack my rod. Still, it's good for the soul to know that the trout are there."

Roger Payne (page 40) earned his doctorate from Cornell University in 1962 with a dissertation on owls that locate prey in total darkness by sound. His research on owl and bat acoustics eventually led him to study whales and to finding things out through observation rather than experimentation. An accomplished cellist by avocation, Payne is particularly attuned to the sounds and rhythms of whales. "I have been studying whales continuously since 1967," Payne says, "and one must be content to observe these animals with a metronome on adagio." Payne, who in 1971 established what is now called the Whale Conservation Institute in Lincoln, Massachusetts, plans to continue investigating whale vocalizations, as well as the effects of pollution on whales and other marine mammals. For more information, Payne recommends: *The Sierra Club Handbook of Whales and Dolphins,* by Stephen Leatherwood and Randall R. Reeves (San Francisco: Sierra Club Books, 1983) and *Dolphins, Porpoises and Whales of the World: The IUCN Red Data Book,* by M. Klinowska (Washington, D.C.: Island Press, 1991).

As a high-school student, **Michael Boppré** (page 26) took a summer job at the Max Planck Institute for Behavioural Physiology at Seewiesen, an isolated "science village" in an idyllic landscape in the German countryside. The atmosphere there—a satisfying mix of work and private life, with many interesting research groups and famous visitors ("most coming

to see Konrad Lorenz")—convinced Boppré to "study biology and nothing else." When he did his university studies at Marburg, he continued to spend most of his holiday time at Seewiesen. A 1972 trip to Kenya sparked a great interest in the tropics and fieldwork. Now a full professor and director of the University of Freiburg's Institute of Forest Zoology, Boppré continues his work in the interdisciplinary field of chemical ecology, which includes the study of behavior, physiology, morphology, taxonomy, and evolutionary biology. For more on butterflies, Boppré recommends *The Biology of Butterflies,* edited by R. I. Vane-Wright and P. R. Ackery (Princeton: Princeton University Press, 1989), in which he has a chapter entitled "Chemically Mediated Interactions Between Butterflies."

Bat researchers **Scott C. Pedersen** (in a Costa Rican field, right) and **Rick A. Adams** (in Colorado, with a chiropteran friend, above) coauthored "Wings on Their Fingers" (page 48) despite the 3,000 or so miles that separate them. Both are assistant professors: Adams teaches zoology at the University of Wisconsin at Whitewater and Pedersen is currently at the American University of the Caribbean School of Medicine, at Montserrat, British West Indies. Pedersen's lifelong interest in aircraft flight led to his study of biological flight systems. Some of his bat research has also focused on echolocation. Adams has had a special affection for bats ever since his childhood in Bethesda, Maryland, when he accidentally killed one with a frisbee. ("Something about the twirling attracts them" he says, "and may distort the readings of their echolocation systems.") The two met during graduate studies at the University of Colorado at Boulder, where they discovered a mutual interest in bone development. Adams is president and founder of the Colorado Bat Society, which is dedicated both to educating the public about bats and to conserving Colorado species. For more on bats, Adams and Pedersen recommend *Just Bats,* by M. Brock Fenton (Toronto: University of Toronto Press, 1983); *America's Neighborhood Bats,* by Merlin Tuttle (Austin: University of Texas Press, 1988); and *Bats: A Natural History,* by John Hill and James Smith (Austin: University of Texas Press, 1984).

A former bus driver and car dealer, forty-three-year-old wildlife photographer **Seiichi Meguro** (page 76) nightly wanders the forests near his home in the Kamikawa District of Hokkaido, Japan, searching for suitable subjects. "I was following some red foxes over a mountain," he says, "when I encountered an appealing little fellow—a flying squirrel—gliding from tree to tree." Fascinated, Meguro spent years observing the squirrels' habits. His "Natural Moment" photographs were taken near Takasu-Town on snowy evenings in January and March, when "an unskilled observer would not even have noticed the gliding squirrels." Using a Canon F1, with a Canon FD 85mm f1.2 lens, and two flashes (one mounted on each side of the camera), he froze the squirrel's flight on Kodachrome 64 film. Meguro takes photographs "in the hope that if people learn more about wildlife, they will not be so thoughtless in destroying habitats for the sake of human convenience. Even a very small child does not step on vegetation if he or she knows the name of that plant." Some of Meguro's photographic sequences have been published in Japan as popular children's books. They include *A Fox Called Boro and a Flying Squirrel Called Nenai* (Tokyo: Gakken, 1984), and *The Forest of Akkamui* (Tokyo: Kumon Publishing, 1987).

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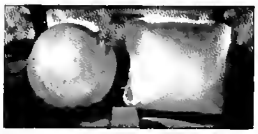

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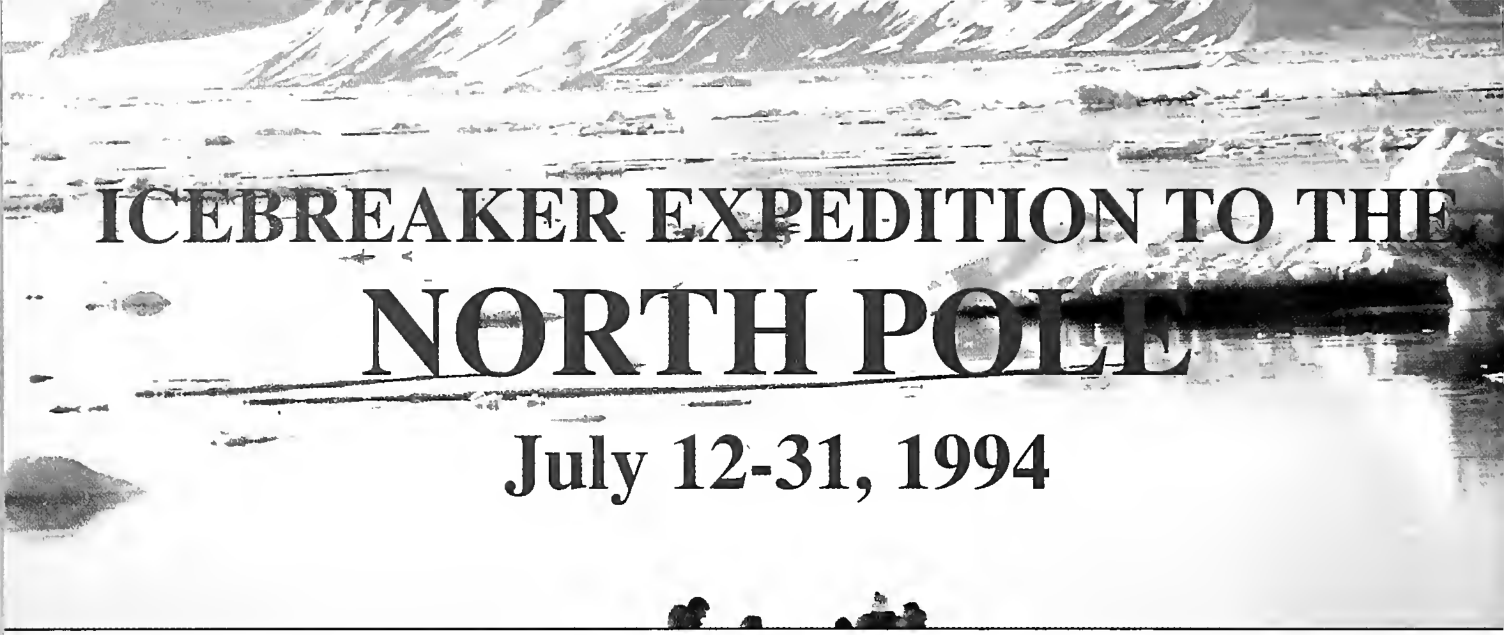

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COVER: *A hawkfish hovers above an antler coral in the sea near Maui. Story on page 50. Photograph by Andrew G. Wood; Photo Researchers, Inc.*

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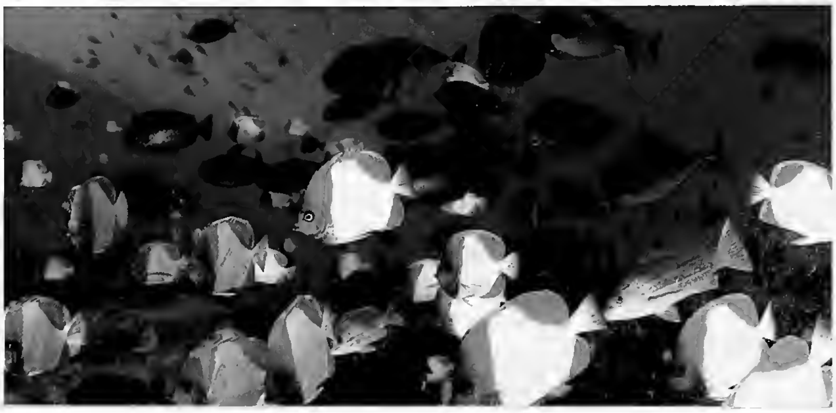

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Stinking Birds and Burning Books

Want to make new discoveries in chemical ecology? Talk with a tribal hunter

by Jared Diamond

Most scientists think of the golden age of field biology, when explorers could travel to any part of the globe and count on returning with amazing discoveries and undescribed species, as a bygone era. The dwindling number of biologists who still journey to remote lands are suspected of doing it for the adventure. Other scientists would have us believe that biology's real discoveries today are being made in the laboratory, where molecular biologists are supposedly closing in on the secrets of life. Attention has also shifted to extraterrestrial space, whence some astronomers continue to await radio signals from intelligent beings on other planets.

Actually, the vast majority of this planet's species are still undescribed and unknown. In addition, remarkable new knowledge has only recently been gained about many previously described species—such as the mouse that sheds its skin, the frog that broods its young in its stomach, the naked rat that lives underground in colonies, the African monkeys that use different, gruntlike "words" to warn one another of particular species of predators, and the chimpanzees that use stone tools and wage genocidal wars.

To scientists, these are exciting discoveries. But they are not really discoveries, because much of this was already known to indigenous peoples. Technologically "primitive" peoples, who still depend heavily on hunting and gathering for their subsistence, routinely distinguish and name hundreds of species of local plants and animals and can recite the species' individual life histories. The New Guineans who guide me in the jungle, for example, often point out plants that they use as contraceptives, antimalarials, wound-healers, and abortion-inducing agents.

Much of this knowledge would be commercially valuable in the outside world. As a result, drug companies hire ethnobiologists—biologists who study the folk knowledge of natural phenomena—to collect plants and animals for testing as sources of new drugs. Tribespeople tell ethnobiologists which species to collect and what to test each species for. The scientific study of the chemicals produced by living plants and animals is called chemical ecology. A promising trend in conservation biology is for drug and chemical companies to buy "chemical prospecting licenses" in remnants of the world's beleaguered tropical rain forests.

The encyclopedic knowledge of the natural world possessed by New Guineans (*see* "This-Fellow Frog, Name Belong-him Dakwo," April 1989, and "The Ethnobiologist's Dilemma," June 1989) is on my mind now, as I have just returned from a month studying birds among the Ketengban people of Indonesian New Guinea. Showing the voluminous knowledge typical of New Guineans, my Ketengban guides described the habits of 165 local bird species. They did not, of course, use English or Latin names but names in their own language, such as toktokpáni, búlabúla, and amkeri-tololóp. Much of what my guides told me I knew to be scientifically correct; other things were new to me, but they sounded plausible. Some of them must have taken great acuity to observe.

For example, one morning my one-eyed guide, Robert Uropka, claimed that

he had just glimpsed, high above our heads in the jungle, a small bird known locally as máwe. Looking through my binoculars, I identified it as Lorentz's whistler and objected that Robert had already applied that name to another bird, which I knew as the regent whistler. Robert then gave me a short lecture (in the Indonesian language that we shared) on the distinctions. "Yes, we use the name 'máwe' for two different birds. This one lives high on the mountain, and the male and female have identical plumage. The other one lives lower on the mountain, has a different song, and the male differs in its black crown and yellow nape." I was flabbergasted, because both sexes of Lorentz's whistler are so similar to female regent whistlers that even ornithologists poring over stuffed specimens didn't recognize them as distinct species until 1939.

While Robert was demonstrably right about the whistlers, he also described to me some bird lore that sounded wildly implausible—stories of birds that stink and birds that act as living flytraps. But those stories, too, may be true; an equally wild tale, told by other New Guineans about supposedly poisonous birds, has just been confirmed by scientists. Such confirmation illustrates that major scientific discoveries, perhaps of great economic value, await teams of chemical ecologists and ethnobiologists. The stories also carry a larger message about the tragedy of shrinking human knowledge.

The recent "Case of the Poisonous Birds" has to do with three common, conspicuous, and very noisy species of jay-sized New Guinea birds called pitohuis, which have been known to scientists since 1827. Thousands of specimens are in the world's museums, and hundreds of tourists visiting New Guinea observe them in the jungle every year. I have caught hundreds of pitohuis in nets, watched and tape-recorded thousands, and published two papers on their behavior. None of us "professional" scientists suspected poison. The sole hint was a single sentence in a long book published in 1977 by the Kalam villager Ian Saem Majnep, in collaboration with New Zealand ethnobiologist Ralph Bulmer. Detailing what Kalam villagers knew about each of 137 bird species living in their valley, Majnep wrote of the hooded pitohui, "Some men say that the skin is bitter and puckers the mouth."

Pitohuis in general, and that sentence in particular, were far from the mind of American graduate student Jack Dumbacher in 1989, when he set up nets in the New Guinea jungle to trap birds of paradise. Hooded pitohuis got caught in the nets and had to be removed. In the process, the birds scratched Dumbacher's hands with their claws and bills, and he noticed that the birds had a strong, sour smell. When he licked off his wounds, his lips and mouth began to tingle and burn and then went numb for several hours. His New Guinea field assistants later told him that the hooded pitohui was "good for nothing, a rubbish bird" and was not to be eaten unless carefully skinned.

The explanation began to emerge when Dumbacher sent dead specimens of hooded pitohuis to National Institutes of Health scientists for chemical testing. Injection of pitohui skin or feather extracts into mice caused the mice to develop hind-leg prostration and paralysis, leading to convulsions and death in as little as fifteen minutes. Dumbacher's belated discovery came as a real surprise. Although many other animals, such as monarch butterflies, were known to accumulate or synthesize poisons to make themselves unappetizing to predators, this was the first well-documented example among birds. Presumably such would-be predators as snakes and possums would be driven off after one bitter, mouth-puckering lick of the pitohui's feathers, and the bird's sour smell and bold, orange-and-black coloration would help them remember the experience.

Another surprise emerged when the hooded pitohui's poison was extracted, purified, and chemically identified. It proved to be the nerve and muscle poison homobatrachotoxin—a substance otherwise known only from a different continent and different vertebrate class—in South and Central American poison-dart frogs, so called because Indians use the animals' skins to poison blowgun darts. Homobatrachotoxin is one of the most poisonous substances known, hundreds of times more powerful than strychnine. One hooded pitohui contains enough of the poison to kill more than 500 mice. How the pitohui's nerves and muscles resist its own poison is not known.

The appearance of the same toxin in frogs and birds exemplifies, astonishingly, the phenomenon of convergent evolution at the molecular level. Just as birds, bats, and pterodactyls independently evolved wings, pitohuis and poison-dart frogs have converged on each other by evolving homobatrachotoxin. The poison itself has no odor, so pitohuis seem also to have evolved some as-yet-unidentified, sour-smelling chemical to warn off predators before they can take a bite.

Dumbacher and his colleagues identified homobatrachotoxin not only in hooded pitohuis but also (albeit at lower concentrations) in two related species, the variable pitohui and the rusty pitohui. As its name implies, the variable pitohui shows far greater geographic variation in plumage than any other New Guinea bird species. Until now, no ornithologist had the faintest idea why two populations of variable pitohui, from opposite ends of New Guinea, are orange and black like hooded pitohuis; why some are uniformly

New Guinea's rusty pitohui: common, noisy—and poisonous.
Brian J. Coates; Bruce Coleman, Inc.

rusty, like rusty pitohuis; and why some have color patterns that differ from those of the first two.

Now we have a clue: "Müllerian mimicry," the phenomenon, well known in tropical butterflies, whereby several poisonous species share the same bold pattern. As a result of this mutual mimicry, each species benefits by the other's poison, because a predator that tastes and spits out one species thereby learns to avoid the other species as well. In the two parts of New Guinea where I collected pitohuis, however, not only did I smell and taste nothing after handling the birds myself, but the local New Guinea tribesmen working with me also stuffed and ate them with no ill effect and volunteered no stories about their being "rubbish birds." Perhaps the presence of poison varies geographically in New Guinea pitohuis, and the variable pitohuis resemble the hooded pitohui, rusty pitohui, or neither, depending on which species is locally poisonous.

But the pitohui story has still bigger implications. All three pitohui species are leaders of wandering flocks, composed of several dozen different species belonging to at least seven different families. All members of the flocks are various shades and combinations of rust and black. And several flock members also mimic other member species' calls. Why?

When I published an article on the flocks six years ago, I advanced the usual two explanations that ornithologists have invoked to explain convergence in other flocks of unrelated species: the mimicry may make it hard for a would-be predator to concentrate on following any single potential victim and easy for each flock member to stay with the group. Now, as a result of the discoveries by Dumbacher and his colleagues, I have to wonder whether the flock members are also simultaneously signaling or pretending to be poisonous.

And yet another big question arises. In the rusty-and-black flocks are individuals (mostly females) of at least fifteen species of New Guinea's most famous birds, the birds of paradise. Male birds of paradise have attracted much scientific attention because they evolved through sexual selection to have the world's most bizarre plumage. Females have drawn much less interest, their rusty-and-black plumage being much more conservative. But note a comment of feather collector A. E. Pratt, reduced by starvation nearly a century ago to eating a bird of paradise. He wrote of his dinner: "The most shocking flesh I have ever eaten...as bitter as gall...it was truly abominable, and after the first spoonful we got no further." While ornithologists have been concentrating on the gaudy bird of paradise males and ignoring the females, could they have been missing another story of poison and Müllerian mimicry on a grand scale?

Thus, behind one sentence in the ethnobiological literature lurked a cascade of major discoveries and questions: the first proven examples of poisonous birds; a case of convergent evolution at the molecular level; a case of Müllerian mimicry; a possible explanation for geographic variation in plumage; a force behind mixed-species flocking; and a major selective force on birds of paradise. In retrospect, one might ask why none of the biologists who had read Majnep's and Bulmer's book beat Dumbacher to his discovery of poisonous birds. Undoubtedly, the main reason is that Majnep's clue was no more than a single, qualified sentence in a long book. Dumbacher discovered the bitter skin for himself and came across Majnep's sentence afterward. But there is also another reason: chemists aren't yet accustomed to asking New Guinea villagers for suggestions about promising research projects. Here's one hint to chemists who may now be starting to regret their past oversight: also buried in Majnep's book is a paragraph about the bitter, mouth-puckering taste of the blue-capped ifrita, a New Guinea bird quite unlike pitohuis.

In the case of the pitohuis, we now know that local folk knowledge was scientifically valid. Next, let's consider the "Case of the Stinking Birds."

The case began one morning in July 1967, when a group of New Guineans and I were sitting in a tent in the jungle, skinning some bird specimens that we had just caught. A Foré tribesman named Esa was working on a mound builder, a large bird famous for incubating its eggs with the heat of scraped-together mounds of rotting vegetation. Esa complained of feeling sick from the carcass's stink; then he abruptly vomited. This surprised me because the bird had been shot only that morning, it had had little time to rot, and the temperature was cool. None of my field assistants had vomited over a carcass before, and, in fact, they had struck me as notably unfastidious in their willingness to eat birds that had been killed the day before.

Another New Guinean present, who was more familiar with mound builders than Esa or I, explained that they were distinctive in stinking much sooner after death than other bird species. When I later traveled to the Solomon Islands, where mound builders are abundant, I was given the same information. My Solomon Island friend Alisasa Bisili told me the following traditional story of how his people hunt mound builders (called e-yo in Alisasa's Roviana language):

> If you want to eat an e-yo, here's what you have to do to cook it before it can start stinking. During the day, go into the jungle and look for a low branch with a white stain on it. That stain is the e-yo's droppings. The stain tells you that that's the branch on which an e-yo roosts at night. Then go back there after sunset with a pot of water and a bow and arrow. When you spot the e-yo sleeping on the branch, light a small fire on the ground directly under it, and set the pot on the fire. When the water reaches boiling, shoot the e-yo with your bow and arrow, so that it falls straight into the pot of boiling water. That's the only way that we can kill an e-yo and cook it soon enough that it won't start to stink!

Mound builders aren't the only stinking New Guinea bird, as I learned in 1966 when I took the Tudáwe tribesman Omwai to Utai village in the Sepik Basin. An Utai villager named Uténo had earned Omwai's dislike by threatening to poison him and by nevertheless coming to our hut every morning to cadge bird carcasses and tobacco. On this particular occasion, I saw Omwai give Uténo the skinned carcass of a giant cuckoo known as Menbek's coucal, and named píni in Omwai's Tudáwhe language. I asked Omwai with surprise why he had given so much meat to a man whom he despised. Omwai explained—and I confirmed with my own nose the next time we shot a píni—that the píni is the only other bird that starts to stink as quickly as does a mound builder. The gift of the píni was Omwai's revenge against Uténo.

We all know that dead animals smell bad, but we rarely pause to reflect on the smell's possible function. Think of any dead body as a potential battleground between hyenas, beetles, other animal scavengers, and many species of microbes, all seeking to digest the carcass for themselves. If a hyena swallows the carcass, it thereby becomes unavailable to bacteria. Biologically synthesized poisons, bad-tasting substances, and evil-smelling gases are weapons of chemical warfare by which a microbe attempts to drive other microbe species and scavenging animals off the battlefield. The best-known such weapon is penicillin, a potent chemical secreted by a mold to kill bacteria (and now

one of the most valuable natural products ever appropriated by humans).

For a microbe, a stinky chemical represents a flag of possession. For a hyena, it's a deterrent. But what about the dead bird itself? If the bird had wanted to deter potential predators by a stink, shouldn't it have had to stink while it was still alive? Perhaps the post-mortem stink should be viewed as just a chemical weapon evolved by a microbe without any cooperation from the dead bird.

Nevertheless, I'm suspicious because the only two New Guinea bird species that I've known to stink so quickly are both big, clumsy, noisy, slow-moving species that represent lots of meat for a potential predator, and that seem otherwise ill-equipped to deter predators. If you fill yourself with a stinking poisonous chemical while you're still alive, you have to develop resistance to the chemical yourself. You might find it much better to harbor potentially stinky microbes and keep them suppressed while you're alive, but ready to stink as soon as you die. Or you could design your tissue chemistry to attract a stinky microbe after you die. If a predator then makes the mistake of killing and eating you, it will get sick and learn to avoid killing your relatives in the future. In the language of population genetics, that's called "increasing your inclusive fitness," or passing on your genes by aiding the survival of relatives sharing your genes, even though you yourself don't survive. That's why animal parents risk their lives to defend their young, and why worker ants in an ant colony forgo reproduction.

A female crested bird of paradise: does her plain plumage encode an untold evolutionary story?
Frithfoto; Bruce Coleman, Inc.

Naturally, all that I can offer at present to explain stinking birds is this speculation without evidence. It might prove to be nothing more than one of those "just-so stories" that biologists are often accused of dreaming up to provide a functional explanation where there really is none. But I have a clearly formulated, testable hypothesis. I propose that an ambitious chemical ecologist with a weak nose and strong stomach (1) measure the rates at which e-yos and pínis stink after death, compared with other birds, (2) identify the stinking chemical, (3) identify the microbe or enzyme synthesizing the stinking chemical, (4) test the stinking chemical or other chemicals in a dead e-yo or píni carcass on various microbe and scavenger species, and (5) do feeding trials to see if experienced New Guinea predators avoid e-yos and pínis when given a choice of non-stinking, similar-sized birds. Might stinking birds prove to harbor another drug like penicillin?

The "Case of the Living Flytrap" is my other speculative example, designed to tantalize chemical ecology graduate students still searching for a thesis project. This case began one afternoon in August 1965, when the Foré tribesman Paran brought in a Papuan frogmouth (yása in the Foré language) that he had shot. As its name implies, this raven-sized bird has a very wide mouth reminiscent of a frog's. Supposedly, the bird is strictly nocturnal, catches large prey like mice, lizards, and large beetles, and sleeps during the day. Paran insisted that this yása, which he had just shot that afternoon, had been sitting motionless on a branch of a tree, with its mouth wide open. He explained that he had often seen yásas in that posture during daylight hours, and that insects flew into the bird's cavernous maw, attracted by a smelly, sticky paste on its palate.

My first thought was, nonsense! If so, frogmouths would have achieved every species' evolutionary dream—getting food without work or cost. Then I reflected that there was indeed a cost, that of synthesizing the sticky chemical bait. On the other hand, a raven-sized bird would have to attract a lot of flying insects before its strategy of setting itself up as a living flytrap could rate as successful. Then again, Paran was a cautious observer who had been right about everything else that he reported to me. My confidence in Paran increased when I read a note by an Aus-

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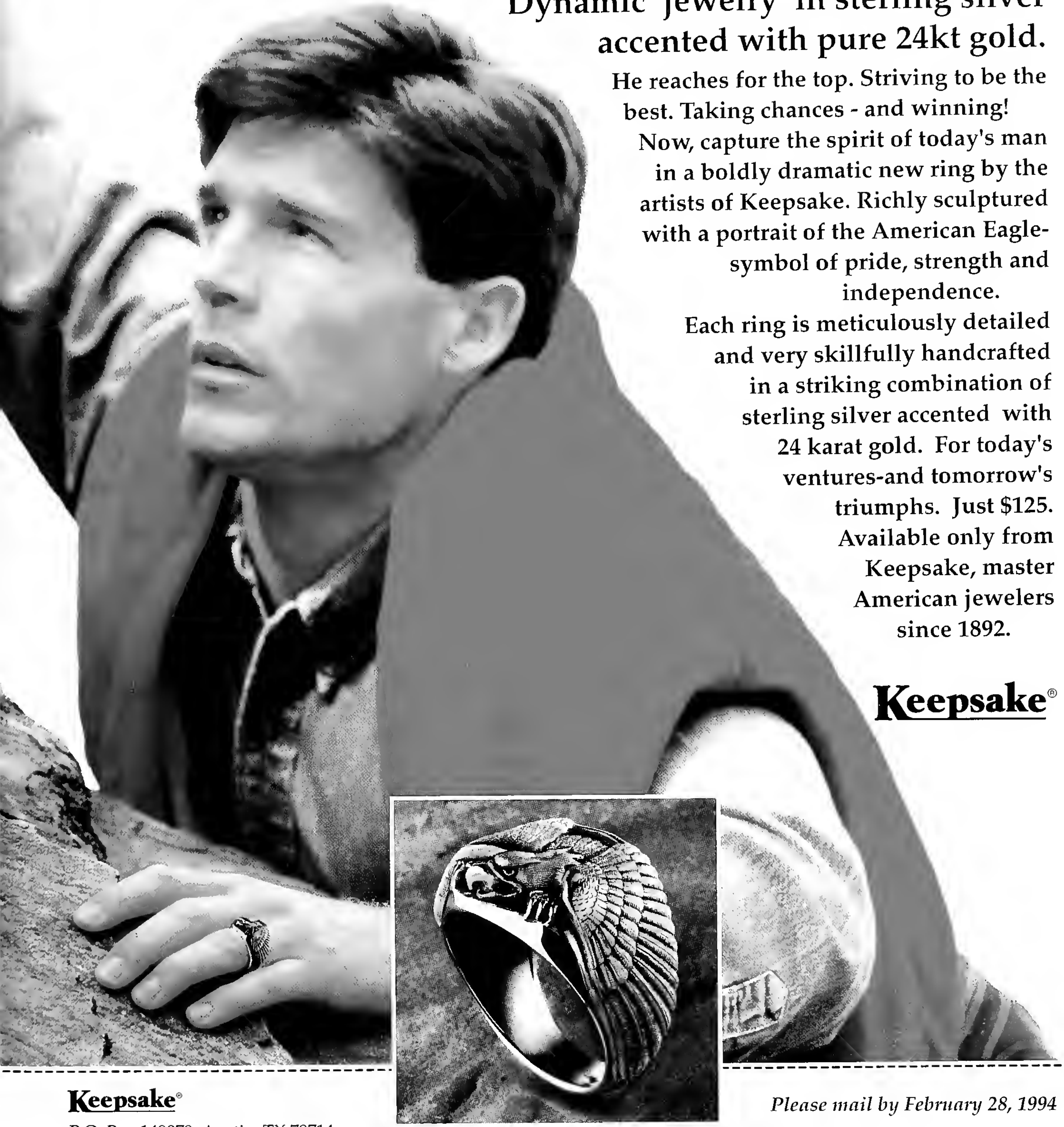

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tralian birdwatcher who had a pet frogmouth, and who saw it sit during the day with its mouth open, snapping its mouth shut when an insect flew in. Since no further information came to my attention, all I could do was to mention the behavior briefly in a book on New Guinea highland birds that I published in 1972.

There the matter rested until last month, when my Ketengban guide, Robert Uropka, was lecturing me on the habits of birds. He eventually described a big, nocturnal bird with a large mouth, convincingly imitated the call of the Papuan frogmouth, and called it sumé in the Ketengban language. "And by the way," he said, "the sumé sits during the day with its mouth wide open and"—I held my breath—"Binatang masuk sendiri!" he concluded in Indonesian ("insects fly in of their own accord!").

Does the Papuan frogmouth really secrete a chemical insect attractant and fly-catching paste on its palate? If so, I'd invest my pension in the stock of the chemical company that isolates and manufactures the attractant and paste. Or did Paran and Robert and the Australian birdwatcher all misinterpret the frogmouth's behavior? And did Paran misinterpret the paste on its palate? I've done what I can as an ethnobiologist; it's now up to a chemical ecologist to confirm or explode the "Case of the Living Flytrap."

We think of human knowledge today as undergoing explosive growth. In many respects, that's true. Laboratory biologists, for instance, are learning more about a few species that are superabundant—lab rats, lab mice, fruit flies, the bacterium *Escherichia coli*, and *Homo sapiens*.

In other respects, though, our knowledge is shrinking. Over the course of millions of years, humans throughout the world have built up a knowledge of their local natural environment so extensive that not even professional biologists can hope to capture more than a small fraction of it, and other members of urban and industrialized societies can scarcely imagine it. At the end of the twenty-four days that I spent with the Ketengban people, I felt like a Philistine because I had so often nudged the subject back to birds when they began to talk of anything else. Even for very rare bird species, such as New Guinea's leaden honey-eater and garnet robin, they rattled off the altitudes at which the birds lived, the other species with which they associated, the height above the ground at which they foraged, their diet, adult call, juvenile call, seasonal movements, and so on. Only by cutting short the Ketengbans' attempts to share with me their equally detailed knowledge of local plant, rat, and frog species could I record even fragments of their knowledge of birds in twenty-four days.

Traditionally, the Ketengbans acquired this knowledge by spending much of their time in the forest, from childhood on. When I asked Robert Uropka how, lacking binoculars and the sight of one eye, he had come to know so much about a tiny, dull-plumed warbler species that lives in the treetops, he told me that as children he and his playmates used to climb trees, build blinds in the canopy, and observe and hunt up there. But all that is changing, he explained, as he pointed to his eight-year-old son. Children go to school now, and only at vacation times can they live in the forest. The results, as I have seen elsewhere in New Guinea, are adult New Guineans who know scarcely more about birds than do most American inner-city dwellers. Within a decade or two, drug companies carrying out chemical prospecting will have to go in blind, lacking guidance as to which of tens of thousands of species to collect or what to test each species for.

Compounding this problem, education throughout Indonesian New Guinea is in the national language, not in Ketengban and the 300 other indigenous languages. Radio, TV, newspapers, commerce, and government also use the Indonesian language. While the reasoning behind such decisions is, of course, understandable, the outcome is that all but about 200 of the modern world's 6,000 languages are likely to be extinct or moribund by the end of the next century. As humanity's linguistic heritage disintegrates, much of our traditional, mostly unrecorded knowledge base vanishes with it.

The analogy that occurs to me is the final destruction, in A.D. 391, of the largest library of the ancient world, at Alexandria. That library housed all the literature of Greece, plus much literature of other cultures. As a result of that library's burning, later generations lost all but the *Iliad* and *Odyssey* among Greek epics, most of the poetry of Pindar and Sappho, and dozens of plays by Aeschylus and Euripides—to mention just a few examples.

The ongoing loss today that draws most public attention is the loss of biodiversity. In that loss, nature is viewed as the victim, humans as the villains. But there is also a parallel loss in which humans are both victims and unwitting villains. Not only are species going extinct, but so is much of our information about those species that survive. In the future, no children will grow up in the forest, where they could receive or rediscover that knowledge. Certainly, professional biologists don't have the necessary time—I count myself lucky if I can spend one month every year or two in New Guinea. It is as if we are burning most of our books, while the languages of those books that remain become as lost to us as the undeciphered Linear A of ancient Crete.

Jared Diamond is an evolutionary biologist and physiologist at UCLA Medical School.

NPG Statement on Population

We Believe that the Optimum Rate of Population Growth is Negative

We believe that the optimum **rate** of population growth for the United States (and for the world) is **negative** until such time as the **scale** of economic activity, and its environmental effects, are reduced to a level that would be sustainable indefinitely.

We are convinced that if present rates of population and economic growth are allowed to continue, the end result, within the lifetimes of many of us, would inevitably be near universal poverty in a hopelessly polluted nation and world.

We agree with Professor Herman Daly who has pointed out that the human economy is a subset of the biosphere, and that **the current scale of economic activity relative to the biosphere is already far too large to be sustainable indefinitely**.

Stabilization Is Not Enough

We believe that calls for merely slowing down rapid population growth, or for stabilizing population at present or even higher levels, **are totally inadequate**.

Such proposals, while presented as a solution, **fail to address the central issue**: how to create a national (and world) economy that will be sustainable indefinitely.

At present or at even higher levels of population, neither the application of science and technology, nor simplifying life-styles, nor any combination of the two, can offer any hope of reducing our impact on the environment to a sustainable level.

We Need a Smaller Population

We recognize that our impact on the environment in terms of pollution and resource depletion is the product of our numbers times our per capita consumption of energy and materials. Thus, there are only three ways by which that impact can be reduced:

- By reducing the size of our population by a negative rate of population growth.
- By reducing over consumption (in the United States and other developed countries) by simplifying life-styles.
- By reducing resource depletion and pollution per unit of consumption through more efficient use of energy and materials.

Population size is by far the most critical of those three variables. **Nevertheless, our present scale of economic activity is so large relative to the biosphere that all three measures are needed in order to reduce it to a sustainable level.**

An Urgent Need

Over 20 years ago, when our U.S. population was far smaller, (about 202 million, rather than our present 260 million), Professor John Holdren correctly saw the urgent need for a negative rate of population growth. At that time he wrote,

"...What is surprising...is that there is not more agreement concerning what the rate of change of population size should be. For given the uncertain, but possibly grave, risks associated with substantially increasing our impact on the environment, and given that population growth aggravates or impedes the solution of a wide variety of other problems...it should be obvious that the optimum **rate** of population growth is zero or negative until such time as the uncertainties have been removed and the problems solved."

A Population Goal for Our Country

We must have, first of all, a nationally-determined population goal for our country, accompanied by effective policies to achieve it.

We urge Congress and President Clinton to set, as a top priority national goal, **the achievement of a negative rate of population growth for the United States until such time as the scale of our economic activity is reduced to a sustainable level.**

We also call on our political leaders to urge other nations to pursue a similar goal.

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In the Mind of the Beholder

For one observer, the fossil record reveals "a world stunning and fascinating in its chaotic complexity and historical genesis"

by Stephen Jay Gould

A variety of ancient mottoes proclaims that no principle of aesthetics can specify the gorgeous and the ugly to everyone's satisfaction. "Beauty," we are told, "is in the eye of the beholder"; "There is no accounting for tastes"—an observation old enough to have a classical Latin original, *De gustibus non disputandum*, and sufficiently universal to boast a trendier version in our current vernacular, "Different strokes for different folks."

Science, by contrast, is supposed to be an objective enterprise, with common criteria of procedure and standards of evidence that should lead all people of good will to accept a documented conclusion. I do not, of course, deny a genuine difference between aesthetics and science on this score: we have truly discovered—as a fact of the external world, not a preference of our psyches—that the earth revolves around the sun and that evolution happens; but we will never reach consensus on whether Bach or Brahms was the greater composer (nor would scholars in the field of aesthetics ask so foolish a question).

But I would also reject any claim that personal preference, the root of aesthetic judgment, does not play a key role in science. True, the world is indifferent to our hopes—and fire burns whether we like it or not. But our ways of learning about the world are strongly influenced by the social preconceptions and biased modes of thinking that each scientist must apply to any problem. The stereotype of a fully rational and objective "scientific method," with individual scientists as logical (and interchangeable) robots, is self-serving mythology.

Historians and philosophers of science often make a distinction between the logic and psychologic of a scientific conclusion—or "context of justification" and "context of discovery" in the jargon. After conclusions are firmly in place, a logical pathway can be traced from data through principles of reasoning to results and new theories—context of justification. But scientists who make the discovery rarely follow the optimal pathway of subsequent logical reconstruction. Scientists reach conclusions for the damnedest of reasons: intuitions, guesses, redirections after wild goose chases, all combined with a dollop of rigorous observation and logical reasoning to be sure—context of discovery.

This messy and personal side of science should not be disparaged or covered up by scientists for two major reasons. First, scientists should proudly show this human face to display their kinship with all other modes of creative human thought. (The myth of a separate mode based on rigorous objectivity and arcane, largely mathematical knowledge, vouchsafed only to the initiated, may provide some immediate benefits in bamboozling a public to regard us as a new priesthood, but must ultimately prove harmful in erecting barriers to truly friendly understanding and in falsely persuading so many students that science lies beyond their capabilities.) Second, while biases and preferences often impede understanding, these mental idiosyncrasies may also serve as powerful, if quirky and personal, guides to solutions. C. S. Peirce (1839–1914), America's greatest philosopher of science, even coined a word to express the imaginative mode of reasoning involved in such mental leaping: abduction, or leading from (one place to another), to contrast with the more sedate and classical modes of deduction, or logical sequencing, and induction, or generalization from accumulated particulars (all from the Latin *ducere,* to lead).

This general theme leapt (or crept) into my mind as I contemplated the three hottest paleontological news items of 1993 (I am purposely excluding *Jurassic Park,* and anything else with the slightest odor of dinosaur, for personal reasons of oversaturation to the point of brontosaurian boredom; if someone could grant me a two-year's sabbatical from all contact with them, I might even like dinosaurs again.) In particular, I noted a discordance, common to all three items, between their coverage in the press and my personal reaction to the claims. All three were described as particularly surprising (they would not have ranked as "hot" items otherwise)—whereas I found each claim intensely interesting but entirely expected. This led me, naturally, to wonder why these (to me) perfectly reasonable claims seemed so unusual to others.

One might posit that my lack of surprise only recorded the professional knowledge of all practicing paleontologists—and that the discordance therefore lies between public and professional perception (thus reinforcing the myth of an arcane and enlightened priesthood of scientists). But many, probably most, of my professional colleagues were surprised as well—so the reasons for my expectations must be sought elsewhere.

I then recognized an abstract linkage among the three news items and finally understood the coordinated source of my complacency and the surprise of others. On an overt level, the three items could not be more different—for they span a maximal range of time and subject in the evolutionary history of multicellular animals (and this disparity provides an added benefit in making their conjunction a good

theme for an essay—so my literary thanks go out to them as well). The first item comes from the very beginning, the second from the middle, and the third from the latest moment in the history of animal life. The three seem just as different in subject—for the first examines evolutionary rate; the second, interaction among organisms; and the third, biogeography, or place of origin for a key species.

But the three stories are linked at a level sufficiently abstract to evoke the underlying attitudes so basic to one's particular being that popular culture speaks of a person's "philosophy of life," or "worldview." Scholars have also struggled with this notion of a personal or social model so pervasive that all particulars are judged in its light. Being scholars, they may use a fancy German term like *Weltanschauung,* which sounds complex but only means "outlook upon the world." In the most celebrated use in a social sense, T. S. Kuhn referred to the shared worldview of scientists as a paradigm (see his classic 1962 book, *The Structure of Scientific Revolutions*). Such paradigms, in Kuhn's view, are so constraining, and so unbreakable in their own terms, that fundamentally new theories must be imported from elsewhere (insights of other disciplines, conscious radicalism of young rebels within a field) and must then triumph by rapid replacement (scientific revolution), rather than by incremental advance. But the most eloquent testimony to the power and pervasiveness of worldviews was surely provided by Gilbert and Sullivan's Private Willis (in *Iolanthe*), as he mused on guard duty outside the Victorian House of Commons:

I often think it's comical
How Nature always does contrive
That every boy and every gal
That's born into the world alive
is either a little Liberal
Or else a little Conservative!

Nothing is more dangerous than a dogmatic worldview—nothing more constraining, more blinding to innovation, more destructive of openness to novelty. But on the other hand, a fruitful worldview is the greatest shortcut to insight and the finest prod for making connections—in short, the best possible agent for a Peircean abduction. So much in our material culture is both alluring and dangerous at the same time—try fast cars and high-stakes poker for starters. Why shouldn't a fundamental issue in our intellectual lives have the same property?

In short, I realized that my linkage of the three issues, and my lack of surprise at claims reported in newspapers as startling, emanated from a worldview, or model of reality, different in some crucial respects from the expectations held by many scientific colleagues and by the general public. I do not know that my view is more correct; I do not even think that "right" and "wrong" are good categories for assessing complex mental models of external reality—for models in science are judged as useful or detrimental, not as true or false.

I do know that chosen models dictate our parsing of nature and either channel our thoughts toward novel insight or blind us to evident and important aspects of reality. Beauty must be in the eye of the beholder—and our minds are as varied as our hairstyles. "For great is truth, and shall prevail"—but we only get there along pathways of our own mental construction. Science is as resolutely personal an enterprise as art, even if the chief prize be truth rather than beauty (although artists also seek truth, and good science is profoundly beautiful).

"There they go on their annual migration, the wildebeests and Professor Lippincott...."

1. *Timing the Cambrian explosion: How fast is fast?* Paleontologists have long known, and puzzled over, the rapid appearance of nearly all major animal phyla during a short interval at the beginning of the Cambrian period (a subject frequently treated in these essays and in my book *Wonderful Life*). The earth's fossil record extends back 3.5 billion years to the earliest rock sufficiently unaltered by later heat and pressure to preserve traces of ancient organisms. But with the exception of some multicellular algae that play no role in the genealogy of animals, all life, including the ancestors of animals, remained unicellular for five-sixths of subsequent history, until about 550 million years ago, when an evolutionary explosion introduced all the major groups of animals in just a few million years.

When geologists use the word *explosion,* you must take this expression with a grain of salt and recognize that, in our world, explosions have very long fuses. No one has ever doubted that the Cambrian explosion must be measured in millions of years—a long time for anyone who has ever set a dynamite charge, but awfully quick relative to a history of life measured in billions (remember that one thousand millions make a billion). But how many millions?

Paleontologists have always hedged on this crucial question because we had no precise dates for the inception of the Cambrian period. The Cambrian ended some 505 to 510 million years ago, but we had no good fix on the beginning until last September, when several of my colleagues in the Cambridge mafia (Harvard plus MIT) joined with Russian geologists in finally nailing the early Cambrian, based on data "so beautiful you could cry," to quote my grandmother, who would have understood (S. A. Bowring, J. P. Grotzinger, C. E. Isachsen, A. H. Knoll, S. M. Pelechaty, and P. Kolosov, "Calibrating Rates of Early Cambrian Evolution," *Science,* September 3, 1993, pp. 1293–98).

Previous estimates for the Cambrian's beginning ranged from nearly 600 to 530 million years ago (I have been using 590 in my introductory course for years, but must change the date this time around). The older dates (favored by most) permitted quite a good stretch for the Cambrian explosion, perhaps 30 million years or so (still a moment among billions, but at least a relaxed moment). My colleagues have now pinpointed the explosion by calibrating the radioactive decay of uranium to lead within zircon crystals obtained from volcanic rocks interbedded with Siberian sediments containing earliest Cambrian fossils.

The earliest Cambrian, like Caesar's Gaul, is divided into three parts called, from oldest to youngest, Manakayan, Tommotian, and Atdabanian. (The names are all derived from Russian localities where early Cambrian rocks are particularly well exposed.) The Manakayan contains many fossilized bits and pieces of cousins and precursors, but not the remains of major modern phyla. The Manakayan therefore predates the Cambrian explosion. By the end of the Atdabanian, virtually all modern phyla had made their appearance. The Cambrian explosion therefore spans the Tommotian and Atdabanian stages.

My colleagues have dated the base of the Manakayan at 544 million years ago (with potential error of only a few hundred thousand years) and have determined that this initial stage lasted some 14 million years. The Tommotian began about 530 million years ago and—get this, for now the intellectual impact occurs—the subsequent Atdabanian stage ended only 5 to 6 (at the very most, 10) million years later. Thus, the entire Cambrian explosion, previously allowed 30 or even 40 million years, must now fit into 5 to 10 (and almost surely nearer the lower limit), from the base of the Tommotian to the end of the Atdabanian. In other words, fast is much, much faster than we ever thought.

This story rocked the airwaves (insofar as any scientific tale merits the cliché). The *New York Times* awarded front-page billing in its weekly science section; National Public Radio featured my colleagues on its weekly science talk show. The primary theme was intense surprise: evolution means slow; how could so much happen so fast? Was the entire conceptual world of evolutionary theory about to be undermined? I was absolutely delighted by my colleagues' result, but I was not surprised. I have believed for many years that fast was at least this fast. (I had regarded the old limits of 30 to 40 million years merely as an upper bound, and had assumed that the Cambrian explosion only occupied a small segment at the beginning of this full interval.) Why such a difference between public perception and my personal reaction?

2. *Insects and flowers.* Nothing displays human hubris more than the old textbook designation of recent geological times as the "age of man." First of all, if we must use an eponymous designation, we live today, and have always lived, in the "age of bacteria." Second, if we insist on multicellular parochialism, modern times must surely be called the "age of insects."

"We're out of electricity."

Homo sapiens is one species, mammals a few thousand. By contrast, nearly a million species of insects have been described (and several millions more remain undiscovered and uncataloged). Insects represent more than 70 percent of all named animal species.

So why are insects so diverse? Many answers have been offered, and the solution will be some complex combination of the good arguments. Small size, great ecological diversity, rapid geographic dispersal, have all been mentioned and are probably valid as partial explanations, but one other factor always stands out in the conventional list of reasons: coevolution with flowering plants. The angiosperms, or flowering plants, are by far the most diverse group in their kingdom. Many species are fertilized by insects in a mutually beneficial arrangement that supplies food to the insects while transporting pollen from flower to flower.

So intricate, and so mutually adapted, are the features of both flower and insect in many cases—special colors and odors to attract the insects, exquisitely fashioned mouthparts to extract the nectar, for example—that this pairing has become our classic example of coevolution, or promotion of adaptation and diversity by interaction among organisms during their evolution. (Darwin wrote an entire book on the subject, using the classic case of intricately coadapted orchids and their insect pollinators.) Thus, a received truth of evolutionary biology has proclaimed that insects are so diverse, in no small part, because flowering plants are so varied—and each plant evolves its pollinator (and vice versa).

Sounds good, but is it true? The fossil record suggests an obvious test, but curiously, no one had ever carried out the protocol until my colleagues Conrad Labandeira and Jack Sepkoski published a paper last July ("Insect Diversity in the Fossil Record," *Science*, July 16, 1993, pp. 310-15). Insects arose in the Devonian period, but began a major radiation in diversity during subsequent Carboniferous times, some 325 million years ago. Angiosperms, by contrast, arose much later. Their first fossils are found in early Creta-

ceous strata, some 140 million years ago (if they arose earlier, as some scientists speculate, they could not have been very abundant). But angiosperms didn't really flower (pardon the irresistible, if unoriginal, pun) until the Albian and Cenomanian stages of the middle Cretaceous, some 100 million years ago, where their explosive evolutionary radiation stands out as one of the great events of our fossil record.

If insect diversity is tied to the radiation of flowering plants, as traditional views proclaim, then this burst of angiosperms should be matched by a similar explosion of insects in the fossil record. Why has such an obvious test of an important evolutionary hypothesis not been made before? The reason may lie in a common misconception about the fossil record of insects. Many people suppose that this record is exceptionally poor, with so few insects preserved as fossils that we would never be able to get a good enough count to assess the hypothesis of a sharp increase during the Cretaceous when the angiosperms radiated.

To be sure, insects do not fossilize as readily as clams or trilobites, but their record is by no means so sparse as common impressions hold. Jack Sepkoski has spent most of his twenty-year career (he was my graduate student just before then, so I confess my familial bias toward his work) engaged in an enterprise that some traditional paleontologists dismiss with the epithet of "taxon counting"—that is, he sits in the library (which he describes as his "field area") and tabulates the ranges of all fossil genera and families in all the world's literature in all languages. (This is neither so simple nor so automatic a procedure as the uninitiated might imagine. First of all, you need to know where to find, and how to recognize, obscure sources in publications with non-Roman alphabets. Second, you do not merely list what you find, but must make judgments about the numerous taxonomic and geologic errors in such publications. I have never understood why some traditionalists disparage this work. They, after all, have published the literature that Sepkoski uses; don't they want their work so honored and well employed? Through Sepkoski's painstaking effort in full and standardized tabulation, we have, for the first time, a usable compendium of changing diversity throughout the history of life, and for all groups.)

Labandeira and Sepkoski found that the insect record is better than anyone thought (once you add up all the Russian and Chinese publications). In fact, insects are more diverse than that other famous terrestrial group, for which no one has ever been shy about offering conclusions—the tetrapods, or terrestrial vertebrates (amphibians, reptiles, birds, and mammals combined). The fossil record of insects includes 1,263 families, that of tetrapods, 825 families. Moreover, except for the latest Devonian, when insects were young and hadn't yet taken off on an evolutionary radiation, insect diversity has always exceeded tetrapod diversity in every geological epoch.

Looking at the taxonomic level of insect families, Labandeira and Sepkoski could find no evidence for any positive impact of the angiosperm radiation upon insect diversity. The insect radiation began in the early Carboniferous, some 325 million years ago, got derailed once in the greatest of all mass extinctions at the end of the Permian (when eight of twenty-seven insect orders died), began again in the subsequent Triassic period, and has never stopped since. In fact, and if anything, increase in number of families actually seems to slow down somewhat during the Cretaceous as the angiosperms flowered!

Labandeira and Sepkoski then tried a different approach and also found no relationship with angiosperms. Instead of taxonomic diversity, they tabulated ecological variety by dividing insects into thirty-four "mouthpart" categories—that is, different ways of making an ecological living based on modes of feeding. (Many of these categories include insects from several different taxonomic lineages, so my colleagues are measuring ecological disparity, not just numerical abundance.) They found that 65 to 88 percent of these categories were already filled by the middle Jurassic, the period before angiosperms arose. Only one to seven new categories arose after the angiosperms evolved, but most of these have especially poor fossil records, and may well have originated earlier. Of these, only one category is plausibly linked to life with flowering plants. Thus, angiosperms are also not responsible for the morphological variety of insect feeding mechanisms.

Again, the news wires buzzed (more punning apologies) with this story, and the *New York Times* again awarded front-page billing. Again, expressions of profound surprise were the order of the day. Insects evolved independently of the flowering plants to which many are now so strongly tied? How can this be? Doesn't Darwinism proclaim that organisms change within

"Ron, you should have the doctor reset your biological clock."

webs of competition and interaction toward mutually beneficial states? And again, I was pleased but not at all surprised. For I have long felt that images of balance and optimizing competition have been greatly oversold, that major and effectively random forces buffet the history of life, that most groups of organisms make their own way according to their own attributes, and that interactions among most groups are, on the broad scale of time in millions, more like Longfellow's "Ships that pass in the night" than the Book of Ruth's "Whither thou goest, I will go."

3. *Where did* Homo sapiens *originate?* My last issue is a carryover from previous years. Nothing decisive happened in 1993 to resolve this hot debate of the last decade or so. Rather, I am amazed that the story has such fantastic "legs," and remains both the hottest item on the paleoanthropological news wire and a source of dichotomization that has forced a more complex issue into two warring camps (at least in public perception).

One position has been dubbed the "multiregionalist model," or the "candelabra" or "menorah" theory (depending on your ethnic preferences) of recent human evolution. Everyone agrees that our immediate ancestral species, *Homo erectus*, moved out of Africa into Europe and Asia more than a million years ago (where they became Java Man and Peking Man of the old textbooks). Multiregionalists argue that *Homo sapiens* evolved simultaneously from *Homo erectus* populations on all three continents (with necessary maintenance of some gene flow among populations, for they could not otherwise have evolved in such a coordinated way).

The other side has been called the "out of Africa" or "Noah's ark" school of human evolution. They argue that *Homo sapiens* arose in one place as a small population and then spread throughout the world to produce all our modern diversity. If Africa was the single place, then European and Asian *Homo erectus*, and the later European Neanderthals as well, played little or no role in our origin but were replaced by later invaders in a second and much more recent wave of human migration.

The most famous version of "Noah's ark" theory, the poorly named "mitochondrial Eve" hypothesis of modern human origins in Africa, suffered a blow in 1993, when discovery of an important technical fallacy in the computer program used to generate and assess evolutionary trees debunked the supposed evidence for an African source. But in so disproving the original claim, correction only dictated agnosticism, not a contrary conclusion—that is, the new trees are consistent with origin in a single place, but Africa cannot be affirmed as the clearly preferred spot, although Africa remains as plausible as any other place by this criterion. Other independent sources of evidence—especially the greater genetic diversity measured among African peoples—continue, in my view, to favor an African origin. (A thorough and fair review by a partisan of the out-of-Africa school may be found in "DNA and Recent Human Evolution," by Mark Stoneking, *Evolutionary Anthropology*, vol. 2, 1993, pp. 60-73.)

As a student of snails, I have no great personal stake in this argument, although I would be willing to wager that this newfangled Noah's ark will one day find its Ararat (although I won't be shocked if the boat sinks and multiregionalism triumphs). But I am intrigued by journalists' representations of this debate—particularly in their attribution of surprise to one side and expectation to the other (thus linking this tale, through the theme of misplaced surprise, to my previous two stories). Newspaper and science magazines invariably present multiregionalism as the orthodox, or expected, view, and out of Africa (or any other single place) as the surprising new kid on the block.

But this assessment is ass-backwards by any standard rendering of evolutionary theory (divorced from the distortions that intrude upon us whenever we consider something so close to us as human ancestry). Origin in a single place is the expectation of ordinary evolutionary theory, and utterly unsurprising. Species are unitary populations of organisms that split off from their ancestral populations in a limited part of the parental range. Species arise as historical entities in particular places and then spread, if successful, as far as their adaptations and ecological propensities allow. Rats and pigeons live all over the world, just as humans do. Yet we are not tempted to argue that rats evolved in parallel on all continents simultaneously. We suppose that, like most species, they arose in a single region and then spread out. Why, then, does origin in a single place surprise us when we, rather than pigeons, represent the subject? Why do we devise an entirely idiosyncratic and unusual multiregional hypothesis, and then proclaim it orthodox and expected?

I can only suppose that we want to segregate humans off as something special. We wish to see our evolution, particularly the late expansion of our brain to current size, as an event of more than merely local significance. We do not wish to view our global triumph as so fortuitously dependent upon the contingent history of a small African population; we would rather conceive our exalted intellect as so generally advantageous that all populations, in all places, must move in adaptive unison toward the same desired state.

I must try to understand the contrast of public surprise with my personal expectation for these three disparate stories by seeking a difference in worldviews, or general models of reality, between me and most of thee. Under what common paradigm, rejected by me, does a shorter Cambrian explosion, a lack of lockstep evolution between flowering plants and insects, and a single place of origin for *Homo sapiens*, seem so surprising? I can only observe that all three contraries—a more leisurely origin for anatomical designs, a coordinated evolution of coadapted groups, and an intercontinental origin of our most valued features—fit well with a more stately, predictable, and comforting view of life's history than I can see in the fossil record. Traditional concepts of evolution, at least in their translation to popular culture, favor a slow and stately process, ruled by sensible adaptation along its pathways and expanding out toward both greater complexity of the highest forms and more bountiful diversity throughout. Such a view would coordinate all three surprises in my three stories—for the newly shortened Cambrian explosion is decidedly unstately; the independence of insects and flowers seems chaotically uncoordinated; and the emergence of *Homo sapiens*, if viewed as a historical event in a single place, becomes quirky and chancy.

But my worldview accommodated and anticipated all these phenomena of rate, interaction, and place. I have come to see stability as the norm for most times, and evolutionary change as a relatively rapid event punctuating the stillness and bringing systems to new states. A faster Cambrian explosion feeds this expectation. I view lineages as evolving largely independently of one another. I do not deny, of course, that species interact in adaptively intricate ways. But each lineage is a unique entity with its own idiosyncrasies; and each evolutionary trajectory through a temporal series of environments encounters so many random effects of great magnitude that I expect historical individuality to overwhelm coordination. Grand scale independence of insects and flowers (despite the tight linkage of so many species pairs today) conforms to this view. Finally, I regard each species as a contingent item of history with an unpredictable future. I anticipate that a species will arise in a single place and then move along an unexpected pathway. In short, all my nonsurprises are coordinated by a worldview that celebrates quick and unpredictable changes in a fossil record featuring lineages construed as largely independent historical entities. I should also add that I find such a world stunning and fascinating in its chaotic complexity and historical genesis—and I happily trade the comforts of the older view for the joys of contemplating and struggling with such multifarious intrigue.

I've put myself in a tough spot. This essay has veered dangerously close to unseemly self-congratulation. But I do not write to claim that I have a "better" worldview more attuned to solving the outstanding problems of life's history. Nor do I assert the correctness of my position on the three stories, for truth is the daughter of time, and I may be proved wrong about all of them. I developed this topic because I regard the subject of worldviews, or paradigms, as so important for the unification of all creative human thought, and I wrote of my own experience because personal testimony has been an accepted staple of the essay ever since Montaigne invented the genre. (And now I must halt, lest you parry with Shakespeare's observation that the author "dost protest too much, methinks.")

Maybe my worldview, shared by many scholars these days (for I came to it by assimilation, not invention), has power as a more fruitful outlook upon reality than previous paradigms provided. Maybe my horse is coming in. But maybe I am only riding a gelding named "fashion," a nag destined to stumble at the gate next season at Hialeah as the Seabiscuit or Secretariat of deterministic gradualism comes thundering down the homestretch.

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Astrophys Ed

Do you know what famous critical mass was assembled in Cleveland?

by Roger L. Welsch

A few years ago, physicist Stephen Hawking amazed the world of publishing by producing a runaway best seller, putting him right up there with literary giants like Norm Schwarzkopf and Howard Stern. A couple of weeks ago I finally got around to buying a paperback copy of Hawking's *A Brief History of Time: From the Big Bang to Black Holes,* a primer in astrophysics for the popular market. I am now ready to talk with you about the book, even though I haven't quite finished it, putting me right up there with millions of other book buyers.

To begin with, you should know that the word *astrophysics* is a combination of *astronomy* and *physics,* NOT *astrology* and *physics.* Astrology is a belief system based on mystic mumbo jumbo with no demonstrable, substantiating basis in observable phenomena, whereas astronomy has an *n* instead of an *l* and an *m* instead of a *g.* (There is an even bigger difference between *physic* and *physics.* Briefly, *physics* can be the plural of *physic,* but *physic* is not the singular of *physics,* a confusion Hawking promises to explain in a later book.)

Hawking's lesson for us in *A Brief History of Time* is that while we once thought all matter was composed of indivisible elements, and then indivisible atoms, and then indivisible neutrons, all matter is actually made up of indivisible quarks (meant to rhyme, sort of, with "quart," but which, for reasons that physicists who explain the universe cannot explain, has wound up rhyming, sort of, with "smart").

These quarks come in several "colors"—red, green, and blue—even though quarks have no color in reality, if they have a reality. Quarks are further classified into six "flavor" groupings—up, down, strange, charmed (which may explain why no one ever goes to a dinner party thrown by an astrophysicist), Szechuan, and cherry-pistachio—even though cherry-pistachio has no flavor in reality and Szechuan has more than enough to make up for both of them. These taxonomic systems have been constructed by astrophysicists, famous for their quirky (rhymes with "quarky") sense of humor.

The important thing to remember is that astrophysics operates (or operate) primarily within scientists' minds, each step depending on the theoretical soundness of the theses leading up to it, a kind of intellectual pyramid scheme, illegal in most states of the Union but still permitted in astrophysics. The point is, no one is more surprised than physicists when a couple of centuries of theory are suddenly manifested in some actual, observable, physical event—for example, Silly Putty or the atomic bomb.

As you can imagine, everybody in physics circles was considerably relieved when Silly Putty resulted from the critical mass assembled in Cleveland and the A-bomb popped up, so to speak, at Alamogordo. Except maybe for Edward Teller, who still seems disappointed by one or the other of these outcomes.

At any rate, almost everything in Hawking's book is based on his fertile imagination and logical speculation, with almost no visible evidence or proof. This appears to differentiate his work from fiction, which is almost always based on obvious, demonstrable fact. In another way, however, physics is a lot like fiction or income tax calculating, in that when there is a conflict between the world and an intellectual construct, the author adjusts the world to fit an imagined plot.

Take black matter, for example. As fate would have it, the most recent and popular theories in physics just don't work. It's not as if there are some loose threads around the edges; the theories don't work at all. If they did, the universe would instantaneously fall in on itself or fly apart. Now

those of us who are not astrophysicists would probably do something like discard the theories. Not astrophysicists. They readjust the uncooperative universe to fit their theories, postulating a gigantic quantity of invisible gravity-producing stuff they call black matter, even though it's not black and maybe not even matter. And there you are. Just like that, the modern, popular theories are back in business.

I can imagine that readers new to physics and its way of doing things might be skeptical, but those of us who are higher up in the world of science feel nothing but anticipation in all this theorizing. It could, after all, be a step toward a newer and even sillier putty.

So that is how this book proceeds. For instance, everyone—from little kids to retired plumbers—who has heard rumors of theories about an expanding universe is haunted by the same question: If the universe is indeed expanding, what is it expanding into? Isn't the universe everything? I mean, what isn't universe, just isn't. Right? Wrong? (Remember: You have a theory that doesn't fit logic and reality? Simple enough—change logic and reality.) As I understand Hawking's book, time began at the big bang. What was before the big bang doesn't count (in physics you can do that; all you have to say is, "That isn't permitted"). In sum, the universe is expanding into timelessness, filling it with matter. And time. A lot like a dental appointment.

Speaking of time, there's something in Hawking's book about a theory that the farther you are away from the world, the slower you get old—which sounds darned promising for those of us who live in Nebraska.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

During a skirmish near Kuril Lake in Russia's Kamchatka Peninsula, a huge subadult Steller's sea eagle has the advantage over a white-tailed eagle (bottom).

Fire, Ice, and Eagles

In a land shaped by volcanoes and glaciers, birds of prey batten on a winter bounty of salmon

Text and photographs by Alexander Ladigin

Winter nights are long on Russia's far eastern Kamchatka Peninsula, but moonlight brightens the landscape when it reflects off snow some six feet deep. I leave my log cabin before dawn and ski toward Kuril Lake, hoping to elude detection by crows, ravens, and eagles, the better to observe their natural habits. The temperature is barely 0° F, and steam rises from the lake. From the "window" of my second cabin, one that I have built of snow, I see eagles that have left their nighttime communal roost and are soaring over the lake in search of a breakfast of salmon. The eagles are the reason I spend winters in southern Kamchatka, sitting all day in an igloo, brushing snow from my notebook, and hoping my camera will still work despite the frigid temperatures. Although cramped and uncomfortable, my snow cabin, one of many I have built on the very edge of the lake, gives me a view of a teeming oasis in the midst of a white desert.

Kuril Lake, near the southern tip of the peninsula, is the largest sockeye salmon spawning ground in Asia. Traveling from the Pacific Ocean, through the Sea of Okhotsk, and upriver to Kuril Lake, some eight million salmon arrive annually near the place where they hatched some four or five years earlier. Even though the spawning season is unusually long—from July to March—at peak times the huge numbers of fish pack not only the feeder streams but also the shallow edges of the lake itself. Spawning, the laying and fertilization of eggs, takes place over and over again at the same sites. The pileup of eggs and the abundant bodies of adult salmon, which die after reproducing, are the foundation of the winter life of Kuril Lake.

My study area is within the Kronotskiy State Biosphere Reserve, about 2.5 million acres in area and one of the largest in Russia. Kamchatka itself is a land of glaciers and active volcanoes. Some thousand feet deep, Kuril Lake is of volcanic origin and is fed by creeks and springs. The sheer volume of water and the influx of relatively warm spring water keeps the lake from freezing over completely in winter.

Until they begin to hibernate in late December, bears are active fishers of salmon, and the resident foxes, wolverines, otters, and even shrews take advantage of the spawning frenzy.

Thousands of birds of various species are also able to remain all winter because the lake is ice-free. Gulls feed on decomposed salmon carcasses and caviar; common goldeneye ducks and mallards gather dead eggs from the bottom of the lakeshore; mergansers capture young smolts (salmon hatchlings); and swans and mergansers dig up salmon nests and devour the eggs. Even perching birds not usually associated with fish, such as woodpeckers and willow tits, can be seen making a meal of washed-up remains of salmon and eggs. Crows, ravens, golden eagles, and white-tailed eagles also vie for a living on the lake—scavenging carcasses and pirating fish from other birds.

The most impressive of the birds that take advantage of this winter bounty, and the subject that I have studied for more than ten years, is the Steller's sea eagle. True fishing eagles, closely related to North American bald eagles, these birds are named after Georg Steller, the eighteenth-century Russian naturalist who explored Kamchatka, Alaska, and the Aleutian Islands. Steller's sea eagles are characterized by their bright white foreheads, shoulders, and tails, which contrast with their brownish black bodies. Their beaks are massive, deep, and strongly arched. But the most remarkable aspect of these eagles is their size; Steller's sea eagles can weigh up to twenty pounds, about twice as much as a bald eagle, and can have a wingspan of some seven feet. Also known as the white-shouldered eagle, this bird breeds only in Russia; of the total world population of 4,200 breeding pairs, 1,200 pairs nest on the Kamchatka Peninsula. In

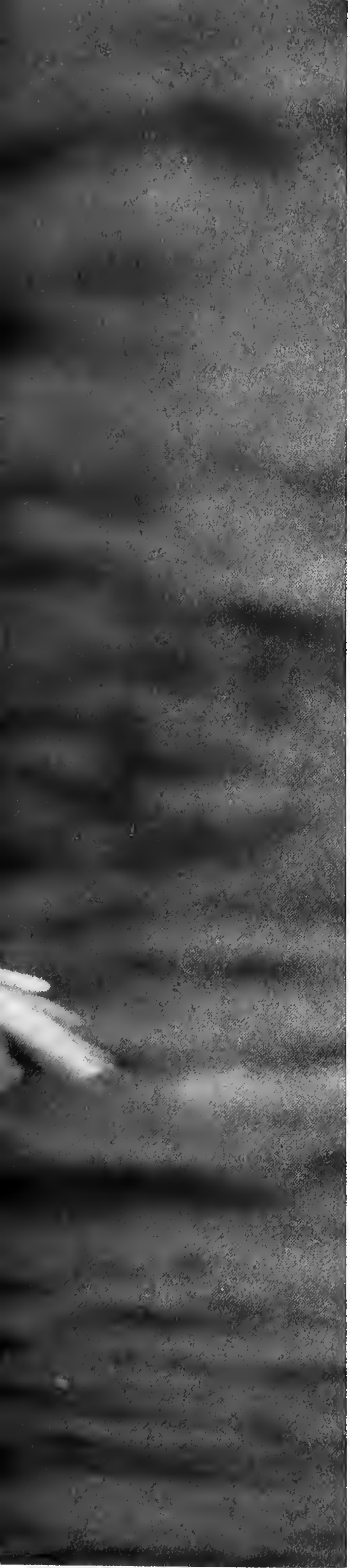
Spawning sockeye salmon, below, choke the feeder streams of Kuril Lake and sustain a wealth of bird life all winter. White-tailed and golden eagles, ducks, swans, ravens, crows, and some small songbirds, as well as Steller's eagles, left, partake of the spoils of salmon eggs and carcasses.

the winter, some of the birds migrate to Japan and Korea, but about 1,000 individuals, or one-eighth of the world's population of Steller's eagles, remain at Kuril Lake to feed on its riches.

Unlike bald eagles of North America, which have attracted the attention of biologists, conservationists, and ecotourists, Steller's sea eagles are little known and are studied today by only a handful of scientists. The haunts of the bird are remote, and this may account for its extreme shyness with humans. No roads lead to Kuril Lake, and the nearest village lies some sixty miles away. A scientific station has an outpost on the one river that flows from the lake to the sea. The limited access to the region and the bitter weather make for hard living conditions for scientists in winter. But like other visitors to this area, we enjoy plenty of fresh salmon and caviar.

Among themselves, Steller's sea eagles are extremely gregarious. Even in the breeding season, when many species of birds forgo flocks for family groups and hunt singly or in pairs, Steller's eagles tend to feed communally. This habit is related to their specialization as fish eaters; fish, their main food year-round, tends to be concentrated in lakes and streams. Most Steller's sea eagles in Kamchatka breed along the more northerly coasts of the peninsula. Beginning in late March, the eagles begin to refurbish their huge nests, which they use year after year. The usual clutch consists of two eggs, and the parent birds raise the eaglets on chunks of freshly caught fish until the young birds fledge by summer's end. As early as September, the leaves fall, the icy winds of winter begin, and the eagles' lives change dramatically. The lakes in northern Kamchatka freeze over, locking up their food supply. Adults, subadults (eagles less than five years old), and the young of the year wander southward and congregate in large groups, becoming even more social than in summer. Of the thousand or so eagles that take up winter residence on Kuril Lake, I have seen more than four hundred gather on one feeder stream choked with salmon. As soon as one eagle finds a carcass, other eagles quickly gather. The evolution of this intensely social foraging system, and the central role it plays in the birds' general ecology, is the focus of much of my winter work.

I believe that the size of their prey explains why feeding Steller's eagles attract one another and, indeed, rarely feed independently, even when food abounds. It certainly contributes to the varied interactions of Steller's and other species of eagles. Adult sockeye salmon average about



In the midst of glaciers and volcanoes, Kuril Lake, below, remains ice-free all winter. An adult Steller's eagle, left, reveals its fully mature plumage as it hoists a scrap of salmon aloft. At six or more pounds, whole salmon are too hefty to allow even the mighty Steller's to become airborne.

six pounds and are sheathed in tough skin. Unless a salmon is dead and decomposing, this hide is difficult for birds other than Steller's eagles to penetrate. The golden and white-tailed eagles that live at Kuril Lake may take hours to pry an opening around a salmon's gills, front fin, or anus, and for the most part, they depend on the massive-billed Steller's eagles to open a fish carcass. Salmon is unusual prey for white-tailed and golden eagles, which in most of their range, and in summer in Kamchatka, prey on other birds and on mammals. They have no specific adaptations for capturing large live salmon and tend instead to scavenge dead fish on the gravel bars of the lake or feed on the leftovers when the Steller's eagles have had their fill. The existence of the golden and white-tailed eagles on the salmon spawning ground is attributable to the presence of the more brawny, fish-eating specialists, the Steller's sea eagles.

In contrast, Steller's sea eagles are active predators on the spawning ground. They can catch and pull live salmon from the water, but sockeye salmon carcasses are simply too heavy for even Steller's eagles to carry away, and they more often feed on dead fish deposited on the gravel bars and icy edges of the lake. One salmon is more than enough to satiate several eagles. The birds seldom bother with rotting fish being picked apart by other species of raptors. While golden eagles form small feeding groups of three or four members, and white-tailed eagles tend to hunt alone, wintering Steller's eagles are attracted in great numbers to other Steller's eagles. The degree of attraction and interaction reaches a peak when dozens of birds converge on a mound of dead salmon—often ignoring other carcasses—and harass and fight one another in an attempt to steal the spoils.

From my snow cabin, I have witnessed some impressive squabbling from just ten to twenty yards away. Although physical injury, or even contact, is rare, the eagles use a number of ritualized displays to convey dominance, submission, and a variety of moods. Wing, tail, and head displays are most common. Sometimes one or more eagles will stretch out their wings and wave their tails to signal their determination to feed on a particular fish. Steller's eagles and their cousins the bald eagles regularly force other birds to give up prey, as when a bald eagle harasses an osprey into dropping its catch. Because of their penchant for feeding together, Steller's eagles also often engage in piracy and steal fish from one another on the lakeshore. Piracy takes place only when the fish is sizable; small fish are not worth the energy expended in a fight or are simply consumed too quickly to allow piracy to occur. Moreover, even though its massive beak enables a Steller's eagle to snatch and swallow large chunks of fish, eating a salmon takes a long time; before it has finished eating, any eagle partaking of such a banquet is likely to be seen by another hungry eagle.

For a long time I wondered why the eagles preferred robbing one another to feeding independently, especially when the lakeshore teemed with living and dead salmon. I now believe that even for such a mighty bird as the Steller's sea eagle, opening large, tough-skinned carcasses is

One feeding eagle invariably attracts a crowd, below. Displays, fights, and piracy ensue as the birds vie for salmon. The Steller's eagle, with its deep, massive beak, opposite page, is the only species of eagle on Kuril Lake able to penetrate the thick skin of sockeyes with relative ease.

a challenge. Cashing in on another eagle's work is quicker and easier than ripping open a fresh carcass and is even worth the energy lost in displaying and squabbling. Subadults, which are not yet adept at manipulating salmon, must either steal part of another bird's fish or resort to eating soft, rotting carcasses.

The dynamics of the Steller's eagles' strategy are not those of classic piracy, in which an entire prey is appropriated. Rather, piracy and scavenging are combined. Because a typical salmon provides more than enough food to satiate a single eagle, intruding birds do not so much steal as use the valuable, surplus salmon. Group feeding may be beneficial to the species because large, unwieldy windfalls of food are ultimately shared by many eagles.

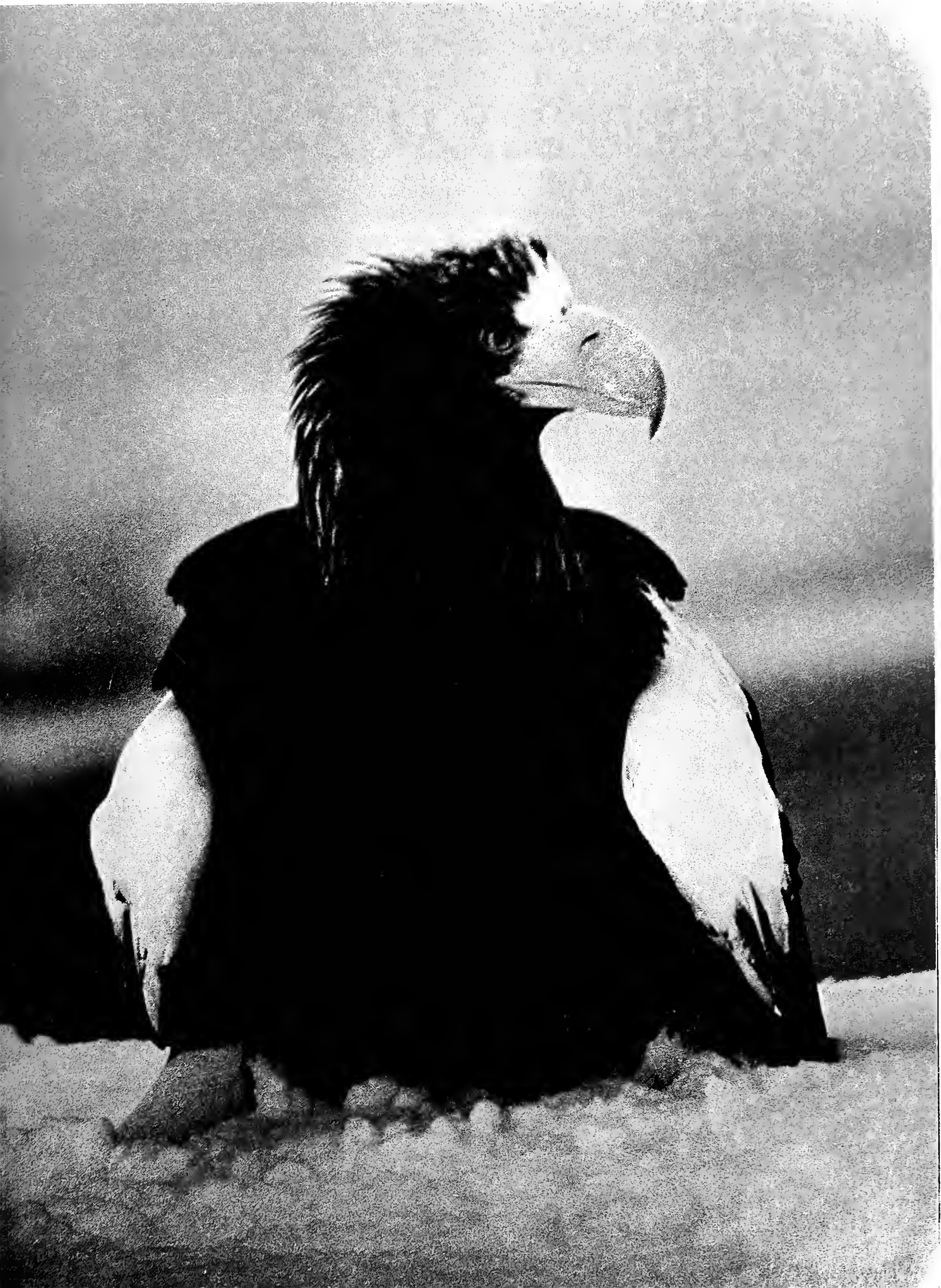
I was surprised to find that conflicts reached their peak in frequency and intensity when food was most abundant. Conflicts between two individuals were rare, but when group size increased to five, the number of conflicts rose exponentially. A major factor affecting the makeup of feeding groups is the age of its members. Adult eagles more often attacked feeding birds and were more successful at piracy than subadults.

As has been suggested for herons, storks, and gulls, the color of plumage may play a role in the formation of Steller's eagles' feeding groups. Subadults must wait five full years before they attain fully mature plumage, with the striking white head, tail, and shoulders. Younger birds are dark brown with a few white spots, and their beaks are pale, lacking the bright orange of their elders'. The contrast between white and deep brown in the adults makes them easy to spot at a feeding site and, I believe, gives other eagles a powerful visual signal of a particular bird's place in the feeding hierarchy—in which adults take precedence. I think this holds true not just on the wintering grounds but also on the breeding grounds, where Steller's eagles tend to nest near one another along salmon rivers and where several nesting pairs may share a common hunting area.

According to my best estimates, each Steller's eagle consumes about fifty fish a season at Kuril Lake. In other parts of the Kronotskiy Reserve where no spawning grounds exist, eagles may die in winter. But on Kuril Lake they tend to gain weight. I was even able to catch some by hand on the ground because, after gorging on several pounds of salmon, the eagles were unable to fly away. Of the seven winters I have spent on the lake, the one exceptional season was the winter of 1992-93. During weather that was unusually harsh, even for Kamchatka, ice covered the spawning grounds, making fish inaccessible to the eagles and all the other birds that rely on salmon for their winter livelihood. Far fewer eagles congregated on the lake. Perhaps the next couple of winters will reveal whether this is a short-lived phenomenon or a climatic trend with greater, and grimmer, implications for the wildlife of the area.

As the spawning season winds down and March approaches, most adult salmon have reproduced and died. Food now becomes scarce. During this time, the communal roost of the Steller's sea eagles, which is located in stands of birch trees some three to six miles from the lake, becomes particularly important as an area where eagles exchange information regarding the location of food. When one scouting eagle finds a spot with a few salmon left, its soaring confreres will readily find and join it. Eagles flapping in a particular direction will soon catch the attention of the birds still in the roost, and the "word" will spread. This continues until the lack of salmon and the hint of spring send the eagles north to nest again.

In the middle of March, when the eagles begin to return to the northern coasts, I too leave Kuril Lake. I board an orange polar helicopter and rise above the deep, bright water. From the air I can see the single river that connects the lake to the sea, the one artery that brings life to Kuril Lake in the form of millions of spawning salmon. □



An Unshaggy Dog Story

A bizarre canine is living evidence of prehistoric contact between Mexico and Peru

by Alana Cordy-Collins

When the Spaniards came to the Americas in the early sixteenth century, among the novel animals they encountered in both Mexico and Peru was the hairless dog. "It is a dog with no hair at all; it goes about completely naked. It sleeps upon a cape which covers it," wrote the missionary-ethnographer Bernardo de Sahagún, who observed that the animal was raised by peoples throughout the warmer parts of Mexico and was frequently sold in the bustling markets. The Aztecs called the hairless dog *xoloitzcuintli*, a name composed of the word for dog, *escuintli*, and the name of a monstrous, doglike deity, Xolotl. Similar dogs existed in China, Africa, and the Middle East, but these were unknown to the Spaniards, who considered the creature one of the extreme oddities to be found in the Americas. Four hundred years later, the descendants of those animals seem no less bizarre, with the wrinkles and warts of their bare and often mottled skin unrelieved by hair except for some on the crown of the head, the feet, and tip of the tail.

The animal's presence in the New World can be traced at least as far back as the Colima culture, which flourished in western Mexico between 250 B.C. and A.D. 450. Colima artists created hundreds of pottery vessels in the shape of dogs, usually in a highly burnished redware, and buried them along with other pottery forms (human, animal, plant) in the deep shaft-tombs of their deceased. Many scholars believe Colima society was shamanistic. Although the culture is long extinct and left no written records, representations of the hallucinogenic peyote cactus, horned warriors, even the occasional horned or masked dog, all give rise to this interpretation. In fact, my initial interest in Colima ceramics was sparked by the possibility that they carried a meaning deeper than met the eye.

Most of the Colima dog vessels are modeled into squat, rotund little animals that probably represent dogs with coats. But not every Colima dog is a sleek, round creature—some are unequivocally bald, displaying the wrinkled skin, warts, and

Incised lines on a dog-shaped pottery vessel portray wrinkles in the skin, showing that the animal lacked a normal coat of hair. The vessel was unearthed from a tomb of the Colima culture of western Mexico, 250 B.C.–A.D. 450.

Perros en las Tumbas de Colima, Universidad de Colima

Los Angeles County Museum of Art

Two hairless puppies at play, right, were immortalized by a Colima artist. The earliest Mexican sculptures of the hairless dog precede by a thousand years the first such portrayals in Peru. Ecuadorean sea traders, such as the Salangone or their predecessors, map below, may have introduced the breed into South America.

Joe LeMonnier

boniness normally concealed by fur. Other Colima pots show dogs whose teeth are abnormal or even misssing entirely, a typical trait of the hairless breed (*see* "A Lethal Gene," page 39).

Early chroniclers do not mention encountering hairless dogs in Peru, although the animals are amply represented in the region's art. Nineteenth-century reports indicate that the animals were confined mainly to the coast, as they are today. The cold Andean highlands offered no haven for such bare creatures. The explorer-cartographer J. J. von Tschudi mentions that in the 1840s hairless dogs were found in the higher altitudes, but only in warm valleys, in carefully protected circumstances. The Inca, who ruled Peru when the Spaniards arrived, probably were unable to maintain the dog in their 12,000-foot-high capital city (today's Cuzco). But the animal does appear in the art of coastal peoples within the Inca empire.

In Peru, the earliest-known representations of hairless dogs date to about A.D. 750. One is a ceramic bottle made by the Moche people, who lived in the coastal river valleys of the north, from Piura south to Huarmey. Modeled on the bottle are two spotted, hairless dogs. Moche pottery was cream and brick red, allowing the artist to show the dogs' spotted markings. (The skin of today's hairless dogs ranges widely in color, from solid black or elephant gray to mottled or spotted combinations of pink, brown, black, and white, and even all white.) Another vessel, in cream and black, shows a wrinkled, bony, black dog. Its shape and style suggest that it is about as old as the Moche bottle, but it cannot be attributed to a particular culture, in part because, like many ceramics, it was not unearthed by archeologists.

Mexico's Colima artists seem to have modeled hairless dogs fully one thousand years before their Peruvian counterparts began to do so. Could the animals have existed in Peru and have simply been ig-

A Moche vessel with a pair of hairless dogs, dating to about A.D. 750, is one of the earliest in Peru. Why the dogs were prized in prehistoric times is uncertain. People may have believed the warmth of the dog's naked skin could relieve some ailments.
Raul Apesteguia Collection, Lima; Photograph by Christopher B. Donnan

nored by earlier artists? That seems unlikely, since they did portray coated dogs, with sleek rather than wrinkled skin. In addition, dozens of mummified dogs from the thousand years before A.D. 750 have been found in Peru and Chile, and none appear to be of the hairless type.

Could the hairless dogs have suddenly appeared in Peru as a result of an independent genetic mutation? Since hairless breeds exist elsewhere in the world, this is a possibility. But some or all of these breeds may turn out to be related. So far, the genetic and osteological studies that would determine the relationships have not been carried out.

A third explanation is that hairless dogs were brought to South America from Mexico sometime in the eighth century. Early contact between the two regions has long been suspected, but proof has been elusive until recently. In 1990, anthropologists Dorothy Hosler, Heather Lechtman, and Olaf Holm published a comparative metallurgical analysis of ancient artifacts from the two regions, demonstrating that the craft of metalsmithing was introduced into western Mexico about 700 years before Columbus arived in the New World. Techniques of alloying copper and arsenic, for instance, have a long history in South America but appear quite abruptly in western Mexico.

Current evidence points to the contact having taken place by sea, rather than by land. At the time the Spaniards arrived, the Salangone kingdom on the coast of Ecuador controlled a lively Pacific coast trade. The Salangone traders plied the waters at least from Colima in Mexico to Chincha in southern Peru. Their vessels were large sailing rafts made of balsa logs, often with a cabin on deck. Francisco Pizarro, the Spanish conqueror of Peru, encountered one such vessel on his southward journey into the Inca Empire. His written account indicates that it was carrying numerous people, animals, textiles, and precious items.

Whether the Salangone kingdom stretched back to the eighth century is uncertain, but my own studies have shown

A Lethal Gene

The Inca hairless dog
Donna McClelland

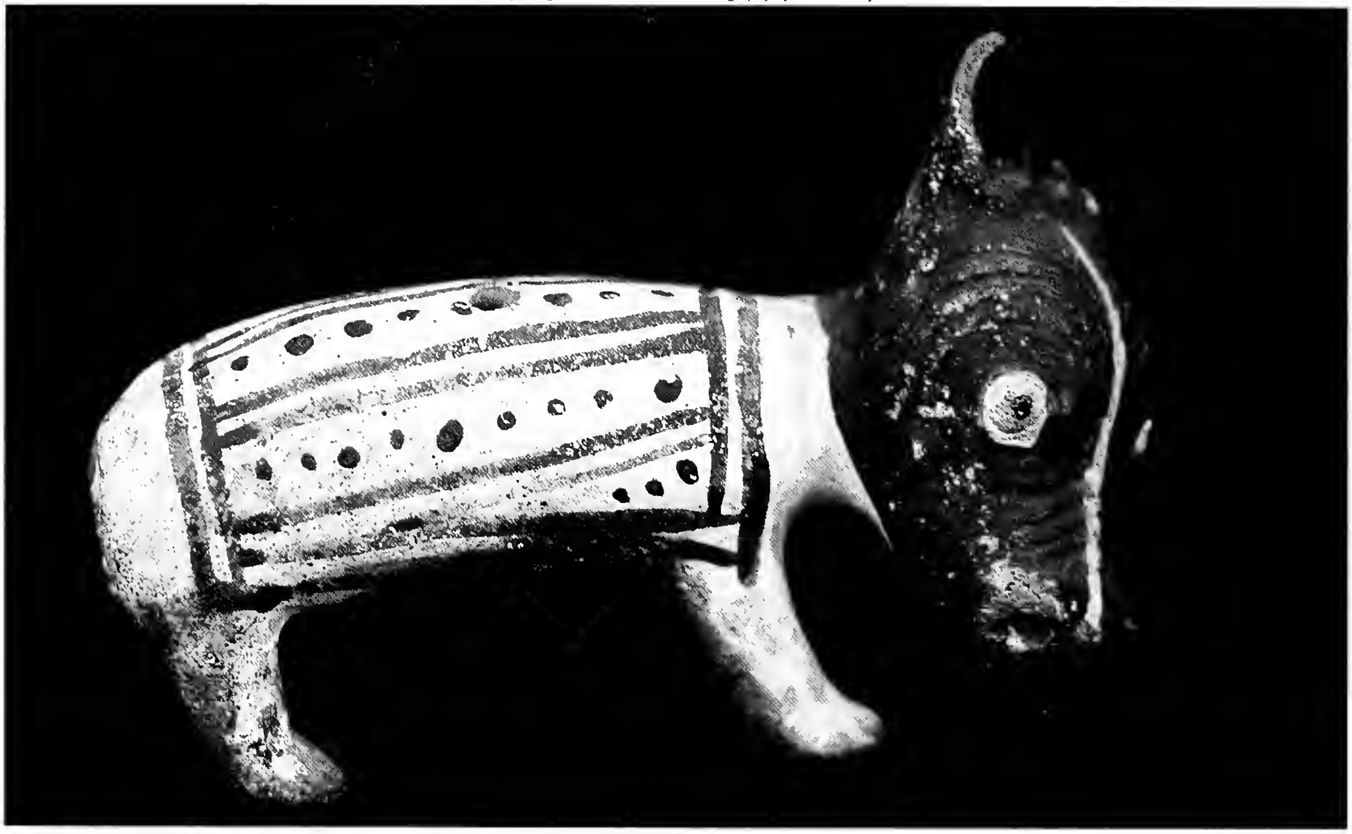
Dog fanciers recognize two breeds of hairless dogs that are descended from ancient New World forebears. Both breeds are uncommon, even in their homelands. The Mexican breed, called *xoloitzcuintli,* is classified in three sizes: standard, miniature, and toy (the popular name "Mexican hairless" generally refers to the toy). A similar Peruvian breed is called the Inca hairless dog or the Peruvian Inca orchid dog. Some writers claim that to protect the animals from excessive exposure to the sun the Inca kept them in orchid-filled rooms during the day and allowed them to run free at night (giving rise to another nickname, "moonflower dog"). This colorful story appears to be a modern invention; it is not supported by any of the early Spanish chronicles.

The hairless trait is hereditary and dominant—a puppy that inherits the gene for hairlessness from just one parent will be born hairless. If genes for hairlessness are received from both parents, the combination is lethal, and the embryo is resorbed or stillborn. Because of this, every hairless dog carries the gene for hair from one parent. When two hairless dogs mate and have a litter, on average one-third of their surviving offspring have hair (breeders call them "powderpuffs"). When a powderpuff and a hairless are bred—a routine pairing done to maintain the breed—the litter averages half coated and half hairless.

Hairless breeds have another abnormality—an incomplete set of teeth. While dogs with coats have ten molars and sixteen premolars, modern hairless dogs usually lack or lose their premolars and may even be nearly toothless. The teeth they do have are often set at peculiar angles. Because hairlessness and faulty dentition regularly appear together, they may both be caused by the same gene.

Other hairless breeds, such as the Chinese crested, may be related to the New World's bald canines. Some breeders speculate that the hairless trait originated in one locale and was then spread as a result of human trade or migration. But the dogs' distribution at widely separated locations suggests that the trait could have arisen more than once as a result of similar genetic mutations.—*A. C.-C.*

A dog protected by a blanket, below, was sculpted by an artist of the Chancay people, inhabitants of the Peruvian coast in the fourteenth century. A less whimsical hairless dog, right, is a member of the Mexican breed known as xoloitzcuintli.
Raul Apesteguia Collection, Lima; Photography by Alana Cordy-Collins



that at least one Ecuadorean sea-trading society existed by that time. Hairless dogs may have originally been brought along on voyages as food, perhaps as a welcome diversion from a diet of fish and seabirds. In ancient Mexico, dogs appear to have been deliberately fattened for human consumption, at least for ritual feasts. And the Andean chronicler Guaman Poma de Ayala mentions that coastal people living in northern Peru had a custom of eating dogs (although he does not mention whether the animals were hairless).

But hairless dogs may have been valued for different or additional reasons. In Mexico and Peru, there is a parallel folklore concerning their medicinal properties: some people believe that the dogs' warmth alleviates rheumatism and associated disorders. Thus they may have been used much as we use hot-water bottles (a common misconception is that hairless dogs have a higher body temperature than other dogs do; actually, they seem warmer to the touch only because of the lack of hair). Furthermore, at least one report indicates that in the Tlaxcala region of Mexico, hairless dogs were sacrificed in times of drought. Such a practice could have been exported to inhabitants of the arid coast of Peru. Finally, the dogs could have been introduced simply as an exotic item.

Some other clues reinforce the conclusion that Ecuadorean traders introduced the hairless dogs from Mexico into Peru. Archeologist Leon Doyon, while excavating a fourth- to fifth-century site on the outskirts of Quito, found what might be a partial mandible of a hairless dog—the teeth seem to have been incompletely developed. The chronicler Juan Velasco reported the dogs' presence in Ecuador during the eighteenth century, referring to them by the local name, *viringo*. And nineteenth-century travelers to Peru noticed them in the northern port town of Paita, close to the Ecuadorean border. (Even now, fanciers of the breed in Peru travel to the north coast in search of new animals to improve their stock.)

After the eighth century, numerous Peruvian peoples depicted the hairless dog in their art. The Lambayeque people, directly descended from the Moche and known to have traded with Ecuador, left us the greatest number of representations. One piece was crafted in silver with gold details: a double vessel with the dog on one side and a drinking cup on the other.

Among the later Peruvian artists to portray the dog were the Chancay, who occupied the south-central coast in the fourteenth century, before the rise of the Inca empire. They sometimes used their black-and-cream pottery to depict the spotted skin of the hairless dog. One of the Chancay dog figures also appears to be wearing a blanket, as indicated by the rectangular motif with geometric designs painted across the animal's back. Perhaps the artist knew a hairless dog that suffered from exposure even on the temperate coast. □

Frithjof Skibbe, Oxford Scientific Films

Some Like It Cold

While most moths are summertime creatures, a few find that flying in winter is safer

by Bernd Heinrich

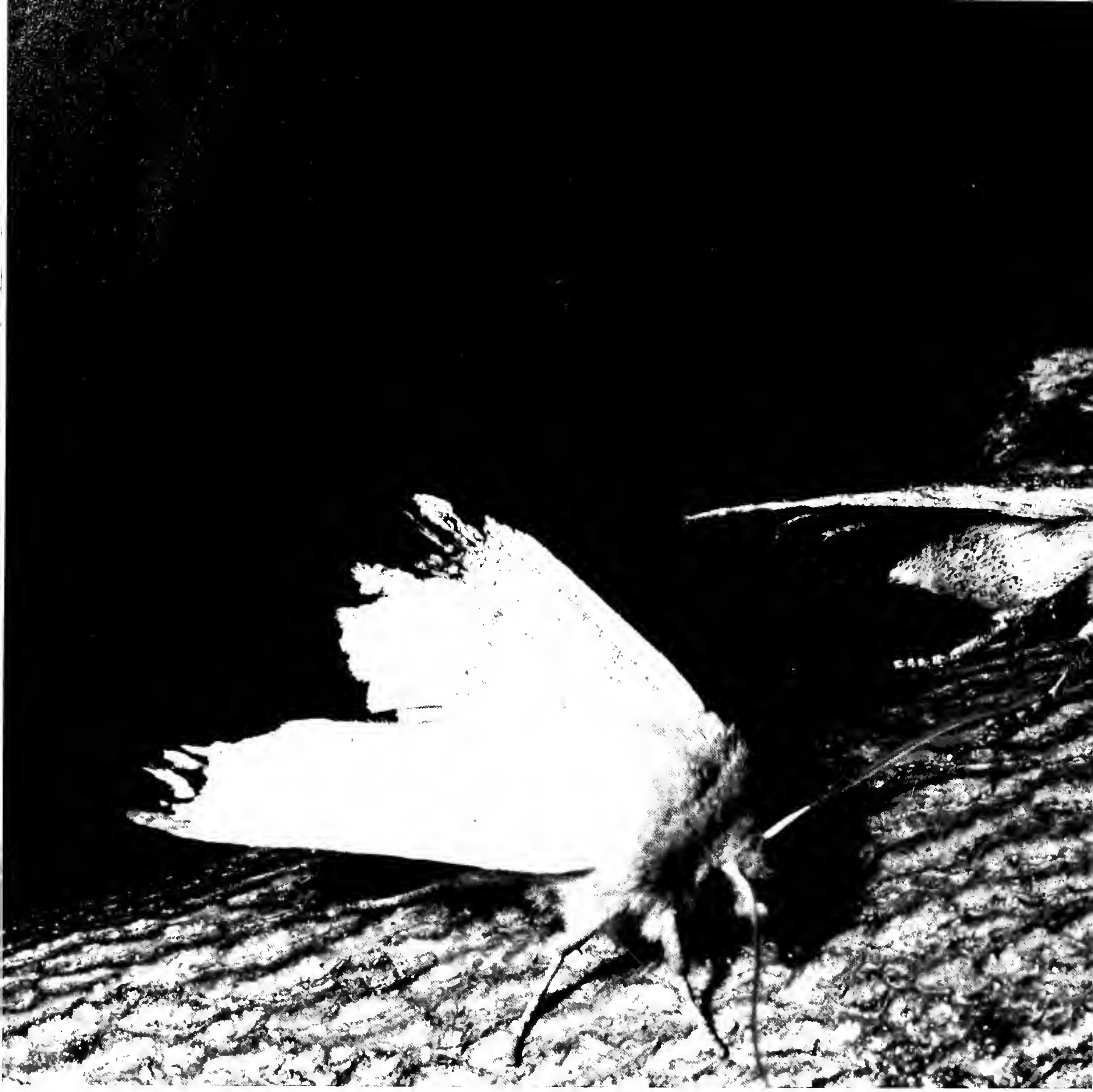
In this world of infinite moments, most are soon forgotten. But some, because of the startling images they produce, are kept forever. I will never forget one that occurred in the woods of western Maine on an early November evening ten years ago. The leaves had fallen from the trees, the last purple New England asters had finished blooming, and even the witch hazel's yellow flowers were finally near their end on leafless branches. The migrant birds had left, and the little brown bats no longer fluttered about the forest clearings. A first snow flurry had already matted the brown leaves, but a melt had uncovered them.

I was sitting on the trunk of a large, wind-felled sugar maple in a hardwood forest, hoping to see a deer in the approaching dusk. The sun was going down in a blaze of color, and frost was starting its bite. But what I saw wasn't stalking among the slowly darkening tree trunks. It was sitting right beside me on the log, shaking violently. No more than an inch long and covered in sienna-brown fur, it was a shivering owlet moth.

The little moth's antennae were partly extended, no longer tucked neatly along its sides under the wings, as they normally are when the insect is at rest. Its legs braced it against the bark, and its wings vibrated so rapidly that they were a blur. After shivering for two or three minutes more, the moth quickly wiped its antennae with its front legs and launched itself into the air, fluttering off into the night.

But why was an owlet moth still active at the threshold of winter? Until then, I had only seen moths in summer. The warmer

On warm winter days in New England, Lithophane patefacta *moths emerge from under leaf litter, above, where they hibernate during the coldest weather. Right: The thick coat of fur covering the thorax of the Old World winter moth* Eupsilia transversa *helps it conserve heat in flight.*
Bernd Heinrich



and balmier the weather, the greater the number of moths that would flutter around my porch light. And these numbers paled when compared with the hordes of moths I have seen attracted to lights in the equatorial jungle.

I later learned that this owlet moth is one of about fifty species of North American moths that are active throughout the winter. Dale D. Schweitzer, an entomologist now with the Nature Conservancy in southern New Jersey, has long studied the life cycles of these winter moths, which are also found in temperate Europe and Asia. He has found that they spend the summer as larvae in a state of suspended animation, or estivation—the warm-weather equivalent of hibernation.

I learned that the best way to catch winter moths was to lure them in with sweet bait. From John G. Franklemont, a Cornell University entomologist who is a world authority on winter moths, I learned a simple method: make a concoction of one can of beer, three-quarters of a pound of sugar, some molasses, and a little mashed fruit. (Adding a little brandy is said to help.) In the evening, smear brushfuls of this mixture on tree trunks. With a little luck, the moths will appear within minutes and become so bloated on this sweet ambrosia that they cannot fly off and will drop to the ground if disturbed. Maple syrup works equally well. In early spring these moths make a nuisance of themselves when droves of them drown in sap buckets.

I was elated when I caught my first winter moths, and I lost no time trying to find out how "winterized" they were. I put several of them in a vial of water and froze it into a block of ice in the freezer compartment of the refrigerator. A little while

Photographed at night, two winter moths, Lithophane hemina, *left, and* Eupsilia morrisoni *(far left) lap up a mixture of beer, sugar, and mashed fruit that the author applied to a tree trunk. Below: Resting in the late fall sunlight,* Eupsilia transversa *will be active in warm winter weather and reproduce in the early spring.*
Archie Allnutt; Oxford Scientific Films

later, I took the block out and let it thaw. Once released from the grip of the ice, the moths righted themselves, shivered for a few minutes, and then flew off. They had me hooked.

Winter moths turned out to be much easier to work with than many other moths I had studied. I found I could catch large numbers of them with stale beer, put them into a jar with moist leaves or tissue, and keep them healthy for months by storing them in the refrigerator at about 32° F. And I could catch them (usually the species *Eupsilia morrisoni*) during any month of the winter, provided there was a thaw of a day or so and the snow cover was not too deep. I caught many more species in late winter to early spring. They had emerged after passing the coldest months totally developed within the pupae. In March and April, when the woodcock had returned and was doing its mating dance on the first bare patches of ground, I would paint swaths of moth lure on the trees lining my driveway and watch as these insects—with their beautifully subtle and muted colors—gorged themselves before disappearing with the next snowstorm. By late April the trees were about ready to burst into leaf, the first bats were flying again, and the warblers were returning. The winter moths were near their end.

The disappearance of winter moths just as the birds are returning is no coincidence; these predators have been a major force in shaping the moths' behavior and appearance. Early in their evolutionary history, moths probably escaped most bird predation by becoming nocturnal. But by the Eocene, some 45 million years ago, echolocating bats evolved, and moths were again vulnerable at night. The late Kenneth Roeder, of Tufts University, conducted experiments showing that some moths, in turn, have evolved ear structures that allow them to hear the bats' sonar, usually in time to take evasive action.

Most moths, cryptically colored to blend into bark or other specific backgrounds on which they perch, rest motionless during the day. Some go beyond mere pattern mimicry and resemble sticks, dry leaves, and even bird droppings. Because birds hunt by sight, detecting prey by movement and contrast, they may fail to detect a resting moth. But as Alan Kamil, a psychologist now at the University of Nebraska, has demonstrated, blue jays can learn to detect even the most well-camouflaged moth. Many moths have therefore evolved other defenses to protect themselves during the day. Underwing moths startle predators by flashing brilliant red, yellow, or white underwings if they are touched or otherwise disturbed while resting. Thus they get a second chance to escape, usually by dropping to the ground. Some large moths have amazingly lifelike eye patterns on their underwings, and still others, such as many of the diurnal tiger moths, are brightly colored to advertise that they are poisonous.

Adapting to extremes of temperature is another way for an insect to escape predation. In the deserts of the American Southwest, for example, the grasshopper *Trimerotropis palladipennis* tolerates body temperatures near 122° F, so it can escape to hot sand where lizards cannot venture. Near Phoenix, the desert cicada is active in the summer, singing on the hottest days at noon, when birds are forced to retreat. (The cicadas are able to do so because their enlarged dermal glands "leak" water, which evaporates and cools them; they replace the lost fluid by tapping into the phloem of mesquite bushes.) Winter moths operate on the same principle, but at the other end of the temperature scale.

Winter moths undoubtedly escape much predation by being active when potential predators are either hibernating or several thousands of miles away. But this stratagem, like other defenses, is not without its costs or problems. To pull it off, the adult moths must find food in the dead of winter, and the larvae must feed quickly on early spring leaves and go into estivation before returning predators can eat them. Perhaps the greatest challenge, however, is the cold itself.

Most overwintering insects—whether adult, larva, pupa, or egg—are laced with antifreeze compounds, but investigations by biologist John G. Duman, of Notre Dame University, and me failed to detect any antifreeze in winter moths. Their blood freezes at 30° to 28° F, as does that of summer insects. Furthermore, they don't "supercool" to temperatures very much lower than those of summer-active insects. (Had my freezer been much colder than 32° F, the moths would have died when they were frozen in the ice.) Why they are not protected from freezing isn't clear, but I suspect that the moths need to retain their ability to become active at a moment's notice on a warm winter day (by "warm" day I mean one with evening temperatures not lower than 32° F). Insects "embalmed" with a concentrated solution of alcohols may be protected from freezing, but the chemicals infringe on an active and coordinated life style.

To maintain high temperatures in their thorax, where the muscles for flight are lo-

Tim McCabe

A Lithophane amanda *caterpillar feeds on beaked willow leaves, left. Having emerged in early spring, it is ready to form a cocoon by early June, when many summer caterpillars are just hatching from their eggs. Some cold-weather moths, such as the pair of Japanese* Erannis obliquaria *below, do not overwinter as adults. They emerge from their cocoons in November to reproduce, but die soon after. The female, which mates and lays her eggs on the same tree on which she hatched, has only small, vestigial wings.*

Fukuo Itoh; Nature Production

cated, the moths have evolved two special adaptations. First, their thoraxes are covered with dense fur that cuts their rate of heat loss in half. The fur is formed from greatly elongated scales, similar to those that color butterfly and moth wings. Like other lepidopteran scales, the fur rubs off easily, making the moths slippery in one's fingers and possibly also in the grip of a potential predator. (Winter moths retain the tympanic air sacs used by their ancestors for listening for bat sonar, but whether or not they still work is uncertain. Nevertheless, these air sacs thermally insulate the thorax from the abdomen.)

Winter moths have also evolved a circulatory system that reduces heat loss from the muscles in the thorax to both the head and the abdomen. As blood flows out of the thorax, it gives up its heat to blood flowing back in. The system conserves the heat in their thorax so efficiently that winter moths have lost the ability to use their abdomen as a radiator for dissipating excess heat, which is a necessity for summer moths that would otherwise overheat. Thus, although winter moths fly at temperatures of 32° F, they fly with thoracic temperatures similar to those of their summer relatives (about 86°–95° F).

Most insects spend the whole winter in a state of torpor; because the cold greatly reduces their metabolic rate, they do not need to eat. Winter moths also spend most of their time in torpor. But when they do warm up and fly, they use up their energy reserves very rapidly. Consider a moth at rest at 27° F. Its metabolic rate is so slow that a full stomach of maple sap containing 6 percent sugar would provide it with enough fuel to last the whole winter. A moth in flight, however, must maintain a body temperature of about 86° F. In cold weather, this means raising its metabolic rate to 8,000 times the resting rate, which would exhaust the fuel reserves in the maple sap in little more than a half hour.

To meet their prodigious energy demands in late fall, cold-adapted adult moths can still tank up on the few late-blooming flowers such as the witch hazel. After that, however, nectar is not available again until the pussy willows bloom in April. In the interim, the moths must feed exclusively on sweet sap oozing from wounds in, or broken branches of, birches and sugar maples or on the maple syrup that runs from cuts made by red squirrels (*see* "Nutcracker Sweets," *Natural History,* February 1991). With this source of sugar, they nearly double their weight in one feeding.

Sap solves the food problem for the adults, and the reversed winter-for-summer life style protects them from predation, but the switch creates a different food problem for larvae, which normally feed on summer foliage. The caterpillars survive because winter moths lay their eggs before the tree buds open, allowing their larvae to hatch and start feeding the minute the new leaves appear. By this time the first migrant warblers have returned, and some, no doubt, are feeding on these caterpillars. But the caterpillars continue to race through their development cycle.

The winter moth Scoliopteryx libatrix *is found in the northern latitudes of North America, Europe, and Asia. Sometimes called "the herald" because it is seen in the spring before other insects, the moth has been found hibernating in deep crevices in the rock.*
Frithjof Skibbe, Oxford Scientific Films

completing both the larval and pupal stages before all the birds return. Then they drop to the ground, bury themselves, and go into suspended animation throughout the summer.

These moths' predilection for cold-weather activity seems to have evolved fairly recently, because their coloration—ranging from charcoal gray to chocolate brown, sienna, white, yellow, and tan—still carries the imprint of a long history of bird predation. I wondered if winter moths would seek the "right" color bark to rest and remain hidden on, as the summer moths do. To find out, I placed twelve sections of birch, cherry, pine, maple, black locust, and elm trunks in a large outdoor cage, and in the evening I released 173 winter moths into the enclosure. The next morning not a single moth could be found on a tree trunk. I searched for six hours among the leaves on the ground and found twenty of them. Because they could not escape the enclosure, I presumed that the rest were hiding in the leaves as well. This explained why I had only seen winter moths on days when the snow cover had partly melted; they had been trapped beneath the snow-covered leaves. Dale Schweitzer has measured temperatures beneath the leaves on the ground during the winter and found that at night (especially when the ground is snow covered) the temperatures rarely fall below 37° F. If the winter moths in northern New England rested on tree trunks (as their summer ancestors undoubtedly did), they would often be exposed to temperatures low enough to kill them instantly. Camouflage has become irrelevant beneath the carpet of leaves, where the moths now rest in relative warmth. Their colors, which have probably changed little since they switched to a winter life style, are now "fossil" adaptations to a previous stage in their evolutionary history.

When I saw my first shivering winter moth on a maple log that November evening years ago, the moth seemed magical. It had traveled a different evolutionary path than the summertime moths, and that had made all the difference. □

The

Not far from its den, a Hawaiian spiny lobster forages on a coral reef.
Mike Severns

Case of the Missing Lobsters

What does a low-pressure system over the North Pacific have to do with the complaints of disgruntled lobstermen?

by Jeffrey Polovina

From the main islands of Hawaii, countless small islands, atolls, and submerged banks stretch northwestward a thousand miles to Midway Island. The islands are part of a wildlife refuge, and except for a few biologists camped out at research stations, they are uninhabited. The archipelago supports a wealth of marine life, including a large population of seabirds and a small population (1,600) of Hawaiian monk seals, an endangered species. This is where, in recent years, lobstermen have begun to harvest Pacific spiny lobsters.

As a marine biologist with the National Marine Fisheries Service in Honolulu since 1979, my job has been to provide lobstermen and managers of the fisheries in the northwestern Hawaiian Islands with biological advice. Thus, I am no stranger to phone calls from unhappy or even irate lobstermen. I still remember a call I received in September 1989. The caller was not angry despite his recent return from a sixty-day fishing trip that had yielded a very poor lobster catch. He was puzzled, however, because on a trip to the same areas a few months before, the catch had been excellent. I told him the reason for the drop was obvious; he had fished out all the lobsters! He was not amused. So I suggested that the low catch was just a temporary aberration. I reminded him that in 1987, colder water seemed to have restricted spiny lobsters' movements, making them harder to trap, and that by 1988, more favorable conditions—and good catches—had returned. I even went as far as telling him that he should look forward to a good year in 1990.

That was a mistake. By the summer of 1990, lobster catches had not improved, and my advice was proving to be an embarrassment. With fishermen grumbling and managers becoming nervous, I was under pressure to find the real reason for the persistent decline in lobsters.

Although my first reaction had been to blame the lobster decline on the usual suspect, overfishing, I had a number of reasons to doubt that this was the cause. First, the proportion of the lobster population

Bill Curtsinger

A red-tailed tropic bird, left, soars through the air above the northwestern Hawaiian islands. An unattended red-tailed tropic bird hatchling, below, waits for its parents to return with a meal.
Erwin and Peggy Bauer; Bruce Coleman, Inc

being trapped in the islands was relatively low compared with other spiny lobster fisheries. Second, sizable areas of the wildlife refuge were closed to lobster fishing. And third, size limits allowed lobsters to mature and spawn at least once before reaching harvest size, which should have been giving the population a chance to renew itself. Furthermore, I had heard rumors of declining numbers of seabirds and monk seals in the area. These two species are often good indicators of changes in the ocean; the number of offspring they raise each year can be strongly affected by the abundance of food in the sea.

Hoping that other parts of the ecosystem would provide clues to the declining lobster catches, I paid a visit to Beth Flint, a seabird biologist working for the U. S. Fish and Wildlife Service. I was fortunate to find Flint in Honolulu; usually, she is out on the islands monitoring seabirds. When I told her my story, she was very interested and told me that since 1985, the reproductive success of the red-tailed tropic bird and the red-footed booby had dropped to half of what had been observed in the early 1980s. She explained that the birds' reproductive success is defined as the fraction of eggs that ultimately hatch and become fledgling chicks strong enough to fly. The number of eggs laid hadn't changed, but the fraction of hatchlings that survived to become fledglings had fallen. Although she didn't know the reason for the decline, she was able to rule out factors such as predators, diseases, and habitat loss and suggested that a scarcity of food would force the adult birds to abandon their nests for longer periods while foraging. This would increase the chances that their exposed eggs and chicks would perish in the hot, subtropical sun.

I spent the rest of the day poring over dusty files of seabird records dating back to the early 1980s. I found that at the beginning of the decade, about 70 percent of the eggs laid produced fledglings, but the success ratio declined steadily through the mid-1980s, so that by the end of the decade, this fraction dropped to about 40 percent, where it has remained. I also learned that red-footed boobies and red-tailed tropic birds feed almost exclusively on squid and flying fish. I wondered if these marine creatures had been reduced in number by some environmental change that had also affected the lobsters. If so, why did the decline in seabird reproductive success precede the decline in lobster catches by three or four years?

Maybe monk seal statistics had some-

Ed Robinson; Pacific Stock

Searching the reef for lobsters, fish, and other creatures on which to dine, a Hawaiian monk seal, left, rolls beneath the surf. A monk seal, below, basks on an atoll in northwestern Hawaii.

Erwin and Peggy Bauer, Bruce Coleman, Inc.

thing to tell me. I turned to Tim Ragen, a colleague at the National Marine Fisheries Service, who monitors the endangered animals. Ragen had worked as a carpenter before becoming a marine biologist. Now he builds models of marine mammal populations instead of furniture. Ragen explained that the records on monk seal pups only went back to 1986, but the data did show a decline in first-year survival rates from about 85 percent in the mid-1980s to about 45 percent in the early 1990s. Like Flint, Ragen didn't know the reason for the decline, but after eliminating possible causes such as disease, he felt that the most likely cause was a scarcity of reef fishes and lobsters, which make up a significant part of a monk seal's diet.

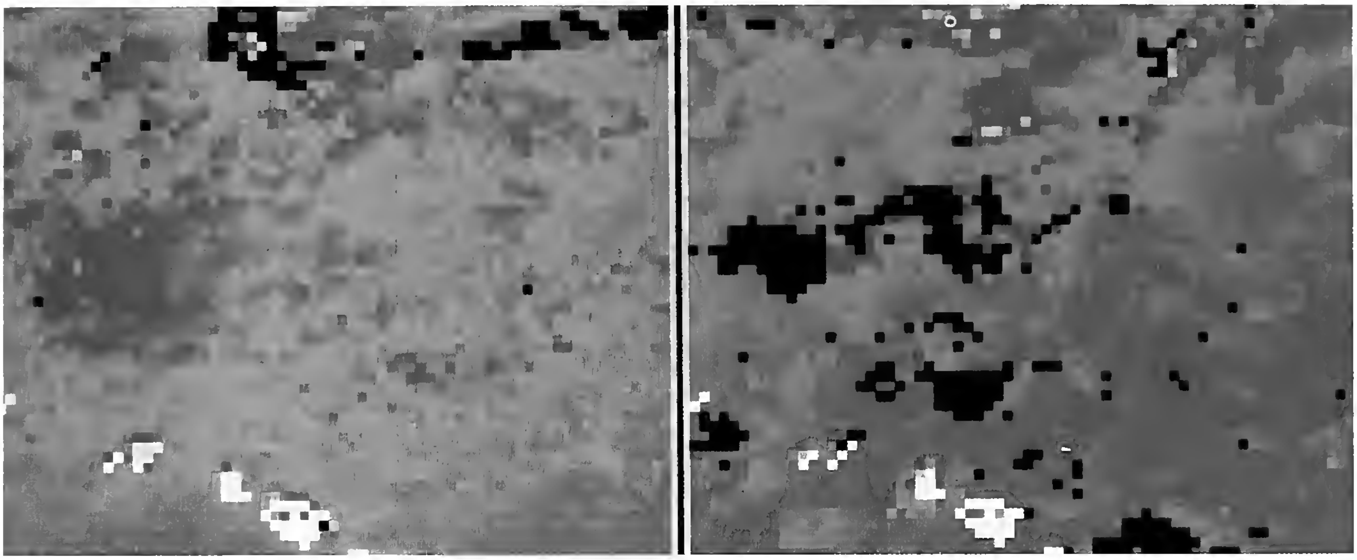
With lobsters, seabirds, and seals all showing strong evidence of decline, I became fairly certain that something had affected the entire marine ecosystem. To test my hypothesis, I looked to the reef fishes. In the early 1980s, their numbers had been surveyed at selected sites throughout the northwestern Hawaiian Islands. Because fishing is prohibited near these shallow reefs, any decline a decade later by a second survey of the same sites would be further evidence of environmental change. To coordinate a field survey to estimate reef fish densities at nine of the original sites, I enlisted the help of Ed DeMartini, a coral reef ecologist.

The last biological data would come from a satellite and would indicate how the marine life at the base of the food chain was faring. Either directly or indirectly, phytoplankton, the microscopic plant life that thrives near the ocean surface, provides almost all the food for the ocean's animal life. From space, the Coastal Zone Color Scanner, a special sensor mounted on a satellite, could measure an index of phytoplankton abundance. Unfortunately, the sensor, which was especially designed to pick up the light reflected from the chlorophyll in the phytoplankton, was only operational from 1979 to 1986, but it did record data during the crucial period of the early to mid-1980s.

While the reef surveys were being conducted, and Mei Zhou, a computer wizard, was computing phytoplankton estimates from satellite data retrieved from a giant NASA data base, I traveled to Victoria, British Columbia, to attend a conference on climate change and northern fish populations. I learned that weather patterns over the North Pacific had changed significantly since the last decade. Every year, the Aleutian low-pressure system is responsible for Hawaii's winter rainy season and the strong winds that blow from January to March, generating rough seas and the huge waves that surfers love. For about a decade, from 1977 to 1988, the Aleutian low was more intense and farther eastward than it had been at any period since the 1940s, causing unusually strong winds in the northwestern Hawaiian Islands. The climate change was not abrupt. There was a gradual increase in the intensity of the Aleutian low, and the winds that accompanied it, from 1977 to the early 1980s, followed by a gradual decline, so by 1988 the climate was back to long-term pre-1977

Jack Jeffrey; Photo Resource Hawaii

A red-footed booby, left, perches in a tree on Kure Atoll in Hawaii. Below: False-color satellite images show the changing distribution of microscopic plant life, or phytoplankton, in the northern Pacific. Green indicates a high phytoplankton concentration; blue, a low one. The white patches are the main Hawaiian Islands, and the black patches are clouds. A drop in productivity to the north of the main Hawaiian Islands is evident between the first quarter of 1982, below left, and the same period in 1986, below right.
Mei Zhou/Gene Feldman; NASA



levels characterized by a weak Aleutian low and weak winds.

I left the conference with a new insight into the changes in the marine community of the northwestern Hawaiian Islands. Since I had no biological data prior to the 1980s, I had assumed that the level of productivity in the early 1980s was the norm and that the recent drop signaled something unusual—a reasonable assumption given that the commercial lobster fishery had only been in operation since 1980, when lobsters were plentiful. Having learned that the early 1980s were characterized by abnormal climate patterns, I realized that the opposite was more likely. What originally looked like an ecological disaster, might be only a return to the usual population levels. The challenge that remained, however, was to determine if the atmospheric changes across the northern Pacific were reflected by equally dramatic changes in the ocean—changes that could effect an entire ecosystem.

Back in Hawaii, I went to see Gary Mitchum, a physical oceanographer at the University of Hawaii. A year before, Mitchum had shown me how a shift in current could have caused a change in lobster distribution, and he thought that his help entitled him to some of the lobsters caught on our research cruises. When I entered his office, he reminded me that he not received a single lobster for his trouble. Once I explained the reason for my visit, however, Mitchum forgot about free lobsters and became intrigued with the idea that a decade of unusually strong Aleutian lows could alter the ocean enough to have drastic effects on marine life. He agreed to sift through the oceanographic data to see if he could find any evidence of such a connection.

Several weeks later, Mitchum came to see me and was quite pleased with what he had found: several large-scale features of the ocean reflected the changing intensity and position of the Aleutian low. The match was good enough to convince him that the link between atmosphere and ocean was real. During the last decade, tide gauges recorded exceptionally high sea levels over the central and eastern North Pacific during the winter months. The increase, which reached about four inches, was probably caused by an eastward shift in ocean waters due to the change in wind strength and pattern resulting from the change in the low-pressure system. At the same time, Mitchum found that water-temperature readings taken from ships showed that from 1977 to 1988, the warm surface layer extended much farther down than it did from 1960 to 1976 or since 1988. This is evidence that from 1977 to 1988, there was an increase in the mixing of deep, nutrient-rich waters with nutrient-poor surface waters. Mitchum and I estimated that during this eleven-year period, the deeper mixing brought five times more nutrients into the surface waters than during the period from 1960 to 1976 or since 1988.

As a biologist, I was more excited by Mitchum's second finding, because it had great consequences for the marine life near the surface. Sun-warmed surface water is less dense and "floats" atop the colder water below. Usually there is very little mixing between the two layers. Without an influx of nutrients from deeper waters, the growth of phytoplankton near the surface—where the sunlight is—is severely limited. The problem is particularly acute in midoceanic regions, such as the waters around Hawaii, where the sea is often described as a desert. Whenever the deeper, nutrient-rich waters are brought to the surface, as in an upwelling system, phytoplankton production soars. This is apparently what happened from 1977 to 1988, when more nutrients from deep waters were mixed into surface waters.

By early 1993, the pieces were all coming together. Ed DeMartini had the results of the reef fish survey, which confirmed that the numbers of most species have dropped 30 percent from what they were in the early 1980s. Mei Zhou's analyses of

Andrew G. Wood; Photo Researchers, Inc.

In the northwestern Hawaiian Islands, pyramid butterfly fish, below, school above a reef. A small basslet fish, right, hugs the reef, looking for food.
Nikolas Konstantinou; Photo Resource Hawaii

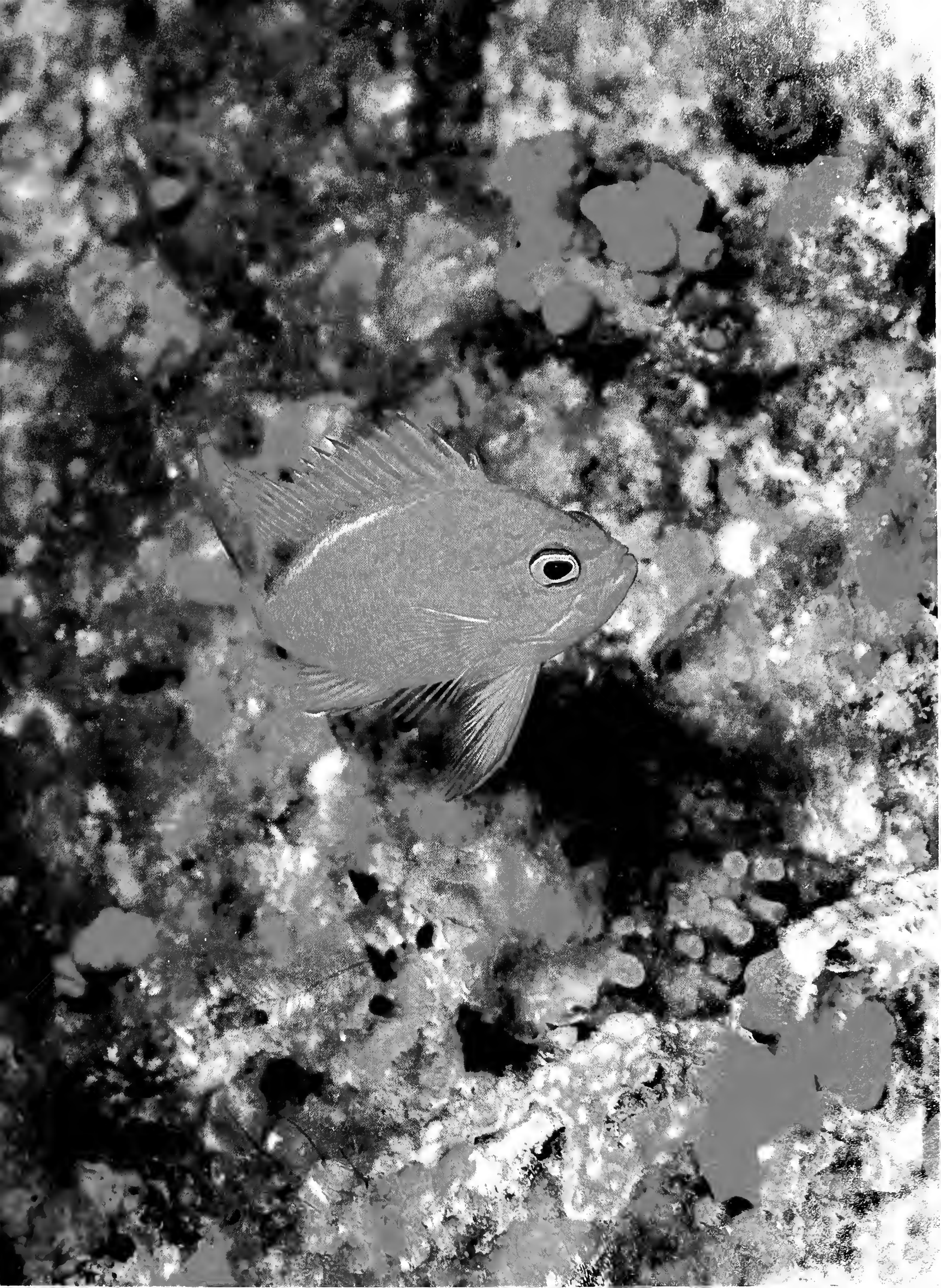
the satellite data were also ready and showed that phytoplankton production around Hawaii was highest during the first quarter of each year when the Aleutian low was strongest. Mean chlorophyll density estimated from the satellite was about 40 percent higher during the first quarter of each year from 1981 to 1983 than during the same period in the years immediately before 1981 and after 1983.

From the bottom to the top, all four major levels of the nearshore marine ecosystem in the northwestern Hawaiian Islands reflected the changing atmospheric conditions. As the Aleutian low reached its greatest intensity and eastward position in the early 1980s, the westerlies blowing across northwestern Hawaii gathered strength. The resultant wind-driven currents and rough seas increased the amount of vertical mixing of ocean waters, so that nutrients were transported from deep waters to the surface, thus increasing phytoplankton production. Higher phytoplankton densities observed in the early 1980s, translated into more zooplankton, which in turn supports a greater abundance of flying fishes and squid, which are prey for seabirds. Abundant plankton could increase the survival of reef fishes and lobsters, which eat plankton during their long larval phase. And expanded populations of reef fishes and lobsters would provide more food for monk seal pups.

The first quarter of each year seems to be a critical time for many animals, so when the Aleutian low began to wane in the mid-1980s, it would have had an immediate effect. As juvenile flying fish and squid declined in number, seabirds would spend more time away from their nests looking for food, leaving their eggs or chicks exposed to the sun. An immediate decline in the survival of lobster larvae would have occurred, but because lobsters trapped by the lobstermen are three to four years old, the decline wouldn't be observed until the very late 1980s and early 1990s. Because monk seal pups will only eat lobsters and reef fishes that are at least several years old, a decline of monk seal pup survival would not have been evident until the late 1980s as well. Thus the time lag between declines beginning in the mid-1980s for seabirds but late 1980s for monk seals and lobsters is explained.

I went back to the lobster fishermen and told them I had good news and bad news: the good news was that the decline in lobster catches wasn't due to overfishing; the bad news was that, unless the Aleutian low strengthened again, they were stuck with the current low marine productivity and poor lobster catches for a long time.

While the case of the vanishing lobster appears solved, I've learned from years of experience that ecosystems are complicated characters. We should not always count on nature to provide the same harvest; natural changes in climate can work for or against us. □



Bagging the Little Green Man

by Gail S. Cleere

The magnificent winter constellations are perhaps the easiest ones of the year to recognize. This is especially true in February, when the evening sky is devoid of planets that might otherwise confuse us. Mercury is low in the west at dusk early in the month, and brillant Jupiter rises in the late night hours. By sunset, Orion the Hunter is high in the southeast. Four bright stars mark his extremities, and three more in a row form his belt, making Orion an easy target, even for the most amateur observer. The Hunter is flanked by the brightest of all the visible stars, Sirius, to the lower left, and the prettiest of all open clusters, the Pleiades, to the upper right just beyond the V-shaped open cluster called the Hyades.

But while we can admire the beautiful stars of the winter season as soon as it gets dark, we can also catch sight of some spring stars that are beginning to appear in the east. Leo the Lion, whose stars form a distinctive "sickle" or backward question mark, can be seen emerging out of the east–northeast horizon just as Orion crosses the meridian. After midnight, as Leo crosses the meridian, Jupiter rises in the claws of Scorpius. At the same time, Hercules is rising in the east–northeast. Hercules is marked by the four brightest stars, which form a pattern called the Keystone.

In the fall of 1974, Hercules was the constellation to which we directed our first intentional interstellar space message. Using the Arecibo radiotelescope in Puerto Rico—the world's largest—astronomers transmitted a three-minute table of binary digits toward M-13, a closely packed star cluster in Hercules. The modern search for extraterrestrial intelligence had begun in 1960, however, when a radio dish at the National Radio Astronomy Observatory in West Virginia was "tuned" to listen to two sunlike stars located a relatively close twelve light-years from us (Tau Ceti and Epsilon Eridani) on the chance that a civilization capable of radio broadcasts might inhabit a planet orbiting one of the stars.

Are we alone? Our chances of finding out any time soon seem to be fading. After years of intermittent studies and short-lived programs, NASA formally inaugurated its Search for Extraterrestrial Intelligence (SETI) and began listening for suspect radio signals in October 1992—the 500th anniversary of Columbus's landfall in the New World. But exactly one year later, a House-Senate conference committee voted to kill funding for the program. According to Senator Richard Bryan of Nevada, "Millions have been spent and we have yet to bag a single little green fellow." Bryan derided the program as "the great Martian chase.... Not a single Martian has said 'take me to your leader.' Not a single flying saucer has applied for FAA approval."

Serious scientists using radio astronomy to search for nonrandom signals in space have battled that kind of rhetoric for years. The search for life on other planets has always been viewed as a somewhat suspect endeavor. Early science fiction was one problem. Science historian Trudy Bell wrote that "heroes swashing their buckles in steaming Venusian swamps or on the shifting sands of Mars, rescuing voluptuous damsels from the clutches of green and drooling monsters" didn't help the more serious scientists. Bell suspects that this notion, coupled with flying saucer cults, not only shelved the idea of extraterrestrial life for many years but also caused it to "fall off the shelf into bad company." This "giggle factor," some experts claim, is what killed the SETI program.

Perhaps to avoid being associated with the supermarket-tabloid brand of interest in extraterrestrial life, in 1992 NASA renamed the SETI program the High Resolution Microwave Survey (HRMS). HRMS was the culmination of a twenty-year project to develop sophisticated digital radio receivers capable of tuning in tens of millions of frequencies at a time, listening for signals of artificial origin against a busy background of interference from terrestrial and astrophysical sources.

Two approaches were being used. One employed the Arecibo radiotelescope to scan a thousand stars within 100 light-years of the sun. The second used the Deep Space Network's radiotelescope in the Mojave Desert to scan the remaining sky with a less sensitive, broader-band coverage. Later, telescopes in the Southern Hemisphere were to be used to cover that half of the sky.

NASA administrator Daniel Goldin is disappointed. "SETI," he says,"is a program that pays for itself [in useful technology] and is inspirational." Project scientist Jill Tarter of NASA's Ames Research Center says that private funding will be solicited for HRMS, which, she claims, "is intrinsically international." Dr. Steven Dick, NASA's SETI project historian, commented, "It's basic human curiosity, and even Congress can't stifle that. One way or another, SETI will be back." As it now stands, E. T. might try to phone home, but we have voted to take the receiver off the hook.

THE PLANETS IN FEBRUARY

Mercury will put in a good evening appearance early this month. On the 1st, approximately one hour after sunset, look for Mercury as a bright, starlike object very near to the western horizon. That night you can also use Mercury as a guide to find Saturn. The two planets will be in conjunction, with the fainter Saturn positioned on a line below and to the left of Mercury. You may need binoculars to locate Saturn in the evening twilight. Mercury will be at its greatest elongation—its greatest angular distance east of the sun (18°) on the 4th, and should remain visible for at least another week before becoming deeply immersed in the solar glare. Mercury will arrive at inferior conjunction with the sun on the 20th.

Venus emerges from behind the sun late this month to become an evening object, but it remains too near the sun to be seen.

Mars is a morning object but, like Venus, is too near the sun to be visible this month. Recent studies of the red planet's southern hemisphere give further support to the theory that water once flowed on Mars. Two astronomers in California have been studying *Viking* images of a large crater called Argyle Planitia. A network of channels on both the north and south sides of the crater could easily have been carved by running water. Sediments deposited in this impact basin indicate that it once contained a large body of water.

Jupiter rises about 12:30 A.M. local time on the 1st, and about two hours earlier at the end of the month. The planet is unmistakable, appearing as a brilliant, silvery-white object in the south–southeast sky at dawn. During the morning hours of the 3d, look for Jupiter hovering well above and to the left of the last-quarter moon. Use Jupiter to locate the star Zubenelgenubi, whose Arabic name means "southern claw of the scorpion." Look just above Zubenelgenubi for another star of similar magnitude, and you will have found Zubeneschamali, the "northern claw of the scorpion." With these two stars located, the curved body of Scorpius, just below them, is easy to find.

Saturn may be glimpsed at the very beginning of the month shortly after sunset by using the brighter Mercury as a guide. But within a few days, Mercury moves up and away from Saturn, while the ringed planet drops toward the western horizon and gets lost in the glow of the evening twilight. Saturn will reach conjunction with the sun on the 21st.

Uranus and **Neptune** are theoretically far enough west of the sun to be seen in predawn skies, although their altitude along the southeastern horizon is low. Both of these blue-green orbs (visible in very dark skies as fuzzy patches of light in binoculars) will remain in Sagittarius all year. On the 8th, a waning crescent moon passes just above them at sunrise, marking their position in the sky.

Pluto is just northeast of Jupiter, not far from the star the Arabs call Zed Prior in the constellation Ophiuchus the Serpent Bearer. This distant planet is only visible with a fairly large telescope.

The **Moon** reaches last quarter on the 3rd at 3:06 A.M., EST; is new on the 10th at 9:30 A.M., EST; reaches first quarter on the 18th at 12:47 P.M., EST; and is full on the 25th at 8:15 P.M., EST.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

Reflections on Slime

by Steven Austad

In his essay *Possible Worlds*, the late British geneticist J.B.S. Haldane imagines the moral and religious sense we might find in dogs, honeybees, and barnacles and concludes: "My own suspicion is that the universe is not only queerer than we suppose, but queerer than we *can* suppose." It is difficult not to be reminded of Haldane's remark when entering the believe-it-or-not world of microscopic invertebrates, where John Tyler Bonner has spent his scientific life.

In Bonner's world, the rules that our five senses have taught us govern animal life simply do not apply. When an amoeba reproduces by splitting in two, is it then both parent and offspring of the same age, or two offspring and no parent? What do gender and age mean? What constitutes an individual? For instance, we normally think of individuals as large, multicellular animals, such as ourselves, that arise from repeated cell divisions of a single fertilized egg. But some organisms become large without becoming multicellular. The "true" slime molds, such as those bright, slimy orange gobs we see on rotten logs, can, under good conditions, grow to the size of a human hand, yet still consist of a single cell.

LIFE CYCLES: REFLECTIONS OF AN EVOLUTIONARY BIOLOGIST, by John Tyler Bonner. *Princeton University Press, $19.95; 206 pp.*

Other organisms become multicellular by aggregating rather than repeatedly dividing. In this category are the "cellular" slime molds, the organisms to which, says Bonner, in his new book's opening sentence, he has devoted his life. They can exist as self-sufficient, single-celled "amoebas" or as multicelled "slugs." Ubiquitous in soil and decaying wood, these creatures emerge from spores and assume a solitary existence, slithering about, eating (by engulfing bacteria), and reproducing (by simply splitting).

When the going gets tough, however, slime molds stick together—literally. That is, food shortages cause certain amoebas to begin secreting attraction chemicals, thus drawing surrounding individuals toward them. The resultant social aggregation of these previously independent cells forms the sausage-shaped "slug." This new individual develops distinctive cell types at its front and back, migrates toward light, and upon finding a suitable spot, forms an erect fruiting body crowned by spores from some of the original amoebas. These spores depend, however, on the altruism of many other amoebas that died in forming the fruiting body's sturdy supporting stalk.

We could delve deeper into what an individual slime mold is, but this book isn't about slime molds. It is about the unusual perspective that a lifetime study of slime molds can give to large biological questions. Bonner says he has "an inordinate fondness for grand ideas." This isn't surprising. Generally, the smaller and less charismatic the study animal, the more we focus on grand ideas. And because our ideas are as heavily influenced by the particular organisms we study as by the environment in which we were raised, thinking about these bizarre creatures has led Bonner to a succession of unusually absorbing ideas and trenchant observations.

For instance, he argues that biologists generally are overly fixated on adult organisms, probably because humans spend so much of their existence as adults. When we think of a dog, we immediately picture some generic adult dog. But a puppy is just as much of a dog as an adult dog—so is the fetus, embryo, and even the fertilized egg. "Organisms are not just adults—they are life cycles," Bonner says. Focusing on the period of the life cycle between fertilization and first production of offspring allowed Bonner to realize that generation length will, to a certain extent, be limited by how much growth an organism requires before reproducing. To demonstrate this, he gathered data, now reproduced in virtually all introductory biology texts, showing that body size and generation length have a consistent relationship whether the organism is a bacterium or a sequoia. He also emphasizes that an adult cannot be altered without altering the process by which adults are created.

Bonner's focus on size and the various routes to multicellularity have led him to additional insights. He notes that increasing cell number is intimately related to increasing division of labor, a theory applicable to microscopic organisms or the workings of a modern city or corporation. A simple division of labor is seen even in filament-shaped colonies of primitive cyanobacteria, which may have some sporelike cells specialized for surviving hard times, other cells specialized for photosynthesis, and still others specialized for chemically processing nitrogen. In case we hadn't thought to ask, he also points out that the multicellularity produced by successive cell divisions is a phenomenon of aquatic organisms, whereas multicellularity by aggregation is primarily a terrestrial phenomenon, thus reassuring us that we did have an aquatic ancestry.

In the latter half of the book, Bonner tackles, in his understated way, the nature of sociality, consciousness, and culture. He considers many animal societies in light of the twin forces holding slime mold societies together, namely, division of labor and communication among the parts. If the terrain covered in this section is less compelling, it is because other popularizers such as evolutionist Richard Dawkins and sociobiologist E. O. Wilson have shown us the same landscape. Nevertheless, I very much enjoyed Bonner's appreciation of a clever experiment—that of biologist Gustav Kramer, who, in experiments with starlings and migration, used mirrors and light bulbs in an indoor enclosure to alter the apparent position and movement of the sun.

The book is leavened throughout with Bonner's own personal history and charming asides. He recalls how his early interest in birds was cleverly deflected by his father, who was afraid ornithologists could not make a living. And during a sabbatical leave in France, he notices how the French mix their protozoan culture medium rather informally. Instead of the American (or German) technique of meticulously measuring ingredients according to a standard recipe, the French mix together a handful of this, a dash of that, a pinch of something else until the mixture seems right. He immediately realizes that the French laboratory tradition comes straight from the French kitchen, and who would presume to dampen the spontaneity of a French chef?

To be compared with Haldane isn't really fair to Bonner—or anyone else for that matter—as Haldane was possibly the best popular biological writer we've had. As veteran baseball manager Sparky Anderson once said of the Cincinnati Reds' nonpareil baseball catcher Johnny Bench, "Don't compare nobody to Johnny Bench, you'll just embarrass that guy." However much one might want to avoid the comparison, Bonner's prose is nonetheless like Haldane's—wonderfully clear and direct. Like Haldane's, Bonner's popular writing is more than a repetition of his scientific work, glitzed and gussied up for a general audience. He develops original ideas and from his unusual vantage considers topics outside the domain of pure science.

Bonner also has a gift for recognizing apt and unexpected examples. When he dismisses evolutionist Jean-Baptiste Lamarck's idea of how we might pass on traits acquired during our lifetime, he chooses not to use the well-known tail-cutting experiments that German evolutionist August Weismann performed on twenty generations of mice. Instead he uses Weismann's more obscure argument that if Lamarck were correct, Jews should no longer require circumcision. Using another original image, Bonner points out how size affects every aspect of an organism's biology—if watermelons grew on trees, their weight would require a stalk as thick as the melon itself.

Unlike Haldane, however, Bonner laces his ideas and arguments with self-deprecating and humorous personal anecdotes. My favorite one concerns Haldane himself, whom a diffident young Bonner encountered in the lavatory after lecturing at University College in London. "Bonner, we don't make jokes in lectures in this country," boomed the always intimidating Haldane.

If we measure books by the degree to which they alter our perceptions, then this one is certainly a winner. We will never be able to look at a rotting log in quite the same way again or dig through the soil in the garden. In one of Saul Bellow's novels, a character offers an opinion that aptly describes Bonner's perspective—"Nothing is too rum to be true." Indeed!

Former lion trainer Steven Austad is now an associate professor in the Department of Biological Sciences at the University of Idaho. He studies evolutionary biology and the biology of aging, and combines laboratory research on opossums with fieldwork on the arboreal marsupials of Papua New Guinea.

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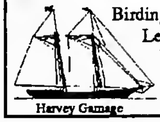

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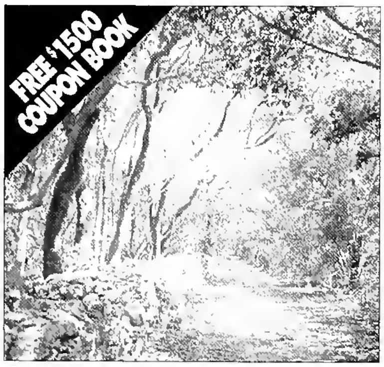
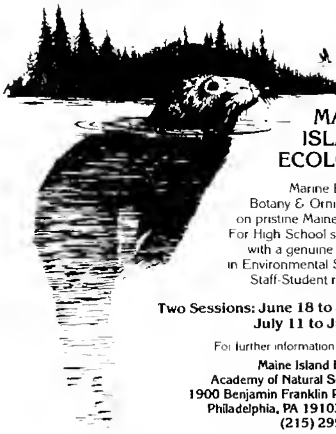




THE ACCELERATING GLOBAL CRISIS

The final two lectures of the free series "The Accelerating Global Crisis: Meeting the Challenges" will take place in February. On Tuesday, February 15, Benjamin R. Barber, Whitman Professor of Political Science at Rutgers University and author of *The Congress of Politics*, will discuss the ways in which globalization and tribalism conflict and counter democracy. A panel discussion will follow. Philosophical and spiritual solutions to global crises will be the subject of the series' concluding talk on Tuesday, February 22, by American novelist Hortense Calisher, who will explore the complexity of human experience in today's world. Both lectures begin at 7:30 P.M. in the Main Auditorium and are part of the Education Department's year-long program "Global Cultures in a Changing World." For information and free tickets, call (212) 769-5315.

SHAMANIC RITUALS

A two-day conference, sponsored by the Museum in association with the Asia Society, will explore the Korean shaman's world through traditional and contemporary music, drama, dance, visual arts, and film. Sessions will be held in the Museum's Hall of Ocean Life and the Kaufmann Theater on Saturday, February 26, and at the Asia Society on Sunday, February 27. Both programs begin at 1:00 P.M. Call (212) 769-5315 for ticket prices and further information.

BOLSON TORTOISE RESERVE

A 45,000-acre reserve in northern Mexico has been established to protect the dwindling population of North America's largest land turtle, the Bolson tortoise. Through the initiative of the Turtle Recovery Program, a project of the American Museum of Natural History's Center for Biodiversity and Conservation, scientists and ranchers have cooperated to conserve one of the last intact tracts of Chihuahuan desert grassland, the ecosystem upon which the tortoise, as well as many other animals and plants, depends.

EVOLUTION OF DWARF GALAXIES

Studies of the formation and evolution of the Milky Way's nine companion dwarf galaxies will be discussed by Kenneth Mighell, of Columbia University's astronomy department, on Tuesday, February 8. The lecture, part of the "Frontiers in Astronomy and Astrophysics" series, will begin at 7:30 P.M. in the Sky Theater. Tickets are $8 ($6 for members). For Planetarium information, call (212) 769-5900.

SHARK! FACT AND FANTASY

The habitat, anatomy, behavior, and evolution of sharks will be the focus of an exhibit in Gallery 3, opening Friday, February 4. Models and interactive exhibits will demonstrate how sharks perceive their environment and prey through highly specialized senses of sight, hearing, and smell. Some of the many scientific and medical uses of sharks will also be shown.

SEARCH FOR THE GREAT SHARKS

Sharks have lived in the world's oceans for more than 350 million years, and the new IMAX film, opening in the Naturemax Theater on Saturday, February 5, will document scientists' underwater research on these creatures. Featured are a view of the largest and most rarely seen species, the whale shark, and the birth of a baby shark. Daily showtimes for *Search for the Great Sharks* are 10:30 and 11:30 A.M., and 1:30 and 3:30 P.M. *To the Limit*, an IMAX film exploring the body's ability to adapt to the demands of intense physical action, will be shown at 12:30, 2:30, and 4:30 P.M. daily.

CHINESE SHADOW THEATER

The ancient Chinese folk art of shadow theater was brought to this country in the 1850s by Chinese immigrants who worked on the railroads and in the gold fields. In this art form, figures constructed from colored and perforated translucent animal hides are manipulated behind a backlighted screen. On Tuesday, February 1, at 7:00 P.M. in the Kaufmann Theater, the Yueh Lung Shadow Theater will enact folk tales and epics from Chinese literature using exact Peking-style puppet replicas from the Museum's collections. Call (212) 769-5606 for ticket availability.

SAVING GRACE AT ANGKOR WAT

Up until the last twenty years of war and civil strife, Cambodia's Angkor Wat had survived threats from humans and nature for more than a thousand years. On Tuesday, February 8, at 7:00 P.M., Bonnie Burnham, executive director of the World Monuments Fund, will describe the efforts to conserve and restore Angkor's temples and monasteries. This talk takes place in the Kaufmann Theater. For more information, call (212) 769-5606.

A SOCIETY OF WOLVES

By the 1950s, wolves in the United States had been shot, trapped, and poisoned to near-extinction. Rick McIntyre, a photographer, author, and naturalist who has spent sixteen years observing wild wolves in Alaska and Montana, will talk about the battle for the wolf's survival, attitudes toward wolves throughout recorded history, and the controversial issue of reintroducing wolves to Yellowstone and areas in the Southwest and Northeast. This slide-illustrated lecture will be given on Thursday, February 17, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for information.

A Bolson tortoise in the Chihuahuan desert grassland
Michael Klemens

THE SEARCH FOR OUR HUMAN ORIGINS

Paleoanthropologist Donald Johanson, author of *Lucy: The Beginnings of Humankind* and adviser to NOVA's television series *Ancestors: The Search for Our Human Origins*, will give a talk on Monday, February 14, at 7:00 P.M. in the Main Auditorium. Among the topics he will cover are the discovery of the newest fossils of *Australopithecus afarensis* and whether *Homo* survived as a noble hunter or a cunning scavenger. Tickets are $25. Call (212) 769-5310 for ticket availability.

THE LANGUAGE AND MEANING OF DNA

The semiotic analysis of languages and texts as sets of signs and symbols offers a new way of looking at DNA. On Thursday, February 24, at 7:00 P.M., Robert Pollack, biologist and former dean of Columbia College, will talk about how DNA affects our understanding of common chemistry. Tickets are $25. Call (212) 769-5310 for more information.

SPRING LECTURE SERIES

Native American life in New York City—from prehistoric times, through the colonial period and into the modern era—will be the subject of four consecutive Monday evening lectures beginning February 28. Tickets for the series are $35.

The forests of North America, from the temperate rain forest of the Pacific Northwest to the deciduous woodlands of the East, will be discussed in a series of five slide-illustrated lectures. The series will be given twice: On five consecutive Thursday evenings, starting February 24, the talks will begin at 7:00 P.M.; and on five consecutive Monday afternoons, starting February 28, the talks will begin at 2:30 P.M.

Call (212) 769-5305 for a full schedule of lectures and field trips.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Traverse Creek, California

by Robert H. Mohlenbrock

Originating in the foothills of California's Sierra Nevada Mountains, rocky-bottomed Traverse Creek descends south for more than a mile through a tree-covered canyon and then passes gently through the middle of a shallow basin. The basin, carved out by the creek in ages past, is only slightly lower than the neighboring, flat terrain, but it is easily distinguished by what grows there. Surrounded by a dense, green forest of ponderosa pine, Douglas fir, and incense cedar, the basin itself contains only shrubs and a scattering of digger pines—often multitrunked trees with large, heavy cones and long, pendulous, gray-green needles. Because of its unusual vegetation, the basin's 200 acres are managed as a botanical special interest area by the Eldorado National Forest.

As I learned from forest botanists Mike Foster and Mark Williams, digger pine grows in the basin, and ponderosa pine, Douglas fir, and incense cedar do not because Traverse Creek is adjacent to deposits and rock outcrops made of the mineral serpentine. Geologists believe that serpentine rock, or serpentinite (named for its undulating, layered texture and mottled coloring), was first exposed in California about 150 million years ago. Today it is common enough to be California's state rock, covering many discontinuous areas for a total of about 1,100 square miles. It is most common in the South Coast Range, the North Coast Range, the Bay area, and the western foothills of the Sierras.

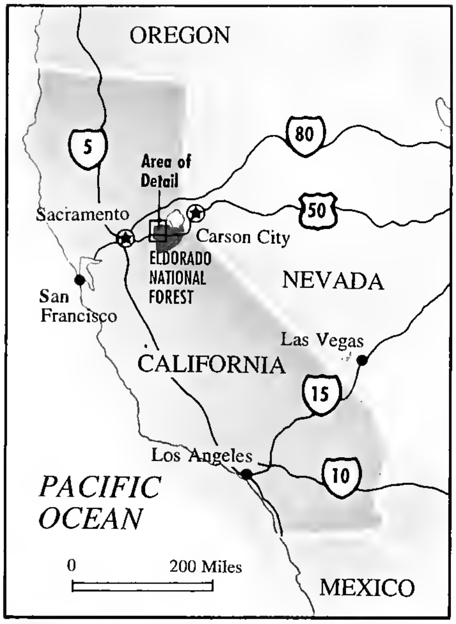
Pine cones rest at the base of a digger pine, above. Right: Bitterroot grows in arid habitats.
Thomas Hallstein; Outsight

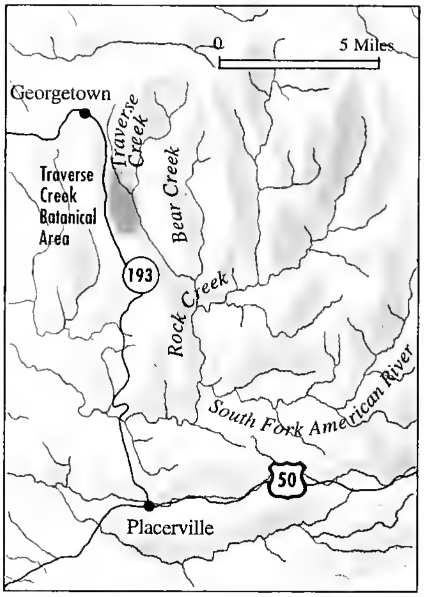
The soil that forms when serpentine rock weathers is so low in some of the elements plants depend on—calcium, potassium, and even the molybdenum needed in trace amounts—that most plants can't survive in it. In addition, the soil is unusually high in nickel, cobalt, chromium, and magnesium, which are toxic to most plants. As a result, serpentine soils usually have a sparse cover of plants that can extract the minerals they need while coping with the toxic chemicals. For example, a wild mustard known as milkwort jewelflower, which grows only near Traverse Creek, can take up nickel in excess of 1,000 parts per million without any apparent harm. Other serpentine species of jewelflower and many other serpentine-tolerant plants take up nickel in modest amounts or exclude it altogether. Plants not found on serpentine soil, including some species of jewelflower, may die in soils containing only a few parts per million of nickel.

Arthur Kruckeberg, an authority on the botany of serpentine areas, notes that the vegetation in such relatively arid locales as Traverse Creek is made up of chaparral with a sprinkling of digger pines. In the Traverse Creek basin, the chaparral consists of four- to eight-foot-tall bushy shrubs, including four species in the buckthorn family—buckbrush, deerbrush, California coffeebush, and red inkberry—as well as leather oak and white manzanita. Most of these shrubs bloom in May. The manzanita is notable for bearing its little, white, bell-shaped flowers at the tips of very sticky stalks. The stalks impede ants that might crawl to the flower in search of a pollen meal: instead, the pollen is reserved for the flying insects that pollinate the plants.

Edward S. Ross

Joe LeMonnier





Traverse Creek
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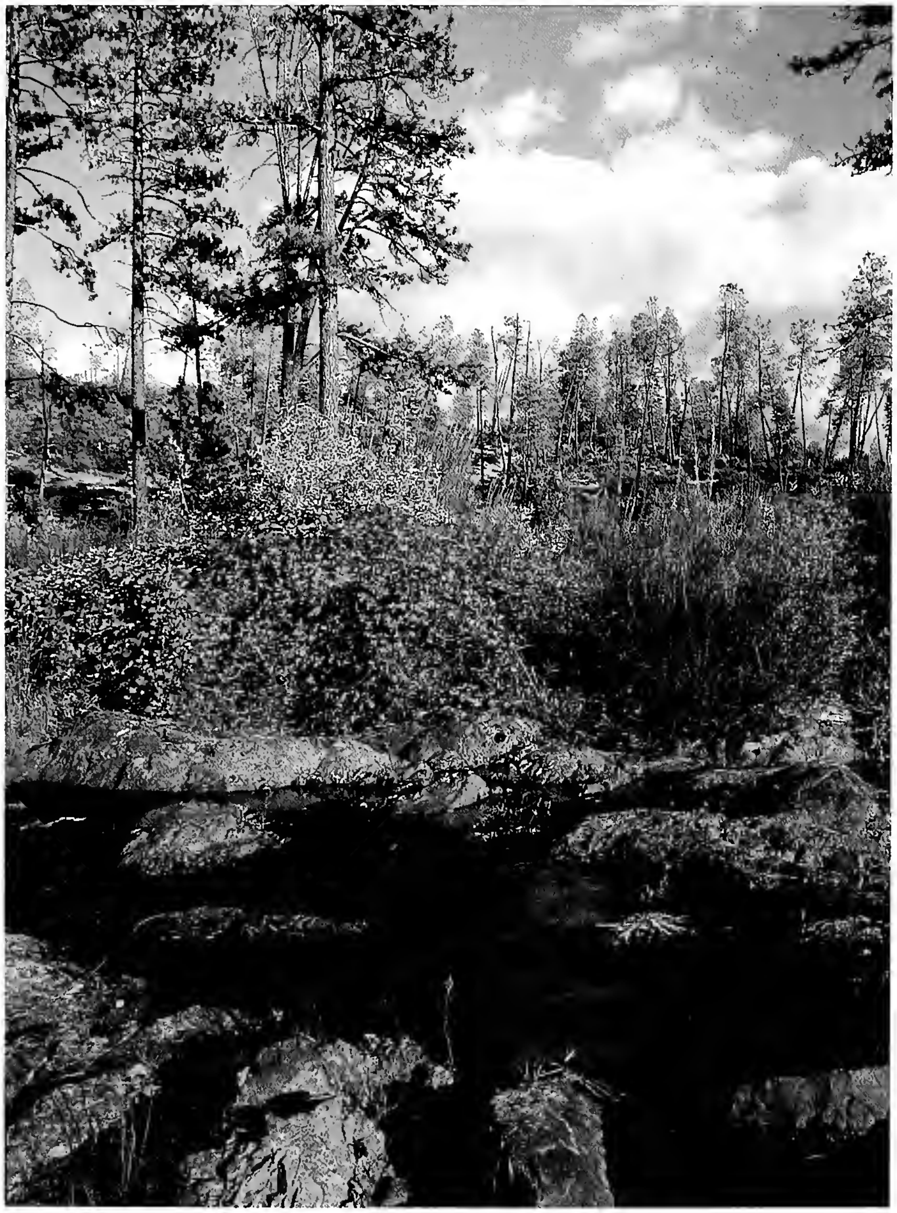

Shrubs and digger pines grow near Traverse Creek.
Thomas Hallstein; Outsight

Since chaparral plants are adapted to arid terrain, all these shrubs have water-saving adaptations, such as small leaves, leathery leaves, or leaves with a whitish, waxy coating or hairy surface. Sometimes the microscopic openings, or stomata, in the leaves are sunk deep in the leaf tissue to further reduce evaporation. The leaves of the white manzanita, which are relatively broad, stand upright so that the rays of the midday sun fall obliquely on their surface.

Between April and June, many wildflowers bloom in scattered openings in the Traverse Creek chaparral. These colorful "serpentine flower fields" consist of low-growing species that are tolerant of serpentine soil, although many grow elsewhere as well. Most of these wildflowers are also drought-tolerant; among them are a dwarf sedum with succulent leaves, a wiry buckwheat with a three-pronged flowering cluster, Sanborn's wild onion, Congdon's lomatium, and the brilliant, rose-pink bitterroot. One species found only at Traverse Creek is the rare Layne's groundsel.

Some moisture-loving plants inhabit shallow depressions that accumulate water when it rains. Among them are yellow monkey flower, which has five bright-yellow petals; bicolored monkey flower, with two white petals and three yellow petals; pink-flowered whisker brush, with five pink petals and a rosy center above a tuft of short, slender, green leaves; a yellow violet; a two-inch-tall wild white clover; and an equally small native plantain.

Seeming anomalies at Traverse Creek, not far from the visitors' parking area, are a few large ponderosa pines and an incense cedar. According to the forest botanists, enough nonserpentine soil has washed down from higher terrain to create a foothold for these conifers.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

february calendar

S	M	T	W	TH	F	S
		1	2	3	4	5
6	7	8	16	10	11	12
13	14	15	23	17	18	19
20	21	22	23	24	25	26
27	28					

1 TUESDAY
Traditional Shadow Theater ■
PERFORMANCE, 7:00 p.m. Kaufmann Theater,$7.00 members, $10.00 nonmembers

3 THURSDAY
Shark! Fact and Fantasy ■
MEMBERS' PREVIEW: Exhibition Viewing (Participating and Higher Members), 4:00, free, and Naturemax screening (all members), 7:30 p.m., $6.00

4 FRIDAY
Shark! Fact and Fantasy
SPECIAL EXHIBITION, Public opening

Search for the Great Sharks ▲
IMAX FILM, public opening, Naturemax Theater

5 SATURDAY
Wonderful Sky ●
SKY SHOW FOR CHILDREN, 10:30 and 11:4S a.m., Hayden Planetarium, $7.00 adults, $4,00 children

8 TUESDAY
"The Formation and Evolution of Dwarf Galaxies" ●
LECTURE, 7:30 p.m., Hayden Planetarium, $6.00 members, $8.00 nonmembers

"Saving Grace at Angkor Wat" ■
LECTURE, 7:00 p.m., Kaufmann Theater, $6.00 members, $9.00 nonmembers

13 SUNDAY
Afro-Dominican Music and Dance ✚
PERFORMANCE, 2:00 and 4:00 p.m., Kaufmann Theater

14 MONDAY
"Ancestors: The Search For Our Human Origins" ✚
LECTURE, 7:00 p.m., Main Auditorium, $25.00

15 TUESDAY
Understanding the Global Crisis: The Role of Ethnicity, Religion, and Nationalism ✚
PANEL DISCUSSION, 7:30 p.m., Main Auditorium. Limited seating, call in advance for free tickets.

17 THURSDAY
"A Society of Wolves" ■
LECTURE, 7:00 p.m., Kaufmann Theater; $8.00 members, $11.00 nonmembers

22 TUESDAY
Global Renewal: The Search East and West for Philosophical and Spiritual Vision ✚
PANEL DISCUSSION, 7:30 p.m., Main Auditorium. Limited seating; call in advance for free tickets.

24 THURSDAY
"Signs of Life: The Language and Meanings of DNA" ✚
LECTURE, 7:00 p.m., Main Auditorium, $25.00

26 SATURDAY
Shaman Ritual: Practice, Performance, & Metaphor ✚
TWO-DAY CONFERENCE and PERFORMANCES, 1:00 – 5:30 p.m., Hall of Ocean Life, call for ticket and schedule information.

27 SUNDAY
Shaman Ritual: Practice, Performance, & Metaphor ✚
CONFERENCE and PERFORMANCES continue, 11:00 a.m. – 4:30 p.m. at The Asia Society. Call for ticket and schedule information.

Malaki Ma Kongo (Big Feast of the Congo) ✚
PERFORMANCE, 2:00 and 4:00 p.m., Kaufmann Theater

THROUGHOUT FEBRUARY

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Global Cultures in a Changing World ✚
LECTURES & PERFORMANCES

Star Trek Exhibition: A Retrospective of the 60's
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Laser Light Shows ●
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Shark Surprise ■
MEMBERS' BIRTHDAY PARTIES in the special exhibition *Shark! Fact and Fantasy,* Wednesdays, 3:30 p.m.; Fridays, 4:00 p.m.; Saturdays and Sundays, 11:00 a.m. and 2:30 p.m. $275.00, plus $1S.00 per child

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Through a Mill, Coarsely

The laborious art of hand-grinding flour is not entirely lost

by Raymond Sokolov

When people say that wheat and rice are grains, they think they have said something simple and obvious. But as a Supreme Court Justice once remarked about obscenity, he knew it when he saw it, but defining it was the hard part.

The etymologist will tell you that our word *grain* comes from the Latin *granum,* meaning "seed," as in *cum grano salis,* "with a grain of salt." Which is what you have to take that definition with, because by no means are all seeds grains. Think of potato seeds or sesame and poppy seeds. Nevertheless, the etymological approach has its grain of truth. Let's try saying that grains contain the seeds of grasses.

At least, they start that way. The major grains are, in a botanical sense, the fruits of true grasses from the Gramineae family. There, however, the universality of the definition comes to an end. Ears of corn and drooping green rice plants do not seem to have much in common, but that has more to do with their history under cultivation than with any underlying botanical dissimilarities. The grain, or useful part of these plants in terms of human consumption, is the endosperm, the little packet of starch, protein, and other nutriments meant by nature to nourish the true seed (the germ, or embryo, it encloses).

This starchy packet is many times larger than the seed it accompanies. Like some bloated commissary of carbohydrate, it is properly referred to as the fruit of the grass plant, just as the orange, fleshy globe surrounding the seed-containing pit of the peach is its fruit. Both organs are primarily food sources (for the seed or for ambulatory and flying animals that will eat the seed along with the delicious fruit and then spread the seeds around the landscape in their dung).

Each major grain is slightly different from the others, but they all share two features: a dry, fibrous outer layer and an inner kernel of useful starch. The whole of grain technology after harvest aims at min-

A Navajo woman in Arizona grinds corn for tortillas.
John Running

imizing or removing the outer layer and at making the inner starch packet available for human consumption.

Grain harvests are generally the equivalent of mass mowings. Then comes a threshing stage, which separates the grain from the chaff, the grassy part of the plant that ends up, when dried, as straw. Of the major cereal grains, three—rice, barley, and oats—come wrapped in hard husks formed from leaflike structures. Corn, wheat, and rye are, as Harold McGee reminds us, "naked," or huskless, fruits. But even they are not ready to eat after harvest.

At this point, the wheat farmer finds himself with millions of grains covered with a fibrous "skin" known as bran. These so-called wheat berries can be eaten as they emerge from the threshing floor. Indeed, modern health food stores sell them and some restaurants do an inventive job of cooking them. But the brownish, unpolished wheat berry takes a long time to cook and is an indelicate food, although not without appeal as an occasional item in a modern diet.

The bran layer spoils easily, however. And in the dawn of grain agriculture, storage and convenience had to have been paramount goals. We cannot prove it, but it seems overwhelmingly plausible that a desire to keep the harvest safe led early men and women to exhaust themselves by grinding their wheat or rice between two stones. This loosened the bran and, incidentally, turned the interior starch into an appealing powder we call flour or meal.

Of course, it is possible, when milling, to stop short of pulverization. White rice is the leading example of that. After its bran has been rubbed off, it can easily be steamed or boiled to a wonderful tenderness. Rice can also be pulverized into flour, and often is, with rice cakes and noodles the result.

Wheat is most often milled into flour, as is rye. But oats and barley are usually not, in our day, because their flours lack gluten and can't compete with wheat in elasticity for baking pastry, and, most important, they don't rise.

Corn is *sui generis*. Its kernels can be eaten whole (steamed on the cob or gently heated in almost any way). On the other hand, the bran or hulls can be removed when exposed to an alkali such as wood ash, yielding a beneficially altered starch, hominy, that needs no milling. (Alkalization makes the corn's natural niacin available to human digestion and it also realigns the corn's amino acids so that they offer the human consumer a better balance of useful nutriments.) Or untreated corn can be ground into meal. Early Americans prepared corn in all three ways.

Hand-milling techniques have persisted in isolated pockets of traditional American culture right up to the present. Primitive millers grind one rock, or quern, against another. One of these rocks tends to be concave, the other convex. The mortar and pestle are slightly more efficient tools derived from these primordial hand mills. Such laborious techniques eventually gave way in many places to a true mill, a fixed machine run by animal or water power. In industrial societies, electrical power runs giant roller mills, and stone grinding has survived only sporadically. But educated opinion has set its face against roller-milled, pure white flour.

In her authoritative *English Bread and Yeast Cookery* (1977), Elizabeth David campaigned for the preservation of England's historic stone mills. She rhapsodized about the hard emery stones with their carefully cut grooves. She printed a detailed schematic diagram of a working mill, with its quants and shoes and damsels all neatly labeled. In the end, like proselytizers for stone-ground corn and rice meals, David was making a case for imperfectly pulverized and sieved (the technical term is bolted) flour.

The big machines work so well, she argued, that they remove virtually all the bran and germ—and with them the traditional flavor of bread flour. Gone, too, was the appealing texture of less completely milled wheat.

The Chinese food expert Florence Lin does not say whether the advent of machine grinding of fresh water-ground rice flour yields an inferior product. And even though the hand grinding and stone wheels of her childhood are gone, modern methods (themselves now obsolescent) as she describes them in her *Complete Book of Chinese Noodles, Dumplings and Breads* (1986) offer an eloquent testimonial to the importance of specific milling

Nian Gao
(Plain Rice Cake)

As Florence Lin explains in her *Complete Book of Chinese Noodles, Dumplings and Breads* (1986), this apparently simple, pure dish, eaten at Chinese New Year as a symbol of prosperity, has quite special flour requirements. The two kinds of rice flour should ideally be water-ground shortly before use (the moist flours spoil easily even under refrigeration, and the ratio of long-grain flour to sticky-rice flour determines the ultimate consistency. For a softer cake, use slightly more long-grain. For a harder one, more sticky-rice. For a chewier cake, use Japanese rice, as Koreans do. Since most U. S. cities now have thriving Asian markets, there is no need for most of us to grind whole rice grains with water in a blender and then press out the moisture. Commercial, dried, water-ground rice flour is, therefore, the ingredient anticipated in this recipe. If you want to start from scratch, presoak whole rice for four hours, then blend, water and all, to a fine wet powder. Tie up in a muslin bag and press out moisture by weighting with a heavy object, a big iron skillet or a large pot of water, for several hours, until the water stops coming out of the bag. The flour will have the consistency of a damp dough.

2 cups long-grain rice flour
1 cup sticky-rice flour

1. Put rice in a processor fitted with the steel blade. Turn on the motor and pour ¾ cup cold water through the feed tube. The flour will soon look like granulated sugar. If it gathers into a dough, there is too much water. Add a little flour so it separates again.
2. Line the basket of a steamer with aluminum foil. Shake the flour loosely and evenly into the steamer. Steam over high heat for 20 minutes.
3. Rinse but do not dry the processor bowl and the steel blade. Reattach the bowl and replace the steel blade in it.
4. When the flour has been steamed, return it immediately to the processor and process for 30 seconds or just long enough to produce a smooth dough that does not stick to the bowl. Oil fingers and remove the dough to an oiled surface. Knead while still hot, until very smooth. This takes about a minute.
5. Roll the dough into a sausage shape about an inch in diameter. Cut the tube into four equal lengths. Flatten them to a thickness of ¾ inch. Cover and let cool to room temperature. Then they are ready to eat. They will keep for a week submerged in water in the refrigerator or frozen in small pieces (1½ inches long by ¼ inch thick) sealed in tight plastic.

Yield: 4 cakes

methods to the ultimate food on the table:

In New York's Chinatown there is a factory still making fresh old-fashioned plain rice cakes. It does use machines to speed the process, however. Electric-driven grinders grind the presoaked rice. Then the ground rice, including the water, is put in a muslin bag and the water is pressed out by machine. The result is fresh water-ground rice flour. A powerful steamer then steams the wet ground flour, which is immediately kneaded by machine into a soft dough. The cakes are formed by hand. The only cooking in the process is the steaming of the flour. No seasoning is added.

It was difficult for me to read that as an account of a degraded, industrialized process. After all, I normally buy anonymous wheat flour in five-pound bags in a supermarket. But that passage got me thinking. I remembered visiting the Hopi villages in Arizona, distant mesas with captive eagles flapping from adobe rooftops. There I bought blue cornmeal from a woman who had ground it by hand at home. It was superbly fresh tasting and finer than any flour I had ever seen before.

Why not try this with wheat? I could buy wheat berries at a health food store. True, I wouldn't know what kind of wheat it was or where it came from or when it had been harvested. But I could mill the wheat berries myself, with one of the hand-powered European mills now on the market in this country. I could grind them to an appealing coarseness. I could sift out only as much of the bran as pleased me.

I was unable to find the hand-operated French stone mill that David described, but I did find an Italian metal model. Since I would not be operating it at high speed, perhaps its metal rollers would crush the wheat berries just like a stone mill, instead of shearing them to dust. As a control, I decided to grind some wheat berries with a mortar and pestle.

The results by both methods were greatly different from supermarket flour. The "grain" of my flour was appealingly unfine. I also found that bolting flour is an exacting task. I did not have the right cloth; so I ended up with a product flecked with brown specks. Both methods yielded flour full of personality and excellent, rustic bread. Fortunately, I have ready access to commercial stone-ground bread flour at a nearby water-powered country mill. Hand milling is a fine thing, but I already have a full-time career.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

The Quick and the Dead

"Its highways are mighty limbs of the best big evergreens," wrote naturalist Ernest Thompson Seton. "Of all the Weasel tribe, the Marten most is at home in the trees. He delights in climbing from crotch to crotch, leaping from tree to tree, or scampering up and down the long branches with endless power and vivacity." These solitary predators of northern forests bring the same exuberance to the hunt. Two pounds of unbridled ferocity, a marten will ambush and devour red squirrels, marmots, voles, mice, and birds.

In southeastern Idaho's Targhee National Forest, this American marten left plenty of tracks in the deep snow, giving photographer Michael Quinton a clue to its whereabouts in a lodgepole pine. By climbing an adjacent tree, Quinton was able to focus on the marten (inset). Only then did he see the carnivore's prize, a ruffed grouse that appeared to have been cached in the conifer a day or so earlier (right). Martens are usually extremely wary of humans; this animal was aware of its observer but not alarmed. It proceeded to pluck the feathers from the grouse and then began to feast on the bird's head.

Despite the bitter temperatures and heavy snows in this mountainous region, neither martens nor ruffed grouse migrate or hibernate. When the snow is deep, grouse will sometimes roost in trees, but often they will burrow—or even fly—directly into the snow and roost there. Martens, which can move easily both in the trees and atop the snow, quickly dispatch any such prey they may detect. On days when hunting fails, a vole or grouse safely stashed in a pine will insure the marten of a meal.—*J. R.*

Photographs by
Michael S. Quinton

AUTHORS

"Watching Steller's eagles wintering on Kuril Lake in Russia is not like watching bald eagles in the United States," says **Alexander Ladigin** (page 26). "At Kuril Lake, there are no roads, cars, or human inhabitants for many miles around. It is not possible to drive by the river in a car

After observing modern hairless dogs kept as pets and show dogs in Peru, **Alana Cordy-Collins** (page 34) committed the gaffe of mistaking a dog in San Diego to be of the same breed. The indignant owner informed her that it was Mexican, not Peruvian. Intrigued by the similarity of the two breeds, she has traced their possible prehistoric connection. Cordy-Collins is a professor of anthropology at the University of San Diego and curator of Latin American archeology at the San Diego Museum of Man. She has done archeological fieldwork in Ecuador and Chile, as well as Peru. For additional reading, she recommends *Atlas of Dog Breeds of the World,* by Bonnie Wilcox and Chris Walkowicz (Neptune City: T. F. H. Publications, 1989); "Axe-Monies and Their Relatives," by Dorothy Hosler, Heather Lechtman, and Olaf Holm, *Studies in Pre-Columbian Art and Archeology,* no. 30

and observe eagles from a window." Ladigin, a native of Moscow who has lived on the Kamchatka Peninsula in the far east of Russia for seven years, watches eagles the hard way. He spends his days in igloolike snow cabins on the edge of the lake for an up-close view of the hundreds of eagles

that congregate there in the winter. His permanent residence, in a village on the Bering Sea coast, is a log cabin, which he shares with his anthropologist wife and their four-year-old daughter. A graduate of Moscow State University, Ladigin, currently on the staff of Kronotskiy State Biosphere Reserve in Kamchatka, is completing his doctoral dissertation on adaptive radiation in birds of prey. In addition to observing Steller's eagles, he has studied their cousins, bald eagles, in the Pacific Northwest. Future projects include more studies of the winter ecology of sea eagles. Emulating his favorite study subjects, he plans to raise his offspring far from the press of civilization. More on birds of prey can be found in *Vanishing Eagles*, by Philip Burton, with paintings and drawings by Trevor Boyer (Secaucus: Chartwell Books, Inc., 1987). The natural history of bald eagles is the subject of Mark V. Stalmaster's *The Bald Eagle* (New York: Universe, 1987) and Jon Gerrard and Gary R. Bortollotti's *The Bald Eagle: Haunts and Habitats of a Wilderness Monarch* (Washington, D.C.: Smithsonian, 1988).

(Washington, D.C.: Dumbarton Oaks, 1990); and "Ancient Cultural Contacts Between Ecuador, West Mexico, and the American Southwest," by Patricia R. Anawalt, in *Latin American Antiquity*, vol. 3, no. 2, pp. 114–29, 1992.

Jeffrey Polovina (page 50) has been interested in Pacific marine life since 1974, when he was twenty-six years old. Fresh out of the University of California at Berkeley with a Ph.D. in mathematical statistics, Polovina decided to spend nine months island hopping across the western Pacific, often making the jumps by small boat. His travels ultimately brought him to Hawaii, where, in 1979, he joined the National Marine Fisheries Service, and was immediately sent on a research cruise to the northwestern islands. With his statistical background, Polovina was well prepared to study the population dynamics of the archipelago. He also recognized that the widely separated atolls and reefs offered an excellent opportunity to investigate the mechanisms that create biological variation. Polovina has also done research on coral reefs around the Pacific, including a five-year study in the Marianas. In 1993, he was awarded a Fulbright Research Award to study lobster population dynamics off the coast of Kenya, and in 1994 he will be heading off to the Antarctic for further marine studies. He is currently chief of insular resource investigations at the Fisheries Service. For further reading, the author recommends D. H. Cushing's book *Climate and Fisheries* (London: Academic Press, 1982).

Living in southeastern Idaho on the edge of Yellowstone Park, **Michael Quinton** (page 76) doesn't have to go far to find subjects for wildlife photography. A full-time photographer for the past fifteen years, Quinton particularly enjoys taking pictures in winter. While Quinton sees marten tracks, like the ones that led him to this month's "Natural Moment," just about every day in winter, he actually spots the animals only once or twice a year. For these photos, he used a Nikon F3 and a 400mm lens with tele-extender. Quinton has produced several wildlife books, including *The Ghost of the Forest: The Great Gray Owl* (Flagstaff: Northland Publishing, 1988), and is currently at work on a project on grizzlies. Quinton, his wife, and their two small children enjoy living in the wilderness; for most of the winter they get around on skis and snowshoes, and by snowmobiles. Although Yellowstone has provided them with wildlife and winter on a grand scale, the Quintons have been thinking of moving on to Alaska.

Bernd Heinrich (page 42), shown here with his son, Stuart, is a frequent contributor to *Natural History*. Heinrich's interest in entomology began at the age of seven, when he started keeping bees and collecting insects. He earned his B.S. and M.S. from the University of Maine at Orono and his Ph.D. from the University of California at Los Angeles in 1970. Although his subjects have ranged from squirrels to birds, Heinrich has specialized in studying thermoregulation in insects. Some of his earliest work in this area was on moths, the subject of this month's article. Heinrich has done fieldwork in Africa and various tropical and arctic locations, but Maine, where he has a cabin in the woods, is his favorite locality. Heinrich has been a professor of entomology at the University of California at Berkeley and is currently a professor of zoology at the University of Vermont, where he is studying the sociobiology of ravens. Further reading on thermoregulation in moths and other insects can be found in his book *The Hot-blooded Insects* (Cambridge: Harvard University Press, 1993).

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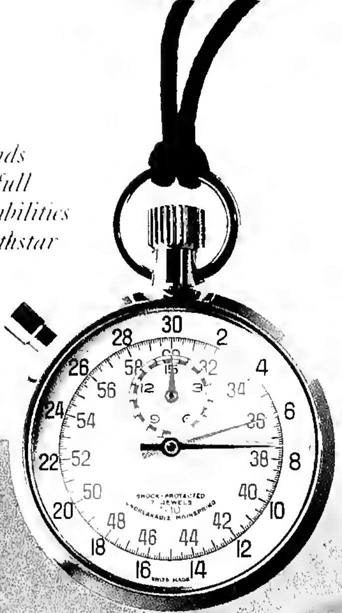

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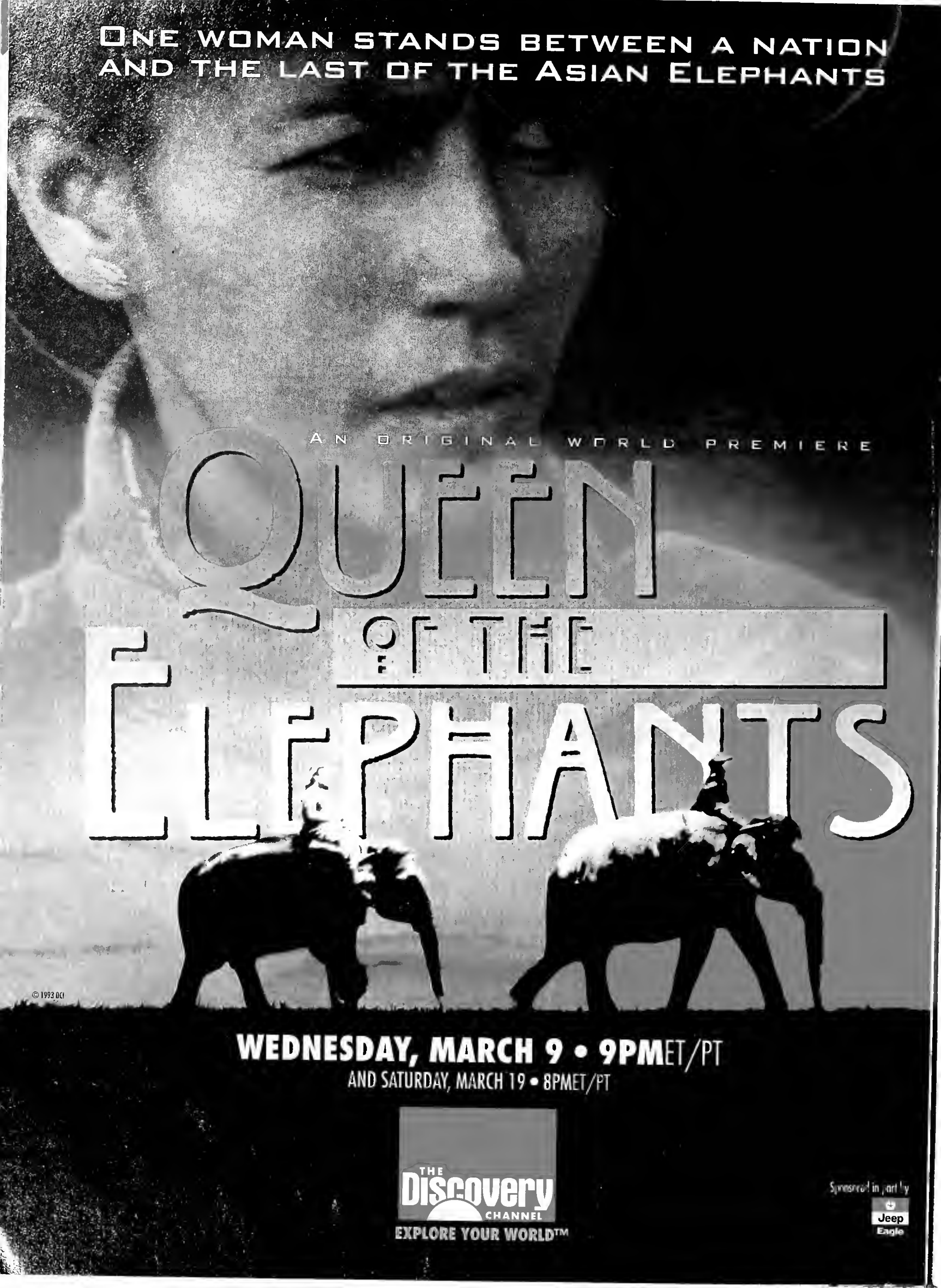
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COVER: *A feral Soay ram in winter fleece mounts the crest of a hill in Scotland's Saint Kilda archipelago, where 70 percent of the sheep die off every three to four years. Story on page 28. Photograph by Laurie Campbell.*

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How to Catch a Gator

Or, the limits of professional ecology

by J. Whitfield Gibbons

Several years ago, I had the opportunity to conduct ecological research and, at the same time, make what I thought would be a modest personal contribution to environmental preservation. All I needed to do was catch a mother alligator and her young. The management of a South Carolina coastal resort had told me that a large alligator had been pestering golfers, and that they intended to notify the state, which meant the animal could be legally killed as a nuisance. I asked if, instead, we could catch it and remove it to the Savannah River Ecology Laboratory (SREL) for behavioral study. Both the resort owners and wildlife officials agreed.

But why did we want a large, pesky female alligator at the lab? My research interest in alligators had begun twenty-six years ago when I caught my first one while doing a project on freshwater turtles. Because they are coldblooded, alligators reflect environmental conditions more directly than mammals and birds, whose body temperatures are regulated internally. But crocodilians are linked closely to birds—indeed, they are possibly the avians' closest living relatives. I wanted to continue investigating the evolutionary and ecological mysteries of these reptiles.

Nest building and protection of the young are distinctive behaviors of the American alligator. All crocodilians lay eggs on land near the fresh to slightly brackish water of coastal marshes, swamps, rivers, and lakes. In early summer, the female alligator builds a large nest—about three and a half feet high and up to seven feet in diameter—of mud and vegetation along the shore and deposits twenty to sixty white eggs before sealing the nest with more mud and vegetation. (The decomposition of the nesting material produces heat, which incubates the eggs at a relatively constant temperature.)

Because of a powerful protective instinct, however, the mother often remains in the vicinity of the nest until the late summer when the young hatch. Thus anybody inadvertently approaching the nest area may suddenly find an enormous, hissing reptile charging overland. If one stands one's ground and does not molest the nest or pick up a baby, the mother alligator usually retreats. Or she may not. If the mother hears the babies hatching, she may remove the vegetation and even help the eight-inch-long hatchlings to the water by carrying them in her mouth.

Indeed, this strong parental care in alligators indeed seems more closely allied to birds than to other groups of reptiles. A female turtle, for example, digs a nest, deposits her eggs, and returns to the water, leaving the eggs behind. Prior to egg laying, she stores energy and nutrients in her fatty tissues. These resources are allocated to each egg in the form of a large yolk reserve and provide all of the nourishment needed both for embryonic growth in the egg and for early growth and maintenance of the hatchling turtle.

Some years ago, Justin Congdon, my colleague at SREL, and I discovered that in alligator eggs the proportion of original egg lipids that remained in the hatchling was actually higher than that in turtles. Thus, the newborn alligator entered the aquatic habitat with more fat reserves than any species of turtle we had studied. In capturing the alligator and her babies, I hoped to find out more about alligators and their young.

This particular mother alligator didn't intend to be a pest, but people kept hitting little white balls close to the lake where she and her babies lived. She would emerge from the lake, chase the golfers

away, and occasionally eat a golf ball. Alligators are known to ingest stones, pine cones, and other nonfood items that are retained in a part of the stomach equivalent to a bird's gizzard. Such materials may help grind food that is swallowed whole.

One preeminent question a person should ask when wading through swamps and along lake margins in search of North America's largest reptile is whether alligators attack humans. After all, male American alligators often grow to more than thirteen feet and females to nine feet. This particular six-foot animal was impressive, too; and enough rare and spectacular reports of seemingly unprovoked attacks on humans had made me aware that alligators can be highly dangerous. Plus, this alligator was a mother, and the good behavior record of mother alligators had been tarnished before, especially in situations when maternal instinct overrode a presumably innate fear of humans.

Alligators have a problem faced by a lot of us—you can pick your friends but not your relatives. Not that alligators have many friends, but as one of almost two dozen crocodilian species, they do have some notorious Old World kin. Instances of crocodiles eating humans in Africa and Indonesia mean that New World crocodilians will never be completely above suspicion. Yet American alligators, if unmolested, are shy and peaceful and, based on the evidence, do not consider humans a standard menu item. They unfortunately exemplify how a species can have its natural rights violated because of public misunderstanding.

I took two students, Jeff Lovich and Tony Mills, out at night to make the capture. Night is usually the best time to find alligators, both big and small, because of the reflective eyeshine that ranges from red to yellow. This particular September night was absolutely gorgeous, the perfect setting for a Gothic novel. The light from the recently risen full moon was splintered by pine and palmettos and turned the fairway into slivers of white, black, and shades of gray. Scattered ground fog and mist gave the surroundings an eerie appearance, and the only sounds were a distant chorus of green tree frogs and the hooting of a faraway barred owl. We peered ahead searching for the pond where the alligators lived.

With Tony being six four and Jeff six two, I anticipated no problem in handling this six-foot mother alligator. I even brought along my twelve-year-old son Michael to watch the show. When we got to the lake, our flashlights revealed the reflected red eyeshine of a pair of gator eyes. The big, gleaming eyes were surrounded by what seemed like a swarm of fireflies on the water's surface—two dozen pairs of little yellow eyes, those of the babies.

Our plan: We had a noose attached to a cable on a bamboo pole. When the mother came near shore, we planned to slip the noose over her head and pull it tightly around her neck. We would then put big rubber bands on her snout to keep the mouth closed while we carried her back to the jeep. Her plan: Swim around in the middle of the lake with the babies. And so she did. Our revised plan: Catch one of the babies. Since baby alligators in distress make a distinctive grunting sound, the mother should come close to shore to investigate. When she got close enough, we could snare her with the noose, and that would be it.

Most of the babies were with the mother, but a few adventurous ones were in the vegetation along the shore, perhaps foraging for crustaceans and insects. (Alligators more than five feet long will eat any creature inhabiting the land or water that they can catch and swallow, including muskrats, cottonmouths, fish, turtles, raccoons, and waterfowl.) We walked around the edge of the lake and caught one of the babies. It immediately started making the sound of a frightened baby alligator and, to our satisfaction, along came the mother. The two crimson eyes headed straight toward the shore, fast. I handed the baby alligator to Michael; the rest of us hid behind two big pine trees.

As the mother reached the shoreline, Tony got ready to jump down and use the noose. Only she didn't slow down at the water's edge. The next thing we knew, she was up on land with a startlingly loud hiss, lumbering toward Michael as fast as her chunky legs could carry her. Her heavy tail swished against the sweet myrtle bushes along the shoreline. The crushed leaves filled the air with a pleasant, perfumy scent incongruous with the charging, hissing reptile.

Michael was holding the baby up in the air and saying, "Dad, Dad, what do you want me to do now?" Being trained professionals, we each offered expert advice. Jeff said, "Climb a tree!" Tony said, "Throw the baby in the lake!" I said, "Run!" Responding to my attempt at parental care, Michael turned and disappeared into the woods, still holding this squeaking toy of an alligator. With a slight head start, a scared twelve-year-old can run a lot faster than an angry alligator, but the mother was still in pursuit.

She was moving pretty fast when she passed the three of us, but Tony managed to slip the noose over her head, and Jeff and I grabbed the bamboo pole. We braced ourselves, ready for the cable to tighten. But instead of continuing forward, she abruptly reversed her direction, catching the three of us completely by surprise. She turned back toward the lake, dived into the water, and plunged to the bottom.

Unfortunately, we all had good grips on the pole. The three of us were yanked down the slippery bank into the lake. The noose had slipped off, and the thought of being in the water with an irate, unfettered mother alligator impelled us to scramble out almost as fast as we had gone in. Michael emerged from the woods and returned the baby to the water. With some discussion about safer and more successful previous collecting expeditions, we slunk home in defeat.

Catching an alligator should have been no problem for trained professionals from an ecology lab, but this encounter left me with some questions about how well trained we were and whether we should really be classified as professionals. Research ecologists must be reminded occasionally that they do not know everything about animals, plants, and the environment. Alligators have effectively brought this to my attention more than once. They also serve as a strong reminder that biologists still have much to learn about the behavior, ecology, and evolutionary relationships of even the most familiar species.

One of our current questions is whether female American alligators, like birds, directly or indirectly provide food to their young in some situations. This seems like a reasonable extension of their demonstrably complex parental care and was one reason we wanted a mother alligator with recently born young. I still have not observed a mother alligator feeding her young. However, after seeing the intense interest at least one mother had for taking care of her offspring, I feel certain that if parental feeding by alligators does not already exist, evolutionarily it may be only a baby step away.

J. Whitfield Gibbons is a University of Georgia professor of ecology at the Savannah River Ecology Laboratory. This article is adapted from his new book, Keeping All the Pieces: Perspectives on Natural History and the Environment *(Smithsonian Institution Press, 1993).*

Macaque See, Macaque Do

At tourist sites in Bali, humans are teaching their fellow primates some bad habits

by Meredith F. Small

Early last July, I boarded a plane for a thirty-six-hour journey to Bali, the tropical island vacation spot. Contrary to what most of my friends thought, this eight-week trip to Indonesia was not really intended as a holiday of sun, surf, and shopping—my assignment was to evaluate the effect of tourism on the native Balinese monkey, the long-tailed macaque.

My last research project on monkey behavior had taken place five years earlier, and I felt a surge of excitement when I reached my primary research site, the Sangeh Monkey Forest in the center of Bali. As I walked down a winding cement path through a lovely patch of nutmeg forest to Sangeh's central temple, Pura Bukit Sari, I suddenly saw them, scampering among the tourists, leaping over temple walls, and generally acting like monkeys—curious, social, and full of energy.

Watching them, I felt the old observation skills click back into gear: That one with a bent tail will be easy to identify again. The female over there is in heat. Two babies are less than three months old. I see at least four young infants. This group has few subadult males.

Lost in this primatological reverie, I failed to see an adult female approaching to my left. Suddenly she streaked past me, a blur of green-gray fur so close I could smell the familiar monkey odor. In midleap, her tiny fingers gripped the earpiece of my brand-new sunglasses. She unceremoniously yanked them off my face and sped into the forest.

I was stunned. The swiftness of her calculated thievery was breathtaking. (More important, how could I spend day after day recording the minute details of monkey behavior without a decent pair of shades?) Accompanied by a temple guard, I tracked my assailant deep into the woods. She finally stopped running, only to sit and chew contemplatively on my glasses, her brown eyes shifting back and forth between her pursuers. The guard tossed her a few bags of peanuts. Needing both hands to collect this booty, she dropped the glasses in favor of something more digestible and sped away.

"You must not wear glasses near the monkeys," instructed the guard. "They also steal wallets, money, hair ribbons, and handkerchiefs. And don't try to hide anything in your pockets, because they will find it." His description sounded more applicable to big-city pickpockets than to monkeys on their home turf. As I returned to the main area, I noticed tourists holding on to their possessions for dear life, and monkeys clearly poised for thievery. Animals stood up on two legs and yanked on clothes. They jumped on people, pulled hair, and rifled pockets. These normally gentle and friendly animals had turned into beggars and thieves. Something had gone terribly wrong at Sangeh.

As my study progressed, I realized that I had been a victim of a monkey mugging only because the monkeys were victims themselves. Bad management of a tourist site, coupled with uneducated visitors with no appreciation of macaques as fellow primates, had resulted in a twisted relationship between the visitors and the very animals they had come to see.

All monkeys have a special place in Hindu religion. This reverence stems partly from the role of the monkey god, Hanuman, in the classic Hindu epic *Ramayana*. According to the story, Prince Rama's beloved wife, Sita, was kidnapped by the evil giant King Rawana. The monkey king, Sugriva, had once aided Prince Rama, so Sugriva's general, Hanuman, was enlisted to gather an army, wreak havoc, and rescue the princess.

Sangeh itself also features importantly in the Balinese version of the *Ramayana* story. Clever Hanuman and his monkey battalions capture Mount Mahameru and use the two halves of the holy mountain to crush the giant. Part of the mountain falls to earth and lands at Sangeh with a troop of monkeys hanging tight.

Monkeys thus retain the status of privileged visitors, especially on temple grounds, where they are treated with great tolerance. Like all living objects, monkeys also embody the spirits of Hindu gods, both good and evil. When a monkey leaps onto a temple altar, destroying carefully placed palm baskets of sacred offerings and gorging on the fruit and rice intended for higher powers, the Balinese ignore the vandalism—after all, a spirit might now reside in that monkey and might need the food.

Macaques are highly adaptable monkeys that live in deep forests, on high mountains, or along the seaside. About five million years ago, the genus *Macaca,* of which longtails are one of nineteen species, radiated out of North Africa into Europe and east into Asia. Macaques now inhabit Morocco and Algeria, India, Pakistan, China, most of Southeast Asia, and Japan; and long-tailed macaques (*Macaca fascicularis*) have lived on Bali longer than humans. Although they eat just about anything, they prefer fruits and vegetables. In a sense, they are the cockroaches of the primate world, able to adapt well to changes, move into new environments, and scrounge when food gets scarce.

Their humanlike sociality makes these monkeys tourist attractions. We aren't as genetically related to macaques as we are to the apes, such as chimpanzees, but we see ourselves in their behavior—the constant social interactions, the jostling for hierarchical position, the bickering and making up are all similar to the daily machinations of human society. This connection between humans and the macaques either fascinates or repels tourists, and I saw both types of visitors in Bali.

During my weeks at Sangeh, I watched monkeys eat 409 peanuts, 67 bits of bread, 49 chunks of fruit, and endless quantities of crackers, cookies, and candy. I saw them chew on cigarettes, suck on matchsticks, rip apart film boxes, and play with discarded plastic bags. Feeding the ani-

Article adapted from "The Monkey Bandits of Bali," by Meredith F. Small. Reprinted by arrangement with Cornell Magazine.

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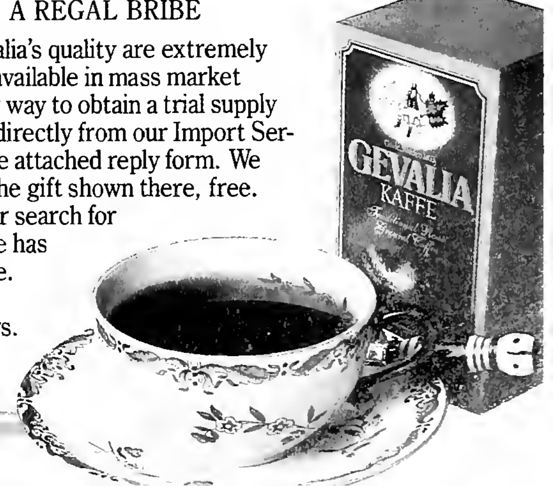

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mals was encouraged by locals outside the forest; at dozens of stalls, men and women relentlessly hawked both monkey food and souvenirs. Huge buses and smaller minivans disgorged more than a thousand people a day to view the monkeys. Although many of the tourists were Asian, Australian, or European, by far the greatest number of visitors were from other Indonesian islands, such as Java.

After a few days of observation, I understood why the monkeys were so badly behaved—they have been taught to be obnoxious. At the entrance to the temple at the Sangeh Monkey Forest, about thirty men who call themselves "guides" sit and wait for the tourists. Although dressed in appropriate temple garb—a sarong and scarf wound at the waist—they are not officials of the temple; this is a business. Each man owns a Polaroid camera, and his job is to manipulate the tourist into buying a photograph. The method is simple: As a tourist enters, a guide tags along offering tidbits of information (mostly incorrect) about monkey behavior. At the first sight of a monkey, the guide pulls bits of food out of his pack and puts it on the tourist's shoulder. The monkey, of course, leaps up. The animal quietly munches away, and the Polaroid camera flashes. The monkey is then shooed off, often hit, and the guide demands 6,000 rupia (about $4).

In most cases, people are amused and give the money. But sometimes the clammy toes of a monkey on an unsuspecting neck cause real terror. The tourist will twist and turn, while the monkey, tossed about and confused, becomes agitated and bites. These protest bites never break the skin, but they do hurt and bruise—I know from personal experience (about thirty bites).

The guides—I called them the Polaroid gang—also foster mass thievery among the monkeys. When a monkey steals a nonfood item, such as a pair of glasses, it gets rewarded with a bunch of bananas or a bag of peanuts from the guide. The purpose is to distract the thief and grab the goods back. From the monkey's point of view, stealing translates into an edible reward. This destructive cycle instigated by the Polaroid gang guides, who are just trying to make a living in a poor country, has been going on for over a decade.

The scene at Sangeh brings out the worst in both human and monkey behavior—stealing, screaming, injury, and intimidation. The day I was attacked by a large subadult male who gnawed on my neck to get my glasses, I decided it was time to leave. I was beginning to hate my subjects—the tourists *and* the monkeys.

On an obliging tourist's shoulder, a monkey takes time to eat a banana.
Meredith F. Small

I expected the situation at Sangeh to be repeated all across Bali because of the pressure of tourism. The island is the starting point for most tours of Indonesia. It is easily accessible from Asia and Australia and has been known for decades to European tourists as the land of perfect beaches. Bali also has cultural allure, revolving around its own brand of Hinduism. To visit Bali is to see a delicate ballet accompanied by a mystical gamelan orchestra, watch women with huge loads of fruit balanced on their heads move in an undulating line toward a temple, or bargain with fine craftsmen for carved wooden masks or intricately cut shadow puppets. Until now, the Balinese have been able to retain their culture, despite the onslaught of two million tourists annually. But as the monkeys of Sangeh demonstrate, the relationship between Bali and its tourists is wearing thin.

I left Sangeh and headed south to one of the more remote temples, Pura Uluwatu. Perched on the southwestern tip of the island, the temple looks like the prow of a ship thrust into the sea. A troop of about fifty longtails come and go here, wandering through the low scrub and out on the cliffs. "I feed them whenever I see them," the guard told me, "but that isn't every day." He pointed out that there are monkeys living along the edge of the sea on the cliffs, undisturbed by the surfers who come from all corners of the world to work the waves of Uluwatu Beach.

My time at Uluwatu was spent in peaceful reflection. The monkeys came around, checked me out, took a few peanuts from the hundred or so tourists that passed by daily, and left. They only became aggressive when they spied a plastic water bottle. To these inhabitants of the dry Bukit Peninsula, water—not food—was the limiting resource. Monkeys would sneak up to tourists, grab bottles right from their hands, and empty them. Monkeys only sat on people—myself included—to get a good view of other group members or maybe to groom their hosts, systematically flicking through hair in search of dry flakes of skin.

Uluwatu is the opposite of Sangeh. The wheels of tourism have not yet been set into motion at Uluwatu. Consequently, fewer tourists are around to lure the monkeys with food, and there are fewer hawkers and no Polaroid camera guides.

Evidence of a peaceful monkey–human interaction made me wonder how an area could develop from the low-key situation at Uluwatu to the intense arena at Sangeh. I began hearing about another temple, Alas Kedaton where, according to many travelers, "the monkeys are nice." This I had to see—a highly visible tourist site with "nice" monkeys?

Alas Kedaton is a tiny scrap of forest near the city of Tabanan, west of Sangeh. In addition to two troops of monkeys, several hundred flying foxes, or fruit bats, inhabit the trees. The site doesn't yet have the constant influx of tourists that Sangeh has, but a visit to Alas Kedaton now appears on many day-tour packages. The major difference between Sangeh and Alas Kedaton, however, is the attitude of the people in charge. The nearby village of Kukuh has taken an active interest in the welfare of both the tourists and the monkeys. As a result, this site offers the most pleasant interaction between humans and their primate cousins.

Like Sangeh, the approach to Alas Kedaton is flanked by rows of souvenir shops. But no one harasses the traveler into buying food for monkeys, a cold drink, or yet another sarong. Instead, the community has installed a system to tone down the pressure on tourists. A designated guide, usually a woman, accompanies each group of tourists into the forest. She encourages the tourists to buy only potatoes for the monkeys from one vendor. ("It's better for the monkeys," she will say, and this is true.) The guide then puts tourists through explicit monkey-feeding paces. "Bend down, open your hand, give only one piece at a time."

Although no tourist could possibly imitate the graceful genuflection of a Balinese woman, the action does put the giver on the same level as the monkey. As a result, monkeys never jump on anyone. In addition, the guides are constantly on the alert for actions that might harm the animals. They seem to know how to say "Don't touch the monkeys" in about five languages. When the guide has taken the visitors on a short stroll to see the flying foxes, and once around its small temple, she requests a visit to her shop. If the tourists say no, they are free to head for the parking lot.

Nyoman Oka, nicknamed Juli, is the principal monkey-food seller. Her husband is responsible for the organization and growth of Alas Kedaton as a tourist attraction. She explained to me, over a lunch of hot Balinese chicken and rice: "If any shop owner bothers a tourist, they are fined 25,000 rupia [about $12]. It isn't nice for tourists to always have someone asking them to buy things." When I inquired about the rows and rows of new shops appearing near the gate, thinking only of the pressure of more human traffic on the monkeys, she laughed. "Those aren't new shops. We are moving the ones here out there, and we will build more forest or perhaps a garden here." In their ambition to increase the flow of tourists through the area, the people of Kukuh have taken into consideration not only what the visit will be like for tourists, but also what will be best for the monkeys. With the appropriate controls, monkeys and tourists can have a reasonable experience.

A statue of a Hindu deity at Sangeh Temple serves as a look-out for a long-tailed macaque.
Hutchinson Library

A comparison of the three temples gave me the data I needed as an academic, but my memories of the summer were of more than maps of forests and counts of peanuts snatched from pockets. Most of all, I remember time spent with the animals, deep in the forest away from the intrusive gaze of tourists. I often sat quietly with a group of females as they groomed one another, and smiled as babies made their first wobbly steps away from mom. Sometimes I ran after screaming males as they fought out a hierarchical disagreement.

I also remember moments with my other subjects, the tourists. At all three sites, I was repeatedly asked about my research. I always responded with my most used Indonesian sentence, "Saya menyedlidiki monyet" (I study monkeys), followed by a quick natural history of macaques. I emphasized the macaque's attachment to family and friends and explained specific behaviors as they unfolded right in front of us. Balinese tour guides often sat with me and watched me watch monkeys while their human charges wandered through the temple grounds. We talked together about the long history of macaques on Bali and compared notes on the different sites around the the island. I soon realized that educating an eager public was as much my job as collecting data for analysis. Obviously, the best way to save the monkeys from exploitation and extinction is to create a mutually respectful alliance between the tourists and the animals.

Back home, a carving of the monkey god, Hanuman, hangs over my desk and watches as I enter endless columns of numbers into my computer. Hanuman laughs because he knows that these data mean little in the real world of his monkey armies. Once more, he is needed to battle an evil foe, but this time, the monkeys themselves need Hanuman's protection.

Meredith F. Small is an associate professor of anthropology at Cornell. Her book Female Choices: Sexual Behavior of Female Primates *was published last year by* Cornell University Press.

The Persistently Flat Earth

Irrationality and dogmatism are foes of both science and religion

by Stephen Jay Gould

The mortal remains of the Venerable Bede (673–735) lie in Durham Cathedral, under a tombstone with an epitaph that must win all prizes for a "no nonsense" approach to death. In rhyming Latin doggerel, the vault proclaims: *Hac sunt in fossa, Baedae venerabilis ossa*—"the bones of the Venerable Bede lie in this grave" (*fossa* is, literally, a "ditch" or a "trough," but we will let this gentler reading stand).

In the taxonomy of Western history that I learned as a child, Bede shone as a rare light in the Dark Ages between Roman grandeur and a slow medieval recovery culminating in the renewed glory of the Renaissance. Bede's fame rests upon his scriptural commentaries and his *Historia ecclesiastica gentis Anglorum* (Ecclesiastical History of the English People), completed in 732. Chronology sets the basis of good history, and Bede preceded his great work with two treatises on the reckoning and sequencing of time—*De temporibus* (On Times) in 703, and *De temporum ratione* (On the Measurement of Times) in 725.

Bede's chronologies had their greatest influence in popularizing our inconvenient system of dividing recent time into B.C. and A.D. on opposite sides of Christ's supposed nativity (almost surely incorrectly determined, as Herod had died by this time of transition and could not have seen the Wise Men or slaughtered the innocent at the onset of year one). In his chronologies, Bede sought to order the events of Christian history, but the primary motive and purpose of his calculations centered on a different, and persistently vexatious, problem in ecclesiastical timing—the reckoning of Easter. The complex definition of this holiday—the first Sunday following the first full moon that occurs on or after the vernal equinox—requires considerable astronomical sophistication, for both lunar and seasonal cycles must be known with precision.

Such computations entail a theory of the heavens, and Bede clearly presented his classical conception of the earth as a sphere at the hub of the cosmos—*orbis in medio totius mundi positus* (an orb placed in the center of the universe). Lest anyone misconstrue his intent, Bede then explicitly stated that he meant a three-dimensional sphere, not a flat plate. Moreover, he added, our planetary sphere may be considered as perfect because even the highest mountains produce no more than an imperceptible ripple on a globe of such great diameter.

I also once learned that most other ecclesiastical scholars of the benighted Dark Ages had refuted Aristotle's notion of a spherical earth and had depicted our home as a flat, or at most a gently curved, plate. Didn't we all hear the legend of Columbus at Salamanca, trying to convince the learned clerics that he would reach the Indies and not fall off an ultimate edge?

The human mind seems to work as a categorizing device (perhaps even, as many French structuralists argue, as a dichotomizing machine, constantly partitioning the world into dualities of raw and cooked [nature versus culture], male and female, material and spiritual, and so forth). This deeply (perhaps innately) ingrained habit of thought causes us particular trouble when we need to analyze the many continua that form so conspicuous a part of our surrounding world. Continua are rarely so smooth and gradual in their flux that we cannot specify certain points or episodes as decidedly more interesting, or more tumultuous in their rates of change, than the vast majority of moments along the sequence. We therefore falsely choose these crucial episodes as boundaries for fixed categories, and we veil nature's continuity in the wrappings of our mental habits. (If I may venture into a "hot" area mentioned before in these columns, the abortion debate in contemporary America suffers greatly under this error when partisans try to find a moment, usually construed as fertilization, for the unambiguous origin of a human being. But no such moment exists in this true continuum; fertilization may be a more interesting episode than most, but so is the initiation of quickening, or the first perceived motion of the fetus in the womb—and quickening set the favored criterion of personhood through most of classical and ecclesiastical history.)

We must also remember another insidious aspect of our tendency to divide continua into fixed categories. These divisions are not neutral; they are established for definite purposes by partisans of particular viewpoints. Moreover, since many continua are temporal, and since we have a lamentable tendency to view our own age as best, our divisions often saddle the past with pejorative names, while designating successively more modern epochs with words of light and progress. As an obvious example, many people (including yours truly) view the great medieval cathedrals of Europe as the most awesome of all human constructions. (For me—and I say this as a humanist and nontheist—Chartres is off-scale, a place of mystery and magic, not truly of this world. Chartres is not just better than Amiens or Rheims or Notre Dame de Paris.) Yet we designate the style of these buildings as "Gothic"—originally a pejorative term (traced to seventeenth-century origin in the *Oxford English Dictionary*) applied by self-styled sophisticates who viewed medieval times as a barbaric interlude between the classical forms of Greece and

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Rome and their revival in Renaissance and later times. These cathedrals, after all, were not built by German tribes who had their heyday in the third to fifth centuries. The names of several peoples who conquered the waning classical world—Goths and Vandals in particular—became pejorative terms for anything considered rude or mean. For that matter, the word *barbarian* comes from the Latin term for foreigner.

Our conventional divisions of Western history are mired in these twinned errors of false categorization and pejorative designation. I know that professional historians no longer use such a taxonomy, but popular impression still supports a division into classical times (glory of Greece and grandeur of Rome), followed by the pall of the Dark Ages, some improvement in the Middle Ages, and an éclat of culture's rediscovery in the Renaissance. But consider the origin of the two pejorative terms in this sequence—and the relationship of taxonomy to prejudiced theories of progress becomes clear.

According to historian J. B. Russell, Petrarch devised the term *Dark Ages* in about 1340 to designate a period between classical times and his own form of modernism. The term *Middle Ages* for the interval between classical fall and Renaissance revival originated in the fifteenth century but only gained popularity in the seventeenth century. Some people consider everything from the fall of Rome to the Renaissance as Dark, others as Middle. Still others make a sequential division into an earlier dark and later middle, separated by Charlemagne or the arbitrary millennial transition of 1000. Such uncertainty only shows the foolishness of attempting to define fixed categories within continua. In any case, the intent of darks and middles could not be more clear—to view Western history as possessing a Greek and Roman acme, with supposed loss as tragic, followed by the beginning of salvation in Renaissance rediscovery.

Such prejudicial tales of redemption require a set of stories to support their narrative. Most of these legends feature art, literature, or architecture, but science has also contributed. I write this essay to point out that the most prominent of all scientific stories in this mode—the supposed dark and medieval consensus for a flat earth—is entirely mythological. Moreover, when we trace the invention of this fable in the nineteenth century, we receive a double lesson in the dangers of false taxonomies—the second and larger purpose of this essay. For the myth itself only makes sense under a prejudicial view of Western history as an era of darkness between lighted beacons of classical learning and Renaissance revival, while the nineteenth-century invention of the myth, as we shall see, occurred to support another dubious and harmful separation wedded to another legend of historical progress—the supposed warfare between science and religion.

Classical scholars, of course, had no doubt about the earth's sphericity. Our planet's roundness was central to Aristotle's cosmology and assumed in Eratosthenes's measurement of the earth's circumference in the third century B.C. The flat earth myth argues that this knowledge was then lost when ecclesiastical darkness settled over Europe. For a thousand years of middle time, almost all scholars held that the earth must be flat—like the floor of a tent, held up by the canopy of the sky, to cite a biblical metaphor read literally. The Renaissance rediscovered classical notions of sphericity, but proof required the braveness of Columbus and other great explorers who should have sailed off the edge but, beginning with Magellan's expedition, returned home from the opposite direction after going all the way around.

The inspirational, schoolchild version of the myth centers on Columbus, who supposedly overcame the calumny of assembled clerics at Salamanca to win a chance from Ferdinand and Isabella. Consider this version of the legend, cited by Russell from a book for primary-school children written in 1887, soon after the myth's invention (but little different from accounts that I read as a child in the 1950s):

> "But if the world is round," said Columbus, "it is not hell that lies beyond that stormy sea. Over there must lie the eastern strand of Asia, the Cathay of Marco Polo."... In the hall of the convent there was assembled the imposing company—shaved monks in gowns...cardinals in scarlet robes.... "You think the earth is round.... Are you not aware that the holy fathers of the church have condemned this belief.... This theory of yours looks heretical." Columbus might well quake in his boots at the mention of heresy; for there was that new Inquisition just in fine running order, with its elaborate bone-breaking, flesh-pinching, thumb-screwing, hanging, burning, mangling system for heretics.

Dramatic to be sure, but entirely fictitious. There never was a period of "flat earth darkness" among scholars (regardless of how many uneducated people may have thus conceptualized our planet both then and now). Greek knowledge of sphericity was never lost, and all major medieval scholars accepted the earth's roundness as an established fact of cosmology. Ferdinand and Isabella did refer Columbus's plans to a royal commission headed by Hernando de Talavera, Is-

"Capistrano—every year Capistrano—Can't we ever go anywhere else?"

abella's confessor and, following defeat of the Moors, Archbishop of Granada. This commission, composed of both clerical and lay advisors, did meet at Salamanca, among other places. They did pose some sharp intellectual objections to Columbus, but all assumed the earth's roundness. As a major critique, they argued that Columbus could not reach the Indies in his own allotted time because the earth's circumference was too great. Moreover, his critics were entirely right. Columbus had "cooked" his figures to favor a much smaller earth and an attainable Indies. Needless to say, he did not and could not reach Asia, and our Native Americans are still called Indians as a legacy of his error.

Virtually all major medieval scholars affirmed the earth's roundness. I introduced this essay with the eighth-century view of the Venerable Bede. The twelfth-century translations into Latin of many Greek and Arabic works greatly expanded general appreciation of natural sciences, particularly astronomy, among scholars—and convictions about the earth's sphericity both spread and strengthened. Roger Bacon (1214–1292) and Thomas Aquinas (1225–1274) affirmed roundness via Aristotle and his Arabic commentators, as did the greatest scientists of later medieval times, including Jean Buriden (1300–1358) and Nichole Oresme (1320–1382).

So who, then, was arguing for a flat earth if all the chief honchos believed in roundness? Villains must be found for any malfeasance, and Russell shows that the great English philosopher of science William Whewell first identified major culprits in his *History of the Inductive Sciences,* published in 1837—two otherwise entirely insignificant characters named Lactantius (245–325) and Cosmas Indicopleustes, who wrote his *Christian Topography* in 547–549. Russell comments: "Whewell pointed to the culprits...as evidence of a medieval belief in a flat earth, and virtually every subsequent historian imitated him—they could find few other examples."

Lactantius did raise the old saw of absurdity in believing that people at the antipodes might walk with their feet above their heads in a land where crops grow down and rain falls up. And Cosmas did champion a literal view of a biblical metaphor—that the earth is a flat floor for the rectangular, vaulted arch of the heavens above. But both men were minor and largely ignored figures in medieval scholarship. Only three reasonably complete medieval manuscripts of Cosmas are known (with five or six additional fragments), and all in Greek. The first Latin translation dates from 1706—so Cosmas was invisible to medieval readers in their own lingua franca.

Purveyors of the flat earth myth could never deny this plain testimony of Bede, Bacon, Aquinas, and others—so they argued that these men were rare beacons of brave light in pervasive darkness. But consider the absurdity of such a position. Who formed the orthodoxy representing this consensus of ignorance? Two pipsqueaks named Lactantius and Cosmas Indicopleustes, known to practically nobody? Bede, Bacon, Aquinas, and their ilk were not brave iconoclasts. They were the establishment, and their convictions about the earth's roundness were canonical, while Lactantius and his colleagues remained entirely marginal. To call Aquinas a courageous revolutionary because he promoted a spherical earth would be akin to labeling Fisher, Haldane, Wright, Dobzhansky, Mayr, Simpson, and all the other great twentieth-century evolutionists as radical reformers because a peripheral creationist named Duane Gish wrote a pitiful book during the same years called *Evolution: The Fossils Say No.*

Where, then, and why, did the myth of medieval belief in a flat earth arise? Russell's historiographic work gives us a good fix on both times and people. None of the great eighteenth-century anticlerical rationalists—not Condillac, Condorcet, Diderot, Gibbon, Hume, or our own Benjamin Franklin—accused the scholastics of believing in a flat earth, although these men were all unsparing in their contempt

for medieval versions of Christianity. Washington Irving gave the flat earth story a good boost in his largely fictional history of Columbus, published in 1828—but his version did not take hold. The legend grew during the nineteenth century but did not enter the crucial domains of schoolboy pap or tour guide lingo. Russell did an interesting survey of nineteenth-century history texts for secondary schools and found that very few mentioned the flat earth myth before 1870, but that almost all texts after 1880 featured the legend. We can therefore pinpoint the invasion of general culture by the flat earth myth to the period between 1860 and 1890.

These years also featured the spread of an intellectual movement based on the second error of taxonomic categories explored in this essay—the portrayal of Western history as a perpetual struggle, if not an outright "war," between science and religion, with progress linked to the victory of science and the consequent retreat of theology. Such movements always need whipping boys and legends to advance their claims. Russell argues that the flat earth myth achieved its canonical status as a primary homily for the triumph of science under this false dichotomization of Western history. How could a better story for the army of science ever be concocted? Religious darkness destroys Greek knowledge and weaves us into a web of fears based on dogma and opposed to both rationality and experience. Our ancestors therefore lived in anxiety, restricted by official irrationality, afraid that any challenge could only lead to a fall off the edge of the earth into eternal damnation. A fit tale for its intended purpose, but entirely false because few medieval scholars ever doubted the earth's sphericity.

I was especially drawn to this topic because the myth of dichotomy and warfare between science and religion—an important nineteenth-century theme with major, and largely unfortunate, repercussions extending to our times—received its greatest boost in two books that I own and treasure for their firm commitment to rationality (however wrong and ultimately harmful their dichotomizing model of history) and for an interesting Darwinian connection with each author (I have often said that I write these essays as a tradesman, not a polymath, and that my business is evolutionary theory). Russell identifies these same two books as the primary codifiers of the flat earth myth: John W. Draper's *History of the Conflict between Religion and Science,* first published in 1874; and Andrew Dickson White's *A History of the Warfare of Science with Theology in Christendom,* published in 1896 (a great expansion of a small book first written in 1876 and called *The Warfare of Science*).

Draper (1811–1882) was born in England but emigrated to the United States in 1832, where he eventually became head of the medical school at New York University. His 1874 book ranks among the great publishing successes of the late nineteenth century—fifty printings in fifty years as the best-selling volume of the *International Scientific Series,* the most prestigious and popular of nineteenth-century publishing projects in science. Draper states his thesis in the preface:

> The history of Science is not a mere record of isolated discoveries; it is a narrative of the conflict of two contending powers, the expansive force of the human intellect on one side, and the compressing arising from traditionary faith and human interests on the other.... Faith is in its nature unchangeable, stationary; Science is in its nature progressive; and eventually a divergence between them, impossible to conceal, must take place.

Draper extolled the flat earth myth as a primary example of religion's constraint and science's progressive power:

> The circular visible horizon and its dip at sea, the gradual appearance and disappearance of ships in the offing, cannot fail to incline intelligent sailors to a belief in the globular figure of the earth. The writings of the Mohammedan astronomers and philosophers had given currency to that doctrine throughout Western Europe, but, as might be expected, it was received with disfavor by theologians.... Traditions and policy forbade [the papal government] to admit any other than the flat figure of the earth, as revealed in the Scriptures.

Russell comments on the success of Draper's work:

> *The History of the Conflict* is of immense importance, because it was the first instance that an influential figure had explicitly declared that science and religion were at war, and it succeeded as few books ever do. It fixed in the educated mind the idea that "science" stood for freedom and progress against the superstition and repression of "religion." Its viewpoint became conventional wisdom.

Andrew Dickson White (1832–1918) grew up in Syracuse, New York, and founded Cornell University in 1865 as one of the first avowedly secular institutions of higher learning in America. He wrote of the goals he shared with his main benefactor, Ezra Cornell:

> Our purpose was to establish in the State of New York an institution for advanced instruction and research, in which science, pure and applied, should have an equal place with literature; in which the study of literature, ancient and modern, should be emancipated as much as possible from pedantry.... We had especially determined that the institution should be under the control of no political party and of no single religious sect.

White avowed that his decision to found a secular university reflected no

hostility to theology, but only recorded his desire to foster an ecumenical religious spirit:

It had certainly never entered into the mind of either of us that in all this we were doing anything irreligious or unchristian.... I had been bred a churchman, and had recently been elected a trustee of one church college, and a professor in another...my greatest sources of enjoyment were ecclesiastical architecture, religious music, and the more devout forms of poetry. So far from wishing to injure Christianity, we both hoped to promote it; but we did not confound religion with sectarianism.

But the calumnies of conservative clergymen dismayed him profoundly and energized his fighting spirit:

Opposition began at once...from the good Protestant bishop who proclaimed that all professors should be in holy orders, since to the Church alone was given the command "Go, teach all the nations," to the zealous priest who published a charge that...a profoundly Christian scholar had come to Cornell in order to inculcate infidelity...from the eminent divine who went from city to city denouncing the "atheistic and pantheistic tendencies" of the proposed education, to the perfervid minister who informed a denominational synod that Agassiz, the last great opponent of Darwin, and a devout theist, was "preaching Darwinism and atheism" in the new institution.

These searing personal experiences led White to a different interpretation of the "warfare of science with theology." Draper was a genuine antitheist, but he confined his hostility almost entirely to the Catholic church, as he felt that science could coexist with more liberal forms of Protestantism. White, on the other hand, professed no hostility to religion, but only to dogmatism of any stripe—while his own struggles had taught him that Protestants could be as obstructionist as anyone else. He wrote:

Much as I admired Draper's treatment of the questions involved, his point of view and mode of looking at history were different from mine. He regarded the struggle as one between Science and Religion. I believed then, and am convinced now, that it was a struggle between Science and Dogmatic Theology.

White therefore argued that the triumph of science in its warfare with dogmatism would benefit true religion as much as science. He expressed his credo as a paragraph in italics in the introduction to his book:

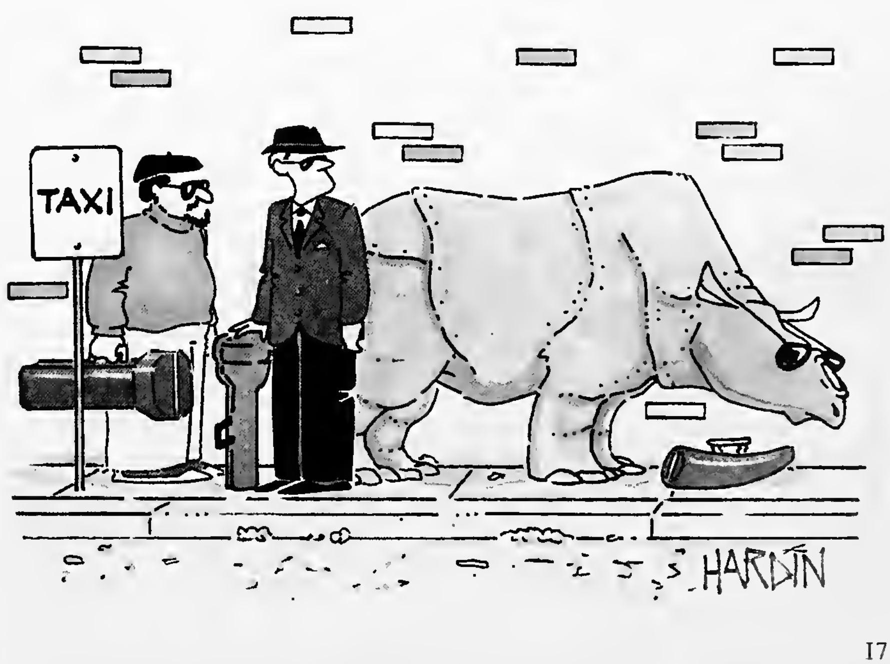
In all modern history, interference with science in the supposed interest of religion, no matter how conscientious such interference may have been, has resulted in the direst evils both to religion and to science, and invariably; and, on the other hand, all untrammelled scientific investigation, no matter how dangerous to religion some of its stages may have seemed for the time to be, has invariably resulted in the highest good both of religion and of science.

Despite these stated disagreements with Draper, their accounts of the actual interaction between science and religion in Western history do not differ greatly. Both essentially tell a tale of bright progress continually sparked by science. And both develop and utilize the same myths to support their narrative, the flat earth legend prominently among them. Of Cosmas Indicopleustes's flat earth theory, for example, White wrote:

Some of the foremost men in the Church devoted themselves to buttressing it with new texts and throwing about it new outworks of theological reasoning; the great body of the faithful considered it a direct gift from the Almighty.

As another interesting similarity, both men developed their basic model of science versus theology in the context of a seminal and contemporary struggle all too easily viewed in this light—the battle for evolution, specifically for Darwin's secular version based on natural selection. No issue, certainly since Galileo, had so challenged traditional views of the deepest meaning of human life, and therefore so contacted a domain of religious inquiry as well. It would not be an exaggeration to say that the Darwinian revolution directly triggered this influential nineteenth-century conceptualization of Western history as a war between two taxonomic categories labeled science and religion. White made an explicit connection in his statement about Agassiz (the founder of the museum where I now work and a visiting lecturer at Cornell). Moreover, the first chapter of his book treats the battle over evolution, while the second begins with the flat earth myth.

Draper wraps himself even more fully in a Darwinian mantle. The end of his preface designates five great episodes in the history of science's battle with religion—the debasement of classical knowledge and the descent of the Dark Ages, the flowering of science under early Islam, the battle of Galileo with the Catholic church, the Reformation (a plus for an anti-Catholic like Draper), and the struggle for Darwinism. No one in the world had a more compelling personal license for such a view, for Draper had been an unwilling witness—one might even say an instigator—of the single most celebrated incident in the overt struggle between Darwin and divinity. We all have heard the famous story of Bishop Wilberforce and T. H. Huxley duking it out at the British Association meeting in 1860. But how many people know that their verbal pyrotechnics did not form the avowed agenda of this meeting, but only arose during free discussion following the formal paper officially set for this session—an address by the same Dr. Draper on the "intellectual development of Europe considered with reference to the views of Mr. Darwin." (I do love coincidences of this sort. Sociologists tell us that we can touch anyone through no more than six degrees of separation, given the



density of networks in human contact. But to think of Draper, taking the first degree just inches from Huxley and Wilberforce, can only be viewed as God's gift to an essayist who traffics in connections.)

This essay has discussed a double myth in the annals of our bad habits in false categorization: (1) the flat earth legend as support for a biased ordering of Western history as a story in redemption from classical to dark to medieval to Renaissance; and (2) the invention of the flat earth myth to support a false dichotomization of Western history as another story of progress, a war of victorious science over religion.

I would not be agitated by these errors if they led only to an inadequate view of the past without practical consequence for our modern world. But the myth of a war between science and religion remains all too current and continues to impede a proper bonding and conciliation between these two utterly different and powerfully important institutions of human life. How can a war exist between two vital subjects with such different appropriate turfs—science as an enterprise dedicated to discovering and explaining the factual basis of the empirical world, and religion as an examination of ethics and values?

I do understand, of course, that this territorial separation is a modern decision—and that differing past divisions did entail conflict in subsequent adjustment of boundaries. After all, when science was weak to nonexistent, religion's umbrella did cover regions now properly viewed as domains of natural knowledge. But shall we blame religion for these overextensions? As thinking beings, we have no option *not* to ponder the great issues of human origins and our relationship with the earth and other creatures. If science once had no clue about these subjects, then they fell, albeit uncomfortably and inappropriately, into the domain of religion by default. No one gives up turf voluntarily, and the later expansion of science into rightful territory temporarily occupied by religion did evoke some lively skirmishes and portentous battles. These tensions were also exacerbated by particular circumstances of contingent history—including the resolute and courageous materialism of Darwin's personal theory and the occupation (at the same time) of the Holy See by one of the most fascinating and enigmatic figures of the nineteenth century, the strong, embittered, and increasingly conservative pope Pio Nono (Pius IX).

But these adjustments, however painful, do not justify a simplistic picture of history as continual warfare between science and theology. Exposure of the flat earth myth should teach us the fallacy of such a view and help us to recognize the complexity of interaction between these institutions. Irrationality and dogmatism are always the enemies of science, but they are no true friends of religion either. Scientific knowledge has always been helpful to more generous views of religion—as preservation, by ecclesiastical scholars, of classical knowledge about the earth's shape aided religion's need for accurate calendars, for example.

I began this essay with a story about the Venerable Bede's use of cosmology to set a chronology for the determination of Easter. Let me end with another story in the same mold—and another illustration of science's interesting and complex potential bond with religion. Two days before my visit to the Venerable Bede's tomb in Durham, I marveled at an intricate astronomical device prominently displayed in the Church of Saint Sulpice in Paris. Each day, precisely at noon the sun's light shines through a tiny hole in a window high in the south transept and illuminates a copper meridian laid into the floor of the transept and ending at an obelisk surmounted by a globe at the north wall.

The line and obelisk are appropriately marked so that the days of solstices and equinoxes can be determined with precision by the position of noon light. Why should such a scientific instrument be contained within a church? The inscription on the obelisk gives the answer—*ad certam paschalis* (for the determination of Easter), a calculation that requires precise reckoning of the vernal equinox. Interestingly, to further spin out the complexities of relationship between science and religion, Saint Sulpice became a temple to humanism during the French Revolution, and most of the religious glass and statuary was smashed. The names of kings and princes carved on the obelisk were thoroughly obliterated, but the beautiful blue marble balustrade of the choir was preserved because the copper meridian passes through it, and the revolution did not wish to disrupt a scientific instrument.

I would not choose to live in any age but my own; advances in medicine alone, and the consequent survival of children with access to these benefits, should preclude any temptation to trade for the past. But we cannot understand history if we saddle the past with pejorative categories based on our bad habits for dividing continua into compartments of increasing worth toward the present. These errors apply to the vast paleontological history of life as much as to the temporally trivial chronicle of human beings. I cringe every time I read that this failed business or that defeated team has become a dinosaur in succumbing to progress. *Dinosaur* should be a term of praise, not of opprobrium. They reigned for 100 million years and died through no fault of their own; *Homo sapiens* is nowhere near a million years old and has limited prospects, entirely self-imposed, for extended geological longevity.

Honor the past at its face value. The city of York houses the next great cathedral south of Durham. As Durham displays an amusing Latin rhyme to honor the Venerable Bede, so does York feature a verse to illustrate this principle of respect for the past in the service of understanding. On the wall of the chapter house, we read:

Ut rosa flos florum
Sic est domus ista domorum.

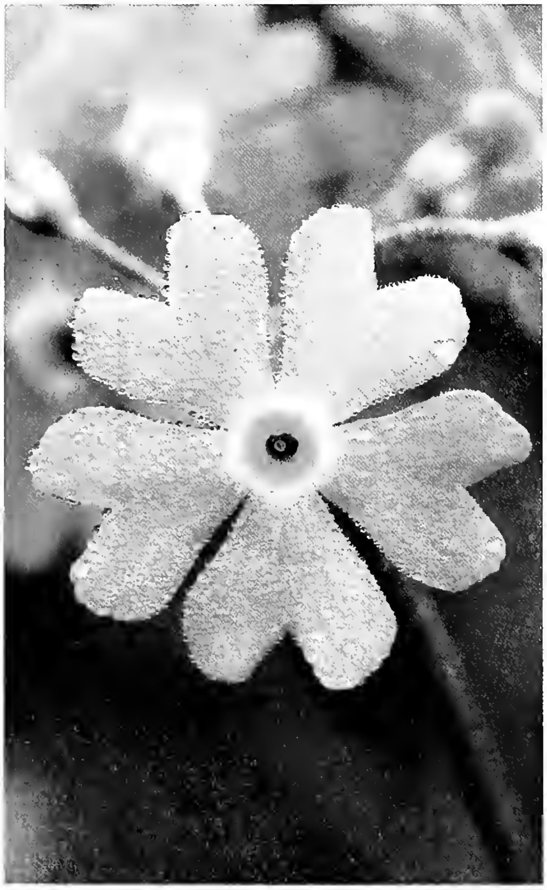
As the rose is the flower of flowers, so is this the house of houses.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Summerby Swamp, Michigan

by Robert Mohlenbrock

Summerby Swamp, in Hiawatha National Forest, is among the countless wetlands that dot northern Michigan, northern Minnesota, and adjoining parts of Canada. Bisected by Michigan Highway No. 123, the swamp covers about three square miles. On one side of the road, the swamp is rather soupy looking, with hummocks of vegetation forming hundreds of tiny islands in shallow, standing water. On the other side it is forested with northern white cedar trees. The contrast in vegetation is related to differences in soil chemistry and drainage. This type of variation in wetlands is also a clue to how these habitats gradually change from one type to another, or even into a dry habitat, as a result of plant growth.



Bird's-eye primrose, above, grows in Summerby Swamp, but is more commonly found farther north. Right: Cattails and flowering asters border the swamp.
Rod Planck; Photo Researchers, Inc.

Terms such as *bog, fen, marsh,* and *swamp* are often used interchangeably, even by professional botanists. But biologist Howard Crum, in his book *A Focus on Peatlands and Peat Mosses* (1988), proposes a more precise terminology. One of the differences he emphasizes is between peatlands, where sphagnum (peat moss) grows and accumulates, and nonpeatlands. Peatlands develop where the ground is water-soaked throughout the growing season, causing the sphagnum to grow faster than its dead remains can decompose. The built-up deposit is known as peat.

Peatlands vary depending on the degree of acidity. Fens, according to Crum, are peatlands that are rich in minerals and low in acidity or even slightly alkaline. They develop where water near the surface of the wetland is well aerated and supplied with minerals such as calcium. Northern Michigan has "rich fens" that have abundant calcium and a pH value between 6.0 and 7.5. (On the pH scale, 7 is neutral, values from 7 to 14 indicate increasing alkalinity, and values from 7 down to 0 indicate increasing acidity.) Where the calcium is low, a sedge-dominated "intermediate fen" will develop, with a tendency to become increasingly acidic. Crum designates a wetland a "poor fen" when the pH is between 4 and 6 and the vegetation, dominated by sphagnum, is still in contact with groundwater. If the pH falls to 3 or less, it is a "bog."

Crum notes that peatlands form in lowlands that have a constant water supply and may even encroach on open water. In a fen, where the water is well aerated and not too acidic, the habitat will support a diversity of plants, often dominated by sedges. But sphagnum mosses are the key to the peatland ecosystem: usually several species are present, and they may come to dominate, depending on conditions.

In some calcium-rich fens in Michigan, spring flooding or other changes in water level may restrict the growth of sphagnum, which is a perennial. Such locales may be invaded by white cedars to become cedar swamps. But in fens where peat accumulates rapidly, the water flow is restricted,

Jack W. Dykinga

trapping nutrients so that they are no longer recycled. Such fens end up as bogs, as the waterlogged peat slows down oxygen movement and reduces the rate of decomposition. Fewer and fewer plant species other than sphagnum are able to survive in the habitat. Some, perched on the peat, must obtain their water and nutrients strictly from rain, absorbing these necessities mostly through above-ground tissues rather than through roots.

As a bog matures, more and more shrubs invade it, most of them members of the heath family. In northern Michigan, bogs eventually become dominated by black spruces, forming a type of swamp referred to as a muskeg. This process may take several thousand years.

Unlike peatlands, marshes and swamps are flooded at least part of the year, so sphagnum has little chance to become established and to accumulate. Their soils are well aerated and rich in minerals. Marshes are dominated by grasses, with few woody plants. Similar habitats, when dominated by sedges, are called sedge meadows, and when forested, they are called swamps.

In Crum's terms, Summerby Swamp consists of both rich fen and cedar swamp zones. (Another type of wetland found in Hiawatha National Forest will be explored in next month's article on Shingleton Bog.) I toured the area in early July, accompanied by botanist Donald Henson. The fen, on the north side of Michigan Highway No. 123, was dotted with sphagnum hummocks. Although the fen's surface water and groundwater are charged with magnesium and calcium, these sphagnum hummocks are acidic enough to accommodate the growth of acid-loving plants, including wintergreen, leatherleaf, cranberry, and Labrador tea, all members of the heath family. Scattered throughout were thickets of stunted tamarack, white cedar, and black spruce.

The fen was colorful with the orange flowers of wood lily, the yellow and orange blossoms of Indian paintbrush, and the purplish pitchers of pitcher plants. Closer observation revealed the much smaller flowers of arrowgrass (not a true grass) and a diversity of sedges and rushes.

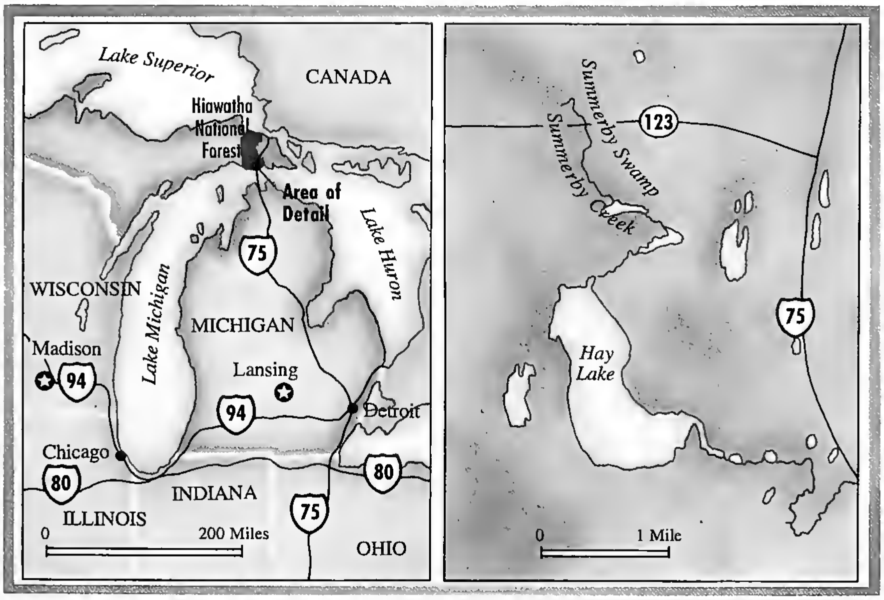
After surveying the fen, we crossed to the south side of the road. Here we observed a mature white cedar swamp with occasional stands of black spruce. Beneath the trees grew royal fern and many species of flowering plants that had bloomed earlier in the year, including starflower, goldthread, and bunchberry (a dwarf type of dogwood). Henson speculates that the construction of the road has restricted the draining of water from the north to the south side, speeding the establishment of the swamp zone.

Wood lily
Rod Planck; Photo Researchers, Inc.

While most of the plants in the fen and cedar swamp are common throughout northern Michigan, several are rare for the region. Black crowberry, bird's-eye primrose, butterwort, and the hyssop-leaved fleabane (which looks like a small daisy), all more common much farther to the north, have found the right conditions to thrive in Summerby Swamp.

Worldwide, peatlands are often found in cool temperate zones near oceans. This is because mild winters and long growing seasons with cool, humid, foggy conditions favor the growth of sphagnum moss. Peatlands also arise in poorly drained topography sculpted by glacial action. This is true of the Great Lakes area, where the poor drainage of the shallow soil, combined with an even distribution of rainfall throughout most of the year, allows peatlands to form despite short growing seasons, low humidity, and long, cold winters.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.



Joe LeMonnier

Summerby Swamp
For visitor information write:
Forest Supervisor
Hiawatha National Forest
2727 N. Lincoln Road
Escanaba, Michigan 49829
(906) 786-4062


ZEISS
8x20 B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West Germany

The Hyphenated American

What did Catherine the Great, Attila the Hun, and Jabba the Hutt have in common?

by Roger L. Welsch

It was a remarkable moment in my life: (1) my mother agreed with me, and (2) she agreed with me that my name—Roger Lee Welsch—was dumb. "Roger" has no meaning in our family (or in all history, so far as I can determine), and neither does "Lee." Heaven knows, the combination was not chosen for euphony, since it sounds like the sloshing of a bucket of slops. "Yes, Roger" my mother confessed tearfully. "I wish I had given you a name like your cousin RoseMary's."

"Who was RoseMary named after?" I asked.

"Well, no one, but her middle name is her mother's maiden name, Welsch."

Naming a human being is a ferocious responsibility and should be done with at least as much consideration as naming a pickup truck. My children's names are heavy with family and cultural history. My youngest daughter is Antonia (after two ancestors and Cather's fictional peasant heroine) Emily (after two other ancestors) Celestine (after a grandmother) Welsch (representing two millennia of endless German migration).

These days people want their children to have cuddly names, apparently content that they will never amount to much. Some people—a lot of people—work hard at finding names for their children that are without substance, evocation, or poetry. One of my own grandchildren has a set of labels so hopelessly trendy (and which will be as silly as a Nehru jacket by the time the kid graduates from high school) that I cannot bring myself to refer to him as anything but C. B.

Of course, one can go too far, loading a kid down with a meaning-drenched name. I recently met a woman, for example, who proudly told me she had named her son after her favorite place in the world, Rocky Mountain National Park. "You named him 'Rocky?' " I asked.

"No," she smiled. " 'Rocky Mountain National Park.' "

So what are these kids going to do when they are older and embarrassed by their names? Until recently a woman cursed with a goofy last name could hope to marry a man with a heroic family name, take it as her own, and cut her losses. I think of the child whose mother was in the hospital bed next to my wife's at the birth of our son Chris (for his grandfather) Edward (for his uncle, on whose birthday he was born). This lady named her daughter Michelle Renee. Michelle Renee Bierschluckenhausen. I am sure that Michelle Renee, and probably her mother, lived their lives anticipating a minister saying, "I now pronounce you husband and wife. You may kiss the bride, Mr. DuPont."

She probably married a guy named Lukosolowicz, because that's the way the gods work. Or she got liberated and hyphenated: Michelle Renee Bierschluckenhausen-Lukosolowicz. Don't get me wrong: I have trouble only with the Michelle Renee part. Bierschluckenhausen-Lukosolowicz rolls off this German tongue like a poem by Goethe.

My father is Christian Welsch. That's it. No middle name. He says his family was too busy having other children and working like slaves to think up middle names. And there's Marky Mark (of padded underwear fame) and Dougie Doug (television "personality"). I think of them as nominally challenged. Not to mention United Nations Secretary General Boutros Boutros-Ghali. Or Cher and Madonna, who have not exactly distinguished the mononominal system.

The customary Nordic system was to base the second name on the first name of the father or mother—so you got names like Eric Ericson and Sigrid Egilsdottir. This procedure makes sense to me because, even though it can raise all sorts of hell with a telephone book, it provides tradition-rich names and plenty of conversational material.

As a fat old man, I have great fondness for George Foreman, another fat old man and—not incidentally—a formidable prizefighter. It takes ego to step into a boxing ring, which probably explains why George named all of his sons George. George Foreman, George Foreman, George Foreman, and George Foreman. Consistency like that may result from the fuss Cassius Clay raised when he changed his name to Muhammad Ali, annoying the mainstream not only because it confused heavyweight boxing records but also because this guy sounds like he's from Qatar or something. The world of boxing, of which I have been a modest part myself now and then, is not noted for its social progressiveness.

As usual, my Omaha Indian friends have, over the years, arrived at a resolution to the problems of naming. Traditionally, the Omahas bestowed tribal names that carried great meaning, but a person's name could be changed now and then to suit important developments in his or her life. Moreover, new names were occasionally brought into the tribal inventory. When the French began to ply the Missouri and make themselves comfortable among the Omaha, French names found their way into the tribe—LaFlesche, Saunsoci, Fontenelle. (Sometimes even those names seem eerily appropriate: Frances LaFlesche, for example, an ethnologist of Omaha and Ponca parentage, had as her mentor the non-Indian ethnologist Alice Fletcher. *La flèche* is French for "the arrow," while fletcher is English for "arrow maker.")

Things got nasty for the Omaha when the next wave of non-Indians—missionaries and soldiers—came across the Plains. Missionaries unwilling to learn the Omaha language and determined to crush Omaha traditions assigned new names to their young charges—Grant, Canby, Sheridan, Phillips, Stabler—names of America's great military leaders, the very men who were wiping out the Omahas' Native American kin. It was a cruel process, comparable to naming a Republican conservative's children Eleanor, JFK, or Jane (as in Fonda) or a left-winger's offspring Rush or Orrin. The elegant Omaha solution is to have two names, an Omaha name for use within Omaha culture and an "English" name for use within non-Native American contexts.

In 1967, when my Omaha brother Alfred Gilpin, Jr., was preparing to give me an Omaha name, he flew in the face of an Omaha taboo and gave me his own name, Tenuga Gahi, or Bull Buffalo Chief. I sat uncomfortably in his yard one September afternoon and listened to a heated debate as his brothers argued with him that giving away his own name was bad luck. They felt he should follow tradition by presenting me with a choice of four or nine names, from which I could choose one, thus leaving the name to chance and absolving him of any responsibility. (Gilpin persisted, my name is Tenuga Gahi, and Gilpin spent much of the next year in the reservation hospital—for reasons, his family told me, that were unclear to medical experts.)

So I have been spared the usual confines of our naming system. The spit-sloshing Roger Lee Welsch may be there on my birth certificate, but in my mind I am also the considerably more splendid Bull Buffalo Chief.

I have been concerned about names for a long time—and concerned about being concerned, since a preoccupation with names can be a symptom of Huntington's chorea, Woody Guthrie's fatal disease (thus his songs "All they will call them will be 'deportees,' " or "What were their names, the men who went down on the good *Reuben James*?" and others composed in large part of the names of rivers and dams). Thirty years ago, before I was graced by the Omahas, I was discussing the subject of names in a class and observed that I admired names of grandeur and poetry, especially when they included hyphens (hyphenation was not so common then). "One of the regrets of my life," I said, "is that I will never have a name with a hyphen in it."

A young man who had been sitting in the back row all semester without saying a word slowly raised his hand, a look of discovery on his face. Surprised, I called on him. "But, uh, Professor Welsch," he said, "doesn't 'son-of-a-bitch' have hyphens in it?" (Actually, it doesn't.)

Well, what do we do when a shoe doesn't fit? We change it. Aren't our names even more our personal possessions than our shoes? We could argue that a name belongs not only to the recipient but also to the donor, but my mother was just as uncomfortable as I was with this name of mine that sounded suitable for that fat baby more than a half century ago. So this year, as a birthday present for my mother and a long overdue relief to myself, I decided to change my name—just a little, but enough to make both of us a good deal happier.

I am now Roger Lee-Flack Welsch. I have my longed-for hyphen, Mom's maiden name (Flack) is preserved in mine, and there's a nice staccato punctuation in the middle of all those ruminating sounds. So what if now, maybe, I will never wear the heavyweight boxing belt?

(Solution to the riddle in the subtitle: They all have the same middle name.)

Folklorist R. Lee-Flack Welsch lives on a tree farm in Dannebrog, Nebraska.

Getting Through the Night

by Gail S. Cleere

The vernal equinox occurs at 3:28 P.M., EST, on March 20, marking the beginning of spring in the Northern Hemisphere. The vernal equinox also marks a place in the sky where the celestial equator (the earth's equator stretched into space) and the ecliptic (the path of the sun across the sky) intersect. These imaginary lines also intersect at the autumnal equinox, but the vernal equinox is special; it is used as the standard reckoning point for determining the position of every object in the sky. On the vernal equinox, the sun's right ascension and declination (the celestial equivalents of longitude and latitude) are both zero. This position is also called the First Point of Aries (even though over the years it has drifted into neighboring Pisces).

Most astronomical outsiders are less than thrilled with this dry, mathematical definition of spring, the season that brings us warmer days, flowers, and green buds. Since ancient times, however, people have used the vernal equinox to mark the passage of the seasons. On the equinox, which means "equal night," the days and nights are roughly twelve hours long everywhere on the planet. Also on the equinox, the sun rises precisely in the east; and at local noon, it reaches an altitude that is halfway to the highest point it reaches in the sky all year. This event signals that the harsh days of winter are finally over. Because of the unseen tilting of the earth to the sun, spring finally arrives.

We no longer depend on the sky to mark the seasons, so most of us are not in the habit of keeping track of the shifting constellations and the whereabouts of the moon and planets each night. But for those who wish to give it a try, help is now as close as the nearest telephone. Every state in the Union has at least one astronomy club that can provide information on celestial highlights. One directory is published every March by *Astronomy* magazine. An even better source of information is the Astronomical Directory in *Sky and Telescope* magazine's September 1992 issue, in which twenty-nine phone numbers are listed as "telephone hotlines" for astronomical information and notes about the current night sky. Some of these hotlines are provided by museums and planetariums, such as the Smithsonian's Air and Space Museum in Washington, D.C., and the Hansen Planetarium in Salt Lake City, Utah. Some are run by astronomy clubs, but these have mostly news about club events and members.

If taped messages go by too fast for you (most have a three-minute limit in which the announcer must describe the night sky from horizon to horizon), a better solution is a computer bulletin board (*Sky and Telescope*'s September 1992 issue lists fifty-one of them). If you have a computer and a modem, you can gain access to them. Some give the same text given on the astronomy telephone hotlines, and some are entirely different. Now, armed with your computer printout or your notes from the telephone hotline message, you are ready to brave the night.

As the sky darkens on clear March evenings, and the lovely Pleiades and Hyades pull Orion from the southern skies to the western horizon, watch as Leo the Lion lumbers up over the eastern edge of the sky with his signature star, Regulus, in the lead. Leo is easy to find if skies are dark, for it is one of the few constellations to actually look like what it's supposed to be. Spica in faint Virgo is the next bright star to come up over the eastern horizon. Just about midnight, watch as the two stars that mark the claws of the Scorpion reach out toward Spica. These are *Zubenelgenubi* and *Zubeneneschamali,* now designated as part of the constellation Libra.

And that mysterious bright object near the Scorpion's southern claw? A quick call to a hotline will reveal that it's Jupiter, the planet that will linger in the same area for the rest of 1994.

THE PLANETS IN MARCH

Mercury remains a difficult planet to spot this month, although it is up in the morning skies. The sun's closest neighbor reaches greatest elongation west (28°) on the 19th, but despite the large separation from the sun, this is an unfavorable elongation for Northern Hemisphere skywatchers because of the low angle of the ecliptic. Perhaps the best time to try to spot Mercury this month will be within a few days of March 10, when you might spy it looking like a bright zero-magnitude "star" very low above the east–southeast horizon about an hour before sunrise. On the morning of the 24th, Mercury will stand less than half a degree (about the width of a full moon) south of Saturn.

Venus slowly emerges from the glare of the evening twilight this month, as the time of its setting after sundown increases from about forty-five minutes on the 1st to ninety minutes on the 31st. On the evening of the 13th, look to the west shortly after sunset and you should find a very young crescent moon. Below and slightly to the left of this delicate crescent, just above the western horizon, you should find brilliant Venus.

Mars rises only one-half to one hour before the sun this month. Shining at magnitude +1.2, the red planet will be extremely difficult to see in the bright morning twilight. Mars passes Saturn on the mornings of the 13th and 14th, but because of their low altitude and proximity to the sun, you probably won't see them.

Jupiter is in Libra, to the west of the curved body of Scorpius. This gas giant rises before midnight and is in the southwest sky by sunrise. The waning gibbous moon pays Jupiter a visit twice this month: during the predawn hours of the 2d, you'll find it below and to the right of Jupiter and on the night of the 29th-30th, the moon lies below and to the left.

Saturn might be seen by month's end, low in the southeast and rising just over an hour after the sun. Because of the low angle of the planet's orbital path relative to our horizon, Saturn will probably not be visible when it is passed by Mars on the 13th-14th. You might catch a glimpse of Saturn near Mercury on the 24th.

Uranus and **Neptune** remain in eastern Sagittarius, inching their way toward Capricornus, until late April and early May, when the two of them become "stationary" as they begin their retrograde motion across the sky as seen from the earth's perspective. Binoculars, dark skies, and sky charts are essential for spotting these two blue-green planets. The waning moon points the way on the 7th, when both planets are 4° and 5°, respectively, below it.

Pluto hugs the northeast corner of the constellation Libra this month and remains there all year long, not far from Jupiter. Only the largest telescopes, steady atmospheric conditions, dark skies, and good star charts permit a view of Pluto.

The **Moon** reaches last quarter on the 4th at 11:53 A.M., EST, is new on the 12th at 2:05 A.M., EST, and reaches first quarter at 7:14 A.M., EST, on the 20th. The full moon occurs on the 27th at 6:09 A.M., EST.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

Three Soay ewes and three young rams graze on Hirta. Feral for at least a thousand years, the breed is the most primitive of Europe's domestic sheep. Both sexes usually have horns.
Tim Clutton-Brock

Counting Sheep

Every few years, most of the feral sheep on a Scottish island perish—yet the flock survives

by Tim Clutton-Brock

In the Atlantic Ocean, off the northwest coast of Scotland, lie the Outer Hebrides. Forty miles farther out, the shattered rim of an extinct volcano forms another archipelago known as Saint Kilda. Its rugged, rocky islands are home to huge colonies of puffins, gannets, fulmars, and shearwaters. The archipelago also contains its own subspecies of mouse and a wren whose songs are strikingly different from those of its mainland cousins. But the most unusual inhabitants of Saint Kilda are the small, feral Soay sheep, named for a small island in the archipelago on which they have grazed since ancient times. Precisely when they were introduced to Soay is unknown, but it may have been as early as 3,000 years ago; even the most conservative estimates place them on the island for at least a thousand years. Soays are the most primitive breed of domestic sheep in Europe; their skeletons closely resemble the remains of sheep from early Neolithic sites. Although their fleece is generally brown, it can range in color from cream to black. Both sexes usually have horns, and their partly woolly fleece also sports long, straight hairs.

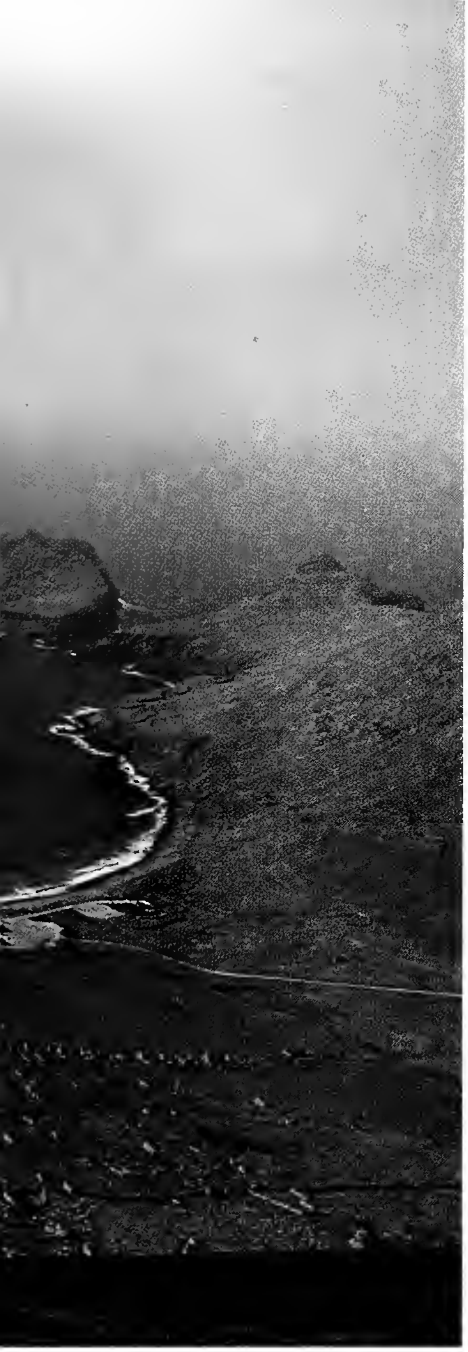
Hirta, the largest of Saint Kilda's islands, supported a population of crofters that dwindled until 1930, when the thirty remaining villagers were relocated to the mainland. In 1932, 107 feral sheep from Soay were introduced to Hirta by the island's owner, the Marquis of Bute. They quickly increased to colonize the whole island, reaching 500 in less than ten years. When the first organized census was taken in 1952, there were 1,114 sheep on the island. To a zoologist, however, the striking feature of Hirta's Soay sheep population is that it appears to rise and fall in cycles. Every third or fourth winter, after numbers have passed the 1,400 mark, the sheep on the island begin to starve. In their weakened condition, many seek the sanctuary of the oblong dry-stone shelters, or cleits, that the islanders once used to dry seabirds harvested for their meat and feathers. Seventy percent of the sheep succumb, mostly in February or March. Their bodies pile up, and by April, many of the cleits are choked with rotting carcasses.

Until recently, zoologists thought that regular population cycles were confined to small-bodied mammals in the Arctic and sub-Antarctic (*see* "The Lemming Phenomenon," *Natural History,* December 1989). At intervals of between two and nine years, populations of voles, lemmings, and snowshoe hares commonly rise and fall, with populations sometimes falling to less than one-tenth of peak numbers. Cycles may have dramatic effects both on these animals' food supply and on the prosperity of their predators, whose populations may decrease rapidly as their own food supply disappears. We are not accustomed to thinking of such dramatic cycles in larger mammals. Imagine, for example, a tenfold increase in American white-tailed deer populations over three years, or a sudden 90 percent reduction in their numbers.

But population cycles may not be confined to small mammals after all. Ten years ago, Rolf Peterson and his colleagues at Michigan Technological University showed that, across species, the length of cycles increased with the body size of animals. The most rapid cycles—two to three years—are found among mice

Joe LeMonnier

and voles. Lemmings, which are larger, sometimes show cycles of three to four years. Muskrats may peak every seven years and snowshoe hares at nine years. Peterson's group suggested that the cycle length depends on the rate at which the population can expand, which, in turn, depends on generation length. Because large mammals mature more slowly and breed less frequently than small ones, they have longer generation times and lower rates of increase and therefore may show longer cycles. Using the known relationship between body size and cycle periodicity in smaller animals, Peterson scaled up the figures and predicted that cycles might occur every thirty years in moose and every seventy years in elephants. We do not yet have data spanning many decades,



Colin Baxter

Although sheep graze all over Hirta, in winter they spend most of their time on low ground, especially in the abandoned fields of Village Bay, left. The dry-stone shelters, or cleits, that dot the lower slopes were built to dry and store seabirds. A yearling ram, below, is already sexually mature. During rut, rams wander widely in search of ewes in estrus.

Laurie Campbell

but Peterson expects that the occasional oscillations we see in some larger ungulates may eventually turn out to be part of such long-term cycles.

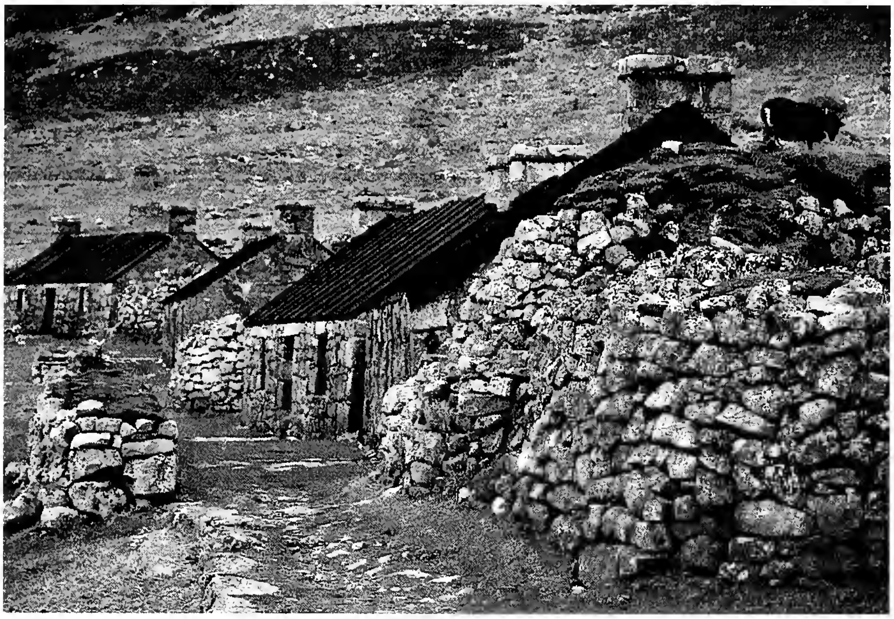
My colleagues and I have followed the Soay sheep on Hirta through three cycles, but we weren't the first to observe the phenomenon. Previous studies of the island sheep by Morton Boyd, of the British Nature Conservancy Council, and by zoologists Peter Jewell and Peter Grubb, of the University of London, show that similar die-offs occurred every third or fourth year during the 1960s. Regular oscillations have not been reported in any wild sheep populations in North America or Asia, nor do other ungulates on Scottish islands show similar peaks and crashes. The number of red deer on the island of Rum, for instance, where zoologist Fiona Guinness and I have studied them for more than twenty years, remains remarkably stable, declining slightly after hard winters and increasing after good ones. Then why should Soay sheep behave like voles or lemmings?

Over the last three years, Steve Albon, Josephine Pemberton, and I, together with other biologists from Cambridge and Edinburgh, have begun to glimpse an answer. After a population crash, sheep numbers increase rapidly. Unlike North American wild sheep, Soay ewes first conceive when they are less than a year old, birthing their first lambs in April, soon after their first birthday. Up to 20 percent of the pregnant females bear twins. Since Hirta has no carnivores, more than 80 percent of the spring newborns usually survive to the beginning of winter, and animals obviously cannot disperse from the island. When the population is small, winter mortality of lambs is less than 10 percent, so that by the end of the first year following a crash, total numbers usually have risen by 50 percent or more. Fecundity and lamb survival remain high through the following year, when the sheep increase by 40 to 50 percent again. In the summer of the third season, they increase by another 40 percent. At this stage, there are more than three times as many sheep on Hirta as there were immediately after the crash, but they still begin the winter in good health.

In late September or October, however, grass growth ceases at this latitude, and the sheep must winter on the remnants of summer's vegetation. When sheep numbers are high, little food remains by January or early February, and the animals begin to lose weight rapidly. Rams, which burn much of their fat in the November rut, are the first to die, followed by lambs, which suffer more heat loss than ewes because of their smaller size. During February and March (the last two months of gestation), the energy costs of supporting growing fetuses increase sharply, and pregnant ewes (especially those carrying twins) are the final casualties.

At least two other factors may contribute to the crash. First, the sheep suffer from infestations of nematode worms in their gastrointestinal tracts. As the flock increases, more worms are passed out in their dung, so the density of worms in the pasture also rises. Second, as Dawn Bazely and Mark Vicari of Canada's University of York have shown, heavy grazing may reduce the production of summer grasses immediately before a crash, fur-

Glyn Satterley Book; National Trust for Scotland



Houses on a village street, below, abandoned by the islanders after 1930, have been restored and are used to accommodate work parties and visiting scientists. Right: Sheep graze among the dry-stone cleits. When their numbers peak, the animals closely crop abandoned fields and lower slopes, even devouring rushes.

Tim Clutton-Brock

ther depressing the autumn food supply. These factors help to answer the immediate question of why the population shows periodic, dramatic die-offs. They do not tell us, however, why Soay sheep populations should oscillate while those of other ungulates are stabilized by the effects of increasing density on reproduction or mortality. Do similar processes not occur in Soays—and, if not, why not?

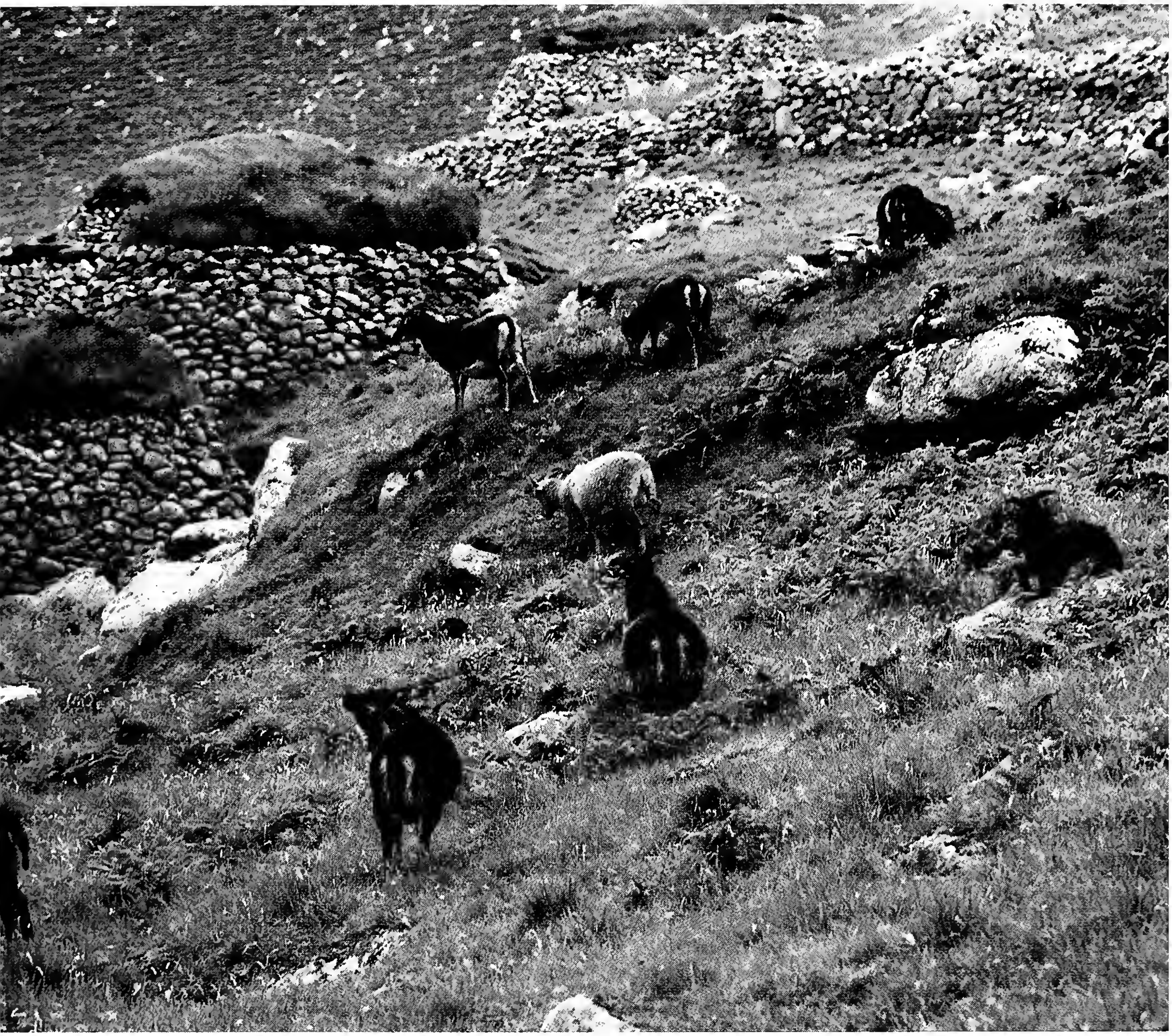
We have found that rising population density has little effect either on the fecundity of the ewes or on neonatal mortality in the sheep through the first two years of the cycle. Even in the third year, 90 percent of the flock's adult ewes become pregnant. Why increasing numbers have so little effect on neonatal survival is easy to see: food is plentiful on Hirta, even in the third year of the cycle. On Hirta, which is about as far north as southern Alaska, days are long and nights are short in early summer, and there is a burst of plant production. Growing lambs have plenty of food during their first months of life, even when summer population is highest, so that population density itself has little or no effect on lamb survival. The relatively high lamb mortality during the summer following a crash—when population size is low but food is plentiful—occurs because light, weak lambs have been produced by ewes that have barely survived the winter.

The same burst of plant growth in early summer helps to explain why the sheep can remain fecund as their population density increases. After the middle of June, lambs suckle infrequently, and their mothers then have several months to recover the condition lost during lactation. As a result, they can reach the necessary weight to conceive by the time of the late October rut, and summer numbers have little effect on the proportion that conceive.

This situation differs from the breeding cycle of most other ungulates, which wean their offspring much later in the year. For example, red deer on Rum bear their calves in June and continue to suckle them until November or December, after the annual rut in October. During lactation, especially in the weeks when their milk production is highest, the daily energy requirements of females increase as much as fourfold, and mothers typically lose a substantial proportion of their body weight.

Unlike Soay sheep, female red deer cannot begin to regain this lost weight until the latter months of lactation in late summer, when the demands of suckling calves have dropped. By this time, days are shortening, plant growth has dropped back, and food is no longer superabundant. High numbers of red deer deplete the food supply in late summer. Consequently, many mothers cannot regain body weight before October and fail to conceive during the rut. As a result, when deer density is high, the majority of mothers breed every other year, substantially lowering the growth rate of the deer population.

To explain the apparent lack of relationship between population density and fecundity in Saint Kilda's sheep, we needed to compare the weights of mothers that had raised lambs during late summer with the weights of those that had not. But to weigh a sample of ewes, one must first catch them—and these animals are unaccustomed to humans. Unfortunately, sheepdogs are of no use, for the sheep scatter, rather than bunch, when they are



chased. We initially tried a number of different roundup methods, and one of the simplest proved the most effective. On rainy nights, the sheep take shelter in the cleits; by moving very quietly, we were able to block the entrance before any could escape. Then one of our team would crawl through the low entrance into the cleit with a flashlight, grab a sheep, and drag it out to the open, where it could be weighed, measured, and have its blood sampled. Sometimes after crawling down the low, muddy entrance into pitch blackness and switching on his helmet lamp, a catcher would confront a ram with its head down, ready to charge directly at the light.

We found that the least painful method of capture was a large-scale netting operation. With volunteers from the Mammal Conservation Trust, who are experienced in netting deer, we learned to build corrals of netting, well hidden behind the derelict cottages of the village street; to erect hundreds of feet of side nets around the meadows where the sheep collect; and then to slowly ease the sheep up the tunnels of netting into the corral, where they could be caught and weighed. This way, we eventually trapped enough sheep to allow us to compare the weights of mothers that had raised no lambs with those that had raised singletons or twins. As predicted, all three categories of mothers proved to be of similar weight in August—two full months before the rut—showing that mothers are able to regain weight lost during lactation in the two months following the weaning of their lambs. This contrasts strongly with red deer on Rum, where mothers that have raised calves are still in poor condition in September.

So what does our understanding of sheep cycles on Saint Kilda tell us about cycling in other ungulates? The features of the Soay sheep population that create cycles are the high rate of population increase (caused by first-year breeding, low juvenile mortality, and no dispersal) and the absence of any strong effect of population density on fecundity and lamb mortality (fostered by the superabundance of food in early summer and by early weaning). This combination of factors is not common in ungulates. Most ungulate females do not conceive until their second, third, or fourth year of life; twinning is rare; and neonatal mortality is high. As a result, unlike Soay sheep, populations of other ungulates cannot exceed by a large margin the number of animals that the winter food supply can support.

Some wild ungulates do parallel the sheep's situation, however. The Saiga an-

I Stevenson

A hornless ewe suckles her lamb, below. Between 10 and 20 percent of mothers produce twins, which weigh less at birth and are somewhat less likely to survive than are singletons. Bearing the remains of winter fleece, a two-year-old ewe, right, licks her newborn lamb.

Tim Clutton-Brock

telopes of the Asian steppes, for instance, conceive in their first year of life and usually produce twins; their numbers, like the sheep's, can increase very rapidly. Their populations are unstable, but we don't yet know whether they oscillate regularly. White-tailed deer, too, commonly conceive in their first autumn of life, and mature females often produce twins. But here, natural predators and human hunters constrain population growth, usually preventing local populations from exceeding their food resources.

One other ungulate population that appears to cycle is the Corsican mouflon sheep, which was introduced to the subantarctic Kerguelen Islands in the 1950s. As on Hirta, there are no effective mammalian predators, and mouflon numbers have increased rapidly. Unlike the Soays, however, Kerguelen mouflon do not conceive until their second year. But twins are common and neonatal mortality is low. Patrick Boussés, of the French National Museum of Natural History, has recently shown that population crashes comparable to those we have observed on Hirta occur every fourth year among the mouflons. I am not surprised that the periodicity of these cycles is rather longer than in Soay sheep, for the mouflon are larger animals and their delayed age of first breeding slows the population's growth rate. (Similarly, as Peterson has suggested, the relationship between small body size, high fecundity, and rapid population growth probably explains why smaller rodents recover from crashes more quickly than larger ones, generating shorter cycles.)

So might population cycles be a much commoner phenomenon than we imagine? Can we expect to find thirty-year moose cycles and seventy-year elephant cycles, as Peterson and his colleagues suggest? That is not inconceivable, but I'm skeptical. As body size increases and fecundity falls, we see a decline in a population's capacity to exceed winter food supplies by multiplying during the boom months of early summer. Weaning occurs later, limiting mothers' ability to regain condition before the autumn rut. Populations increase more slowly, providing more opportunities for density-dependent changes in predation or starvation to depress further increases in numbers. Although moose and elephant populations may oscillate, and crashes may occur when winter or dry-season food supplies are suddenly restricted, I doubt that future generations of wildlife biologists will discover that they show regular cycles. □

Tropical Liaisons on a Beetle's

In the rain forests of Central and South America, pseudoscorpions and harlequin beetles are more than fellow travelers

by Jeanne A. Zeh and David W. Zeh

The forest of Panama's Soberania National Park felt almost cool after a torrential afternoon downpour. It was early May 1988, and the wet season had just arrived. The forest, parched after four months without rain, was springing back to life. Near dusk, a shaft of pale light still penetrated the dense canopy. After a long day, we were tired, drenched, and mud spattered. We took a compass reading and headed back toward a trail. Suddenly, we spotted what we had been searching for. Lying amidst the tangled green wreckage of a newly opened forest gap was the trunk of a huge, fallen fig tree. Struggling through the chaos of twisted lianas and splintered black palms, we hacked a path to the tree. Pungent, milky sap still oozed from the fig's broken limbs. We could hardly believe our luck at finding a fig tree that must have fallen only a day or two before. We had previously come across a few fallen fig trees, but they had all been well along in the decay process.

A recently fallen fig, we knew, was sure to attract the most striking of all the long-horned beetles, the harlequin, named for the pattern of swirling crimson, black, and greenish yellow that decorates its body. As arachnologists, our main interest was not in this magnificent beetle itself, but in its tiny passengers, pseudoscorpions belonging to the species *Cordylochernes scorpioides*. The false scorpions lack a tail tipped with poisonous stingers, but they can immobilize prey with poison produced by a gland in their pincers. If you were to prize open a harlequin's wing covers, you would almost certainly find at least one pseudoscorpion, maybe more. The record stands at fifty-four, all clinging tenaciously to the abdomen of a single, large male beetle. Naturalists have been aware of this curious association ever since Linnaeus described it in 1758, but why the pseudoscorpions engage in this beetle-riding behavior has been a mystery. Do they climb on board to feed on the mites that infest the beetles? Do they spend their entire lives on the beetles? Or are they simply catching a ride, with the harlequins providing jumbo jet service be-

Back

A harlequin beetle rests on a fallen rain forest tree. Female beetles use their powerful mandibles to cut holes in the wood where they will deposit their eggs.
George D. Dodge, Bruce Coleman, Inc.

tween one habitat and the next? Having located the harlequin's prime habitat, perhaps we could unravel this mystery.

As night closed in, we checked our headlamps. Equipped with red filters, the lights would be invisible to insect eyes while providing us with a little illumination on this moonless night. We waited silently, hoping that we would not encounter a deadly fer-de-lance coiled beneath the tree trunk (as we had on two previous occasions). Within moments, our apprehension was forgotten as a large male harlequin descended from the canopy. The size of a small bird, it flew in slow motion, its enormously elongated forelegs outstretched and its body held vertically. Minutes later, the buzzing of large wings signaled the arrival of a second big male.

The scene was set for one of the most remarkable displays of male combat in the insect world, a struggle to gain control of prime egg-laying sites on the tree. In a coleopteran version of jujitsu, each male repeatedly reared up on his hind legs, lunged forward, and using his forelegs as hooked levers, tried to overturn the other and toss him from the tree. Victory usually goes to the male with the longest forelegs, but these combatants were closely matched, and all attempts at tossing failed. Not the hard-wired robots insects are often thought to be, the beetles abandoned their standard tactics as the contest escalated, and their attacks and counterattacks grew more complex and less predictable. Finally, after a frenzied ten minutes of vicious bites, flailing forelegs, and wildly waving antennae, one contestant retreated, part of his left antenna amputated by his opponent's powerful mandibles. The victor then took up the task of guarding his mating territory. Within an hour a female arrived, and the pair began to copulate.

For harlequin beetles, mating is a protracted affair. After copulation, the male guards the site as his mate chews a hole in the half-inch-thick bark, an arduous task that may take her an hour. Excavation completed, the female injects a single egg into the pit and again copulates with the male. She may continue this sequence through the night until she has left a telltale line of five to ten holes in the bark.

As the pair we watched began to copulate a second time, we crept a little closer, confident that the harlequins were too preoccupied to notice. To couple with the female, the male arched his abdomen downward, leaving the space beneath his wing covers exposed. Straining to see in the dim red light, we spotted a pseudoscorpion moving down the male's abdomen. Climbing onto the female beetle's ovipositor, it paused and raised its pincers. Apparently

Two male harlequins butt heads in a battle over prime mating territory on a fallen fig tree. When the combatants are equally matched in size, as these are, the fight may last as long as half an hour.
David W. Zeh

irritated by the probing claws, the female harlequin flexed her abdomen and the pseudoscorpion crawled aboard, disappearing beneath her wing covers.

Just from the size and bulbous appearance of its claws, we could tell that this pseudoscorpion was a big male. This marked external difference between the sexes—known as sexual dimorphism—suggested that strong sexual selection (either through female choice or male competition) had exerted its force on this species. Darwin was the first to recognize that sexual selection might exaggerate and perpetuate certain male traits, but more than a century after he first drew attention to this phenomenon, an unresolved problem still puzzles evolutionary biologists: If, over long spans of evolutionary time, champions of male combat or the flamboyant beaus preferred by females consistently sire more offspring than do their smaller or less showy rivals, the "lesser" males should eventually disappear from populations. But they don't. Indeed, the enormous variability in the size of *C. scorpioides* males in museum collections prompted Austrian taxonomist Max Beier to describe it as the most variable pseudoscorpion known.

We realized that the beetle-riding pseudoscorpion was an ideal species for studying how male variability is maintained, but finding pseudoscorpions and the beetle hosts in their natural habitat had always been difficult.

When we first began our research in 1987, we searched the Panamanian forests for two months without finding a single dead fig tree. Then, one morning in early December, we decided to combine fieldwork with sightseeing and hiked Las Cruces Trail. Cut through the forest by slaves, this pathway was once the conquistadors' major route across the isthmus. Our only companion was a giant *Morpho* butterfly fluttering erratically down the path ahead of us, its metallic blue wings flashing against a background of lush green. Following our lepidopteran scout around a bend, we came upon a dead, but still standing, fig tree, a mere twenty yards from the infamous trail.

The roots that buttressed the 130-foot-tall tree were surrounded by fallen bark and mounds of pale yellow sawdust, conspicuous evidence of harlequin beetle larvae tunneling within its trunk. The tree was pockmarked with dozens of elliptical holes, tunnel entrances leading deep into the heartwood. Most striking was the rippled appearance of the exposed outer sapwood, where the beetle larvae had gouged large, curving tunnels just beneath the surface. The decaying tree was an oasis in an otherwise hostile environment. The wood of fig trees is very soft compared with most other tropical species, and the copious, nutrient-laden sap supports thriving colonies of bacteria and yeast, the basis of the rotting tree's food web.

The dead tree itself seemed strangely alive, with loud gurgling noises emanating from the trunk. (These sounds, we learned later, were produced by the wood-boring larvae of pantophthalmid flies, feeding ravenously as they cut perfectly cylindrical holes. One of the largest flies in the world, it has its own species of pseudoscorpion hitchhiker.) The rotting wood was an entomologist's paradise, buzzing with anvil-headed fruit flies; stilt-legged flies; blue-bodied, yellow-headed stratiomyid flies; weevils; giant orange click beetles; rove and bark beetles; and four-inch-long cockroaches. And there were predators: female parasitic wasps, tailless whipscorpions, ambush bugs disguised as miniature garbage heaps, and raiding hordes of ants. All were feeding, fighting, mating, or depositing their eggs.

In the sawdust and under the bark, we found *C. scorpioides* by the dozen—large males, small males, females carrying brood sacs, nymphs. This was the primary habitat of the beetle-riding pseudoscorpion. (The trees provide an ideal nursery for developing young, and fly and beetle larvae growing in the wood provide the adult pseudoscorpions with an abundant food supply.) To exploit such a rich, but ephemeral, resource, a small, flightless arthropod first faces the daunting challenge of dispersal. Traveling between these patchily distributed habitats is well beyond its own abilities. While other pseudoscorpions hitch rides by hanging on to the legs of various flying insects, *C. scorpioides* has evolved behaviors that allow it to travel in relative luxury aboard the abdomens of harlequin beetles, a far less hazardous method of dispersal.

Four to twelve months after the female harlequin deposits her eggs, her offspring develop into five-inch-long larvae and are ready to pupate. But first the larvae prepare for their emergence as adults by cutting a disk eight inches in diameter in the bark covering their tunnel entrances. By the time the adult beetles begin to emerge from their pupal chambers, the resources of the decaying fig tree have become severely depleted, and its population of several hundred pseudoscorpions is ready to disperse. Attracted by chemical cues and surface vibrations, the pseudoscorpions

Beneath the open wing covers of a harlequin beetle, below, two closely matched male pseudoscorpions are locked in battle. More than a dozen pseudoscorpions, right, hitch a ride on a small male harlequin that has just emerged from its pupal chamber in a rotting fig tree. When the beetle takes flight to search for another tree, it will transport the false scorpions and a number of much smaller mites.

Photographs by Jeanne A. Zeh

converge on adult beetles. Equipped only with a pair of poorly developed eyespots, the pseudoscorpions unerringly head straight for the "boarding gate," the rear end of a beetle's abdomen. One by one, males and females raise their claws, pinch the beetle's rear, and as the harlequin reacts by flinching its abdomen, the pseudoscorpions quickly clamber on board.

Heavily laden with the stowaways, the harlequin climbs to the highest available point on the trunk and launches itself into the air in search of another fig tree on which to mate.

We have found that the female harlequins are extremely fastidious in their choice of trees. Our survey of a 150-acre tract of forest showed that 80 percent of the beetles we located were on newly fallen trees. Depending on their size, the trees attracted adult harlequins for only a brief period of from four to twenty-six days. We found the remaining 20 percent of the beetles on standing dead trees.

While a harlequin flies in search of a fallen tree, the pseudoscorpions must avoid falling off the vertically held abdomen of their host. Instead of simply clinging to the segments of the beetle's abdomen, they attach themselves with a safety harness of silk, produced by a gland in their pincers. When the harlequin finds a suitable fig tree, the pseudoscorpions use silk again. They cannot fly or jump, but, undaunted, they spin a silken thread and rappel down to their new habitat.

Our field observations confirmed that the pseudoscorpions use the beetles to disperse from old, exhausted trees to newly fallen ones. In examining more than 150 beetles, we have found only adult pseudoscorpions. Because mature pseudoscorpions are voracious and opportunistic predators not averse to cannibalism, the crowded beetle abdomens are no place for the weak and vulnerable. (We have often seen adults in trees feeding on nymphs, as well as older nymphs feeding on younger ones.) What was unexpected was the large number of beetles carrying just one pseudoscorpion, always a male. Of the fifty-eight harlequins we examined on recently fallen trees, fifty-three were occupied by lone males. Their pincers, used for fighting, were markedly larger than those of the average males collected from the trees. These big males remained on board even when their host beetles stayed on the trees for several days.

To investigate this perplexing finding, we marked 136 virgin male and female pseudoscorpions and allowed them to mount beetles in the laboratory. Then we released the harlequins on a newly fallen fig tree. Recapturing the beetles a few hours later, we identified the remaining pseudoscorpions and found that the females and small males had disembarked rapidly, but the bigger males had stayed aboard. Only when there were no females aboard did large male pseudoscorpions show any inclination to abandon their hosts, and in such cases they often simply transferred to another beetle. In a few cases, we recaptured marked beetles for a second and a third census. On one, a male pseudoscorpion was still present after fourteen days, and in the interim, two females had come aboard. Because female pseudoscorpions disembark rapidly, we were only able to recapture ten on their original beetles. Of these originally virgin females, eight subsequently produced brood sacs and nymphs in the lab, indicat-

ing that the pseudoscorpions had almost certainly mated on board their host.

With the discovery that the beetles served as mobile mating territories, our previous observations began to make sense. For several generations, pseudoscorpion populations thrive within the decaying fig trees, until the trees' resources are exhausted (about a year). As new harlequin beetle adults emerge from the rotting wood, large numbers of pseudoscorpions climb on board. A high proportion of the female stowaways are sexually receptive. Males therefore compete intensely to establish a mating territory on a beetle's abdomen. When a harlequin locates a recently fallen fig tree, inseminated female pseudoscorpions disembark to colonize the tree, and smaller males are forced off by larger rivals. After the beetle's maiden flight, it continues to search the forest for suitable trees and mates, typically carrying a single, large, male pseudoscorpion under its wing covers. Females or challenging males may come aboard when the harlequin visits dead trees that are mosaics of old and new decay. The resident male may disembark to reconnoiter other beetles as its host beetle copulates, but in the meantime he may be supplanted by a larger intruder.

In this cycle of population growth and dispersal, we saw how sexual selection could act to maintain the striking size variability among *C. scorpioides* males. In essence, variability persists because of the two very different habitats in which male pseudoscorpions must compete: on the backs of beetles and within decaying trees. During the pseudoscorpion's brief dispersal episodes on beetles, it pays to be large, but during the several generations spent living within the trees, big males seem to have no advantage. In laboratory experiments, we found that big males were able to monopolize matings only under crowded conditions. In trees, where mates are spread out, siring more offspring may depend more on a male pseudoscorpion's mobility and his ability to find mates quickly. Selection may therefore favor small size and rapid maturation. Thus, rather than leading toward a single ideal male, oscillating sexual selection alternately favors small and then large males.

Simply tallying the number of females with which a male mated was not enough to prove this hypothesis, however. Mating itself does not guarantee the siring of offspring. As British biologist Geoffrey Parker pointed out more than twenty years ago, sexual selection does not necessarily end with copulation. Female pseudoscorpions are able to store sperm. If a female opts to mate with more than one male, the sperm from each male may have to com-

Stephen Dalton; NHPA

Beneath the bark of a rotting tree, below, a female pseudoscorpion carries developing embryos in an external brood sac. Despite its vivid colors, a harlequin beetle, right, blends into the bark of a tree in a Venezuelan rain forest.

Edward S. Ross

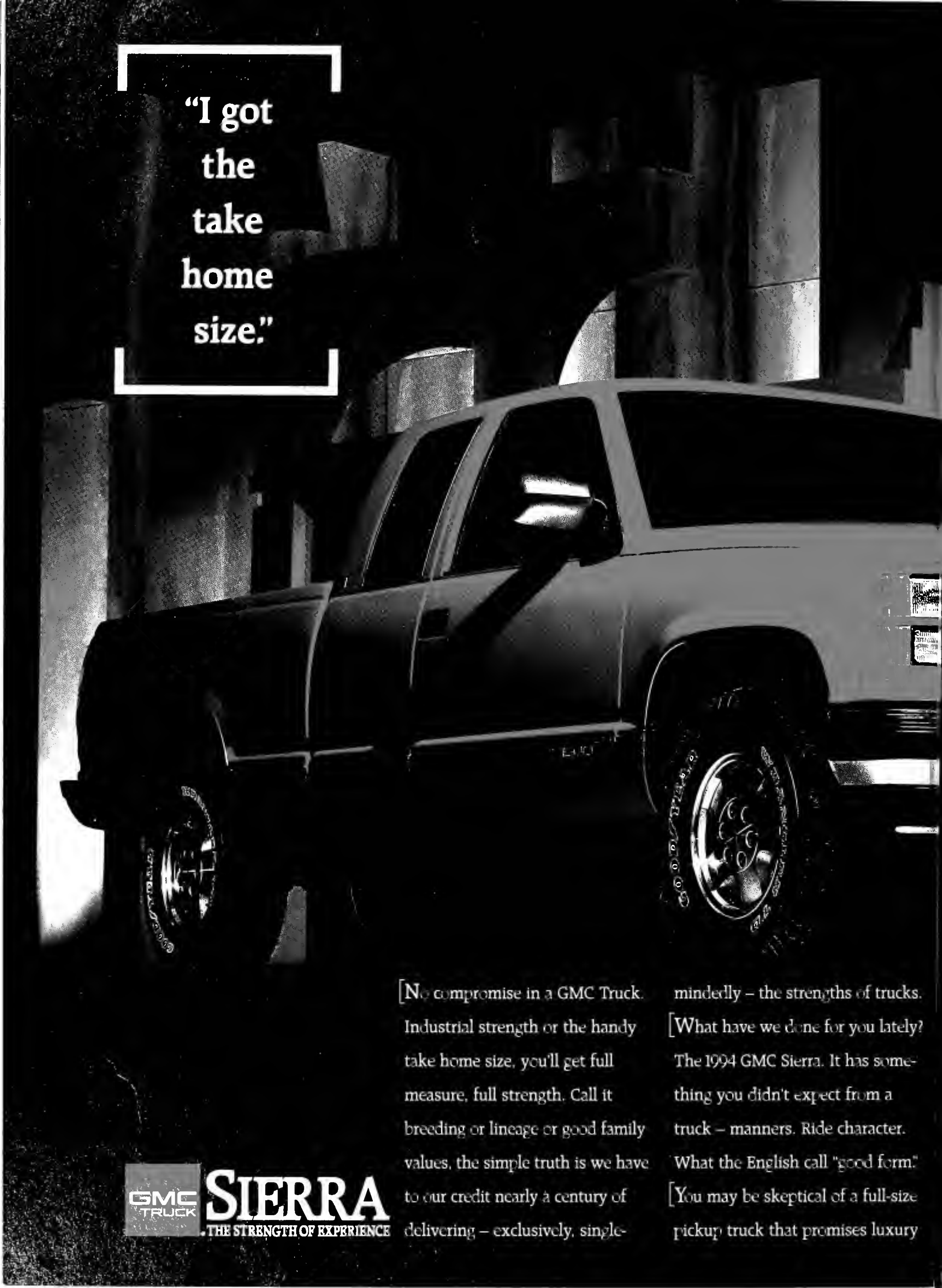
pete to fertilize her eggs. Female promiscuity makes paternity hard to establish.

Fortunately, DNA fingerprinting now offers a direct way to measure a male's success in fertilizing the eggs of his mate. By cloning DNA from the beetle-riding pseudoscorpions, we were able to identify two regions of DNA that were particularly useful for tracing relationships between individuals. These probes enabled us to test our oscillating-selection hypothesis. We needed beetles from recently fallen trees, but few fig trees fell in Soberania Park that season. We traveled to French Guiana, where, we were told, we might find sufficient numbers of harlequins to complete the study. In the Kaw Mountains southeast of Cayenne, we found harlequins in abundance, collected breeding pseudoscorpions from beneath the beetles' wing covers, and reared their offspring.

Back in Panama, we found that DNA fingerprints of these families demonstrated that in the beetle environment sexual selection does favor large male size. Only very large males are able to monopolize beetles. Yet even within this elite, the DNA fingerprints revealed a strong, positive relationship between size and fertilization success. To study the relationship between male size and reproductive success in trees, we now need to develop additional DNA probes that will allow us to determine paternity among large numbers of putative sires.

Taking a break from the long hours in the molecular lab, we spent a day in the forest, returning to the tree where we had seen the two harlequins fight a year before. A small male beetle, newly emerged from his pupal chamber, was resting on the trunk. All around him, pseudoscorpions were emerging from beneath the bark. One by one, they pinched his abdomen and disappeared on board. That night, we knew, the beetle would abandon the old tree and set out on his maiden flight. Already overgrown with saplings, the remains of the fig tree would soon rot away completely, returning its precious nutrients to the soil.

Somewhere in Soberania Park another old fig tree will crash to the forest floor, but for the harlequin, for the beetle-riding pseudoscorpion, for an entire community of arthropod species, the death of this magnificent tree will present an indispensable ecological opportunity. □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THE STRENGTH OF EXPERIENCE

An effigy of Judas is venerated in Zunil, Guatemala, where the Maya have infused Christianity's villain with a combination of ancient and modern attributes.
Tom Owen Edmunds

Judas Transformed

During Holy Week, the Maya confront the man they love to hate

by June Nash

When I saw Judas last year in Guatemala, he was wearing a sport shirt, jogging pants, running shoes, and a blue hard hat—at least that was how some Maya portrayed this reviled figure. The conquering Spaniards had introduced him as the betrayer of Jesus, a personage in the drama of the Crucifixion. But in the delicate operation of imposing and maintaining the Catholic religion in Mexico and Central America, the priests could not prevent Judas from slipping away and taking on a life, and meaning, of his own.

I first encountered a Maya Judas forty years ago, when I began anthropological fieldwork in Cantel, a township in the western highlands of Guatemala. Inhabited by Quiché-speaking Maya, Cantel was a farming center with a large textile factory. The settlement clustered around the large colonial church that stood atop a high hill. Below flowed the Samalá River, which had run red with the blood of the slain in 1524, when the Maya king Tecum-Uman fought and died in battle with the conqueror Pedro de Alvarado.

The Maya still spoke of that battle, and during Carnival they subtly reenacted it. The conquerors had introduced a dance commemorating the Spaniards' struggle with the Moors, which the Maya continued to perform. The dancers dressed in costumes of both roles but, embracing the enemy of the Spaniards as their own race, they mingled brown masks of Tecum-Uman with the black masks of the Moors. In everyday life as well, the Maya remained hostile to those they called Ladinos, those of mixed Indian and Spanish descent who identified with the foreign culture. Their attitude was a result of a long history of exploitation and oppression by Ladinos, who controlled the plantations, markets, and institutions of government.

Judas was one of the effigies paraded about during Holy Week each year, when the priest and the catechists (loyal followers of orthodox Catholicism) stage-managed the Passion of Christ. In 1954 the priest was a young Franciscan, newly arrived in Guatemala after previous service in China. His goal was to rescue Catholicism from the folk traditions that had been shaping religious practices during the previous decades, when communities like Cantel did not have resident priests. His major adversaries were the groups of devotees, known as brotherhoods, that had arisen around various saints. Particularly resistant were the mayordomos, or caretakers of the brotherhood houses, who were responsible for the saints' figures. Even Judas had his own brotherhood, being granted a far less negative role in the folk tradition than by the church.

At times during Holy Week, the two religious factions came into conflict over the ceremonial use of public space. For example, on Holy Saturday, those upholding the folk traditions took the figure of the body of Christ, recumbent in its bower of flowers and pine needles, on a slow march through the town, accompanied by the mournful tune of trumpets and wooden ratchet noisemakers. The priest tried to get them to return the figure while it was still daylight, but the mayordomos insisted on a very slow pace, out of respect. The sacristan was obliged to allow the mayordomos to reenter the church after midnight.

Generally, however, the two groups coordinated their activities, the catechists exerting their control in the church while the mayordomos held sway in the plaza and the brotherhood houses. For example, on Holy Thursday, in dramatizing the biblical scenario, the catechists set the image of Christ bearing the cross in the center of the nave. But outside the church that evening, under the direction of the mayordomos, the folk-traditionalists played the role of "the killers of Christ." The streets filled with the spectators' raucous cries of "the Jews!" as participants ran through the town seeking the one who played the role of Jesus. Often pausing to rekindle their energies in the liquor shops, they continued their search until they discovered "Jesus" and dragged him to an improvised jail in the corner of the plaza.

Judas, a straw figure with a wooden mask, belonged to one of the brotherhoods and was entirely defined by folk tradition. Costumed in a black wool suit, felt hat, and laced shoes, he was a caricature of a Ladino (in those days, Indians typically went barefoot or wore sandals and had straw hats and cotton clothing). Among his devotees were those who wished to gain commercial success or who profited from Indian labor. Some were Ladinos from outside Cantel; most were *de vestido* Indians (Indians "of clothing"), those in transition from their Maya culture.

On Saturday, the brotherhood dedicated to Judas, who was also called San Simón, removed his effigy from the brotherhood house, mounted it on a donkey, and led it around town to visit all the shops, including the liquor stores in the town center. Each shop owner gave Judas a five-dollar donation to insure luck in business. Many also plied him with drinks, pouring *posh,* a distilled cane liquor, through a funnel into his open mouth. The drinks, collected through a tube that extended into a rubber "stomach" bag, were later consumed by his followers.

These offerings were considered an important part of business management. I recall the great anxiety of the druggist, a *de vestido* Indian, when she learned that the image had passed her shop while she was out, and how she ran to catch up with the entourage to make her offering. Although presumably introduced into the local culture as a villain, Judas was welcomed in his peregrination, at least by those engaged in commerce. Perhaps they recognized, in his transaction for thirty pieces of silver, Judas's commitment to commerce at any cost.

The priest frowned on the whole Judas cult and had even ordered the catechists to raid the brotherhood house and destroy the figure. But although the catechists had apparently succeeded on several occasions in burning the straw body and wooden mask, the brotherhood always secreted the "true" mask, tying it to a new straw effigy each year. Except for his appearance during Holy Week, Judas remained safe in an altar in the brotherhood house.

I met Judas in another guise in 1957, when I was assigned to do fieldwork in the Tzeltal-speaking Maya community of Amatenango del Valle. A pottery-making town in the highlands of Chiapas, Mexico, Amatenango was known to outsiders as one of the most hostile of nineteen indigenous communities surrounding the Spanish "royal city" of San Cristóbal de las Casas. Early in my fieldwork, I learned that the homicide rate was high and rising. I also learned that two anthropologists had been ordered to leave there because the community did not appreciate their presence. I found it difficult to start a conversation with any of the Indians. The area priest who served the community confirmed my impression, adding that the hostility of the inhabitants to outsiders made his work easier because it kept away the Protestant missionaries. Despite the proximity of the (as yet unpaved) Pan-American highway, the only Ladino living in town was the schoolteacher, who barricaded himself with his family in the large adobe schoolhouse on the plaza, with an arsenal of rifles for protection.

In the house of a brotherhood devoted to Judas, his figure gets a morning kiss from the caretaker's wife. The choice of a coffin for Judas's resting place may be unique to this brotherhood in a Maya village near Santiago Atitlán.
Jim Pieper

As might be expected, folk beliefs had made severe inroads on whatever Catholic orthodoxy the community had absorbed. Mariano Lopez Shunton, one of the town elders, gave me a vivid example of this when he told me the story of "How Jesus Gained Control over the World." In ancient times, Mariano said, Judas prevented the corn plants from growing by making them come out with one "arm" and one "leg," so that they fell over. Jesus and Mary outwitted him by enticing Judas, whom Mariano called "the leader of the Jews," to a fiesta. Mary danced with Judas and plied him with liquor so that he forgot the fields. Meanwhile, Jesus guarded the fields of corn so that the plants grew straight and tall. In this role, Jesus was identified with the preconquest deity Cananlum, "caretaker of the earth," while Mary was identified with Me'tikchik, "our grandmother the moon," who was also in charge of crops.

While in this story Christ appeared in a positive light, images of Christ—especially the figure of Christ on the Cross—were regarded with ambivalence. In Amatenango, men who claimed extraordinary powers over life and death without validation as folk healers were killed as witches. Saint Peter the Martyr, whose image in Amatenango showed him with a cleaver imbedded in his skull, was taken to have been a powerful witch, later redeemed by his role as the protector against lightning. Similarly, the crucified Christ could have been viewed as a punished witch, evoking little sympathy.

I spent varying amounts of time in Amatenango over the next decade. During the Holy Week rituals, the Crucifixion was reenacted in the church under the supervision of the Ladino priest, with the assistance of the mayordomos, who manipulated the images like puppets. The participation of the mayordomos in the official drama was welcomed, in contrast to the situation in Cantel, where members of the religious brotherhoods were in conflict with the priest.

Although Judas enjoyed some popularity as a cult figure in Cantel, in Amatenango he was almost universally reviled. The priest referred to him as the King of the Jews and identified him as the "killer of Christ." And on Good Friday, following the enactment of the Crucifixion, the mayordomos hauled the effigy of Judas up the belfry "to show the world that he killed Christ." They jabbed him with long poles, laughing when one well-directed blow landed and someone yelled, "Eunuch!"

Jim Pieper

As part of Holy Week in Santiago Atitlán, left, Judas is hanged on a rack beside the church. In that town he is commonly called Maximón and incorporates the role of a Maya fertility spirit. The Maya area, below, where cults devoted to Judas flourish, crosses the frontier between Guatemala and Mexico.

Joe LeMonnier

As I had observed in Cantel, however, Judas was something more than the betrayer of Christ. In the 1960s, when men of the town universally wore white cotton shirts and large-waisted trousers tied with a red sash, the effigy was costumed in the canvas pants, black jacket, boots, and cowboy hat of a Ladino rancher. And Judas's ride around town on Saturday, reminiscent of the one carried out in Cantel, further identified him as a Ladino, since riding a horse was a prerogative of Ladinos during colonial times. As I watched his image, tied to the saddle and with a cigarette in his mouth, I realized that under cover of the role of Christians outraged by the killing of Christ, the Indians were acting out their own hatred of Ladinos.

The priest did not acknowledge this performance, calling it a "pagan" practice, but as soon as his Volkswagen left the churchyard, the entourage set out. Although in Cantel the merchants had showered Judas with donations, in Amatenango only the folk healers gave money. Perhaps they felt an obligation toward Judas as one source of their power over illnesses caused by witchcraft (I could only speculate, since none of them confirmed this). Following Judas's ride around town, the effigy was dismembered and later burned, the wooden mask being saved to be used the following year. The money that had been collected was used to buy liquor—associated with the water used to bathe the body of Christ—that was served to the mayordomos and their assistants.

Another variation on the theme of Judas was described in a 1965 monograph, *Los Escándalos de Maximón* (The Scandals of Maximón), by anthropologist E. Michael Mendelson. Mendelson reported that among the Atitec-speaking Maya of Santiago Atitlán, one of Guatemala's beautiful lake towns, the figure wore a shirt, pants, and belt similar to those worn by the Indians, but along with them he wore a Ladino-style blue jacket, boots, and a broad-brimmed hat. He had a large cigar placed firmly in his mouth. Despite his role in the Christian Holy Week enactment, everyone (except for the clerics) called him Maximón. The Indians told Mendelson that Maximón was the oldest of the animal spirits; he was also called the Black Magician, patron of those "prayer makers" who, like the curers of Amatenango, divine the cause of illness.

To Mendelson, Maximón seemed to be the incarnation of a traditional fertility spirit. This association was evident in the fruit offerings displayed on his altar and the corncobs hung on the image during the cult celebrations of Holy Week. Christ might have redeemed humanity from original sin, but in the eyes of the Indians—given the Catholic church's identification of sexuality with sin and portrayal of Jesus as an ascetic—he exposed the world to sterility. In one of the myths they recounted to Mendelson, "God cooperated with the ancient kings to sow the world with good things, but something happened and the world has died." Through Max-

imón, the Maya restored the positive aspects of sex and fertility.

According to one myth of Maximón's origin, the ancient authorities decided to make a talking figure to scare men away from other men's wives, who would otherwise be seduced during their husbands' trips to the plantations or the capital city. Created as a guardian of sexual morality, however, Maximón became the principal transgressor. He would impregnate women, whose children would then resemble him or perhaps show some deformity. Or he would transform himself into a woman and lure men into sexual relations, after which they would die in three days.

Thirty years later, anthropologists Nathaniel Tarn and Martin Prechtel report that the cult of Maximón is still alive and well in Santiago Atitlán. In their research, they identify Maximón with Mam, the


June Nash

With a cigar planted in his mouth, Judas, left, departs with the figures of the Virgin Mary and Our Lady of the Rosary for a procession through Santiago Atitlán on Easter Sunday of 1953. Clothed in a hard hat, sweat pants, and jogging shoes (opposite page, bottom), a more contemporary Judas is paraded through Amatenango del Valle in 1993. In the same year, dressed as a Ladino rancher, Judas hangs over the entrance of the church in Zinacantán, below.

June Nash

Maya god of the underworld, and describe him as "the changing power who maintains the world in movement while changing people's sexual partners."

They point out that Judas-Maximón represents negative, as well as positive, aspects of sexuality. Young men ask the prayer makers to intercede for them with Maximón, viewed as the patron of romantic love. But the Maya of Santiago Atitlán also regard romantic love itself as destabilizing, posing a threat as it does to parental control over the selection of mates. As the deity of unbridled sexuality, according to Tarn and Prechtel, Maximón stimulates both desire and its aftermath, disorder.

Cantel, Amatenango del Valle, Santiago Atitlán, and other Maya communities have all placed their own peculiar stamp on Judas, using the figure to embody different local concerns. (In the 1980s, one anthropologist even found a Judas figure in a guerrilla camp in Guatemala, where Maya were counterattacking the genocidal forces of Gen. Efraín Rios Montt.) Judas has also responded to change over time. The Judas I saw in Amatenango in the 1960s had changed by 1992, as the community itself became more engaged in commerce with the outside world. That year I arrived on Holy Saturday, as the new young priest directed the drama in the church. The effigy of Judas was already hanging over the entrance. Instead of his predecessor's gloomy rancher's clothing, he was dressed in a jogging suit with his feet stuffed into Nike sneakers.

On Sunday a boisterous and jocular group of mayordomos bore the hanged body of Judas on muleback, greeting the householders and asking for offerings. Now, all the people—not just the curers—offered money. Also carried in the procession by the women prayer makers was the church's statue of Our Lady of the Rosary weeping over the recumbent body of the crucified Christ. When I lived in the village in 1965, the priest had not permitted the removal of saints' statues from the church for fiestas, because of the conflicts that often arose between villagers and visiting Ladinos, and women did not play any public role in ceremonies.

The sporty Judas of 1992 was greeted more peacefully than in the past. While before, Ladinos were perceived as dominating the commercial world as marketers and plantation bosses, more Indians now had gained, or hoped to gain, a piece of the action. Many of them owned trucks, and dozens of television aerials poked up from the cement block houses that had replaced many of the old wattle-and-daub dwellings. The women who were active in the saints' associations, and who bore the statue of Our Lady of the Rosary, were full-time potters, some who had good trade networks with national museums and tourist shops.

Holy Week was celebrated more lavishly than ever, with eating and drinking in most of the houses. Even the Judas figure had proliferated, with several families hanging effigies in their own courtyards. As before, the mayordomos cheerfully imbibed the drinks that were their reward for carrying out the fiesta. Most of them preferred the soft drinks that were rapidly replacing the strong, home-brewed liquor.

In the nearby city of San Cristóbal, the custom of hanging Judas in effigy had developed into a competition of Holy Week figures, promoted by the municipal authorities. The offer of a cash prize had generated some lively dioramas, which were displayed under bright lights in the garden of the newly painted gray-and-white municipal building. Drawing from a variety of themes, the tableaux departed widely from the Passion Play. First prize, appropriately in the quincentennial year of Columbus's arrival, went to a local sculptor's depiction of a Spanish conquistador beating an emaciated, Christlike Indian with a sword.

One contestant mounted a multitiered tableau of the class system, showing the rich landlords on top, stamping out the life of the gasping peasants. Another depicted the police evicting families from the San Juan Chamula barrio (this dispute reflected religious differences within the Indian community and a land grab by local elites). Yet another tableau sought to raise people's consciousness about sexual harassment and violence toward women by dramatizing the American prizefighter Mike Tyson's jailing for rape. These new conflicts cut across the division between Indians and Ladinos, which was no longer so keenly felt.

Last year I again made my pilgrimage to Amatenango on Holy Saturday. As the time came on Sunday for Judas's ride around town, at ten in the morning, his hanged effigy was unceremoniously cut down from the belfry and hoisted on the back of a horse. He was still garbed in a gaily colored sport shirt and jogging pants as he had been the year before, but this time, strapped above his flaming pink face was a blue hard hat. When I asked his caretaker what he represented, he said, "A government agent," and his assistant added, "Yes, a forestry agent!" and they both laughed. Judas's identity now centered on a specific Maya conflict with the government. New laws limited the cutting of trees; in addition, I was told, the forestry agents would sometimes solicit bribes from violators or even confiscate the cut wood and sell it for their own profit.

As the Maya gain greater entry into the Ladino world, the animosity is still there, but now it is focused on particular adversaries instead of on the generalized Ladino. This January, a local rebellion gained international attention as a group of indigenous people calling themselves the Zapatista Army of National Liberation attacked the military barracks near San Cristóbal and seized nearby towns. They specifically rejected the North American Free Trade Agreement and the reform act permitting the sale of communal lands. Perhaps this year, Judas will be dressed as a Mexican soldier. □

Elsewhere, his effigy is often burned, but in Cuajimalpa, a papier-mâché figure of Judas, below and right, is exploded. The town, on the outskirts of Mexico City, holds elaborate festivities that include individuals who dress as Judas and whip people in the crowd.

Photographs by Tom Owen Edmunds

Its black head and blue-green flight feathers are among the many traits that suggest the magpie's family relationship with crows and jays. The wear and tear on this bird's black wingtips indicates that it is an adult, in at least its second year of life.
Manfred Danegger

Britain's Magpie Parliament

These crowlike birds hold boisterous sessions every year in early spring

by Tim Birkhead

On the outskirts of Sheffield, one of Britain's largest industrial cities, lies the Rivelin Valley, a microcosm of traditional rural England. Woodland borders the stream that flows through the valley floor, and cattle and horses graze in the tree-dotted fields of the valley and surrounding hillsides. This region has long been home to a thriving population of black-billed magpies, a species that farmers and gamekeepers invariably regard as pests. The British naturalist Charles Dixon wrote in 1900 that "nowhere else in our experience have the magpies been allowed to live in such peace as they enjoyed in this romantic valley."

Magpies still inhabit the Rivelin Valley, where I have studied their breeding behavior for the past fifteen years. These colorful, long-tailed relatives of crows first captured my attention when I was a schoolboy birder. Magpies are hard to miss. Beautifully plumaged, large, loud, and social, they are renowned for their noisy "ceremonial gatherings." More than a hundred years ago, these aggregations were brought to Darwin's attention by his cousin William Darwin Fox, the rector of Delamere, who referred to them as "the great magpie marriage." Darwin later used this information in *The Descent of Man and Selection in Relation to Sex*:

> They [the magpies] had the habit very early in the spring of assembling at particular spots, where they could be seen in flocks, chattering, sometimes fighting, bustling and flying about the trees. The whole affair was evidently considered by the birds as of the highest importance. Shortly after the meeting they all separated, and were then observed by Mr. Fox and others to be paired for the season.

I had long been intrigued by these ceremonial gatherings, but I had a gut feeling that Darwin was wrong in thinking them to be mating ceremonies. By marking several hundred birds with unique combinations of color bands and following them through the course of their lives, I was able to discover the true function of the yearly gatherings.

Black-billed magpies are found in a variety of habitats across much of the North-

E A Janes, NHPA

Between bouts of chasing and calling, a moment of peace prevails among a small congregation of magpies, right, in Hertfordshire, near London. Such ceremonial gatherings precede the breeding season, typically occurring in early spring before the trees are in leaf. Below: Two magpies vie for dominance in a heads-up display that often takes place when opponents are evenly matched.

Mike Wilkes

ern Hemisphere. They are basically monogamous: a male and female usually work together to rear offspring. In my study area, pairs defend an all-purpose territory of about twelve and a half acres. All activities—wintering, feeding, roosting, breeding, nesting, and chick rearing—take place here, and some birds spend their entire life within the boundaries of their territory. In rural England, an ideal magpie territory contains areas of close-cropped grass suitable for foraging for adult and larval insects (the birds may also eat grain, berries, and carrion) and has either thorny bushes or tall trees for nesting. Although territories are occupied throughout the year, they are actively defended only in March and April—the early part of the breeding season.

The domed nest is bulky and conspicuous. Birds will sometimes reuse a nest from the previous year, but more often they build a new one. If good nest sites are in short supply, the new nest is often constructed directly on top of the old one, and stacks of four or five nests are not uncommon. Of the normal six-egg clutch, usually only three or four of the chicks fledge. The young birds are fed by their parents for six weeks after fledging—a long time by songbird standards.

As young magpies become independent, sibling groups start to coalesce into loose flocks that remain close to home. One of the most unusual aspects of magpie behavior is this tendency of young birds to remain within a few hundred yards of their natal nest. A nonbreeding flock is a weakly structured group of from ten to fifty birds that share a common home range of about thirty-seven acres. Flock members fly and forage alone or in bands of three or four birds, coming together only at common food sources, such as a small carcass, or when roosting for the evening. Within a flock a hierarchy soon becomes established. Males, perhaps because they are slightly larger, dominate females, but a hierarchy exists for each sex. About 80 percent of the birds within a flock are in their first year of life, most of the rest are in their second, and even fewer are in their third or fourth year. Although less numerous, older birds generally dominate the younger ones.

Magpies express their social rank most commonly around food: dominant individuals drive away subordinates, and males displace females. Rank is vitally important because it ultimately determines who will and will not get to breed.

Although magpies usually pair off in their first spring after hatching and may remain together for years, they need a territory to breed. In the Rivelin Valley, almost all of the suitable habitat is carved up into magpie territories, and with more than seventy-five breeding pairs per square mile, the breeding density here is among the highest ever recorded for these birds. Territories, and hence actual opportunities for reproduction, are hard to come by. Magpies may breed in their first spring after hatching, but do so more usually in their second. In contrast to most other birds, they do not wait for a territory vacancy to occur naturally, but go out as a pair and actively try to create one. This driving need for space, the prerequisite for breeding, proved to be the key to the magpie congregations.

On bright, crisp mornings in late winter and early spring, a high-ranking pair of magpies from the nonbreeding flock may leave their normal home range and fly deliberately into the heart of an occupied territory. The territory owners' response is immediate—they fly out to threaten and chase the intruders. The raucous chattering that accompanies these encounters rapidly attracts other magpies, both breeders and nonbreeders. Within a minute after the two dominant birds invade a territory, up to twenty magpies will be flitting about in the treetops, calling noisily. After carefully observing my banded birds, I realized that most of the action was between the intruders and the territory owners; the other birds were merely noisy spectators, drawn into the melee only when they got in the way of the protagonists.

The usual outcome of such a gathering was the eviction of the intruders within a few minutes. When this occurred, all the participants quickly dispersed and resumed whatever they had previously been doing. If the initiators of the invasion, and indirectly of the gathering, were particularly highly motivated, they might fly off to another territory and start the process again. I once watched one such pair start no fewer than seven gatherings, one after the other over a thirty-minute period, being evicted each time.

Once in a while the outcome is different. If the territory owners are less than forceful, the ritualized threats of the two parties can end up as a serious fight. During such a battle, male grapples with male, and female with female, with both sets of birds on the ground with their feet firmly interlocked. Eventually one will gain the upper hand and begin to rain heavy blows with its beak on its opponent's head. In several cases I witnessed, the intruders defeated the owners and drove them from the territory. The vanquished pair usually disappeared (and were presumed dead), but in one case, they were forced to swap places with the invaders and had to live out the rest of their lives in the nonbreeding flock, while the intruders settled into the territory.

What is going on is that just prior to the breeding season, the dominant members of the nonbreeding flock visit established territories to assess how well they are defended. In the majority of cases, territories are under adequate guard and the intruders retreat gracefully, albeit after a brief burst of aggression. But territory tenure is limited—owners eventually age or become sick and are less able to defend their patch. These are just the opportunities intruders are looking for, and once they find a weakness, they are relentless in pressing home their attack.

Why does this territorial probing by dominant nonbreeders provoke the rapid and dramatic gathering of so many other magpies? What is the advantage to those that turn up as spectators? I believe that these other birds can benefit by knowing the outcome of a gathering. For example, if the gathering results in a change of territory ownership, this sometimes precipitates several other shifts in territory in a domino effect, creating new breeding opportunities for both established breeders (hoping to move up market) and nonbreeders (hoping to obtain some space).

Over the duration of my study, I found that about one third of all territories were acquired during a ceremonial gathering, while another third were obtained simply as one magpie replaced another that had died in an occupied territory. The last third were won by pairs squeezing themselves in between the boundaries of existing territories late in the season. The last strategy was successful because it was undertaken only after most other birds had started to breed and when their territoriality was waning. It was, however, the least productive strategy, because by the time latecomers had established sufficient space to call a territory, the breeding season was over. Like other perching birds of similar body size, 30 to 40 percent of breeding magpies die between one year and the next, so only a few individuals using the "squeezing" strategy will survive to see their tactic pay off in terms of producing chicks during the next year's breeding season.

The only other bird species known to similarly acquire territory through ceremonial gatherings are the Eurasian carrion crow and the acorn woodpecker in California, whose gatherings are referred to as "power struggles." (Other bird species form noisy aggregations, but for different reasons; the ubiquitous house sparrow, for example, performs communal sexual chases.) More attention has been paid to magpie gatherings than to the congregations of other species, perhaps because of the magpie's striking plumage, brash manner, and dramatic interactions, which have earned it a place not only in the scientific literature but also in local folklore.

The acquisition of territory is only one of several hurdles a magpie has to overcome if it is to leave any descendants. Once a pair have secured a territory, the

Like their crow relatives, magpies will harass hawks that approach the nest or otherwise threaten their livelihood. In this case, a magpie unsuccessfully attempted to divert a buzzard from feeding on a dead rabbit.
Mike Wilkes

serious business of breeding ensues, and here, too, competition is rife and vigilance necessary on the part of the male. Although Darwin knew about the magpies' gatherings and recognized the general significance of reproductive competition, he assumed that the females of monogamous species—in which a mated pair raise young—were strictly monogamous. As in many species of birds long considered faithful within pairs, the truth is more complex, as revealed by a particular incident I witnessed one day at the beginning of the breeding season.

The pair I was observing had laid part of their clutch, and the female was still fertile. As she searched for insects in a field, her mate sat on a nearby stone wall eyeing her every move. To my surprise, the male's head gradually sank onto his chest, and he fell asleep in the spring sunshine. No sooner had he stopped observing his partner than the male from the neighboring territory flew over and, without any of the usual precopulatory niceties, mounted the female. Although receptive, she chanced to utter a cry and awake her spouse. He swooped down to attack the intruder, who coolly retreated to his own partner and territory. Calling noisily, the wronged male then chased the female back to their nest tree, and the two birds disappeared into the dense vegetation. A day or two later, I noticed the male building a new nest in a tree near the one that housed their original nest. This action would have been normal if the first clutch had been taken by a predator, but on checking, I found the partly completed clutch intact. The male appeared to be starting over and siring a new clutch of eggs in order to avoid the risk of rearing one or more of his neighbor's offspring.

This incident was unusual only in that the male fell asleep. Male magpies are especially keen to obtain sneaky matings with breeding females, but must also guard their own mates to prevent being cuckolded. Males do not take this threat—known as extra-pair copulation—lightly. During the time that his female can be fertilized, a period of about one week, the male stays within a few yards of her from dawn until dusk, following her every move. He remains close enough to intercept any males trying to sneak a mating.

Only already mated males, rather than single males, sneak matings, and they do so when their own females are just past the fertile stage and the pressure of guarding her is relieved. Females accept the attentions of interlopers and readily mate with them, but conversely, do not appear to condone the extra-pair activities of their own males. Each member of a magpie pair appears to attempt to optimize its own chances of copulating with more than one partner, while retaining a mate with which to rear chicks. On several occasions, I placed a caged female bird in an occupied territory. If the male territory owner approached this decoy bird alone, he invariably started to court her, singing and trying to mount her by placing his foot on her back through the bars of the cage. If, however, he was caught in such behavior by his partner, he instantly switched from courting the decoy to displaying aggression toward her.

The black-billed magpie was one of the first bird species in which mate guarding was described. Subsequent studies over the past fifteen years have shown that such behavior by males during their partners' fertile period is standard in many birds. However, guarding does not guarantee paternity. In many so-called monogamous species, such as the reed bunting in Eurasia and the splendid fairy wren in Australia, more than a third of all the offspring in a population are fathered through extra-pair copulations, and some males help to rear young that are not genetically their own. We suspect that the same may be true for magpies and hope to ascertain this by testing for paternity through DNA fingerprinting.

Over the course of the study, I have fol-

Magpies are notorious egg predators, but this bird mistakenly attempted to make a meal of a golf ball.
Maurice Tibbles; Survival Anglia

North America's Magpies

A magpie feeds on an elk carcass in Yellowstone National Park, Wyoming.
Rod Planck; Photo Researchers, Inc.

The black-billed magpies of Eurasia, Africa, and North America belong to the same species, *Pica pica*. They are nearly identical in physical appearance, but the North American subspecies (*P. p. hudsonia*) has a higher-pitched voice and is somewhat smaller than its Old World counterparts. The ecology of these Old and New World magpies also differs. Ceremonial gatherings and much of the associated competitive behavior do not exist in North America, probably because the magpies' food, invertebrates, is patchily distributed. American black-billed magpies nest wherever suitable habitat is found, often in proximity to one another, but they forage away from the nests on communal feeding grounds. With no need to secure a year-round nesting and feeding territory, competition for space and breeding opportunities is much reduced. Interestingly, in its behavior, America's black-billed magpie more closely resembles the yellow-billed magpie of California, which is considered a separate species (*P. nuttali*), than it does other black-billed magpies.—*T. B.*

lowed many magpies from hatching to death. For every hundred chicks that fledge, only ten survive to rear young, and only one or two of these produce offspring that survive to breed. Longevity is the key to success. The longer an individual lives and the more seasons it attempts to breed, the greater the likelihood of its producing offspring. Our most successful female bred for six seasons and had seven young that survived to breed. Our most successful male lived eight years, but as far as we could tell, produced only three breeding offspring. However, this figure does not take into account any young he may have fathered with females other than his mate or, indeed, any paternity he may have lost to other males in the race to get genes into subsequent generations.

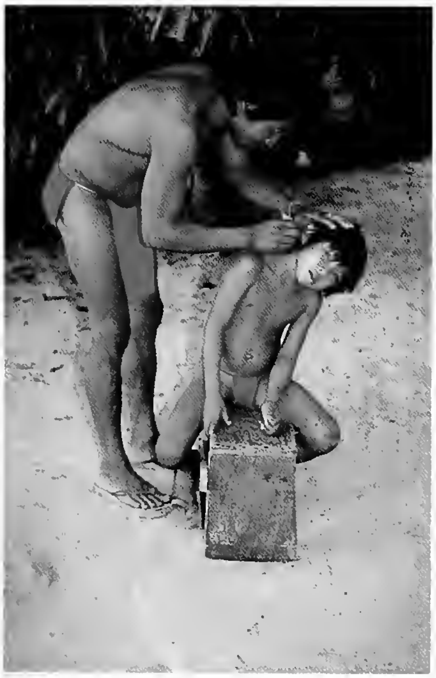
The first step in this race, beyond surviving the first year or two of life, is to stake out a territory. By becoming an initiator of, or simply a spectator at, a gathering, a nonbreeding magpie can assess the competition and potentially learn enough to wrest a territory from the owners. The gatherings are neither great magpie marriages nor mating celebrations, but arenas in which the competitive business of breeding begins. □

A Quixotic Search for New Drugs

by J. Worth Estes

According to Mark J. Plotkin, ethnobotanists have three major goals. The first is "to record and preserve the plant knowledge of forest peoples"; the second is to use their expertise to "benefit the tribes in their dealings with the outside world"; and, third, to possibly "uncover new, potentially useful plant-based medicines." In an engaging book, Plotkin recounts his adventures among tribes in Suriname, Guyana, French Guiana, and Venezuela, where for the first ten years of his career he worked toward fulfilling these goals. The third goal, finding plant-based medicines, remains as elusive today as it was to the first explorers of the Americas.

The typical shaman of the Amazonian rain forest is the village physician, pharmacist, and psychiatrist, as well as mediator with the spirit world—at least in cultural enclaves that have not been affected by the advent of outsiders, such as missionaries or gold miners. In these communities, the young graduate student Plotkin followed the pioneering footsteps of his mentor, ethnobotanist and Harvard University professor Richard Evans Schultes, and earned the trust of several shamans, who willingly passed on detailed knowledge of the plants they used in healing or in communicating with the spirits of the forests.



A Tirio Indian treats a child's ear problem with a medicinal plant.
Mark J. Plotkin; Conservation International

TALES OF A SHAMAN'S APPRENTICE: AN ETHNOBOTANIST SEARCHES FOR NEW MEDICINES IN THE AMAZON RAIN FOREST, by Mark J. Plotkin, Ph.D., *Viking, $22.00, 318 pp., illus.*

Plotkin's tales permit the reader who has never ventured into any rain forest, much less eaten the rodent meats or tasteless fruits that are part of the conventional human diet there, to experience almost at firsthand the hazards, as well as the pleasures, of studies with witch doctors. His accounts of hacking his way through lianas thick and thin, of being soaked in sweat and rain, of avoiding large crocodilians, and of being bitten by vampire bats are the stuff of adventure movies. His accounts of how shamans strip tree bark and make arrow poisons are the stuff of ethnobotany—as is Plotkin's quasi-mystical story of how a Wayana shaman in French Guiana treated his sore elbow. However, one does wonder how Plotkin managed to carry in his backpack all the newspapers he needed for pressing his hundreds of botanical specimens.

The visions he experienced under the influence of the Yanomamö tribe's hallucinogenic snuff called *epena* illustrate how a shaman can control the minds and, therefore, the forest spirits of his village or tribe. In this case, the shaman's control was total, because he blew the snuff through a long tube into the communer's nostrils—one puff at a time—until the desired effect was achieved.

During stays among several tribes, Plotkin observed that their shamans' learning was not being transmitted to a new generation. Young men were more interested in maintaining their gardens or their families than in the work of healing. Thus, Plotkin realized that shamans were in danger of disappearing, even without the cultural disintegration that accompanies the appearance of missionaries or miners who actively oppose retaining the old ways of the forest.

The denouement of Plotkin's adventures occurred when he returned to the village of Kwamala, in Suriname, after an absence of several years. He brought with him a book-length typescript of his notes on how the tribe used its local plants and presented it to the local headman. Without consulting Plotkin, the headman and villagers decided to use it for teaching new generations of shamans. Shamans' learning would be passed on to "apprentices," using the American scientist's notes as their textbook.

Plotkin has achieved, in part at least, his second goal—insuring that Amazonian tribes will share in financial profits from remedies discovered in their territories. Early on, he had decided that he would not submit his botanical specimens for laboratory analysis until one or more drug companies had shown definite interest—and until a mechanism for channeling some of the profits back to the Indians had been developed. His efforts prompted the establishment of both the nonprofit Healing Forest Conservancy, whose goal is to return a percentage of the profits on any remedies identified in Amazonian flora to the peoples of the forest, and a firm called Shaman Pharmaceuticals, which is currently developing potential antiviral drugs from shamans' remedies; several major drug houses appear to be following suit. Plotkin himself is now vice-president for plant conservation at a Washington-based environmental organization, Conservation International.

His third goal—to discover important new botanical remedies—is unfortunately likely to remain elusive. Although he is certain that there is "no shortage of 'wonder drugs' waiting to be found in the rain forests," there is little evidence from any quarter to validate this hypothesis.

Columbus and other early explorers also sought drugs in the Americas. My own research shows that a few dozen did appear in European markets between 1492 and 1632, but only four drugs of enduring value—cinchona (the source of quinine, used for malaria), ipecac (used to make people vomit certain poisons), curare (used to relax patients undergoing surgery), and coca (the source of cocaine, the prototype of the local anesthetics used today in dentistry and surgery)—have come from plants that are indigenous to the Americas, and then only after 1632; curare was put to clinical use only in 1942.

Plotkin cites the more recent examples of the anticancer alkaloids derived from the pink periwinkle, and of taxol, found in the Pacific yew. As he describes it, however, the discovery of the effect of the anticancer alkaloids on malignant white cells was the result of a purely serendipitous laboratory observation. Moreover, even if the periwinkle had been employed in some folk healing traditions, its active principles had to be highly concentrated in order to treat cancer. And although taxol does help in the management of some cancers, its usefulness has proved to be limited (although more promising analogues are under development).

We would be unrealistic if we expected

the forest peoples of the Amazon to have employed the negatively controlled studies that we deem an absolute necessity for evaluating putative new remedies adequately. Such methods did not become standard even in the United States until the 1960s. Nevertheless, Plotkin takes it as axiomatic that "if a plant is used [by shamans] to treat a number of afflictions, it likely contains an active chemical compound and merits investigation in the laboratory."

This astonishingly quixotic statement seems to arise from his assumption that a purported remedy causes relief of one or more symptoms if they disappear following administration of the remedy. My own studies of the drugs doctors prescribed between 1700 and 1850 suggest that in the absence of a virulent epidemic, about nineteen out of twenty adult patients recovered regardless of how they were treated, with a wide variety of agents that are now recognized as incapable of any truly beneficial pharmacological effect. These recoveries can best be attributed to what was even then called the healing power of nature—today we recognize that that power lies chiefly in the body's ability to heal itself via the immune and inflammatory responses to microorganisms and tissue injury.

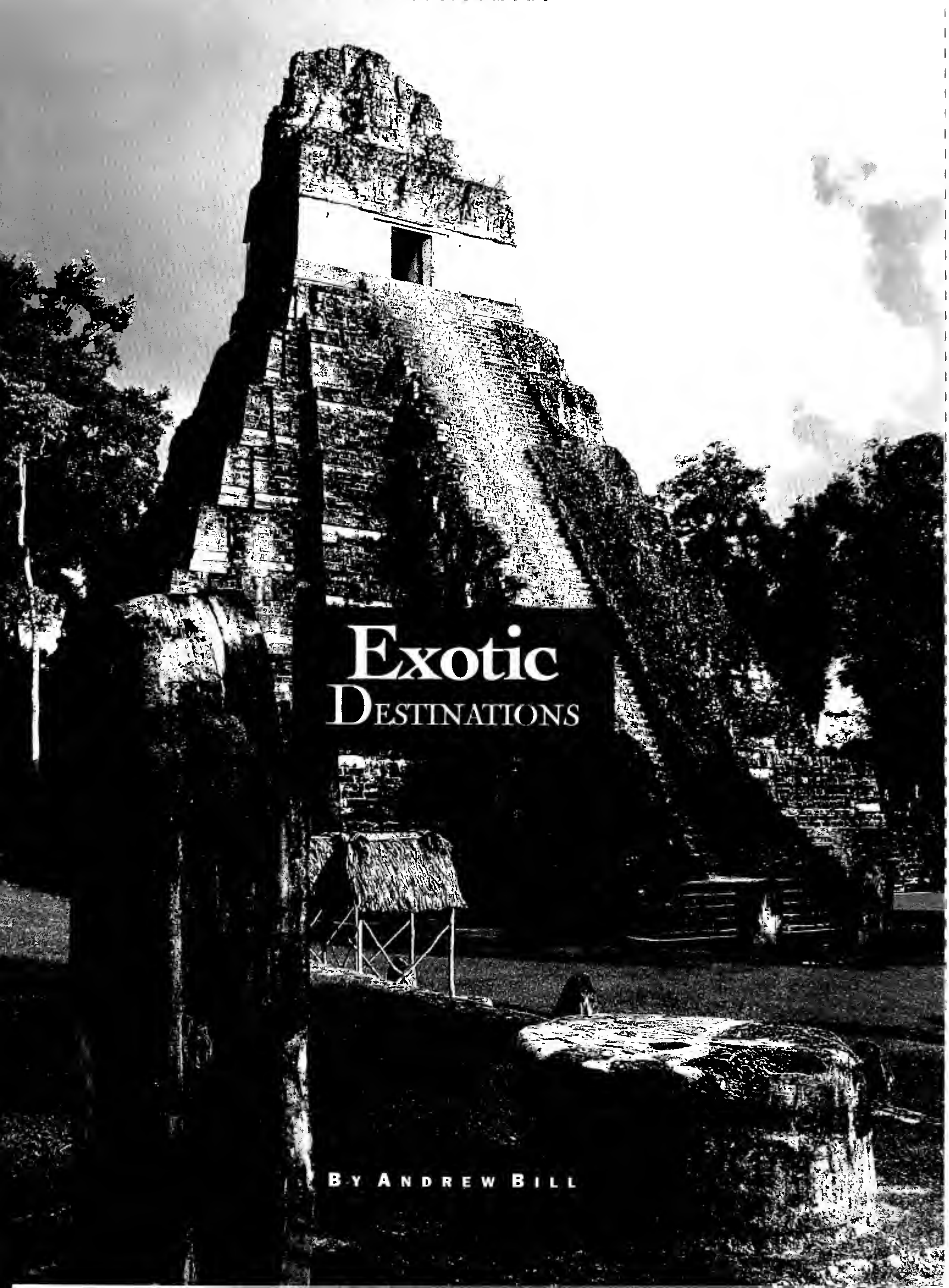
Many argue that the world's rain forests should be preserved for their traditional human inhabitants and for the nearly infinite variety of plants and animals that live there. (By contrast, the arguments with which missionaries and gold miners, who are Plotkin's villains, support their claims to the same land and its dwellers are persuasive only to themselves.) But so far, I have found no convincing evidence that untold numbers of valuable medicines await us in the Amazon basin, although they may be there. Plotkin seems to wonder why the headman of Kwamala regarded the white man's medicine as superior to that of his own tribe; perhaps the village leader was more realistic than the ethnobotanist.

Almost no other errors mar these splendid tales (although Linnaeus was Swedish, not Swiss). Unfortunately, however, Plotkin does not explain the shamans' reasons for choosing, from among the array of plant remedies available to them, those they administer for a given condition. Do the Amazonian witch doctors have a notion of body balances analogous to the four humors we inherited from the Greeks or to the more complex system of balances envisioned by the Chinese? Do they have a more static view of the body in health and disease? Or do the shamans that Plotkin studied simply choose their remedies on the basis of the tradition that plant X will cure symptom Y? Do other kinds of reasoning associate specific symptoms with specific plants?

The elucidation of comparable rationales for prescribing remedies in Western medicine's Hippocratic-Galenic tradition has helped us understand the use of historical remedies, such as emetics, strong cathartics, bleeding, and blisters, that would otherwise seem bizarre today. A multitude of written texts helps explain these ancient European treatments; perhaps the shamans, who rely only on orally transmitted traditions, simply did not tell Plotkin why they did what they did.

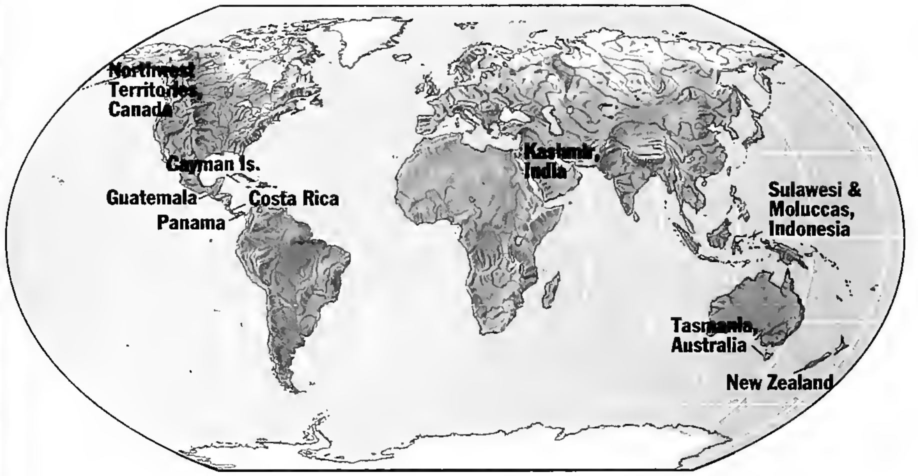
Nevertheless, as he demonstrates so well, ethnobotanical research is an inherently interesting and exciting pursuit of knowledge about the world around us. But we should not expect more of the shamans or their forests than they can deliver.

J. Worth Estes teaches pharmacology at the Boston University School of Medicine. He is the author of many books, including The Medical Skills of Ancient Egypt.



Exotic Destinations

By Andrew Bill



PRECEDING PAGE: TIKAL, GUATEMALA. PHOTO BY KEVIN SCHAFER

Exotic
Destinations

Broadly speaking, today's vacationers fall neatly into two groups—passive tourists and active travelers. The first go in search of familiarity, albeit spiced with sun and sea, while the second group travels primarily to explore and learn. Not content with pre-packaged culture, travelers prefer to dig down through the thin crust of modern civilization to their destination's ancient core; unexcited by nature that has been brought to heel, they want it without fences, untamed and pristine. Instead of resorts, they visit exotic destinations.

Discovering these destinations is part of the game—often requiring several detours off the thruway of mass tourism. To indicate some of the signposts, we present nine recommendations, all suitable for a week-long trips and all guaranteed to uncover the traveler in you.

DOUGLAS WALKER, ECONOMIC DEVELOPMENT & TOURISM, NWT

Houseboat and sailboat, on Great Slave Lake, in Yellowknife.

TASMANIA DEPARTMENT OF TOURISM, SPORT & RECREATION

A view of Hobart, Australia's second oldest city, as seen from Mount Nelson

TASMANIA, AUSTRALIA

With a gamut of ecosystems, from dust deserts to dripping rainforest, and a collection of fauna that looks like the output of evolution's test laboratory, Australia presents a dilemma — where to start? One option is Tasmania, historical and scenic, a bite-size version of its mother continent.

As is often the way with islands, time has moved more slowly here, making the past easier to catch. A rosy picture of early British settlement is conjured up by the historic center of Hobart, Battery Park, the city's early warehouses at Salamanca Palace and small country towns like Stanley, ancient and atmospheric. The rolling, grassy pastures of the midland region combine with enduring habits like afternoon tea served with scones to complete the colonial connection. But its harsher realities are visible at Port Arthur in the southwest, where ruins of the old penal settlement are said to be overrun by the ghosts of ill-treated prisoners.

TASMANIA DEPARTMENT OF TOURISM, SPORT & RECREATION

Hikers' "Cradle Hut" with a view of Cradle Mountain, Tasmania

Tasmania's other allure is one noticeably unaffected by the course of time — a range of spectacular wilderness areas and coastlines. One of the most dramatic hikes in the world runs through 50 miles of rugged mountains and alpine moorlands from Lake St. Clair to Cradle Mountain. Another park on the Freycinet Peninsular has a 17-mile loop around travel-poster country. And wherever you go, you will be met by Australia's Alice-In-Wonderland cast of animals and birds — from the shy platypus and friendly wallaby to the Tasmanian devil and screeching cockatoo.

NORTHWEST TERRITORIES, CANADA

There are national parks and there are wilderness areas, but few come close to the immense region of the Northwest Territories sandwiched between the Yukon and Hudson Bay, on the roof of Canada.

Home to only 60,000 people, it's one of those rare places where mankind is dwarfed by nature's sheer scale and majesty.

The gateway for most travelers is Yellowknife, the capital and main jumping-off point for the many activity options. To get your bearings, both historical and visual, climb up to Old Town where the Bush Pilot's Monument recalls your pioneer predecessors. Below, the city spreads out to the scalloped bays of Great Slave Lake. Then, after a lunch of caribou steak at the nearby Wildcat Café, it's time for a cultural immersion course at the Prince of Wales Northern Heritage Centre where local carvings and dioramas capture local life. If you still have time, take the four-hour barbecue trip to Great Slave Island aboard the MV Naocha, drive the six miles north to the Takhini Hot Springs for a soothing dip, or drop by the Book Cellar to load up on Jack Londons for the next part of the trip.

Nobody travels to the top of the world just to tour Yellowknife. Instead they come to indulge their passion, whether it be hiking into virgin territory — especially the national parks of Auyuittuq and Nahanni — and camping by lakes as reflective as mirrors, or canoeing through the lace-work of tributaries that filter out from the Mackenzie River. The biggest draw, however, is to stay in the wilderness lodges like Blachford Lake, Drum Lake, or Sitidgi Lake and test your skill against lake trout, char, and grayling so big they stretch even a fisherman's imagination.

CAYMAN ISLANDS, THE CARIBBEAN

Most people think of the Caribbean in terms of developed pleasures where local culture is something you see on the cabaret stage and "getting away from it all" means going back to your hotel room. The Caymans, however, offer another perspective — three islands each with its own unique slant on the sun, sand and sea experience.

There is the modern allure, a pleasure ground, centered around Seven Mile Beach on the western end of the biggest island, Grand Cayman. This is the place to lie on the beach

KEVIN SCHAFER

A red-eyed leaf frog in the tropical rain forest of Costa Rica

(it's almost as long as it says it is), sit sandy-footed at any of the outdoor bars of the luxurious hotels, and crack lobsters by candlelight. If your hotel doesn't have in-house facilities, this is also the place to arrange diving excursions, exploring the crystalline waters and bright marine gardens for which the Caymans are justifiably renowned. Then, when you're ready to duck into the shade, wander around the streets of Georgetown, the capital at the beach's southern end, where the old wraps around the new.

The islands' colorful past is brought to light in their two museums — the Maritime and Treasure Museum and the McKee's Treasure Museum — filled with precious salvage from Spanish galleons which met their undoing by offshore reefs. Modern bounty, meanwhile, beckons from the boutique windows of Cardinal Avenue and the Kirk Freeport Plaza. Walking away from downtown, the modernity falls away in favor of simple wooden cottages dressed with fading gingerbread details and the occasional cemetery, their "A" frame "pirate" graves.

Cayman Brac, the second in size of the three Cayman sisters, lies like a beached whale with a prominent backbone 89 miles to the east. Many people fly over for the day to explore the caves and wilderness areas. Little Cayman, meanwhile, with its population of 50 and three small lodges is the ultimate place to shrug off the 20th Century.

CENTRAL VALLEY, COSTA RICA

When asked for reasons for traveling to Costa Rica, devotees cite the sincerity of the locals and their commitment to preserving a natural splendor rich in ecosystems and thronged with tropical flora and fauna. They also speak of convenience, of how all the attractions are within striking distance of the capital, San José.

The city itself is bustling, endearingly chaotic. Among its many sites, dotted around its geometric grid, your first stop should be the Museo Nacional (National Museum) to delve through the nooks of Costa Rica's evolution, to see how the heavy hand of Spanish colonialism overturned the pre-Columbian tranquillity. The Gold Museum explains, through dazzling showcases of early jewelry, the reason why. Then stroll through the shaded alleys of the Mercado Central (Central Market), the air heavy with herbs, the stalls loaded with a gaudy array of unrecognizable fruits and vegetables. The features on upturned faces reflect, in varying degrees, the successful merger between the "new" and "old" worlds.

After a few days of drinking in the atmosphere and sampling the local cuisine — such as the hearty stew *olla del carne* and spicy *cerviche,* it's time for day trips into the Central Valley. Just over an hour's drive takes you through farmland to the bleak, black, and sulphurous mouth of

Irazú Volcano, the highest of the country's many active craters. The havoc they have wreaked over the centuries is most visible in Cartago, once the country's cultural heart, now known for its ruins and aura of "once was." Slightly further southeast lies the Tapantí Wildlife Refuge, a small taste of rainforest where glimpses of the endangered quetzal, cheeky howler monkeys, and even a jaguar reward the patient.

GUATEMALA

From a historical and cultural perspective, Guatemala is one of the Latin American leaders. Like a well-ordered museum, it's divided into chronological galleries, each region separate from the others and condensed in its focus.

A short drive from the modern gallery — the capital, Guatemala City — takes you to the colonial one. From 1543 to 1773 the ancient capital, Antigua, ranked third behind Lima and Mexico City in Latin American importance. Finally undone by a series of volcanic tremors and mud-slides, it was by-passed by the last two centuries of progress. Today you can walk its cobbled streets and catch glimpses, through heavy gates left ajar, of cool, shaded courtyards. You can wander through the broken convent of Las Capuchinas, now containing a museum and garden, and visit the church of San Francisco which rises like the proverbial Phoenix from the ruins of its former grandeur. Comfortable hotels and cafés are woven seamlessly into the ancient fabric.

To see the gallery of native cultures, drive north on the Interamerican Highway until the terrain shifts into the Western Highlands. Glinting cooly at the foot of three volcanoes lies Lake Atitlán, a natural wonder that has left everyone from the first conquistadors to writer Aldous Huxley short of words. On market days (Thursdays and Sundays) in nearby Chichicastenango, hundreds of locals in traditional garb materialize from surrounding villages to hawk their handicrafts.

But Guatemala's oldest and most renowned galley is surely Tikal, the massive and mysterious city of the Mayas that has been wrestled from the jungle in the north. Reaching the site by plane from the capital, you are awed by

Effigies of dead ancestors "guard" a grave site at Tarajaland, Sulawesi.

DISCOVERY TOURS, AMNH

the scale of temples, the network of houses, and the sophistication of the city where 100,000 once lived, at its zenith in 600 A.D., with greater sophistication than their counterparts in Europe.

THE OUTER ISLANDS, INDONESIA

Certainly the spiritual beauty of Bali has always played a part on the stage of international tourism, with the larger islands of Java and Sumatra playing supporting roles. But Indonesia's outlying islands — like Sulawesi and the Moluccas — have stayed out of the glare, retaining a shy innocence so rare in this age of go-anywhere jet travel.

It's apparent in their range of wildlife, from the submarine variety (visible in some of the world's best diving waters) to land-based fauna — like the pygmy buffalo and the pig-deer with its idiosyncratic tusks. The human interest is no less rewarding. In Sulawesi, formerly called the Celebes, a one-day drive from the capital, Ujung Padang, brings you to the land of the Taraja, where the once warlike tribe keeps 500 years of tradition intact while being welcoming to modern travelers at the same time.

Even more isolated, the Moluccas (also known as the Spice Islands) are rimmed with reefs and untrodden beaches, topped with volcanoes rising out of a carpet of jungle. Visitors, most of them traveling by small cruise ship, are rewarded for their efforts with an introduction to one of the last truly unspoilt places on earth.

KASHMIR, INDIA

India is such a colorful tossed-salad of cultures that it's nearly impossible to recommend one week-long bite over another. Yet there is one region, high in the shadow of the Himalayas in the north, that offers the intense taste of the country mixed with a scenery and climate that is truly unforgettable — Kashmir.

Although most visitors fly into the region's capital, Srinigar, the options from there are numerous. Start by marinating yourself in the flavor of northern India, browsing through the alleys and carpet shops of the city, famous as a center of the arts. And, when it's time to escape the frenetic pace of the streets, you could duck into the cool interiors of the many splendid mosques or head out to the lake-side baghs or gardens, formal reminders of the different moghuls who took refuge here from the heat of the plains. Looking for accommodations with a difference? Try staying on one of the houseboats clustered at the southern end of Dal Lake, the Indian version of Venice, where multi-hued shikaras take the place of gondolas.

But the real flavor of Kashmir becomes apparent when you leave the urban center for one of the hill stations, like Pahalgam. Here, in a town surrounded by fir woods and snow-capped peaks, the major attraction is hiking through the mountains to Kolahoi Glacier, or taking a rod and line out to a trout stream, originally stocked by the British as a diversion from serving the Empire.

THE WESTERN ROAD, SOUTH ISLAND, NEW ZEALAND

New Zealand's unique charm is that it's so comfortable to visit and yet so untamed at the same time. English-speaking, it has a sound and intriguing tourist infrastructure and yet has only three million people (most in the major cities) scattered around a stunningly-beautiful country that's green, pristine, and untrammeled by the 20th Century.

Just a short but dramatic ferry crossing from the capital city of Wellington brings you to Picton, the top of the South Island and the beginning of the 700-mile drive down the west coast. It winds first through towns like Nelson, with its Bishop Suter Art Gallery and even the odd winery, before the towns thin out, separated by long expanses of coast torn by bleached-white breakers, lonely moorland, snow-capped mountains, and stands of deciduous woods. Distractions along the way include national parks — Abel Tasman and Mount Cook among others —

NEW ZEALAND TOURIST BOARD

The *Earnslaw* on Lake Wakatipu with the Remarkable Mountains in the background

NEW ZEALAND TOURISM BOARD

Milford Sound, on New Zealand's South Island, is unspoiled by tourism.

hardly necessary among this wilderness, and a helicopter ride high up to the snow fields atop the mighty Fox Glacier. By night you can choose between rustic inns serving piping bowls of lamb stew, or more sophisticated inns and hotels in the farm towns that intermittently dot the route.

Your final destination is Queenstown, the outdoor activity center of New Zealand. Tumbling down the hill to Lake Wakatipu, the town is buzzing with options from hiking down the now-legendary trails like the Routeburn and Milford Sound and rafting or jet-boating down the Shotover River to the more extreme thrills of bungee-jumping and para-gliding in the Remarkables, the local mountain range.

THE PAN-AMERICAN HIGHWAY, PANAMA

Its position as the land bridge between North and South America has given Panama two distinct pluses in the modern travel department. It has attracted the advances (always unwelcome) of the major powers since the days of Columbus and it has become home to an enormous wealth of wildlife. Passing through over millennia of migration, hundreds of species liked it and stayed.

The first plus is easily appreciated upon landing in the capital of Panama City, one of the more exciting Latin American cities. Strolling the narrow streets of the old quarter, you will find solid colonial facades ornate with ironwork, the baroque affluence of the Church of San José, and the tree-shaded French Plaza. The Promenade of the Dungeons, along the top of the city walls, hints at a darker past. But probably the best place to soak up the tales of Spain's gunpowder and attack-dog diplomacy is the nearby former capital, Viejo Panama, founded in 1513 by the dubiously named Pedrarias the Cruel and once the Fort Knox of Pissaro's looting of the Inca Empire. Crumbling walls, torn down by marauding buccaneers under Henry Morgan, have survived to mock colonial conceit.

The other plus is best uncovered by taking the 350-mile stretch of the Pan-American Highway that runs from the Canal up to the Costa Rican border. This is the quieter side of Panama, where traditional ways of life have flourished far from world affairs. The pleasures here are long beaches empty of people, wilderness areas filled with over 800 species of native birds (not including the 200 seasonal visitors), and volcanoes, stark against the sky. Here you can find Guaymi Indian culture unchanged since the days of the conquistadors and small towns like Los Cantos and El Valle that come alive in the Sunday morning markets and folkloric celebrations.

Andrew Bill is a free-lance journalist based in New York and specializing in travel and design.

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Breaking Bread, Tradition, and a Long Run

After two decades of columns, our food writer pushes back from the table

by Raymond Sokolov

Exactly twenty years ago, I began writing this column without the slightest idea of what it should be. All I knew was that it should be about food and "reflect the interests of the Museum." Since my main experience at the American Museum of Natural History before 1974 had been accompanying young children excited by the simulacrum of the giant whale and various stuffed large mammals, I briefly considered printing recipes for blubber and hartebeest steak.

Sensing that this was not the correct approach, I made a solo pilgrimage to the Museum, passing through gallery after gallery devoted to artifacts of daily life among peoples from hot and cold lands with distinctive solutions for survival. There were baskets and masks and weapons and costumes; totems and paddles and canoes. You could stand there and imagine culture after culture from the materials in those cases. Yes, but what did they eat? That was what I needed to know to write a column for *Natural History*.

I ascended to the library, the old library with the leaky roof. And I found...almost nothing. The ethnography of food was not a lively field, never has been. There were, of course, brilliant—and brilliantly erratic—exceptions. But by and large, one had to make one's way as best one could.

I learned to squeeze the anthropological literature for tidbits dropped among the exhaustive studies of kinship, geomancy, and body decorations. While slogging through this swamp of data, I learned a new word, or thought I had: *balanophagy,* "eating acorns." A little learning is a dangerous thing. I dropped that mouthful in a column, only to get a hooting letter from a medical student in Boston pointing out that the Greek word *balanos* was an alternate anatomical term for *glans*. He asked for further information.

After a column on cannibalism, for which I scoured the literature to determine what adepts considered the best cuts, I was encouraged to shift my focus from anthropology to botany. Now the documentation was vast. Edible plants had been studied from every angle, and the cookbook literature of the post-World War II period offered reliable accounts of food preparation in most major cultures. So I embarked on a series of monographs on corn and potatoes and coriander and on and on, until the editor encouraged me to get out of the library and hit the road.

First I pursued endangered American regional dishes among hostile Indians and wary heartland farmers. In southern Indiana, outside the hamlet of Gnaw Bone, a dog bit me while I gathered native persimmons from a field next to a dilapidated house. The reward was that back home in New York County (a k a Manhattan) at a Museum event, the distinguished anthropologist Marvin Harris dignified my hapless forays by calling them fieldwork.

Well, I was spending a lot of time in fields. But soon my travels extended to South America and even the Philippines, in search of the colonial heritage of cuisines created by the collision of cultures in the Spanish empire after 1492. Most recently, I have been getting back to basics, thinking about grain. At the same time, I have been trying out a new diet that treats grains almost like poison.

I'm speaking of the much-ballyhooed diet of Michel Montignac, the self-proclaimed Descartes of weight loss and author of *Je Mange, Donc Je Maigris* (I eat, therefore I reduce). In America, he has a book called *Dine Out and Lose Weight,* but the idea is the same and just as radical: Avoid consuming carbohydrates when eating fat.

The theory, roughly speaking, is that sugars and starches have the effect of provoking a sudden increase of insulin in the blood. And when that insulin butts up against fat, it wraps its arms around the fat and stores it. If there isn't any carbohydrate, there isn't any insulin; so the fat does not get stored.

Ergo, peel the bread off that ham sandwich. Throw out your pasta and Frosted Flakes. Kiss potatoes goodbye. Eschew coffee, which also stimulates insulin production. And tell your friends who have followed current nutritional orthodoxy and filled their larders with bulgur, quinoa, amaranth, and other grains that they are indulging in glycemic folly. You can also stop counting calories. Montignac is withering on calories as well as exercise.

It isn't hard to see why this diet would have a certain appeal to people who don't want to give up animal fat and who hate going to the gym. But does it have any scientific validity? Since in some ways it resembles diets prescribed by conventional doctors for diabetes, the Montignac diet makes theoretical sense (in its own terms) only if there is reason to believe that overweight people are quasidiabetic, that is, if their sugar–insulin metabolism is out of whack.

Some researchers believe this may be so. I am certainly unqualified to pronounce on any of this, but I have been impressed by dramatic weight loss experienced by several former fatties of my acquaintance who have been following Montignac. Seeing them, I thought I should try Montignac too, even if there was nothing to his hypothesis. Results were what mattered, after all.

Well, it didn't work for me because I simply could not deal with the bizarre mayhem the Montignac diet does to culinary tradition. My friend Jeffrey Steingarten, the *Vogue* columnist, reveled in the freedom Montignac offered him to have eggs and (lots of) bacon for breakfast. I found it almost impossible to enjoy the

same breakfast without toast, which Montignac will not countenance in tandem with fatty bacon.

As a person who has been unhappily heeding medical warnings about cholesterol intake, I ought to have been overjoyed since Montignac made it sound as though I had the chance to eat as much cheese as I wanted, but again the bread prohibition made me very uncomfortable. I wanted rice with fish, and potatoes with steak. Naked salmon and sirloin on a plate looked mournful. Adding broccoli or fennel, so as to have a permissible vegetable, which also served as a substitute for the bulk that starch normally provides, did not satisfy me.

In the end, I just found Montignac too heterodox, too unplugged from the semantics of engrained culinary combinations. At first, this realization made me sorry I was such a slave to traditional habits and biases. But then I remembered how often I had written in these pages about the predicament we all face, having inherited foodways that evolved in the strenuous, farm-based past and that do not suit modern life. Why should I find it easier than anyone else to unplug myself from the pegboard of culinary assumptions?

Indeed, I should have more trouble than most people since I have spent the past twenty years cataloging and analyzing the logic of cuisines for this magazine. You could say, in fact, that that was the unifying theme of all my columns: traditional diets and how they have evolved, slowly, organically. These natural cuisines are all systems of tastes that have been selected by societies because they harmonized with natural possibilities and collective preferences. Of course, these preferences are to a large extent arbitrary, but once the basic outlines are set, it takes a major effort for people raised eating in a particular cuisine to alter them. Change does occur, but always within the preexisting frame. At any given moment, a cuisine makes sense of the world (while a radical, dadaist reshuffling of a cuisine, à la Montignac, creates chaos, mental indigestion).

The truth of this emerges on every page of Anna Tasca Lanza's *The Heart of Sicily: Recipes and Reminiscences of Regaleali, a Country Estate*. Lanza lovingly describes the food year on her family's big farm. Regaleali is so old-fashioned it even has a Frenchified chef, a *monzù* (dialect for *monsieur*): Mario is Italian, the last in a line of Gallic-style chefs that goes back to

Sfincione
(Sicilian Pizza)

Adapted from Anna Tasca Lanza's *The Heart of Sicily: Recipes and Reminiscences of Regaleali, a Country Estate* (Clarkson Potter, $40, 255 pages)

2 medium onions, sliced
¾ cup olive oil
2 cups all-purpose flour
1 cup semolina flour
1 teaspoon salt
1 package dry active yeast
1 egg
2 tablespoons butter, diced
4 anchovy fillets, cut into 4 pieces
¾ pound fresh mozzarella, sliced
¼ pound Emmentaler, julienned
¼ pound Gouda, julienned
½ cup grated Parmesan
¼ cup grated caciocavallo or pecorino
2–3 tablespoons dried oregano
¾ cup bread crumbs

1. Sauté the onions in ½ cup of olive oil over medium heat until golden, 15 to 20 minutes. Set aside.
2. Combine flours with salt in a bowl. Make a well in the center and add yeast, 1 cup warm water, egg, and butter. Work the dough until it makes a ball, and turn it out onto a work surface. The dough will be wet initially but will become smooth after you work it for 3 to 4 minutes. Continue to knead the dough for 10 to 15 minutes, until it is smooth and elastic.
3. Oil a 9 by 13 baking sheet. Roll out the dough and shape it to fit. Place the anchovy pieces on the dough in rows, cover with mozzarella, sprinkle with the Emmentaler and Gouda, and spread the onions on top. Mix the Parmesan and caciocavallo or pecorino together and spread over the onions. Sprinkle with oregano. Spread the bread crumbs evenly on top. Press all the ingredients into the dough, using the palms of your hands. Drizzle the remaining olive oil on top and cover with a kitchen towel. Place in a warm spot, and allow the dough to rise until it doubles in volume, about 45 minutes.
4. Preheat oven to 400 degrees.
5. Bake the *sfincione* until the crust is browned underneath and the cheese has melted, about 40 to 50 minutes. Let it stand for 15 minutes, then cut it into squares and serve.

Yield: 12 servings as a snack, 6 as a first course the eighteenth century in Sicily. He makes pasta with truffles and cream and does fancy saucing.

But most of the food at Regaleali is countrified and springs from the earth. There is *pasta con le sarde* (noodles with fresh sardines and wild fennel), the signature dish of the island. Tomatoes, assimilated long ago, now provide the ground bass of the kitchen. Dependable sun and bumper crops make the laborious job of drying tomatoes and extracting their essence an almost mythic adaptation of a New World ingredient to local conditions.

The century, even the millennium, is the time frame here. From ancient days, Sicily was the wheat-growing center of the Greeks and then the Romans. Recently, wine grapes replaced wheat in the fields. Lanza is too polite, perhaps, in a book aimed at Americans, to say the reason for the change is unbeatable competition from North American flour.

In Lanza's amiable, confident text, the engine of progress roars dully offstage, but it is there, threatening the old way of life. Her sense of her cuisine is what gives this drama of devolution its point. The knowledge of how to make the intricate sweets invented by gifted nuns is dying out, but the local ricotta continues to be made as it always has, from the whey of Regaleali's hundreds of ewes:

> One dish that is absolutely unforgettable when Mario makes it with our ricotta is *Guastelle* (Spleen Sandwiches). *Guastella* is actually the name for a certain kind of soft roll with sesame seeds on top; it resembles a hamburger bun. You cut it in half and fill it with warmed ricotta, caciocavallo [a hard cheese made from cow's milk], and beef spleen, an organ meat that is much appreciated in Sicily. The spleen is sliced and cooked literally swimming in lard. Since spleen is not available in the United States, you will have to have *schiette* (spinster) *guastelle,* as we say at Regaleali. *Maritate* (married) would be with spleen. (Elsewhere in Sicily these terms refer to the absence or presence of ricotta.) *Guastelle* are really street food, and there is a focacceria in the Piazza San Francesco in Palermo where they still make them.

Perhaps soon no one will make *guastelle* any more. Myself, I am trying to imagine their taste. I have no idea if I would like them, but I am sure, *pace* Montignac, neither Lanza nor I would feel comfortable eating one without the bun.

This is the final column of writer Raymond Sokolov, who will be pursuing less-fattening endeavors (see page 88).

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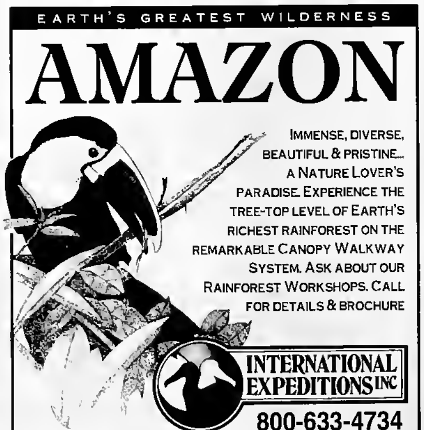

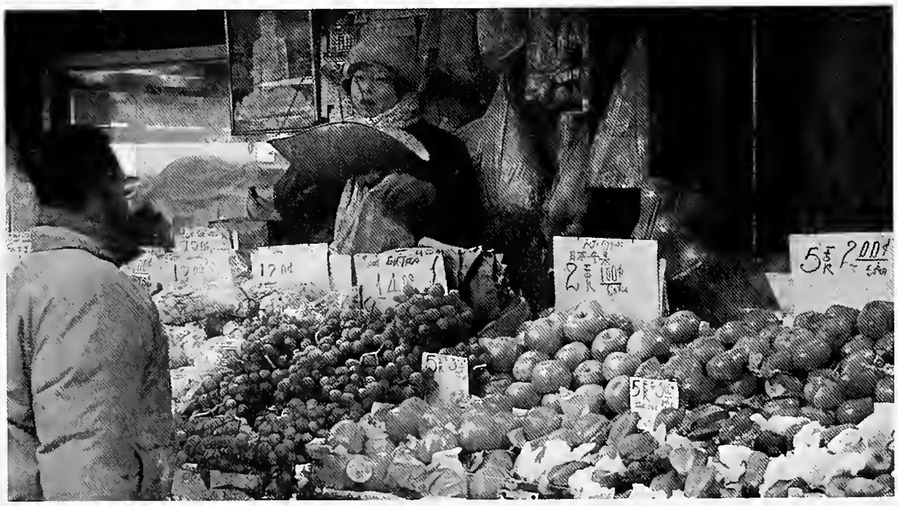

Chinatown fruit market, New York City
David Ortiz

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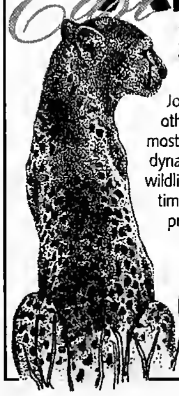
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A NIGHT OUT WITH THE NEANDERTHALS

European and Near Eastern Neanderthals are the best known of premodern humans. Erik Trinkaus, chairman of the Department of Anthropology at the University of New Mexico, will talk about fossil clues and archeological remains that are helping to clarify the relationship of Neanderthals to modern humans. The lecture will be given on Thursday, March 10, at 7:00 P.M. in the Main Auditorium. Call (212) 769-5606 for ticket information.

RAIN FOREST CONSERVATION IN MADAGASCAR

The creation of the Ranomafana National Park in southeastern Madagascar will be the subject of a slide-illustrated lecture by Patricia C. Wright, associate professor in the anthropology department of the State University of New York at Stony Brook. She will also discuss her work with lemurs and her discovery of a previously unknown lemur species, *Japalemur aureus*. This event takes place on Thursday, March 3, at 7:00 P.M. in the Kaufmann Theater. Tickets are $15. Call (212) 769-5310 for information.

THE KINGDOM OF MUSTANG

Mustang, formerly part of Tibet, is one of the last semiautonomous principalities in Nepal. Mountaineer and scholar Edwin Bernbaum will talk about this remote sanctuary of Tibetan culture, which has been spared the ravages of modernization and the Chinese occupation of Tibet. The program will be held on Monday, March 7, in the Kaufmann Theater at 7:00 P.M., and tickets are $15. Call (212) 769-5310 for additional information.

Neanderthal scene depicted in an 1873 issue of Harper's Weekly
Erik Trinkaus

VOLCANOES

Volcanic origins, types of eruptions, and their effects on life and the evolution of the atmosphere will be discussed by Sidney Horenstein, coordinator of environmental programs at the Museum, on two Monday evenings, March 7 and 14, at 7:00 P.M. in the Kaufmann Theater. Slides and videotapes will accompany the presentation. Tickets for the two lectures are $25. For more information, call (212) 769-5310.

VANISHING JEWISH COMMUNITIES

The rituals and life styles of a Middle Eastern and an Indian population of Jews has been documented in two films, *The Samaritans* and *Jews of India*. Filmmaker Johanna Spector will introduce and comment on the documentaries before they are presented on Wednesday, March 30, at 7:00 P.M. in the Main Auditorium. Call (212) 769-5606 for more information and ticket availability.

PLANET PLUTO

On Monday, March 14, Dale Cruikshank, of NASA's Ames Research Center, will discuss "The Icy Edge of Our Solar System: Pluto and Beyond." This lecture, part of the series "Frontiers in Astronomy and Astrophysics" will take place at 7:30 P.M. in the Sky Theater. For all events at the Planetarium, including the Sky Show, "Orion Rendezvous: A Star Trek Voyage of Discovery," call (212) 769-5900.

FOOD AS MEDICINE

In China, foods are divided into two categories, *yin* and *yang*, depending on the energy they release in the body. *Yin* foods (such as fruits, vegetables, crab, and fish) are believed to reduce the heat in the body; while *yang* foods (such as eggs or fatty meats) are thought to heat the system. Li Lian Xing, an herbalist and traditional Chinese doctor, will talk about the medicinal properties of Chinese food and offer possible individual diagnoses. In addition, gold-medal master chefs Shi Lian Yong and Bian Jian Nian will demonstrate the art of vegetable carving and offer samples of healthful teas and foods. This presentation will take place on Sunday, March 6, at 2:00 and at 4:00 P.M. in the Museum's Auxiliary Dining Room. Tickets are $5. For information, call (212) 769-5315.

TRADITIONAL HEALING IN SENEGAL

Healing ceremonies of Lebou women in the Senegambia region of West Africa will be presented by the Sabar Ak Ru Afriq Ensemble on Sunday, March 13, at 2:00 and 4:00 P.M. The free program, which is part of the Woman's Month celebration at the Museum, will take place in the Kaufmann Theater. Call (212) 769-5315 for information.

ALL ABOUT SHARKS

Eugenie Clark, a professor of zoology at the University of Maryland and coauthor of the children's book *The Desert Beneath the Sea*, will recount her adventures swimming with and studying sharks. The program, for children from preschool through grade 6, will be given in the Kaufmann Theater at 10:30 A.M. on Saturday, March 12.

John Maisey, a curator in the Museum's Department of Vertebrate Paleontology, will talk about shark evolution and fossils on Friday, March 18, at 7:00 P.M. in the Hall of Ocean Life. The program will also include a discussion of shark adaptation and biology by painter and author Richard Ellis.

These programs are being presented in conjunction with the exhibition *Shark! Fact and Fantasy* showing in Gallery 3 until Sunday, May 1. Call (212) 769-5310 for ticket information.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

march calendar

S	M	T	W	TH	F	S
		1	2	3	4	5
6	7	8	16	10	11	12
13	14	15	23	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

3 THURSDAY
"Tropical Rainforest Conservation in Madagascar: The Making of a National Park" + LECTURE, 7:00 p.m., Kaufmann Theater, $15.00

5 SATURDAY
"The World of Animals" ■
LECTURE & DEMONSTRATION for ages 5 and up, 11:30 a.m. & 1:30 p.m., Kaufmann Theater, $5.00 members, $8.00 nonmembers

6 SUNDAY
"Food as Medicine" +
LECTURE & DEMONSTRATION, 2:00 & 4:00 p.m., Auxiliary Dining Room, $5.00

7 MONDAY
"Mustang: The Opening of a Forbidden Himalayan Kingdom" +
LECTURE, 7:00 p.m., Kaufmann Theater, $15.00

"Volcanoes: Their Origins and Distribution" +
LECTURE, 7:00 p.m., People Center, $15.00

10 THURSDAY
"A Night Out with the Neandertals" ■
LECTURE, 7:00 p.m., Main Auditorium, $10.00 members, $15.00 nonmembers

11 FRIDAY
"Artistic Expression in an Amazonian Culture" ■
LECTURE, 7:00 p.m., Kaufmann Theater, $7.00 members, $10.00 nonmembers

12 SATURDAY
Shark Tales +
CHILDREN'S PROGRAM, 10:30 a.m., Kaufmann Theater, $10.00

13 SUNDAY
NDEPP: A Traditional Lebou Healing Ceremony +
PERFORMANCE, 2:00 & 4:00 p.m., Kaufmann Theater

14 MONDAY
"Volcanoes: Their Eruptions and Emanations" +
LECTURE, 7:00 p.m., People Center, $15.00

"The Icy Edge of Our Solar System: Pluto and Beyond" ●
LECTURE, 7:30 p.m., Hayden Planetarium, $8.00

18 FRIDAY
"Sharks: Ancient Stories and Current Affairs" +
LECTURE, 7:00 p.m., Hall of Ocean Life, $10.00

20 SUNDAY
Ladyfingers +
PERFORMANCE, 2:00 & 4:00 p.m., Kaufmann Theater

30 WEDNESDAY
The Samaritans and *The Jews of India* ■
FILM SCREENINGS, 7:00 p.m., Main Auditorium, $7.00 members, $10.00 nonmembers

THROUGHOUT MARCH

Sharks! Fact and Fantasy
SPECIAL EXHIBITION, Gallery 3

Search for the Great Sharks ▲
IMAX film, Naturemax Theater

Space Places: A Photographic Art Exhibit
SPECIAL EXHIBITION; with *Orion Rendezvous: A Star Trek Voyage of Discovery* ●
SKY SHOW, Daily Showings, Hayden Planetarium, $5.00 adults, $2.50 children

Waura: Drawings of the Waura Indians
SPECIAL EXHIBITION, Akeley Gallery

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The Eggs and I

At first glance, this male Masai ostrich in Kenya's Nairobi National Park appears to be poking its head up from one of the eggs. A closer look, however, reveals the bulk of the bird in the background. A male ostrich incubates—and guards—the clutch during the night and for part of the day and then relinquishes the job to his mate. The two birds take turns incubating between late August and October, when the young hatch during Kenya's brief rainy season.

The eggs in the foreground have been abandoned by the "major" hen, the female with which the male has formed a more or less permanent bond. Although she lays about seven eggs, as many as a dozen minor hens (which may or may not have mated with the male) can also contribute to the clutch.

eggs. Zoologist Bryan Bertram discovered that the major hen can identify her own eggs, allowing her to discard those belonging to others.

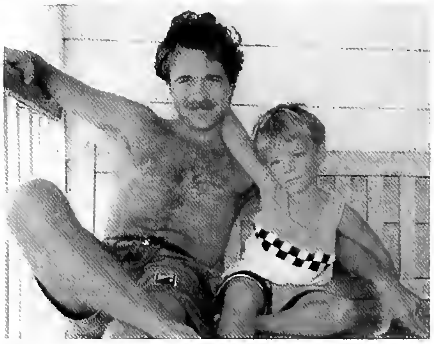
But why would the nesting pair want to incubate *any* eggs for another bird? Lewis M. Hurxthal, a zoologist who has studied the communal breeding of ostriches, suggests that the extra eggs provide a buffer zone around the nest. Jackals, hunting dogs, cheetahs, leopards, lions, and vultures routinely steal or break eggs; but with unrelated eggs on the periphery, the nesting pair can better protect their own. The strategy of sweetening the odds also applies to the chicks. Hatchlings from several nests form groups called crèches, so that two or three adult ostriches often end up raising from thirty to a hundred young.—*R. A.*

Photograph by
Robert Caputo

Tim Clutton-Brock (page 28) has earned two doctorates in zoology from Cambridge University, where he teaches animal ecology and heads the Large Animal Research Group. Ten years ago, while attending a scientific meeting about animal demography, Clutton-Brock became interested in studying the population cycles of large mammals. Searching for "a cyclical population where large numbers of individuals could be marked and their behavior, survival, and breeding success monitored," he remembered reports about the Soay sheep on Hirta, an island in the Saint Kilda archipelago off the northwest coast of Scotland, owned and managed by the National Trust for Scotland and Scottish Natural Heritage. When Clutton-Brock and his colleague Steve Albon visited there, they were "astonished by the ease with which information could be collected." With funding from the Natural

Environment Council and assistance from the Royal Artillery on Saint Kilda, Clutton-Brock returned the next year to begin a systematic study. For more information, he recommends *Island Survivors: The Ecology of the Soay Sheep of St. Kilda,* by P. A. Jewell, C. Milner, and J. M. Boyd (London: Athlone Press, 1974).

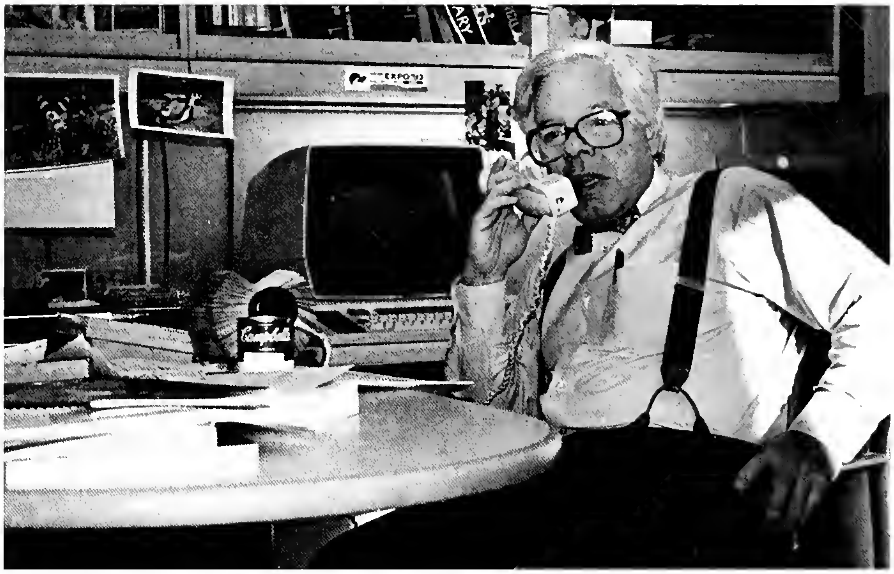
In the Panamanian rain forest, **Jeanne A. Zeh** (page 36) stands on a fallen fig tree. Ten years ago Zeh moved from England to Arizona to pursue a career in photojournalism. Falling in love with the Sonoran Desert, she changed direction and in 1986 received an undergraduate degree in ecology and evolutionary biology from the University of Arizona. There she met her husband, **David W. Zeh** (pictured here with their son, Adrian), who was just finishing his Ph.D. at the time. Their lives—and their work—have been closely entwined ever since. Staying at the university, David began studies of desert pseudoscorpions, which travel from one rotting giant saguaro to another on the legs



of cactus flies—the insects whose mating strategies were the subjects of Jeanne's graduate research. For the past six years, the Zehs have been with the Smithsonian Tropical Research Institute in Panama, where their studies of the pseudoscorpion that rides harlequin beetles have led them from fieldwork on sexual selection to DNA research on speciation and the genetic causes of promiscuous behavior in female arthropods. They recently returned to the United States, where Jeanne is completing her graduate studies at Rice University and David is an assistant professor in the biology department of the University of Houston. In their spare time, they enjoy hiking, playing tennis, and snorkeling in the Caribbean.

A veteran field researcher in Guatemala and Mexico, **June Nash** (page 46) has long followed the career of Judas among the Maya. Other themes that intrigue her are the organization of work and the persistence of cultural traditions in peasant and industrial societies, as well as in the cosmopolitan settings of the "post-industrial" era. Nash, a Distinguished Professor of Anthropology at the City College and the Graduate Center of the City University of New York, has written *In the Eyes of the Ancestors: Belief and Behavior in a Maya Community* (New Haven: Yale University Press, 1970). She recommends *The Indian Christ, The Indian King: The Historical Substrate of Maya Myth and Ritual,* by Victoria R. Bricker (Austin: University of Texas Press, 1981) and *Comiéndose la Fruta: metafores sexuales e iniciaciones en Santiago Atitlán,* by Nathaniel Tarn and Martin Prechtel, in *Mesoamerica,* vol. 19, pp. 73–82.

With this issue, **Raymond Sokolov** (page 76) retires as the writer of "A Matter of Taste," having completed a stint of exactly twenty years as an analyst of cultural foodways in these pages. Sokolov's other labors are not winding down, however. He continues as editor of the Leisure and Arts section for the *Wall Street Journal,* where his responsibilities have recently been expanded to include the creation of a culture page for the European edition. Time-consuming travel to Europe (and occasionally to Asia, where the *Wall Street Journal* has another edition) is one of the reasons Sokolov has decided to round off his *Natural History* career after meeting 229 deadlines. He is also finishing off a book on grain and claims to be "incubating another secret project."



Because magpies are "common, extroverted, and conspicuous," writes **Tim Birkhead** (page 54), he remembers being aware of them even as a small child in Yorkshire. Later, as a schoolboy birder, he used to watch magpies and try to count them as they flocked at their large winter roosts. Birkhead went on to study zoology at the University of Newcastle upon Tyne and eventually discovered that next to nothing was known about magpie breeding biology. Nonetheless, he didn't start his formal research on the species until after he earned his D. Phil. from Oxford's Edward Grey Institute in 1976. Meanwhile, other birds have drawn Birkhead far afield. He has studied marine species in Arctic Canada, zebra finches in Australia, buffalo weavers in Africa, and yellow-billed magpies in California. Along the way he earned a D.Sc. from Newcastle and is now a professor of behavioral ecology at the University of Sheffield. Married, with three children and two dogs, he likes to paint, play the guitar, and write about birds. His book *The Magpies: The Ecology and Behaviour of Black-billed and Yellow-billed Magpies* (London: T & A. D. Poyser, 1991) is available in bookshops, and he recommends going to the library to find the out-of-print *Natural History of Magpies,* by J. Linsdale (Berkeley: Pacific Coast Avifauna 25, 1937).

Robert Caputo (page 84), who photographed this month's "Natural Moment," is pictured here, showing his equipment to a group of Kenyans. After graduating from college in 1976, he went to Africa as a tourist. "I was so taken with what I saw that I wanted to show it to my friends—and, of course, I wanted to continue seeing more of it myself. Photography accomplished both." Caputo was surprised to find that jobs were relatively easy to find in Africa; he started his photography career working for Jane Goodall, shooting movies of the chimpanzees she studied. Later, he became a Nairobi-based stringer for *Time, Life,* and other magazines. After his years in the bush, Caputo attended New York University's film school, where he earned his B.F.A. He is now based in Washington, D.C., but frequently travels back to Africa. He has completed a number of wildlife books for children and adults, all displaying his work his work on that continent. Caputo says he was surprised that the bird he photographed for this issue allowed him to get so close, because "ostriches are shy and usually run away before you can get within about twenty yards of them." This nest-sitting male stayed put as Caputo approached to within ten yards. The photograph was taken with a Nikon F3 camera and a Nikkor 300mm f 2.8 lens.

DESERT ◆ BISBEE ◆ FESTIVALS AND FAIRS ◆ MONUMENT VALLEY ◆ PHOENIX

WICKENBURG ◆ ROCK HOUNDING ◆ CANYON DE CHELLY ◆ GHOST TOWNS ◆ BACKPACKING ◆ RESTAURANTS

BOATING ◆ INDIAN RUINS ◆ YUMA ◆ GOLF ◆ OLD TUCSON ◆ HAVASUPAI FALLS ◆ SHOPPING ◆ COWBOYS

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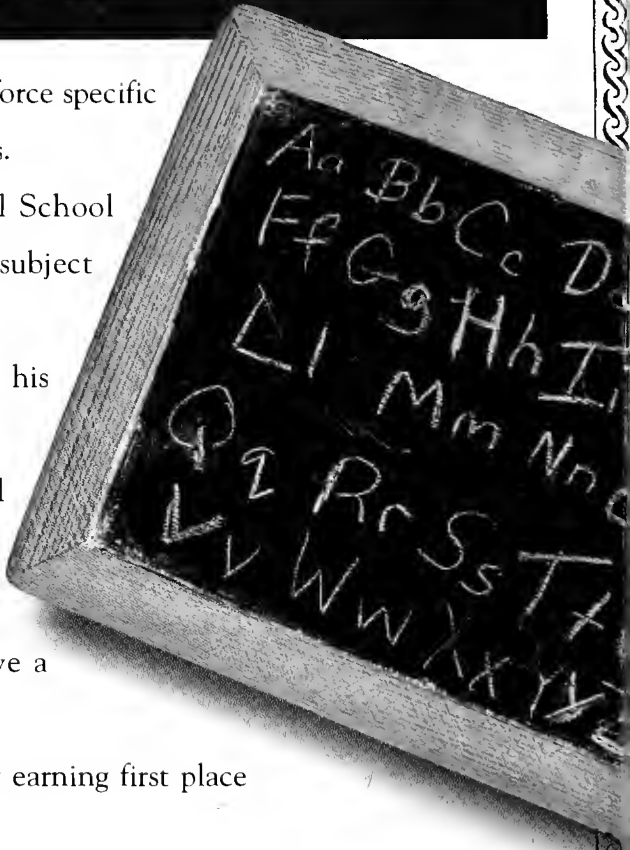

Drexel Sammons uses a variety of games to reinforce specific learning objectives in his sixth grade Social Studies class.

From Mock Sessions of Congress to Colonial School Days, his classes foster participation by making the subject matter come alive.

In Colonial School Days he attires himself and his students in period garb.

They sit on wooden benches, read material written in 18th century style, and discover first-hand how hard it was to write with a soapstone and slate.

It's no wonder Drexel Sammons' students have a superior grasp of their subject matter. They've lived it.

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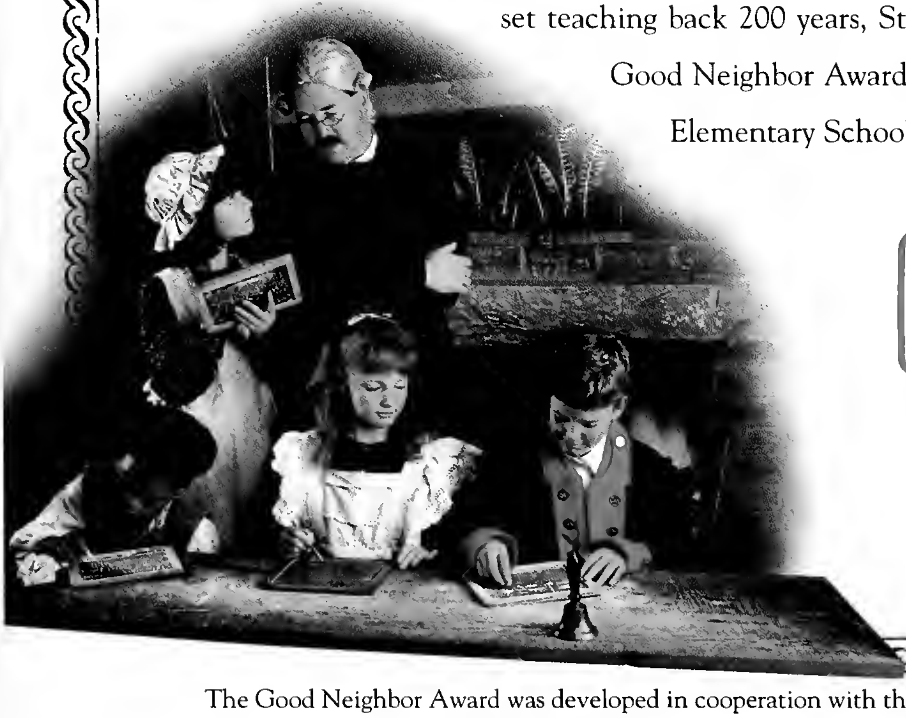
For consistently maintaining an atmosphere that encourages learning, even if he has to set teaching back 200 years, State Farm is proud to award him the Good Neighbor Award, along with $5,000 to the Crescent Elementary School of Beckley, West Virginia.



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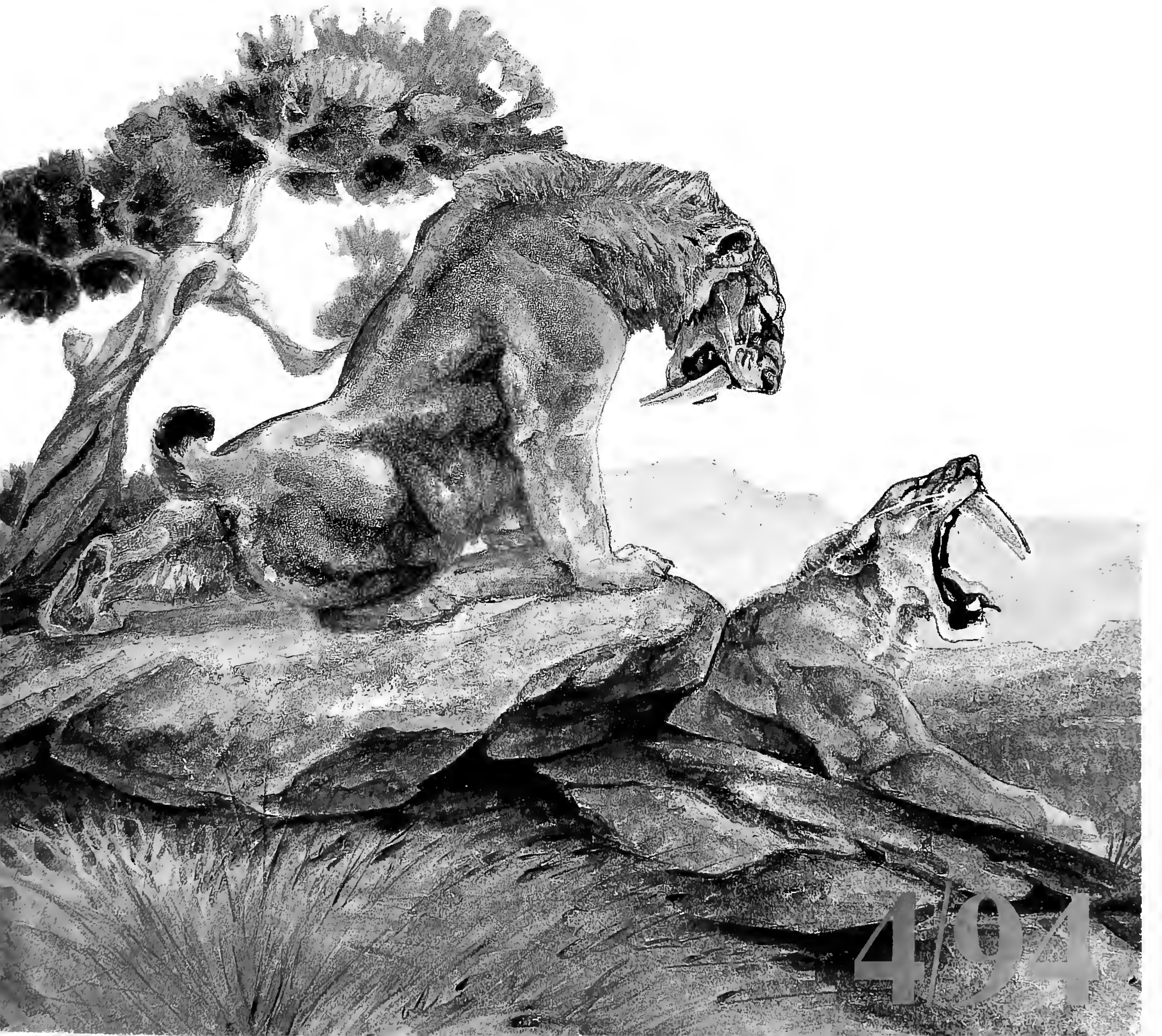


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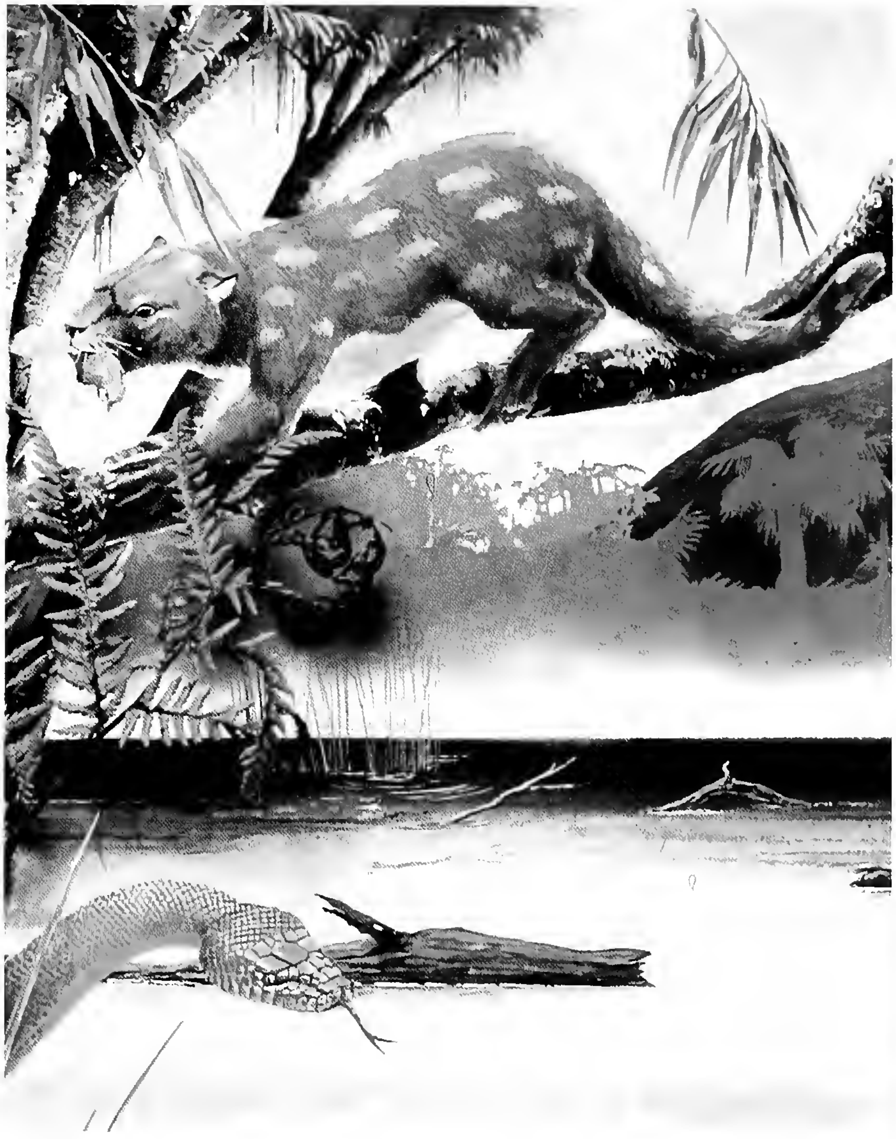


In a Class by Themselves

This month, in conjunction with the opening of the American Museum's Halls of Fossil Mammals and Their Extinct Relatives, *Natural History* celebrates the class Mammalia. Sixteen articles offer a sampling of the diversity of these beasts and discuss the ways in which paleontologists continue to learn about mammalian evolution and natural history.

Although we include no articles on human ancestors, no snub is intended: Human evolution commanded special sections in last year's April and May issues, and an article containing an elegant theory of the evolution of bipedalism ("Human Ancestors Walked Tall, Stayed Cool") appeared in August 1993. But perhaps most memorable was Roger L. Welsch's September column, "For Immediate Release," which finally explained the Ice Age origins of snoring.

Contents

Vol. 103, No. 4, April 1994

The Marvelous Mammalian Parade

Departments

COVER: *A pair of* Smilodon, *saber-toothed cats, yawn and stretch on a warm rock. Painting by Marianne Collins; © 1993 by W. W. Norton and Company. Stories on pages 74, 78, and 84.*

Dousing Diminutive Dennis's Debate

(DDDD = 2000)

by Stephen Jay Gould

In 1697, on the day appointed for repenting mistakes in judgment at Salem, Samuel Sewall of Boston stood silently in Old South Church, Boston, while his confession of error was read aloud. He alone among judges of the falsely accused (and truly executed) "witches" of Salem had the courage to undergo such public chastisement. Four years later, the same Samuel Sewall made a most joyful noise unto the Lord—and at a particularly auspicious moment. He hired four trumpeters to herald, as he wrote, the "entrance of the 18th century" by sounding a blast on Boston Common at daybreak. He also paid the town crier to read out his "verses upon the New Century." The opening stanzas seem especially poignant today, the first for its relevance (I am writing this essay on a January night in Boston, and the temperature outside is –2° F), and the second for a superannuated paternalism that highlights both the admirable and the reprehensible in our history:

Once more! Our God vouchsafe to
shine:
Correct the coldness of our clime.
Make haste with thy impartial light,
and terminate this long dark night.

Give the Indians eyes to see
The light of life, and set them free.
So men shall God in Christ adore,
And worship idols vain, no more.

I do not raise this issue either to embarrass the good judge for his tragic error or to praise his commendable courage, but for an aspect of the tale that may seem peripheral to Sewall's intent, but that nevertheless looms large as we approach the millennium destined to climax our current decade. Sewall hired his trumpeters for January 1, 1701, not January 1, 1700—and he therefore made an explicit decision in a debate that the cusp of his new century had kindled and that has increased mightily at every similar transition since (see my main source for much of this essay, the marvelously meticulous history of *fins de siècles,* by Hillel Schwartz—*Century's End,* Doubleday, 1990). When do centuries end? At the termination of years marked '99 (as common sensibility suggests) or at the close of years marked '00 (as the narrow logic of a peculiar system dictates)?

The debate is already more intense than ever, six (or is it seven?) years from our own forthcoming transition, and for two obvious reasons. First—O cursed spite—our disjointed times and our burgeoning press provide enhanced opportunity for rehearsal of such *narrishkeit* ad nauseam; do we not feast upon trivialities to divert attention from the truly portentous issues that engulf us? Second, this time around really does count as the ultimate blockbuster, for this is the millennium,* the great and indubitable unicum for any human observer (although a few trees and maybe a fungus or two, but not a single animal, have been through it before).

I had originally intended to treat this subject in my last essay of this series—to be written for January 2001. But the cascade of preemptive discussion has given me a strong case of anticipatory seven—or is it six?—year itch. For a man who really does yearn to lead a useful life and who glimpses a little strategy for steering fellow human sufferers away from embittered discussion about essentially meaningless and formally unresolvable questions, the time can only be now—or never. (How I wish I had better clues about answers to such truly resolvable and desperately important issues as hunger, poverty, xenophobia, and environmental degradation!) The dominant force of commercial culture has already honed in, and scholars can no longer afford the niceties of delay.

On December 26, 1993, the *New York Times* ran a piece to bury the Christmas buying orgy and welcome the new year. This article, on commercial gear-up for the century's end, began by noting: "There is money to be made on the millennium...in 999 feelings of gloom ran rampant. What the doomsayers may have lacked was an instinct for mass marketing." The commercial cascade of this millennium is already in full swing—in journals, date books, the inevitable coffee mugs and T-shirts, and a thousand other products being flogged by a full gamut, from New Age "fruitcakes" of the counterculture to hard-line apocalyptic visionaries at the Christian fringe to a bunch of ordinary guys out to make an honest buck. The article even tells of a consulting firm explicitly established to help others market the millennium—so we are already witnessing the fractal recursion that might be called metaprofiteering, or growing clams of advice in the clam beds of your advisee's potential profits.

I am truly sorry that I cannot, in current parlance, "get with the program." I feel compelled to mention two tiny difficulties

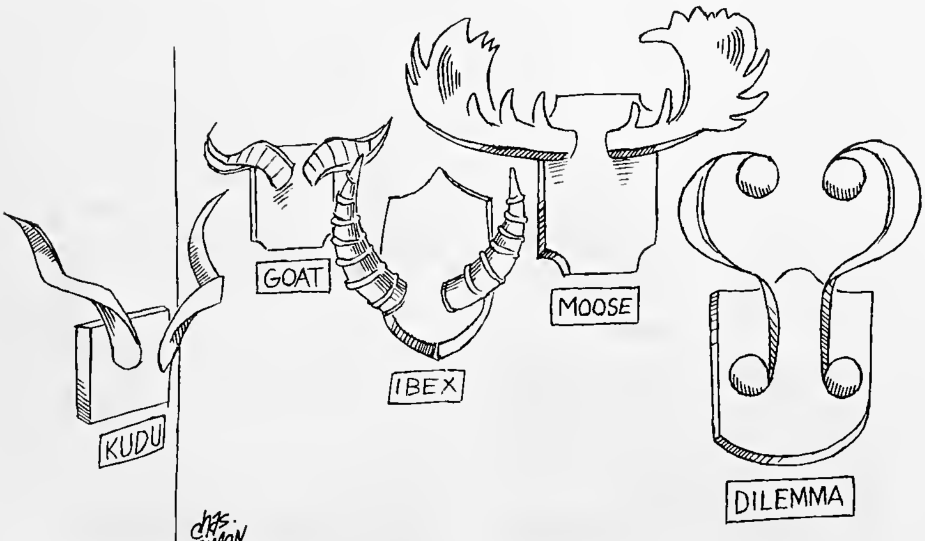
*In this essay's spirit of dispelling a standard set of confusions that have already surrounded the forthcoming millennium, may I at least devote a footnote to the most trivial, but also the most unambiguously resolvable? *Millennium* has two *n*'s—honest to God, it really does, despite all the misspellings, even in most of the books and product names already dedicated to the event. The adjective millennial also has two, but the alternative millenarian has only one. The etymologies are different. Millennium is from Latin *mille,* "one thousand," and *annus,* "year"—hence the two *n*'s. Millenarian is from the Latin *millenarius,* "containing a thousand (of anything)," hence no *annus* and no two *n*'s.

that could act as dampers upon the universal ballyhoo. First—although I will not make a big deal of this technicality—millenniums are not transitions at the ends of thousand-year periods, but particular periods *lasting* one thousand years; so I'm not convinced that we even have the name right. Second, if we insist on a celebration (as we should) no matter what name be given, we had better decide when to celebrate. I devote this essay to explaining why the second issue cannot be resolved—a situation that should not be viewed as depressing, but enlightening. For just as Tennyson taught us to prefer love lost over love unexperienced, it is better to not know, and know why one can't know, than to be clueless about why so many people are so agitated about 1999 versus 2000 for the great divide. At least when you grasp the conflicting, legitimate, and unresolvable claims of both sides, you can then celebrate both alternatives with equanimity—or neither (with informed self-righteousness) if your persona be sour or smug.

Rightful names: Millennium does mean, by etymology, a period of one thousand years. However, the concept did not arise within the field of practical calendrics, or the measurement of time, but in the domain of eschatology, or futuristic visions about a blessed *end* of time. Millennial thinking is embedded in the two apocalyptic books of the Bible—Daniel in the Old Testament and Revelation in the New. In particular, the traditional Christian millennium is a blessed future epoch that will last for 1,000 years and end with a final battle and Last Judgment of all the dead, as described by Saint John in one of his oracular visions:

> And I saw an angel come down from heaven, having the key of the bottomless pit.... And he laid hold on...Satan, and bound him a thousand years,
>
> And cast him into the bottomless pit, and shut him up, and set a seal upon him, that he should deceive the nations no more, till the thousand years should be fulfilled....and I saw the souls of them that were beheaded for the witness of Jesus...and they lived and reigned with Christ a thousand years....
>
> And when the thousand years are expired, Satan shall be loosed out of his prison,
>
> And shall go out to deceive the nations which are in the four quarters of the earth, Gog and Magog, to gather them together to battle...and fire came down from God out of heaven, and devoured them.
>
> And the devil that deceived them was cast into the lake of fire and brimstone, where the beast and the false prophet *are*, and shall be tormented day and night for ever and ever....
>
> And I saw the dead, small and great, stand before God, and the books were opened....
>
> And whosoever was not found written in the book of life was cast into the lake of fire [Revelation 20:1–15].

How, then, did this original concept of a forthcoming reign of Christ become transmogrified in popular speech into a word for calendric transitions at multiples of one thousand? The main reason must be simple confusion and loss of knowledge about the original meaning, as apocalyptic versions of Christianity, not to mention Bible reading in general, decline in popularity (despite, to say the least, vigorous, continuing support in some circles!). But a rationale of sorts for the transfer of meaning does exist within the history of eschatology, particularly in its intersection with my profession of geology in attempts to ascertain the age of the earth.



Many biblical passages state that God's day may be compared with a thousand human years: "Be not ignorant of this one thing, that one day *is* with the Lord as a thousand years, and a thousand years as one day" (2 Peter 3:8; see also Psalm 90). This comparison, read literally, led many interpreters to conclude that the seven days of Creation must correspond with a maximal duration of 7,000 years for the earth from Creation to final destruction at the Last Judgment. In this scheme, the seventh or last cosmic epoch, corresponding to God's day of rest after six days of furiously creative activity, would be a thousand-year period of bliss, the grand sabbath of the traditional millennium. If either science or hermeneutics could then determine the time of the earth's origin, we might know the moment of inception for this last happy age.

Most calculations of the earth's age, if done literally from biblical life spans and other ancient sources, place the Creation somewhere between 3761 B.C. (the Jewish calendar) and more than 5500 B.C. (the Septuagint, or Greek Bible). Therefore, a transition into the millennial age might well be on the horizon—or should have occurred just a while ago, according to your favored calculation. True, none of the suggested times of Creation give any reason to redefine a millennium as a transition around a date with three zeros in its written form, but at least we may understand why people might conflate a future period of millennial bliss with some system for counting historical time in periods of one thousand years.

Rightful times: As a man of below average stature myself, I am delighted to report that the source of all our infernal trouble about the ends of centuries may be laid on the doorstep of a sixth-century monk named Dionysius Exiguus, or (literally) Dennis the Short. Instructed to prepare a chronology for Pope Saint John I, Little Dennis decided to begin countable years with the foundation of Rome. But, neatly balancing his secular and sacred allegiances, Dionysius then divided time again at Christ's appearance. He reckoned Jesus' birth at December 25, near the end of the year 753 A.U.C. (standing for *ab urbe condita*, or "from the foundation of the city," that is, of Rome). Dionysius then restarted time just a few days later on January 1, 754 A.U.C.—not Christ's birth, but the feast of the circumcision on his eighth day of life, and also, not coincidentally, New Year's Day in Roman and Latin Christian calendars.

Dionysius's legacy has provided little but trouble. First of all, he didn't even get the date right, for Herod died in 750 A.U.C. Therefore, if Jesus and Herod overlapped (and the Gospels will have to be drastically revised if they did not), then Jesus must have been born in 4 B.C. or earlier—thus granting the bearer of time's title several years of life before the inception of his own era!

But Dennis's misdate of Jesus counts as a mere peccadillo compared with the consequences of his second bad decision. He started time again on the eighth day of Jesus' life, January 1, 754 A.U.C.—and, get this, he called the date January 1 of A.D. 1 (*Anno Domini*, or, "year of the Lord").

In short, Dennis neglected to begin his new time with year zero, thus discombobulating all our usual notions of counting. During the year that Jesus was one year old (by Dennis's state of reckoning), the time system that supposedly started with his birth was two years old. (Babies are zero years old until their first birthday; modern time was already one year old at its inception.) The absence of a year zero also means that we cannot calculate algebraically (without making a correction) through the B.C.–A.D. transition. The time from 1.5 B.C. to A.D. 1.5 is one year, not three years.

The problem of centuries also arises from this peculiarity—and for no other reason. If we insist that all decades must have ten years, and all centuries one hundred years, then year 10 belongs to the first decade—and, sad to say, year 100 must remain in the first century. Thenceforward, the issue never goes away. Every year with a '00 must count as the hundredth and final year of its century—no matter what common sensibility might prefer. The year 2000 must complete the twentieth century—and not launch the next millennium. Or so the pure logic of Dennis's system dictates. If our shortsighted monk had only begun with a year zero, then logic and sensibility would coincide, and the wild millennial bells could ring forth but once and resoundingly at the beginning of January 1, 2000. But he didn't.

Since logic and sensibility both have legitimate claims upon our decision, the great and recurring debate about century boundaries simply cannot be resolved. The logic of Dionysius's arbitrary system dictates one result—that centuries change between '00 and '01 years. Common sensibility leads us to the opposite conclusion: we want to match transitions with the extent or intensity of apparent sensual change, and 1999 to 2000 just looks more definitive than 2000 to 2001, so we set our millennial boundary at the change in all four positions, rather than the mere increment of one to the last position. (I refer to this position as "common sensibility" rather than "common sense" because support invokes issues of aesthetics and feeling rather than logical reasoning.)

One might argue that humans, as creatures of reason, should be willing to subjugate sensibility for logic; but we are, just as much, creatures of feeling. And so the debate has progressed at every go-round. Hillel Schwartz, for example, cites two letters to newspapers, written from the camp of common sensibility in 1900: "I defy the most bigoted precisian to work up an enthusiasm over the year 1901, when we will already have had twelve month's experience of the 1900s." "The centurial figures are the symbol, and the only symbol, of the centuries. Once every hundred years there is a change in the symbol, and this great secular event is of startling prominence. What more natural than to bring the century into harmony with its only visible mark?"

I do so love human foibles; what else can keep us laughing (as we must) in this vale of tears. The more trivial an issue, and the more unresolvable, so does the heat of debate and the assurance of absolute righteousness intensify on each side (just consider professorial arguments over parking places at university lots). The same clamor arises every hundred years. An English participant in the debate of 1800 versus 1801 wrote of "the idle controversy, which has of late convulsed so many brains, respecting the commencement of the current century." On January 1, 1801, a poem in the *Connecticut Courant* pronounced a plague on both houses (but sided with Dionysius):

> Precisely twelve o'clock last night,
> The Eighteenth Century took its flight.
> Full many a calculating head
> Has rack'd its brain, its ink has shed,
> To prove by metaphysics fine
> A hundred means by ninety-nine;
> While at their wisdom others wonder'd
> But took one more to make a hundred.

The same smugness reappeared a century later. The *New York Times*, with anticipatory diplomacy, wrote in 1896:

> As the present century draws to its close we see looming not very far ahead the venerable dispute which reappears every hundred years—*viz*: When does the next century begin?... There can be no doubt that one person may hold that the next century begins on the 1st of January, 1900, and another that it begins on the 1st of January, 1901, and yet both of them be in full possession of their faculties.

But a German commentator remarked:

> In my life I have seen many people do battle over many things, but over few things with such fanaticism as over the academic question of when the century would end.... Each of the two parties produced for its side the trickiest of calculations and maintained at the same time that it was the simplest matter in the world, one that any child should understand.

You ask where I stand? Well, publicly of course I take no position because, as I have just stated, the issue is unresolvable—for each side has a fully consistent argument within the confines of different but equally defensible systems. But privately, just between you and me, well, let's put it this way: I know a young man with severe cognitive limits as a result of inborn mental handicaps, but who happens to be a prodigy in day–date calculation (he can instantaneously give the day of the week for any date, thousands of years past or future; we used to call such people idiot savants, a term now happily fading from use, although I have no love for its euphemistic substitute, "savant syndrome"). I asked him recently whether the millennium comes in 2000 or 2001—and he responded unhesitatingly, "In 2000. The first decade had only nine years."

What an elegant solution, and why not? After all, no one then living had any idea whether they were toiling in year zero or year one—or whether their first decade had nine or ten years, their first century ninety-nine or a hundred. The system wasn't invented until the sixth century and wasn't generally accepted in Europe until the eleventh century. So why don't we just proclaim that the first century had ninety-nine years? Centuries can then turn when common sensibility desires, and we underscore Dionysius's blessed arbitrariness with a caprice, a device of our own that marries the warring camps. Neat, except that I think people want to argue passionately about trivial unresolvabilities—lest they be compelled to invest such rambunctious energy in real battles that might kill somebody. So be it.

What else might we salvage from rehearsing the history of a debate without an answer? Ironically, such arguments contain the possibility for a precious sociological insight: since no answer can arise from the "externalities" of nature or logic,

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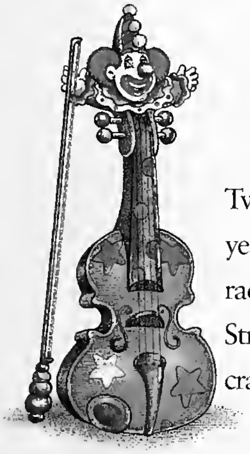

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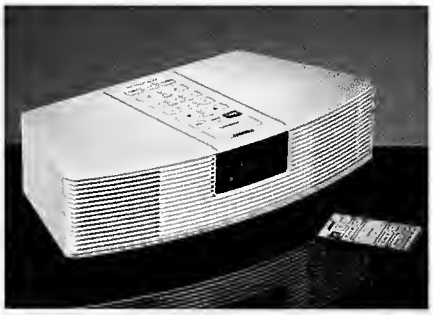

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changing viewpoints provide "pure" trajectories of evolving human attitudes—and we can therefore map societal trends without impediments of such confusing factors as discovered truth.

I had intended to spend only a few hours in research for this essay, but as I looked up documents from century transitions, I noticed something interesting in this sociological realm. The two positions—I have called them "logical" and "common sensible" so far in this essay—also have clear social correlations that I would not have anticipated. The logical position—that centuries must have a hundred years, and transitions must therefore occur, because Dionysius included no year zero, between '00 and '01 years—has always been overwhelmingly favored by scholars, and by people in power (press and business in particular), representing what we may call "high culture." The common sensible position—that we must honor the appearance of maximal changes between '99 and '00 years and not fret overly about Dionysius's unfortunate lack of foresight—has been the perpetual favorite of that mythical composite once designated as John Q. Public, or "man in the street," and now usually called vernacular, or "pop," culture.

The distinction goes back to the very beginning of this perpetually recurring debate about century transitions. Hillel Schwartz traces the first major hassle to the 1699–1701 passage (place the moment where you wish), the incarnation that prompted Samuel Sewall's trumpeting in Boston. Interestingly, part of the discussion then focused upon an issue that has been persistently vexatious ever since: namely, did the first millennial transition of 999–1001 induce a period of fear about an imminent apocalyptical ending of the world—called "the great terror" by supporters of this position. Opinions range from the luridly supportive (see the remarkably uncritical book by Richard Erdoes, who elevates every hint of rumor into a dramatic assertion—*A.D. 1000,* Harper and Row, 1988), to the fully debunking (see Hillel Schwartz, previously cited, and scores of references cited in chapter one therein).

I will, in my ignorance, take refuge in the balanced position of the French historian Henri Focillon (*The Year 1000,* Frederick Ungar, 1969). Focillon allows that apocalyptic stirring certainly occurred—at least locally in France, Lorraine, and Thuringia—toward the middle of the tenth century. But he finds strikingly little evidence for any general fear surrounding the year 1000 itself—nothing in any papal bull, nothing from any ruler.

On the plus side, one prolific monk named Raoul Glaber certainly spoke of millennial terrors, stating that "Satan will soon be unleashed because the thousand years have been completed." He also claimed, although no documentary or archeological support has been forthcoming, that a wave of church building began soon after 1000, when folks finally realized that Armageddon had apparently been postponed: "About three years after the year 1000," wrote Glaber, "the world put on the pure white robe of churches."

Glaber's tale provides a striking lesson in the dangers of an *idée fixe.* He was still alive in 1033, still trumpeting the forthcoming millennium—although he admitted that he must have been wrong about Christ's nativity for the beginning of a countdown, and now proclaimed that the apocalypse would surely arrive instead at the millennium of Christ's Passion in 1033. He read a famine of that year as a sure sign: "Men believed that the orderly procession of the seasons and the laws of nature, which until then had ruled the world, had relapsed into the eternal chaos; and they feared that mankind would end."

I doubt that we should grant much critical acclaim to Fra Glaber (who, according to other sources, was quite a wild character, having been expelled from several monasteries during his checkered career). I do tend to side with critics of the great terror. Why, after all, should the year 1000 have provoked any great reaction at the time—especially since Dionysius's system had not been generally accepted, and different cultures hadn't even agreed on a date for the inception of a new year. I suspect that the notion of a great terror must arise largely as an anachronistic backreading, combined with clutching at a few legitimate straws.

As another reason for doubting a great terror in 999–1001, the legend of such an episode begins with only a brief mention in a late sixteenth century work by the Vatican librarian Cardinal Cesare Baronio. Once the debate on century endings got started in the 1690s, however, backreading into the first millennium became inevitable. Did the legendary terror occur at the end of 999 or 1000? Interestingly, the high-culture versus pop-culture distinction can be traced even to this anachronistic reconstruction, with scholars favoring 1000, and popular legends 999. Hillel Schwartz writes:

> Sarcastic, bitter, sometimes passionate debates *in re* a terminus on New Year's Eve '99 vis-à-vis New Year's Eve '00, have been prosecuted since the 1690s and confusion has spread to the mathematics of the millennial year. For Baronio and his (sparse) medieval sources, the excitements of the millennium were centered upon the end of the year 1000, while the end of 999 has figured more prominently in the legend of the panic terror.

The pattern has held ever since, as the debate bloomed in the 1690s, spread in the 1790s with major centers in newspapers of Philadelphia and London (and added poignancy as America mourned the death of George Washington at the very end of

1799), and burst out all over the world in a frenzy of discussion during the 1890s.

The 1890s version displays the clearest division of high versus vernacular culture. A few high-culture sources did line up behind the pop favorite of 1899–1900. Kaiser Wilhelm II of Germany officially stated that the twentieth century had begun on January 1, 1900. A few barons of scholarship, including such unlikely bedfellows as Sigmund Freud and Lord Kelvin, agreed. But high culture overwhelmingly preferred the Dionysian imperative of 1900–1901. An assiduous survey showed that the presidents of Harvard, Yale, Princeton, Cornell, Columbia, Dartmouth, Brown, and the University of Pennsylvania all favored 1900–1901—and with the entire Ivy League so firmly behind Dionysius, why worry about a mere Kaiser (even though the king of Sweden rallied to Wilhelm's defense).

In any case, 1900–1901 won decisively in the two forums that really matter. Virtually every important public celebration of the new century throughout the world (and even in Germany) occurred from December 31, 1900, into January 1, 1901. Moreover, essentially every major newspaper and magazine officially welcomed the new century with their first issue of January 1901. I made a survey of principal sources and could find no exceptions. *The Nineteenth Century,* a leading British periodical, changed its name to *The Nineteenth Century and After,* but only with the January 1901 issue, which also featured a new logo of bifaced Janus, with an old, bearded man looking down and left into the nineteenth century, and a bright youth looking right up into the twentieth. Such reliable standards as the *Farmer's Almanack* and the *Tribune Almanac* declared their volumes for 1901 as "first number of the twentieth century." On December 31, 1899, the *New York Times* began a story on *The Nineteenth Century* by noting: "Tomorrow we enter upon the last year of a century that is marked by greater progress in all that pertains to the material well-being and enlightenment of mankind than all the previous history of the race." On January 1, 1901, the lead headline proclaimed "Twentieth Century's Triumphant Entry" and described the festivities in New York City: "The lights flashed, the crowds sang, the sirens of craft in the harbor screeched and roared, bells pealed, bombs thundered, rockets blasted skyward, and the new century made its triumphant entry." Meanwhile, poor Carry Nation never got to watch the fireworks, or even to raise a glass, for a small story on the same first page announced "Mrs. Nation Quarantined—smallpox in jail where Kansas saloon wrecker is held—says she can stand it."

So high culture still held the reins of opinion last time around—even in such organs of pop culture as the *Farmer's Almanack,* no doubt published by men who considered themselves among the elite. But consider the difference as we approach this millennium—for who can doubt that pop culture will win decisively on this most important replay. Arthur C. Clarke and Stanley Kubrick stood by Dionysius in book and film versions of *2001,* but I can hardly think of another source that does not specify the inception of 2000 as the great moment of transition. All book titles of our burgeoning literature honor pop culture's version of maximal numerical shift—including Ben Bova's *Millennium: A Novel about People and Politics in the Year 1999;* J. G. de Beus's *Shall We Make the Year 2000;* Raymond Williams's *The Year 2000;* and even Richard Nixon's *1999: Victory Without War.* Prince's album and lead song "1999" cite the same date from this *ne plus ultra* of pop sources.

Cultural historians have often remarked that expansion of pop culture, including both respect for its ways and means and diffusion of its influence, marks a major trend of the twentieth century. Musicians from Benny Goodman to Wynton Marsalis play their instruments in jazz bands and classical orchestras. The Metropolitan Opera has finally performed *Porgy and Bess*—and bravo for them. Scholars write the most damnedly learned articles about Mickey Mouse.

This remarkable change has been well documented and much discussed, but commentary has so far missed the importance of this example for the great century debate. This distinction still mattered in 1900, and high culture won decisively by imposing January 1, 1901, as the inception of the twentieth century. Pop culture (or the amalgam of its diffusion into courts of decision makers) may already declare clear victory for the millennium, which will occur at the beginning of the year 2000 because most people so feel it in their bones, Dionysius notwithstanding—and again I say bravo. My young friend wanted to resolve the debate by granting the first century only ninety-nine years; now ordinary humanity has spoken for the other end—and the transition from high-culture dominance to pop-culture diffusion may resolve this issue of the ages by granting the twentieth century but ninety-nine years!

How lovely—for eternal debates about the unresolvable really do waste a great deal of time, put us in bad humor, and sap our energy from truly important pursuits. Let us, instead, save our mental fight—not to establish the blessed millennium (for I doubt that humans are capable of such perfection), but at least to build Jerusalem upon our planet's green and pleasant land.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Socket to Me

It all started with that jerk Phillips...

by Roger L. Welsch

Thomas Carlyle, Scottish essayist and historian, wrote in the early nineteenth century, "Man is a tool-using animal.... Without tools he is nothing, with tools he is all." French philosopher Henri Bergson wrote in the early years of this century, "Intelligence...is the faculty of making artificial objects, especially tools to make tools." American anthropologist and ultimate toolman Tim Allen said a few months ago, "Man is the only animal to borrow tools."

I've already covered borrowing tools in a previous column. Now I am interested in the nature of tools themselves, the quintessential artifact (from the Latin, "made by skill"). Now comes Welsch's corollary: Man (or Woman) is not simply a tool-using animal, or a tool-making–tool-using animal, or even a tool-borrowing animal, but a *tool-loving* animal. The team of six accountants at Sears who handle my Craftsman tool account will verify that.

I'm kidding, of course. I have a set of tools I use for working on old tractors—a modest set of tools. Well, maybe it isn't really a modest set of tools. Lots of tools. Okay, most of my estate is tied up in socket wrenches.

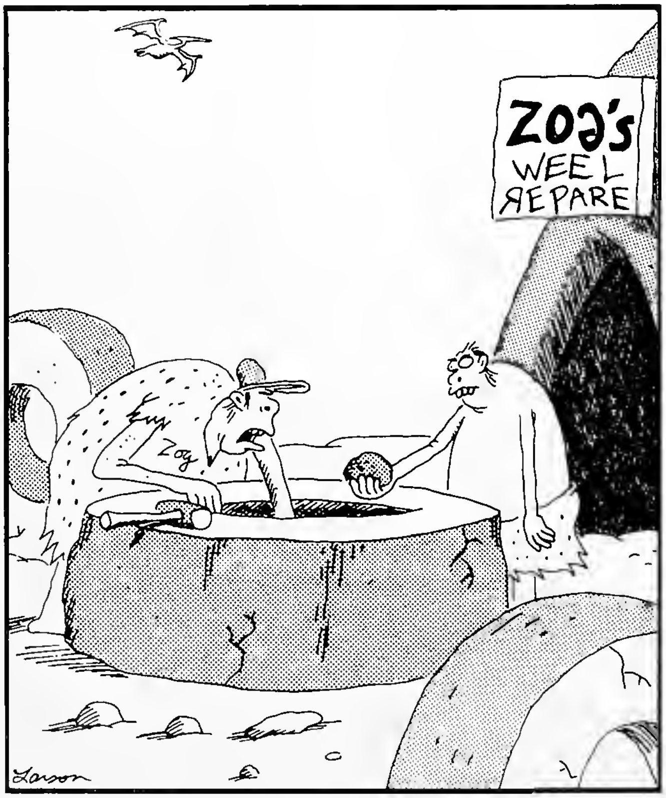
More tools than I need? Well, actually I don't need any tools at all. I could take my tractors up to town and let a real mechanic work on them. I don't even need the tractors, since my farm isn't much in the way of a farm. And my taste in tractors leans toward tractors that aren't much in the way of tractors. In fact, I make more money writing about tractors than sitting on them. But I like working on tractors and I like tools, so I have tools. Lots of tools.

I don't really need many tools to work on these tractors, which are each and every one of them an Allis Chalmers WC tractor, made between 1935 and 1942. Frankly, about all you need to work on a 1937 Allis Chalmers WC is a medium-size crescent wrench, a claw hammer, and a screwdriver. Two of each would be nice, but I suppose I could jam the bolt of a stuck nut with any old piece of yard iron if I had to.

The old maintenance and service manuals for WCs do call for some fancy tools such as torque wrenches, bushing pullers, and feeler gauges, but most of these old machines, if they could talk, would tell you that they never in their sixty years of life felt a torque wrench, bushing puller, or feeler gauge.

Most old mechanics I know never use phrases like "foot-pounds torque" or ".019 tolerance." They tell me to turn down the oil pan bolts until the gasket puckers out a trifle, and to be sure the cylinder sleeve doesn't sit above the block more than will catch on a fingernail. "Tighten the nut finger tight," they say, "and then turn it another quarter of a turn." Or, "Use an eight-inch crescent to tighten it just enough that your eyes pooch out a little."

Oh, but you should see how pretty that set of sockets looks, all in a row on that pegboard. Here, try the heft on this three-quarter-inch ratchet. And listen to the musical click it makes on the return pull. Take a look at this two-ton engine hoist; isn't that pretty? And when I put the load-lev-



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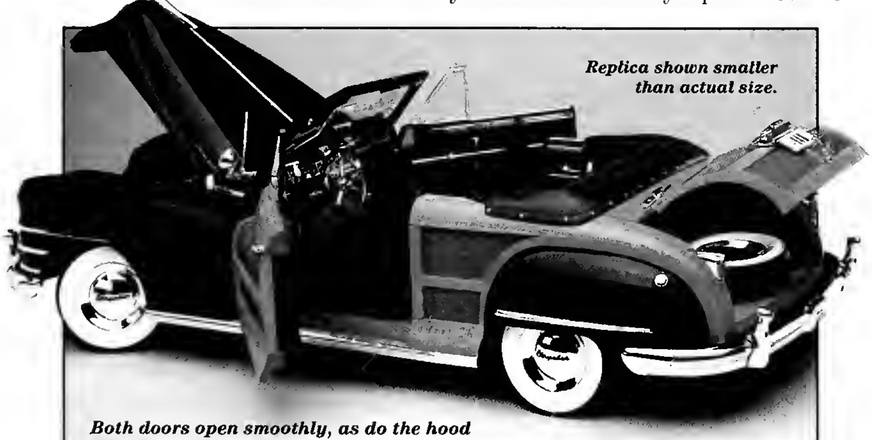

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eler on it, pulling an engine is as easy as sucking the pimento out of a cocktail olive.

I love tools, but I have my limits, and I suspect that humanity does too. Two things in my life have generated and agitated (in that order) those suspicions during the past couple of weeks. First, I sent a note to our household insurance carrier requesting coverage for my shop and modest set of tools. The woman who handles our account wrote back, telling me I would have to list all my tools and the value of each one. I want you to imagine for a moment going to your agent to get collision coverage on your new Taurus and having that person say to you, "I'll need a list of all its parts and their value." You could get a second job and earn enough to buy another Taurus before you could put together an inventory like that!

I went out to my shop and looked around. Where would I start an inventory? Socket wrenches? Metric sockets? Crow's-foot metric sockets? Three-eighths-inch drive crow's-foot metric sockets? Wobble-mount, three-eighths-inch drive, crow's-foot metric sockets? The good set from Sears that I don't like to get dirty, or the cheap set from Taiwan that is missing the 9/16-inch socket (which doesn't really matter, I guess, because for some reason it never fit a 9/16-inch bolt anyway)?

Inventory my tools? Lady, you must be crazy!

The second life-crisis that focused my attention on tools was when Lovely Linda asked me to install a window air conditioner in her studio. Easy enough. I grabbed a hammer, a screwdriver, a tool knife (to cut plastic sealers), and a crescent wrench and headed up the stairs. I pulled the machine out of its box, pried loose the window I had painted shut last summer, and got to work. As is her custom, instead of letting me get on with the job, Linda made a nuisance of herself and insisted that I waste even more time by reading the instructions.

That done, I proceeded to do what I would have done anyway. But when it came time to adjust the side curtains (never mind what side curtains are; just take my word for it that the time did come when I needed to adjust them), I found that the screws were not the good, old-fashioned slotted kind, so I had to go down two flights of stairs and out to my shop to get a Phillips screwdriver. When I got back upstairs, I found that the screws weren't even Phillips screws (the ones with the little cross on the top); these were something-else-head screws with a little star on the top. I don't know what they're called and I don't have a driver for them. I took a hacksaw and cut a groove across each one so I could use a regular screwdriver. (Early in this process Linda took our daughter Antonia and fled to a safe house in a city not far from here.)

It's the same thing these days with nails, bolts, brackets, zippers, staples, knife blades, nuts, washers, whatevers. A bolt is no longer a bolt. There are Torx drivers, Allen wrenches, Pitman pullers, bastard files. I can't say for sure, but I think it all started with that jerk Phillips who invented the aberrant screwdriver. I was ready to tell him off, but when I checked my dictionary I found that Henry F. Phillips died in 1958. Just as well: if I had done something that stupid, I wouldn't want to be around when Roger L. Welsch found out either.

As soon as Mr. Phillips worked his evil, every nut-case in the world wanted a screwdriver named after him, and there went the pure and beautiful principle of a toolbox that could be carried by something less than dump truck. Moreover, different groups use different terms for tools. Take men and women, for example. My daughter Joyce is painting our kitchen cabinets and not ten minutes ago she came into my office and asked where she could find "a teeny-weensy sharp-end screwdriver" and "squinch-nose pliers."

Someone somewhere along the line has taken my modest fetish and degraded it into an obsession. A perversion. Even though my tractors don't need all those tools, all those tools need me. Now, when I cast about for the only 9/32-inch box-end crescent wrench I own, I can't find it. I can't find it because it is buried somewhere under all those other tools I need for installing dumb things like window air conditioners. The only solution is to buy another 9/32-inch box-end wrench, or maybe two, so when I can't find the second one, I can maybe find the third. And then maybe a spare I can keep in my last-resort drawer.

The natural consequence of that process is that on my next project I can't find my 7/16-inch ratchet wrench because it suddenly seems that all I can find is a 9/32-inch box-end wrench. Maybe I need a couple more 7/16-inch ratchets. And so it goes.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

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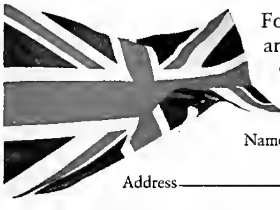

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Shingleton Bog, Michigan

by Robert H. Mohlenbrock

In Hiawatha National Forest, in Michigan's Upper Peninsula, a five-square-mile wetland is known locally as Shingleton Bog. But because most of the area is not very acidic, the term *bog* is inappropriate under the definitions developed by Michigan botanist Howard Crum (*see* "This Land," March 1994). Since it contains ample sphagnum, or peat moss, it is a peatland. Its various open areas, which are best termed "fens," are interspersed with tree-studded patches known as white cedar swamps and black spruce muskegs.

Among its habitats, Shingleton Bog has a "poor" fen and a "patterned" fen. To see them, I followed Hiawatha National Forest ecologist Jan Schultz, regional forest botanist Lawrence Stritch, and research natural area coordinator Lucy Tyrrell through a rather impenetrable white cedar swamp adjacent to Forest Highway 2251. The white cedar swamp is a natural community that gradually arose following the retreat of the great glaciers that covered the region some 12,000 years ago. At that time, heavy, waterlogged soil began to build over the limestone bedrock. Sphagnum mosses eventually covered much of the soil, and their decomposed remains began to accumulate as peat.

The considerable calcium in the underlying limestone kept the peatland from becoming acidic, so that the fen maintained itself until white cedar seedlings began to invade. As more and more trees became established and grew to maturity, their dense cover promoted the growth of shade-tolerant plants.

Jack W. Dykinga

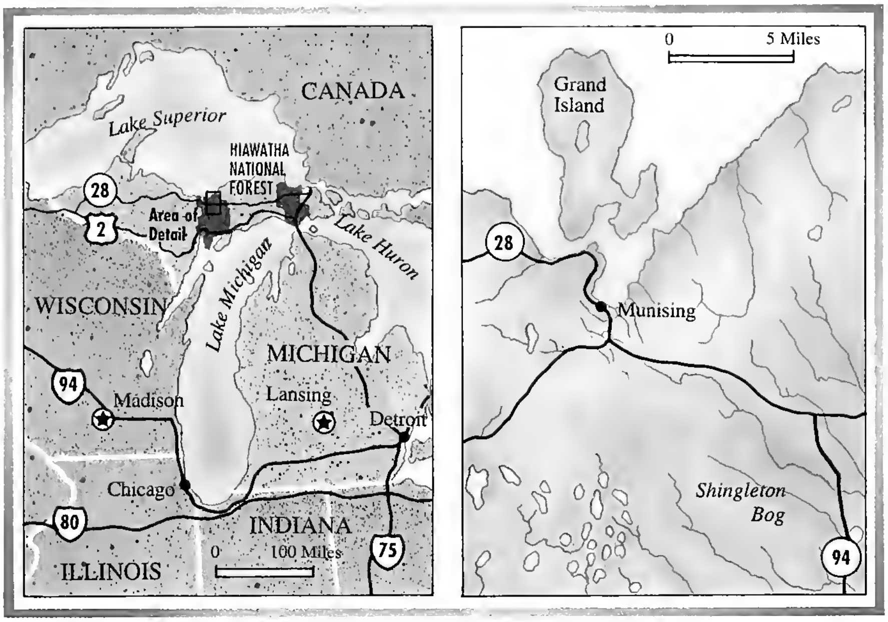
The white cedar swamp was difficult to walk through because of the low-hanging branches, which often reach the ground. In addition, there were weak areas in the mat of sphagnum beneath the trees where one could easily step through and twist an ankle. Filling the understory were shoulder-high clumps of royal fern and cinnamon fern. Here and there, occasional pink lady's-slipper orchids and bluebead lilies grew among thick patches of low-growing, evergreen club mosses.

The ground sloped down imperceptibly as we made our way through the cedar swamp. Even though I could not detect the difference, the plants responded to the slight change in soil and moisture. Almost abruptly, the crowded, large white cedars gave way to open habitat containing few woody plants, all of them dwarfed and gnarled. Apart from cedars, there was an occasional tamarack, a few red maples, and a scattering of shrubs—red chokeberry, mountain holly, and raisin tree. As we proceeded, the ground became wetter, and water rose above the toes of our boots with every step.

Crum describes this type of community as a poor fen because of its greater degree of acidity, not because it lacks a diversity of plants. Dozens of low-growing wild-

Tamaracks and cattails, left, grow in Shingleton Bog's "poor" fen. Right: Pink lady's-slipper orchid.
John Gerlach; Dembinsky Photo Associates

Joe LeMonnier



Shingleton Bog
For visitor information write:
Forest Supervisor
Hiawatha National Forest
2727 N. Lincoln Road
Escanaba, Michigan 49829
(906) 786-4062

flowers grow on the sphagnum-dominated soil, all species adapted to saturated soils, cool summers, and frigid winters with long durations of snow cover. They include bushy-branched horsetail, wintergreen, starflower, and bunchberry (a four-inch-tall, nonwoody type of dogwood). Carnivorous sundews and pitcher plants, as well as a wide variety of slender, delicate sedges, are also common.

After making our way for a few hundred feet through this fragile, watery terrain—being careful not to step on the flowering plants—we left behind most of the scraggly trees and faced a meadowlike area with small rivulets of water running between ridges covered by sphagnum moss and other vegetation. This was the patterned fen, although the pattern was not immediately visible. If we could have looked down from above, however, we would have seen that the ridges and rivulets were all more or less parallel to one another, oriented east–west at right angles to the slight slope of the terrain.

Peatlands all across the more northerly regions may contain patterned fens. Scientists in Europe recognized them many years ago, calling them aapamires. The rivulets are referred to as flarks, while the adjacent ridges of soil and vegetation are called strings. Biologists have come up with several hypotheses concerning the origin of patterned fens. One suggestion is that the alternate freezing and thawing of the soil over a long period of time eventually gives rise to the alternating flarks and strings.

While freezing and thawing may play a role in creating patterned fens, there may be a more important factor. Patterned fens usually arise where the terrain has a gradual, nearly imperceptible grade of about 2 percent. Through time, soil slides down this small gradient. When one edge of the slipping soil hooks onto something, such as a small tree or even a rock, the soil tears, forming a flark along the tear line. After many years of constant sliding and tearing, a distinct pattern of alternating flarks and strings becomes evident.

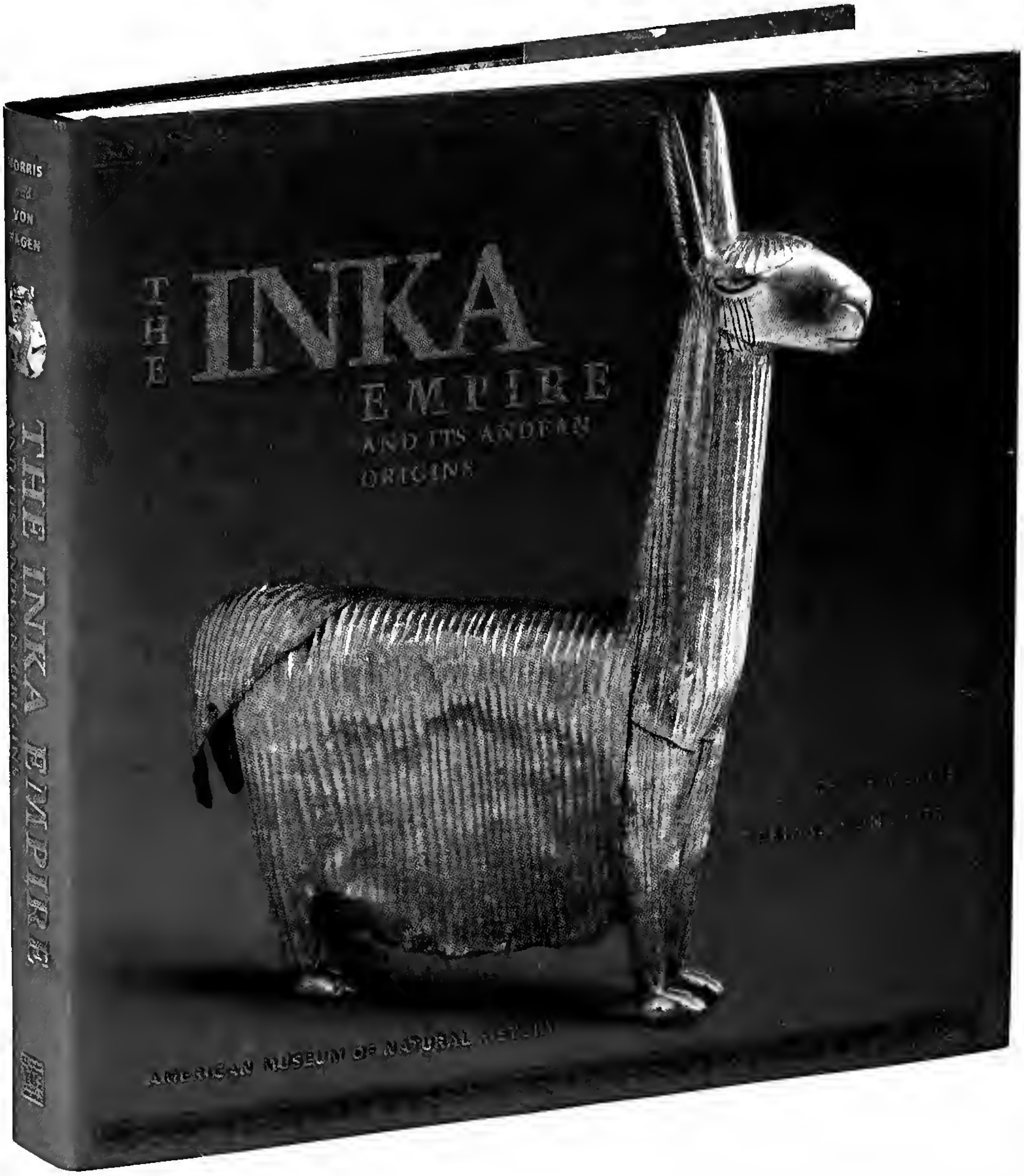
At Shingleton Bog, the strings and flarks may be as narrow as one foot or as much as thirty feet wide and are usually from ten to one hundred or more feet long. The strings may stand as much as three feet higher than the flarks, but usually the contrast is more subtle. The amount of water in the flarks varies with rainfall, ranging from inconspicuous amounts up to pools six inches deep. The water is nearly neutral, with a pH of about 6.

Several plants seem confined to the flarks: a tufted little sedge known as *Carex exilis,* the intermediate sundew, one kind of bladderwort, and the white beaked rush. The strings, on the other hand, provide habitat for Kalm's lobelia, bog rosemary, shrubby cinquefoil, a wild lily, and several flowering plants exceptionally rare for the region. Most of the rarities, including a sedge, an orchid, a sundew, a tiny raspberry, and a willow herb, are arctic species that were left behind when the great glaciers of the Ice Age receded northward.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Bunchberry is a nonwoody type of dogwood.
Doug Locke; Dembinsky Photo Associates

THE INKA EMPIRE AND ITS ANDEAN ORIGINS



Trace the story of the Andean peoples with this beautifully produced new appraisal of the ancient Inka and the remarkable cultures that preceded them.

Written by Dr. Craig Morris, American Museum of Natural History Curator of Anthropology, and noted journalist Adrianna von Hagen, this comprehensive study describes their agricultural methods, social organizations, political structure, religious beliefs, ceremonial practices, technologies, and artistic expression. The text resonates with more than one hundred exquisite color photographs of objects from the Museum's rich collection of artifacts and offers compelling panoramas of the spectacular and diverse Andean landscape.

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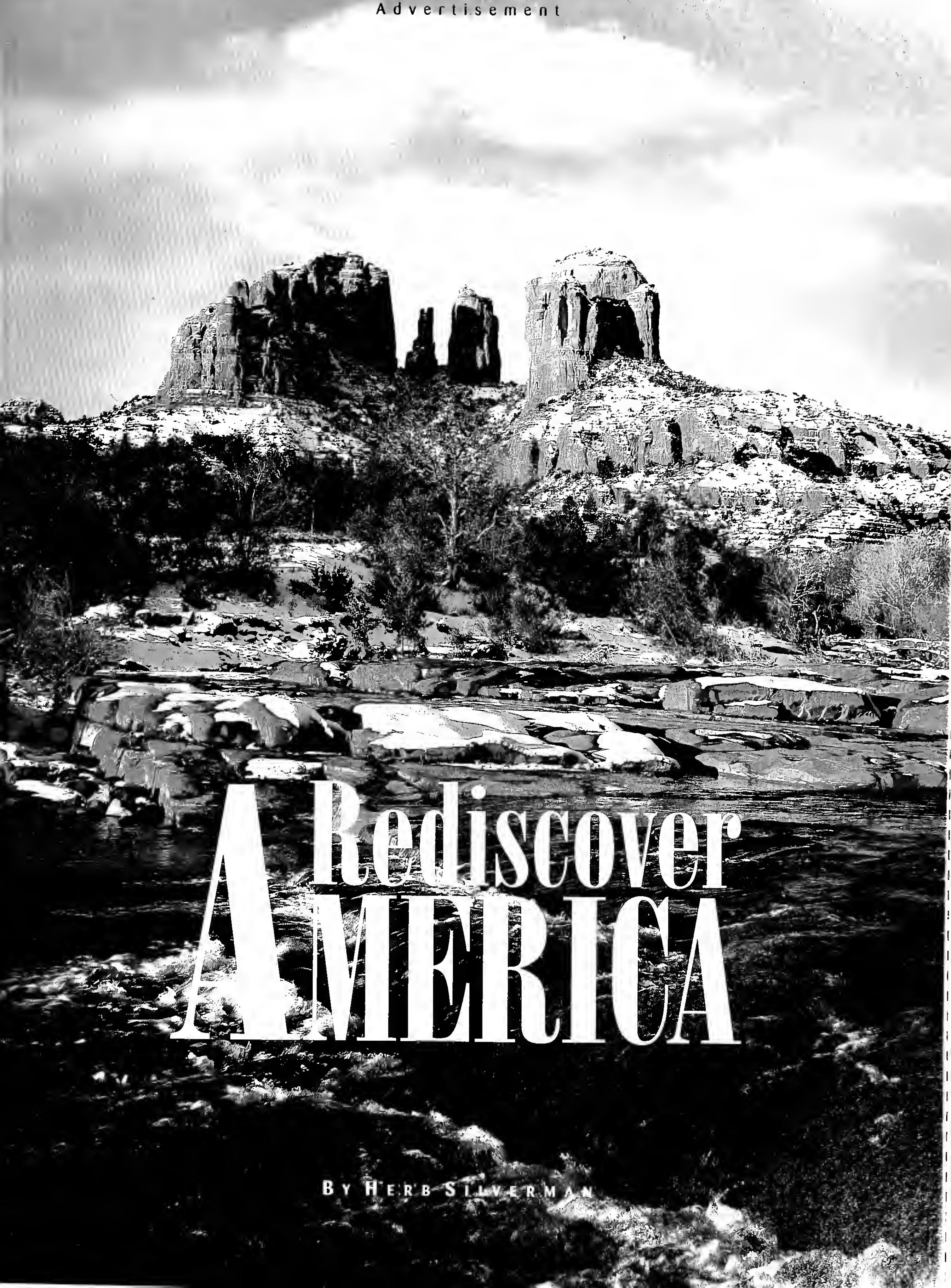
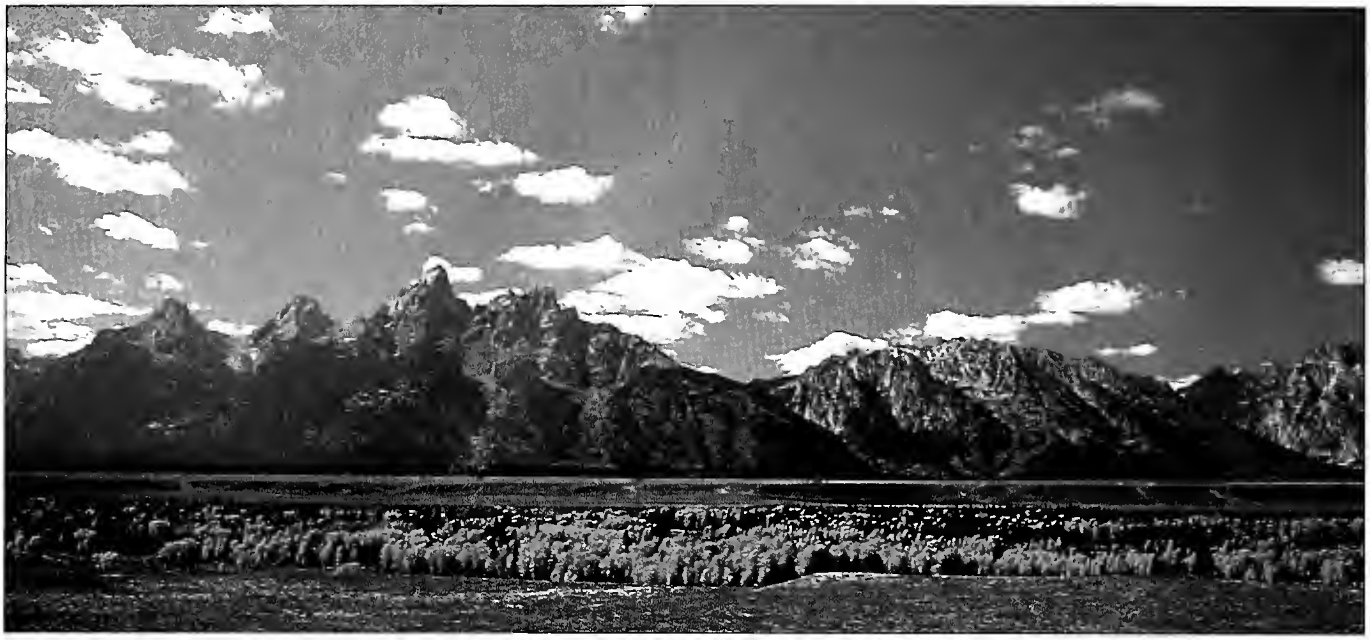


Rediscover America

By Herb Silverman



TETON MOUNTAINS, WYOMING, COURTESY OF WYOMING DIVISION OF TOURISM
PRECEDING PAGE: CATHEDRAL ROCK, SEDONA, ARIZONA, PHOTO BY RAY MANLEY/SUPERSTOCK

Rediscover AMERICA

Alabama • Arizona • Georgia • Kentucky Mississippi • New Hampshire • New Mexico New York • Wisconsin • Wyoming

Has there ever been a more lyrical description of this country than the verses of America the Beautiful, *written by Katherine Lee Bates in 1893?*

Today, ecotourism is reinforcing America's pride in its natural assets. A nationwide preservationist drive is keeping a richly varied environment in a state of grace. Travelers are seeking out those purple mountains and fruited plains, not overseas but in their own homeland–aided by well-planned travel itineraries, economic air fares and attractive car rental packages.

They undoubtedly agree with Alexis de Tocqueville, who in 1835 made the cogent comment, that "America is a land of wonders, in which everything is in constant motion and every change seems an improvement."

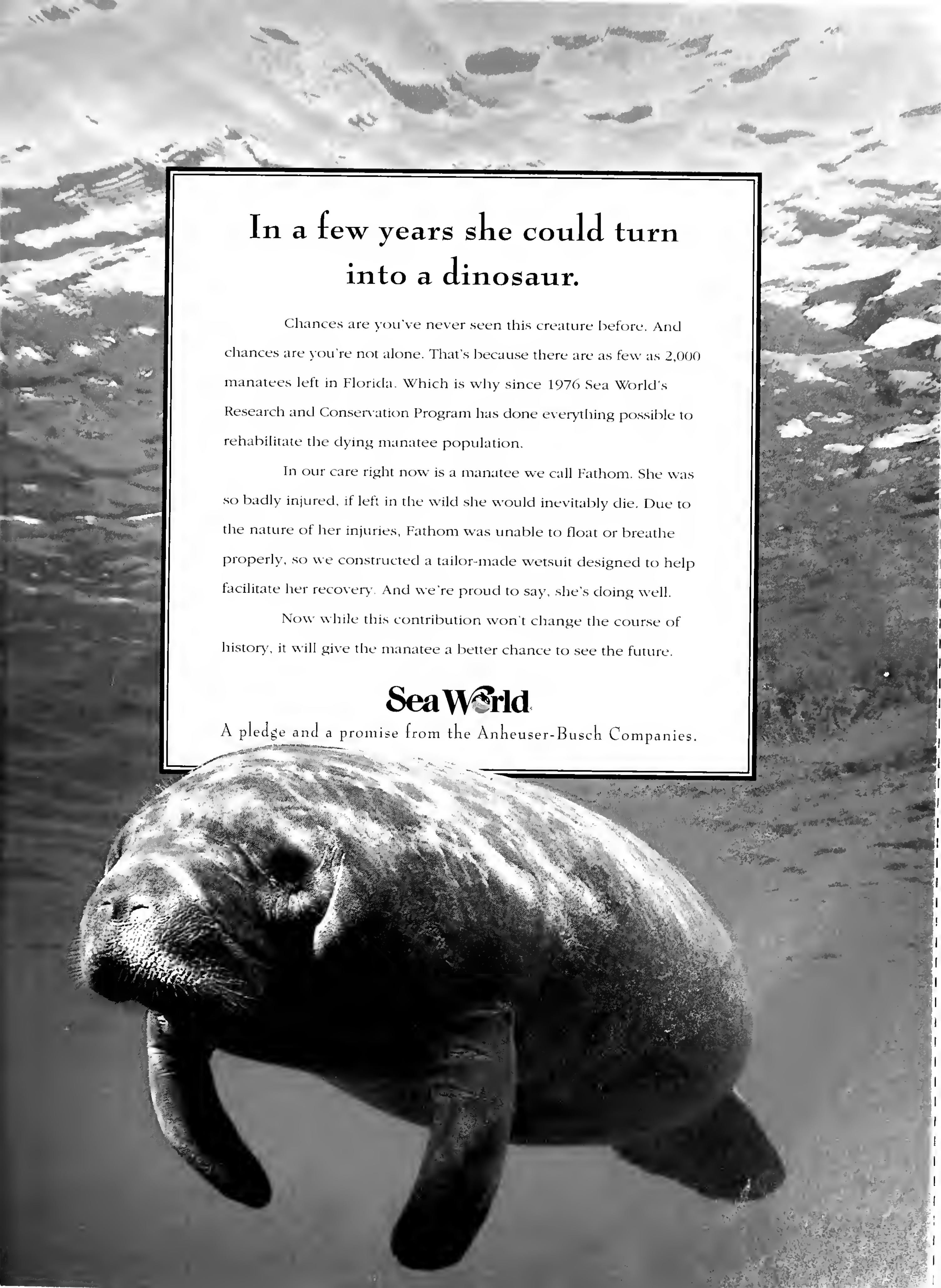
ALABAMA

The Camellia State is home to a memorable group of public and private parks, one of which was founded with the immense profits from the creation of a soft drink. Mobile's Bellingrath Gardens is a 65-acre expanse of spring-blooming azaleas, autumn chrysanthemums, and winter poinsettas. The gardens were established in 1917 on the family estate of millionaire Walter D. Bellingrath, a founding father of Coca Cola.

Another "not to be missed" natural resource is the Alabama Wildlife Center, open to the public and nestled among ten wooded acres within Oak Mountain State Park, near Birmingham. The Center has treated thousands of injured wild birds and mammals and has returned them successfully to the wild. Its Treetop Nature Trail is an elevated boardwalk flanked by spacious tree houses on stilts whose elevation allows recovering birds to follow their natural instinct of being high off the ground.

The Wheeler National Wildlife Refuge and Visitor Center, north of Birmingham, is a protected wildlife refuge. Its innovative crop-sharing programs with local farmers produce waterfowl food on 4,000 acres; and its corn, sorghum, millet, and soybean crops attract geese, mallards, wigeon, pintail and black ducks.

The Sequoyah Caverns, in the northeastern corner of the state, are noted for their clear "Looking Glass Lakes." Above ground is a protected home for buffalo, white fallow deer, and peacocks.


In a few years she could turn into a dinosaur.
Chances are you've never seen this creature before. And chances are you're not alone. That's because there are as few as 2,000 manatees left in Florida. Which is why since 1976 Sea World's Research and Conservation Program has done everything possible to rehabilitate the dying manatee population.
In our care right now is a manatee we call Fathom. She was so badly injured, if left in the wild she would inevitably die. Due to the nature of her injuries, Fathom was unable to float or breathe properly, so we constructed a tailor-made wetsuit designed to help facilitate her recovery. And we're proud to say, she's doing well.
Now while this contribution won't change the course of history, it will give the manatee a better chance to see the future.
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A. FELIX/SUPERSTOCK

Bellingarth Gardens, Mobile, Alabama

ARIZONA

Canyon Country—the name alone conjures up wild natural beauty, spectacular vistas, majestic rock formations. Its lure begins with the mightiest spectacle of them all, the Grand Canyon.

A mile deep, 277 miles long, and two billion years in the making, it's one of America's most awesome spectacles. Canyon afficionados can view this wonder from rim-side or while hiking or white-water rafting at the bottom of the Canyon. Air tours take off from Tusayan near the South Rim, where an IMAX Theatre projects the Grand Canyon story on a massive indoor screen.

Lesser known Oak Creek Canyon, a dreamworld of red rock cliffs carved through forests by a mountain stream, is accessible by highway and has a half-dozen national forest campgrounds. Nearby Sycamore Canyon has no roads at all and is a remote wilderness accessible only to hikers and horseback riders.

Less than an hour from the art colony of Sedona en route to the Grand Canyon are two national monuments: Walnut Canyon, with a series of cliff dwellings situated in a deep gorge, and Wupatki, with some 800 prehistoric rock abodes.

The 12,643 San Francisco Peaks north of Flagstaff offer challenging high altitude trails for hikers as well as lower elevations walks through a blanket of wildflowers in summer.

Note: The Arizona Department of Tourism has just published an EcoTourism Guide to Canyon Country which focuses on archaeological excavations, remote nature preserves and Indian reservations.

GEORGIA

Spring is the ideal time to visit the Golden Isles, part of a chain of barrier islands stretching 120 miles along Georgia's coast to Florida's border.

The gem of the group is Little Saint Simons Island, off the coast at Brunswick. An environment geared to the conservation and preservation of natural resources, this secluded enclave has the greatest concentration of shore-birds on the Georgia coast. The six-mile long, three-mile-wide retreat is an ideal nature preserve with rare flora and fauna inhabiting its protected sandy beaches, salt marshes, tidal flats, and pine forests.

Little Saint Simons is a private island with a handsome rustic pine lodge owned by the Berolzheimer family dating to the turn-of-the century. Accommodating a scant two-dozen guests, it's known for its Southern "home-cooked" cuisine featuring such regional dishes as oyster stew and fried chicken.

The island is accessible by boat from its sibling, the larger Saint Simons Island, whose charms include horseback riding, salt water fishing for red fish and flounder, or fly fishing

COURTESY GEORGIA DEPT OF INDUSTRY, TRADE & TOURISM

Wading bird, St. Simons Island, Georgia

Show me a square and I'll show you a soul.

Architect Robert Parker Adams considers Mississippi's courthouse squares.

Out on the bypass and the edge of town you'll always find the discount stores and burger barns, symbols of growth and what some would call progress. But if you're searching for the elusive Southern soul, set your watch back a generation or two and head straight for a courthouse square.

The old men are still there on the magnolia-shaded benches, whittling and talking like their fathers before them. The day's topic may be politics or the upcoming flea market or crafts show. Or Friday night's showdown against the gridiron warriors from a county away.

The shopkeepers still sweep the sidewalks in front of the stores where business is done on a personal level. The dark drama of misdeeds and justice is played out in the Greek Revival courthouse, the focus of the community.

The scale of Mississippi's courthouse squares isn't architectural. It's human.

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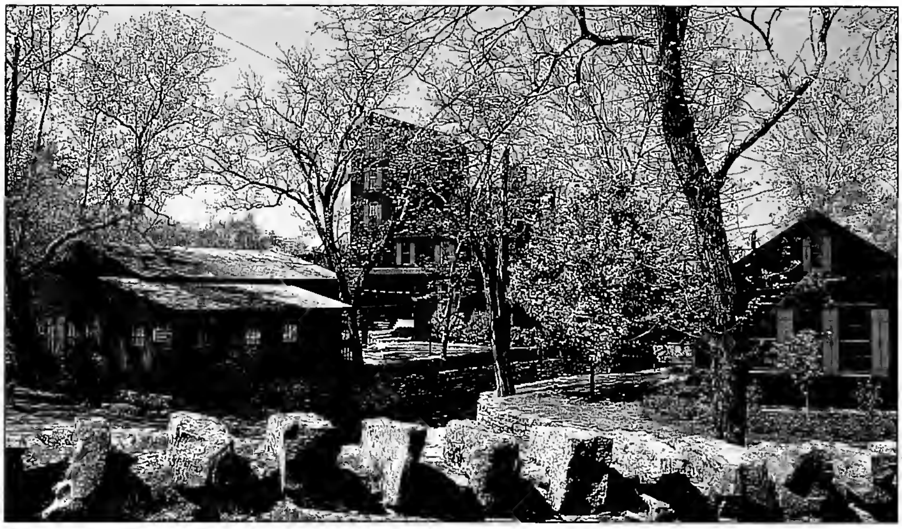
The South's Warmest Welcome
MISSISSIPPI



Maker's Mark Distillery, Loretto, Kentucky

for trout. There's canoeing and boating on tidal creeks, bicycling, hiking, and bird watching for painted buntings, great blue herons, and osprey. Naturalists on staff bring guest and wilderness together in compatible harmony.

KENTUCKY

The Bluegrass State has some remarkable museums and historic sites dedicated both to its natural and manmade wonders.

Among Kentucky's natural wonders is Mammoth Cave National Park, whose explored passages extend 330 miles through five levels of subterranean limestone chambers. Rangers lead visitors to such sites as Frozen Niagara, Fat Man's Misery, and the Bottomless Pit.

Here in mint julep land, the running of the Kentucky Derby, on the first Saturday in May at Churchill Downs, is a tribute to the state's great horse farms. The local museum has a multi-image show highlighting the Derby, past and present, with hands-on exhibits.

Bourbon was a drink created by a Baptist minister in Bourbon County in 1798. The Getz Museum in Bardstown has a unique collection of whiskey memorabilia, including a license issued to Kentucky-born Abraham Lincoln in 1833 to operate a tavern with the proviso that "said Lincoln shall be of good behavior and observe the laws of Illinois." Among the museum's nonpotable artifacts are Jenny Lind's velvet cape and tools used by Trappist Monks in the nearby monastery where Thomas Merton lived and prayed.

A noted National Historic Landmark is Maker's Mark, one of the oldest working distilleries in the United States. Dating to 1805, it is located in Loretto and has regular tours.

MISSISSIPPI

Mississippi is more than just a river. This state was once the secluded domaine of the Choctaw, Chickasaw, and Natchez Indians—until the French arrived in 1699. Before the Civil War, when cotton was king, it was one of the nation's wealthiest states.

The era of affluence, splendour, and grace is preserved in more than 500 antebellum properties throughout Mississippi, still standing amid lush gardens. Possibly the finest are centered in Natchez. The city survived the Civil War, as did its opulent plantation homes, some of which are open year-round. Others are only open during Natchez Pilgrimage weeks, which were. started in 1932 by the women of the city to raise money for preservation. These tours are given twice a year: three weeks in October and four weeks in March and April.

Civil War memories come alive at Vicksburg National Military Park, where the fall of the "Gibraltar of the Confederacy" to Ulysses S. Grant on July 4, 1863, is remembered by monuments and battle markers.

The 8,000-year-old Natchez Trace, now a scenic autoroute without billboards, winds 400 miles through the state to Nashville. A reminder of the ancient trading trail of Native Americans, it's home to protected wildlife.

Mississippi also has more tree farms than any other state and the world's only cactus plantation, with more than 3,000 varieties, is located near Edwards, Mississippi.

E. COOPER/SUPERSTOCK

Longwood Plantation, Natchez, Mississippi

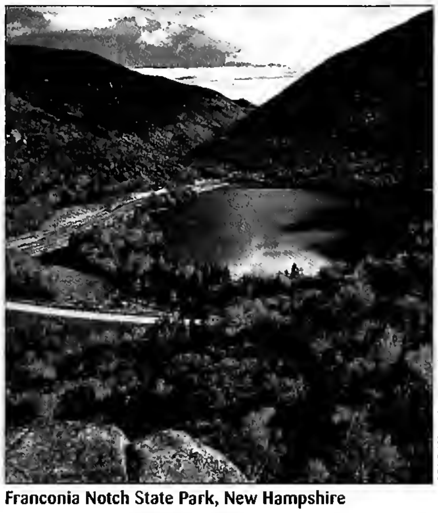
NEW HAMPSHIRE

Ecotourism could well have its roots in the Granite State, which holds nearly two million acres of parkland and forest as a public trust. Half of the narrow coastline is public parkland.

The White Mountains have attracted nature lovers and ordinary tourists ever since the area was first settled in the 1600s. Although heavily deforested in colonial days, the mountains are now almost completely wooded, with white birch and maple replacing green fir and spruce.

Julia Ward Howe wrote: "If there is any kinship with nature in you, here is this place the attractions of society pale before the quietness, the simplicity, the freshness of nature."

The exemplar of that freshness is arboreal Franconia Notch, a pass through the mountains. Its most noted feature is the "Old Man of the Mountain," an incredible rock formation once said to resemble the profile of either God or President Jefferson.



COURTESY NEW HAMPSHIRE OFFICE OF TRAVEL & TOURISM

Franconia Notch State Park, New Hampshire

Mount Washington, the tallest peak in New England, has attracted hikers for centuries. Ascent takes about five hours along a challenging ravine trail edged with waterfalls and ponds. If you're a railroad buff, ride the famed Cog Railway, dating to 1869, which once carried President Grant to the summit. A vintage coal-powered steam engine pulls the train up the steep grade. A third choice is a highway to the top, where a souvenir shop sells bumper stickers proclaiming "I climbed Mt.Washington."

NEW MEXICO

The unoffical name of New Mexico is "Land of Enchantment" which the state lives up to happily. Its potpourri of activities that include spring festivals colorfully marked by blooming of yuccas (candles of the Lord), summer mountain climbing, rodeos, fall aspen leaf watching, and winter skiing.

The state's forty-eight parks range from high mountain lakes and forests in the north to the Chihuahua desert lowlands in the south. The popular Carlsbad Caverns' "Big Room" is large enough to hold a dozen football stadiums.

Albuquerque (easier to find than to spell) is dominated by the Sandia Mountains ("watermelon" in Spanish)–a paradise for hiking and horseback riding, with miles of nature trails, streams, canyons and picnic sites. The city, founded in 1706, is vibrant with theatre, opera, and ballet. Its "Old Town" has been restored, and is now filled with trendy shops, galleries and ethnic restaurants.

Santa Fe and Taos are paradise for painters, poets, writers and artists. In celebration of their Native American heritage, publeos near Santa Fe (noted for their traditional polychrome pottery handicrafts) have ceremonial dances on feast days to which visitors are welcome.

New Mexico's official state flower is the yucca (a lily that grows to tree-like heights); the state bird is the roadrunner; the state tree, the pinus edulis, or Rocky Mountain nut pine; the state vegetables, pinto bean and chili peppers.

NEW YORK STATE

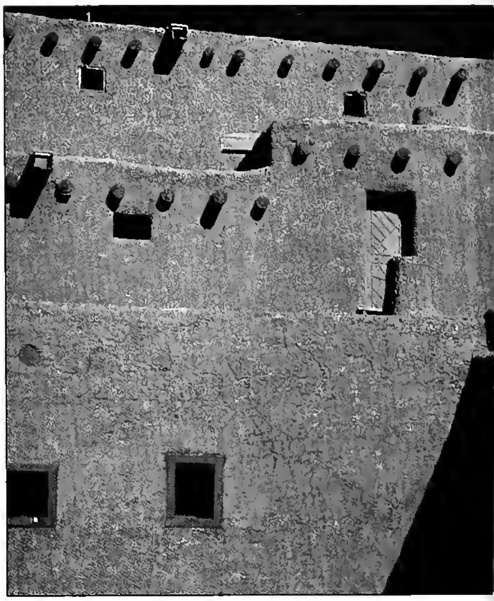
The sheer breadth of the Empire State tends to obscure the curious fact that nearly 20 percent of it lies within the Blue Line of the Adirondack State Park. In this region, such magnificos as Morgan and Vanderbilt created grand estates and contributed to preserving much of the mountain wilderness. The park, a patchwork of private and public lands, is more accurately

JEFF GNASS

Autumn on East Branch, Ausable River, New York

called a preserve. It includes an astonishing six million acres of forest (or an area more than twice the size of Yellowstone) with an estimated 2,000 lakes and 40 mountain peaks.

The revolutionary Fort Ticonderoga complex on Lake Champlain, open to visitors since the 1820s, was one of the first historic sites to be preserved for the public. As a major tourist at-



Taos Pueblo, New Mexico

traction, it has a museum and a fife-and-drum corps that performs in summer.

The Erie Canal, the longest linear park in the country, stretches 363 miles from Buffalo to Albany, connecting the Great Lakes with the Atlantic Ocean. In the words of an old chanty, mules toiled along a tow path hauling lumber, coal, and hay. Passengers "got to know every inch of the way" at an average speed of four miles an hour. Today's voyagers may travel at about the same rate but can also tarry at nine lock parks, twenty historical sites, and at such inns as Richardson's Tavern in Bushmill Basin, the oldest on the canal.

WISCONSIN

Wisconsin has developed a unique series of twenty-three heritage road adventures. They range from an annotated trip along the Mississippi "road" to a Lake Michigan Circle tour and a Frank Lloyd Wright routing that marks the legacy of this native son who designed structures at forty-two sites in the state.

Typcially, the Lake Michigan Shoreline Tour #1 starts at Kenosha (named by the Potawatomi Indians for the resident pickerel) just north of the Wisconsin/Illinois border on the lake. A recommended stop here is the Kemper Center, a complex of mid-1800s historic buildings in a county park.

At Racine motorists can visit the Wind Point Lighthouse, built in 1880. It's one of the tallest still standing on the lake. Port Washington, once a major commercial fishing port, is now a

M. KELLER/SUPERSTOCK

center for "big game" fishing, where deepwater charter boats take anglers after chinook, coho salmon, or lake trout.

In and around Sheboygan, where Jack Benny learned to play the violin, the Indian Mound Park contains 18 original effigy burial grounds of the early Woodland Indians which are listed on the National Register of Historic Places.

In nearby Kohler, the American Club is (quixotically) also on the Register. It was built in 1918 as a dormitory for immigrant factory workers who were taught English in night school at company expense and who were provided these "hygienic surroundings." Today, the American Club is a five-star country inn; the workers' "plain washroom" is now a gourmet dining room.

WYOMING

Among the many protected natural environments in Wyoming, Yellowstone is the star. It is not only the world's first national park but also the largest. Sprawling across volcanic plateaus in the northwest corner of the state, Yellowstone contains more than two million acres of steaming geysers, crystalline lakes, thundering waterfalls, and panoramic vistas.

Its companion park is Grand Teton, called Teewinot (Many Pinnacles) by the Indians. The French trappers more graphically and romantically referred to the area – Grands Tetons means "large breasts" in French.

Just south is Jackson Hole, a stunning 48-

mile-long valley redolent of elk, the great American buffalo, bald eagles, and trumpeter swans. The town of Jackson, one of the West's major cultural centers, has been hosting visitors for more than a century, first as a rendezvous for fur trappers and now the center of a booming ski industry.

The nearby Spring Creek Resort, with its lodge-pole buildings, is a registered game refuge that offers a mountain "safari" led by a wildlife biologist—perfect for spotting moose, elk, and mule deer.

Healing mineral baths aren't found only in Europe. The world's largest hot spring is located in Big Springs, whose waters were given to the people of America by Chief Washakie of the Shoshones in 1896.

STEAMBOAT'S A'COMING

When Mark Twain wrote *Life on the Mississippi,* he immortalized the majestic river "rolling its mile-wide tide along, shining in the sun."

These days, the last two overnight passenger paddle wheelers in the country—the National Historic Landmark Delta Queen and the smaller Mississippi Queen—wind their way through Louisiana's Cajun country and the Atchafalaya River Basin, a wildlife refuge with some of the most graceful birds in the world.

Cruises may also traverse the wilderness region of the Ohio, Tennessee and Cumberland Rivers or sail northward to Saint Paul and the river's headwaters.

The upper Mississippi encompasses the largest wildlife refuge in the country. This is a migratory path for birds such as bald eagles, ducks, and even Arcitc whistling swans.

Oldtime river gamblers might envy such contemporary touches as fresh-cut flowers on dining room tables, a praline on a stateroom pillow, or afternoon tea on a two-tiered sundeck. Memories of the past are evoked by calliope concerts and ragtime music.

On board, "riverlorians" lecture on every subject from river folklore and legend to regional wildlife. Often the captain will order his crew to "choke a stump," or tie the boat to a tree, so passengers may explore the countryside. During spring, flowers and trees planted more than century ago still blossom in a profusion of color—pastel-shaded magnolias, brilliant azaleas, and dozens of species of roses in every hue.

For advertising information, contact Ted Dolan at (212) 599-5555.

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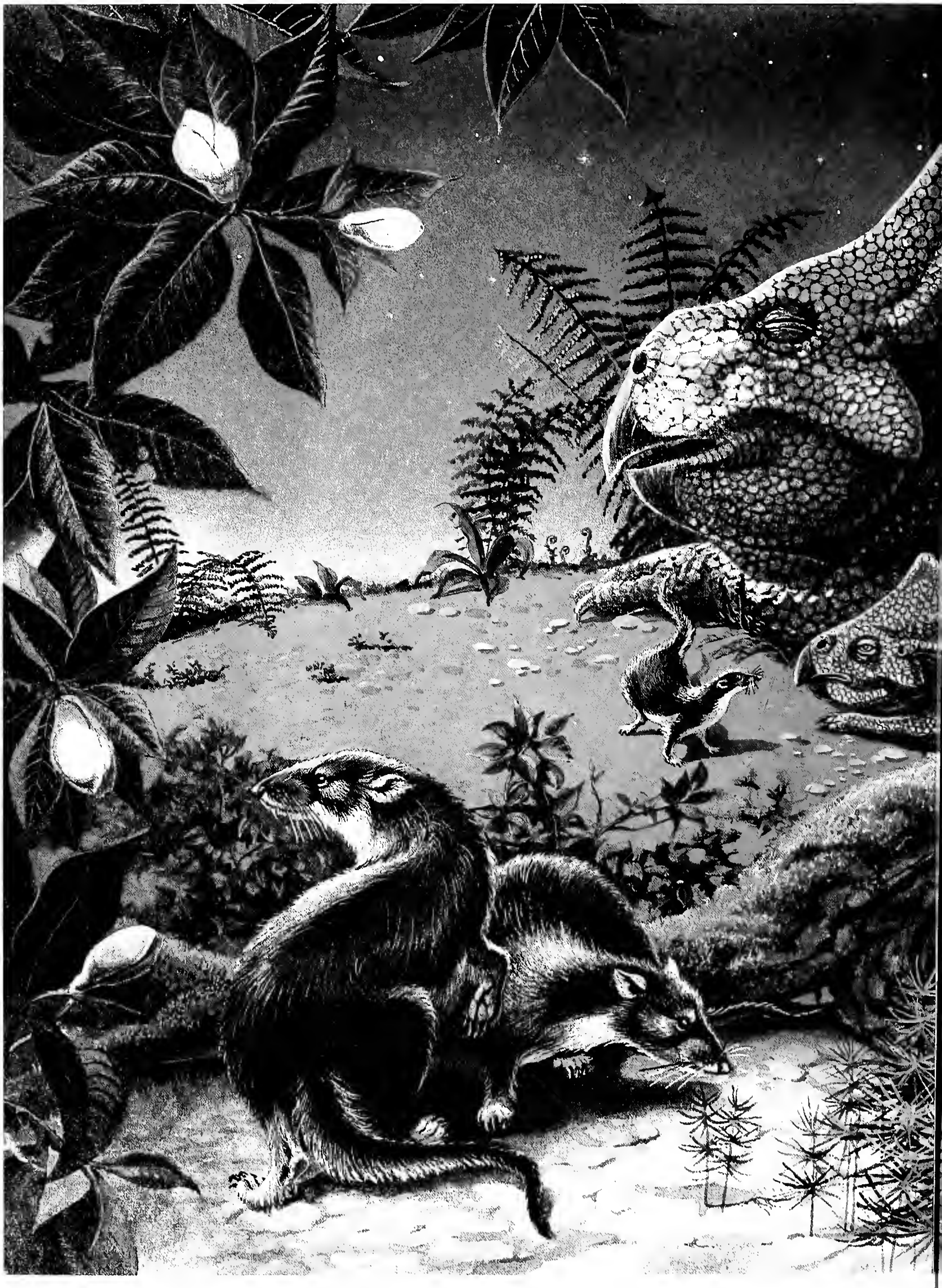
The Marvelous Mammalian Parade

Whether they were enormous, like the leaf-eating *Indricotherium* on the left (the largest land mammals ever) or tiny, most of the marchers in Earth's marvelous mammalian parade have fallen…are extinct. The animals that remain today (ourselves included) pale in comparison with the mélange of mammals of the past. But the survivors have overcome countless trials and accidents and squeezed through many keyholes over the last 200 million years. And they contain traces of their lost ancestors' many fascinating experiments in adaptation. The fossil record is little more than a few torn and scattered pages from the immense history book of mammals. But even these bits tell wondrous tales.

And, as shown in the articles and artistic reconstructions that follow, paleontologists continue to dig up new clues and to reinterpret the story of life on Earth.

This special section of *Natural History* was prepared by consulting editor Judy A. Rice.
Scientific consultant: Richard H. Tedford, chairman and curator, Department of Vertebrate Paleontology, American Museum of Natural History

Painting by Ely Kish



A Pocketful of Fossils

by Michael J. Novacek

Tugrugeen Shireh, a line of cliffs near an alkaline lake in the Gobi Desert of Mongolia, is not marked on any road map. Indeed, there are virtually no maps for this poorly charted region of the world. But over the past four summers, "Tugrug" has become a paleontological mecca for our joint team from the American Museum of Natural History in New York and the Mongolian Academy of Sciences. Not only have we found exquisitely preserved theropod dinosaurs, such as the agile flesh-eater *Velociraptor*, and the dinosaur-like bird *Mononykus* (*see* "New Limb on the Avian Family Tree," *Natural History*, September 1993), but we have also uncovered a wealth of tiny fossil skulls and skeletons, remains of mammals that lived in the shadows of the dinosaurs.

These mammal bones are preserved in Brazil-nut–sized concretions of hard, dark sandstone and iron-bearing minerals. These concretions continually erode from the soft, white sandstone that makes up the bulk of the Tugrug cliffs as they are battered by high winds and seasonal rainstorms, but they still provide a durable coating that protects the more fragile fossil bone underneath. Such conditions practically guarantee our discovery of more mammals every season, even on slopes we have crawled across many times before.

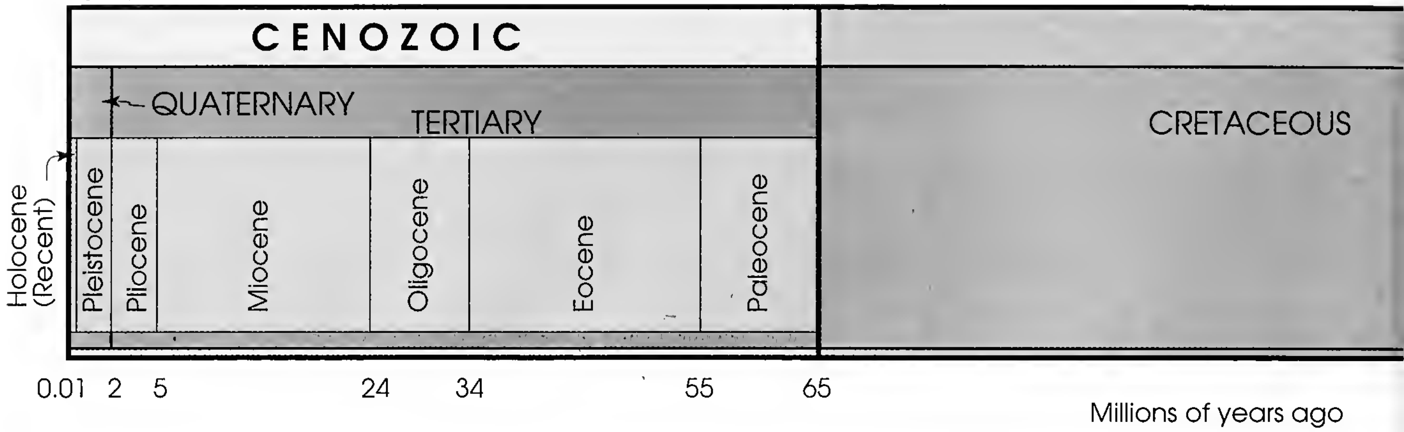
These fossils represent mammal communities that lived about eighty million years ago, near the end of the Mesozoic era, the Age of Dinosaurs. Although the following period, the Tertiary, is considered the Age of Mammals, the first two-thirds of the entire history of mammals was played out in the Mesozoic. Unlike most Mesozoic localities, which yield only isolated teeth or bits of jaws with teeth, Tugrug and other Gobi sites have given us fine skulls and entire skeletons. The fossils have provided critical clues to the evolutionary steps linking Mesozoic with modern mammals, as well as with their primitive vertebrate relatives. The more complete fossils have also revealed secrets of locomotion, feeding, sensory systems, and possible life styles of these ancient creatures.

The earliest mammals were the triconodonts, shrewlike creatures that appeared some 200 million years ago, during the Triassic period. They were tiny; an adult could snooze comfortably curled up in a teaspoon. Most likely, triconodonts laid eggs, as do the living duck-billed platypus and echidna. During the succeeding Jurassic and Cretaceous periods, the triconodonts were joined by other mammalian lineages. Although many of these Mesozoic "experiments" waned and died out before or at the time of dinosaur extinction, sixty-five million years ago, some survived and diversified into the modern mammals—animals as different as kangaroos, koalas, primates, bats, whales, elephants, and aardvarks.

Thus, mammals from Mesozoic sites reveal a biological empire in transition, with archaic creatures destined to go extinct before the Age of Mammals had even begun, living nose to nose (or fang to claw) with the precursors of modern mammals. Tugrug preserves a pastiche of mammal species. These cliffs do not contain the generally older triconodonts, but they have yielded abundant remains of a group known as the multituberculates. With their long, gnawing incisors; blade-

Some eighty million years ago, in the arid regions of central Asia, a family of Protoceratops *sleeps while rat-sized mammals known as* Deltatheridium *forage by night.* Deltatheridium, *which may have been a marsupial, or pouched mammal, may also have used its acute sense of hearing and smell to detect live prey such as insects or tiny lizards.*
Painting by Ely Kish

Diagrams by Joe LeMonnier



like, nut-cracking premolars; and broad, many-cusped molars, "multis" filled the role later taken over by rodents. They thrived in the Mesozoic and even persisted in respectable numbers for some fifteen million years after the demise of the dinosaurs. Their subsequent decrease in diversity and eventual extinction coincides with the rise of the mouselike and squirrel-like early rodents that were their main competitors.

While the most abundant skulls and skeletons at Tugrug are those of the possibly egg-laying multis, a few fossils from this site may belong to marsupials, or pouched mammals. The rat-sized *Deltatheridium*, for instance, had triangular-shaped molars much like those of living opossums. *Deltatheridium* and its close relatives are known only from the Cretaceous of central Asia. A great variety of Cretaceous marsupials inhabited North America, but their record is largely one of isolated teeth and partial jaws. *Deltatheridium* is known from some excellent skeletons; a nearly complete skeleton found at Tugrug in 1993 by American Museum preparator Amy Davidson may also prove to be *Deltatheridium*.

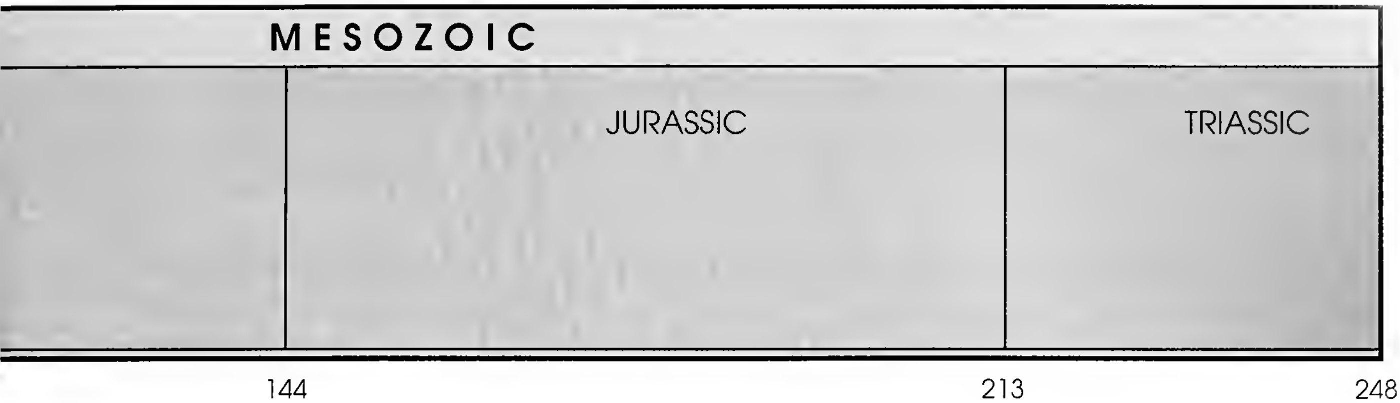
Of all the Mesozoic mammals from the Gobi, the *pièce de résistance* is the placental group. These were among the prizes of Roy Chapman Andrews's expeditions to the Gobi for the Museum in the 1920s. In the 1960s, joint Mongolian-Polish teams, and later Mongolian-Soviet teams, retrieved an impressive suite of placental skulls from new Gobi sites, including the Tugrug beds. These rare skulls are among the tiniest of Gobi fossils. They range from less than an inch to two inches long.

On the last day of our fieldwork at Tugrug in 1991, Museum postdoctoral research associate James Clark strolled into camp; from his pocket he extracted a small collecting bag containing a nodule carefully wrapped in toilet paper. He unraveled the paper to reveal a small skull, crudely outlined in the matrix. The snout region, however, was clearly delineated and was that of a placental animal. Months later, laboratory preparation confirmed our impression in the field that this nearly perfect skull belonged to *Zalambdalestes*, a species whose relationship with more modern placental orders greatly interests us. *Zalambdalestes* has long front incisors, a gap between the incisors and the anterior premolars, and long hind limbs, a combination of features reminiscent of rabbits. Indeed, my colleague Malcolm McKenna had a long-term hunch that *Zalambdalestes* was a granddaddy rabbit—a rather dramatic connection, since the first undoubted lagomorphs (the order to which rabbits and pikas belong) appear in the fossil record some twenty million years later (see "Early Relatives of Flopsy, Mopsy, and Cottontail," page 56). I was skeptical about Malcolm's idea, and we had a running debate on the matter. The Tugrug skull might determine the answer; it is certainly the finest known skull of *Zalambdalestes*, or indeed of any Mesozoic mammal from Mongolia. At this early stage of study, we have not resolved the rabbit origin problem, but we have already turned up some intriguing clues.

In collaboration with Tim Rose, of the University of Texas, we put our rat-sized *Zalambdalestes* skull under an industrial strength CAT-scan. The machine made 1,600 high-resolution "slices" in cross section, from which a computer program generated an animated sequence. Of course, fossils do not preserve soft tissue such as nerves and blood vessels, but various holes and canals in the skull indicate the pathways of these structures. From the CAT-scanned images, we could tell that the main pathway of the carotid artery ran in two branches on either side of the midline of the skull. This is a striking departure from the usual situation in placental mammals, in which the carotid crosses the base of the skull away from the midline and through the middle ear cavity. The artery's position in *Zalambdalestes* may reflect the problem of packing a great deal of equipment—in the form of nerves, blood vessels, small ear muscles, and middle ear bones—into the diminutive skulls of these mammals.

The carotid arteries are also known to take this middle route in some rabbits and rodents. Could this indicate affinity? At this stage the answer is not clear. The midline route could be a very primitive condition merely retained in rabbits and some rodents, but modified in most other modern placentals. It might also occur in other Mongolian species. We are eager to resolve this dilemma by casting a broader net of comparisons over fossil and living mammals and by CAT-scanning skulls of other Mongolian animals, such as *Kennalestes* and *Asioryctes*. These shrewlike forms are even smaller than *Zalambdalestes*, but we should be able to study details of their skulls with the high-intensity scanner.

Anatomical data on *Zalambdalestes* and other Mesozoic creatures dispel some myths about the roles of the earliest mammals. The popular scenario depicts a swarm of stealthy, sharp-toothed shrews puncturing and consuming dinosaur eggs. Doubtless some of these creatures were capable of such habits, but a wide range of feeding preferences existed, as demonstrated by the seed-eating, nut-cracking multis or the larger and possibly carnivorous beasts like *Deltatheridium*, which could have devoured tiny *Asioryctes* or the abundant lizards known from the Gobi's Cretaceous period. The portrait of a shrew that lived on and walked across the ground also fails to describe adequately the variety of movements that different species used in getting around their Mesozoic habitats. Highly mobile ankle joints and

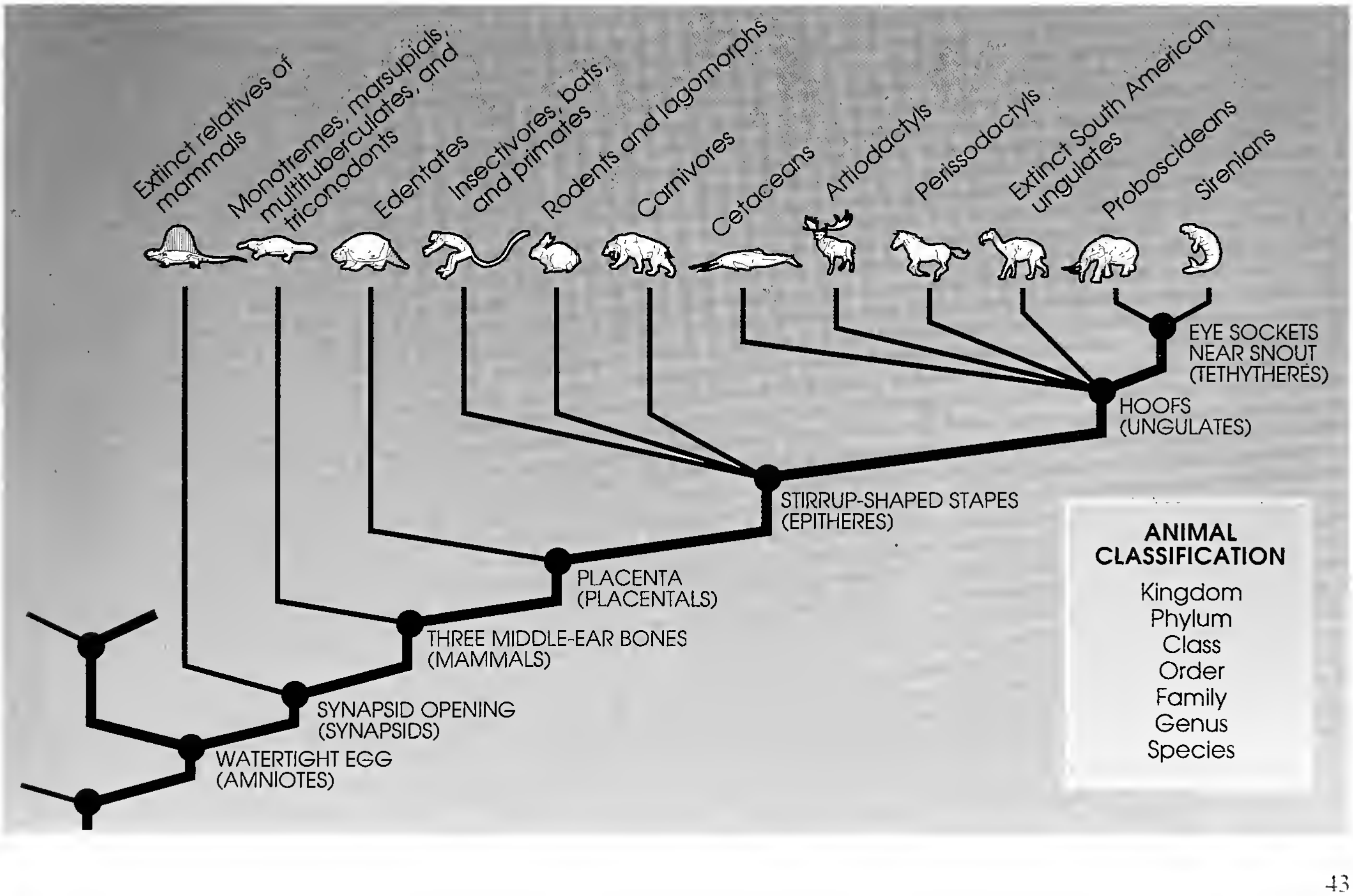


grasping digits suggest that some multis were adept at climbing trees. Long-limbed animals like *Zalambdalestes* were capable runners and leapers and might have dashed about like rabbits or jumping mice.

Yet what we know of the anatomy of Mesozoic mammals suggests they had a narrower adaptive range than their modern counterparts. Our Mesozoic antecedents are all small; certain triconodonts are comparable to the tiniest living shrews, and even the largest of the multis only reach the size of opossums. (Size itself puts limitations on adaptive virtuosity. An animal had to be sizable to eat the fishes and large lizards that survived beyond the end of the Cretaceous. In addition, larger mammals are capable of behaviors such as long-distance migration.) Mesozoic mammals were constrained not only by small size but also by a rather standardized and primitive sensory system. This observation is based on the study of endocasts, casts of the brain formed by the infilling of sandy matrix in fossil skulls. Endocasts of multis and other Mesozoic creatures show a relatively small cortical area with few, if any, folds, or sulci, suggesting limited intelligence. (In contrast, think of the intricate folding of the human brain, which greatly increases the cortical surface.)

By and large, Mesozoic mammals are all noses and ears. Their olfactory lobes, or smelling centers, are well developed in contrast to their optic regions, or vision centers. Lobes near the back of the brain that represent hearing centers are also well developed. Most of these mammals would seem to have had a keen sense of smell and acute, high-frequency hearing, but rather poor vision, like living shrews and hedgehogs. Presumably they were most active at night, a time when the senses of hearing and smell, as opposed to vision, are critical.

Our team will continue to crawl compulsively along the Tugrug slopes in order to piece together a more complete picture of the evolution and natural history of Mesozoic mammals. We are elated that an assortment of skeletons that can fit comfortably in a shoe box has helped illuminate the first two-thirds of mammal evolution. And this summer we hope to experience once again the elation of trundling down the cliffs of Tugrug with a pocketful of fossil skulls.



World Furry-weight Champions

by Michael Archer

Of the many kinds of extraordinary mammals that have come and gone, only three subclasses survive today: the egg-laying monotremes (platypuses and echidnas); the usually pouched marsupials (for example, opossums, honey possums, wombats, koalas, kangaroos, and bandicoots); and the unpouched placentals (such as rats, bats, elephants, and humans). Although not all marsupials have a pouch, this external nursery is one of the most commonly recognized features of the group. To anatomists, details of the reproductive system and remarkably early births (some only eleven days after fertilization) are even more distinctive features. Early births and an accessible pouch have given marsupials more control over the business of raising offspring. If times are tough, as they frequently are in the unpredictable deserts of Australia, a mother can decide whether or not to continue to invest precious energy in a pouched young. If the decision is against, she can "diapause" the young developing in the uterus, or if an offspring is suckling, she may reach into the pouch, remove the young from the nipple, and discard it— increasing the chances that she will live to breed again when conditions are better. This and other reproductive differences have probably distinguished marsupials from placentals for more than ninety million years, dating from the time when marsupials and placentals diverged from a common ancestor, probably somewhere in the dinosaur-ridden forests of North America.

Because many of Australia's marsupials, such as the koala, are cute and cuddly, as well as biologically different from our own group, they have attracted a lot of attention since their discovery in the 1700s—unfortunately, not all of it magnanimous. Most of us who have fallen in love with the marsupials of this continent have at one time or another suffered a condescending smile from a North American or English colleague. Some of these Northern Hemispherites think of marsupials as evolutionary casualties that should be shoe-horned into a single order—rather than the eleven in which they are currently placed. Placentals are dignified as Eutheria (meaning "good" mammals—because we are one of them), while marsupials are humiliated taxonomically as Metatheria (which means "between" mammals).

I've often wondered if marsupials were described in this way because they inspired feelings of subclass inadequacy in their pouchless placental classifiers—"pouch envy," to give the embarrassing condition a name. Placental males, however, have even more to worry about. As if nifty female pouches weren't threatening enough, the pendulous scrota of some male marsupials, such as the honey possum's, contain testicles that weigh in at 4

A rhino-sized marsupial Diprotodon *emerges from the undergrowth at far right, startling a threesome of giant "kangaroos." This painting from the 1920s was originally intended by artist Charles Knight to highlight* Palorchestes, *an animal known at the time from just a few bones. The beast was later found to be, not a kangaroo, but a vastly different, quadrupedal Australian herbivore. Although the depiction arose from a misconception, the magnificent Pleistocene bounders featured here still convey a sense of the strange kangaroos that once dominated the island continent.*
Painting by Charles R. Knight; courtesy of the Field Museum of Natural History, Neg. No. CK27T

percent of their body weight (human testes account for a mere 0.04 percent of the average male's weight). Honey possum spermatozoa, at 360 μm long, are also the largest in the whole class Mammalia. To further prick placental inadequacy, members of one subfamily of dasyurid marsupials have two decidedly impressive erectile organs, one in front of the other.

True, the less spectacularly equipped placentals do tend to dominate the Northern Hemisphere—today. But this was not always the case. In the last days of the dinosaurs, more kinds of marsupials than placentals existed, even in the Northern Hemisphere. Long after *T. rex* gasped its last, marsupials persisted in showing off their pouches and dangly bits in North America until about fifteen million years ago. Then after a brief period of inexplicable absence, they reinvaded this placental bastion from South America about one million years ago, strong-arming placentals all the way to Canada. In fact, marsupials have left their bones on every continent. Ice probably forced them out of Antarctica, but the reasons for their disappearances from Europe (by ten million years ago) and Asia and Africa (by thirty million years ago) remain a mystery.

Over the last hundred million years or so, the world's placentals have indeed produced an impressive array of pouchless orders. But on the single continent of Australia, some of the world's most distinctive mammals make their home, among them noolbengers, wambengers, and wombats. If we dip into Australia's fossil record, such as that tumbling out of the middle Tertiary sediments of Riversleigh, Queensland, even more distinctive groups abound, with 50 percent greater diversity at the family level than survives today. Remarkable marsupials have similarly emerged from the fossil record of South America, once home to the parrot-faced groeberiids, leaping argyrolagids, tusked bonapartheriids, and grizzly-sized borhyaenids that every edible placental in the place called "Sir." While confined for the most part to the Southern Hemisphere today, marsupials still exhibit a range of diversity nearly as spectacular as that of the world's placentals.

The curious events of South America are further humbling to the placental ego. Although both marsupials and placentals arrived there from North America sometime between seventy and sixty-three million years ago, the placentals became the highly edible mammalian herbivores of that land. In contrast, the marsupials became the small- to giant-sized carnivores, roles they held against almost all comers until they were shouldered a bit to one side by giant, meat-sucking phorusrhacid birds (some of which had skulls nearly three feet in length). Admittedly, one group of placental carnivores did manage to sneak in about eight million years ago—the raccoon family, which persists today as kinkajous, olingos, and coatis. The marsupial saber-toothed "lions" may also have lost out in competition with invading placental saber-toothed lions about two million years ago. But overall, placental chauvinists can take little solace from the history of South America.

For centuries after the discovery of Australian marsupials, biogeographers assumed that the failure of placentals to dominate this island continent must have had to do with Australia's history of isola-

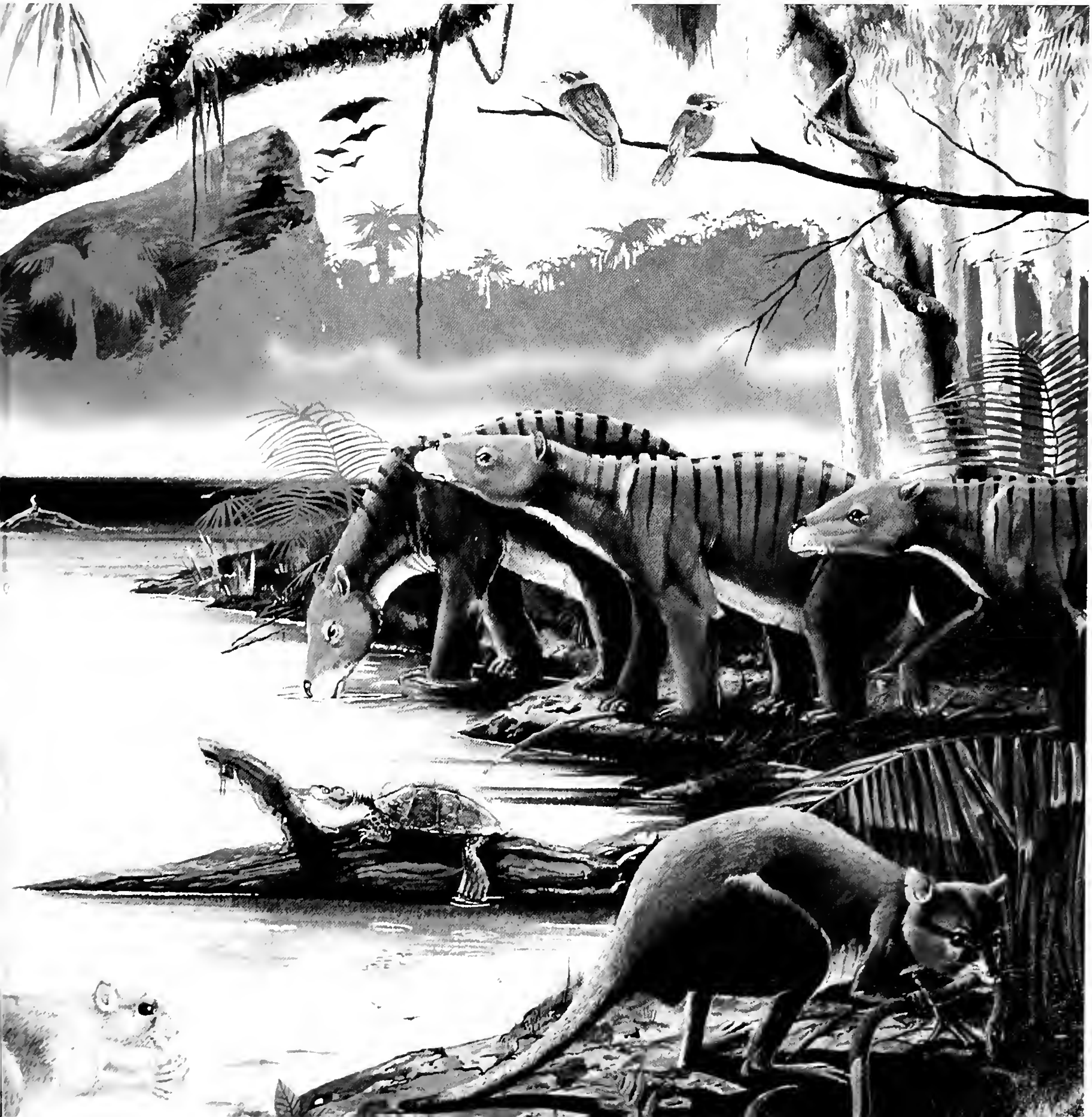
Twenty million years ago, the dense, warm rain forests of what is now Queensland were home to a strange menagerie of furry, pouched, feathered, and scaly beasts, among them, marsupial lions, giant snakes, and flesh-eating kangaroos.
Painting by Jim Reece

tion: Somehow marsupials reached Australia from South America and only managed to hold the territory because Australia broke free from east Antarctica (to which it had been attached as part of Gondwana), presumably moments before the hordes of competitively superior placentals came to a screeching halt at the new, still-crumbling continental edge.

Unfortunately, recent discoveries provide little support for this view. In 1983, Henk Godthelp and I filled three gunny sacks with fifty-five-million-year-old clay from the town of Murgon in Queensland. When this clay was mud, Australia was still part of Gondwana with land connections, via Antarctica and South America, to the Northern Hemisphere. After drying and washing the clay in the lab, we found to our delight Australia's oldest—by twenty-five million years—marsupial, bat, snake, frog, and bird bones. But the biggest shock was a distinctive tooth that resembled those of placental condylarths, the group that gave rise to a wide variety of placental orders on other continents including South America.

We concluded that marsupials and placentals were both present in Australia between seventy and fifty-five million years ago. But then, contrary to the expectations of some paleontologists, the marsupials ran the placentals out of town.

We placentals should also recall that doe-eyed Australian kangaroos, introduced last century to the remaining wild places of England and Germany, have since toughed out ferocious placental competition and Europe's worst winters to hoist the flag of "pouched and pendulous" on those lands. Like eucalyptus and wattle trees, these rampaging Australians have done much to dispel the myth that Australia is a sanctuary of competitively inferior bits of biological history. Marsupials may seem unlikely contenders in the world furry-weight title, but when it comes to their going a round or two with placentals, you should probably put at least half your money in the pouch for safekeeping.



Mammals Eggstraordinaire

by Michael Archer

The first duck-billed platypus to set webbed foot in Europe arrived in 1798 at the Literary and Philosophical Society of Newcastle on Tyne, England—pickled in a wooden cask. It had been sent by the governor of New South Wales, His Excellency Mr. John Hunter, who had watched a "native" spear this "animal of the mole kind" in the Hawkesbury River. Unfortunately, the courier who carried the cask into the Society's rooms on her head was nearly suffocated when the bottom of the crate caved in, and the cask and its contents dropped over her head. An English historian, commenting later about the event and the wretched woman, mused that "apart from her physical nausea one can picture her mental horror on seeing a strange creature, half bird, half beast, lying at her feet."

The unfortunate accident, however, had an instructive aspect; like the defunct cask, the platypus exhibited to the gentlemen of the Society a most unexpected opening. The animal's cloaca not only voids refuse from the intestinal tract and bladder but also ushers into the world the most remarkable production of the platypus—eggs. In contrast, placental mammals have up to three external openings, two used for excretion and one (in females) dedicated to reproduction. The members of the order Monotremata—platypuses and echidnas, or spiny anteaters—are the only living mammals that reproduce by laying eggs. This distinction, in combination with such seemingly archaic features as the unusual structure of the shoulder girdle, has led to a common and not unfair view that monotremes are the most "primitive" order of living mammals. But add to these so-called primitive features the electric sensors in the bill that can detect the muscular activity of fleeing prey, and you have a very odd blend of archaic and super-specialized structures.

Arguments about the evolutionary relationships of monotremes have run the gamut from the bizarre (cousins of turtles) to the implausible (degenerate marsupials) to the possible (direct descendants of Mesozoic eupantotheres) and the tantalizing (surviving mammallike reptiles). The best bets at the moment are the last two: monotremes may be either long-lasting descendants of eupantotheres (tiny mammals common in Europe and in the Americas during Mesozoic times) or mammallike reptiles that have independently acquired mammalian hallmarks, such as three middle ear bones.

Part of the difficulty in working out the relationships of monotremes has been their lack of well-formed teeth. Platypuses gum their food to death, their grossly degenerate teeth being lost early in life. Echidnas, having lost all trace of teeth, tongue-slurp worms, ants, and termites. Thus, comparisons with extinct mammals, which are often known *only* from fossil teeth, are difficult to make. After a brave attempt to make sense of the structure of the platypuses' vestigial teeth, mammalogist George Gaylord Simpson concluded in 1929 that whatever monotremes were, they were something "quite distinct" from all other groups of mammals.

Little further light was shed on the origins of monotremes until 1971, when two discoveries were made in South Australia. In the Tirari Desert, Mike Woodburne, of the University of California at Riverside, and I found a fully formed fossil tooth of an early Miocene platypus (later named *Obdurodon insignis*—"significant lasting tooth"). That same year, Dick Tedford, of the American Museum of Natural History, and his colleagues unearthed another platypus tooth in a fossil deposit near Lake Frome. But it was not until 1984, when our research group at the University of New South Wales found a whole skull and most of the teeth of a fossil platypus some fifteen million years old at Riversleigh, Queensland, that we at last had the first complete and well-formed dentition of an adult monotreme.

Hot on the heels of this discovery came another. Fossil fish expert Alex Ritchie, of the Australian Museum in Sydney, was mulling over a collection of opalized early Cretaceous fossils (about 120 million years old) gathered from Lightning Ridge, New South Wales, by the Galman brothers, two amateur collectors. Among the brilliantly flashing specimens, he spotted a little jaw fragment sporting three gemlike teeth. Suspecting that it belonged to a mammal but not sure what kind, he suggested that I have a look. In their basic structure, the three molars in this jaw were so similar to the teeth we were examining from Riversleigh that we had no doubt that this, Australia's earliest known Mesozoic mammal, was a monotreme. We named the creature *Steropodon galmani*, "Galman's lightning tooth." Not only was this the oldest mammal so far found in Australia but its discovery sextupled the known age of monotremes.

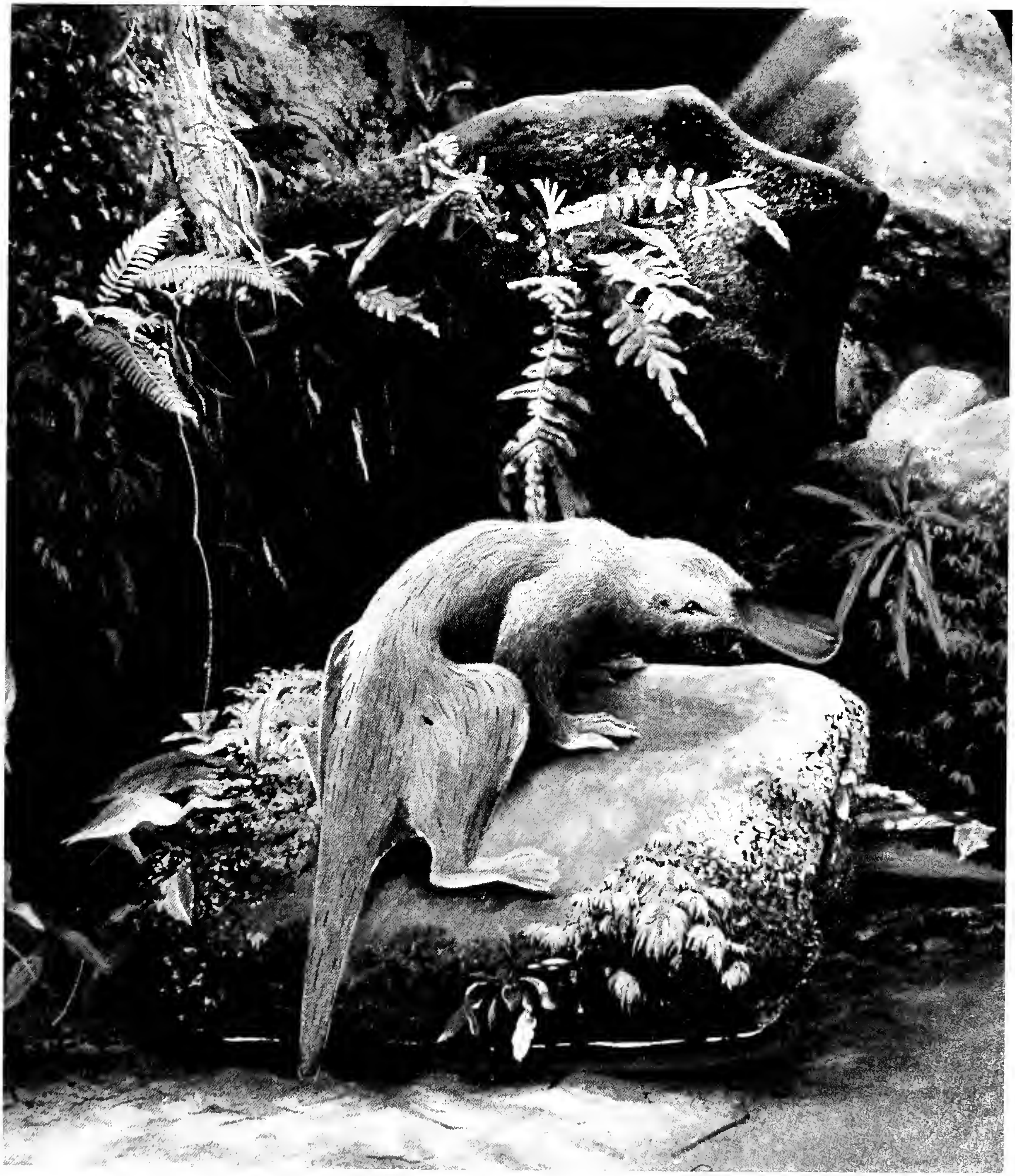
The surprises continued. In 1991 Rosendo Pascual, of the Museo de La Plata in Argentina, wrote to Mike Augee, who was organizing a symposium on the biology of monotremes, telling of a strange tooth he and his team had collected from Patagonia, in southern Argentina, at a site that was sixty-one to sixty-three million years old. Although much older, it resembled the teeth that had been described from the Tirari Desert. After Rosendo sent a photograph, the Australian Geographic Society, the Royal Zoological Society of New South Wales, the Riversleigh Society, and the University of New South Wales quickly offered to fly him and his tantalizing tooth to Sydney. When he arrived and we set his find alongside the teeth from Riversleigh, the only comments were gasps. The two forms were almost identical despite a separation of nearly forty million years and three continents.

The Patagonian platypus, which could be called nothing else in view of its striking similarity to Australian fossil platypuses, was named *Monotrematum sudamericanum*, "the South American monotreme." The next year, supported by the Australian Geographic Society and

In 1984, the fifteen-million-year-old skull and teeth of a platypus came to light in the rich fossil beds of Riversleigh in Queensland, Australia. In this reconstruction, the ancient platypus Obdurodon dicksoni *basks on a mossy rock in its lush rain forest home.*
Painting by Jeanette Muirhead

Paddy Pallins of Sydney, we joined Rosendo's team in an effort to find more of this expatriate platypus and, delightfully, unearthed two more teeth in the same windswept area as the first. Although a bit of a blow to Australian pride, we now have to allow that platypuses, those biological paradigms of the island continent, once waddled, swam, and probably electrolocated their way across the then-united lands of South America, Antarctica, and Australia.

What light do these spectacular fossils shed on the mystery of monotreme relationships? Unfortunately and intriguingly, not as much as we would like. If by 120 million years ago (the age of the Lightning Ridge platypus), monotremes were already distinct as a group, we should be searching the stream deposits of Jurassic Park, looking for older, more "primitive" members of this group. But where? Considering the antiquity of monotremes in Australia and the intermittent connections between South and North America, could a monotreme bill or beak be jutting out of a Jurassic cliff somewhere in the United States? Considering the rush of unexpected monotreme discoveries in the last decade, we might be wise to wait and see.



Successful in Spite of Themselves

by S. David Webb

Our team of scuba divers had been working the Withlacoochee River in central Florida for two weeks when I spotted the hand-sized jaw with its strange, warped teeth in a dark depression below the main channel. Other fossils gathered from this rich green clay pocket thirty feet below the surface indicated a deposition date of about seven million years ago. The identity of the animal to which the teeth belonged was unmistakable: the last of the four teeth in the jaw had a long figure-eight crown and very tall sides, diagnostic features of a mylodont sloth. An hour later, nearing the end of my air supply, I fanned the clay away from a mandible about the size of a human's. It contained the nearly square-crowned teeth and elongate chin "spout" of a small megalonychid sloth. These finds astonished me. Two kinds of sloths had apparently lived in Florida in the mid-Miocene.

While plenty of sloth remains had been found at La Brea and other Pleistocene sites, the Florida fossils were at least three times as old as the earliest Pleistocene sloths. Two million years ago, many South American groups had already entered North America via the Panamanian land bridge in a mass movement known as the Great American Interchange (*see* page

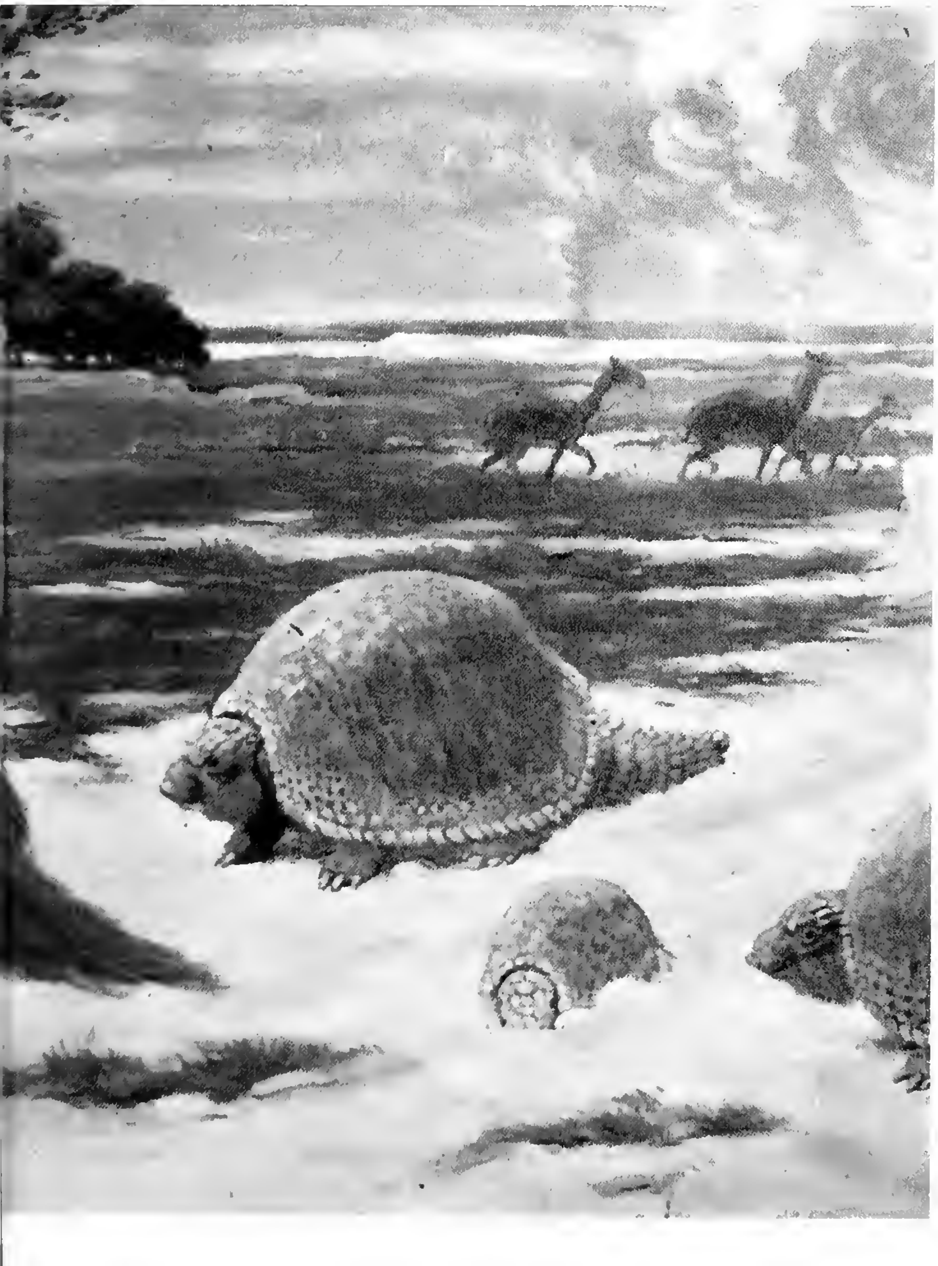
52). These two sloths had reached Florida at least five million years ahead of this pack, a finding now confirmed from fossils at other rare sites in Oklahoma, New Mexico, and California. I like to think of the Withlacoochee sloths as the "heralds," in contrast to the "legions," of animals that later immigrated to North America.

The megalonychid sloth I found in the Withlacoochee River was an unusually small species, but a later member of the family was the ox-sized *Megalonyx*, which pushed north and eventually reached Alaska. The real giant of the sloth tribe was the elephant-sized *Eremotherium,* whose remains are found most abundantly at Daytona Beach, Florida, but which has also been discovered north to New Jersey. These animals' long, curved claws were at first thought to be evidence that they were lionlike carnivores. But in 1853, Joseph Leidy, the father of vertebrate paleontology in North America, realized that both species had used their claws to gather edible leaves, twigs, and branches. This was reinforced by his recognition that the extinct ground sloths were related to the living tree sloths of South America. Recent studies have shown that modern three-toed tree sloths are more closely related to *Eremotherium,* and that living two-toed tree sloths share their ancestry with *Megalonyx*. Throughout its long, successful history, the sloth family tree has produced both small arboreal and large terrestrial branches.

Sloths, armadillos, and anteaters, along with the extinct glyptodonts—armored creatures superficially resembling tortoises more than other mammals—make up the most peculiar and the most primitive group of placental mammals, the edentates, also known as the xenarthrans. The latter name, meaning "strange joint," refers to their unusual backbones. In most mammals, the paired overlapping surfaces that prevent dislocation between vertebrae are flat or faintly curved, but in these animals, the surfaces are scrolled into an elaborate set of interlocking ridges and valleys. In glyptodonts, as well as in modern armadillos, such infrastructure supported the heavy carapace above the hindquarters (in full-grown glyptodonts, the shell weighed up to 200 pounds). In sloths and anteaters, the trait has no obvious utility, but suggests that the animals are descended from shell-bearing ancestors. A shelled ancestry is also supported by the presence of a sheet of small, overlapping bony scales, a kind of chain mail, in the skin of many mylodont and some megatheriid sloths.

Edentates, the ordinal name of this curious assemblage of animals, is a misnomer, implying that they lack teeth. However, only anteaters, with their long, tubular snouts and sticky tongues, are truly toothless. The other groups of edentates have teeth but lack enamel, distinguishing them from other orders of mammals, in which enamel-crowned teeth are a hallmark. The exception that proves the rule is the oldest armadillo jaw, which bears ten peglike teeth, typical of many later, insect-grubbing armadillos, except that each tooth retains a thin enamel coat on its sides. (The oldest-known edentates are armadillos and glyptodonts found near the Rio de Janeiro airport, in a sinkhole filled with sediments about sixty million years old.)

If a scale-covered carapace were not unmammalian enough, modern (and presumably extinct) edentates have less ability to thermoregulate than any other order of warm-blooded vertebrates. In addition, armadillos have a "dumbbell bone" near



Herbivorous edentates reached giant proportions in their native South America; ground sloths, such as the twenty-two-foot-long Megatherium, *browsed placidly from trees by rising to a tripod stance with their tails as buttresses. Their fellow edentates, the tanklike glyptodonts, had 200-pound carapaces that were sixty feet in diameter.*

Painting by Charles R. Knight; AMNH

The Great American Interchange

More than twenty million years ago, huge pieces of the earth's crust, moving to the slow rhythms of continental drift, encroached upon the western margins of the American continents, pushing up the mountain ranges that still form the "backbone of the Americas" from Alaska to Tierra del Fuego. These global forces were also responsible for forging, two to three million years ago, a land bridge in Panama between North and South America. To creatures that could not swim or fly, the bridge opened continent-sized new realms and unleashed hordes of competitors and predators.

In a movement known as the Great American Interchange, land animals expanded their ranges north and south in one of the greatest-known minglings of distinct continental faunas in the earth's history. A dozen land mammal families from South America ranged northward through the tropics into temperate North America. Nearly half were edentates—mainly sloths, but also armadillos, glyptodonts, and anteaters. Other kinds of animals that made the trek north included porcupines, the giant aquatic capybaras, opossums, and the now-extinct, rhino-sized plant eaters known as toxodonts.

North America's emigrants were even more varied. South America had previously hosted no carnivores. The indigenous hoofed animals and rodents had been nearly free of predation. During the Interchange, raccoons, weasels, dogs, bears and cats, including sabertooths, entered the continent. The hoofed contingent included mastodonts, tapirs, horses, peccaries, llamas, and deer. Rabbits and various rodent families also seized new opportunities in the vast lands south of the equator. Most of the newcomers spread and diversified, many traversing the tropics and following the high Andean route before reaching south temperate lands.

The most successful of the northerners by any measure were the cricetid rodents, or New World mice. Within two million years, they produced some fifty new genera, bursting into arboreal and terrestrial settings, sylvan and pastoral habitats, lowlands and uplands, and even producing one offshoot that specializes in fishing in Andean streams.

Fully half of the land mammal genera that now live in South America came by way of the Panama land bridge during the Interchange. In contrast, only three genera from South America still survive in temperate North America—the porcupine, opossum, and armadillo.—*S. D. W.*

The formation of the Panama land bridge opened the way for two-way traffic between the American continents. In this scene of Florida some two and a half million years ago, a sloth known as Glossotherium; *an armadillo; a large, flightless ground bird; and aquatic capybaras—all immigrants—share a cypress swamp with native North American beavers.*
Painting by Ely Kish

the tip of their nose. Useful in burrowing for food and shelter, this extra bone, called a prevomer, is retained from the ancient mammallike reptiles. These traits, as well as molecular comparisons, indicate that the edentates were the first branch from the base of the placental mammal tree.

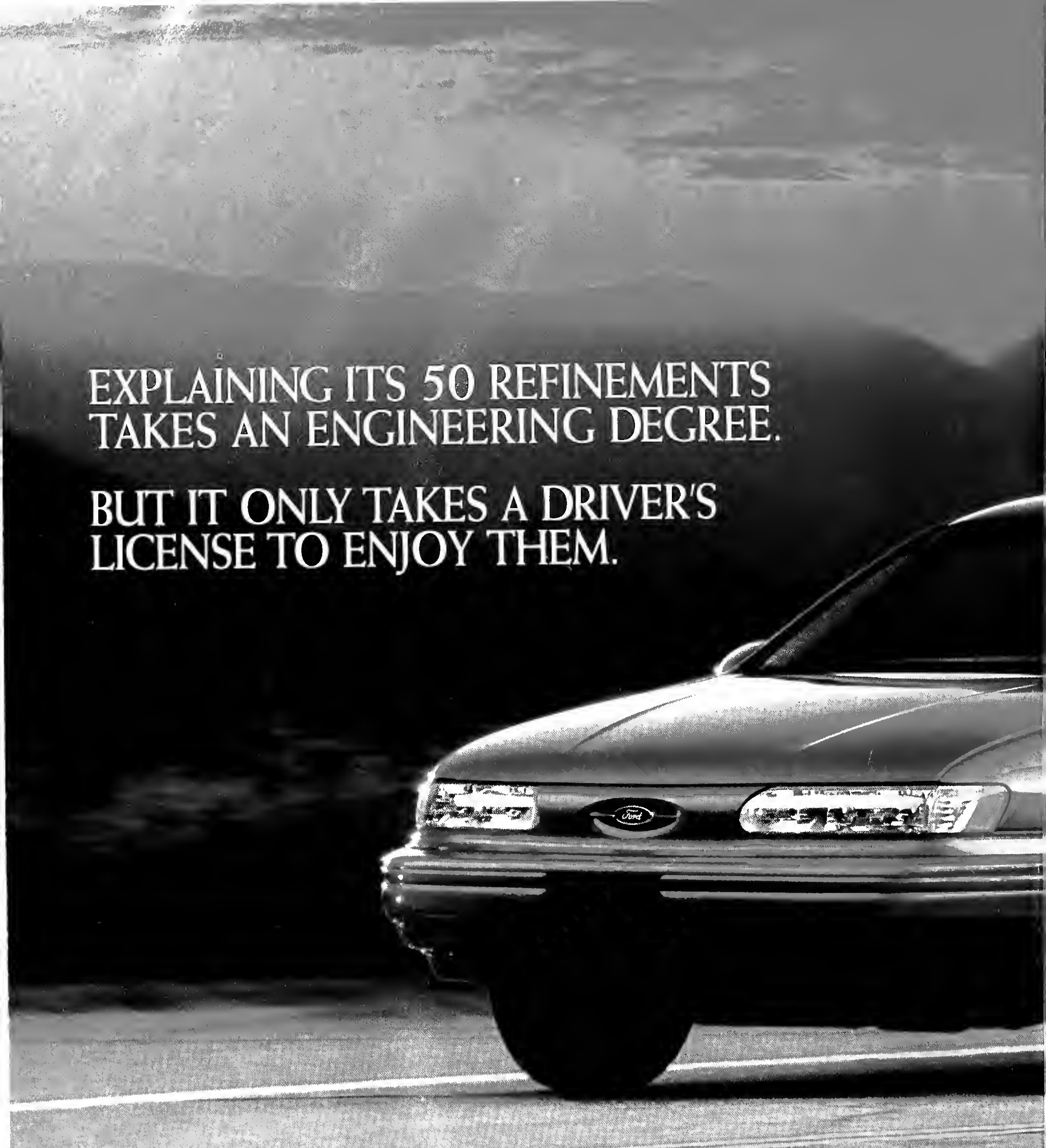
Sloths arose from armadillo stock, but starting more than thirty million years ago, they made an extraordinary switch in adaptive strategy, becoming plant-eating giants. They played as important a role as the native South American ungulates, rivaling these other large herbivores, such as the now-extinct toxodonts, in abundance and diversity. Their success as herbivores is quite remarkable when one considers their descent from short-legged, armor-encased burrowers, with shallow, feebly muscled jaws and peglike teeth with no enamel. How could sloths even begin to compete with fleet ungulates whose deep jaws and elaborately enameled teeth were already well adapted to processing coarse vegetation?

Perhaps part of the explanation for the improbable success of herbivorous edentates was that South America had no efficient carnivores to take advantage of the sloths' lack of speed. Evolution does not produce perfection in all departments; rather, like politics, it is the art of the possible. South America, with its great tropical girth, offered vast opportunities for beasts that could feed readily and live well on low-grade fodder. With no need for speed, sloths had the advantage of low metabolism, and they easily converted their powerful digging claws and feet into leaf- and branch-stripping devices. Their hind feet became twisted, so that the claws faced inward, while the outer side faced the ground. This allowed the smaller sloths to climb trees and the bigger ones to clear their claws from the ground. With the aid of a powerful tail, they rose up on a solid tripod base to feed from trees. A set of fossilized sloth tracks found in the prison

yard of the Nevada State Penitentiary in Carson City shows just how sloths ambulated on huge, splayed-out feet.

By making just a few modifications in their unimpressive teeth, sloths were able to chew vast quantities of leaves. (Glyptodonts, too, with some orthodontia, became efficient large herbivores.) Despite their lack of enamel, sloths developed tall-crowned, elaborately folded teeth with tracts of a hard substance called vitrodentine to supplement the soft dentine. Although sloth teeth wore down faster than enameled teeth, they compensated by growing continuously throughout the animal's life. The jaws deepened, and the cheek bones expanded to support a complex set of chewing muscles. In short, sloths cobbled together the necessary biological machinery to overcome the inadequacies of their armadilloid heritage.

All of the ground sloths, and the glyptodonts as well, slid into extinction just over 10,000 years ago in North and South America. The climate had changed, and bands of human hunters had swept across the Bering Strait and throughout the New World. At about the same time, most of the hemisphere's other large herbivores disappeared. When the first *Megalonyx* was unearthed at Big Bone Lick on the Kentucky frontier some 180 years ago, its dense, iron-stained bones were brought to the White House, where President Jefferson, an avid amateur paleontologist, studied them. When Jefferson commissioned Lewis and Clark to explore the western territories, he also asked them to make a careful search for living *Megalonyx*. If not for the deadly combination of climate change and overhunting of the creatures by Paleo-Indians a few thousand years earlier, Lewis and Clark might have been successful. Instead, sloths are now discovered and studied mainly by paleontologists. Today only two kinds of tree sloths exist, diminutive tropical survivors of their big, far-ranging, extinct brothers.



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Early Relatives of Flopsy, Mopsy, and Cottontail

by Malcolm C. McKenna

Paleontology is a combination of good science and good luck. Most of the time, we paleontologists work at determining the meaning of what has already been brought to a museum's storage cases. As a new field season approaches, however, we head for distant parts of the planet in hopes of finding something important that will improve our understanding of geological history and biological evolution. Thus, in June of 1991, a joint Mongolian-American expedition, including two Mongolian paleontologists and six of us from the American Museum of Natural History, headed for Naran Bulak ("Sunny Spring"), a remote oasis in the otherwise sere Gobi Desert of southwestern Mongolia.

Due to Naran Bulak's coveted water—and because many eighty-million-year-old dinosaurs have been found in late Cretaceous sediments nearby—it has become an important base for deeper paleontological exploration of the Gobi. The area's Mesozoic dinosaurs are about the same age as those at Mongolia's famous Flaming Cliffs—where, in the 1920s, the American Museum's own Mongolian expeditions first found dinosaur eggs, dinosaur skeletons such as those of *Protoceratops* and *Velociraptor* (of cinematic fame), and skulls and jaws of early mammals such as *Zalambdalestes* (*see* "A Pocketful of Fossils," page 40).

Since the late 1940s, many expeditions from scientific institutions in Russia, Poland, and Mongolia, as well as our own from New York, have used Naran Bulak as a center from which to radiate in search of extinct remains of late Cretaceous dinosaurs, lizards, birds, crocodiles, turtles, and mammals. Our main interest in 1991, like that of most of our predecessors, was to explore the Cretaceous outcrops reachable from Naran Bulak. But equally important was the presence of younger fossils in the multicolored Cenozoic sands and clays overlying the dinosaur beds, where we unexpectedly had a stroke of good luck, practically within shouting distance of camp, that set us off on a new path of discovery.

One day, research fellow James Clark decided to prospect for fossils by following a fifty-five-million-year-old Eocene band of red early Cenozoic sediments that extended southeast and east of camp. The red layer rested on slightly older white-colored sands, so we could easily trace the boundary through the badland exposures. Clark was almost immediately rewarded by a hard nodule of stone that he found a few feet above the base of the red layer. It contained a complete skull and jaws of what at first appeared to be some sort of rodent. The fossil was mostly encased inside a limey nodule with only a couple of front teeth protruding, but the nodule was vaguely skull-shaped, which was what had attracted Clark's attention. Being an expert anatomist, he could almost see the rest of the specimen through its coating of limey silt.

When a paleontologist finds and collects a fossil, the next thing he or she does (after wrapping it up and recording the details of its location on a map and its position in the rocks) is to follow the same layer of rock that produced it wherever the layer can be seen. We often do this on our hands and knees. Jim was not lucky again that day, but in the ensuing days Priscilla McKenna and I diligently continued the search several miles to the east. We knew where to look: just a few feet above the base of the Eocene red layer. We had only to follow the red and white boundary wherever it went and then prospect a few feet above it. We also knew what to look for: not so much for actual bones but rather for limey rock nodules that looked vaguely skull- or bone-shaped, distributed in the red beds like raisins in raisin bread. After much effort in these areas both east and west of Naran Bulak, we eventually found about fifty nodules with skulls or other bones inside. Most of the specimens were skulls and jaws of adult animals, but juveniles with milk teeth were also present. We even have a curled-up, articulated partial skeleton that looks as if the animal had died in a burrow. All these specimens in their stony coatings had been completely overlooked by our many predecessors who had not had our expedition's brand of educated luck.

Our first impression—that the specimens belonged to some unknown member of the Rodentia, the varied order that includes mice, rats, beavers, and porcupines—was based on what we could see of the front teeth, often the only part visible at the surface of our rock nodules. They looked like rodent incisors.

When we returned to New York, our attention was riveted by the dinosaurs, birds, and lizards that we had found in the late Cretaceous sediments far older than the Eocene red beds. But finally, we found time to begin removing some of the rock from our red bed "rodents." We have been able to dissolve some of the rock nodules in weak acetic acid, leaving the specimens inside more or less intact. We also have used sharp needles and other tools to get at the specimens. Gradually, some skulls and jaws have emerged. However, behind the gnawing front pair of their rodentlike incisors were some surprises.

A second pair of incisors bolstered the front ones, not only in the upper teeth but also in the lower jaw. Rabbits, hares, and their short-eared relatives the pikas, collectively known as lagomorphs, have a second upper incisor pair, just behind the main pair—but rodents do not. Modern lagomorphs, as well as all known rodents, have only one incisor in each lower jaw; because our Naran Bulak specimens still had two on each side, they are more primitive. (Still more primitive mammals have even more sets of incisors.) Thus, in the early Eocene red beds at Naran Bulak, we had found, not rodents, but early and primitive Asian fossil lagomorph skulls and bones, about twenty million years older than any previously well-known lagomorph skulls.

Members of the mammalian order Lagomorpha are well known from many fine specimens, including complete skulls and skeletons of *Palaeolagus,* dating back to about thirty-five million years or so ago.

But since then, they haven't changed much compared with the evolutionary changes that must have occurred earlier. Paleontologists have had only a few glimpses of the jaws and teeth, often of just a few isolated teeth, of earlier specimens. Thus we have had no clear picture of what whole skulls or whole skeletons looked like in those early days of lagomorph history. *Palaeolagus* is much more like modern lagomorphs than like the animals we began to find in 1991 near Naran Bulak. For example, since about thirty-five million years ago, rabbits, hares, and pikas have had high, prismatic, rootless cheek-teeth, used for grinding up vegetation with a side-to-side motion quite different from that of primitive mammals or rodents.

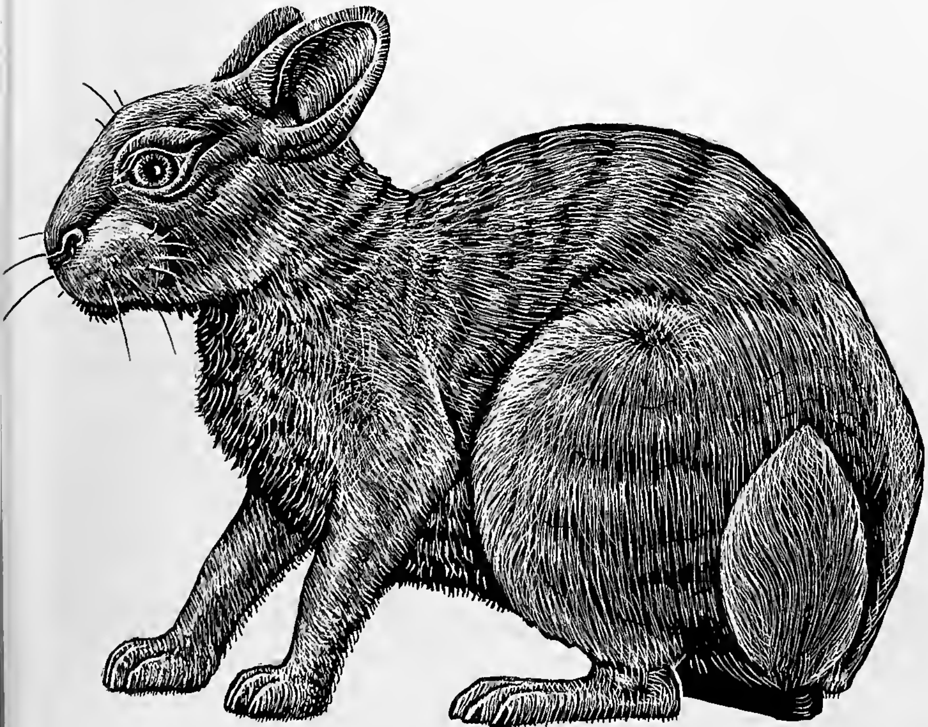
The lagomorph pattern of folded enamel and dentine on the tops of the high cheek-tooth crowns is unique, and its origin has puzzled generations of paleontologists. Although theories abound, no one has been able to figure out exactly how the lagomorphs' pattern of cusps and valleys originated from the simpler triangular cusp pattern of more primitive mammals. But the teeth of our Naran Bulak specimens are not high-crowned, folded, or rootless like the cheek-teeth of advanced lagomorphs. Rather, the Naran Bulak animals have cheek-teeth that are rooted and low-crowned, with a triangular cusp pattern that is little modified, even though the enamel on the inner side of the upper teeth sometimes enters partway into a tooth socket. Their low enamel crowns have a clear dental pattern that can be related to that of many primitive mammals, as well as to the highly modified design of advanced lagomorphs. We now know how the dentition of lagomorphs has changed from a structure like that of primitive mammals to the unique pattern shown by modern representatives.

Other lagomorph features are shared by our Naran Bulak finds. For instance, the joint between the jaw and the skull is high on the side of the skull, as in later lagomorphs. Another feature shared with later lagomorphs is the projection of a sliver of the frontal bone of the skull roof forward onto the side of the snout, between the main bones on the face (maxillary) and snout (premaxillary). The incisive foramina, the holes in the front of the palate behind the two pairs of upper incisors, are very elongated, another telltale clue of linkage with more modern lagomorphs. In still another traditionally lucky feature, the rabbit's foot, the anatomy of the ankle in our specimens is far more lagomorphlike than rodentlike, although we don't know whether the Naran Bulak animals hopped.

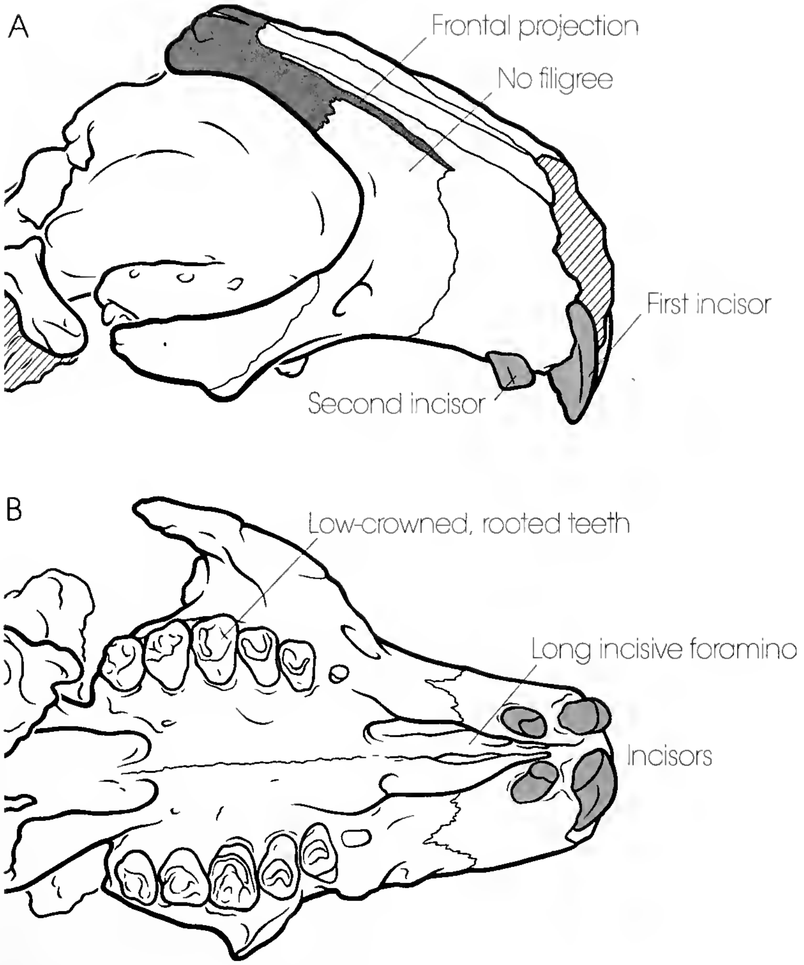
Other characteristics of our Naran Bulak fossil lagomorphs are primitive, not yet modified from features shared with other (nonlagomorph) mammals of the time. The typical flexure of the snout and the shortening of the palate of modern lagomorphs' skulls are not present in our specimens, nor are certain changes in the bony parts of the ear region that took place closer to thirty-five million years ago. The lacy filigree of bone on the sides of the snout in modern rabbits is only faintly suggested by some tiny openings in the Naran Bulak lagomorphs. The upper cheek-teeth in our creatures still had fairly large roots but these are much reduced in size in some and wholly lost by other, later lagomorphs. These technical anatomical details help to establish our Naran Bulak fossils as primitive members of the mammalian order Lagomorpha, and they also show that different parts of organisms can evolve at different rates. Thus the long incisive foramina and upper incisor distribution evolved long before the palate shortened or the molars became prismatic.

But the evolutionary trail does not end here. The teeth in our Naran Bulak skulls are closely similar to those of the Mimotonidae, an extinct family of lagomorph-like mammals known from snouts and jaws but not from well-preserved complete skulls. Mimotonids occur mostly in southern China in rocks about sixty million years old. Our colleague Li Chuan-kuei in Beijing has been amassing a large and important collection of mimotonids for years and has recognized their affinities with Lagomorpha. His fossils, as well as our more completely preserved ones from Naran Bulak, suggest to me that a Mongolian late Cretaceous mammal known as *Barunlestes* may also be related to lagomorphs. Their teeth share some features: an enlarged pair of anterior incisors accompanied by other, smaller rear incisors, a developing gap between the incisors and the cheek-teeth, and inner enamel of the upper cheek-teeth that sometimes enters the tooth sockets. The lower incisor of *Barunlestes* extends far back in the jaw, beneath the anterior molars, and its enamel is restricted to an outer U-shaped band of single-layered enamel, like that of later lagomorphs. However, the creature does not have the peculiar lagomorphlike forward-extending sliver of frontal bone that our Naran Bulak specimens share with lagomorphs.

Barunlestes, in turn, is closely related to the enigmatic *Zalambdalestes,* one of the Mongolian late Cretaceous mammals first collected by the American Museum's Central Asiatic Expeditions in the 1920s

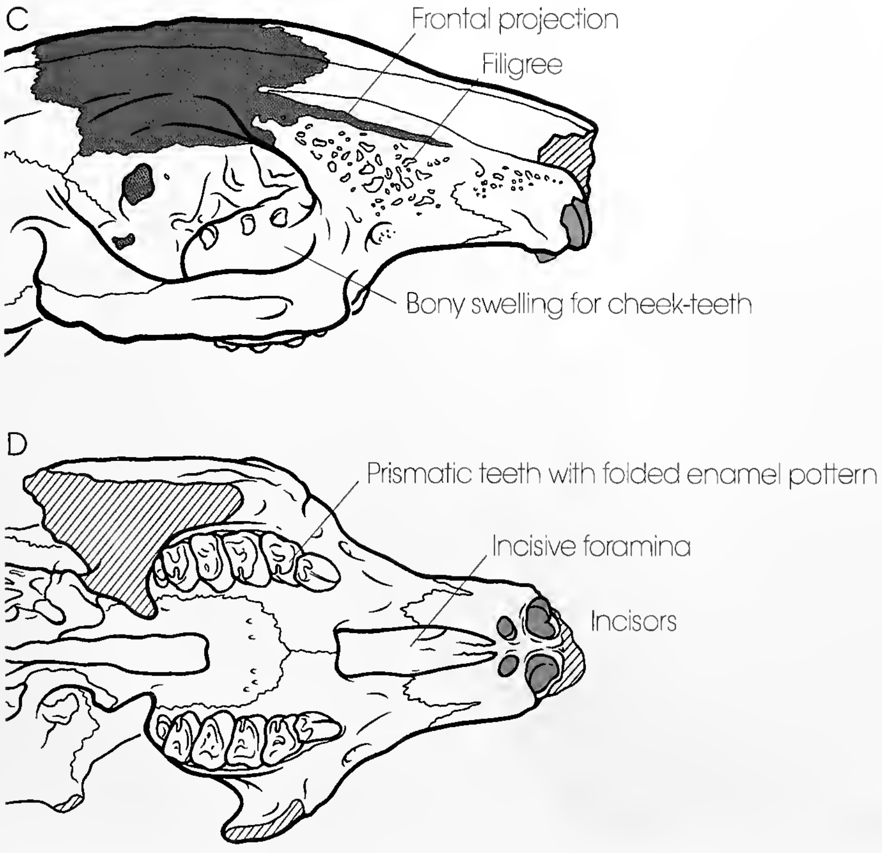


An artist's interpretation of Palaeolagus, *an early rabbit that lived in North America some thirty-five million years ago*
Drawing by Frank Ippolito



*Fine details of the skull show that the fifty-five-million-year-old Naran Bulak animal was starting to become more like a modern lagomorph. A side view (*A*) of the skull reveals two pairs of incisors (blue), and a frontal bone (purple) that juts forward; but no network of openings on the snout. (The diagonal stripes indicate rocky matrix.) A view of the upper jaw and palate (*B*) shows this animal's rodentlike, low-crowned teeth and relatively long palate; but unlike a rodent's, its incisive foramina openings are long.*

and by later expeditions (including our own in the 1990s). Now *Zalambdalestes,* too, seems to me to be a distant relative of lagomorphs—closer to them than to many other kinds of mammals because it seems to share at least a few derived features with them, the rest of its features being either primitive characteristics that were not later modified or peculiarities unique to it. This conclusion may be proved wrong by study of further evidence, but perhaps the relationships of lagomorphs to other mammals have been available to us all along, right in museum collections, unappreciated. That is why museums need to keep and augment large collections for future researchers. Someday, someone may see a specimen in our collections that has features currently unknown to paleontologists, or someone may be able, through new insight, to reinterpret prevailing ideas in a new and interesting way.



A Palaeolagus *species from thirty-five-million-year-old North American rocks reveals a much more rabbitlike creature. Visible from the side (*C*) is the frontal bone projection (purple), as well as a rabbitlike lacy filigree on the snout and a swelling that housed the cheek-teeth. The palatal view (*D*) shows that the incisive foramina are still long, but the palate is short, the first incisors are grooved, the second incisors small (blue), and the cheek-teeth are prismatic, with enamel patterning, more appropriate for a lagomorph's diet than a primitive mammal's.*

Illustrations by Ed Heck

The Devil's Corkscrew

by Larry D. Martin

Geologist Erwin Hinkley Barbour knew that he was looking at a spectacular new fossil, but he couldn't figure out what it was. In 1891, when he made his first expedition to the fossil-rich White River Badlands of Nebraska, the local ranchers had called his attention to the nine-foot-long, sand-filled tubes, enclosed within white fibrous material, that spiraled down into what was thought to be the remains of an ancient lake bed. Barbour was at no loss, however, for a scientific name for the weird spirals; he called them *Daimonelix,* the classical language equivalent of their local name, devil's corkscrews.

Soon after, Barbour proposed that his *Daimonelix* were the remains of giant freshwater sponges. He also noted that at least one sponge had become entangled with the bones of an extinct rodent. When further research revealed that the deposits had never been associated with a lake but more likely with a semiarid grassland some twenty-two million years ago, Barbour recovered grandly by suggesting that the spirals were a new order of gigantic fossil plants. Again, a few rodent bones had turned up with the *Daimonelix.* While Barbour never gave up his fossil plant scenario, his fellow paleontologists had some

A herd of slender three-toed horses bypass mounds of dirt encircling beaver burrows. In the American West, twenty-two million year ago, these burrowing rodents constructed colonies analogous to those of today's prairie dogs.

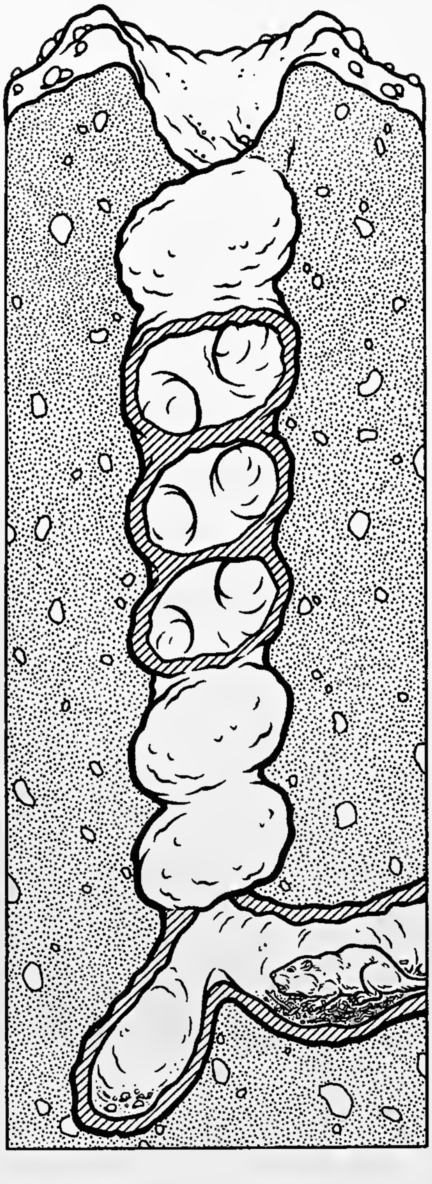
Detail of painting by Jay Matternes; courtesy of the Smithsonian Institution ideas about the presence of the rodents.

In 1893, Edward Drinker Cope and Theodor Fuchs independently suggested that the *Daimonelix* were not remains of organisms themselves, but were trace fossils of structures excavated by the rodents. In 1905, Olaf A. Peterson, of the Carnegie Museum, examined the fossils and determined that the bones were the remains of beavers and that the spirals were burrows. Like old sewer lines, the burrows were lined with roots (Barbour had been right about the plant tissue). The surrounding sediments were so rich in volcanic glass that the groundwater was charged with silica, and plant roots became embedded in a glassy matrix (the hard, white exterior of the burrows). This "cast" led to the preservation of the *Daimonelix*.

The burrowing beavers were about the size of woodchucks or smaller. Like other digging vertebrates, they had short tails and small ears and eyes. They also had long claws and superlong front teeth, or incisors, that grew rapidly to counteract the wear that results from digging. Three species are known, the large *Palaeocastor magnus*, middle-sized *P. fossor*, and the small *Pseudopalaeocastor barbouri*. The burrows of each species can be distinguished by the diameter within the spiral and the width of the dig marks. (North America was also home to aquatic beavers that lived at the same time as *Palaeocastor*, and the oldest-known beaver, *Agnotocastor*, was aquatic. However, the modern North American species, *Castor canadensis*, is descended from neither the burrowers nor *Agnotocastor;* it is an immigrant from Eurasia that arrived here some five million years ago.)

Not long after coming to the University of Kansas in 1970, I began a detailed examination of more than one thousand devil's corkscrews. By bringing casts and actual specimens of corkscrews back to my laboratory, I discovered that the ancient beavers had left clues to their engineering strategy in the form of twenty-two-million-year-old dig marks in the burrow walls.

Instead of the narrow claw marks that I had expected, the walls were covered with broad grooves that I could match by scraping the incisors of the fossilized beaver skulls into wet sand. The beavers had used their teeth to scrape dirt off the walls. The very regular spirals were constructed by a continuous series of either right- or left-handed incisor strokes, and the burrows are divided almost fifty-fifty into right- and left-handed spirals. A burrowing beaver must have fixed its hind feet on the axis of the spiral and literally screwed itself straight down into the ground. Two or three yards underground, the burrow extended into a straight chamber slightly inclined upward where right- and left-handed incisor strokes alternate. These are the living chambers; some have low pockets that may have served as sinks for water or as latrines and side passages. This is where the skeletons of beavers and their cubs are usually found. Some burrows also contain highly inclined (about 45°) living chambers, which may have been estivation chambers, where the beavers stayed cool during hot, dry summers.



Devil's corkscrews spiraled some nine feet into the ground. Equipped with chambers and side passages, they provided beavers with safe, cool living quarters and possibly latrines and water "sinks."

Drawing by Ed Heck

As they dug, the beavers had to dispose of the loose dirt they had scraped away with their front teeth. My investigations showed that the beavers scooped up the dirt with their paws and thrust it behind them. I think too that every so often the rodent must have used its remarkably flat head to push the accumulations out of the burrow. Burrow entrances would have been marked by high mounds of excavated soil.

I once mapped more than two hundred separate burrows that all seemed to be part of one colony. Like modern prairie dogs, these beavers may well have had extensive networks of colonies, towns covering acres. The existence of more complex social behaviors is easy to imagine but hard to prove. Did rodent guards stand on lookout on the mounds to give warning whistles of danger to other colony members? We do know that the beavers had enemies. An ancient raccoon relative, *Zodiolestes daimonelixensis,* as its name suggests, was found curled up in a *Daimonelix* looking completely at home. It may have lived within the colony and preyed predominantly on the resident beavers, much as the black-footed ferret does today in prairie dog colonies. When pursued on the surface, a *Palaeocastor* could attempt to escape by plunging headfirst into its burrow. The tops of burrows reveal expanded areas that would have allowed a fleeing beaver to turn around and then pop its head over the mound or to back down the hole, only a little broader than its body, then face the predator with strong jaws and formidable teeth.

The fossil record is full of examples of evolutionary developments, such as the beavers' colonies of spirals, which have now disappeared. The magic is in the reappearance of many of these developments at different times. Long before *Palaeocastor*, and for that matter, before any true mammals existed, some members of a group called mammallike reptiles, the dicynodonts, took to burrowing and created spiral burrows so remarkably like those of *Palaeocastor* that they should probably be included in the same trace-fossil genus, *Daimonelix*. And today, while modern beavers have undertaken new engineering feats, the spirit of burrowing *Palaeocastor* echoes in the subterranean labyrinths of prairie dog towns.

Distant Thunder

by Bryn J. Mader

Long before people of European descent came to the Great Plains of North America, the remains of extinct creatures that would later be called titanotheres were known to the native inhabitants of this region. Many fossil bones of these mysterious "titan beasts" had weathered out in the Badlands, and over time, the bones were woven into legend. According to the Sioux, the bones were those of the great "thunder horse," a gigantic creature that would occasionally descend to earth to hunt buffalo.

Western science first learned of titanotheres in 1846, when a fur trader brought an unusual fossil to Hiram Prout, a medical doctor living in Saint Louis. The fossil, a section of a massive lower jaw, had been found in the Badlands, along the White River in what is now South Dakota. Prout's specimen, which is still preserved in the collections of the Smithsonian Institution, has a double significance because it was also the first fossil land vertebrate to be collected from the western territories of the United States. The strange fossil caused much excitement in scientific circles and was largely responsible for the geological exploration of the territories in the decades that followed. All of the spectacular discoveries of dinosaurs and giant mammals in the American West owe much to the finding of this first, fragmentary fossil.

After the discovery of the first titanothere specimen, more than a quarter century passed before scientists began to piece together an accurate picture of what titanotheres were truly like. Not surprisingly, the image that emerged was quite different from the fabulous creatures of Sioux legend; nevertheless, titanotheres turned out to be extraordinary animals.

Titanotheres belong to the mammalian order Perissodactyla, which includes modern-day horses, tapirs, and rhinoceroses, and are members of a distinct perissodactyl family known as brontotheres (which means "thunder beasts"). Although many titanotheres were superficially rhinoceroslike in appearance, they were a distinct lineage and left no descendants in our modern world.

Titanotheres appeared in western North America in the early Eocene, approximately fifty-one million years ago, and soon spread across the Bering land bridge into eastern Asia. The earliest titanothere, *Eotitanops borealis,* was a relatively small creature, no bigger than a large dog. Over the course of their twenty-million-year history, however, titanotheres evolved into giants such as *Megacerops platyceras,* more than seven feet high at the shoulder.

The titanothere was massive and powerfully built. It had four hooflike toes on its front feet and three on the hind feet. The head was oddly proportioned, with an extremely short face on an otherwise elongated skull. Both eyesight and smell were poorly developed, and the brain was extraordinarily small. In a giant skull more than three feet long, the brain was only slightly larger than a human fist.

Like all perissodactyls, titanotheres were herbivores. Their very low-crowned teeth suggest that they fed primarily on soft leaves. On occasion, they may have eaten grass, but it does not seem to have constituted a large part of their diet. Grass is a highly abrasive substance that wears teeth down very quickly. If titanotheres subsisted primarily on grass, their teeth would have been worn to stubs in a very short period.

Perhaps the most conspicuous feature of many titanothere species were the horns located on the front of the skull. Titanothere horns differed from those of modern-day antelope and cattle in that they were blunt and covered with tough hide rather than with a horny sheath. They were present in both sexes, and in primitive horned species, the horns of males and females were about the same size. In the gigantic forms of later eras, however, the horns of males were larger than those of females.

On exhibit at the American Museum, a skeleton of the titanothere Brontops *reveals a broken and subsequently healed rib (fourth rib visible from front). Such an injury could have resulted from rivalry between herd members.*
Photograph by Denis Finnin; AMNH

Titanothere horns had a variety of shapes and probably served a number of purposes: for species recognition, as displays in courtship, and as weapons during combat with other titanotheres.

When titanotheres fought with their horns, they probably did so in one of two different ways. Most titanotheres had horns that were directed to the side, suggesting that the combatants might have circled one another while delivering lateral blows to the unprotected flank of the opponent. In other titanotheres, however, the horns were directed forward, indicating that these species probably fought head to head, locking horns with those of their adversary, much as deer and cattle do today. Although these head-to-head contests were primarily wrestling matches, the focus of the attack probably remained the opponent's flank, which would be rammed with the horns if the opportunity arose. The American Museum's new fossil mammal exhibition includes a remarkable titanothere skeleton belonging to the genus *Brontops* in which one rib had been broken during the life of the animal, probably during a sparring match with another titanothere.

At the end of the Eocene epoch, approximately thirty-two million years ago, all titanothere species suddenly became extinct. Despite their abrupt disappearance from the fossil record, titanotheres were not casualties of a sudden cataclysmic event. Instead, their disappearance can probably be explained by a simple change in the earth's climate.

The classical explanation for the extinction of these huge browsers holds that as the Eocene passed into the Oligocene, the environment became cooler and drier, transforming the open woodland habitat inhabited by the last titanotheres into relatively open grassland. Many of the trees and shrubs that had furnished titanotheres with their primary source of food disappeared over time, leaving only the expanding fields of grass to provide sustenance. Other perissodactyls, such as horses and rhinoceroses, developed higher-crowned teeth in response to this ecological challenge, but titanotheres never evolved a truly high-crowned tooth. With their feeble teeth basically unmodified, titanotheres were not able to efficiently utilize the primary source of food, and were doomed to extinction.

In the grand scheme of things, titanotheres did not survive on this planet for long, but while they were here they were one of the dominant herbivores and thrived in great numbers. The last titanotheres were among the largest land mammals of their time and reigned virtually unchallenged for six million years. Like all creatures, however, they were subject to nature's great dictum: Adapt to the changing world or pass into oblivion. Titanotheres could not adapt to the rigors of the new environment and passed from the scene, leaving only their fossil bones to intrigue *Homo sapiens*, the dominant creature of the present era.

In the late 1920s, artist Charles Knight depicted a magnificent bull titanothere, of the genus Megacerops, *intimidating a would-be predator, the carnivore* Hyaenodon, *at the edge of a watering hole. The rest of the titanothere herd dust-bathes and feeds in the background.*

Charles R. Knight; courtesy of the Field Museum of Natural History, Neg. No. 121T

The Heyday of Horses

by Bruce J. MacFadden

North America is the ancestral home of horses, and many fossil sites across the continent contain abundant remains of ancient members of the family. During the past fifteen years, my colleagues and I have excavated fossil horses at Thomas Farm, a site in Florida that some eighteen million years ago was a sinkhole and perfect trap for animal remains. In addition to such long-vanished creatures as extinct rhinoceroses and bear-dogs, we have unearthed thousands of teeth and bones of fossil horses.

Three different kinds of fossil horses are found at Thomas Farm, but by far the most common we have encountered is *Parahippus*—"side-toed horse," so named because of the toes flanking either side of the central digit. About the size of a small white-tailed deer or pronghorn, *Parahippus* probably lived in small bands, or harems (as do many modern horses in the wild), consisting of a dominant male, several females, and juveniles. It may have inhabited both woodlands and grasslands and fed on leaves from trees and shrubs, as well as on grasses. Thus, in its social structure, habitats, and diet, this early horse combined characteristics of primitive, ancestral horses with more modern traits. With its hoof—and toes—in two worlds, *Parahippus* stood on the verge of the great heyday of horses during the Miocene.

At any given fossil locality in North America from about fifty-five to twenty-five million years ago, we usually can find two to four species of horses that presumably lived side by side. Thereafter, from about twenty to ten million years ago, horses evolved rapidly and adapted to various environments and ways of life. Horse diversity increased so dramatically that at some fossil sites from fifteen million years ago as many as a dozen species can be found. Today, the world's horses (and their relatives the zebras, asses, and onagers) are reduced to the single genus *Equus*, whose wild members live only in parts of Asia and Africa. All are powerful runners and feed predominantly on grass. Such uniformity contrasts starkly with fossil horses, a group with a rich fifty-five-million-year-old history, represented by some three dozen extinct genera.

The coexistence of so many species of similar ancestry and general adaptive traits in the same ecosystems suggests that, as in modern-day communities, horses divided up the niches and resources available to them. Before about twenty million years ago, most horses were predominantly browsers, feeding on leaves of trees, bushes, and low-lying shrubs and supplementing this diet with whatever soft vegetation formed the local ground cover. This appears to have been the main feeding strategy not only of primitive horses but also of most other herbivorous mammals of the time. With rapid diversification, however, this feeding strategy changed. We know this because about twenty million years ago, fossil horse teeth changed dramatically.

Today, for example, many browsers, such as giraffes and camels in Africa, have relatively short-crowned teeth; in contrast, all grazers, or mammals whose diet consists predominantly of grasses, have tall teeth. These high-crowned teeth evolved to crop and process grasses, an adaptation that has immediate and long-term "costs." Grasses contain abrasive compounds called phytoliths (microscopic, elongated structures with the same chemical composition as glass, SiO_2). When grazers eat grasses, they acquire nutrients, but the phytoliths cause much more wear on the grinding teeth than do grit-free leaves and the softer vegetation favored by browsers.

During the Miocene, several groups of horses throughout the Northern Hemisphere evolved high-crowned teeth at about the same time. Based on our knowledge of modern herbivores and the nature of grasses, the acquisition of these new, taller teeth suggests that Miocene horses were becoming predominantly grazers. Recent chemical analyses of Miocene horse teeth indicate that during that time most grasses were primitive, photosynthesizing carbon in the manner of trees and shrubs rather than the way modern temperate and tropical grasses do. Thus, coexisting horse species of the Miocene not only divided up the available browse more narrowly but also began to exploit the grasslands and savannas that were becoming more widespread.

The addition of grass to ancient horses' diets, and the possibility of grazing rather than browsing as a way of life, are reflected in horse biology. Fossil horses have been thought to exemplify Cope's Rule (in which an increase in body size over time results in descendant species being larger, on average, than their ancestors). The dog-sized eohippus (the dawn horse more properly known as *Hyracotherium*), the smallest and oldest member of the horse family, lived at the far end of the spectrum, fifty-five million years ago. The large modern-day *Equus* species is at the other end, with a gradual continuum of horses of increasing size between the extremes. Recent work has shown this evolutionary pattern to be grossly oversimplified, if not incorrect, for fossil horses. In the first half of their evolutionary history, horses changed very little in body size. Then, during the Miocene, they diversified rapidly to include large species and even a few dwarf lineages. Browsing and grazing species of this period ran the size gamut. Thus, Miocene horses appear to have minimized competition for the available food and space by occupying slightly different niches.

During the Miocene, a major adaptive shift in horse locomotion occurred. In general, fossil horse limbs lengthened, and side toes were reduced and ultimately lost. While the evolutionary advantages of having a foot with one rather than three toes are not clear, the classic interpretation for limb elongation holds that it allowed horses to better escape fast-running predators. Another factor may also have favored longer limbs. The late Miocene, from about ten to five million years ago, was a time of great climate shifts and increased seasonality—more defined dry versus rainy and warm versus cold cycles. The ability to travel longer distances may have enabled horses to migrate hundreds of miles to take advantage of local plant foods available at certain times of the year, as do zebras and wildebeests in Africa today. About five million years ago, horses also evolved functional locking mechanisms of the forelimbs and hind limbs, allowing them to stand for long periods without great fatigue (modern horses can stand for about eighteen to twenty hours a day). These physiological changes endowed some groups of Miocene horses with great speed and stamina.

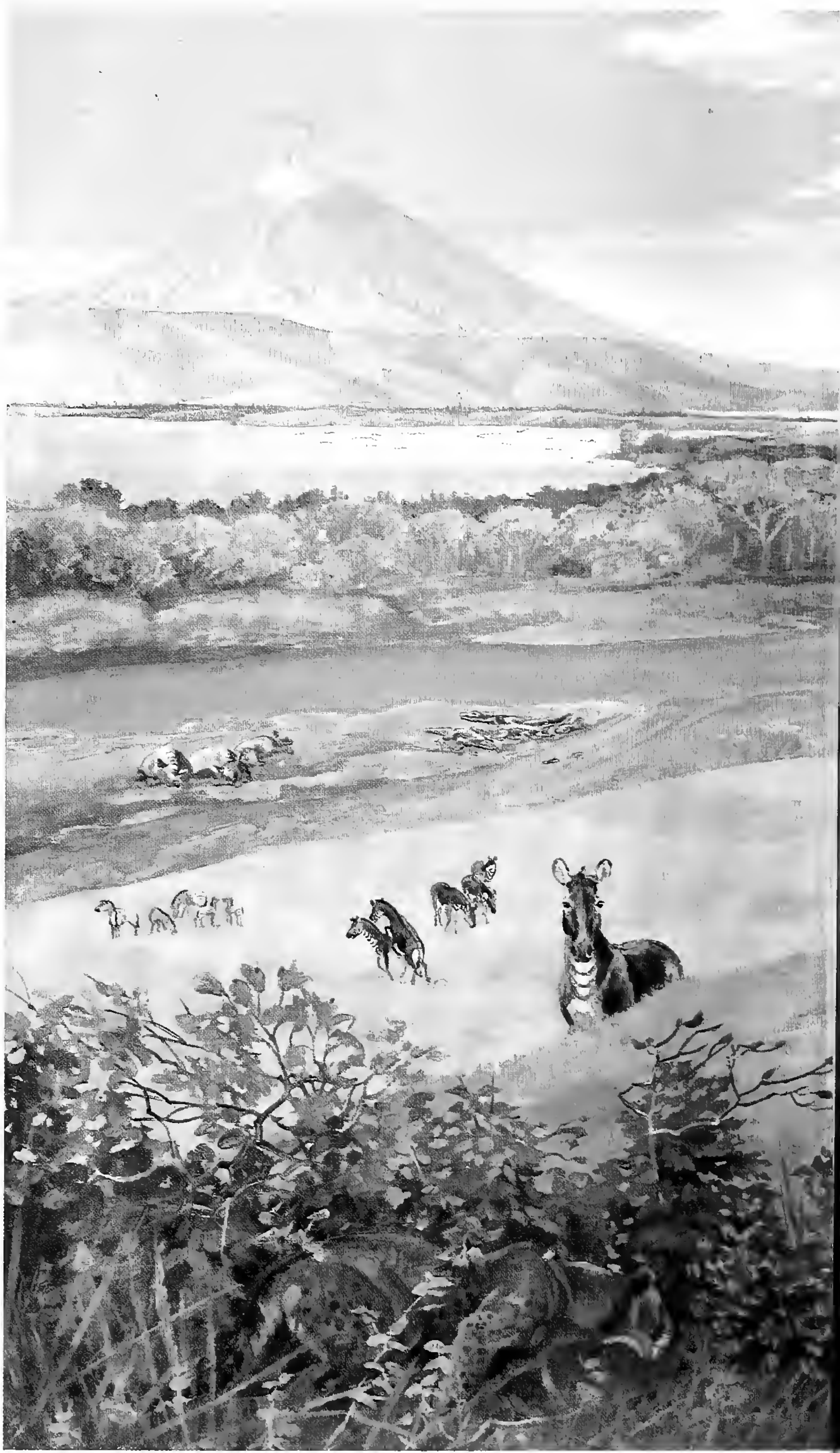
While behavior does not fossilize, body

size, teeth (which give clues to diet), local climate conditions, and vegetation, as well as comparisons with some kinds of modern mammals, can help us reconstruct the social systems of fossil horses. During the Eocene, the small, forest-dwelling browsers, such as *Hyracotherium*, were probably solitary or lived in small bands within small home ranges, as do modern forest-dwelling tapirs and Chinese water deer. In contrast, more open landscapes and mixed forest and grassland habitats of the Miocene enabled early horses to broaden their range of behaviors. Both the kind of territoriality observed today in Grevy's zebra and the more nomadic life in bands, or harems, seen in Burchell's zebra, have probably existed in horses since the Miocene.

Fossils from individual quarries sometimes represent particular populations of extinct horses. They also provide insight into the longevity and reproductive biology of various species. Little *Hyracotherium* probably had a potential life span of three or four years. Females would have given birth to at least one foal a year, although, based on local climate reconstructions, breeding cycles in the Eocene were not synchronized or concentrated at any particular season. During the Miocene, however, the average life span of horses increased to about nine to fourteen years, depending upon the species. Within local populations, many of these horses gave birth during the season when food was most abundant.

Starting about eight million years ago, horse diversity dropped drastically, returning to pre-Miocene levels of only three to five species at any given fossil locality in the Northern Hemisphere. Studies of ancient climate indicate increased global aridity. This, in turn, seems to have led to less productive land ecosystems. The heyday of horses ended. In addition, competition with cud-chewing, hoofed herbivores such as deer and bison may also have affected horse diversity. By two million years ago, only the single horse genus *Equus*, consisting of a few species, remained in the Northern Hemisphere.

About three million years ago, during the Pliocene, *Equus* emigrated from North America across the Bering land bridge into the Old World and, after the formation of another dry-land connection to the south, crossed the isthmus of Panama

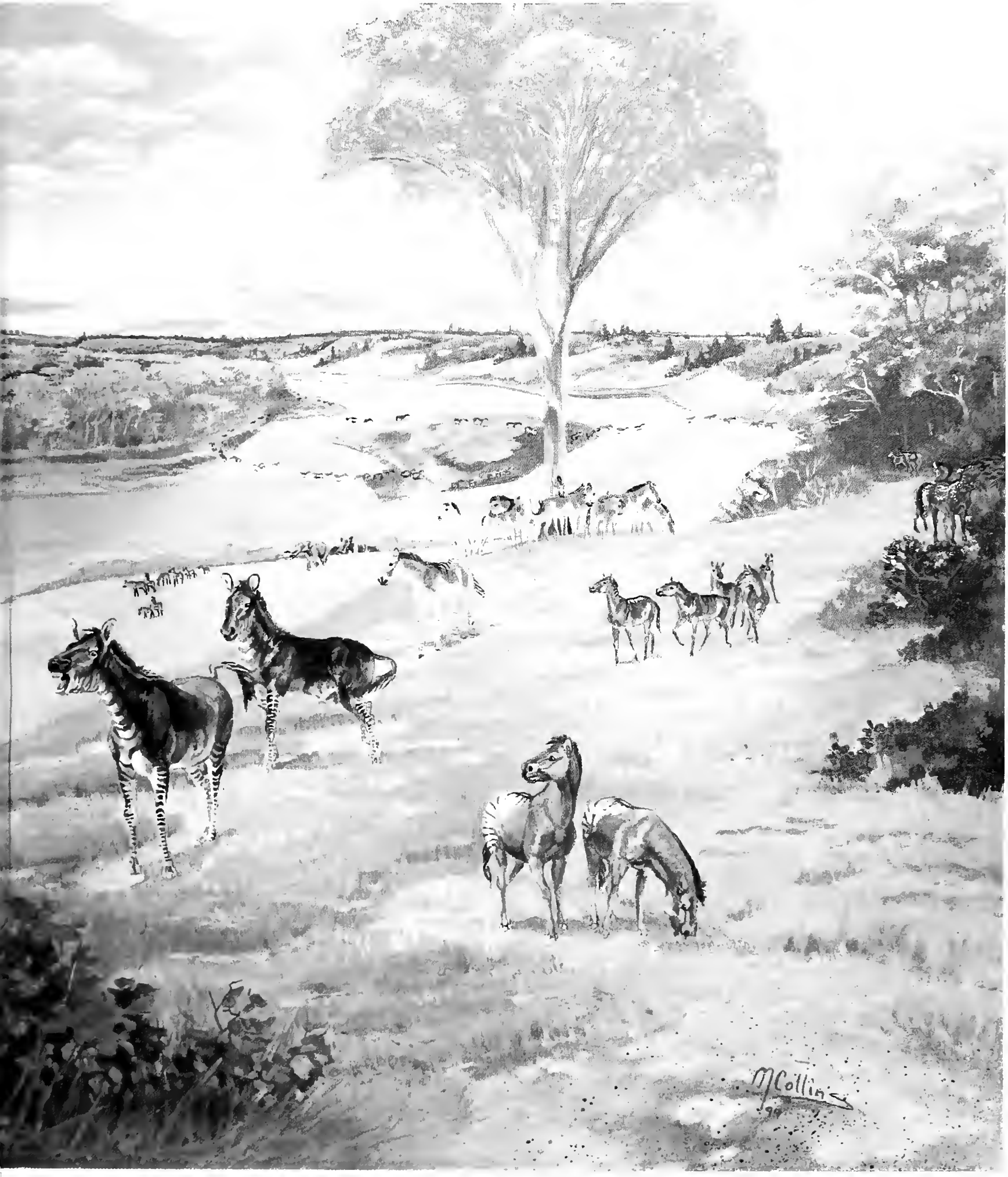


In a panorama depicting life ten to fifteen million years ago on the Great Plains, three-toed open-country grazers dominate the foreground; one, detecting the furtive cat in the ground cover, neighs a warning to herd members. Other three-toed grazers and one-toed Pliohippus, *near the elm tree, gather in small bands, or harems. At the far right, a contingent of three-toed browsers barely emerge from their forest home. Crocodiles, rhinos, and shovel-tusked elephants share the valley stream.*

Painting by Marianne Collins

from North to South America. Dramatic climatic fluctuations within the past million years and the arrival of humans in the New World during the late Pleistocene contributed to the extinction of *Equus* in the Americas. In the Old World, the range of *Equus* became restricted to portions of Africa, where it gave rise to modern zebras and their relatives, and to the dry steppes of central Asia. The Asian equids, including the now-endangered Przewalskii's horse, apparently provided the stock from which the horse was domesticated five to six thousand years ago.

Over the past several million years, species of *Equus*, both extinct and extant, adapted to a wide variety of ecological situations and successfully spread throughout the Old and the New Worlds. Yet the familiar horses, zebras, asses, and onagers that share our modern world represent but a single surviving branch on a once luxuriant equid family tree that reached its full glory during the Miocene.



Why Antlers Branched Out

by Valerius Geist

Every large museum of natural history has its collection of ungulate heads, horns, and antlers—mostly donated by nineteenth-century sportsmen obsessed by such trophies of the hunt. These same institutions amassed fossilized Irish elk antlers and skulls of extinct giant moose and bison. Hoofed mammals have evolved many types of horns: the antlers of deer; the true horns of cattle, sheep, and antelopes; the false horns of North America's pronghorns; and the hairy, skin-covered horns of giraffes. Several extinct species sported horns of odd architecture. But of what scientific value is this jumble of diverse heads and horns, ancient and modern? What might they tell us about the evolution of hoofed mammals?

Observing living animals may help answer such a question. In December 1961, during a three-year field study of mountain goats in the Cassiar Mountains of northern British Columbia, I watched a typical territorial dispute near my cabin. A female mountain goat, her short, sharp horns lowered, rushed a much larger male. The big billy jumped aside, turned away, and hastened down the hill, with the female in pursuit. As he looked back over his shoulder, she jerked her head up sharply, prompting the male to accelerate his departure. I did not see him for the rest of the winter.

The female had a more difficult time with a young billy that was about two or three years old and about her size. When she advanced menacingly, he arched his back into a dominance display, but the female charged nevertheless. A brief, violent fight erupted on the snowy slope as the goats whirled about, thrusting their sharp horns into each other. Finally, the younger billy, too, took flight and never returned.

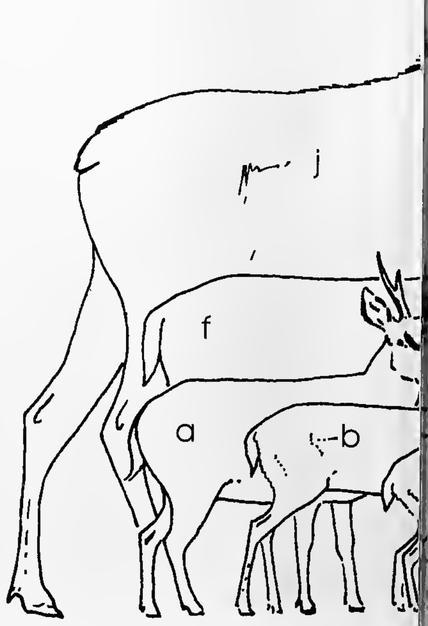
Such dramas, which follow the mating season in early winter, are part of the mountain goat's biology: dominant females with kids clear out other goats (including the largest males) from chosen areas of superior habitat, known to scientists as "resource territories." The steep, jagged cliff near my cabin was regularly swept of snow by strong, warm chinook winds, making it a good place for goats to forage, even after a blizzard. The female's relentless aggression, enforced by her horns, insured that she and her offspring—one by her side, one growing in her uterus—had the food they needed to survive and thrive.

Mountain goats' short, slightly curved, needle-sharp horns make ugly wounds that hemorrhage beneath the skin. Wounded goats hobble about for a long time after a fight and give every indication of being hurt. The species' horns seem to have evolved to cause a maximum of pain and to enable them to be quickly withdrawn from the victim's body before they can become caught and snap the neck of the aggressor. The short, spiky shape of the horns proclaims the species to be one that aggressively defends resource territories—although in this case only the females do the defending.

Other living animals with similar horns and territorial behavior include the duikers of Africa, dwarf antelopes that inhabit scrub and forest; the little brocket deer that range from Argentina to Central Mexico; and the Indian nilgai, Asia's largest antelope. Fossil antelopes going back to the late Oligocene or early Miocene periods, some twenty-five million years ago, include several duikerlike forms from Europe, Asia, and North America. In most cases, the evolution of antlers went along with the diminution of large canines, although some modern species (such as the muntjac of Southeast Asia) retain large canines as well as horns.

Stabbing horns represent the earliest and simplest type of armament among a great diversity of horn shapes and sizes. But very soon after this type of antler appeared in the late Oligocene, many large, gregarious antelopes with antlerlike horns were beginning to populate the newly spreading grasslands of the Northern Hemisphere. In open landscapes, the animals banded together to avoid predators, for the larger the herd, the less likely that any particular individual at its periphery would be caught. Those in the center were the safest of all. Zoologists call such aggregations "selfish herds" because individuals do not cooperate but stay together strictly in their own self-interest.

In closely packed herds, a wounded an-



Living New World deer are arranged, front to back, from tropical dwarfs with short spikes to caribou and moose that evolved giant antlers during the ice ages. The species are (a) *Andean deer, or guemal,* (b) *pampas deer from South America,* (c) *mazama, one of the brocket deer,* (d) *pudu, the smallest living deer, from the Andes,* (e) *white-tailed deer of the tropics,* (f) *marsh deer from South America,* (g) *mule deer of western North America,* (h) *white-tailed deer of northern temperate zones,* (i) *caribou, or reindeer, which live in arctic and alpine areas of both the New and Old World, and* (j) *moose from the subarctic and subalpine regions of the Old and New World.*

Drawing by Valerius Geist

imal quickly attracts predators, putting all at risk. Thus, disputes over mating or foraging are best resolved by wrestling or other forms of bloodless combat. Some deer and antelopes evolved antlers and horns that functioned as shields to parry an opponent's attack and as grappling hooks to wrestle with rivals. Simultaneously, antlers became the focus of mate selection by females, since they advertised a male's superior health and strength. As with the peacock's tail, sexual selection helped make antlers increasingly complex.

Both stabbing and wrestling horns evolved not only among males but also in the females of some species. In every case, the female's horns mimic those of the age-class of males that she must confront and defeat. In reindeer, for instance, females most often clash with two-year-old males, which—unlike older males—retain their antlers long after the rut. When females dig deep craters in the snow to reach buried lichens, they must frequently defend their costly efforts from young males that try to steal the food. In woodland caribou, however, which feed mainly on arboreal lichens, females rarely grow antlers.

Because we have a fairly complete fossil record of Old World deer from the mid-Tertiary onward, this group best illustrates the evolutionary sequence of antler forms. And for each type, one also finds a palmated version (as in moose) and one with extra "twigs" branching off the main tines. Moreover, virtually every type of antler that has ever evolved is still represented in living species.

The first true deer resembled the small, antlerless ruminants from which they evolved. The water deer of Korea and China, with its long, tusklike canines, represents this stage today. Deer with both long, sharp upper canines and small antlers represent the second stage. A plethora of muntjac species in Asia's tropical and subtropical forests are similar to this ancient type, which goes back about twenty million years. Muntjacs hold down territories, and males use both antlers and teeth in combat. Three-pronged antlers arose within the deer lineage during the Pliocene in southern Eurasia. Upper canines regressed or disappeared in adults. Today, such deer species remain in tropical southern Asia and fill many ecological niches. They range from the very large sambar, a coarse-grass feeder, to the small hog deer and its island relatives. None are territorial.

Sociality increased in tandem with four-pronged antlers, which evolved during the late Pliocene in warm temperate climates at the beginning of some two dozen 100,000-year cooling cycles. Modern representatives of this group include the gregarious sika and fallow deer, both from temperate zones. Five-pronged antlers appeared in cool climates in the early ice ages. These gregarious ungulates are exemplified today by the red deer and its many subspecies. Also during the ice ages, the closely related six-pronged North American elk appeared.

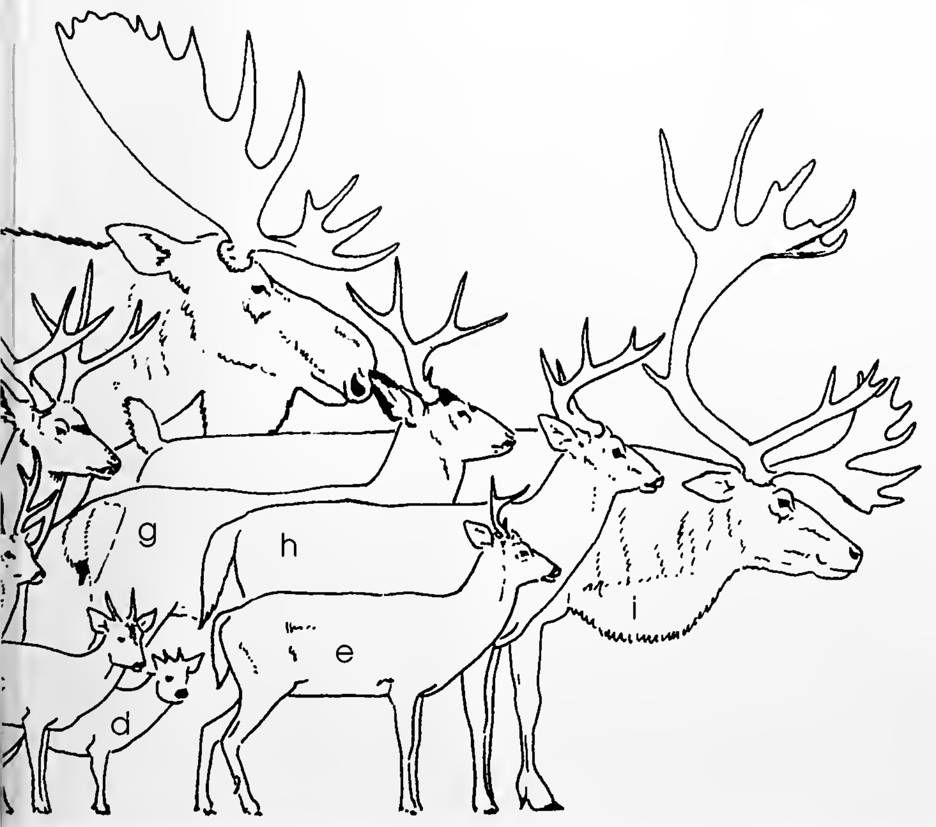
On the vast expanses of open terrain during the ice ages, a number of very large deer appeared: the large-antlered giants, such as the Irish elk and its relatives; the "brush-antlered" deer; and—in the New World—the large-antlered moose and caribou. In the Southern Hemisphere, antlers reached their largest size in the extinct deer from the Patagonian steppes.

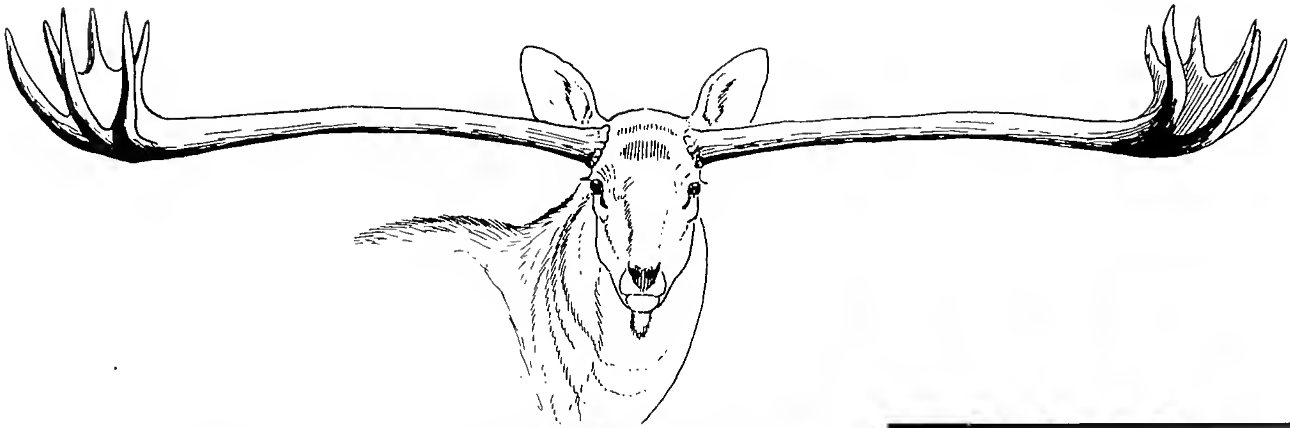
At high latitudes, the deer enjoy a "vacation from want" in early summer, when plant food abounds and antlers can grow large without much risk or effort on the animal's part. Tropical deer have no such seasonal riches. Beyond sixty-five degrees north latitude, however, the summer boom in vegetation is much too brief to offset the long winter's scarcity of food. Antler size generally increases with latitude and altitude, with the trend reversing in the highest latitudes. Thus, the Tibetan white-lipped deer from the subalpine above timberline carries very large, elklike antlers. The sambar from the tropics, its rival in body size, does not.

Even when rich habitat permits the luxury of large antlers and horns, vigorous males take risks—sometimes skirting predators—to get the very best food for increasing antler and body size. Large, symmetrical horns are visible proof of superior ability at foraging and efficiency in maintenance metabolism, and they proclaim the bearer's skill at avoiding predators (*see* "A Consequence of Togetherness," *Natural History,* October 1967).

Large horns among males also appear in other species that live in open habitats, where the deer are under threat from predation. Here the young run with the female, so they must be well developed at birth and grow rapidly. A mother needs to be a fast runner and to excel at obtaining nutrients and converting them to rich, plentiful milk. Today's caribou, which have the largest relative antler mass of any living deer, also have a very showy antler display during courtship, the richest milk, and the most highly developed young at birth among the whole deer family. When a female picks a mate with large antlers under these conditions, she is choosing an individual that may pass on to her daughter the traits necessary for superior lactation and for protecting young.

Everyone curious about horns has mar-





veled at the immense antlers of the extinct Irish elk, which appeared half a million years ago and persisted in Europe until about 11,000 years ago. Neither an elk nor restricted to Ireland, the Irish elk had huge antlers—twice the weight of those of a big Alaskan moose—which indicate that the species was an open plains dweller. Its bodily proportions suggest that it was also the most highly evolved runner among all deer. It had a huge chest to hold a big heart and lungs, large shoulder blades, and light-boned legs of nearly equal length, enabling it to run very fast over flat or even ground (*see* "The Paradox of the Great Irish Stags," *Natural History*, March 1986).

Like today's diminutive fallow deer (close relatives of the Irish elk), which carry the largest relative antler mass among Old World deer, Irish elk bulls may have gathered in small groups on the open plains, then marked out individual courtship territories, or leks. In the slanting rays of the morning and evening sun, their enormous but relatively lightweight antlers could have been seen for miles by interested females.

Another fantastic antler shape evolved in the extinct Gallic moose, the earliest-known member of a family that appeared 2.6 million years ago in Europe. Two excellent skeletons are preserved in France. Their antlers carried tiny palmate branches on the ends of very long beams. A small moose by today's standards, barely as large as a yearling elk, it was, judging by its proportions, also a speedy runner that evolved in open plains. (One can imagine the problems it would have had navigating through forests.)

Over time, the deer family elaborated their antlers, but not all ungulates developed large horns as they evolved from forest dwellers to plains dwellers. Some plains species, such as camels and their relatives, retained territories and continued to defend them with sharp teeth. Others, such as horses, lost their "fighting teeth" as evolution emphasized their kicking and neck wrestling equipment. When bison came to North America from Siberia in the middle of the Pleistocene, they first evolved into giants with huge horns but later shifted to developing a luxuriant display coat and smaller horns. Like antlers in deer, the bull bison's coat advertises both its competence at foraging and its general state of vitality.

When the stag moose came here, it too developed antlers much larger and more complex than did either its ancestors or descendants. Body measurements confirm that these animals not only had large horns but were also specialized for fast locomotion with generally larger hoofs and long, slim legs of equal length.

During the Pleistocene, many large-bodied predators roamed North America. Several species were specialized as fast runners, including the huge, short-faced bear, a large American lion, and two spe-

A forerunner of modern species, the Gallic moose, top of page, lived in Europe about 2.6 million years ago. Straight beams that ended in small, palmate branches stuck out three to four feet on each side of its head. Right: An Irish elk stag, the largest-antlered deer that ever lived, was depicted by painter Charles R. Knight about seventy years ago. Knight apparently based its facial features, neck ruff, and coloration on those of modern red deer. Current phylogenetic studies and Ice Age cave drawings indicate that the extinct ungulate's markings and coat resembled those of the fallow deer, its closest living relative.

Drawing by Valerius Geist/Painting by Charles R. Knight; courtesy of the Field Museum, Chicago, Neg. No. CK1T cies of saber-toothed cats. They had a tough time making a living by hurling themselves against America's giant ungulates; the predators show an unexpectedly high percentage of fractured teeth and partly healed breaks in bones.

These giant, ever-hungry predators would have made short shrift of any hunter so bold or foolish as to confront them with the puny weapons of the time. My guess is that humans could only colonize North America late in the Pleistocene because the ungulate-hunting predators formed a barrier until relatively recently. We don't know why, but by 12,000 years ago, the largest of these predators, the giant short-faced bear, had died out.

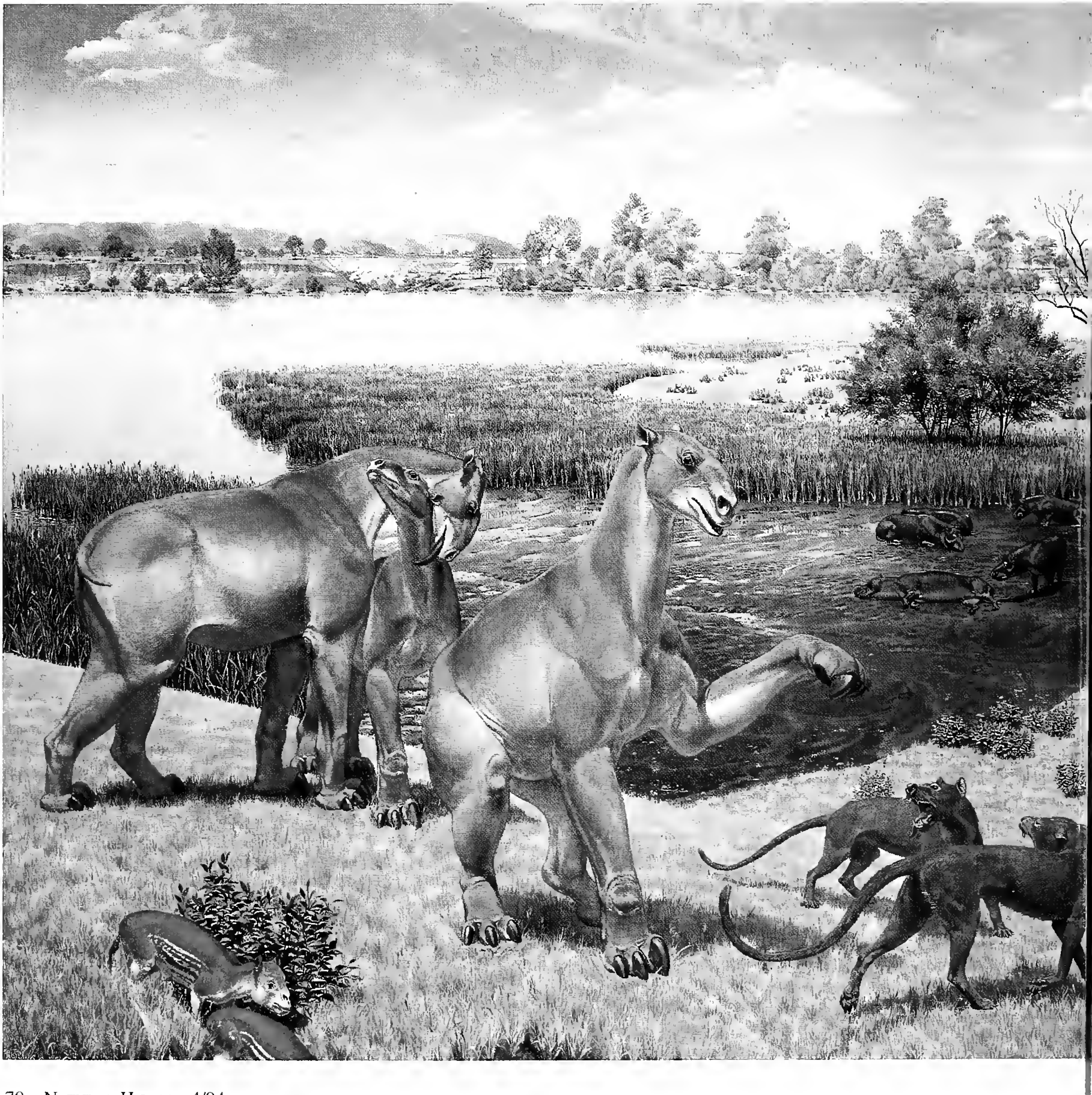
According to recent studies by paleontologist Jerry McDonald, who examined remains of North American hoofed animals going back to 20,000 years ago, the number of ungulate fossils dramatically increases after the bear's extinction, suggesting a much greater abundance of large herbivores after about 12,000 years ago. That is also the date of the Folsom stone tools, the first major evidence of humans in North America. Perhaps only with the disappearance of the short-faced bear—humankind's single most ferocious predator—could New World hunters live off ungulates like the proverbial mice in cheese. Eventually, human dependence on the ungulates that sustained them may well have contributed to the extinction of the great Pleistocene herds.

Green in Tooth and Claw

by Margery C. Coombs

In the early 1800s, the French anatomist Baron Georges Cuvier noted that claws are usually associated with sharp teeth and carnivorous habits, while hoofs are associated with grinding teeth and a plant diet. Using this rule, he could reconstruct much of the morphology of an animal from a small part of the skeleton. A few exceptions to this generalization have existed: clawed animals such as extinct ground sloths and sauropod dinosaurs, which despite their simply shaped teeth are thought to have been herbivores. (Only one large clawed herbivore exists today, the endangered giant panda.) Another successful group of large clawed plant-eaters, the chalicotheres, appeared first in the Eocene, about forty-five million years ago, in Eurasia and North America. The last of their line lingered in Africa and Asia until the early Pleistocene.

Because of their oddity, chalicotheres posed some problems for paleontologists. In the 1820s through the 1840s, chalicothere claws from some European quarries were attributed to a "gigantic pangolin" or "colossal edentate," perhaps a



giant sloth. Teeth found in the same deposits were assigned to the Perissodactyla, the order that includes horses, tapirs, and rhinoceroses. Not until 1890 did the French paleontologist Henri Filhol realize that the horselike animals never seemed to have feet nor the slothlike animals a head. He concluded that the claws and teeth belonged to a single beast. Instead of having toes like their horse and rhino relatives, chalicotheres had hooklike claws.

I first became interested in chalicotheres as a graduate student some twenty years ago, and my work involved not only their morphology but also their habits and natural history. Most early speculations about how chalicotheres used their claws came down on the side of digging; chalicotheres were envisioned clawing through earth in search of water or edible roots. As more fossils came to light, thought shifted, and chalicotheres were seen as browsers of leaves. I spent a lot of time comparing chalicothere skeletons with those of possibly analogous diggers and browsers, both living and fossil. Diggers generally have strong forelimb muscles and short, forceful forearms and hands, enabling the animal to move earth easily. Chalicotheres have long forelimbs that are not particularly muscular. They also lack vertebral, pelvic, and hind limb modifications usually found in habitual diggers, and their teeth are relatively low crowned, with no signs of the heavy wear they would sustain if chalicotheres had chewed on a diet of coarse, gritty roots. Instead, the teeth are like those of animals that feed on leaves and twigs. I concluded that chalicotheres were not diggers, or at least that digging was not the major function of their claws, and that they browsed rather than grazed or grubbed for a living.

Two basic designs of chalicotheres existed. One, exemplified by the Old World genus *Chalicotherium,* had gorillalike proportions and may have engaged in something like knuckle walking. The other, exemplified by *Moropus,* which inhabited North America in the Miocene, some twenty-four to eight million years ago, had a longish neck and was shaped rather like an okapi (a giraffe relative that today lives in African rain forests). *Moropus* could extend and lift its claws clear of the ground to keep from blunting them when it walked. The hind limbs of both creatures were shorter than the forelimbs and had weight-bearing adaptations not found in the forelimbs. Both groups of chalicotheres could probably stand up on their hind limbs as they browsed. The clawed digits on the hands may have functioned like hooks, helping the animal to support itself against tree trunks or to pull branches down to mouth level. Possibly the claws served as occasional weapons for defense or, in the case of breeding males, for intimidation of competitors.

Chalicothere fossils are relatively rare, and the animals were probably never particularly numerous. The evidence suggests that *Chalicotherium* may have lived in forests, while *Moropus* inhabited more open environments, perhaps tree-lined areas around streams or water holes. Large concentrations of chalicothere fossils are found in only three places worldwide—in the Czech Republic, in Kazakhstan, and in northwest Nebraska. In the 1920s, the American Museum of Natural History collected eighteen skeletons of *Moropus* from what is now Agate National Monument in Nebraska. In the 1970s, I excavated fossils from a nearby quarry in which more than 50 percent of the total specimens belonged to *Moropus*. This creature was the largest animal living in the early Miocene assemblage in the Agate area. It shared its habitat with medium-sized and small rhinos, three-toed horses, and large piglike beasts known as entelodonts. Preying on all of these were "bear-dogs" and early canids. Small camels and a sheeplike group called oreodonts roamed nearby.

The Agate fossils shed some new light on chalicothere life style. When I examined the specimens of *Moropus* at the American Museum, I found two size groups: the larger ones probably representing males; the smaller, females. Such sexual dimorphism, which is also found in chalicotheres from Eurasia and Africa, is common when animals breed in a group. The bony dome on the skull of another North American chalicothere, known as *Tylocephalonyx,* may have been used in low impact butting, a behavior common today in male giraffes and many other hoofed animals when they compete for females. Thus, chalicotheres may have gathered in at least seasonal groupings.

Reconstructing the lives of chalicotheres expands our knowledge of mammal evolution and of the variety of ecosystems during the Age of Mammals. The existence of a clawed, herbivorous chalicothere, for which there are now no exact biological equivalents, opens a window on a world that is not quite like our own.

The chalicothere Moropus *easily fends off two snarling* Dapheonodon *bear-dogs by simply raising its long front limb equipped with six-inch claws. Its mate grooms their offspring nearby. Other fauna of this North American Miocene environment are camels, three-toed horses, sheeplike oreodonts (far left), and piglike entelodonts (upper right).*

Detail of painting by Jay Matternes; courtesy of the Smithsonian Institution

West Indian Tuskers

by Daryl P. Domning

Amid the contemporary traffic of the Florida and Caribbean coasts, the rotund marine mammals known as West Indian manatees attempt to live the slow, deliberate life of aquatic grazers. Found in both tropical salt water and the fresh waters of inland springs, these sirenians, or sea cows, placidly paddle through warm waters, grazing on a wide assortment of fibrous-leaved water plants, including the introduced water hyacinth. Intermittently, a manatee snout breaks the surface; after a breath of air, the animal closes its nostrils and silently submerges. Half a world away, the manatees' look-alike but strictly saltwater cousins, the dugongs, quietly ply warm shallows of the Indian and southwestern Pacific oceans. While manatees have an ever-growing series of teeth adapted to the abrasive grasses that grow in fresh water, dugongs specialize in eating softer, less abrasive sea grasses that they uproot with a pair of tusks in their upper jaws.

Sirenians have a long history, first appearing on earth some fifty million years ago, and their family tree has included denizens of cold as well as warm waters. The huge Steller's sea cow, for example, inhabited the waters of the North Pacific and Bering Sea, until it was hunted to extinction in 1768, just twenty-seven years after its discovery (*see* "A Sea Cow Family Reunion," *Natural History*, April 1987). Nor have dugongs and manatees always so neatly divided their tropical realms between the Atlantic and Indopacific oceans. West Indian manatees are, geologically speaking, relative newcomers to the Caribbean; for millions of years, their cousins the dugongs dominated the tropical Western Hemisphere. Not only were these ancient dugongs abundant, they were diverse. From the Oligocene to the Pliocene—that is, from more than thirty to less than five million years ago—at least three, probably more, kinds of dugongs lived together in the Caribbean.

This newly discovered diversity raises the question of how these different species, which had such similar diets, could have coexisted in the same environment. Today, no place in the world supports more than a single species of sirenian. What, if anything, was different about the Caribbean during much of the Age of Mammals that promoted a degree of sea cow diversity unknown today? And what caused these animals to later die out? Much of my work with fossil sirenians has focused on how various combinations of anatomy and behavior might have allowed these separate species to share the available marine plant foods.

Most of the extinct Caribbean dugongs, like their living Indopacific relatives, wielded impressive tusks. Some were more than a foot long and were shaped like knives or chisels, with self-sharpening enamel edges. These were not carried for show; lodged solidly in deep sockets in the upper jaw, with only a few inches of tip exposed, they were powerful tools that could have been used in combat, as are the tusks of modern male dugongs. But while

in the living species males have the larger tusks, we have no evidence for a difference in tusk size between the sexes in ancient dugongs. I believe that these big, bladelike tusks were used by both males and females to dig up and consume the large, woody rhizomes, or underground stems, of the largest sea grasses, for example, those of turtle grass (*Thalassia*), which are inaccessible to tuskless sirenians such as manatees. (Dugongs eat the whole plant, half of which is the nutritious rhizome. Manatees can chew gritty grass but can't get at the rhizomes.)

Another dugong that inhabited the ancient Caribbean at the same time as the great tuskers was *Metaxytherium*. Some ten feet long, this creature also sported a pair of tusks at the front of its upper jaw, but these appendages were so tiny, with conical crowns only about half an inch long, that they appear useless compared with the daggers and hoes of other dugongs. *Metaxytherium* was probably a relatively unspecialized feeder. It most likely grazed on the leaves of various sea grasses and on the nutritious rhizomes of the smaller sea grasses, which would not have been hard to uproot. This is the strategy that the completely tuskless Florida manatee uses in salt water today.

Was the ancient Caribbean full of big sea grasses with tough rhizomes that filled the bill for an array of sea cows? Evidence in the form of fossil sea grasses is rare. At one Florida site, however, fossil sea grass some forty-five million years old was found, giving us a window on the past plant life of the Caribbean. These fossils reveal that, while sea-grass beds must have looked much the same for as long as sea cows have been on earth, at one time, sea-grass communities in the Caribbean were somewhat more diverse than those of today, which comprise a mere four genera.

Did the abundance of robust sea grasses permit the evolution of several kinds of large-tusked dugongs? Did the plants survive throughout the dugongs' twenty-million-year heyday? We have only clues, but after studying them, I find the following scenario to be a plausible one. I suspect that sea-grass beds supported diverse species of plants until about two to three million years ago, and that these sea grasses in turn supported a contingent of large-tusked rhizome eaters. Turtle grass, for example, is considered a climax species and characterizes the stable composition toward which sea-grass communities tend if left to themselves. Suppose, however, these grasses were not left alone, but were periodically ripped up by mammalian digging machines in the form of dugongs? Rather than maintain a static climax community, this would enhance plant diversity and productivity and maintain ecological niches that could have supported other, less capable diggers such as tiny-tusked *Metaxytherium*. The large-tusked dugongs would have acted as keystone species in the ecosystem, keeping both sea-cow and sea-grass diversity at higher levels than they would otherwise have attained.

Two to three million years ago, in the grip of a major ecological upheaval, the Caribbean saw the extinction of many shallow-water mollusks and other invertebrates and most likely some of the marine plant life. This upheaval, like most in the earth's history, stemmed from the movements of crustal plates and the building of mountains. The isthmus of Central America was completed, joining North and South America but also separating the Caribbean and Pacific and disrupting currents that had flowed between them. The changes in water circulation and salinity that produced the mass extinction of Caribbean invertebrates could explain the disappearance of dugongs from the area at roughly the same time.

At this time too, manatees made their first appearance in the Caribbean and in southern North America. They had evolved in the rivers of South America (*see* "Marching Teeth of the Manatee," *Natural History*, May 1983) and only now spread northward into marine waters. Perhaps their constantly replenished, wear-resistant batteries of grinding teeth, which were superior to those of dugongs, gave them a competitive edge; or maybe the decline of the dugongs simply created an ecological vacuum into which the manatees expanded. Surviving sea grasses with the biggest rhizomes—such as turtle grass—could now live happily ever after, their manatee-proof root systems undisturbed by hungry plowers of the sea.

An underwater panorama depicts, from left, the ancient whale Basilosaurus, *two dugongs, and a variety of other marine mammals and fishes.* Metaxytherium, *a tiny-tusked dugong, and her calf feed on Caribbean sea grasses. Before three million years ago, the Caribbean was a garden of sea grasses with large, nutritious roots that were plowed up and savored by resident dugongs, many with long tusks. Today only tuskless manatees inhabit these waters.*

Mural by Ely Kish; courtesy of the Smithsonian Institution

Key to the Carnivores

by Richard H. Tedford

At dawn in Tanzania's Serengeti National Park, a lioness creeps close to the ground, stalking a young wildebeest that has drifted from the herd. She must narrow the distance to her prey as much as possible because her powerfully built body cannot sustain a lengthy run. Her eyes fixed on the wildebeest's neck, she judges the distance to be proper and lunges at full speed. The wildebeest realizes something is wrong only a fraction of a second before it feels the crash of the lioness's body and the suffocating grasp of her jaws upon its throat. The force of the attack topples the wildebeest; the lioness holds on until the thrashing ends.

A mile or so away, a pack of hunting dogs have harassed a herd of zebras for many minutes, looking for prey. Their teamwork has isolated an old mare, and they close in for the kill. Although small and slender, the dogs have broad muzzles and powerful jaws. They nip and bite the zebra's flanks and hind legs. A dog seizes the soft muzzle with its large incisors and holds on with a viselike grip; the rest of the pack begins to eat the immobilized zebra as it stands.

Across the plain, a jackal is hunting springhase, rabbitlike rodents whose agile jumping poses a challenge to any predator. The jackal pirouettes and leaps as it follows the evasive action, finally securing its prey using the quick snapping action of its long jaws.

These killing techniques are examples of the special behavior that carnivorous mammals painstakingly learn. Killing is a function of the front part of their mouths. Nipping incisors, piercing canines, and tight-gripping, bladelike premolars are strategically set in skulls of different length and width to take advantage of the muscular force of the bite. Yet the teeth that lions, dogs, and jackals use for killing are not radically different from those found in many noncarnivorous mammals. Farther back in their mouths lie some special teeth known as the carnassials. These are the hallmark of the true carnivores, or carnivorans—members of a great order of placental mammals, the Carnivora. Useful for shearing meat, these teeth are fundamental to feeding as opposed to killing.

In an adult animal, the carnassials consist of the upper last premolar and lower first molar on both sides of the jaws. These bladelike teeth, which oppose each other, can scissor through flesh and slice off morsels of meat. Each carnassial has two narrow cusps, separated by a notch that holds the piece of meat in place as it is being cut. Even newborn carnivores are equipped with carnassiallike baby teeth that function this way. Young carnivores are introduced to meat before they are weaned, and these baby carnassials are important to their nutrition and survival. The baby carnassials, however, consist of the third upper premolar and last lower premolar (the permanent premolars that eventually replace them are much simpler in form).

The carnassials in all true carnivores, large and small, always fall about halfway between the jaw joint near the ear and the front end of the jaw. This corresponds with the position of maximum bite force delivered by the great temporalis muscles, which originate on the side of the skull and, in large carnivores, often extend from the flanks of a prominent crest of bone, the sagittal crest, at the top of the skull.

Although the muscles on both sides of the head operate together, a carnivore chews off pieces of meat using the carnassials on only one side at a time. Astute

analysis and electric stimulation of specific jaw muscles have established that the fulcrum of the jaw–skull lever is the jaw joint on the side of the mouth opposite the carnassial pair in use. The maximum bite force is transmitted across the head and focused on the midpoint of the opposite jaw, where the carnassials are situated.

Since carnassials are so distinctive and since teeth in general are the most enduring fossils, their presence in the fossil record enables us to estimate the antiquity of the order Carnivora. The earliest-known carnassials date from at least sixty-five million years ago, the time when dinosaurs became extinct and mammals began to gain ascendancy. There are hints of carnassial development in even earlier mammalian predators, perhaps seventy million years old.

The development of carnassials was such a pivotal adaptation that it governed all subsequent carnivore evolution. The system has been fine-tuned within limits for various species, and in some cases the original shearing function of the carnassials has been lost. But the teeth themselves have never been lost in the course of evolution of any of the carnivore lines.

The teeth of dogs and cats exemplify the differences in skeletal structure that separate the two major divisions within the order Carnivora—the suborders Caniformia and Feliformia. Among living carnivores, those whose carnassials are least modified from the original type include the members of the dog, wolf, and fox family—the Canidae. In canids the lower carnassial retains a broad shelf (talonid) at its back end that occludes with the upper first molar (the tooth that lies immediately behind the upper carnassial). The lower carnassial thus has a dual function, shearing at the front and crushing behind. Farther back in the jaw, the second molars above and below have several cusps and continue this crushing function.

Like many other mammals, therefore, dogs and their close relatives use molars for chewing, mixing their food with saliva so that digestion begins in the mouth. As a result, dogs can process a variety of foods, including meat, bone, sinew, invertebrates, and plants. This has great survival value because the wider the range of food, the greater the animal's ability to shift from resource to resource as local conditions dictate.

Cats, on the other hand, lack the talonid "heel" on the lower carnassial and have also lost all the other lower molars. Their only upper molar is a tiny bladelike tooth lying directly behind the large upper carnassial. In some cats, the upper carnassial has an extra cusp in front that may be enlarged, extending the carnassial blade forward. Thus, cats have become specialized for a purely meat-eating life style: they are "hypercarnivores." Their teeth slice meat and deliver the chunks whole to the stomach, with little digestion in the mouth.

The dog family, Canidae, originated early in the evolution of the caniforms. Another early group to appear was the family of giant bear-dogs, the Amphicyonidae. Members of this lineage—now extinct—retained three upper molars, as did the most primitive canids. But in the evolutionary line leading to all other caniform families—which include bears, sea lions, weasels, and raccoons—the last upper molar was lost at least thirty-five million years ago. Eventually, raccoons, weasels, and their relatives also lost the last lower molar. These modifications do not signal greater specialization for eating flesh because the remaining molars, including the lower carnassial, retain their crushing function.

Early in the evolution of the bear lineage, the carnassials themselves began to take on a greater crushing function. The upper carnassial became smaller, and its inner cusp became prominent, approximating an upper molar in form. In the lower carnassial the shearing cusps became blunted and lowered, while the crushing talonid "heel" enlarged to make up half or more of the tooth crown. The upper and lower molars behind the carnassials also grew larger as their low, broad cusps formed effective crushing surfaces. These transformations, accomplished by twenty-five million years ago, were structural responses to omnivorous and herbivorous diets, resembling those of living bears.

This adaptation away from carnivory is called hypocarnivory. It is not confined to the bear lineage but also appears in roughly similar form among raccoons, badgers, and even some fossil canids. It is most spectacularly developed in the dentition of the giant panda, an herbivorous member of the bear lineage that feeds exclusively on bamboo in the mountains of southeastern Asia.

Among the pinnipeds—sea lions, walruses, and seals—all the teeth behind the canines have the same simple shape. How the carnassials evolved to this form can be traced through a succession of fossils. An extinct, twenty-four-million-year-old species of the genus *Enaliarctos,* whose skeleton indicates it was fairly well adapted for open-ocean swimming, still retained carnassials and molars. Successive species of this genus possessed progressively modified carnassials that eventually came to resemble the premolars in front of them. This transformation may have followed a shift from larger prey, eaten in shallow water or on land, to small fish, swallowed whole in the manner of living pinnipeds.

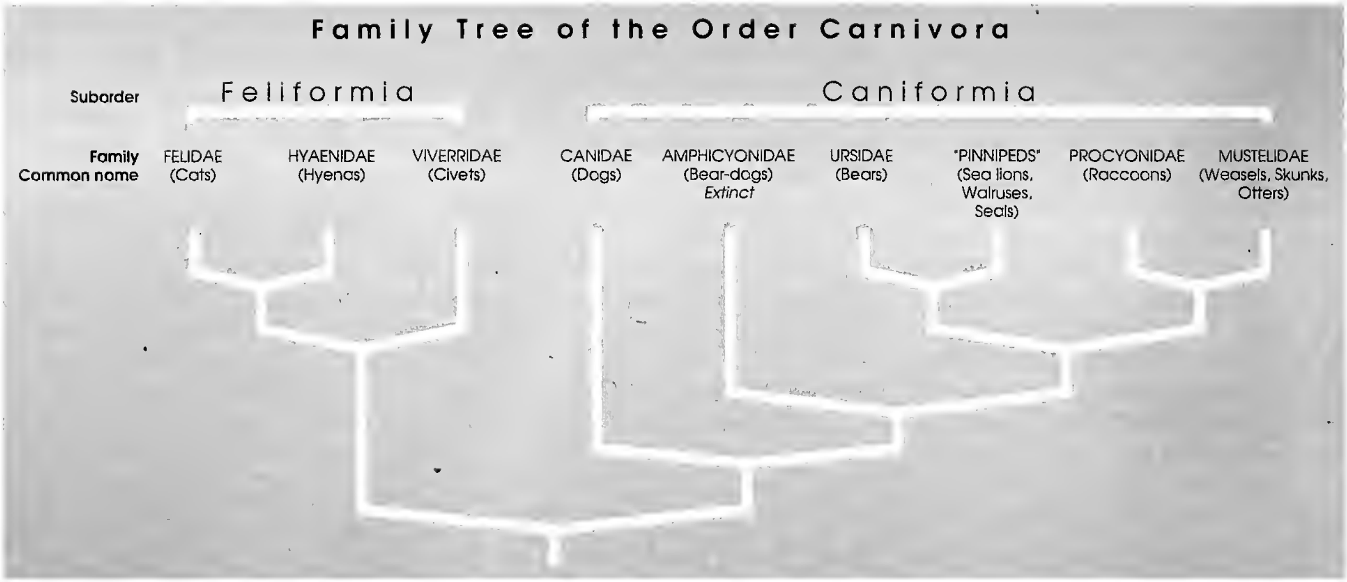
The feliform group also has evolved striking modifications of the carnassials and succeeding molars. The hypercarnivorous cats occupy an extreme branch of the feliform evolutionary tree. Other feliform families, including those containing the civets, mongooses, and hyenas, eat a wider range of food. Still, all feliforms have reduced the molar teeth involved in mastication. Living hyenas, which crush bone with their robust premolars, have gone as far as cats in the loss of all lower molars behind the carnassial, and their only upper molar is a small blade.

Only a few feliform species have become adapted to an otterlike life in streams. None have evolved that are comparable to seals or walruses. But two species, the aardwolf of Africa (an ant-eating hyena) and the falanouc of Madagascar (a civet), have become specialists in feeding on insects, especially ants and termites, an abundant tropical protein resource. As in other ant-eating mammals, whose prey need little mastication, their teeth are very small and simple. The aardwolf's carnassials no longer have a shearing function.

Within the order Carnivora, certain distinct groups have come to resemble one another in details of their teeth. For example, the hunting dog and the Asian

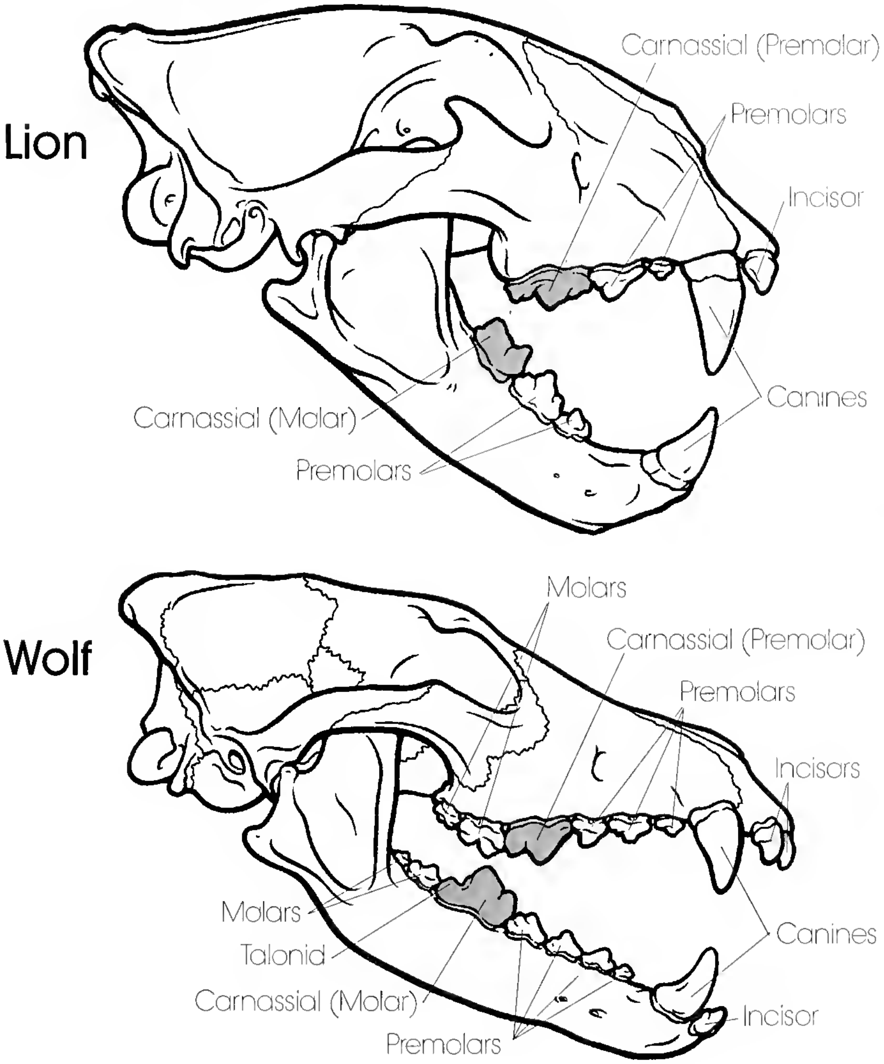
In a scene set in the Great Plains six million years ago, distant relatives of modern dogs (lower right) feed on a camel carcass. These extinct carnivores, known as Osteoborus, *sheared meat and crushed bone with their carnassials—the teeth that are the hallmark of the order Carnivora.*
Detail of mural by Jay H. Matternes; National Museum of Natural History, Smithsonian Institution

Joe LeMonnier



dhole, the most hypercarnivorous living canids, have the most catlike teeth. Similar teeth are found in some extinct amphicyonids and several groups of fossil canids. This phenomenon, called parallel evolution, is widespread among mammals in general. It occurs when closely related groups of mammals follow similar adaptive paths.

A related phenomenon is convergent evolution, in which distantly related species achieve similar adaptations and come to resemble each other superficially. For example, different skeletal parts of the forelimb were modified in bats, birds, and pterosaurs to produce the same adaptation, flight. Similarly, some mammals outside the order Carnivora have evolved teeth that resemble carnassials. These include the Tasmanian devil, which is a primarily carnivorous marsupial, and the extinct creodonts, placental mammals usually regarded as distant relatives of the Carnivora. In these relatively primitive animals, all the molars have a carnassial-like form, functioning together like pinking shears. Similar teeth also characterize early members of the order Insectivora. In one insectivore, the hedgehog, the same teeth as in true carnivores have become specialized carnassials—the upper last premolar and lower first molar. This appears to be an unusual case of convergent evolution, in which the same structures are involved among animals only distantly related to the Carnivora.



A comparison of the skulls of a lion and a wolf reveals the cat family's extreme adaptation to carnivory. The lion lacks crushing teeth; its only lower molar is the meat-shearing carnassial. Its sole upper molar is a tiny, bladelike tooth, here hidden behind the upper carnassial. The wolf retains molars for crushing, and even its lower carnassial has a shelflike section, the talonid. In this view of both skulls, the canines and larger incisors hide the smaller incisors.

Illustration by Ed Heck

The Sabertooth's Repeat Performances

by Christine Janis

The immense diversity of mammals living today is the legacy of historical events. One was the Cretaceous extinction of the dinosaurs, which had monopolized most of the earth's living space for millions of years. With the dinosaurs gone, a major constraint on mammalian evolution and radiation was removed. But perhaps even more important was the breaking up of the supercontinent Pangaea, which began some 130 million years ago and was still going on in the early Cenozoic, about 65 million years ago, when the modern radiation of mammals began.

As the continents went their separate ways, they carried their mammals with them. Separated from other populations of their kind, these "seed faunas" of small, early mammals were free to evolve in isolation. Each continental block developed its own group of mammals. Placental mammals, for example, probably originated in Asia, in the early Cretaceous. Monotremes (the egg-laying platypus and echidnas) were almost certainly native to Australia. Other animals endemic to that continent today—the marsupials—came somewhat later, their ancestors crossing over Antarctica from South America in the early Cenozoic, before the final separation of the southern continents.

Sometimes continental blocks gained mammals from ancestors that dispersed, by chance, across the still-widening oceans. In some cases, chance dispersal added to an already existing fauna. In others, however, it was the sole source. Madagascar and New Zealand, for instance, apparently broke away too early to have their own mammal contingents, but while Madagascar developed a rich mammalian fauna by waves of dispersal, New Zealand has no native mammals other than bats.

The results of all this mammalian radiation were widely diverse, but certain similarities can be found among mammals that are only distantly related. Some of the similarities—such as the production of milk to feed the young—are attributable to the shared ancestry of all mammals, but others came about as long-separated types of mammals independently discovered similar "solutions" to the "problems" posed by similar environments. Examples of such convergence can often be seen in the body forms of mammals from different continents. Such forms are referred to as convergent ecomorphological types. The term *ecomorph* refers to the impact of behavior and ecology on the evolution of an animal's anatomy.

The most familiar examples of convergence today are those of Australian marsupials and placental mammals that evolved elsewhere in the world: the thylacine, or Tasmanian "wolf" (believed by most people to have gone extinct earlier this century, although tantalizing reports of its continued survival appear now and then), and the wolf of the Northern Hemisphere, for instance. A striking amount of convergence can also be seen in the "flying"—actually gliding—possums of Australia and the two separate groups of placental "flying" squirrels (one in the Northern Hemisphere and one in Africa), as well as Asia's so-called flying lemurs (not only do they glide, they are also not true lemurs).

Australia is a fruitful place to look for examples of convergence because of its long history of isolation. Madagascar, too, has produced many native mammals convergent with mammals elsewhere: the fossa (a giant civet), almost indistinguishable from a cat; tenrecs, some of which resemble Northern Hemisphere hedgehogs and moles; and lemurs, primates that radiated into a wide variety of forms. Some extinct giant lemurs appear to have been ecomorphs of such animals as the marsupial koala, the placental orangutan, and the extinct placental ground sloths.

In many other parts of the world, the continuing shifting of the continents and the migrations that follow the periodic lowering of sea levels have blurred much of the originally distinct character of the various continental faunas and annihilated many unique forms. Africa was the first to suffer, when it docked with Eurasia in the late Oligocene or early Miocene, between twenty and thirty million years ago. The little rock hyrax, or coney, for example, is the sole survivor of a great diversity of hyraxes that once included piglike, hippolike, and antelopelike forms.

North and South America have lost much of their early mammalian diversity as well. Hippolike rhinos and giraffelike camels no longer roam the savannas of North America, and five entire orders of native ungulates—which evolved into forms paralleling rhinos, horses, and camels living elsewhere in the world—are now extinct in South America. Enough species remain to bear witness to each continent's period of isolation, and plenty of examples of convergence can still be found—the South American armadillos and African pangolins, for example—but the faunal blending that has occurred over time has reduced the opportunities to observe the phenomenon in living animals.

The fossil record offers a chance to discover more instances of convergence. It also provides an example of an evolutionary phenomenon that resembles classic convergence, but that takes place over time rather than over space. "Iterative" evolution involves the appearance, extinction, and reappearance of the same ecomorphological type, sometimes (but not always) in the same taxonomic group. The best-known and most dramatic examples of iterative evolution are the saber-toothed carnivores. The saber-toothed ecomorph—a predator with elongated canines and a powerful body—has existed several times in the past, which raises the question of what factors may dispose certain types of animals to extinction.

The most familiar of the sabertooths is the Pleistocene saber-toothed tiger (*Smilodon*) of the La Brea tar pits in California. This animal was a true cat (family Felidae) but was only distantly related to the animal we call tiger today. Saber-toothed cats first appeared in the Old World in the later Cenozoic, but the earliest version of a saber-toothed mammalian predator, *Machaeroides,* had evolved some fifty million years before, in the Eocene, and belonged to the extinct carnivorous order Creodonta. Marsupial versions of saber-

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The most familiar of all sabertooths, Smilodon *belonged to the family Felidae, although it was not in the same genus as present-day big cats. As recently as 12,000 years ago, this predator roamed North America, perhaps using its long, daggerlike canines to slice open it victims' bellies.*
Illustration by Pat Ortega

toothed predators also existed in South America, with the extinct borhyaenid carnivorous marsupials (distantly related to opossums) producing the leopard-sized *Thylacosmilus* in the Pliocene-Pleistocene. (Another interesting case is presented by the thylacoleonids, an Australian lineage possibly related to koalas and wombats. Descended from an ancestor that had lost its canines, they developed caninelike incisors. Thylacoleonid anatomy indicates that they, like true saber-toothed ecomorphs, were heavy-set predators.)

But the real stars in the saber-toothed predator game were the nimravids, an extinct family of placental mammals that belonged to the extant order Carnivora. Despite their remarkable resemblance to true cats, nimravids were only distantly related to the family Felidae. Sometimes known as "false sabertooths," nimravids were especially diverse in Eurasia and North America during the Oligocene, about thirty-four to twenty-three million years ago.

Bobcat to jaguar sized, nimravids were in general smaller than the Pleistocene saber-toothed true cats, but like the true cats, they also developed two ecomorphological types within the broader role: a more lightly built, "scimitar-toothed" form with somewhat elongated, bladelike canines; and a more powerful, shorter-legged, "dirk-toothed" form with very long, daggerlike canines, in some cases supported by a corresponding flange on the lower jaw. (The placental creodonts and the South American marsupials mostly resembled the dirk-toothed type.) How these teeth were used to kill prey is a subject of debate. A normal, catlike bite to the top of the neck might snap the flattish blades, so the saberlike teeth were probably used to slice open the victim's belly or the underside of its neck.

Larry Martin, of the University of Kansas, has traced the iterative evolution

of the dirk-toothed type of saber-toothed carnivores in the Great Plains of North America. He found that following the extinction of the creodont *Machaeroides,* the role was empty until the appearance in the late Eocene, some five million years later, of the nimravids, probably representing immigration from Asia. Several different types of jaguar-sized nimravids alternated as "top cat" in this role during the Oligocene, but all nimravids went extinct in North America about twenty-three million years ago.

There was another saber-toothed "cat gap" for the next twelve million years or so, until the immigration, probably via Asia, of *Barbourofelis,* a lion-sized nimravid. *Barbourofelis* lasted until near the end of the Miocene, becoming extinct about seven million years ago. Shortly after the extinction of *Barbourofelis,* another dirk-toothed predator—*Megantereon*—immigrated from Asia. A true felid, *Megantereon* was an ancestor of *Smilodon,* which thrived as recently as 12,000 years ago, during the late Pleistocene.

Why has the saber-toothed ecomorph been so vulnerable to extinction, and why is it not present today? Large carnivores are, in general, highly susceptible to extinction. The skeletons of all sabertooths suggest predators built for power, not speed (the dirk-tooths were more powerfully built than present-day lions or tigers). That, in turn, implies a hunting style that relies on ambush rather than the long chase, a style associated in carnivores today with a more-or-less solitary life style and large individual home ranges. If the density of prey decreases, perhaps because of environmental changes, the home range of such a predator has to increase to insure enough food for survival.

Sabertooths faced with a scenario of declining prey and, thus, increasing home-range size would also be less and less likely to encounter potential mates. Eventually, the chances of a sabertooth finding a mate in a neighboring territory would become remote, and the population would decline, with extinction inevitable unless environmental circumstances improved and prey increased. Lending some support to this idea is evidence that some of the North American sabertooth extinctions overlap with turnovers and extinctions in the ungulate faunas, particularly in the late Miocene. The megafaunal extinctions of large herbivores that took place at the end of the Pleistocene may have sounded the death knell for the saber-toothed ecomorph worldwide.

Will there ever be another saber-toothed ecomorph? We cannot know, of course. But one candidate for a saber-toothed ancestor might be the Asian clouded leopard, *Neofelis nebulosa,* a forest-living, jaguar-sized cat with the longest canines of any extant felid.

Some mammalian traits appear to have evolved only once, with no evidence of convergence over time or space. For example, although a variety of families contain gliding mammals, all true flying mammals—bats—belong to a single order, the Chiroptera. (The only other vertebrates to have evolved powered flight are birds and the extinct pterosaurs.)

Our own mode of bipedalism, with an upright torso and a striding gait, is also unique. Many mammals (such as kangaroos and many types of rodents) have a hopping mode of bipedal locomotion in

Pogonodon platycopis *(once regarded as being in the genus* Dinictis*) was one of the nimravids, an extinct family of carnivorous mammals only distantly related to true cats.* Pogonodon *had scimitarlike canines shorter than those of* Smilodon; *it was also smaller and more lightly built and—as this artist's rendition suggests—may have had body markings like an ocelot (far right, bottom).*
Illustration by Pat Ortega

which the trunk is held horizontally and a long tail is used as a counterbalance. Bipedal dinosaurs walked with a similar body posture, and their descendants, the birds, still maintain a horizontal torso (penguins are the only exception), compensating for the loss of the bony tail by pivoting the body over the knees. But humans, evolving as we did from African apes that had already lost the tail and developed an upright torso, inherited a unique set of design constraints and adaptations that made the "normal" mode of vertebrate bipedality impossible.

The great South American radiation of primates produced no upright ape, which is surprising since a remarkable example of convergence exists between the Asian gibbon, the most primitive of the living apes, and the South American brachiating spider monkey, although the latter differs in possessing a long, prehensile tail. I suspect that the South American monkeys never experienced an apelike radiation because the role of a terrestrial, at least partially bipedal herbivore was already taken up by the endemic ground sloths.

The uniqueness of the human ecomorph is often a source of pride. However, with all the problems facing the planet today—so many seemingly a result of the spread of civilization—we might perhaps be wise to hope that if the human species ever does succeed in doing itself in, our particular ecomorphological type will not reemerge any time soon. The world might survive a reappearance of the sabertooths, but could it take another round of us?

Tough Times in the Tar Pits

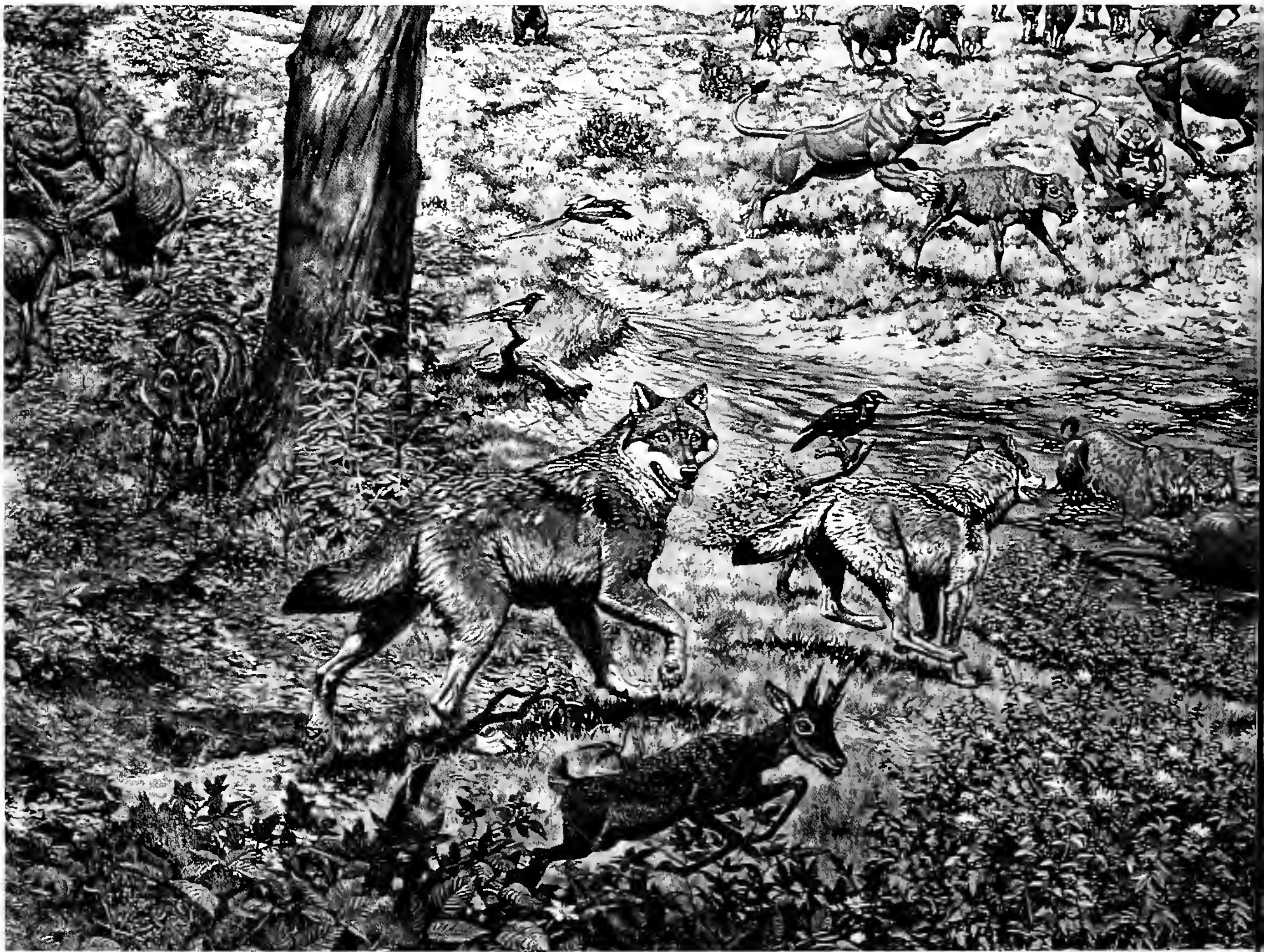
by Blaire Van Valkenburgh

The camel had been a quick kill. Its struggles at the stream's edge, where it had been trapped in quicksand saturated with asphalt, had attracted a pack of dire wolves. They dispatched the huge beast quickly with multiple, ripping bites to its abdomen.

Now the feeding wolves rapidly pull muscle and viscera from the carcass, stopping occasionally to scan their surroundings. Condors circle above and a coyote paces nearby, eager to clean up any scraps. At the sound of a warning growl, all the wolves stop feeding and turn toward the sound; the fur on the back of their necks stands erect, and their lips pull back to reveal their upper canines. Two sabertoothed cats approach, each twice the mass of a dire wolf. The cats display their canines—long, slightly curved daggers that extend well below their lower jaw. Although only two sabertooths are challenging the pack of eight wolves, the wolves are unwilling to engage the big cats in battle. The sabertooths move closer, lunging and swiping at the wolves, paws spread wide and claws extended. All the wolves move away from the camel and watch as the sabertooths feed on the catch.

After the big cats have left, the hungry wolves will return to eat what remains of the carcass. By the following day, little evidence will be left of the camel's death on the sand's surface; all exposed bones will have been carried off and chewed by scavengers such as the coyote. Those bones mired in the sticky sand will be entombed and preserved—and will emerge as fossils from the tar pits of Rancho La Brea some 20,000 years later.

The array of fossil mammals from this Los Angeles site, which began to accumulate 36,000 years ago, reveals the diversity of large animals that inhabited North America until the late Pleistocene, only about 10,000 years ago. Today only eleven species of hoofed mammals the size of a peccary or larger exist in North America; in the past, fifty-six lived on this continent. They included giant camels, horses, bison, mastodons, and mammoths. These herbivores were preyed upon by a rich array of carnivores: fifteen species the size of a coyote or larger, as opposed to just seven today. In addition to sabertooths, dire wolves, and coyotes, North America was home to black, grizzly, and short-faced



bears, gray wolves, pumas, and American lions that were nearly twice the size of their African cousins.

Recently, with the help of graduate student Fritz Hertel, of the University of California at Los Angeles, I conducted studies that provided some unexpected findings about the intensity of competition for food among late Pleistocene carnivores. After studying the frequency of broken teeth in modern lions, wolves, and hyenas, we found that, on average, one out of four adults had suffered at least one broken tooth during its lifetime. However, the spotted hyena, a habitual bone-crusher, had a higher frequency of broken teeth, approaching 40 percent. In all species, the most commonly broken teeth were canines (fangs, or eye teeth), followed by incisors and premolars toward the front of the mouth and carnassials (shearing teeth) and molars along the sides. The increased fracture frequency in hyenas probably reflects their tendency to consume carcasses more fully, sometimes breaking teeth as they crunch bones.

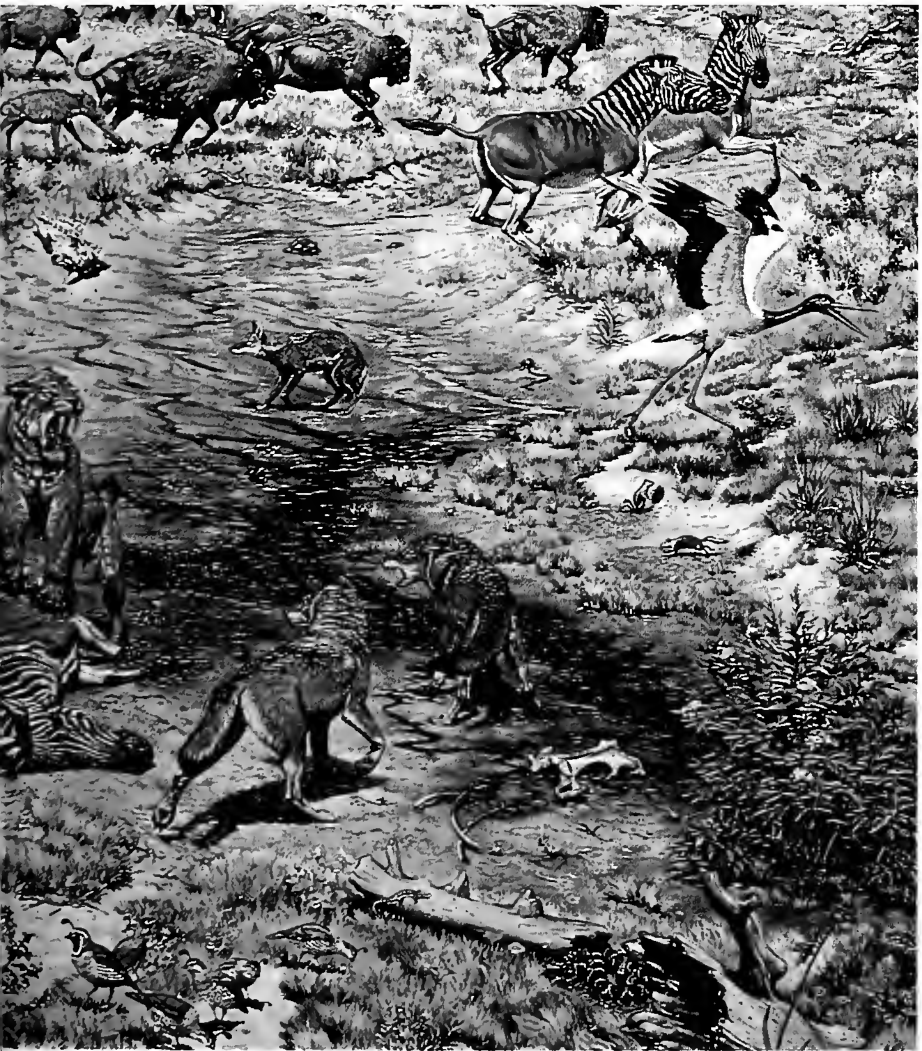
These data suggested that tooth breakage could be used as an index to reflect the level of competition for food in extinct predators—the hungrier the predators, the more fully a carcass would be devoured, down to and including the marrow-rich bones. To obtain a good estimate of fracture frequency in extinct carnivores, we had to look at a lot of teeth. While most fossil sites yield few carnivore teeth, the tar pits of Rancho La Brea are an exception. Here, approximately ten carnivores were lured to their death by each herbivore that was trapped. We were able to examine more than 4,000 teeth of Rancho La Brea carnivores and 550 teeth of dire wolves from two other late Pleistocene sites. All of the teeth were attached to skulls or jaws, and we considered teeth to have been broken only if they showed distinct signs of wear after the break occurred. To our surprise, the frequency of broken teeth in dire wolves, sabertooths (*Smilodon*), American lions, and coyotes was three to five times that observed for modern carnivores, including hyenas. This held true for dire wolves at all three sites and, since we accounted for age, was not the result of age differences in individuals in the ancient and modern samples. (Bobcats and pumas left few fossil teeth, having been only occasional visitors to the tar pits, but none of their teeth were broken.)

The fossil record of carnivores (teeth included) before 40,000 years ago is meager compared with that of the late Pleistocene. Our studies do suggest, however, that for predators such as sabertooths, tooth breakage increased over time; that is, sabertooths that hunted 40,000 years ago had relatively fewer broken teeth than sabertooths that lived 10,000 years ago.

What could account for tough times in the late Pleistocene that made broken teeth more frequent than seems to have been the case before and since? One possibility is that the tar pits attracted injured or old—and weak-toothed—predators because prey were so vulnerable when mired. Based on their relatively slight tooth wear, however, most of the lions, dire wolves, sabertooths, and coyotes that died at Rancho La Brea were young adults seemingly in the prime of life. A single broken canine or premolar is unlikely to have severely affected their ability to hunt.

I believe the increased tooth breakage in late Pleistocene large predators suggests that at that time, competition for food was more intense than it had been previously and much fiercer than it is today. Having secured a carcass, a carnivore needed to extract as much nourishment from it as possible, a process that led to broken teeth. The extinction of the huge and once abundant prey species—American camels, giant sloths, mammoths, and others—could have been the late Pleistocene turning point, subjecting the predators to a fight for life that most of them lost.

Of the four La Brea species we studied that had broken teeth, only the most omnivorous survived and is today one of the most adaptable of carnivores. The coyote continues to thrive today in habitats as different as the wilds of Yellowstone and the backyards of Beverly Hills.



In a detail of a scene at La Brea some 20,000 years ago, sabertoothed cats drive dire wolves away from the carcass of a horse. The asphalt in which so many Pleistocene animals became mired rarely formed lakes; it usually collected in shallow seeps, sometimes camouflaged by debris.

Painting by Mark Hallett

The Whales of Tethys

by Philip D. Gingerich

In Greek mythology, Tethys is the wife of Oceanus and a sea goddess in her own right. About a hundred years ago, geologists appropriated her name for the ancient sea that once divided the earth's great northern and southern continents. Today the Mediterranean is a mere suggestion of what Tethys must have been in its time. Stretching from what is now Spain to Indonesia, Tethys was an ocean when trilobites and other early forms of life flourished, and it lasted more than 500 million years, through the Age of Dinosaurs and into the Age of Mammals. The inexorable drift of continental plates finally obliterated Tethys. India and central Asia converged and raised the Himalayas; Arabia pushed into western Asia and uplifted the Zagros; Africa encroached on Europe and raised the Alps. Tethyan sea sediments now lie dry and exposed in the Sahara Desert and in the folded foothills of the Himalayas and the Alps.

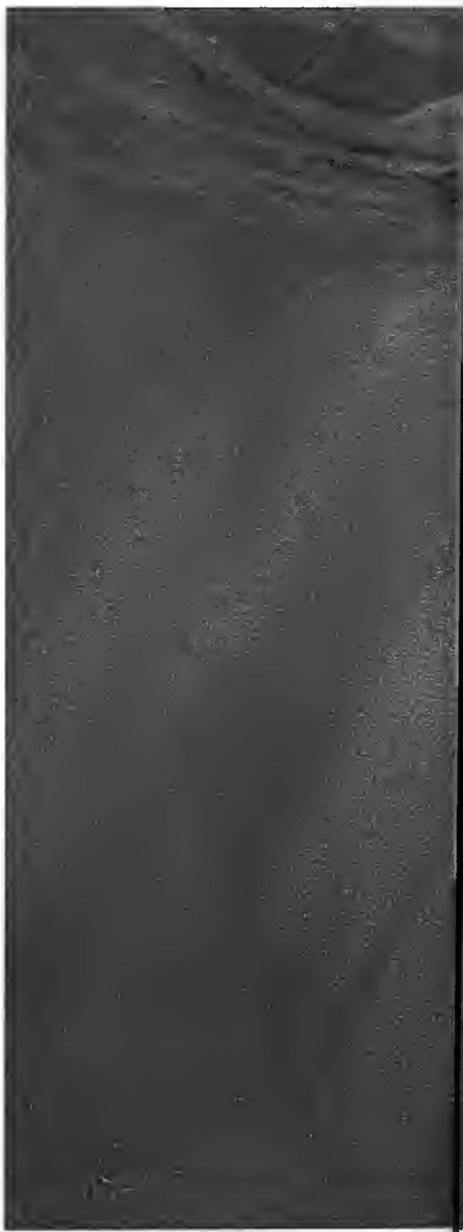
Extensive and relatively shallow, the waters of Tethys would have been warm and well stocked with fish and mollusks. It must also have been inviting to mammals that lived at its edge. Three hundred million years after vertebrates first colonized land, some mammals reversed their pattern and returned to Tethys. Today, the descendants of those seagoing pioneers—toothed porpoises and dolphins and the toothed and baleen whales that make up the order Cetacea—have adapted fully to life in water. All have a streamlined body, a blowhole or pair of holes on the top of the skull for breathing, simplified teeth (replaced in some by keratinous baleen), a specialized system for underwater hearing, and locomotion powered by a fluked tail instead of by limbs or flippers. These advanced cetacean features were acquired in steps over time, but the prototype was a land mammal living on the shores of Tethys.

The oldest-known fossil whales come from the Kuldana Formation, a stratum of rocks in northern Pakistan deposited by ancient rivers and sandwiched between Tethyan marine formations. In the Eocene, some fifty million years ago, Tethys could not have been far downriver from this site. In 1979, I led an international team from the United States, France, and Pakistan to search the Kuldana Formation for fossils of early land mammals. One December day, Jean-Louis Hartenberger, a rodent specialist, hammered open a rock with what looked like a small bone on its surface; the bone turned out to be a crest on the back of a beautifully complete fossil skull. Because the skull was relatively large but the braincase was small, we began to suspect that he had found an archaeocete, a member of an ancient family of whales. These now-extinct relatives of today's toothed and baleen whales had some modern features, such as a dense tympanic bone for hearing, but lacked many others, including a blowhole on the top of the skull.

When I returned to my lab at the University of Michigan, my colleagues and I removed the remaining rock from the new skull. The configuration of bones in the skull base confirmed that it was indeed an archaeocete; we named it *Pakicetus inachus*. We later speculated that this dog-sized whale first entered Tethys from its riverside home to take advantage of easy fishing in the warm waters.

Pakicetus, which lived about fifty million years ago, had not evolved the ability to hear directionally, or perhaps to hear well at all, in water, a hallmark of modern whales. Archaic features such as this, along with its discovery among remains of land animals, makes *Pakicetus* a very primitive whale indeed. In time and in its morphology, *Pakicetus* is perfectly intermediate, a missing link between earlier land mammals and later, full-fledged whales.

Our unexpected discovery and our subsequent investigation of *Pakicetus* made me realize how little was known about the



Basilosaurus, *an ancient whale that lived some forty million years ago, had front flippers and tiny but functional hind limbs, complete with thigh, femur, and three toes. It may have used its feet to guide its fifty-foot-long body during copulation. A fossil of the whale was unearthed in 1989 in what is now the Egyptian Sahara.*

Painting by Marianne Collins; © 1993, W. W. Norton and Company transition of whales from land to sea. I also reasoned that we need not remain in the dark. After all, whales live and die in water, where they are easily buried and fossilized, and their fossils are large and relatively easy to find. Furthermore, marine rocks of Eocene age cover vast areas of the earth's surface. Since finding *Pakicetus*, my colleagues and I have been exploring whenever possible the deserts of Pakistan and Egypt for whales to fill the gaps in our knowledge. Our results have been gratifying.

In 1989, I was working with paleontologists Elwyn Simons and Holly Smith in Tethyan sediments of the Egyptian Sahara, where we found another archaeocete. In addition to a hefty, four-foot-long skull and huge ribs, we found a thigh bone, then lower leg bones, then an ankle. Finally, we also unearthed, one by one, three tiny toes. These, the first complete hind limbs and feet of an archaeocete to be discovered, belonged to the forty-million-year-old *Basilosaurus isis*, a large early whale that must have been one of the most ferocious marine carnivores of its time. Because the hind limbs (about eighteen inches long) were not connected to a sacrum in the spinal column as are the hind limbs of land mammals, *Basilosaurus* could not possibly have used its feet to lift or support its eellike, fifty-foot-long body. Yet the bones and joints are so well formed, with strong processes for the attachment of muscles, that the limbs appear to have been functional. I suspect that *Basilosaurus* used its legs and feet as guides during copulation.

Basilosaurus exhibits not only an unusually elongated shape but also oddly proportioned vertebrae that lead me to believe that it was on a side line, rather than on the main path to the evolution of modern whales. Another cetacean from the same era, found in Egypt and known as *Prozeuglodon atrox*, combines normally proportioned vertebrae with hind limbs much like those of *Basilosaurus* and is a better candidate for a direct ancestor of modern whales.

Paleontologists have long believed that because whales evolved from land mammals, they must have had hind limbs and feet early in their history. What surprised me most about finding hind limbs on *Basilosaurus* and *Prozeuglodon* was that these archaeocetes lived ten million years after *Pakicetus* and the origin of whales. Ten million years is a long time, even to a geologist, and finding hind limbs on such "late" whales means that the transition from land to sea took time—time enough to allow us to study the intermediate stages

in the fossil record. Evolution is dynamic, but change doesn't happen in a flash. Thus, we can expect to unearth many more missing links.

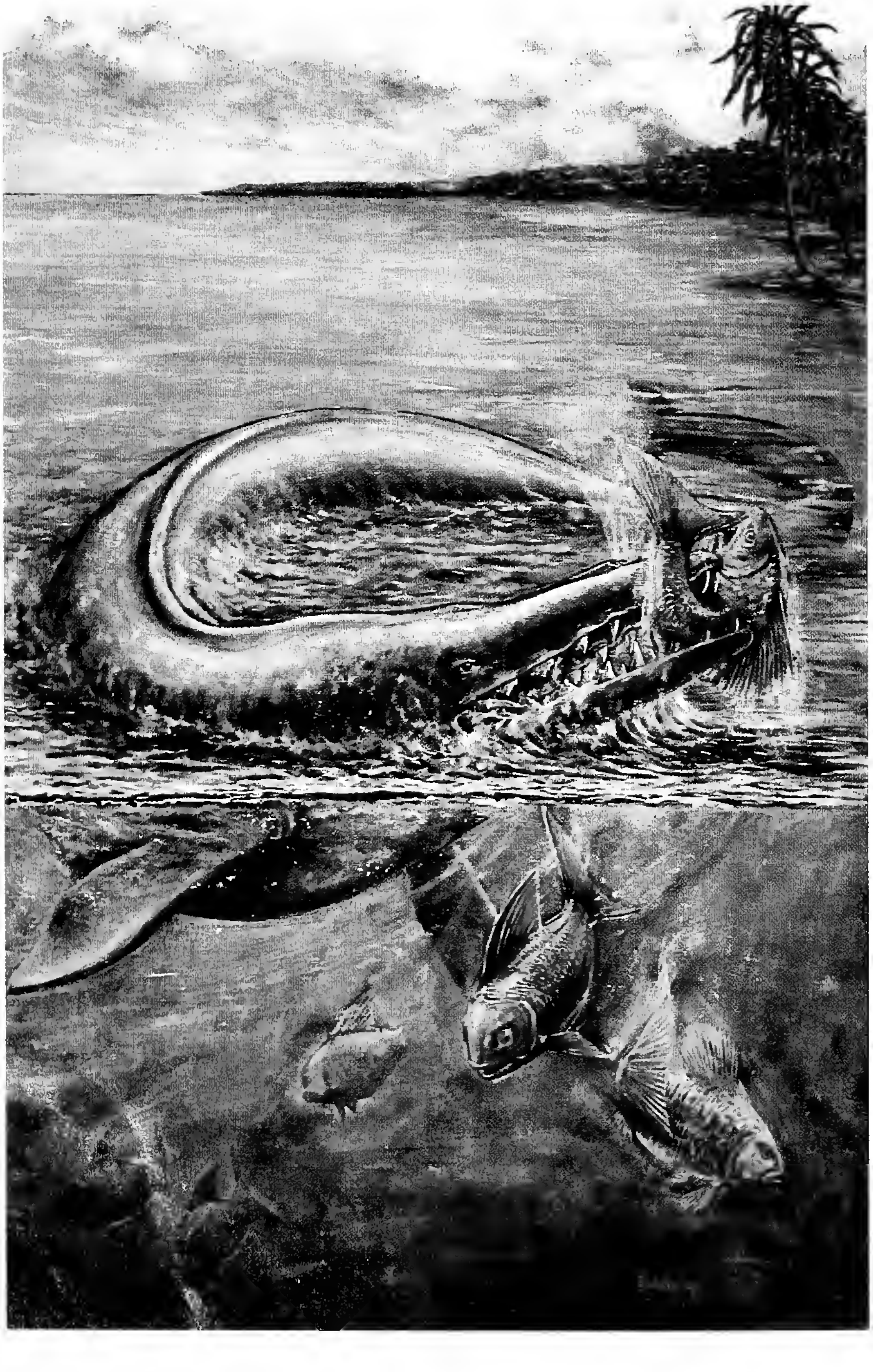
Further rungs in the cetacean evolutionary ladder have already come to light. Recently, paleontologists Hans Thewissen, Taseer Hussain, and Muhammad Arif were working in Pakistan when they found a partial skeleton of a brand-new species of a forty-nine-million-year-old Tethyan archaeocete, with important parts of both front and hind limbs. The femur, or thigh bone, is large, like that of a land mammal, but the feet are long, like those of a seal. The scientists named the animal *Ambulocetus natans,* "the walking whale that swam," in recognition of its amphibious nature. *Ambulocetus* was possibly like an otter or seal in its behavior. It most likely came ashore to breed and give birth. Using its flipperlike front limbs, it may have moved about on land by hitching itself forward, similar to the way a sea lion moves on land. Its hind legs and feet evidently propelled it through the water when it returned to Tethys to feed on marine fare.

The Tethyan sediments of Pakistan continue to be a mine of ancient whale remains. In December of 1992, University of Michigan graduate student Xiaoyuan Zhou found an archaeocete about forty-eight million years old in sediments that were deposited in deeper water than all older finds. It has a nearly complete vertebral column, a small femur, and short neck vertebrae, indicating some streamlining of the head and body. Land mammals and some early fossil whales have fused sacral vertebrae and therefore rather stiff hips and tails, but this creature's sacral vertebrae were not fused, giving its back and tail a flexibility approaching that of later whales. It is thus an important link in the transition to fully whalelike swimming, in which the animals undulate their body and move their fluke up and down.

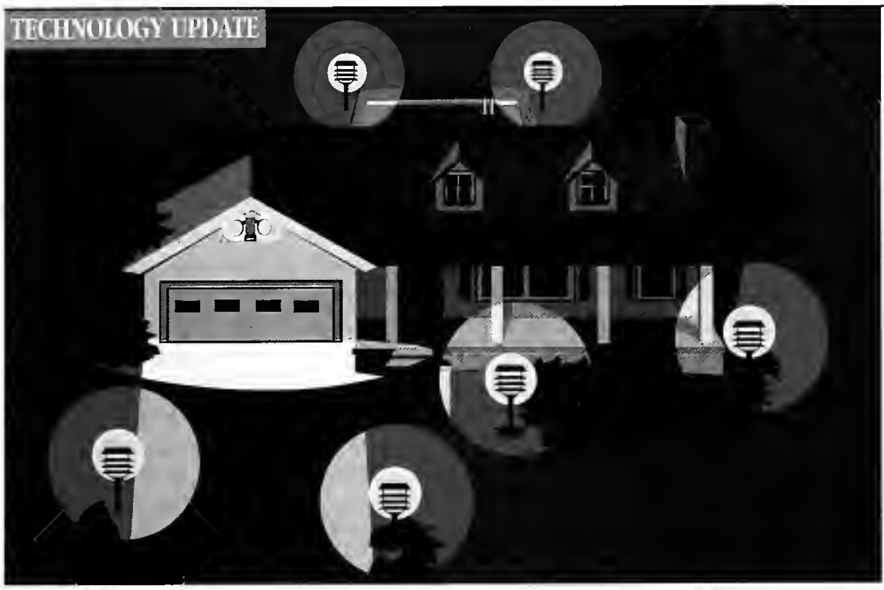
In the same month, Muhammad Arif and I were again scouring the shallow Tethyan sediments of Pakistan when he found two forty-seven-million-year-old partial skulls and skeletons of a previously poorly known whale called *Indocetus*. The new fossils showed that the animal was long necked and still had long hind limbs, a rigid sacrum, and a robust tail. As in our earlier *Pakicetus,* we saw many similarities between this primitive animal and land mammals known as mesonychids. A varied group ranging from cat size to bear size, mesonychids lived between sixty and thirty-seven million years ago. They were principally carnivorous scavengers.

Was the first land mammal to return to the sea and start the wheels of whale evolution a mesonychid? This theory—originally put forth in the 1960s by Leigh Van Valen, an American Museum graduate student at the time—is based on similarities in tooth structure. Subsequent discoveries, particularly of similarities in whale and mesonychid skeletal structure, have upheld this view.

As the fossil record of early whales continues to grow, our knowledge of the evolution of advanced cetacean traits becomes clearer and more complete. Fossils contradict the notion that whales suddenly appeared full-blown, without intermediate forms. I am a skeptical soul, but I have seen a lot of Tethys and excavated a lot of whales in the past fifteen years. Intermediates, missing links, are everywhere.



Along the coast of Tethys, an ancient warm ocean that stretched from Spain to Indonesia, an undulating Basilosaurus *catches fish with its four-foot-long jaws and battery of sharp teeth.*
Painting by F. Heimberg; collection of G. Pilleri



It's midnight in Richmond, Virginia and the sun is still shining?

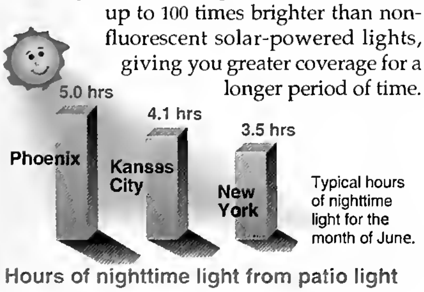
Brinkmann's advanced solar-panel technology captures the sun's energy, providing the brightest solar lighting ever available.

By Charles Anton

Solar lighting wasn't invented yesterday. But the truth is, most people couldn't afford to put this powerful technology to work for them... until now. Brinkmann, the leader in solar lighting technology, has teamed up with Comtrad to offer the first affordable home solar lighting system.

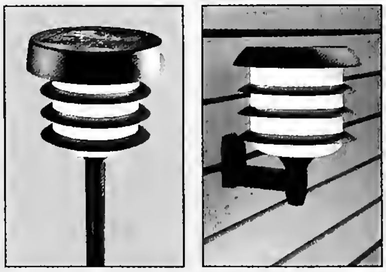
No bills, no wires. Now you can take advantage of the natural gift of sunlight to better your home and yard, with the solar patio light. All the connections are internal, so no wires are needed. And because solar lights gather energy from the sun, you'll never get an electric bill for them.

Fluorescent advantage. The solar patio light is designed to provide a maximum amount of illumination with only a minimum amount of battery drain. Its unique fluorescent tube is up to 100 times brighter than non-fluorescent solar-powered lights, giving you greater coverage for a longer period of time.



Hours of nighttime light from patio light

These innovative new solar patio lights have a built-in semicrystalline solar panel that gathers energy from the sun by day and uses that energy to recharge the built-in battery.



Versatility. *The solar patio lights come with two 10-inch stakes and a deck mounting bracket for optimum versatility.*

At night, the light uses stored battery power to illuminate your home and yard. Its built-in photo sensor automatically detects darkness and turns the light on. When fully charged, the lights will shine for up to seven hours using energy stored during the day.

Versatile design. With solar patio lights, your yard will be the envy of the neighborhood. The expertly designed lights add life to your landscaping by adding light to your walkway, deck or garden. They come with two 10-inch stakes for adjustable height. Use one stake for walks and steps. Use two stakes for shrubs or flower beds. The light also comes with a bracket for wall, fence or deck mounting. For a different look, the three tiered rings can also be removed. Whether for safety or for decoration, these solar powered lights are the most affordable way to light up your home.

Easy installation. The patio light installs in seconds. To assemble, simply snap fit the stakes and light together and place it in the ground. Or if you want to use the wall mount, simply fasten the bracket with two screws and insert the solar light.

Security light with motion sensor.

Now you can add security, safety and light to your home with Brinkmann's solar-powered security lighting system. The powerful floodlights not only use solar power, but utilize a motion sensor. When the infrared sensor detects a motion, its super-bright quartz-halogen bulbs automatically turn on for a full minute and a half. Never again will you have to fumble around in the dark trying to find your keys. Never again leave your lights on all night just to warn off burglars. The security lighting system will turn lights on up to 120 times per full charge. A built-in photo cell prevents daytime operation.

Solar security light *with motion sensor.*

Easy set-up. *The solar panel mounts directly on the roof of your house or garage. It has an adjustable bracket which allows you to angle the panel towards the sun. The security lighting system also comes with a 15 foot cord so that the panel can be mounted on your roof or other remote location. The cord simply plugs into the side of the light.*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Caught in Time

by Richard H. Tedford

The scene—a chase—is one that has been enacted. throughout the history of mammals. The time is some fourteen and a half million years ago, and the place is a mud flat in what is today northeastern Colorado. In a burst of power, a huge carnivore known as a bear-dog lunges at a tiny pronghorn antelope, which leaps in an attempt to elude its pursuer. In an evolutionary sense, the two main players are at opposite ends of their destiny—the bear-dog being on the verge of extinction, the pronghorn near the beginning of its kind's history. The scene, presented in the American Museum's new Hall of Mammals, with mounted skeletons of predator and prey, has a timeless quality. While the scene is red in tooth and claw, the predator and prey are caught, like the figures on Keats's Grecian urn, in an action just before closure.

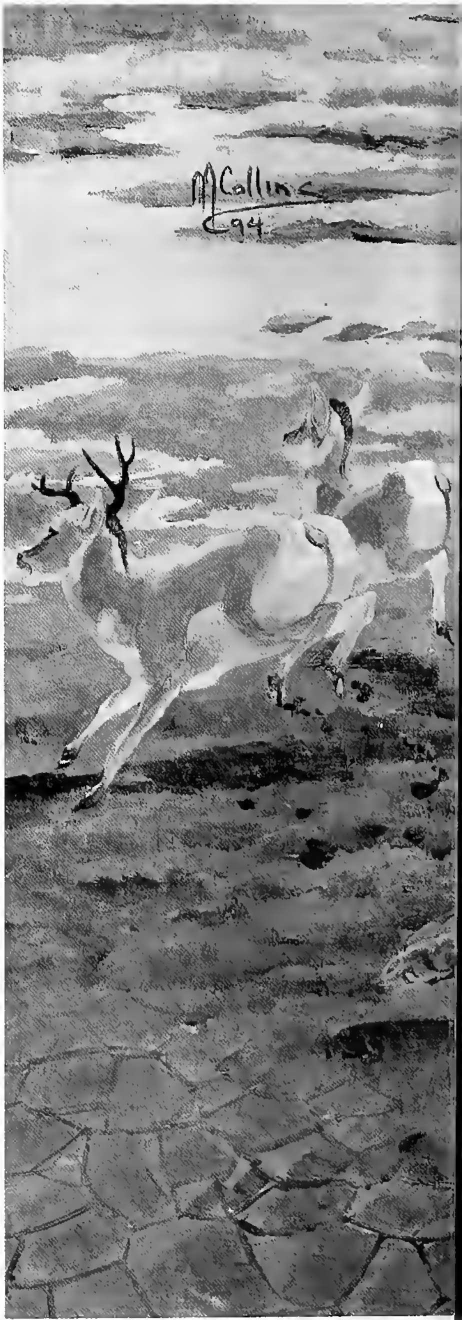
This depiction for the new exhibition came about as a result of serendipitous discoveries of bones in Colorado and a dramatic set of fossilized tracks in California. It is not an exact reconstruction; the predator and prey did not drop dead and fossilize in tandem, but we have good reason to believe the scene is plausible. Both the bear-dog and the pronghorn skeletons were discovered in northeastern Colorado in successive fossil deposits laid down a few hundred thousand years apart. Because this is a short span by geological standards, we believe that the two kinds of animals very likely coexisted for a time in this part of North America.

The bear-dog skeleton, the most complete recovered in North America, was collected in the 1930s by a team from the University of California at Berkeley. The new mount consists of a cast of this material, combined with a more complete skull, jaws, and a few limb bones from the American Museum's collection, which were found in western Nebraska. The pronghorn mount is the actual skeleton of a single individual collected by the American Museum in 1901. A third element in the scene, a cast of the trackway that we have placed beneath the bear-dog, was collected in the early 1960s from the Mohave Desert by Raymond Alf and his students at the Webb School of California. It coincides with the age of the bear-dog skeleton. The bear-dog was the largest terrestrial predator of its time, and the paw prints on the trackway fit those of the large male animal represented by the skeleton.

The bear-dog, *Amphicyon ingens,* was neither a bear nor a dog, but a member of a separate, now extinct family of carnivores, the Amphicyonidae. The evolutionary position of this family lies between that of dogs, the Canidae, and bears, the Ursidae, but is not ancestral to either of them. Between about thirty-seven million and nine million years ago, bear-dogs inhabited Eurasia and North America. A species closely related to *A. ingens* has been found in contemporaneous French deposits, indicating that the geographic range of the giant species of *Amphicyon* was comparable to those of present-day brown and grizzly bears.

Not counting its long, doglike tail, *A. ingens* was the size of a northern brown bear, and the relative length of its limbs and feet was comparable to that of a grizzly. However, its body was more slenderly built, suggesting that *Amphicyon,* weighing a little less than the 560 pounds of the average grizzly, could run faster than the grizzly's thirty miles per hour. The trackway shows a stride length about equal to the total length of the body (less the tail) and also indicates that as it moved at this clip, *Amphicyon* was pacing—moving the two left legs and the two right alternately, as bears are known to do at a slower stride. Still, an animal the size and weight of a bear-dog would not have been capable of sustained pursuit. It was built for explosive power rather than stamina. Like a lion, it would have ambushed prey, pressing its attack with a short burst of speed.

The pronghorn *Ramoceros osborni* was a member of the earliest group of pronghorns, known as the merycodonts. These horned animals appear to have lived only in North America, as do their descendants, the antilocaprines, the group to which the living pronghorn antelope of the American West belongs. In both groups, the



Leaving its tracks in the impressionable mud, a bear-dog (Amphicyon), *in one burst of ferocity, isolates a pronghorn* (Ramoceros) *from its herd and lunges in pursuit. The pronghorn veers in an attempt to evade the predator's teeth and claws. In the background, two members of the pronghorn herd dash across the mud flat to safety.*

Painting by Marianne Collins

horns grow directly over the eye sockets. In merycodonts, however, the horns have multiple branches and often have encircling rings of bone, or burrs, on the shaft of the horn. In contrast, antilocaprine horns are burrless and branch just once from a common shaft.

More remarkable is the asymmetry of *Ramoceros* horns. Each side of the horns has three branches, but the branches on the left are twice as large as those on the right. When horns like these were first described scientifically, the unevenness was regarded as the result of injury. But many specimens have now been found and studied, and all show such unequal horns. (The smaller, more horizontal branch may be on either the right or left, the incidence being about fifty-fifty.) Such striking asymmetry is rare in mammals, although perfect bilateral symmetry is also rare.

In large museum collections of some species of merycodonts, somewhat less than 50 percent of the adults are hornless and most likely represent females. We do not yet have a large enough sample of *Ramoceros* species to measure the incidence of hornlessness, but we assume that these merycodonts, too, will eventually show such sexual dimorphism. Both sexes of living pronghorns have horns, although the females' are smaller. Reproduction is strongly seasonal in pronghorns, with males vigorously competing for females in the fall. With even more striking differences between the sexes, merycodonts, including *Ramoceros*, probably also came together in herds and reproduced seasonally. The males' display of horns may have been important in attracting and competing for females.

In the Museum's mount, neither *Amphicyon* nor *Ramoceros* wins out; the predator is always pursuing, the prey ever evading the attack. We have no way of knowing which creature won more often in actual chases those millions of years ago. In the evolutionary stakes, however, *Ramoceros* was the victor. The last *Amphicyon* died out some fourteen million years ago. The family to which *Ramoceros* belonged flourished for twenty million years and gave rise to modern pronghorns, which carry on the lineage today.

At the American Museum of Natural History

Biodiversity and Conservation

The American Museum's Center for Biodiversity and Conservation is sponsoring a series of five evening lectures. On Tuesday, April 19, and Tuesday, April 26, Niles Eldredge, curator in the Museum's Department of Invertebrates, will review patterns of biological evolution and extinction across geological time and show how changing patterns of human culture have affected other species and their habitats. On Tuesday, May 3, and Thursday, May 12, Joel L. Cracraft, curator in the Department of Ornithology and acting director of the Center, will explore the biodiversity crisis, its causes and solutions. On Tuesday, May 17, Michael J. Novacek, vice-president and dean of science at the Museum, will talk about understanding and saving the world's species and the importance of biodiversity. Tickets for the series are $40, and the lectures begin at 7:00 P.M. Call (212) 769-5310 for information.

An Evening with Jean-Michel Cousteau

Son of underwater explorer Jacques Yves Cousteau and founder of the Cousteau Society, Jean-Michel Cousteau will examine the relationship between humans and the ocean environment and illustrate his points with film footage. The program, presented in conjunction with the exhibition *Sharks! Fact and Fantasy* in Gallery 3, will take place on Monday, April 18, at 7:00 P.M. in the Main Auditorium. For more information, call (212) 769-5606.

Food as Medicine

In China, foods are divided into two categories, *yin* and *yang,* depending on the energy they are believed to release in the body. *Yin* foods (such as fruits, vegetables, crabs, and fish) are said to cool the body; while *yang* foods (such as eggs or fatty meats) are thought to heat the system. Li Lian Xing, an herbalist and traditional Chinese doctor, will talk about the medicinal properties of Chinese food and offer possible individual diagnoses. In addition, gold-medal master chefs Shi Lian Yong and Bian Jian Nian will demonstrate the art of vegetable carving and offer samples of healthful teas and foods. This presentation will take place on Sunday, April 10, at 2:00 and at 4:00 P.M. in the Museum's Auxiliary Dining Room. Tickets are $5. For information, call (212) 769-5315.

Evolution Follies

An unorthodox view of nineteenth-century Victorian natural history will be presented by Richard Milner (a senior editor of *Natural History*) and a small musical cast. The program will feature anecdotes and slides, as well as songs about Charles Darwin, Thomas Huxley, and creationism. It will take place on Thursday, April 7, at 7:00 P.M. in the Kaufmann Theater. Tickets are $15. Call (212) 769-5310 for information.

A Historic Look at Building Stones

Geologist Sidney Horenstein, the Museum's coordinator of environmental public programs, will discuss stone architecture from the time of the ancient Egyptians and the Inca Empire until today. The slide-illustrated presentation will take place on Thursday, April 21, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for tickets.

When Worlds Collide

The ultimate disaster movie, *When Worlds Collide* was first released in 1951 and included such calamities as a tidal wave that crashed through Times Square. The film will be shown on Saturday, April 30, at 3:00 P.M. in the Kaufmann Theater. Brian Sullivan, the Hayden Planetarium's production designer, will introduce the program. Call (212) 769-5606 for information.

Central African Art and Dance

The tango, *capoeira angola,* and other New World dances have their roots in Central Africa. Robert Farris Thompson, professor of art, African studies, and African-American studies at Yale University, will talk about Congo-Atlantic traditions in dance and art on Wednesday, April 6, at 7:00 P.M. in the Main Auditorium. Tickets are $5.00. For a complete schedule of events in the Education Department's year-long program "Global Cultures in a Changing World" call (212) 769-5315.

Burroughs Awards

Founded in 1921, the John Burroughs Association owns and maintains Burroughs's rustic cabin, Slabsides, which is in West Park, New York. The association, headquartered at the Museum, will hold its annual meeting on Monday, April 4, at 10:30 A.M. Its annual award for nature writing (the sixty-eighth) will be presented to David G. Campbell, author of *The Crystal Desert.* Natural history books for children and a natural history essay will also receive awards. The meeting is free and will be followed by the award luncheon in the Audubon Gallery. Tickets are $30. Call (212) 769-5169 for information.

Cosmic Background Exploration

Observations from NASA's Cosmic Background Explorer satellite have contributed to an understanding of the universe's creation and evolution. As part of the series "Frontiers in Astronomy and Astrophysics," George Smoot, a research physicist at the University of California's Lawrence Berkeley Laboratory, will give an illustrated talk on Monday, April 11, at 7:30 P.M. Tickets are $8 ($6 for members). For all events at the Planetarium, including the Sky Show, "Orion Rendezvous: A Star Trek Voyage of Discovery," call (212) 769-5100.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

A great white shark cruises in the waters off Australia.
©1991 Chuck Davis

NPG Statement on Population

We Believe that the Optimum Rate of Population Growth is Negative

We believe that the optimum **rate** of population growth for the United States (and for the world) is **negative** until such time as the **scale** of economic activity, and its environmental effects, are reduced to a level that would be sustainable indefinitely.

We are convinced that if present rates of population and economic growth are allowed to continue, the end result, within the lifetimes of many of us, would inevitably be near universal poverty in a hopelessly polluted nation and world.

We agree with Professor Herman Daly who has pointed out that the human economy is a subset of the biosphere, and that **the current scale of economic activity relative to the biosphere is already far too large to be sustainable indefinitely**.

Stabilization Is Not Enough

We believe that calls for merely slowing down rapid population growth, or for stabilizing population at present or even higher levels, **are totally inadequate**.

Such proposals, while presented as a solution, **fail to address the central issue**: how to create a national (and world) economy that will be sustainable indefinitely.

At present or at even higher levels of population, neither the application of science and technology, nor simplifying life-styles, nor any combination of the two, can offer any hope of reducing our impact on the environment to a sustainable level.

We Need a Smaller Population

We recognize that our impact on the environment in terms of pollution and resource depletion is the product of our numbers times our per capita consumption of energy and materials. Thus, there are only three ways by which that impact can be reduced:

- By reducing the size of our population by a negative rate of population growth.
- By reducing over consumption (in the United States and other developed countries) by simplifying life-styles.
- By reducing resource depletion and pollution per unit of consumption through more efficient use of energy and materials.

Population size is by far the most critical of those three variables. **Nevertheless, our present scale of economic activity is so large relative to the biosphere that all three measures are needed in order to reduce it to a sustainable level.**

An Urgent Need

Over 20 years ago, when our U.S. population was far smaller, (about 202 million, rather than our present 260 million), Professor John Holdren correctly saw the urgent need for a negative rate of population growth. At that time he wrote,

"...What is surprising...is that there is not more agreement concerning what the rate of change of population size should be. For given the uncertain, but possibly grave, risks associated with substantially increasing our impact on the environment, and given that population growth aggravates or impedes the solution of a wide variety of other problems...it should be obvious that the optimum **rate** of population growth is zero or negative until such time as the uncertainties have been removed and the problems solved."

A Population Goal for Our Country

We must have, first of all, a nationally-determined population goal for our country, accompanied by effective policies to achieve it.

We urge Congress and President Clinton to set, as a top priority national goal, **the achievement of a negative rate of population growth for the United States until such time as the scale of our economic activity is reduced to a sustainable level.**

We also call on our political leaders to urge other nations to pursue a similar goal.

Please help us build broad public support for a national policy to achieve a negative rate of population growth.

NPG is a nonprofit, national membership organization established in 1972. ***We are the only organization that calls for a smaller U.S. and world population, and recommends specific, realistic measures to achieve those goals.***

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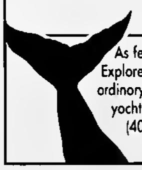

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Moonstruck

by Gail S. Cleere

On April 11, the moon will reach apogee, its farthest distance from the earth all year—252,574 miles. On the 25th, the moon will reach perigee, its closest distance to the earth this year—221,790 miles—and because this is also the date of the full moon, the full power of the moon's gravitational pull will be exerted upon us. Although only one ten-millionth the earth's own gravitational attraction, the moon's pull is enough to drag our oceans over their normal boundaries.

Perigee and the full moon coincide infrequently because the two cycles are not equal. (Full moons occur every 29.53 days, while perigees come every 27.55 days.) This month, the two events occur within three hours of each other, and we should expect the highest and lowest tides of the year on the 25th. Such events, although they are predicted and well-publicized, never fail to take the vast majority of seaside inhabitants by surprise.

"No more of the Universe is visible to our unaided eyes than to the eyes of our Neanderthal ancestors. But science, the product of our imagination, has immensely extended the range of our imagination," wrote astronomer Chet Raymo. Most of us, however, know even less about the moon than our ancestors did. We may know the moon's phases but still consider its monthly and annual motions a mystery. The tides, the most visible result of the earth's interaction with the heavens, were known to our ancestors, but began to be understood only after Isaac Newton published his *Principia Mathematica* in 1687.

Tidal swelling occurs twice a day on both sides of the earth, once when the moon passes overhead, and once when the moon is on the opposite side of the earth. Tidal forces have an appreciable affect only on large bodies—such as oceans—and this explains why soup doesn't spill over the sides of the bowl when the moon is full. The sun's gravitational pull on the earth is roughly half that of the moon's, but when the sun, the earth, and the moon are in a line (during full or new moon phase) the combined force produces the higher than normal "spring" tides in certain areas. The effects are even more amplified when the moon is at perigee, as it will be this month. (Although the moon's distance from apogee to perigee varies only from 9 to 14 percent, tidal influences can be 30 to 48 percent greater. The resulting high tides (which usually peak one or two days after perigee because of "gravitation lag") can cause coastal flooding, and some scientists have suggested that the chances of earthquakes and volcanic eruptions may also be slightly increased.

The actual speed and height of tides are affected not only by the moon but also by land masses, water depth, winds, and barometric pressure. Tides typically range from three to six feet, but some areas show no tides at all, and others, such as the Bay of Fundy, have tides of more than thirty feet. If the barometer drops by one inch, the seas can rise by a foot. A storm can have an even larger effect; when strong winds are blowing ashore, water can pile up against the coast, turning a high-tide–perigee coincidence into a disaster.

The tides do more than merely cause our coastal area authorities to post notices on the beaches. They also keep our earth–moon system evolving. Long ago, when the moon and earth were closer, the earth's powerful tidal effects gradually brought the moon's rotation into agreement with its orbital period, so that we never see its far side. Partly because of tidal action, the rotation of the earth is gradually slowing down—by about one second every 50,000 years. This causes the moon to speed up its revolution about our planet, which, in turn, causes the moon to spiral slowly away from the earth—at a rate of about one and a half inches a year.

Someday, total solar eclipses will be curiosities of the past—only annular eclipses (the sun's edge seen in a ring around the moon) will be possible At the same time, tidal effects are driving the earth–moon system slowly toward a state in which both bodies will each eventually revolve about their common center of gravity in a period equal to forty-seven of our present days, each always keeping the same side toward the other. But on this very distant day, the moon will stop spiraling away from us, and begin its slow journey back toward us.

THE PLANETS IN APRIL

Mercury is all but invisible in the morning sky this month. Although it will shine as bright as –1 magnitude, it is too close to the glare of the sun to be seen. On the 30th, Mercury reaches superior conjunction.

Venus dazzles us at –3.9 magnitude, the brightest object in the evening skies except when the moon is visible. At sunset, it perches approximately 20° above the western horizon. The celestial highlight of the month is the striking conjunction of Venus and the waxing crescent moon, which takes place on the evening of the 12th. Seen from northern Greenland and the Canadian Arctic, the moon will actually pass directly in front of Venus (called an "occultation"), but for the rest of North America, it will appear as a relatively close approach. The best view will be from the eastern seaboard, with Venus appearing only about a moon's width below and to the left of the crescent within a few minutes of 8:30 P.M., local daylight time. By the time darkness falls on the West Coast, the configuration will have changed noticeably with the moon standing about three moon diameters directly above Venus. The *Magellan* spacecraft, meanwhile, is exploring Venus, making its nearly circular orbit around the planet to give us a better understanding of Venus's gravity and interior.

Mars may be visible by the end of the month, though even then it rises barely an hour before sunrise, very low in the east–southeast.

Jupiter rises about two and a half hours after sunset at the start of the month, our only night-sky planet this month. It reaches opposition (opposite the sun in our 360° sky) on the 30th, which means it is up all night—rising as the sun sets, setting as the sun rises. On the 24th, watch as the nearly full moon passes the bright star Spica in Virgo, and then heads toward Jupiter, creating a wonderful spectacle on the nights of April 25 and 26 in the constellation Libra. Jupiter at opposition presents a face to us that is "ornate with dark belts, light zones, and a possible assortment of spots and ovals, festoons and garlands, knots and rifts in its clouds," according to astronomer Fred Schaaf. Find a telescope and enjoy the show. Meanwhile, Jupiter awaits the arrival of the *Galileo* spacecraft, due to arrive at the planet in 1995. Recently, *Galileo*, in its race toward Jupiter, successfully detected the experimental laser beams sent to it simultaneously from Table Mountain Observatory in California and the Air Force's Starfire Optical Range in New Mexico—a distance of 1.3 million miles. The success of this experiment shows that future deep-space missions can use laser beams to send larger volumes of data back to the earth than is currently possible with radio signals.

Saturn rises just an hour before sunrise on the 1st and can be seen very low in Aquarius in the southeast before dawn this month. The ringed planet is a difficult object to spot, especially since it also dims in brightness as its rings slowly tighten the angle they present toward us (they will present an edge-on appearance next year). On the morning of the 7th, use the thin, waning crescent moon to guide you to Saturn, which is well below and to the right of the moon. As the month progresses, Saturn becomes increasingly visible as it climbs higher in predawn skies. Meanwhile, work continues on the development and construction of instruments that will fly on the *Cassini* spacecraft mission to Saturn. *Cassini,* a joint project of NASA and the European Space Agency (ESA), will carry twelve scientific instruments and a probe that will detach from the main craft and parachute to the surface of Titan, Saturn's largest moon.

Uranus and **Neptune** together hug the eastern corner of Sagittarius, high in the southern skies as dawn approaches. On the night of April 3–4, the waning last-quarter moon passes by them both. Neptune is stationary on April 25, and Uranus on April 30. Both will now begin their apparent retrograde (westerly) motion across the sky as the earth overtakes them in orbital speed. They will not resume their proper easterly motions until October. Comet Halley, outward bound, crosses the orbital path of Uranus just about the time your taxes are due—April 15. Halley is on its way to aphelion—its farthest distance from the sun—a point between the orbital paths of Neptune and Pluto. The comet will take another twelve years to reach Neptune.

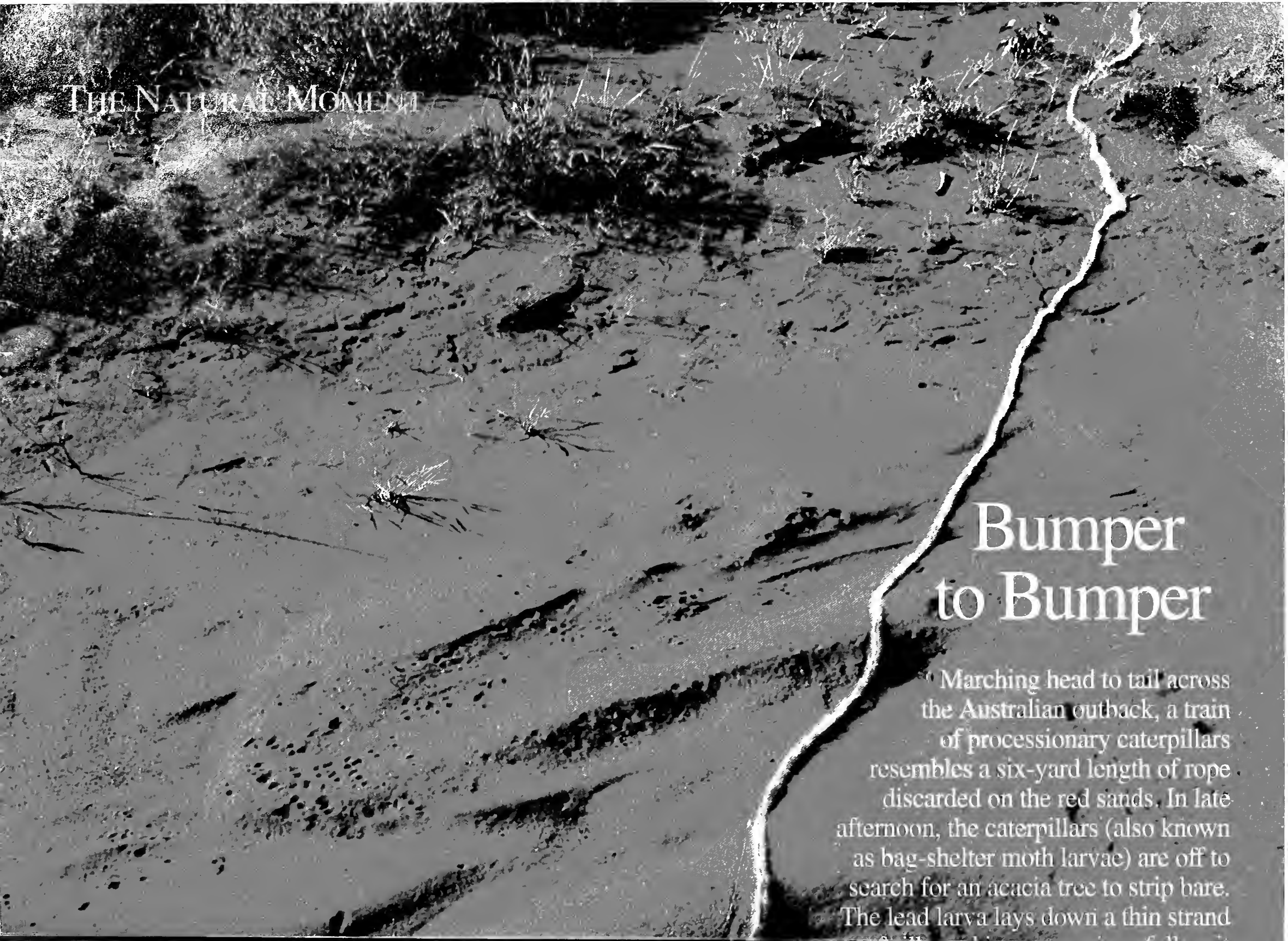
Pluto braces for its big day next month, when it reaches opposition in our nighttime skies—the best time for serious astronomers to try observing it. This tiny planet appears close to Jupiter and the star Zubeneshemali, which is visible with the naked eye in Libra.

The **Moon** reaches last quarter on the 2d at 9:55 P.M., EST; is new on the 10th at 8:17 P.M., EDT; and reaches first quarter at 10:34 P.M., EDT, on the 18th. Full moon occurs on the 25th at 3:45 P.M., EDT.

The Lyrid meteor showers peak just before dawn on the 22d. The full moon sets a few hours before, so the best times to observe these meteors are after moonset and before dawn. The Lyrids are remnants of Comet Thatcher, last seen in 1861, which has an orbital period of 415 years. The Chinese recorded the Lyrids in 687 B.C., and the Koreans noted it A.D. 1136. On average, the Lyrids produce about fifteen to twenty swift, bright meteors per hour, many leaving streaks. Some years have produced tremendous displays of seventy-five meteors or more per hour, the last being in 1981.

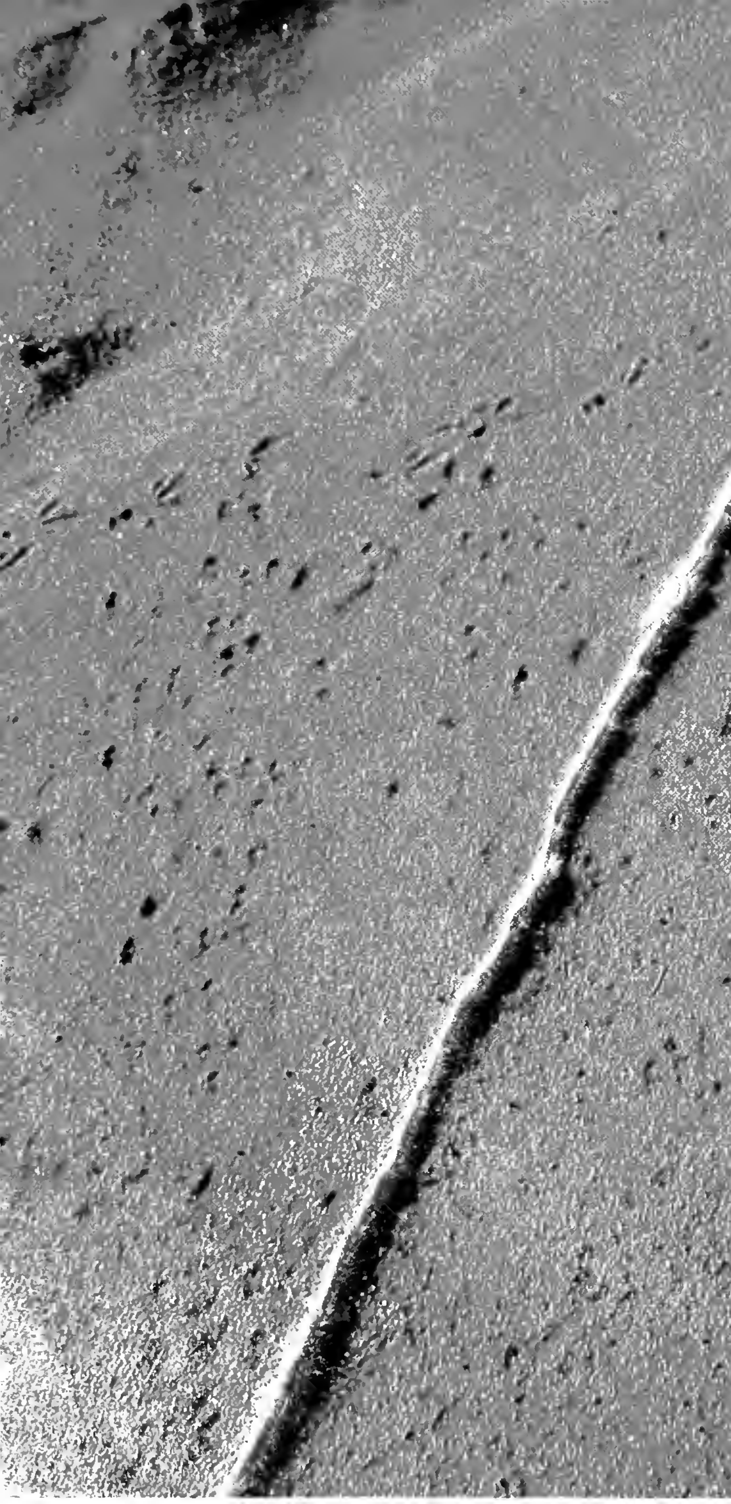
Daylight saving time begins at 2:00 A.M. on Sunday, April 3. "Spring ahead" and add one hour to clocks and watches.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.



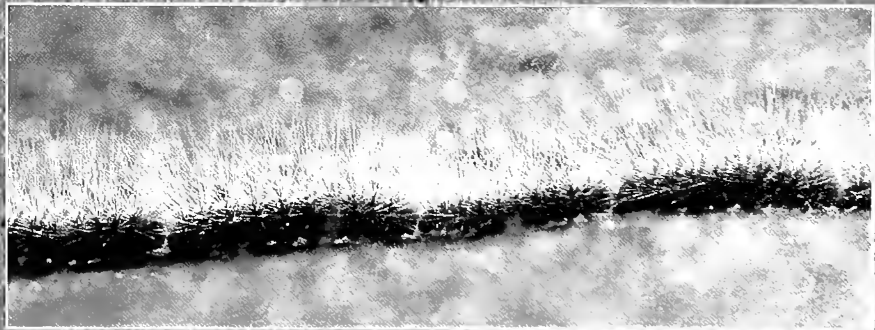
Bumper to Bumper

Marching head to tail across the Australian outback, a train of processionary caterpillars resembles a six-yard length of rope discarded on the red sands. In late afternoon, the caterpillars (also known as bag-shelter moth larvae) are off to search for an acacia tree to strip bare. The lead larva lays down a thin strand



own. The leader probably has no better sense of direction than the others, but the advantage of following one another is simple: after a night of gorging on leaves, the caterpillars will have a silken highway to guide them back to their nest at dawn. (If the trail of silk is disrupted, the whole procession breaks down, with the caterpillars crawling in a chaotic mass.) Back at their home tree, they climb to their shelter—a silken bag suspended between branches. Here they spend the day relatively safe from predators. Found worldwide, communal, tent-dwelling caterpillars share a nocturnal life style, but their daily migrations are not as evident as those in this arid Australian landscape. Processionary caterpillars have a second defense—one that protects them while they commute. Their bodies bristle with barbed, hollow hairs that are loaded with chemical irritants. Once lodged in the skin or inhaled, the hairs cause intense stinging and itching, much like nettles. Any predator intent on gobbling up the whole train will undoubtedly leave after sampling one or two.—*R. A.*

Photographs by Esther Beaton

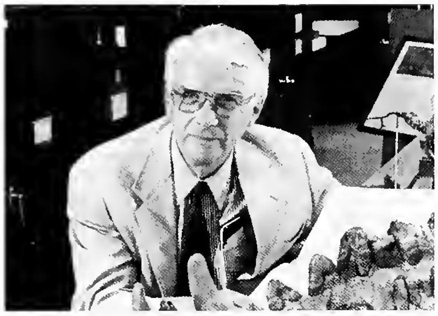


AUTHORS

As a vice president and dean of science of the American Museum of Natural History in New York, **Michael Novacek** (page 40) must attend to the administrative demands of a huge institution. But as a vertebrate paleontologist, he is still involved in the hands-on work of finding fossils. In this instance that means spending each summer with the rest of a Museum team that is navigating the Gobi Desert of Mongolia in jeeps, living in a yurt, and crawling over dry cliffs in search of fossils, from *Velociraptor* to mouse-sized extinct mammals. Novacek has also done fieldwork in other dry, but fossil-rich regions such as the Rockies, Baja California, Yemen, and the Chilean Andes. He plans to return to Chile to look for more evidence of mammal life during the Age of Dinosaurs.

Champion of the pouched, **Michael Archer** (pages 44 and 48) is a professor of biological science at the University of New South Wales, where he has worked since 1978. A citizen of both Australia and the United States, Archer went to Australia on a Fulbright fellowship after completing a bachelor's degree in geology and biology at Princeton University. He chose to remain in Australia because of its fascinating animals and paleontological challenges. He has excavated fossil vertebrates not only in the Riversleigh deposits, but throughout the continent. Archer writes a column for *Australian Natural History* and is actively involved in combating creationism.

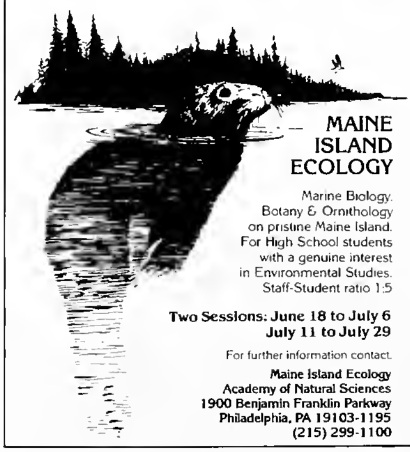
“As a kid,” says **Malcolm McKenna** (page 56), “I read Roy Chapman Andrews’s books and promptly caught ‘Central Asia fever.’ I haven’t recovered yet and don’t plan to.” The American Museum’s Gobi expeditions give him and his wife, Priscilla, the opportunity each summer to build on the work started by Andrews in the 1920s. Frick Curator of Vertebrate Paleontology at the American Museum and a professor of geology at Columbia University, McKenna is also the president of the scientific senate of the Museum. His current research focuses on the family tree of living and extinct mammals. McKenna started to collect fossils in North America as a teen-ager, and

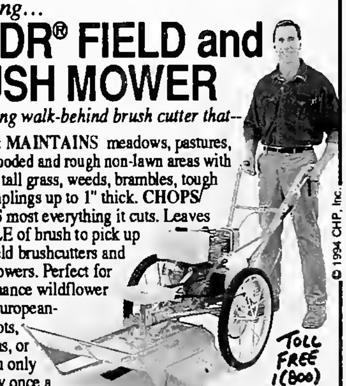


some forty-five years later, he has done fieldwork worldwide. His future plans include studying mammal faunas of the Arctic, South America, and Mongolia; “Wyoming, Colorado, and Montana also beckon.”

S. David Webb (page 50) first started paying attention to fossils when, as a young cowboy, he observed fossil outcrops on the range in Nevada. Later, at Cornell University and at the University of California at Berkeley, he became interested in evolutionary questions. A curator of fossil vertebrates at the Florida Museum of Natural History and a professor of zoology at the University of Florida, Webb notes that “it took me a while to realize that in Florida the best fossil sites are underwater.” Since 1965, he has been diving for fossils. Webb’s research includes the Great American Interchange, late Pleistocene extinctions, and the origin of deer and other ruminants. He and his wife raise horses on their farm near Gainesville, Florida.

A native of Nebraska, **Larry Martin** (page 59) has spent most of his life on the Great Plains. Now a curator of vertebrate paleontology at the Kansas Museum of Natural History and a professor in the Department of Systematics and Ecology at the University of Kansas, he has done extensive fieldwork in those states, as well as in South Dakota, Wyoming, Colorado, and Montana. Martin first saw devil’s corkscrews in 1964 when, during an investigation of a fossil mammal find near Harrison, Nebraska, a local landowner, Lorena Ellicott, showed him the corkscrews in the neighborhood. Martin is the author, with Bruce Rothschild, of the recent book *Paleopathology: Disease in the Fossil Record* (Boca Raton: CRC Press, 1993). His future plans include analyzing the skeleton of *Archaeopteryx* and continuing work on the fossil burrow communities of early Miocene Nebraska.





Valerius Geist (page 66), a Russian-born Canadian of German extraction, is director of the Environmental Science Program at the University of Calgary in Alberta. Since the late 1950s he has conducted zoological fieldwork in various parts of British Columbia and Alberta, in the Yukon Territory, in Texas, and at the Bandipur Sanctuary in India. He first became interested in horns and antlers during his first-year studies in zoology at the University of British Columbia, from which he received a bachelor's degree in science and a doctorate in zoology. In 1971, he broadened his focus to include a new task: developing programs to train young scientists to effectively apply new knowledge in the larger social arena. In addition to ungulates, his present interests include game ranching, Ice Age mammals, the biology of health, and human evolution.

Having grown up on a New Hampshire dairy farm, **Margery Coombs** (page 70) was well acquainted with herbivores of the hoofed variety. But not until she was a doctoral candidate at Columbia University in the 1970s did she meet the clawed kind, chalicotheres: "The American Museum of Natural History has the best overall collection of chalicotheres in the world, and after being introduced to them, I found them to be fascinating." Her interest in the systematics, anatomy, and ecology of these unusual, extinct beasts continues unabated. An associate professor of biology at the University of Massachusetts at Amherst, Coombs is also working on an undergraduate textbook of vertebrate paleontology. For the future, she has her eye on some international cooperative projects, involving chalicotheres in Kazakhstan, India, and China.

A native of Queens, New York, **Bryn J. Mader** (page 61) knew from a very early age that he wanted to be a vertebrate paleontologist. His professional interest in titanotheres, however, began as a graduate student in vertebrate zoology at the University of Massachusetts at Amherst, when he recalled having seen a series of massive, horned titanothere skulls in the American Museum's Osborn Hall of Mammals. When he found that titanotheres had been neglected since Henry Fairfield Osborn published his monograph on them in 1929, he was hooked on studying the extinct beasts. After receiving his Ph.D. from the University of Massachusetts in 1991, Mader moved to the American Museum, where he started in the Department of Vertebrate Paleontology as an assistant collections manager working with fossil mammals. Now collections registrar in the Department of Mammalogy, Mader has traveled to the Badlands of South Dakota to look for more North American titanotheres and hopes to extend his research to Mongolia, where large numbers of titanotheres have been found.

As a graduate student at Columbia University in the 1970s, **Bruce MacFadden** (page 63) had the opportunity to study the extensive fossil horse collection at the American Museum of Natural History with the encouragement of Morris Skinner, the world's foremost horse expert at that time. Since then, MacFadden has focused his studies on the paleobiology and evolution of horses. Now a curator of vertebrate paleontology at the Florida Museum of Natural History, he continues to excavate fossil horses and conduct geochemical studies of their teeth to determine ancient diets and ecology. His book *Fossil Horses* was published by Cambridge University Press in 1992. Also a professor of geology, zoology, and Latin American studies at the University of Florida in Gainesville, MacFadden is currently on a Fulbright fellowship in Bolivia, studying the geology and paleontology of the Andes.

A professor of anatomy at Howard University in Washington, D.C., **Daryl Domning** (page 72) has written several articles on fossil sirenians, or sea cows, for *Natural History*. Much of his fieldwork takes place in such warm parts of the world as Puerto Rico, Mexico, and Brazil, where sea cows and their fossil ancestors can be found. His interest in the Caribbean dugongs was sparked by some surprising fossil discoveries over the past fifteen years, which raised questions about ancient ecology: "The world is always stranger than we imagined," notes Domning, "and life in the past was more different from the present than we know." In addition to piecing together the evolution and natural history of extinct sirenians, Domning is deeply involved in protecting living dugongs and manatees.

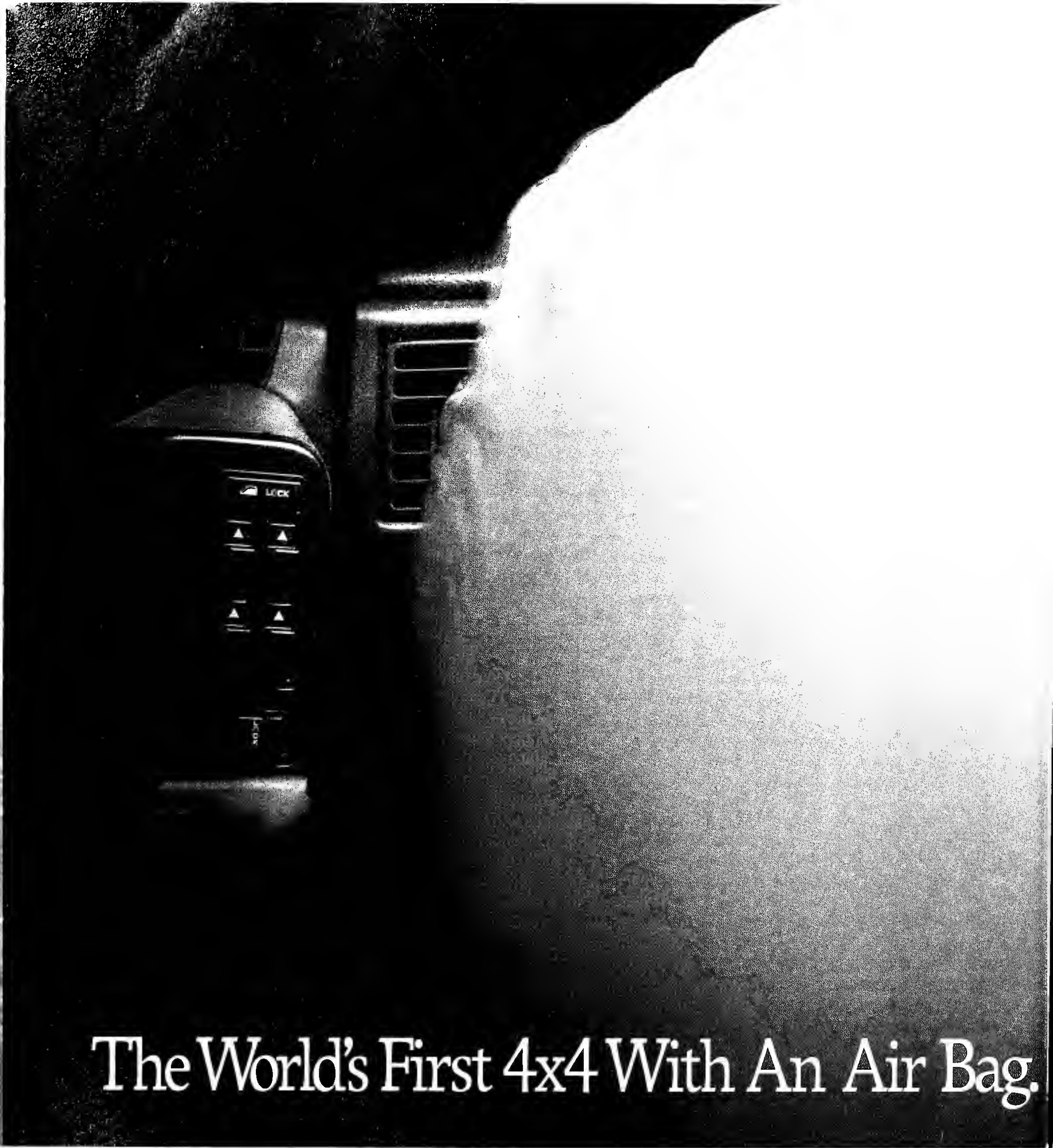
Chairman of the Department of Vertebrate Paleontology at the American Museum of Natural History, **Richard H. Tedford** (pages 74 and 90) began his studies of the order Carnivora while a graduate student at the University of California, Berkeley. He has concentrated on the Caniformia, the suborder that includes dogs, bears, sea lions, raccoons, weasels, and their relatives. "For me," he says, "one of the thrills of the Museum's new exhibition halls is the opportunity to place the skeleton of the extinct bear-dog *Amphicyon* in an active pose corresponding to its fossil tracks." A veteran of fieldwork in the United States, Australia, and China, he has documented the changing composition of fauna in these regions and used these events to measure geologic time and to mark past ecological changes.

Every chance he can get, **Philip Gingerich** (page 86) travels to the sandy Fayum region of Egypt or to northern Pakistan, sites that are the world's most productive whale graveyards. His 1989 Fayum expedition resulted in the first specimen of a whale with functional legs and toes. On his field trips, Gingerich is often accompanied by his wife, Holly Smith, a physical anthropologist and experienced paleontologist. Gingerich grew up in a rural Mennonite community in Iowa, where geological time and evolution were as distant as Egypt and Pakistan. He jumped at the opportunity to study geology in college. Now a professor of geological sciences and director of the Museum of Paleontology at the University of Michigan in Ann Arbor, he is particularly interested in quantifying rates of evolution and using these as guides to understanding the process of evolution.

Esther Beaton (page 100), was born in Budapest, Hungary, and grew up in California. Having lived on two continents, she was attracted to a third and moved to Australia in 1973. Fascinated by the beauty of the animals around her, particularly the brilliantly colored parrots, she began her career in wildlife photography. For six years Beaton photographed wildlife and landscapes for the Parks and Conservation Service. Then she decided to risk self-employment, and with another photographer, founded the well-known stock library Auscape International. Currently, she is free-lancing and living near Sydney. She came across the processionary caterpillars featured in this month's "Natural Moment" while leading a nature tour near Alice Springs. "I had heard drivers and station heads tell how they had mistakenly ridden into masses of the 'bag moths' or 'itchy grubs' and been covered by millions of fiery stings, and I had come across them hanging in their bags from acacia trees. But this was the first time I had actually witnessed this little-seen event." Beaton took the photograph using a Nikon N8008 with an autofocus 12.8 Micro lens.

Christine Janis's interest in paleontology was sparked at age seven by the movie *Fantasia*. She credits her choice of career to an inability to outgrow a childhood love of dinosaurs and horses. Now an associate professor of biology at Brown University, Janis (page 78) has numerous research interests, including the correlation between morphology and behavioral ecology in living and extinct mammals. Her prime interest is in fossil ungulates, although with a horse barn in her backyard and, in years past, hyraxes in her house, she can claim a healthy interest in living ungulates as well. Janis is shown here with a puppet of her favorite fossil mammal, *Sinclairomeryx* (in truth, it's a moose transformed).

In the mid-1980s, **Blaire Van Valkenburgh** (page 84) was in the process of examining carnivore skulls for her doctoral dissertation when she noticed that many of the predators had unusually high numbers of broken teeth. She decided that this finding deserved to be investigated in more detail, and after receiving her degree from Johns Hopkins University, she continued to study tooth breakage, and feeding behavior in general, in living and extinct large carnivores. Now an associate professor of biology at UCLA, Van Valkenburgh has a laboratory a few miles from the downtown Los Angeles site of La Brea, the tar pits where so many Pleistocene herbivores met a sticky end and so many carnivores broke their teeth. She has done fieldwork in East Africa and Chile and plans to study the evolution of canids—members of the dog family—in South America.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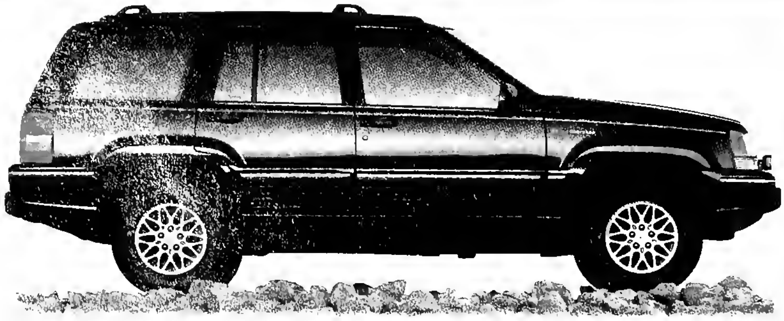


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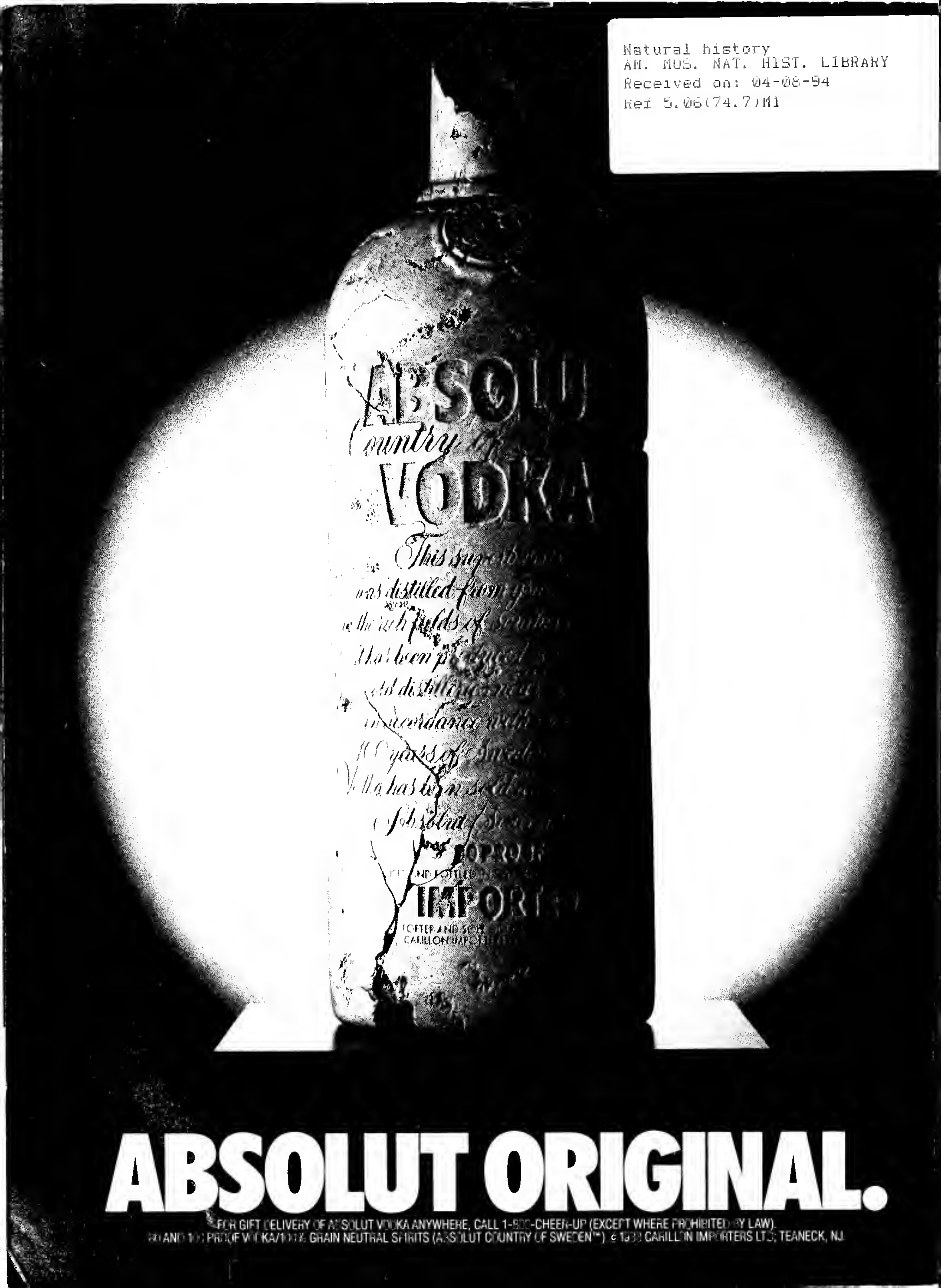
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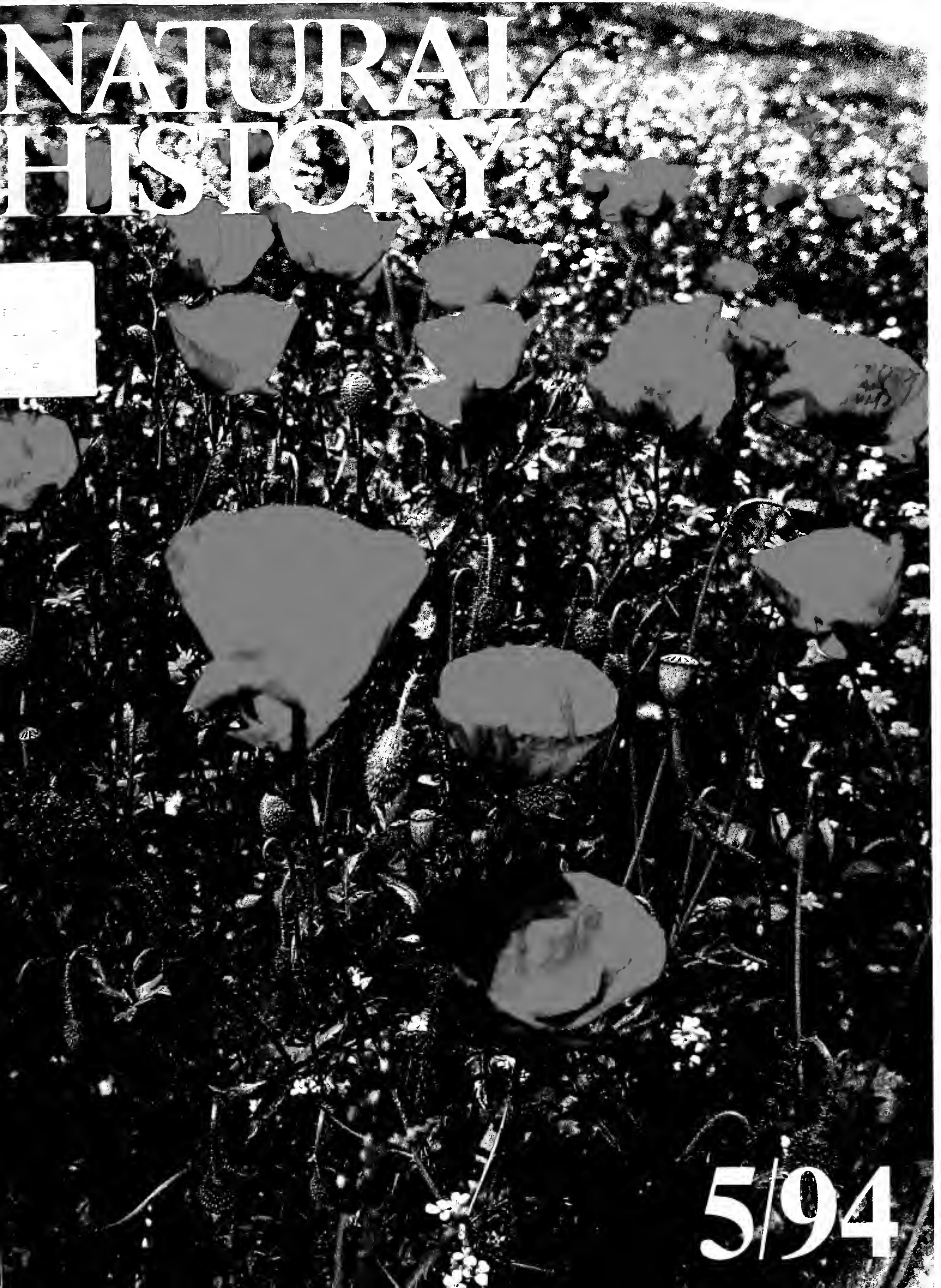
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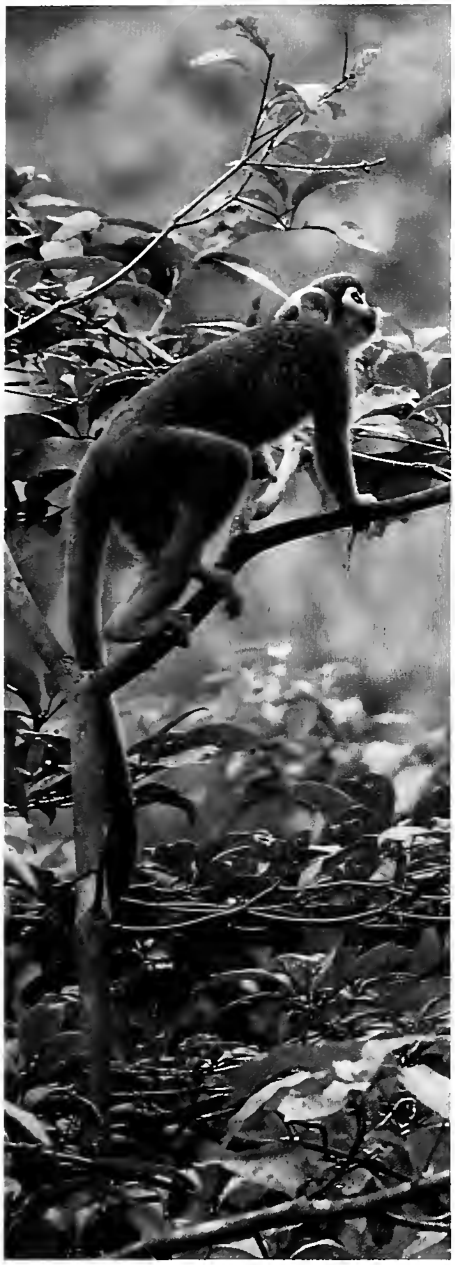

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NATURAL HISTORY

Vol. 103, No. 5, May 1994

COVER: *Poppies bloom in the Judean desert, where red flowers compete for the attentions of beetles. Story on page 52. Photograph by Allen Rokach.*

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LETTERS

THE BATS OF WINTER

Thanks for Bernd Heinrich's fine article and accompanying photographs on winter moths ("Some Like It Cold," February 1994). Being active in winter certainly helps moths avoid bats in cold climates such as that of Vermont. In southern New Jersey where I study winter moths, however, temperatures are often well above freezing on winter evenings at dusk, and big brown bats are virtually always foraging when these moths are flying. Since very few insects besides small flies are active here between December and February, the calorie-rich winter moths may be at even greater risk from bats in January than they are in July.

Another note: the critical need to have larval hatching timed to coincide with budbreak, rather than avoidance of birds, probably affected the evolution of early-spring egg-laying in these and many other moth species.

DALE SCHWEITZER
Port Norris, New Jersey

STILL LOOKING

Regarding the article "Bagging the Little Green Men" ("Celestial Events," February 1994), I am happy to report that SETI (Search for Extraterrestrial Intelligence) is very much alive and well. While it is true that Congress has directed NASA to abandon its attempts to detect radio transmissions from other solar systems, the SETI Institute's efforts to raise private money to keep the search alive have met with success—we are more than halfway to our goal of $7.3 million. These funds will enable us first to modify and improve the digital receivers lent to us by NASA and then to deploy this equipment at the Parkes radio observatory in New South Wales, Australia, for Southern Hemisphere observations in 1995. We then plan to move the receiving equipment to the Northern Hemisphere, beginning with the 1,000-foot-diameter radiotelescope at Arecibo, Puerto Rico. We expect observations to continue into the next millennium. I look forward to a day, perhaps not far off, when we hear the first evidence that we are not alone in the universe.

FRANK D. DRAKE
President, SETI Institute
Mountain View, California

CONVERGENT CHEMICAL EVOLUTION?

In "Stinking Birds and Burning Books" ("Nature's Infinite Book," January 1994), Jared Diamond discusses the recent recognition that certain jay-sized New Guinea birds called pitohuis share a potent defensive toxin (homobatrachotoxin) with Colombian poison-dart frogs. He goes on to suggest that this is a remarkable case of "convergent evolution at the molecular level."

An analogous case suggests that the convergent evolution may rather be the ability of both organisms to safely culture toxin-producing bacteria. The infamous tetrodotoxin, which almost dispatched James Bond in *From Russia with Love*, is an example of this latter convergence. Tetrodotoxin got its name from the pufferfish (of the family Tetradontidae), which is used in *fugu*, the Japanese culinary delicacy. But it has subsequently been found in many other animals, including unrelated fishes, frogs and salamanders, gastropods, crabs, starfish, and the beautiful blue-ringed octopuses of southern oceans. These animals can harbor bacteria that produce the toxin, and indeed one can rear toxin-free pufferfish with appropriate precautions. The pitohuis and the poison-dart frogs may well share an ability to culture toxin-producing bacteria on their skins, and the presence or absence of such bacteria would explain the range of toxicities noted by Diamond in different parts of the birds' range.

An important corollary of such symbioses is that the hosts must be immune to the bacterial poisons. Both homobatrachotoxin and tetrodotoxin bind to sodium channels in the membranes of susceptible

Flying squirrels: two ghosts in a snowstorm
Seiichi Meguro; Nature Production

animal cells; perhaps changes in the proteins that confer resistance demonstrate "convergent evolution at the molecular level."

ROGER PRINCE
Pittstown, New Jersey

INCONSISTENT SEXUAL POLITICS

I have just belatedly received the November 1993 issue of *Natural History* and cannot fathom how you managed to publish Stephen Jay Gould's "The Sexual Politics of Classification" and "A Goddess Unveiled," by Harry Y. McSween, Jr., in the same issue. Gould's article is almost comically sensitive to gender stereotyping in the nature writings of past centuries. Yet a few pages farther on, readers are expected to accept a contemporary author's use of a metaphor in which the planet Venus is a seemingly beautiful goddess who, when stripped naked by science, is revealed as an "old floozy" with pimples, wrinkles, blemishes, blisters, and sores that suggest an interesting past. The latter is far more vicious an image than anything quoted by Gould.

EILEEN FIELDING
Chesterton, Indiana

EVOLUTION OF CAKES

In her sidebar, "The Twelfth Cake" (in "The Rise of the British Wedding Cake," December 1993), Bridget Ann Henisch laments the collapse of the Christmastime and Epiphany celebrations by the end of the last century. Actually, such observances continued in southern Louisiana. Today, the traditions and games linger in the form of King Cakes, which begin to appear with the Twelfth Night parties that launch the Mardi Gras season.

FREDERICK STIELOW
New Orleans, Louisiana

Simon Charsley's article on wedding cakes brought to mind the words of *The Woman's Home Companion Cookbook,* published in New York by Colliers in 1943.

On page 750 we are advised:

The true wedding cake is a rich fruit cake. It may be decorated and placed on a reception table or it may be packed in small boxes to hand to the guests as they leave. In the latter case, a bride's cake may be used on the table. The bride's cake is usually a white cake, pound cake, sponge cake, or light fruit cake. Frequently the true wedding cake is dispensed with and only the bride's cake is used.

Decorate with lilies of the valley....an attractive addition is a series of streamers of lilies of the valley running from top to bottom. Surround the cake with real flowers....

As the baker on the vessel *Inspiration,* I use this cookbook a lot, but I am not going to make such a cake.

WILLIAM F. STEAGALL, SR.
La Paz, Mexico

AN EXTRA GHOST

January's "Natural Moment" photo ("Ghost in a Snowstorm") by Seiichi Meguro was a delight, and the patience of the photographer seems to have been well rewarded. However, you may have missed a second tiny ghost in the snowy scene—another wide-eyed flying squirrel attached to the trunk of a tree, below and to the viewer's left of the featured performer. I feel this apparition should have been given equal billing.

JAMES RANDI
Plantation, Florida

ERRATA: In the April 1994 issue, the article on Caribbean dugongs, "West Indian Tuskers," states that modern dugongs uproot sea grasses with their tusks. This, an editorial extrapolation, is in error. According to author Daryl Domning, dugongs (like manatees) can uproot small rhizomes of sea grasses with their snouts; the tusks are used in combat. We apologize for the mistake.

Clear Creek, shown on page 42 in our November 1993 issue ("Damming the Past"), flows into the Arkansas River, not the Colorado. *Natural History* regrets the editorial error, which several readers brought to our attention.

Hooking Leviathan by Its Past

Two tales of tails confirm the theory of the whale's return to the sea

by Stephen Jay Gould

The landscape of every career contains at least a few crevasses, and usually a more extensive valley or two—for every Ruth's bat, a Buckner's legs; for every lopsided victory at Agincourt, a bloodbath at Antietam. Darwin's first edition of *Origin of Species* contains some wonderful insights and magnificent lines, but this masterpiece also includes a few notable clinkers. Darwin became most embarrassed about the following passage, curtailed and largely expunged from following editions of his book:

> In North America the black bear was seen by Hearne swimming for hours with widely open mouth, thus catching, like a whale, insects in the water. Even in so extreme a case as this, if the supply of insects were constant, and if better adapted competitors did not already exist in the country, I can see no difficulty in a race of bears being rendered, by natural selection, more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale.

Why did Darwin become so chagrined about this passage? His hypothetical tale may be pure speculation and conjecture, but the scenario is not entirely absurd. Darwin's discomfort arose, I think, from his failure to follow a scientific norm of a more sociocultural nature. Scientific conclusions supposedly rest upon facts and information. Speculation is not entirely taboo, and may sometimes be necessary *faute de mieux*. But when scientists propose truly novel and comprehensive theories—as Darwin tried to do in advancing natural selection as the primary mechanism of evolution—they need particularly good support, and invented hypothetical cases just don't supply sufficient oomph for crucial conclusions.

Natural selection (or the human analogue of differential breeding) clearly worked at small scale—in the production of dog breeds and strains of wheat, for example. But could such a process account for the transitions of greater scope that set our concept of evolution in the fullness of time: the passage of reptilian lineages to birds and mammals; the origin of humans from an ancestral stock of apes? For these larger changes, Darwin could provide little direct evidence, for a set of well-known and much lamented reasons based on the extreme spottiness of the fossil record.

Some splendid cases began to accumulate in years following the *Origin of Species,* most notably the discovery in 1861 of *Archaeopteryx,* an initial bird chock-full of reptilian features, and the first findings of human fossils late in the nineteenth century. But Darwin had little to present in his first edition of 1859, and he tried to fill this factual gap with hypothetical fables about swimming bears eventually turning into whales—a fancy that yielded far more trouble in easy ridicule than aid in useful illustration. Just two years after penning his bear-to-whale tale, Darwin lamented in a letter to a friend (James Lamont, February 25, 1861), "It is laughable how often I have been attacked and misrepresented about this bear."

The supposed lack of intermediary forms in the fossil record remains the fundamental canard of current antievolutionism. Such transitional forms are scarce, to be sure, and for two sets of good reasons—geological (the gappiness of the fossil record) and biological (the episodic nature of evolutionary change, including patterns of punctuated equilibrium and transition within small populations of limited geographic extent). But paleontologists have discovered several superb examples of intermediary forms and sequences, more than enough to convince any fair-minded skeptic about the reality of life's physical genealogy.

The first "terrestrial" vertebrates retained six to eight digits on each limb (more like a fish paddle than a hand), a persistent tail fin, and a lateral line system for sensing sound vibrations underwater. The anatomical transition from reptiles to mammals is particularly well documented in the key anatomical change of jaw articulation to hearing bones. Only one bone, called the dentary, builds the mammalian jaw, while reptiles retain several small bones in the rear part of the jaw. We can trace, through a lovely sequence of intermediates, the reduction of these small reptilian bones and their eventual disappearance or exclusion from the jaw, including the remarkable passage of the reptilian articulation bones into the mammalian middle ear (where they become our malleus and incus, or hammer and anvil). We have even found the transitional form that creationists often proclaim inconceivable in theory—for how can jawbones become ear bones if intermediaries must have unhinged jaws before the new joint forms? The transitional species maintains a double jaw joint, with both the old articulation of reptiles (quadrate to articular bones) and the new connection of mammals (squamosal to dentary) already in place! Thus, one joint could be lost, with passage of its bones into the ear, while the other articulation continued to guarantee a properly hinged jaw.

Still, our creationist incubi, who would never let facts spoil a favorite argument, refuse to yield, and continue to assert the absence of *all* transitional forms by ignoring those that have been found and continuing to taunt us with admittedly frequent examples of absence. Darwin's difficulty

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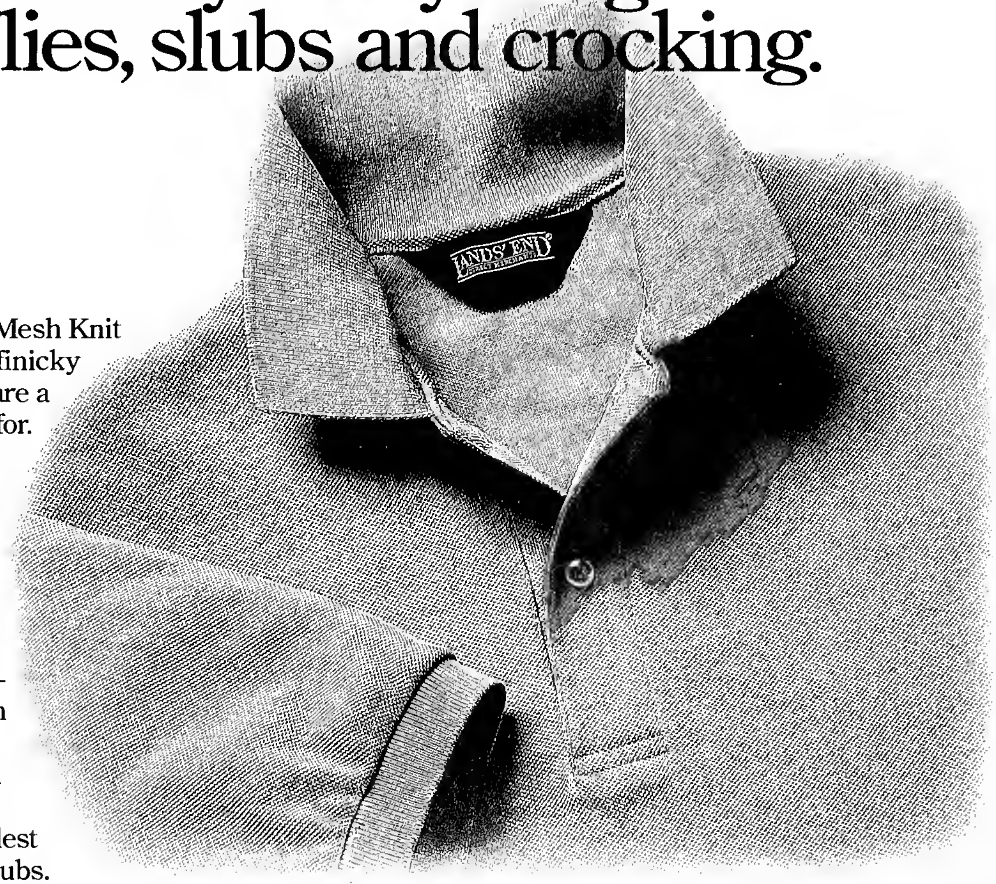

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Or mail: 1 Lands' End Lane, Dodgeville, WI 53595 with the origin of whales remains a perennial favorite. God's taunt to Job might be sounded again: "canst thou draw out leviathan with an hook?" (The biblical leviathan is usually interpreted as a crocodile, but many alternative readings favor whales.)

Every creationist book on my shelf cites the actual absence and inherent inconceivability of transitional forms between terrestrial mammals and whales. Alan Haywood, for example, writes (*Creation and Evolution*, Triangle Books, 1985):

> Darwinists rarely mention the whale because it presents them with one of their most insoluble problems. They believe that somehow a whale must have evolved from an ordinary land-dwelling animal, which took to the sea and lost its legs.... A land mammal that was in process of becoming a whale would fall between two stools—it would not be fitted for life on land or at sea, and would have no hope of survival.

Duane Gish, creationism's most ardent debater, makes the same argument in his more colorful style (*Evolution: The Challenge of the Fossil Record,* Creation Life Publishers, 1985):

> There simply are no transitional forms in the fossil record between the marine mammals and their supposed land mammal ancestors.... It is quite entertaining, starting with cows, pigs, or buffaloes, to attempt to visualize what the intermediates may have looked like. Starting with a cow, one could even imagine one line of descent which prematurely became extinct, due to what might be called an "udder failure."

The most "sophisticated" (I should really say "glossy") of creationist texts, *Of Pandas and People,* by P. Davis, D. H. Kenyon, and C. B. Thaxton (Haughton Publishing, 1989), says much the same, but more in the lingo of academese:

> The absence of unambiguous transitional fossils is strikingly illustrated by the fossil record of whales.... If whales did have land mammal ancestors, we should expect to find some transitional fossils. Why? Because the anatomical differences between whales and terrestrial mammals are so great that innumerable in-between stages must have paddled and swam the ancient seas before a whale as we know it appeared. So far these transitional forms have not been found.

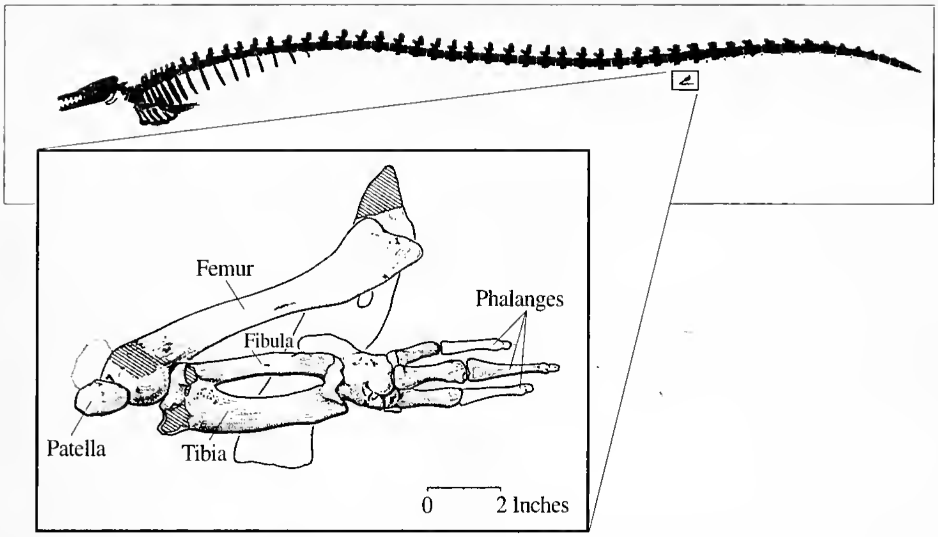
Three major groups of mammals have returned to the ways of distant ancestors in their seafaring modes of life (while smaller lineages within several other mammalian orders have become at least semiaquatic, often to a remarkable degree, as in river and sea otters): the suborder Pinnipedia (seals, sea lions, and walruses) within the order Carnivora (dogs, cats, and Darwin's bears among others); and two entire orders—the Sirenia (dugongs and manatees) and Cetacea (whales and dolphins). I confess that I have never quite grasped the creationists's point about inconceivability of transition—for a good structural (although admittedly not a phylogenetic) series of intermediate anatomies may be extracted from these groups. Otters have remarkable aquatic abilities, but retain fully functional limbs for land. Sea lions are clearly adapted for water, but can still flop about on land with sufficient dexterity for ice floes, breeding grounds, and circus rings.

"I love my kids, but these Mother's Day visits do have their drawbacks."

But I admit, of course, that the transition to manatees and whales represents no trivial extension, for these fully aquatic mammals propel themselves by powerful, horizontal tail flukes and have no visible hind limbs at all—and how can a lineage both develop a flat propulsive tail from the standard mammalian length of rope and then forfeit the usual equipment of back feet so completely? (Sirenians have lost every vestige of back legs; whales often retain tiny, splintlike pelvic and leg bones, but no foot or finger bones, embedded in musculature of the body wall, but with no visible expression in external anatomy.)

The loss of back legs and the development of flukes, fins, and flippers by whales therefore stands as a classic case of a supposed cardinal problem in evolutionary theory—the failure to find intermediary fossils for major anatomical transitions or even to imagine how such a bridging form might look or work. Darwin acknowledged the issue by constructing a much criticized fable about swimming bears, instead of presenting any evidence at all, when he tried to conceptualize the evolution of whales. Modern creationists continue to use this example and stress the absence of intermediary forms in this supposed (they would say impossible) transition from land to sea.

Goethe told us to "love those who yearn for the impossible." But Pliny the Elder, before dying of curiosity by straying too close to Vesuvius at the worst of all possible moments, urged us to treat impossibility as a relative claim: "How many things, too, are looked upon as quite impossible until they have been actually effected." Armed with such wisdom of human ages, I am absolutely delighted to report that our usually recalcitrant fossil record has come through in exemplary fashion. During the past fifteen years, new discoveries in Africa and Pakistan have added greatly to our paleontological knowledge of the earliest history of whales. The embarrassment of past absence has been replaced by a bounty of new evidence—and by the sweetest series of transitional fossils an evolutionist could ever hope to find. Truly, we have met the enemy and he is now ours. Moreover, to add blessed insult to the creationists's injury, these discoveries have arrived in a gradual and sequential fashion—a little bit at a time, step by step, from a tentative hint fifteen years ago to a remarkable smoking gun early in 1994. Intellectual history has



A fifty-foot Eocene whale, Basilosaurus isis, *from the Zeuglodon Valley of Egypt, had tiny hind limbs, shown in detail above.*
Adapted from *Science*, vol. 249, 13 July 1990

matched life's genealogy by spanning the gaps in sequential steps. Consider the four main events in chronological order.

Case One: Discovery of the oldest whale. Paleontologists have been fairly confident, since Leigh Van Valen's demonstration in 1966, that whales descended from mesonychids, an early group of primarily carnivorous running mammals that spanned a great range of sizes and habits from eating fishes at river edges to crushing bones of carrion. Whales must have evolved during the Eocene epoch, some fifty million years ago, because late Eocene and Oligocene rocks already contain cetaceans so fully marine that we must judge them as past any point of intermediacy.

In 1983, my colleague Phil Gingerich, of the University of Michigan, along with N. A. Wells, D. E. Russell, and S. M. Ibrahim Shah ("Origin of Whales in Epicontinental Remnant Seas," *Science,* vol. 220, pp. 403–406), reported their discovery of the oldest whale, named *Pakicetus* to honor its country of present residence, from Middle Eocene sediments some fifty-two million years old in Pakistan. In terms of intermediacy, one could hardly have hoped for more from the limited material available, for only the skull of *Pakicetus* has been found. The teeth strongly resemble those of terrestrial mesonychids, as anticipated, but the skull, in feature after feature, clearly belongs to the developing lineage of whales.

Both the anatomy of the skull, particularly in the ear region, and its environment of deposition testify to transitional status. The ears of modern whales contain modified bones and passageways that permit directional hearing in the dense medium of water. They have also evolved enlarged sinuses that can be filled with blood to maintain pressure during diving. The skull of *Pakicetus* lacks both these features, and this first whale could neither dive deeply nor hear directionally with any efficiency in water.

In 1993, J. G. M. Thewissen and S. T. Hussain ("Origin of Underwater Hearing in Whales," *Nature,* vol. 361, pp. 444–45) affirmed these conclusions and added more details on the intermediacy of skull architecture in *Pakicetus.* Modern whales do much of their hearing through their jaws, as sound vibrations pass through the jaw to a "fat pad" (the technical literature, for once, invents no jargon and employs the good old English vernacular in naming this structure) and thence to the middle ear. Terrestrial mammals, by contrast, detect most sound through the ear hole (called the "external auditory meatus," in more refined language). Since *Pakicetus* lacked the enlarged jaw hole that holds the fat pad, this first whale probably continued to hear through the pathways of its terrestrial ancestors. Gingerich concluded that "the auditory mechanism of *Pakicetus* appears more similar to that of land mammals than it is to any group of extant marine mammals."

As for place of discovery, Gingerich and colleagues found *Pakicetus* in river sediments bordering an ancient sea (*see* "The Whales of Tethys," *Natural History,* April 1994)—an ideal place for the first stages of such an evolutionary transition (and a good explanation for lack of diving specializations if *Pakicetus* inhabited the mouths of rivers and adjacent shallow seas). They judged *Pakicetus* as "an amphibious stage in the gradual evolutionary transition of primitive whales from land to sea.... *Pakicetus* was well equipped to feed on fishes in the surface waters of shallow seas, but it lacked auditory adaptations necessary for fully marine existence."

Verdict: In terms of intermediacy, one could hardly hope for more from the limited material of skull bones only. But the limit remains severe, and the results therefore inconclusive. We know nothing of the limbs, tail, or body form of *Pakicetus,* and therefore cannot judge its transitional status in these key features of anyone's ordinary conception of a whale.

Case Two: Discovery of the first complete hind limb in a fossil whale. In the most famous mistake of early American paleontology, Thomas Jefferson, while not engaged in other pursuits usually judged more important, misidentified the claw of a fossil ground sloth as that of a lion. My prize for second worst error must go to R. Harlan who, in 1834, named a marine fossil vertebrate *Basilosaurus* in the *Transactions of the American Philosophical Society. Basilosaurus* means "king lizard," but Harlan's creature is an early whale. Richard Owen, England's greatest anatomist, corrected Mr. Harlan before the decade's end, but the name sticks—and must be retained by the official rules of zoological nomenclature. (Remember that the Linnaean naming system is a device for information retrieval, not a guarantor of appropriateness. The rules require that each species have a distinctive name, so that data can be associated unambiguously with a stable tag. Often, and inevitably, the names originally given become literally inappropriate for the unsurprising reason that scientists make frequent mistakes, and that new discoveries modify old conceptions. If we had to change names every time our ideas about a species altered, taxonomy would devolve into chaos. So *Basilosaurus* will always be *Basilosaurus* because Harlan followed the rules when he gave the name. And we do not change ourselves to *Homo horribilis* after Auschwitz, or to *Homo ridiculosis* after Tonya Harding—but remain, however dubiously, *Homo sapiens,* now and into whatever forever we allow ourselves.)

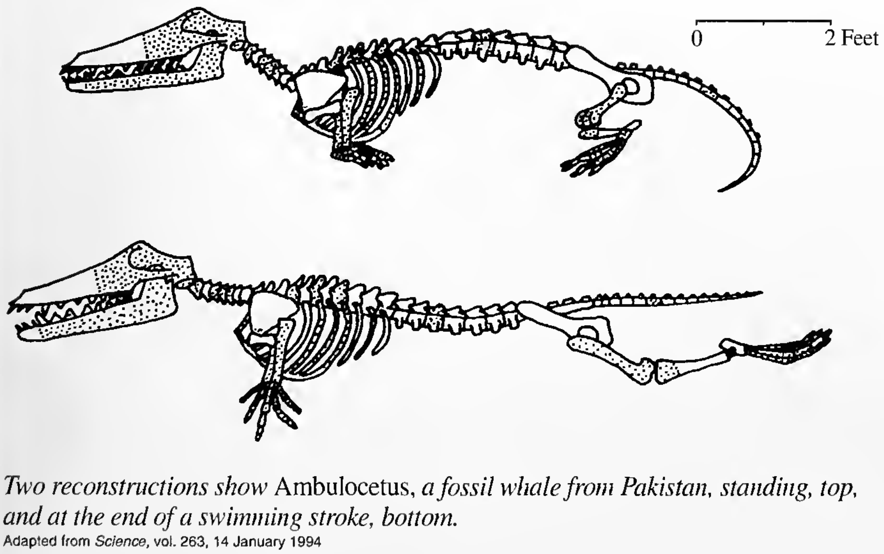
Basilosaurus, represented by two species, one from the United States and the other from Egypt, is the "standard" and best-known early whale. A few fragments of pelvic and leg bones had been found before, but not enough to know whether *Basilosaurus* bore working hind legs—the crucial feature for our usual concept of a satisfying intermediate form in both anatomical and functional senses.

In 1990, Phil Gingerich, B. H. Smith, and E. L. Simons reported their excavation and study of several hundred partial skeletons of the Egyptian species *B. isis*, which lived some five to ten million years after *Pakicetus*. In an exciting discovery, they reported the first complete hind limb skeleton found in any whale—a lovely and elegant structure (put together from several partial specimens), including all pelvic bones, all leg bones (femur, tibia, fibula, and even the patella, or knee cap), and nearly all foot and finger bones, right down to the phalanges (the finger bones) of the three preserved digits ("Hind Limbs of Eocene *Basilosaurus*: Evidence of Feet in Whales," *Science*, vol. 249, pp. 154–57).

This remarkable find might seem to clinch our proof of intermediacy, but for one small problem. The limbs are elegant, but tiny (*see* accompanying figure of *B. isis* on page 12), a mere 3 percent of the animal's total length. They are anatomically complete, and they did project from the body wall (unlike the truly vestigial hind limbs of modern whales), but they could not have made any important contribution to locomotion—the real functional test of intermediacy. Gingerich and his coauthors write: "Hind limbs of *Basilosaurus* appear to have been too small relative to body size to have assisted in swimming, and they could not possibly have supported the body on land." The authors strive bravely to invent some potential function for these minuscule limbs and end up speculating that they may have served as "guides during copulation, which may otherwise have been difficult in a serpentine aquatic mammal." (I regard such guesswork as unnecessary, if not ill-conceived. We need not justify the existence of a structure by inventing some putative Darwinian function. All bodies contain vestigial features of little, if any, utility. Structures of lost usefulness in genealogical transitions do not disappear in an evolutionary overnight.)

Verdict: Terrific and exciting, but no cigar, and no bag-packer for creationists. The limbs, although complete, are too small to work as true intermediates must (if these particular limbs worked at all)—that is, for locomotion on both land and sea. I intend no criticism of *Basilosaurus*, but merely point out that this creature had already crossed the bridge (while retaining a most informative remnant of the other side). We must search for an earlier inhabitant of the bridge itself.

Case Three: Hind limb bones of appropriate size. *Indocetus ramani* is an early whale, found in shallow-water marine deposits of India and Pakistan, and intermediate in age between the *Pakicetus* skull and the *Basilosaurus* hind legs (cases one and two above). In 1993, Gingerich, S. M. Raza, M. Afif, M. Anwar, and X. Zhou reported the discovery of leg bones of substantial size from this species ("Partial Skeletons of *Indocetus ramani* [Mammalia, Cetacea] from the Lower Middle Eocene Domanda Shale in the Sulaiman Range of Punjab [Pakistan]," *Contributions from the Museum of Paleontology of the University of Michigan*, vol. 28, pp. 393–416).



Two reconstructions show Ambulocetus, *a fossil whale from Pakistan, standing, top, and at the end of a swimming stroke, bottom.*
Adapted from *Science*, vol. 263, 14 January 1994

Gingerich and colleagues found pelvic bones, and the ends of both femur and tibia, but no foot bones, and insufficient evidence for reconstructing the full limb and its articulations. The leg bones are large and presumably functional on both land and sea (the tibia, in particular, differs little in size and complexity from that of the related and fully terrestrial mesonychid *Pachyaena ossifraga*). The authors conclude:

> The pelvis has a large and deep acetabulum [the socket for articulation of the femur, or thighbone], the proximal femur is robust, the tibia is long.... All these features, taken together, indicate the *Indocetus* was probably able to support its weight on land, and it was almost certainly amphibious, as early Eocene *Pakicetus* is interpreted to have been.... We speculate that *Indocetus*, like *Pakicetus*, entered the sea to feed on fish, but returned to land to rest and to birth and raise its young.

Verdict: Almost there, but not quite enough. We need more material. All the right features are now in place—primarily leg bones of sufficient size and complexity—but we need a better sense of connection and function.

Case Four: Large, complete, and functional hind legs for land and sea—finding the smoking gun. The first three cases, all discovered within ten years, surely indicate an increasingly successful paleontological assault upon an old classic problem. Once you know where to look, and once high interest spurs great attention, full satisfaction often follows in short order. I was therefore delighted to read an article by J. G. M. Thewissen, S. T. Hussain, and M. Arif in the January 14, 1994 issue of *Science* ("Fossil Evidence for the Origin of Aquatic Locomotion in Archaeocete Whales," vol. 263, pp. 210–12).

In Pakistan, in sediments almost 400 feet above the beds that yielded *Pakicetus* (and therefore a bit younger in age), Thewissen and colleagues collected a remarkable skeleton of a new whale—not complete, but far better preserved than anything previously found of this age, and with crucial parts in place to illustrate a truly transitional status between land and sea. The chosen name *Ambulocetus natans* (literally, the swimming walking-whale) advertises the excitement of this discovery.

A. natans weighed some 650 pounds, the size of a hefty sea lion. The preserved tail vertebra is elongated, indicating that *Ambulocetus* still retained the long, thin mammalian tail and had not yet transmuted this structure to a locomotory blade (as modern whales do in shortening the tail and evolving a prominent horizontal fluke as the animal's major means of propulsion). Unfortunately, no pelvic bones have been found, but most elements of a large, powerful hind leg were recovered—including a complete femur, parts of the tibia and fibula, an astragalus (ankle bone), three metatarsal (foot) bones, and several phalanges. To quote the authors: "The feet are enormous." The fourth metatarsal, for example, is nearly six inches long, and the associated toe almost seven inches in length. Interestingly, the last phalanx of each toe ends in a small hoof, as in terrestrial mesonychid ancestors.

This new bounty of information allows us to infer not only the form of this transitional whale but also, with good confidence, its intermediary style of locomotion and mode of life (an impossibility with the first three cases, for *Pakicetus* is only a skull, *Basilosaurus* had already crossed the bridge, and *Indocetus* is too fragmentary). The forelimbs, smaller than the hind and limited in motion, were "probably used in maneuvering and steering while swimming, as in extant cetaceans ["modern whales" in ordinary language], and they lacked a major propulsive force in water."

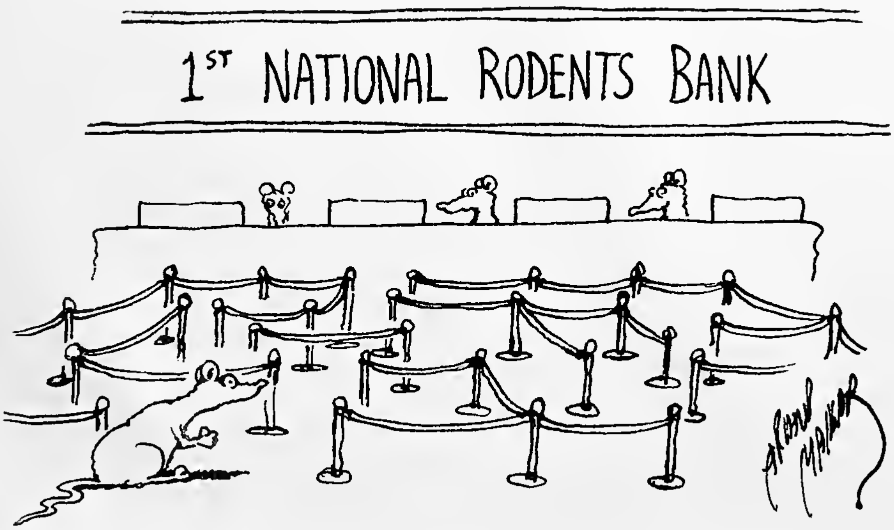
Modern whales move through the water by powerful beats of their horizontal tail fluke—a motion made possible by strong undulation of a flexible rear spinal column. *Ambulocetus* had not yet evolved a tail fluke, but the spine had requisite flexibility. Thewissen and colleagues write: "*Ambulocetus* swam by means of dorsoventral [back-to-belly] undulations of its vertebral column, as evidenced by the shape of the lumbar [lower back] vertebra." These undulations then functioned with (and powered) the paddling of *Ambulocetus*'s large feet, which provided the major propulsive force in swimming. Thewissen et al. conclude their article:

> Like modern cetaceans—it swam by moving its spine up and down, but like seals, the main propulsive surface was provided by its feet. As such, *Ambulocetus* represents a critical intermediate between land mammals and marine cetaceans.

Ambulocetus was no ballet dancer on land, but we have no reason to judge this creature as any less efficient than modern sea lions, which do manage, however inelegantly. Forelimbs may have been held out to the sides, largely for stability, with forward motion supplied primarily by extension of the back and consequent flexing of the hind limbs—again, rather like sea lions.

Verdict: Greedy paleontologists, used to working with fragments in reconstructing wholes, always want more (some pelvic bones would be nice, for starters), but if you had given me both a blank piece of paper and a blank check, I could not have drawn you a theoretical intermediate any better or more convincing than *Ambulocetus*. Those dogmatists who by verbal trickery can make white black, and black white, will never be convinced of anything, but *Ambulocetus* is the very animal that they proclaimed impossible in theory.

Some discoveries in science are exciting because they revise or reverse previous expectations; others because they affirm with elegance something well suspected, but previously undocumented. Our four-case story, culminating in *Ambulocetus*, falls into this second category. This sequential discovery of picture-perfect intermediacy in the evolution of whales stands as a triumph in the history of paleontology. I cannot imagine a better tale for popular presentation of science or a more satisfying, and intellectually based, political victory over lingering creationist opposition.



Still, I must confess that this part of the tale does not intrigue me most as a scientist and evolutionary biologist. I don't mean to sound jaded or dogmatic, but *Ambulocetus* is so close to our expectation for a transitional form that its discovery could not provide a professional paleontologist with the greatest of all pleasures in science—surprise. As a public illustration, and as a sociopolitical victory, transitional whales may be the story of the decade, but paleontologists didn't doubt their existence or feel that a central theory would collapse if their absence continued. We love to place flesh upon our expectations (or put bones under them, to be more literally correct), but this kind of delight takes second place to the intellectual jolting of surprise.

I therefore find myself far more intrigued by another aspect of *Ambulocetus* that has not received much attention, either in technical or popular reports. For the anatomy of this transitional form illustrates a different and vital principle in evolutionary theory—one rarely discussed or even explicitly formulated, but central to any understanding of nature's fascinating historical complexity.

In our Darwinian traditions, we focus too narrowly on the adaptive nature of organic form, and too little on the quirks and oddities encoded into every animal by history. We are so overwhelmed—as well we should be—by the intricacy in aerodynamic optimality of a bird's wing or by the uncannily precise protective resemblance evolved by certain butterflies that mimic dead leaves. We do not ask often enough why natural selection has honed in upon this *particular* optimum—and not another among a set of unrealized alternatives. In other words, we are dazzled by good design and therefore stop our inquiry too soon when we have answered "how does this work so well?"—when we should also be asking the historian's questions: "why *this* and not *that*?" or "why *this* over here and *that* in a related creature living elsewhere?"

To give the cardinal example from seagoing mammals: the two fully marine orders Sirenia and Cetacea swim by beating horizontal tail flukes up and down. Since these two orders arose separately from terrestrial ancestors, the horizontal tail fluke evolved twice independently. Many hydrodynamic studies have documented both the mode and the excellence of such underwater locomotion, but they too often stop at an expression of engineering wonder and do not ask the equally intriguing historian's question. Fishes swim in a truly orthogonal manner—also by propulsion from the rear, but with vertical tail flukes that beat from side to side (seals also hold their rear feet vertically and move them from side to side while swimming). The word *orthogonal* is particularly appropriate here—meaning, literally, "at right angles," but also, in technical scientific parlance, "entirely independent."

Both systems work well; both may be "optimal." But why should ancestral fishes favor one system, and returning mammals the orthogonal alternative? We do not wish to throw up our hands and simply say, "six of one, half a dozen of the other; either way will do, and the one chosen is effectively random in any individual case." "Random" is a deep and profound concept of great positive utility and value, but some vernacular meanings amount to pure cop-out, as in this case. It may not matter in the "great scheme of things" whether optimality be achieved vertically or horizontally, but one or the other solution occurs for a reason in any particular case. The reasons may be unique to an individual lineage, and historically bound—that is, not related to any grand concept of pattern or predictability in the overall history of life—but local reasons do exist and should be ascertainable.

This subject, when discussed at all in evolutionary theory, goes by the name of "multiple adaptive peaks." We have some standard examples, but few with any real documentation; most are hypothetical, with no paleontological backup. (For example, my colleague Dick Lewontin loves to present the following case in our joint introductory course in evolutionary biology. Some rhinoceros species have two horns; others one horn. Either result is probably just as good for whatever rhinos do with their horns, and the pathway chosen may not matter. Two and one are equal solutions, or multiple adaptive peaks. He then points out that a reason must exist for two or one in any case, but that the explanation probably resides in happenstances of history, rather than abstract predictions based on universal optimality. So far so good. History's quirkiness, by its role in populating the earth with a variety of unpredictable, but sensible and well-working, anatomical designs does constitute the main fascination of this theme in evolution theory. But we can go no further with rhinos, for we have no data for understanding the particular pathway chosen in any case.)

I love the story of *Ambulocetus* because it has provided hard data on reasons for a chosen pathway in a classical case of multiple adaptive peaks. Why did both orders of fully marine mammals choose the orthogonal solution of horizontal tail flukes? Previous discussions have made the plausible argument that definite legacies of terrestrial mammalian ancestry established the anatomical predisposition. In particular, many mammals (but not other terrestrial vertebrates), especially among agile and fast-moving carnivores, run by flexing the spinal column up and down (conjure up a sprinting tiger in your mind, and picture the undulation of the back). Mammals that are not particularly comfortable in water—dogs dog-paddling for instance—may keep their backs rigid and move only by flailing their legs. But semiaquatic mammals that swim for a living—notably the river otter (*Lutra*) and the sea otter (*Enhydra*)—move in water by powerful vertical bending of the spinal column in the rear part of the body. This vertical bending propels the body forward both by itself (and by driving the tail up and down) and by sweeping the hind limbs back and forth in paddling as the body undulates.

Thus, horizontal tail flukes may evolve in fully marine mammals because inherited spinal flexibility for movement up and down (rather than side to side) directed this pathway from a terrestrial past. This scenario has only been a good story up to now, with limited symbolic support from living otters, but no direct evidence from the ancestry of whales or sirenians. *Ambulocetus* provides this direct evidence in an elegant manner—for all pieces of the puzzle lie within its recovered skeleton.

We may infer from a tail vertebra that *Ambulocetus* retained a long and thin mammalian tail, and had not yet evolved the horizontal fluke. We know from the spinal column that this transitional whale retained its mammalian signature of flexibility for up-and-down movement—and from the large hind legs that undulation of the back must have propelled the powerful, paddling feet, as in modern otters.

Thewissen and colleagues draw the proper evolutionary conclusion from these facts, thus supplying beautiful evidence to nail down a classical case of multiple peaks with paleontological data: "*Ambulocetus* shows that spinal undulation evolved before the tail fluke.... Cetaceans have gone through a stage that combined hind limb paddling and spinal undulation, resembling the aquatic locomotion of fast swimming otters." The horizontal tail fluke, in other words, evolved because whales carried their terrestrial system of spinal motion to the water.

History channels a pathway among numerous theoretical alternatives. In his last play, Shakespeare noted that "what's past is prologue; what to come, in yours and my discharge." But present moments build no such wall of separation between a past that molds us and a future under our control. The hand of the past reaches forward right through us and into an uncertain future that we cannot fully specify. History has you and me, brother and sister—the whole world—in her hands.

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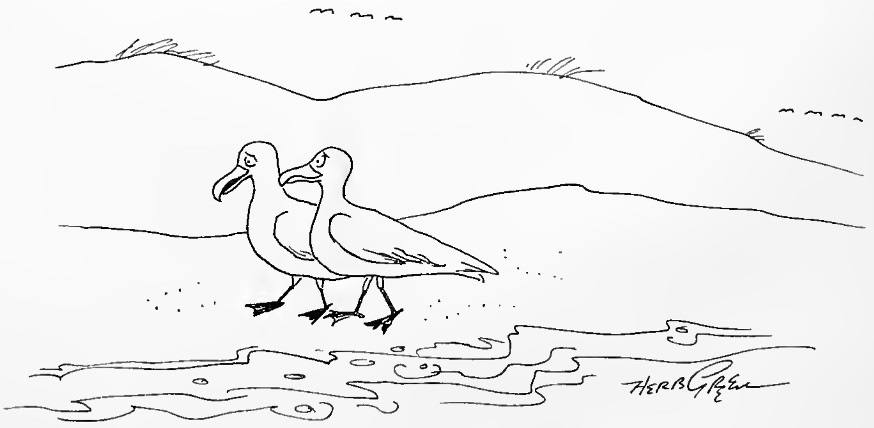


"I guess the hardest thing for me growing up was when I realized I wasn't going to be an eagle."

Spacious Skies and Tilted Axes

Why were plants domesticated so early in the Fertile Crescent? And why did those crops then spread so far and so fast?

by Jared Diamond

On the map of the world, compare the shapes and orientations of the continents. You'll immediately be struck by an obvious difference. The Americas span a much greater distance north to south (9,000 miles) than east to west (only 3,000 miles at the widest, narrowing to a mere 40 miles at the Isthmus of Panama). That is, the major axis of the Americas is north–south. That's also true, although to a lesser degree, for Africa. In contrast, the major axis of Eurasia is east–west. What effect, if any, did those different orientations of the continents' axes have on human history?

Merely posing this question may raise some people's hackles. It seems to invite the label "environmental determinism"—a concept that is sometimes lampooned as implying that human creativity counts for nothing, and that climate irresistibly programs us like computers. Naturally, geographic interpretations can be wrong or carried to an extreme. But denying that geography influences the broad course of history is equally extreme.

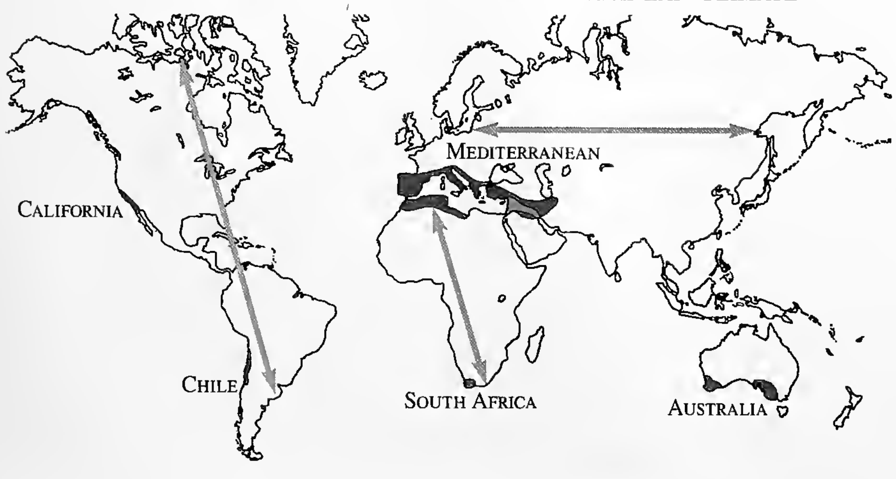
Human societies have evolved at different average rates on different continents for at least the past ten thousand years. Specifically, developments such as agriculture, metallurgy, writing, and empires arose earliest in parts of Eurasia, arose later in the Americas and sub-Saharan Africa, and did not arise indigenously in Australia. Such persistent patterns can hardly be dismissed as accidents reflecting where a few geniuses happened to be born. Bigots prefer to invoke supposed differences in I.Q. among populations, but have conspicuously failed to demonstrate such differences. Instead, these broadest patterns of history seem likely to have arisen from influences of differing geographic factors. I believe that the enormous, sometimes tragic, consequences of those differences in the continents' axes contributed greatly to the very different treatment that history has meted out to Native Americans, Africans, and Eurasians in the last 500 years.

My interest in this question has been restimulated by a recently published, revised edition of a wonderful book, *Domestication of Plants in the Old World,* by Israeli geneticist Daniel Zohary and German botanist Maria Hopf. The book concerns the early importance of that part of Southwest Asia variously known as the Fertile Crescent, or the Near East. This area was the earliest site for a whole string of developments, including towns, writing, empires, and what we term (for better or worse) *civilization.* All those developments sprang, in turn, from the advent of dense human populations and the rise of food production—in the form of agriculture and animal husbandry—that made it possible to store food surpluses and feed nonfarming specialists.

Since food production was the first of the major innovations that arose in the Fertile Crescent, anyone attempting to understand the broad pattern of human history must begin by trying to understand why domestication started so early there. Why, too, did it spread from there so fast and so far? Zohary and Hopf are illuminating on both points.

The early start in the Fertile Crescent, according to Zohary and Hopf, was due to a combination of geographic, climatic, and biotic factors. Western Eurasia (Europe plus Southwest Asia) includes the world's largest zone of so-called Mediter-

THE WORLD'S FIVE REGIONS WITH MEDITERRANEAN CLIMATE



Mediterranean climate—mild, wet winters and hot, dry summers—favored the evolution of big-seeded, annual plants. Such plant species, including the wild ancestors of barley and wheat, were especially abundant in the Fertile Crescent (light green). Arrows indicate the major axes of continents.

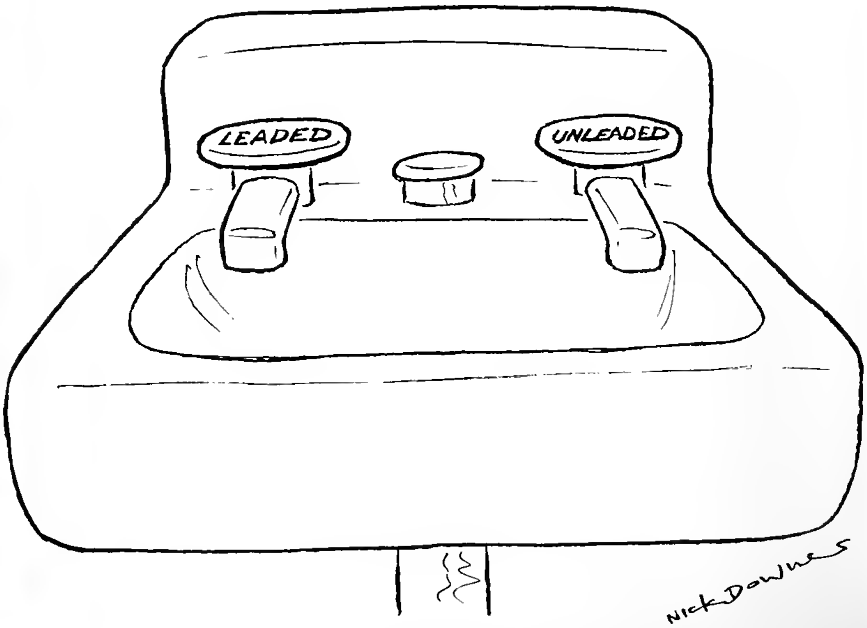
ranean climate, characterized by mild, wet winters and hot, dry summers. The world's other Mediterranean zones are the Cape of South Africa, the central coast of Chile, parts of southern Australia, and my homeland of coastal California. Among those Mediterranean zones, western Eurasia's is not only the largest but may also experience the greatest climatic variation between seasons and years. That climate favored the evolution of annual plants that survived the long, dry summer by putting much of their energy into big, edible seeds, while leaving the inedible remainder of the plant to die back and regrow each year. Because of the Fertile Crescent's extreme Mediterranean climate, its plants provided hungry humans with an exceptionally high percentage of annuals.

The region also has a high percentage of hermaphroditic, predominantly self-pollinating annuals—that is, ones that usually pollinate themselves but are occasionally cross-pollinated. As Zohary and Hopf explain, that feature was also good for the first farmers. Occasional cross-pollination generated several strains to choose from, while the predominant self-pollination insured that varieties selected as superior usually perpetuated themselves unchanged and were not immediately lost by hybridization with less desirable strains.

Some of those big-seeded, self-pollinating annuals, such as the wild ancestors of barley and wheats, were so abundant as wild stands in the Fertile Crescent that they were already being collected by hunter-gatherers before the emergence of farming. Eventually, people began to increase their yields of those wild plants by tilling soil, intentionally sowing seeds, harvesting, and threshing. That new system unintentionally transformed the wild plants into cultivated varieties because people naturally preferred to sow, grow, eat, and resow seeds of those particular plant varieties with desirable features. Depending on the plant species, those features might include larger seeds, a less bitter taste, more uniform germination, and seeds that remain on the parent plant.

The Fertile Crescent also offered other advantages to incipient farmers. Its range of elevations, from the lowest spot on earth (the Dead Sea) to mountains nearly 17,000 feet high, meant that within a short distance there was a corresponding range of environments, hence a great diversity of wild plants available for potential domestication. These varied environments also harbored many species of large wild mammals, some of which were the ancestors of our most important domesticated mammals today. Southwest Asia's few large rivers and short coastline provided scant aquatic resources to make the hunter-gatherer life style competitive with incipient farming. Climatic changes about ten thousand years ago at the end of the Pleistocene—changes that exterminated some large mammal species and expanded habitats rich in annual plants ancestral to crops—quickly tipped the balance from hunting and gathering to domestication.

By about 8000 B.C., the peoples of the Fertile Crescent were domesticating numerous valuable plants. Most of the calories consumed by those first farmers came from high-carbohydrate cereals such as wheat and barley, the most useful of the dozens of wild cereal species in the area by virtue of their large seeds, abundance,

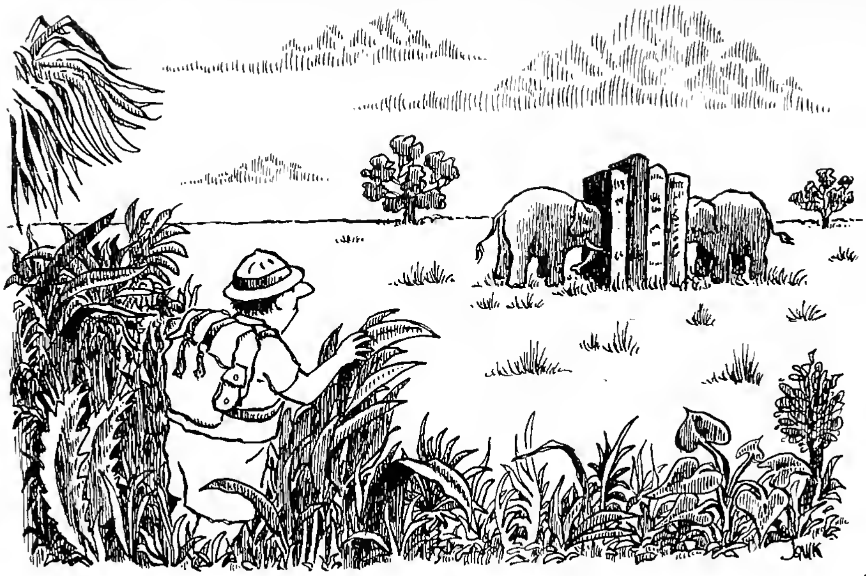


and annual growth. Unlike protein-poor corn and rice, which became the leading cereals of the Americas and eastern Asia respectively, the wheats of the Fertile Crescent had a substantial protein content of 8 to 14 percent.

During or soon after the onset of farming in Mesopotamia, these starchy cereals were complemented by two types of food with an even higher protein content: legumes, especially peas and lentils, which have 20 to 25 percent protein, and domestic animals (sheep, goats, cattle, and pigs). The animals yielded wool and leather as well. One other crop, flax, not only filled out the dietary trinity of carbohydrate, protein, and fat with its very oily seeds but also provided the oldest cultivated source of plant fiber for making clothes. Linen from flax reigned supreme as Europe's preferred plant textile material until it was finally replaced by cotton and synthetics during and after the Industrial Revolution. Thus, the Fertile Crescent's first farmers assembled a balanced package for intensive food production, based on eight main crops and four animals that filled humanity's basic economic needs: carbohydrate, protein, fat, clothing, and, eventually, milk products and animal transport.

Soon after food production arose in the Fertile Crescent, it radiated into other parts of western Eurasia and North Africa, spreading progressively farther west and east. In a striking map, Zohary and Hopf illustrate how agriculture reached Greece and Cyprus by 7000 B.C., Egypt and India soon after 6000 B.C., central Europe by 5400 B.C., and Britain about 4000 B.C. (These are so-called calibrated radiocarbon dates—dates based on the regular decay of the radioactive isotope carbon-14 and corrected for slight fluctuations in atmospheric isotope with time.) Food production in the new areas was launched by the crucial package of the same domesticated plant and animal species that launched it in the Fertile Crescent.

Of course, not all pieces of the package spread to all those outlying areas: for example, Egypt was too warm for einkorn wheat to become established. Some inhabitants of outlying areas went on to domesticate a few local crops of their own, such as poppies in western Europe. But most food production in these regions depended at first on the same group of Fertile Crescent domesticates. Their spread was soon followed by the spread of other innovations originating in or near Mesopotamia, including the wheel, writing, metalwork-



ing techniques, milking, fruit trees, and beer and wine production.

Why did the same plant package launch food production throughout western Eurasia? Was the same set of wild plants found useful in many areas and independently domesticated? No, that's not the case. Many of the Fertile Crescent's "founder crops" (to use Zohary's and Hopf's term) don't even occur in the wild outside Southwest Asia. In Egypt, for instance, of the eight main founder crops, only barley grows wild. Egypt's Nile Valley provides an environment similar to that of the Tigris and Euphrates Valley, so the package that worked well in Mesopotamia also worked well enough in the Nile Valley to trigger the spectacular rise of indigenous Egyptian civilization. The Sphinx and the pyramids, then, were built by people fed on crops originating in the Fertile Crescent, not in Egypt.

Wild ancestors of crops that were first domesticated in Southwest Asia also existed in Europe, Asia, and India, but we can be confident that the crops first produced there were mostly obtained from Southwest Asia and were not local domesticates. All modern cultivated varieties of most of the Fertile Crescent's founding crops either share only one arrangement of chromosomes out of multiple arrangements found in the wild ancestor, or else they share only a single mutation (out of many possible mutations) by which the cultivated varieties differ from the wild ancestor in characteristics desirable to humans. For instance, all cultivated peas share the same recessive gene that prevents ripe pods from spontaneously popping open and spilling their peas, as wild pea pods do. Evidently, most of the Fertile Crescent's founder crops were never domesticated again elsewhere after their initial domestication. Had they been repeatedly domesticated independently, they would exhibit legacies of those multiple origins in the form of varied chromosomal arrangements or varied mutations.

The ancestors of most of the founder crops have multiple wild relatives, in the Fertile Crescent and elsewhere, that would also have been suitable for domestication.

For example, peas belong to the genus *Pisum*, which consists of two wild species: *P. sativum*, the one that became domesticated to yield our garden peas, and the common and widespread *P. fulvum*, which was never domesticated. Yet the latter taste good, either fresh or dried. Similarly, domesticated wheat, barley, lentils, chickpeas, beans, and flax all have numerous wild relatives. Some of those related beans and barleys were indeed domesticated independently in the Americas or China, but in the Near East only one of several potentially useful wild species of a given plant was domesticated—probably because it spread so quickly that people soon stopped gathering the other wild relatives and ate only the crop. As Zohary and Hopf emphasize, the crop's rapid spread preempted any possible further attempts to domesticate its relatives or to redomesticate its ancestor.

Why was the spread of crops from the Fertile Crescent so rapid? The answer has to do with that east–west axis of Eurasia. Localities east and west of one another at the same latitude share exactly the same seasonal variations in day length. To a lesser extent, they also tend to share similar diseases, temperature, and rainfall. For example, southern Italy, northern Iran, and Japan, all located at about the same latitude but lying thousands of miles apart, are more similar to one another in climate than each is to a location lying a mere 1,000 miles due south. And the germination, growth, and disease resistance of plants there are adapted to precisely those features of climate. As a consequence, most of the Fertile Crescent crops grow well in southern Europe and Japan, but grow poorly at the equator.

In other words, Fertile Crescent domesticates spread west and east so rapidly because they were already well adapted to the climates of the regions to which they were spreading. Once farming crossed from the plains of Hungary into central Europe about 5400 B.C., it spread so quickly that the sites of the first farmers in the vast areas from Poland west to Holland (marked by their characteristic pottery with linear decorations) were nearly contemporary. By the time of Christ, cereals of Fertile Crescent origin were growing over the 10,000-mile expanse from the Atlantic coast of Ireland to the Pacific coast of Japan. That west–east expanse of Eurasia is the largest land distance on earth.

Thus, Eurasia's west–east axis allowed Fertile Crecent agriculture to spread over the band of temperate latitudes from Ireland to the Indus Valley and to enrich the agriculture that arose independently in eastern Asia. Conversely, Eurasian crops that were first domesticated far from the Fertile Crescent but at the same latitudes were able to spread back to the Near East. Today, when seeds are transported over the whole globe by ship and plane, we take for granted that our meals are a geographic mishmash. A typical American fast-food restaurant meal would include chicken (first domesticated in Southeast Asia) and potatoes (from the Andes) or corn (from Mexico), seasoned with pepper (from India), and washed down with a cup of coffee (of Ethiopian origin). But 2,000 years ago, Romans were already nourishing themselves with a range of foods that Zohary and Hopf show to have mostly originated elsewhere. Of Roman crops, only oats and poppies were native to Italy. Roman staples were still the Fertile Crescent founder package, supplemented by quince (originating from the Caucasus); millet and cumin (domesticated in central Asia); cucumber, sesame, and citrus fruit (from India); and chicken, rice, apricots, peaches, and foxtail millet (originally from China).

Contrast this easy east–west diffusion in Eurasia with the difficulties of diffusion

along Africa's north–south axis. Most of the Fertile Crescent founder crops reached Egypt very quickly and then spread as far south as the cool highlands of Ethiopia, beyond which they spread no farther. South Africa's Mediterranean climate would have been ideal for them, but the 2,000 miles of tropical conditions between Ethiopia and South Africa posed an insuperable barrier. Instead, African agriculture south of the Sahara was launched by the domestication of such wild plants as sorghum and African yams, which are indigenous to the Sahel and tropical West Africa and are adapted to the warmth, summer rains, and relatively constant day-lengths of those low latitudes.

Similarly, the southward spread of Fertile Crescent domestic animals through Africa was stopped or slowed by climate and disease, especially by trypanosome diseases carried by tsetse flies. The horse never made it farther south than West Africa's kingdoms north of the equator. Cattle remained stuck for 2,000 years at the northern edge of the Serengeti Plain, while new types of human economies and livestock breeds were being developed. Not until about the time of Christ, some 7,000 years after they were domesticated in the Fertile Crescent, did they finally straggle into South Africa along with sheep and goats. Tropical African crops had their own difficulties spreading south in Africa, reaching South Africa with black African farmers (the Bantu) just after the arrival of those Fertile Crescent livestock. However, those tropical African crops were never able to go beyond South Africa's Fish River, stopped by Mediterranean conditions to which they were not adapted.

Because of this, South Africa's indigenous Khoisan peoples (otherwise known as Hottentots and Bushmen) acquired livestock but remained without agriculture. They became outnumbered and were replaced northeast of the Fish River by black African farmers, whose southward spread halted there. Only when European settlers arrived by sea in 1652, bringing with them their Fertile Crescent crop package, did agriculture thrive in South Africa's Mediterranean zone. The collisions of all those elements produced the tragedies of modern South Africa: the quick decimation of the Khoisan by European germs and guns; a century of wars between Europeans and blacks; another century of racial oppression; and now, efforts by Europeans and blacks to seek a new mode of coexistence in the former Khoisan lands.

Contrast also the ease of east–west diffusion in Eurasia with the difficulties of diffusion along the Americas' north–south axis. The cool highlands of Mexico would have provided ideal conditions for raising llamas, guinea pigs, and potatoes, all domesticated in the cool highlands of South America. But the northward spread of those Andean species was stopped completely by the hot intervening lowlands of Central America. As a result, the Olmec, Maya, Aztec, and all other native civilizations of Mexico remained without pack animals and without any edible domesticated mammals except for dogs.

Similarly, domesticated turkeys or sunflowers of North America might have thrived in the Andes, but their southward spread was also stopped at the tropics. For thousands of years after corn was domesticated in Mexico, it was unable to spread farther north because of the relatively cool climates and shorter growing season. About the time of Christ, corn finally took root in what is now the eastern United States, but initially only as a very minor crop. Not until A.D. 800, when a hardy variety of corn adapted to northern climates was developed, did this grain finally trigger the flowering of the most complex Native American society of North America, the Mississippian culture—just in time for it to be decimated by European-introduced germs.

In contrast to the single Fertile Crescent origin that Zohary and Hopf trace for most widespread Eurasian crops, many apparently widespread Native American crops prove, on closer examination, to consist of distinct varieties or related species, independently domesticated in Mesoamerica and South America. That's true, for example, of American cotton, beans, lima beans, chili peppers, and squashes. While Fertile Crescent crops spread rapidly and preempted other incipient developments of domestication, slow diffusion and many independent domestications were the rule in the Americas.

Slower development of Native American agriculture (compared with Old World agriculture) contributed to the slower development of Native American writing, metallurgy, technology, shipping, and empires. Those differences helped seal the outcome of the collision between Native Americans and European settlers that began with Columbus. Yes, I acknowledge other geographic and biological contributing factors as well. Humans colonized Eurasia long before they colonized the Americas. In addition, the Americas had few domesticable large wild animal species, while in Europe many such animals were used to pull plows or make cavalry charges. Those domesticates harbored the animal pathogens from which Eurasia's most lethal weapon, human pathogens such as the smallpox and measles viruses, evolved. But the different orientations of the continents' axes remain an immensely important factor.

In the United States, the patriotic song "America the Beautiful" invokes our spacious skies, our amber waves of grain. Alas, that song reverses geographic realities. No waves of native grain ever reached the Pacific coast of North America, just as none ever stretched from Egypt to South Africa, while amber waves of wheat and barley did come to stretch across the spacious skies of Eurasia. These differences don't prove that widely distributed crops are admirable, nor do they testify to the superior ingenuity of early Eurasian farmers. They reflect instead the orientation of Eurasia's axis compared with that of the Americas or of Africa. Around those axes turned the fortunes of history.

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Life Styles of the Rich and Famous

Beauty meets the Beast

by Roger L. Welsch

I was on tour last fall, peddling my latest book, and was about to appear on a talk show on a Kansas City television station. The producer led me to the studio's "green room," the dressing room where guests brace themselves. I got the distinct feeling that I'd been there before—not *déjà vu,* or *presque vu,* but *vraiment vu.*

"Yes," the producer said to my wonderment. "You were here four years ago to talk about another book."

"Y-e-e-s," I said, the memory becoming clearer. "I shared this dressing room with some tall, sort of attractive young woman who had just appeared on the cover of some fashion magazine or another, right?"

"*Some* tall, *sort of* attractive young woman," the producer sputtered. "That was Cindy Crawford!"

Good grief. I shared a dressing room with Cindy Crawford, one of the most beautiful women in the world. I should have given her a copy of my book. I should have gotten her autograph on her magazine cover. I should have had her scratch her initials on my forehead with a piece of broken glass.

Weeks later, when I told all my buddies this story up at Slick's Tavern, they expressed so much doubt and ridicule (not that I had shared the room with Ms. Crawford, but that I had not taken advantage of the occasion, having instead *forgotten* it), that in order to restore my male credentials I found myself also remembering that as I left the dressing room, Cindy said huskily, "Hey, you in the overalls—nice keister." (Although, now that I think of it and as I have made clear to Lovely Linda, she might actually have said, "Nice to meet you, sir.")

The point is—and I suppose you are wondering by now what the point is—beauty is not something immediately and inherently evident to all observers. In the case of Ms. Crawford, she was to my eye simply a nice-looking young woman until I was instructed by magazines, newspapers, comedians, television, calendars, and male friends that she is a ravishing beauty. Of course, Cindy might have been having a particularly bad day or I might have been preoccupied with my own coif, but the fact remains, physical beauty is cultural, not natural. What is considered beautiful in one culture or era is not necessarily beautiful in another.

If there is a universal rule of beauty, it is that we consider those physical characteristics that reflect wealth to be beautiful. In classic English ballads, which exemplify medieval and Renaissance times and customs, a good deal of plot development revolves around the tensions between characters like "fair Eleanor" and "the nut-brown maiden." Fair Eleanor is attractive, by virtue of her being fair, while the nut-brown maiden—well, you know, as we used to say in college, "She plays the piano and all the girls like her." If you were poor, you had to work, and work was almost inevitably outside. If you were rich, you sat around the castle all day, never venturing into the glare of the sun and dangers of the countryside. Pale skin therefore reflected wealth and came to represent beauty.

So English women went to extremes to have translucently white skin. They carried parasols, swaddled their arms, shaded their faces, and powdered and bleached their skins, right on up to fairly recent times. But these days working women are indoors—sitting behind desks in corporate offices, standing before classrooms, diagnosing patients, checking out books, taking care of kids. On the other hand, the idle rich are outdoors—playing tennis, skiing, and traveling to sunnier climes. Today, the nut-brown English maiden is the wealthy one, and therefore desirable, and the only resort for pasty Fair Eleanor is a tanning salon.

Same with men. Fabio? Marky Mark? Schwarzenegger? Obviously, these guys have enough money to spend their lives lounging around beaches, working out in salons, building their pecs, shaving their chests. Working lugs get their exercise pounding on computer keyboards, checking mortality tables, taking motivation workshops.

In societies where famine is a constant threat, fat is a sign of wealth and, ergo, beautiful. That has historically been true even of European and American culture. Until recently. Now, when plenty is the rule rather than the exception, fat is easy to come by. Fat is no longer a sign of wealth. Just ask me.

These days, models like Kate Moss declare through their physiques (or nonphysiques), "Me worry about famine? You must be kidding." Wow, our greedy little psyches gush: "She's absolutely *skeletal.* She must be stinking rich and is therefore ravishingly beautiful."

Body mutilation, from tattooing to extreme manicure, requires time to achieve and is visible evidence of extended leisure and undemanding physical exertion. Elaborate coiffures—shaved patterns or cornrows—take time, money, and the expensive attention of others. Same with ornate costuming, from lip rings and neckties to high heels and body paint. Squandered energy, self-imposed physical restriction, idle time, and, even better, the consumption of other people's time require and indicate wealth and have come to represent beauty.

The thesis extends beyond human body presentation, of course. The less arable a piece of land is, the more scenic it becomes. So tourists speed past acres of corn and wheat, bored to tears, to gasp at the sterile emptiness of the Grand Canyon or Disneyland. The evident utility of the station wagon makes it hopelessly drab while the total inefficiency of a Lamborghini makes it the stuff of dreams.

But you don't want to know what has determined beauty in the past. You want to be a step ahead for the future, right? What will constitute wealth and therefore symbolize beauty tomorrow? Not voting or owning a firearm, for one thing. These days there's no rich like *felon* rich, so a sure sign of wealth is a solid prison record and all the nonperks of conviction. The only way you can afford a million-dollar fine, after all, is to steal ten million.

Similarly, a sure sign of wealth is spending $6 million being elected to a political job that pays only $213 a month. Everyone knows that if it costs that much to get there, something's going on to make it well worth the bucks.

I'm not as certain about marital records as wealth indicators: will those who have never loved and lost be seen as wealthy, or those who have loved and could afford to lose? A nice combination would be a felon entitled to conjugal visits.

And to my knowledge, only a handful of people left in America can survive financially without having written a book, so a limited bibliography will, I predict, soon be accepted as important evidence of beauty: "I have so much money, I didn't need to reveal how my parents mistreated me when I was a kid."

The most remarkable direction for the future, however, will be homeliness. Beauty has become such an issue in America today, such a factor in social and financial success, that the real extravagance of the future will be being ugly. Anyone wealthy enough not to care about being attractive will be viewed as attractive for that very reason. I know this sounds pretty convoluted, but take a look at the latest fashion magazines. I think I may even be late in my prediction. Homely is in vogue, pretty is passé.

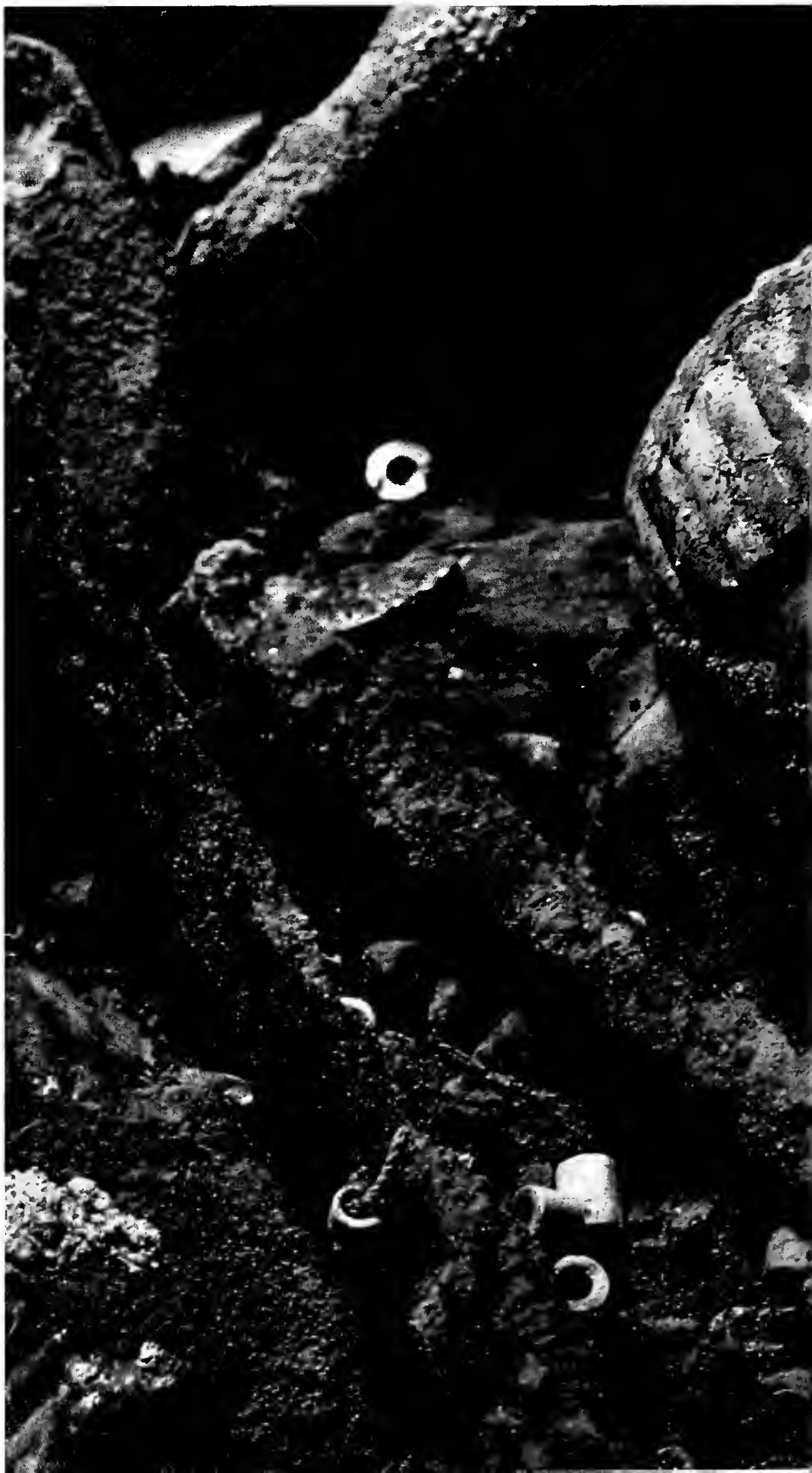
Sorry, Cindy. Looks like you're out and I'm in! By this time next year you'll be telling your boss down at the laundry how *you* once shared a dressing room with *me*.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

Tales from a Peruvian Crypt

The looting of a prehistoric pyramid stimulates an operation in salvage archeology, with unexpected scientific dividends

by Walter Alva and Christopher B. Donnan



In the fertile river valleys that relieve Peru's arid coastal plain, mud-brick pyramids stand as the most visible evidence of the prehistoric Moche civilization, which flourished between the first and eighth centuries A.D. Rising out of agricultural fields in the Moche River valley, the massive Pyramid of the Sun was the largest structure ever built in South America. With a ramp that led up to small buildings on its flat summit, it stood about 135 feet high and sprawled over 12.5 acres at its base. It once contained more than 130 million sun-dried bricks. Some of it has eroded away naturally, while part was demolished in the seventeenth century by Spanish entrepreneurs in search of rich burials or other treasures.

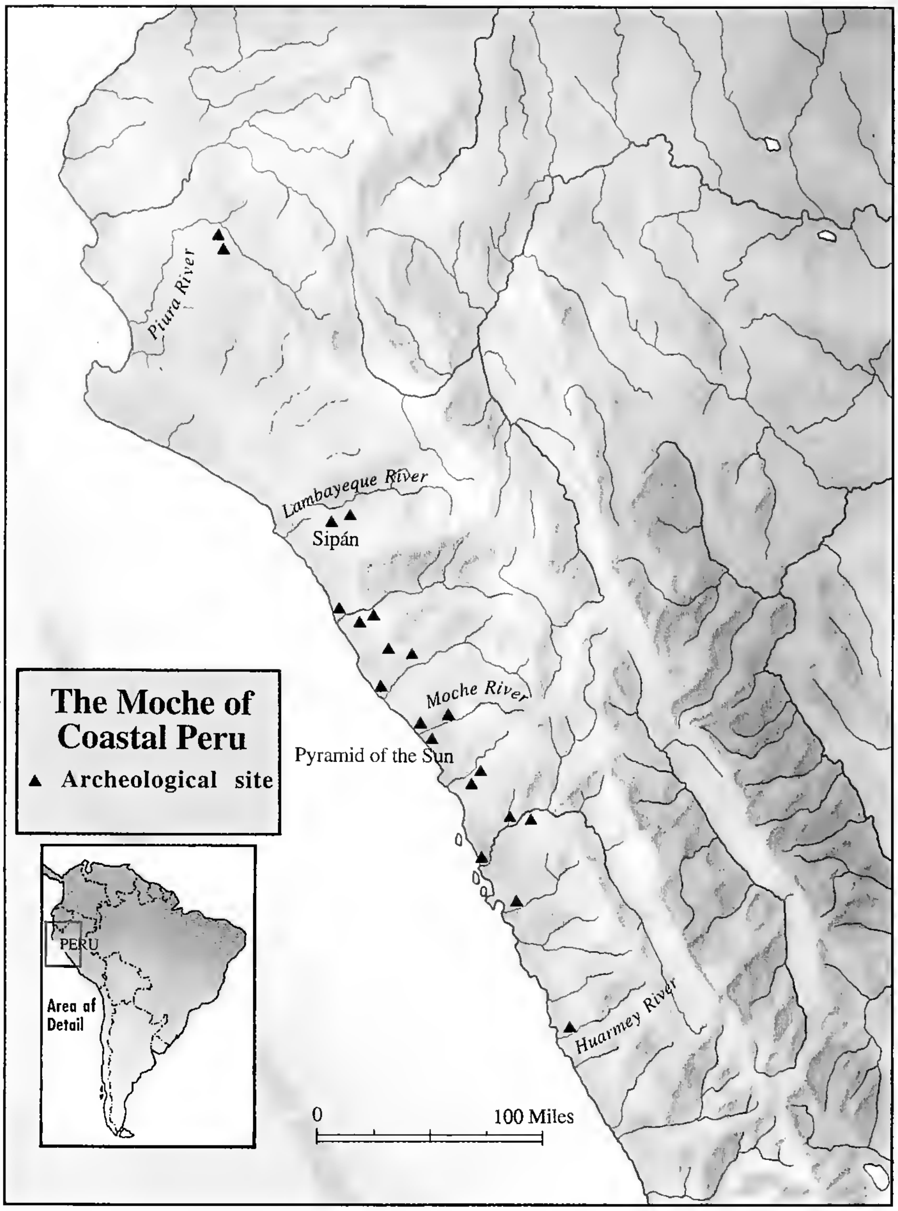
About ninety-five miles north of the Pyramid of the Sun, in the Lambayeque River valley, the Moche cemeteries and three pyramids near the village of Sipán have long been the target of looters. Over the years they have dug many deep holes with picks and shovels in hopes of locating intact tombs containing ceramic vessels, shell and stone beads, and rarer ornaments of silver and gold. By November of 1986, they had nearly exhausted the cemeteries, and one group of treasure seekers decided to focus on the smallest pyramid. Working at night to avoid police detection, they dug a series of holes, but found little of value. Then, on the night of February 16, 1987, at a depth of about twenty-three feet, they suddenly broke into one of the richest funerary chambers ever looted, the tomb of an ancient Moche ruler.

The looters removed several sacks of gold, silver, and gilded copper artifacts. They also took some ceramic vessels, but they broke and scattered many others in their haste. Almost immediately, the looters quarreled over the division of the spoils, and one of them tipped off the police. The authorities were able to seize some of the plundered artifacts, but only a pitiful amount was salvaged from the find. The rest disappeared into the hands of Pe-

Adapted from *Royal Tombs of Sipán*, by Walter Alva and Christopher B. Donnan (Los Angeles: Fowler Museum of Cultural History, University of California, 1993).

A two-inch, hollow gold head, one of ten matching beads that formed a necklace, was part of the finery buried with a Moche lord about A.D. 150. The find came from the third intact tomb excavated by archeologists at Sipán.
Nathan Benn © National Geographic Society

Joe LeMonnier



ruvian collectors or was illegally exported for sale in Europe, Japan, and the United States.

Building on civilizations that preceded them in coastal Peru, the Moche developed their own elaborate society, based on the cultivation of such crops as corn and beans, the harvesting of fish and shellfish, and the exploitation of other wild and domestic resources. They had a dense, socially stratified population, with large numbers of workers devoted to the construction and maintenance of irrigation canals, pyramids, palaces, and temples. Their lords apparently received food and commodities from their subjects and distributed them to lesser nobles and to the potters, weavers, metalworkers, and other artisans who created luxury objects for the elite. In sculptures, decorated ceramics, and murals, archeologists have glimpsed many complex scenes of Moche life, including hunting, combat, and ceremonial practices.

The luxury items from Sipán that were confiscated by the police, including hollow gold beads of various shapes and sizes, hinted at the magnificence of the plundered burial, which must have belonged to one of the Moche elite. More fortune-hunters descended on the site in search of overlooked valuables. They hacked at the tomb walls and sifted through the excavated dirt. By the time the police secured the area, little was left except a boot-shaped hole. Nevertheless, with armed guards stationed around the clock, we hastily organized an archeological survey to learn everything possible of scientific value (author Walter Alva directed the project; coauthor Chistopher B. Donnan was one of the many participants).

We began by making a contour map of the three pyramids and what remained of their ramps and adjacent plazas. The small pyramid, where the tomb had been found, was riddled with looters' tunnels, but in some places, the piles of dirt they had excavated helped preserve the original contours. The tunnels also enabled us to examine the internal construction. The pyramid and the rest of the complex evidently had been built and rebuilt over a long period of time, undergoing many changes as the various parts were enlarged. The small pyramid seems to have gone through six phases, beginning in the first century A.D. and ending about 300.

Although the burial chamber had been gouged out of shape, we were able to determine that it had originally been roofed with large wood beams, which had decomposed. To our great surprise, we were able to uncover some of the tomb's contents that had been missed by the original looters and the subsequent gleaners. Clearing along one side of the chamber, we found the remains of a large, gilded copper crown decorated with metal disks; four ceramic jars modeled in the shape of human figures; and a copper mask with inlaid turquoise eyes. In excavating these, we also discovered a heavy copper scepter forty inches long, pointed at one end and bearing a three-dimensional architectural model on the other. The model depicted a platform with a balustrade, surrounding an open-front building with one back wall and a peaked roof supported by posts. Seventeen double-faced human heads decorated the roof ridge, while depicted in relief on the wall was a supernatural creature, half feline and half reptile, copulating with a woman on a crescent moon.

Knowing that the pyramid would be further plundered once we left, we decided to open up a new section to methodical excavation, choosing a ten-by-ten-meter (1,076-square-foot) area near the summit. Here we came upon a place where the mud brick had been carved out and refilled in ancient times. Digging down, we found eight decomposed wood beams, similar to those that had roofed the looted burial

Between the first and eighth centuries A.D., the Moche occupied a series of river valleys, map left, along the otherwise arid coast of northern Peru. At Sipán, below, the Moche built three mud-brick pyramids, now much eroded. Excavations continue at the smallest of these (foreground), which concealed at least four royal tombs.
Bill Ballenberg

chamber. Buried beneath these, in the debris of what had been a small rectagular chamber, we found 1,137 ceramic bowls, jars, and bottles. They portrayed a variety of human figures: warriors holding war clubs and shields, nude prisoners with leashlike ropes around their necks, musicians with drums, and seated figures wearing beaded pectorals (biblike coverings). Some were arranged in symbolic tableaux, for example, musicians and prisoners ringing and facing noble personages.

As we removed the ceramics, we found several pieces of copper and, finally, a man's skeleton lying jackknifed on its back, with chin, knees, and arms pulled in toward the torso. Since the Moche customarily buried their dead in a fully extended position, we interpreted this individual to be a sacrificial victim, whose body had been shoved into the small chamber as part of the ritual offering.

Even as these offerings were being excavated, we discovered a second, larger rectangular area that appeared to have been carved into the pyramid and refilled. As we carefully excavated this, we found, about thirteen feet below the original surface of the pyramid, the skeleton of a man wrapped in a cotton shroud. He lay stretched out on his back and wore a gilded copper helmet. Over his right forearm, which rested on his chest, was a round copper shield. A little below we found the remains of seventeen parallel beams that, we dared hope, lay over a major, undisturbed burial chamber.

The discoveries that subsequently emerged surpassed our dreams. Buried in the chamber were the remains of a wood coffin that contained the richest grave offerings ever to be excavated scientifically in the Western Hemisphere. The body of a man between thirty-five and forty-five years of age had been laid to rest with a feathered headdress, banners of cloth with gilded copper decorations, beaded pectorals, nose ornaments and necklaces of gold and silver, ear ornaments of gold and turquoise, face coverings of gold, a gold backflap and a silver backflap that would have been hung from the belt, and countless other precious objects. In his right hand the deceased had held a gold and silver scepter topped with a large rattle, and in his left hand, a smaller scepter of cast silver. In relief on the rattle, which was shaped like an inverted pyramid, were scenes of an elaborately dressed warrior subjugating a vanquished opponent. The sculpted head of the smaller scepter echoed this theme.

Working six days a week, it took us four months to document and safely empty the delicate contents of the tomb. As our original budget became exhausted, we received some partial funding from a brewery and a truckload of noodles donated by a pasta manufacturer. At one point we were paying the fieldworkers with a combination of cash and noodles. We eventually secured new support from the Research Committee of the National Geographic Society and were able to proceed with further excavation.

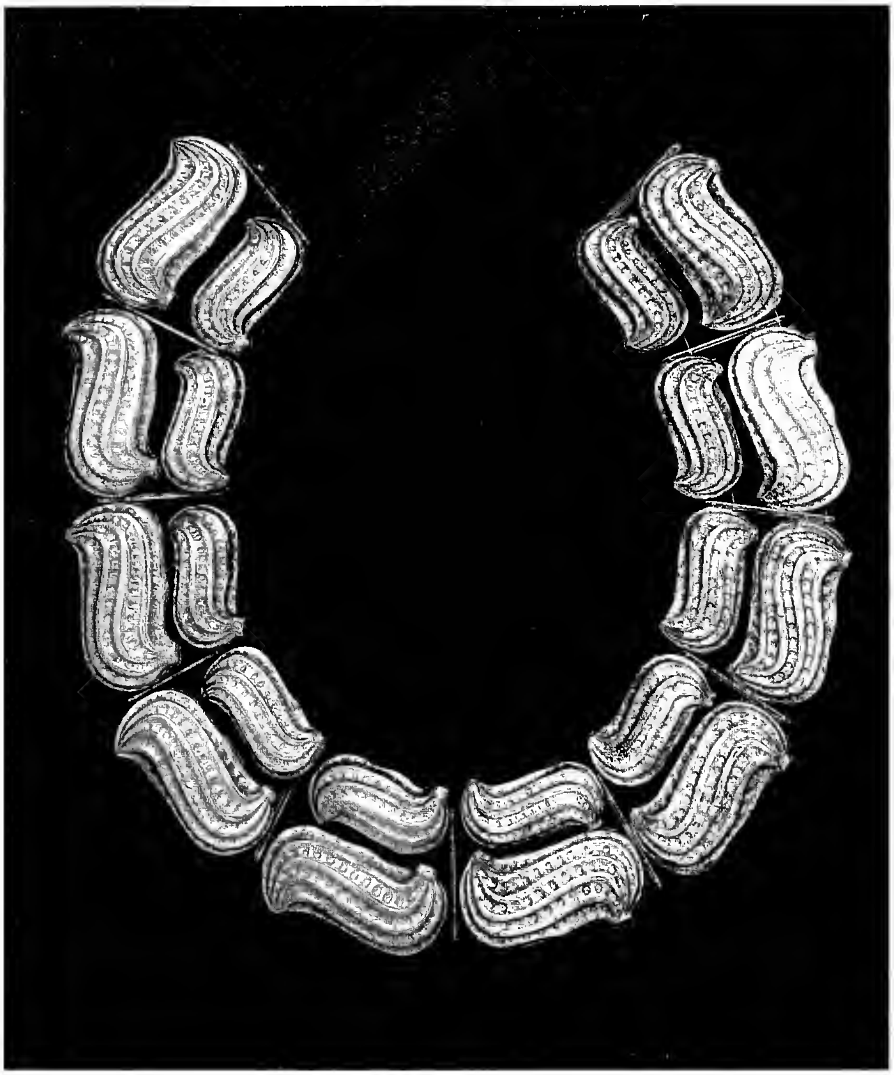
All the while we had been working and moving equipment around the coffin burial, we had been walking only inches above hundreds of ceramic vessels, two sacrificed llamas, a dog, and the burials of two men, three women, and a child of nine or ten. Although we do not know this for sure, the men and the child might have been buried as sacrifices to accompany the principal figure. The remains of the females, however, were partly decomposed at the time they were placed in the tomb, as evident from the way the bones were somewhat jumbled. They had probably died years earlier and their remains maintained elsewhere until this final interment.

As we excavated the tomb and cataloged its contents, we couldn't help wondering who was the important personage buried there. The key to the answer was a major photographic archive of Moche sculpture and drawings at the University of California at Los Angeles. As the tomb was being excavated, photographs of the objects were sent to UCLA for comparative study.

Many of the objects in the coffin suggested the man buried there was a warrior. The archive of Moche art contains hundreds of depictions from which we can reconstruct a sequence of Moche militarism and ceremonial activity. We can see processions of warriors carrying war clubs, spears, and spear throwers, perhaps on their way to battle. We can see warriors in combat, apparently away from settled areas. The essence of Moche combat ap-

A gold and silver necklace of peanut-shaped beads belonged to the warrior priest buried in the first royal tomb to be scientifically excavated. The Moche probably associated gold with the right side and masculinity, and silver with the left side and femininity.
Susan Einstein

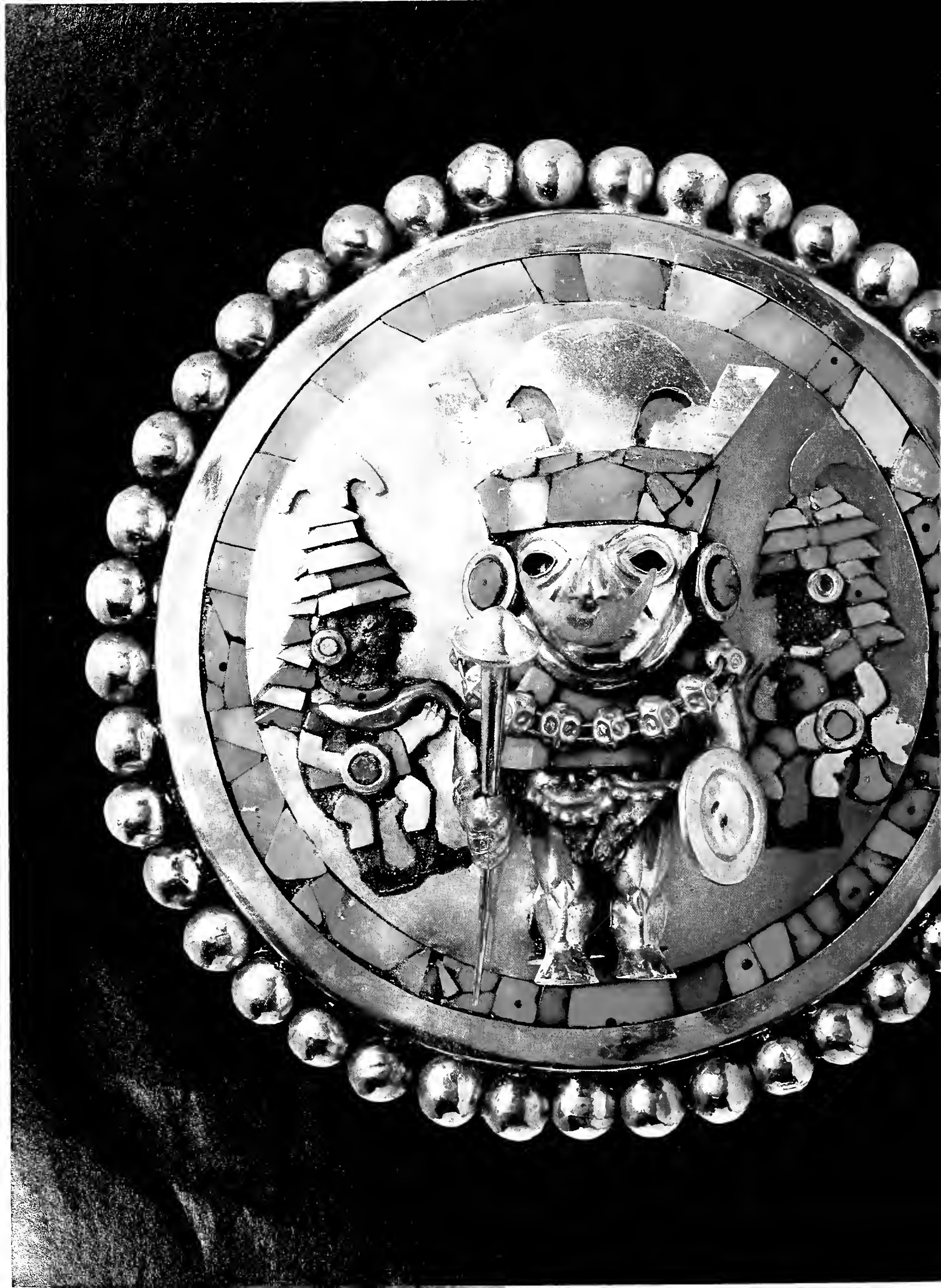
Looted from an unknown grave, a Moche vessel depicts a warrior seizing his adversary by the hair and subduing him with his club. Moche engaged in combat to obtain prisoners for ritual sacrifice.
Nathan Benn © National Geographic Society



pears to have been the expression of individual valor, in which warriors engaged in one-on-one combat, seeking to vanquish, rather than kill, an opponent. The victor is often shown hitting his opponent on the head or upper body with the war club, while the defeated individual is depicted bleeding from his nose or losing his headdress or other parts of his attire. Sometimes the victor grasps his adversary by the hair and removes his nose ornament or slaps his face.

As far as we can tell, the Moche warriors fought with one another, not against some foreign enemy. Once an opponent was defeated, he was stripped of some or all of his clothing and a rope was placed around his neck. The victor made a bundle of the prisoner's clothing and weapons and tied it to his own war club as a trophy. After a public parading of the spoils, the prisoners were arraigned before a high-status individual and finally brought back to the Moche settlements or ceremonial precincts. There the priests and their attendants sacrificed them, cutting their throats and drinking the blood from tall goblets. The bodies were then dismembered and the heads, hands, and feet tied individually with ropes to create trophies.

Many representations of the sacrifice ceremony exist in Moche art. Although



Only three and three-quarters inches in diameter, one of the warrior priest's ear ornaments portrays a warrior complete with a war club, shield, headdress with its crescent-shaped decoration, and ear ornaments of his own.
Susan Einstein

A design from a Moche ceramic bottle depicts the Moche sacrifice ceremony. The conical helmet with a crescent-shaped ornament on one of the larger figures (left) helps identify him as a warrior priest. He holds a goblet of blood taken from sacrificed prisoners, who are shown beneath having their throats cut.
Donna McClelland

they vary, not always depicting all personages in the ceremony, apparently three principal priests and one priestess were involved, each associated with specific garments and ritual paraphernalia. The most important was the "warrior priest," generally depicted with a crescent-shaped nose ornament, large circular ear ornaments, a warrior backflap, a scepter, and a conical helmet with a crescent-shaped ornament at its peak. A comparison of these and other details with the contents of the tomb convinced us that the individual buried there was just such a warrior priest.

When the sacrifice ceremony was first identified in Moche art, in 1974, no one could be sure it was a real practice, as opposed to a mythical event. Now we had archeological evidence that this was an actual part of Moche life. Here was one of the individuals who presided over the sacrifices. Further, because the limited number of objects salvaged from the looted tomb were similar to some of those we had excavated, we could conclude that the looted tomb also must have belonged to a warrior priest.

As if this were not enough, during the excavation of the warrior priest's tomb, we located another suspected tomb elsewhere on the pyramid. We held off excavation until work on the earlier find was nearly complete. The knowledge we gained made it easier to anticipate the sequence of excavation. Again we found the residue of a plank coffin containing the rich burial of a man between thirty-five and forty-five years old. Among his grave goods was a spectacular headdress ornament of gilded copper, in the form of the head and body of an owl from which arched long bands with suspended bangles, representing the feathered wings. Nearby we found the remains of four other individuals: a male between fourteen and seventeen years of age, two females in their late teens or early twenties, and an eight- to ten-year-old child. Buried with the child were a dog and a snake.

The contents of this tomb were only a little less lavish than those of the warrior priest. They suggest that the principal individual was another of the priests depicted in the sacrifice ceremony—one we call the "bird priest." The major clue was the large owl headdress. He was also buried with a copper cup near his right hand, similar in proportion to the cups portrayed in pictures of the sacrifice ceremony.

Having identified these individuals as participants in the sacrifice ceremony, we began to wonder if such ceremonies took place in Sipán itself. The answer was soon revealed when, about eleven yards from the bird priest's tomb, we found several small rooms that contained hundreds of ceramic vessels, human and llama bones, and miniature ornaments and implements, mixed with ash and organic residues. Among the human remains were hands and feet, quite possibly the trophies taken from dismembered sacrificial victims. Altogether these looked to be the residue of sacrifice ceremonies, which the Moche apparently carried out at Sipán, as no doubt they did at their other centers.

The looted tomb, the two excavated tombs, and the sacrificial offerings all

Crafted of gold, a spider with a body in the form of a human head sits in the middle of its web. This intricate bead contains three small gold balls, here hidden from view, that gave it a rattling sound.
Susan Einstein

seem to date to about A.D. 290. While excavating the offerings, we found a fourth, somewhat earlier tomb containing the remains of a man between forty-five and fifty-five years old, also richly endowed with grave goods, including a necklace of gold beads in the form of spiders on their webs, anthropomorphic figures of a crab and a feline, scepters, an octopus pectoral with gilded copper tentacles, and numerous other ornaments and objects. Nearby we found the body of a young, sixteen- to eighteen-year-old woman next to a sacrificed llama. This tomb may also have belonged to a warrior priest, but not all the identifying elements are there. Possibly, this is simply because it dates to an earlier period than the depictions we have of the sacrifice ceremony, which are all from after A.D. 300.

Moche civilization collapsed suddenly, probably as a result of one or more of the natural cataclysms that periodically devastate coastal Peru—earthquake, flooding, or drought. The Moche had no writing system, so they left no records we can hope to decipher. They disappeared before Europeans reached the New World and could leave us eyewitness accounts. Yet with the scientific excavation of these royal tombs, we have gained an intimate portrait of some of their most powerful lords. Work at Sipán continues, now at a promising location near the tomb of the bird priest. As we dig more deeply, we look forward to our next encounter. □

Royal Tombs of Sipán, a special exhibition detailing the 1,700-year-old burials excavated from a Moche pyramid, will appear at the American Museum of Natural History from June 24 until the end of the year. Organized by the Fowler Museum of Cultural History at the University of California at Los Angeles, the exhibition features 115 artifacts of gold, silver, turquoise, and other precious materials on loan from Peru's Brüning Museum.

A necklace of gold spider beads was one of the last objects placed over the principal burial in the third intact tomb. Many other gilded copper ornaments have turned green with corrosion.
Nathan Benn © National Geographic Society

"'Dear Enemy'' Notes

A neighbor's song means more than music to a hooded warbler's ears

by Renée Godard and Haven Wiley

On a balmy April morning, the bottomland hardwood forests near Chapel Hill in central North Carolina are deceptively peaceful. As we stand in the dense understory of arrowwood, with its pale new foliage, two black-and-yellow sprites fly furiously back and forth across an invisible boundary. They are so oblivious to our presence that they almost brush our legs in passing. After about ten minutes of this twisting through the arrowwood, the tiny birds separate by some fifty yards. Each takes a station just below the crowns of the oaks and hickories and begins to belt out its own version of a ringing song. The black cowls over yellow faces reveal that these rivals are male hooded warblers. They have come to the forest to begin the breeding season.

One of the birds wears two lightweight, red plastic bands on each leg. He was one of the first males we banded for identification here at our study site, the Mason Farm Biological Reserve, and he has returned to exactly the same location in this 370-acre woodland for the fourth consecutive year, an exceptional record. His rival, as yet unbanded, is probably less than one year old and is staking a territorial claim for the first time.

Like many migrating songbirds, hooded warblers spend the winter in warmer climes. They winter from Mexico to Panama and begin to make their way north in March. By April, they have reached their summer quarters, which extend from the Gulf coast north to southern Michigan and east to Connecticut. The birds we have been observing have each just returned from their Mexican and Central American retreats and are now in serious competition for real estate. Their female counterparts will arrive in about five to ten days. To attract a mate and eventually raise healthy young, each male needs a territory of some twelve to twenty-five acres of forest with a luxurious understory of shrubs like arrowwood. The old-growth bottomland forests in the Reserve are an ideal habitat; each year five to ten hooded warbler pairs nest here. Only about half of these birds, however, survive the winter and round-trip migration from one year to the next. The color-banded old-timers are among the first to return, and each quickly reclaims his former territory. In contrast, newcomers ready to breed for the first time must find an opening vacated by a male that failed to return. This precise "site-faithfulness" of returning males is one of the remarkable features of migration for many songbirds. Why should males not move from one year to the next? After all, they might have settled for an inferior territory the first year they bred; surely some of them could upgrade their location in a subsequent year.

Part of the answer lies in the relationships of neighbors. Male hooded warblers, like many other male songbirds, have a number of ways of dealing with rivals in adjoining territories. The simplest interaction of neighboring males is simply singing within earshot of one another. Our systematic observations have shown that the average male hooded warbler spends 55 percent of each early spring morning just singing. When, on occasion, a male meets a neighbor at a disputed boundary, singing ceases and chasing begins, sometimes escalating to fighting. When the females arrive, aggression intensifies. Intermittent chasing can last for two days before both parties tentatively accept a boundary. But once boundaries are established, neighbors quickly develop a respect for them. Males can then sing close to the edge of their territory without provoking an attack from a neighbor. Such apparent amicability does not, we have noticed, prevent them from occasionally venturing surreptitiously into one another's territories.

The birds have become what evolutionary biologists have termed *dear enemies.* Instead of constantly battling, two individuals appear to call a truce; while not becoming allies, they can at least avoid continual contests. Our studies suggest that an important factor of this détente is the hooded warbler's ability to recognize a neighbor's songs. Each male's repertoire consists of five to ten stereotypical patterns of notes. Each song is recognizable

A male hooded warbler refreshes himself in a Texas stream.
Barth Schorre, Bruce Coleman, Inc

Townsend P. Dickinson

A female hooded warbler, left, arrives at the species' breeding grounds about a week later than the first males. For an early spring male migrant, below, a still-bare branch in New York City's Central Park provides a perch from which to dart out and catch insects. If males return too early, cold and scarcity of insects can be deadly. But if they arrive too late, all the best territories will be taken.

Arthur Morris

as a hooded warbler's—although some do not come very close to the descriptions in standard field guides—yet each has at least a few details that make it characteristic also of the individual.

The ability of male songbirds to discriminate the fine, individual differences in the songs of rivals, both known and new, was established through experiments several decades ago. Our experiments with hooded warblers in the Mason Reserve since 1987 have demonstrated that these birds are even more discerning. A male hooded warbler can recognize the songs of each one of his neighbors and can also learn their usual locations in relation to his territory. To demonstrate this ability, we chose twelve hooded warblers from the Mason Reserve and adjoining woodlands as study subjects. First, we played a tape recording of a neighboring warbler's songs just inside a subject's territory near the boundary shared with that neighbor. Then we broadcast the same tape, also just inside but now on the opposite side of the subject's territory, near a boundary shared with a different neighbor. (Because in an experiment of this sort, the order of presenting the two playbacks might influence the results, we played neighbors' songs to half of the subjects in reverse order.) Subjects often quickly approached the speaker and searched frantically for the apparent invader. However, our subjects responded much less vigorously to neighbors' songs coming from the expected direction than to the same songs emanating from the opposite direction. Hooded warblers, then, know each neighbor's songs, and know just where they should come from. To our subjects, a playback of a neighbor singing on the wrong boundary signaled a serious territorial invasion.

Many ornithologists have noticed that former neighbors returning from winter quarters act like dear enemies right from the start. As with our red-banded male that early spring morning, returning males are more likely to dispute boundaries with new birds. Do returning neighbors just remember old boundaries, or are they capable of remembering one another's songs? The latter feat would be remarkable: the birds have had no chance to hear the songs for more than six months. They do not sing for most of the winter. We also know that hooded warblers from the Mason Reserve do not migrate together because they do not arrive at the breeding grounds together. Nor, presumably, do they winter together in Mexico and Central America.

To test song memory, we duplicated the experiments just described, with an added element. We started our tests on the very day a male appeared in April on his previously occupied territory. Familiar songs of neighbors from the year before, played near the old boundary, elicited little response; to our subjects they must have sounded like an old friend back in his usual place. In contrast, the same songs played near the "wrong" boundary evoked a strong response—a quick approach and frenetic searching. Male hooded warblers do, in fact, remember each neighbor's songs from one year to the next. These birds provide one of the few demonstrated cases of long-term memory in a nonhuman vertebrate. This ability has important practical consequences for a hooded warbler. By returning to precisely the same territory year after year, a male can expect to avoid "bargaining" for boundaries with about half of its neighbors. The time and energy thus saved can be used to deal with other neighbors and to attract and court a female.

A male reacts strongly to a trespass into its territory, a transgression that amounts to an abrogation of a mutually accepted treaty. Does such a trespass have consequences beyond a chase by the subject male? Evolutionary theory predicts that it should. A dear enemy relationship involves reciprocal respect for an arbitrary boundary. Such reciprocity in a potentially exploitative relationship can persist when rivals play tit-for-tat. Rivals must recognize each other individually, so they can keep track of each other. They also must interact repeatedly over an indefinite period of time, so neither can take advantage of the other on their last interaction. Finally, each must retaliate whenever the pact is broken. Our warblers met the first two conditions, and we devised another test to determine if trespass provoked retaliation by the offended male.

We first presented a neighbor's songs

Russ Kinne, Comstock

Hooded warblers frequent the understory of woodlands. A male in Point Pelee, Ontario, near the extreme northern edge of the hooded warbler's range, peers at sprigs of poison ivy, right. Below: A pair share in the care and feeding of their young, which are within two days of fledging.

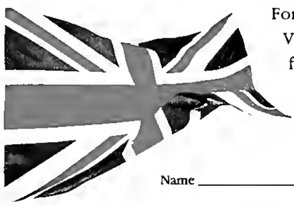
George K. Peck

near the "correct" boundary of a subject's territory. As expected from our previous experiments, the subject's response was weak, the normal result for a dear enemy. Then this same neighbor's songs were broadcast from two locations deep inside the subject's territory (we stopped the playbacks as soon as the subject arrived nearby, so it would not learn that the neighbor was not actually present). Following this simulated trespass, we once again presented the same neighbor's songs near the correct boundary. The result was clear: a subject responded much more strongly to a neighbor's songs following an apparent trespass. When we staged trespasses with a stranger's songs, retaliation toward a neighbor did not occur. Retaliation was therefore restricted to the trespassing individual, just as predicted for rivals playing tit-for-tat.

Over the years, we have come to appreciate the intricate lives led by hooded warblers. They know their neighbors and work out mutually advantageous relationships with them. The trust required for these relationships, however, is not "naïve." While not demanding "an eye for an eye" following trespass, they do become antagonistic toward wayward neighbors. We have also noticed that in the days following a simulated trespass, our subjects' behavior returned to normal. Given a little time, warblers appear to "forgive" their trespassers.

What we have found could well apply to other migratory songbirds that defend territories during the breeding season. If so, our studies suggest another way in which habitat destruction can have devastating effects on populations of migrating birds. For a surviving male hooded warbler headed north for the summer, not all habitat, not even habitat suitable in general for the species, is optimal. Each individual seeks out the one specific place where it has an advantage—its territory from the previous year, where it will meet some of its old neighbors. If a particular stretch of forest has disappeared, our individual migrant must start over.

April is a time of blossoming opportunities. For the hooded warblers arriving on each southerly wind, it is also a time of establishing and renewing relationships, including those with their neighbors. By mid-May, most males in the Mason Farm Biological Reserve will have mates incubating three or four eggs in nests cradled on stems of arrowwood. Those nests that escape predators and cowbirds (about half of the total built) will produce a new generation of hooded warblers to carry on the tradition of dear enemies. □



Owl monkeys have evolved big eyes to help them get around after dark. Not as well adapted to the nighttime as many nocturnal mammals, they are most active on bright moonlit nights.
Tom McHugh; Photo Researchers, Inc., Monkey Jungle, Miami

Night Watch on the Amazon

When dusk falls in the Peruvian rain forest, the world's only nocturnal monkey gears up for a noisy night of feeding in the canopy

by Patricia Chapple Wright

The full moon loomed above the Peruvian rain forest canopy, illuminating even the forest floor where I sat with my field notebook in hand. On this chilly and quiet night, I strained my ears to catch every sound. Suddenly, coming from some one hundred feet up in the canopy, I heard what I was waiting for: the low, mournful hoot of an owl monkey, *Aotus trivirgatus*. Three notes, a pause, and then a lower note. Taking a compass direction, I wrote down the time. The call was repeated for the next ten minutes, then stopped. From a distance came the answering call: five gruff hoots, a pause, and two lower hoots.

I had been listening to calls like this on bright, moonlit nights for almost a year and had begun to piece together certain aspects of owl monkey life. I knew, for example, that these owllike calls are given by a monkey when it is alone, usually near the borders of its family's territory. Calling sessions are restricted to once or twice a month and may be given by an adult male, an adult female, or a subadult. The calls, which can be heard 1,500 feet away, consist of a series of ten to thirty short, low-pitched hoots a minute. The session lasts one to two hours, as the caller moves a few hundred feet along its border. The calls almost always evoke responses from neighboring territories. At the end of this territorial calling session, a calling monkey usually returns to its family, which may be resting in the center of the territory. When a young monkey leaves its natal group, however, it may travel long distances in the forest, calling continually, perhaps advertising for a mate.

As glad as I was to begin deciphering owl monkey calls, no call could tell me what I had come to Peru to find out—why this species is active at night. Found in forested regions from Panama to northern Argentina, it is the world's only nocturnal monkey. All other nocturnal primates—including mouse lemurs and aye-ayes in Madagascar, tarsiers and loris in Asia, and bushbabies and pottos in Africa—are prosimians, a more primitive group that lacks the monkeys' relatively large brain, enclosed eye sockets, dry rhinarium (nose), and impressive manual dexterity. And unlike the eyes of most nocturnal mammals, the owl monkey's eyes have cones for color vision and lack a reflective shield on the retina (the tapetum lucidum), which suggests that its ancestor was active in the daytime only. A question that had long intrigued scientists was why a day monkey had evolved into a night monkey. Since studying monkeys in captivity or skins in a museum could not give satisfactory answers, I decided to go to the Cocha Cashu research station, situated in a pristine rain forest in southeastern Peru's Manu National Park, where I could observe owl monkeys in the wild.

The owl monkey shares its rain forest home with eleven other monkey species, including *Callicebus moloch,* the dusky titi. The diurnal titi and the owl monkey—both about squirrel size—have similar social systems. I decided to compare the life styles of the two species—their diet, sleeping habits, movement patterns—in the hope of gaining insight into the owl monkey's nocturnal life style.

I first needed to survey the area for both species of monkey and to select four groups (two of each species) to focus on. I chose one group of owl monkeys whose territory bordered on the Manu River and another whose territory bordered on Lake Cocha Cashu. Then I identified titi territories that overlapped with the chosen *Aotus* groups. With my study animals targeted, I then began the lengthy process of getting them used to my presence and learning how to follow them through the forest.

Owl monkeys are often habituated to one sleeping tree. Charles Janson, a primatologist studying capuchin monkeys at Cocha Cashu, was the first to find an *Aotus* sleeping tree there. I began my real data

Owl monkeys often sleep and seek shelter in tree holes and vine tangles.
Arthur W. Ambler; Photo Researchers, Inc.

collection sitting under this tree with my binoculars and notebook. Just as dusk fell, the first owl monkey—a male—emerged from his secluded den in the center of the tree and began to scratch himself. Seconds later, three other owl monkeys appeared. From their size, I presumed these three were his mate, an adolescent, and a half-sized juvenile. They spotted me immediately and began to give an alarm call, but they didn't flee. After ten minutes, they began to move on through the canopy. I followed, but by this time it was dark. They were moving quickly and soon disappeared from my view.

Dusk after dusk, I returned to the tree and followed the group as far as I could. Each night, I went a little farther. I cut narrow trails under their arboreal pathways. I listened carefully as group members exchanged contact calls. I was grateful that they dashed carelessly through the trees, making abundant noise as they jumped from branch to branch. Still, several months passed before I could follow them all night long.

During the day, I began tracking the dusky titis. I had a different problem with them. Although they moved much lower in the trees than the owl monkeys (an average of thirty feet above the ground), they were dark and blended into the foliage. They were also cautious in their movements, nearly impossible to hear as they jumped from branch to branch, and they often rested, hidden in tangles of vines. I had hoped that the titis would be the easy part of my fieldwork, but I was often frustrated during the first two months of my effort to keep track of them.

Eventually, however, I could follow both day- and night-monkey groups. I couldn't, of course, keep going twenty-four hours a day, so I developed a routine. First, I would spend five days with the owl monkeys in Group One, following them from dusk to dawn. Then I would switch to five days with dusky titi Group One, this time from dawn to dusk. After that, I'd move on to owl monkey Group Two for five days and finish up with a round of five days with titi Group Two. With such constant disruption to my circadian rhythm, I felt as if I had jet lag for the entire year.

The work proceeded well, but since I was not using radio collars, I was continually plagued with the problem of losing track of the owl monkeys. One night, for instance, they quietly left a large fig tree without my detecting them. When I real-

Carol Farneti, Natural Science Photos

Common in the open Chaco forests of Paraguay, nocturnal great horned owls, left, are capable of carrying off small monkeys. There, the otherwise noisy owl monkey, below, moves more cautiously and quietly than in the rain forest.

Charles Janson

ized they were gone, I reasoned that they had journeyed to the next fig tree, which I knew was about a thousand feet along the river trail. I moved quickly along the trail, making little noise since the leaves beneath my feet were wet from rain that had fallen earlier in the day.

But I wasn't the only one walking quickly and silently along the river trail. As I rounded a bend, I suddenly stood face to face with a large male jaguar. We were less than three feet apart. My headlamp temporarily blinded him, and he blinked five times. I moved slightly off the trail to give him the right of way. At the sound of my movement, the jaguar bounded into action, but—I noticed in a daze—away from me, back into the jungle. I listened as he continued to move into the distance. Suddenly, I was afraid. My heart raced, and I decided to give up monkey watching for the evening. Instead, I visited each tent of sleeping researchers, warning them that a jaguar was in the neighborhood. The next day, we were impressed by the large size of the footprints, but we never saw the jaguar again. He had apparently moved on to another part of his large territory.

Most of my evenings were less eventful, and after a year, I had accumulated basic data about the two species. In both, territory size ranged from seventeen to thirty-four acres. The distance the owl monkeys traveled in one day was 2,100 feet on average; the titis moved an average of 1,950 feet. The average group size of both—five animals—was also similar and included an adult male and female, one adolescent, a juvenile, and an infant. The adults are monogamous, and their offspring remain with the group until they are three, at which time they disperse, usually in the rainy season. Finally, as with most primates, both species ate a combination of fruits, leaves, flowers, and insects.

But the two species also differed in

Like the owl monkey, the dusky titi, facing page, is monogamous and lives in small family groups. It forages in the daytime, however, and is forced to compete—often unsuccessfully—with squirrel monkeys, below, and other monkeys living in Peru's Amazonian rain forest.
Luiz Claudio Marigo

many ways. One of the dusky titi families, for example, slept in a total of forty-three different trees over the course of the year, while owl monkey families used no more than five. As they slept on open branches, the titis were visible from below, whereas the owl monkeys were always hidden from sight as they slept in a tangle of vines or in a tree hole. *Callicebus* was quiet, vigilant, and cautious as it foraged low in the trees during the day; *Aotus* was noisy and careless as it went about its business high in the canopy at night.

I began to suspect that the daytime presented some dangers that the nighttime did not. Circumstantial evidence soon implicated birds of prey as a probable daytime threat. From studies conducted by ornithologist N. Rettig of remains under the nest of a harpy eagle in Guyana, we knew that monkeys were the main item in this eagle's diet. Manu National Park is home to six species of hawks and eagles, including the harpy, that are big enough to eat owl monkeys and dusky titis. During the third month of my research, a harpy eagle was sighted carrying a squirrel monkey in its talons. A few weeks later, a crested eagle attacked a group of capuchin monkeys. And one of the young titis born the year I started my study was last seen in October of his second year in the talons of a crested eagle.

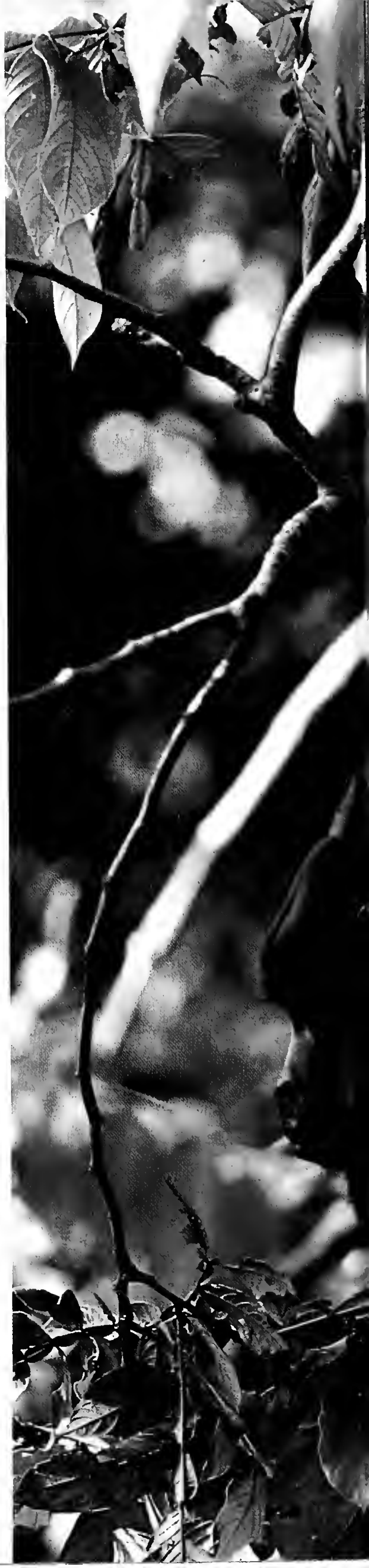
Also suggesting that the monkeys were responding—although in different ways—to the threat of predation were the times monkeys entered and left their sleeping trees. The titis were irregular. Between October and May, when it was warm and fruit was abundant, they would get up at about dawn, but when the weather grew colder, they would stay in their roost until noon. This flexibility fit in with my theory that while escaping predators was crucial for these diurnal monkeys, it was *how* they foraged—quietly, low down—that was important; *when* they foraged was not.

The owl monkeys couldn't have been more different. They regularly left the sleeping tree a few minutes after sunset (after hawks and eagles would have gone to their roosts) and returned to it a few minutes before the sun rose (and diurnal birds of prey awoke). This precision, too, fit my theory, with the monkeys behaving—I fancied—as if they were afraid that if they got up too early or stayed out too long, they might wind up as a meal for some hawk or eagle.

But what about nocturnal predators? Owls were of no concern, as my ornithologist colleagues explained to me, for large species, such as the great horned owl, are scarce in tropical forests of South America, and none of the other owls in the Amazon rain forest were big enough to eat a squirrel-sized monkey. Other nocturnal predators, such as cats and snakes, were primarily terrestrial and no match for an agile monkey in the trees.

Foraging at night may do more for owl monkeys than reduce the risk of being killed by a predator. Different monkey species compete strongly for fruit trees, particularly in the season of fruit scarcity. My data showed that spider monkeys, capuchins, and even squirrel monkeys—all species that are either bigger than the titis or travel in larger groups—are able to chase the titis away from large fig trees. This forced the titis to subsist at this time of year almost exclusively on leaves, which are difficult to digest. The owl monkeys, in contrast, fed in the large fig trees without harassment. Their only nocturnal competitors were opossums and kinkajous. I once observed an owl monkey approach an opossum feeding in a tree; to escape, the small opossum dropped sixty

Luiz Claudio Marigo



Harpy eagles, below, regularly prey on small monkeys of the Peruvian rain forest. The heftier red howler, right, weighing several times as much as a titi or squirrel monkey, rarely winds up as a meal for one of the forest's diurnal birds of prey.

Ken Lucas; Planet Earth Pictures

feet out of the tree, landing at my feet. Kinkajous, at five pounds nearly twice the size of an owl monkey, are not so easily dominated. However, kinkajous are solitary and thus would be no match for a group of four to five owl monkeys; when these two species meet, they usually move apart to feed in different parts of the tree.

To test my theories about the owl monkey's nocturnal life style, I decided to observe the species in a different sort of habitat. After my year in the rain forests of Peru, I visited the dry, open forests of the Paraguayan Chaco. Few diurnal monkey species live in the Chaco, and none of the species that had attacked *Callicebus* in Peru. Diurnal raptors are also rare, but great horned owls are common. One pair raised two young in a nest near my campsite during my time there.

Interestingly, I found that owl monkeys in the Chaco had reverted partly to daytime activity. I watched in amazement as the monkeys browsed on flowers and fruits at the top of the canopy in bright sunlight. They foraged at night as well, but now they moved quietly and avoided the upper canopy, where they would be exposed to the owls. On average, the owl monkeys traveled and foraged one to three hours in daylight and some nine hours at night. In the cold Chaco winter, during the times of the month when there was no moonlight, the monkeys increased their daytime activity, traveling nearly as far in the daytime (850 feet) as in the night (about 1,000 feet). The monkeys' sleeping patterns changed in the Chaco, too. They slept on open branches, not in hidden vine tangles, and used many different sites; one group slept in forty-two different trees in five months. Moreover, they were never chased from a fruit tree, day or night, with their only possible food competitor being *Alouatta*, the howler monkey. Overall, the behavior of the Chaco owl monkeys seemed to support the idea that avoidance of predators and food competitors may have played a role in the evolution of a nocturnal life style in the Peruvian rain forest.

If being active at night can, under the right circumstances, confer so many advantages, why haven't more monkeys adopted it? Most nocturnal mammals, including the nocturnal primates in Asia and Africa, have the tapetum lucidum, which allows them to see in the dark. Monkeys, apes, and humans have lost the tapetum and thus are relatively helpless at very low light levels. A short walk at night without the aid of a flashlight will show just how serious a loss this is.

How, then, does *Aotus* manage? Over the course of its evolution, the aptly named owl monkey evolved very large eyes, which assist it greatly as it searches for food in the dark and jumps from branch to branch high up in the canopy. Some of my findings, however, indicated that the monkeys' movements were restricted by low light levels. On totally dark nights, the owl monkeys I followed in Peru traveled nearly a thousand feet less than on clear moonlit nights; they also tended to stick to the most familiar paths. Certain activities—such as playing, territorial fighting, and calling—are engaged in only when the moon is bright. I gradually realized that I was not alone in my nightly stumbles through the rain forest; even for the successful owl monkeys, night life had its disadvantages. □

Of Bedouins, Beetles, and Blooms

In the Judean desert, wildflowers roll out the red carpet to attract pollinators

by Bernd Heinrich

The winter had been an unusual one. A tenth of an inch of snow and rain—two and a half times the average precipitation—had fallen on the Judean desert. In late March, two months of springtime weather remained. The nights were pleasantly cool, the days warm, and the land refreshed with rains. Rain means life in this small desert, which stretches from 1,200 feet below sea level in the east, where it borders the Dead Sea, to 2,400 feet at the water divide about twelve miles to the west. Along this transect of bare and rocky hills are such well-known biblical sites as Jerusalem and Bethlehem, as well as lesser-known towns such as Beit Fajjar, Abu Dis, Ramallah, and Bir Zeit.

Average precipitation is, however, not what this land sees. Rainstorms are erratic events, and despite this year's winter "excess," the desert would soon be dusty and parched again. The eastern slopes of the north–south-ranging hills lie in the rain shadow of the moisture-laden winds coming from the Mediterranean, another twenty to twenty-five miles to the west. Maps show numerous blue lines going down to the Jordan River and the Dead Sea. But they are not rivers. At least not now. They are wadis, or washes. Most are flood channels that this spring were dry beds filled with rounded limestones.

It was cool, but the sun shone through the cloudy sky as my friend botanist Avishai Shmida, of the Hebrew University of Jerusalem, and I swung onto the paved road in Jerusalem and started our rapid descent east, down to the valley of the Jordan. In the Mediterranean environment near Jerusalem, Avi and his colleagues have cataloged 1,586 species of wild plants. Another 586 species were found in the desert.

Looking over the bare hills, I could scarcely conceive that such diversity existed in a land that was already being intensively used by humans thousands of years before Christ. The rounded limestone hills, terraced into horizontal strips of soil a few yards wide, were yielding grapes, olives, and vegetables in Roman times and long before.

Poppies dominate a patch of wildflowers in the hills near Jerusalem. Like many of the flowers in this heavily grazed land, they have evolved chemical defenses that make them toxic to livestock.
Allen Rokach

Allen Rokach

A lone poppy, right, blooms among unopened buds and seed capsules. Below: Buttercups in the Judean hills have bright scarlet petals. Although most species of buttercups and wild tulips are yellow, those growing in Mediterranean climate zones are commonly red.

Bernd Heinrich

Some of the terraces lay fallow now, or seemed to. But the olive trees in their gray-green foliage and the small almond trees, bare of leaves but covered with sprays of pink flowers, were obviously there as a result of human effort. So was the stonework that held up the terraced strips themselves. Plants here grow in wild profusion, with a mean density of forty species per square yard. Yet only certain types can survive and prosper under the exacting conditions imposed by the environment and humans. Wild trees, obviously, could not. And that exclusion opened a niche for others.

I had just visited the Western Wall, the remnant of the Third Temple built by King Herod (or rather, his slaves), where the cracks between the giant, symmetrical blocks of limestone are stuffed with notes written by the devout. Seeing what people rest their hopes on had left me strangely depressed. But seeing these humble stone walls, holding up earth terraces at least as old as the walls and decorated with gorgeous pink cyclamen sprouting in the cracks, was uplifting. I felt the "cosmic optimism" of the naturalist—someone who, according to the definition of writer and entomologist Robert Michael Pyle, does not have an anthropocentric view of life. Pyle has pointed out that no matter what we humans can dish out, species that "know adversity and eat it up will endure." These flowers have survived the impossible, not so much in spite of us but perhaps because of us.

Deep blue grape hyacinths and bright red tulips grew "wild" along the lips and crannies of these ancient terrace walls. These, and others, were perennials, but at least half of the terrace plants were annuals—tiny herbs that thrived through time, not just because of the modest space they occupied but through their ability to lie dormant through long periods of drought, to be resurrected and to spring up again when sprinkled by rain.

In the valley of the Jordan, where pastoralists, rather than farmers, held sway, not a wild tree is left standing, and there probably have not been any since before the time of Christ. Sheep and goats and the inexorable human hand had seen to that. Now—as they have done for centuries—Bedouins tend flocks of sheep and goats that mow broad swaths over the land, nipping everything to the root. Indeed, the Bedouin is said to be not so much the son of the desert, as its father.

Nothing green or succulent has a chance to survive for long, unless it can retreat again into the ground in bulbs or tubers or unless it is poisonous or prickly. Such defenses are a competitive advantage against plants that don't have them (since grazers exercise choice in what they eat). But none is absolute. Perhaps the plants' most obvious and effective strategy against the grazers and the elements is to grow and flower quickly after the rare rains do come and then to revert quickly to dormant, drought-resistant seeds before the herbivores eat them. In short, the plants are often annuals.

Annuals are necessarily of small size. If conditions are right, then many individuals can exist side by side. But which ones? Why not all of one species, rather than many species? Avi tells me, "If it were not for the grazing, then the grasses would

quickly take over. They would crowd out many of the flowers." And it is not the grazing alone. The drastic fluctuation of rain within the winter period and from year to year reduces competition between species, so that no one species can take over and occupy every niche. What we might generally consider unfavorable conditions for plants are precisely those that have produced tremendous diversity.

As we descend farther into the valley, we can see the hills of the desert greening from the winter rains. From the window of our car, I see patches of yellow composite flowers, patches of light purple crucifers, and some white umbellifers. Above the background of yellow, white, and pale blue, there are also thick dots of red flowers, like flecks of shiny red blood upon the green.

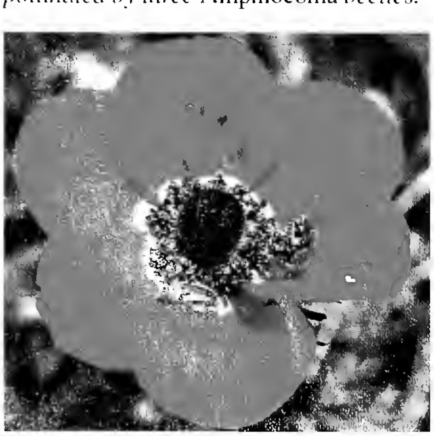
A pleasing wash of colors from a bird's-eye view became a gorgeous mosaic when we parked and I saw it from a bee's eye level. But the beauty that was so striking to the eye was even more fantastic to the mind because behind the show lay a logic. That logic—that competition among pollinators that had helped to arrange the floral display—had first excited me two decades ago and a continent away. Here in the Judean desert was the same play, but all the players were different.

One step into this garden, which nature had been busily arranging for thousands of years (out of parts created over millions of years), I found much to admire. I saw a plant whose blue flowers had at their center tiny dabs of either white or pink. The dots were what Konrad Sprengler, the father of pollination ecology, called *Saftmale* (nectar guides). When white, they indicate (to experienced nectar shoppers) that the flowers are likely unvisited and contain nectar; when pink, they signal that the flowers are already drained (and hence pollinated).

I saw a small umbellifer whose white inflorescence with showy fringe florets

Allen Rokach

The various red-flowered plants of the Judean desert, above, stagger their peak flowering periods. Anemones bloom first, followed by tulips, buttercups, and poppies. Below: A crowned anemone is pollinated by three Amphiocoma *beetles.*



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had an uncanny resemblance to that of hobblebush, a viburnum I knew from the Maine woods.

There was, in this plant community as in any other, a demand for flowers that were best suited to the specific tastes and physical requirements of the various pollinators. A broad, economic analogy applies. If there is a market in Israel for pizza, and there are no Italians around to make it, then even some Israelis might be induced to become pizza makers. The venture could be a risky one, but high risks can yield high rewards as well as extinction. In other words, beyond the plants' struggle for existence in the physical environment is a second fierce struggle among themselves to be serviced by the pollinators. Each gets pollinated by practicing a specific "line" or profession. As in Adam Smith's idealized free-market economy, specialization and "perfection" are the result of fierce competition.

In the vast sea of varied flowers stretching before me, not many "shoppers"—bees, flies, butterflies—were to be seen. Therefore, at least at this time, the plants were competing to attract pollinators. I casually followed one honeybee whose thorax was dusted with yellow pollen. It flew slowly without landing among the sea of yellow composites, blue-and-yellow mints, and pink stork's bills, passing also red anemones and white stars-of-Bethlehem. After several yards of careful search, it landed on an almost-hidden plant, a parasitic figwort with blue flowers and white nectar-guides on its lips. After a second or two, the bee came out of the deep flower, scraped pollen from its thorax, and then

patiently resumed its search for another flower of the same kind. The figwort, blooming close to the ground and isolated from others of its kind, was undoubtedly not visited by many shoppers. But those that found it—probably randomly at first—became flower constant, hooked on the good bargain because of its good crop of nectar. In the flower supermarket, the choices faced by bees are like those facing a human shopper—dozens of brands, all with different, showy labels.

Flowers must provide a good reward to insure repeat visits from a pollinator. In a meadow, as in a supermarket, competing product displays lure the buyer. But in the meadow, shoppers (pollinators) going down the "aisles" are free to snack. In order to keep them constant to any one brand, the manufacturer (the plant) not only has to advertise but also has to try to keep thievery (taking nectar without paying the plant with with pollen transfer) to a minimum. One way to do that is to limit access to the flowers. (Loyalty, or flower constancy, is important because each flower "wants" its pollen to be deposited in the stigma of its own kind, not that of another kind). Complex flowers are like puzzles, solvable only by those pollinators able to gain information denied others.

Perhaps no competitors are more bizarre than the Mediterranean *Ophrys* orchids. I had read about this group of a dozen or so species, each catering to a different, winged pollinator. Nevertheless, I was startled to have one pointed out to me at my feet. Barely six inches tall, its solid green stalk supported two exquisite, tiny flowers and three to four unopened buds. The flowers, about half an inch long, could be easily missed by the human eye, unless one knew what to look for. The two tiny flowers resembled bees. It didn't take great leaps of the imagination to see a small, bulbous, buzzy "abdomen" and even "wings" at each side. We have no idea what a bee or wasp sees, but the mimicry is undoubtedly much greater to the insect than it is to us. In mounting these flowers, male insects are probably attracted by the perfume, which in this case mimics the sex scent of the intended mate, but then orient themselves to the flower form.

I gently inserted the end of a twig to where I presumed the head of a copulating bee might reach, and when I withdrew it, it held a yellow packet of pollen such as a male might transfer to the next *Ophrys* it finds of that species.

Persian buttercup
Avi Hirschfield; ASAP

But in the end, the wild tulips (and other flowers like them) were what surprised me the most. Tulips had, before this, occasionally caught my interest, but only because of their shock value, their superfluous show. But these tulips were organisms in an ecological context where everything about them held meaning. If there was show, then that show was important beyond mere appearance, in the same way that a Hebraic text has significance; it is not just a page of attractive markings.

The bright red tulip stuck out like the proverbial sore thumb from the yellows, whites, and blues of the crowd. It offered only pollen, not nectar. The pollen-bearing anthers were almost black, as were the bases of the petals in the center of the cup-shaped flower.

This color pattern excited me because I had in the previous hour admired very similarly sized, shaped, and colored flowers of a quite different plant family. They had belonged to a poppy. The resemblance seemed too close to be accidental.

With my interest aroused, I examined red flowers more closely in the large patches that were everywhere. I found other red flowers with petals of a red so pure and brilliant they almost made me squint. As it turned out, they were buttercups, *Ranunculus asiaticus,* also known as Persian buttercups or scarlet crowfoot. I knew only the yellow-stamened, small waxy yellow *R. acris* flowers from back home, and these took me by surprise. I found still other flowers that seemed almost identical to those of the tulips, poppies, and buttercups—also large and bowl-shaped, with black stamens, and brilliant scarlet petals. These, Avi told me, were crowned anemones. What a contrast to the small, delicate, white-petaled anemones with yellow stamens in a Maine spring woodland!

A phenomenon so striking as these red flowers—all apparently mimicking one another—had not escaped the attention of local botanists, especially Avi. By 1981 he had already systematically studied and described the convergent evolution of the "poppy guild" of red flowers in the Mediterranean region of Israel. The group includes about fifteen species of large, red, bowl-shaped flowers of six genera from three plant families, and is dominated by poppies of two genera. The convergence is most striking when one considers how some of these flowers differ from their likely ancestors. *Ranunculus,* the buttercup, for example, has about 400 species worldwide. Only three, all in the Mediterranean region, are red. And all of these have cup-shaped flowers at least twice as broad as those of the predominantly yellow or white species. Wild tulips in Europe are also predominantly yellow, but in the Mediterranean region, red predominates. All poppy guild flowers provide only pollen, and no nectar, whereas some of their presumed progenitors also provided nectar. The various species do not, however, bloom simultaneously. Anemones are usually first, followed by tulips, buttercups, and finally, poppies.

Wild tulip
Allen Rokach

Why did this very distinctive, red, bowl-shaped pollen flower evolve in so many different kinds of plants in one geographical area? From behavioral studies of bees, I had speculated that once a pollinator becomes "hooked" on one commodity of the market—such as red flowers—it could then be more easily exploited by other plants, provided they are rare or bloom slightly out of phase with their models. It is as if *A* has developed a market for pizza, but is unable to continue production after, say, April. In May, *B* can step in, utilizing an already-established market. If a product is a success, it will be widely copied as closely as possible (given the absence of patent laws).

But these red flowers are rarely pollinated by bees. Instead, they are primarily serviced by a group of scarab beetles of the genus *Amphiocoma.* Beetles had been thought to pollinate only flowers that smell foul and are white or greenish. But in an elegant and classical series of field experiments, Amots Dafni, of the University of Haifa, and six colleagues from other institutions reported in 1990 that these beetles have a relatively weak response to shape or scent, but exhibit a strong attraction to the color red. Dafni and colleagues distributed unscented, flower-shaped plastic cups of various colors (red, blue, yellow, green, brown, white) in the field to serve as beetle traps. Of the 146 beetles captured, 127 were caught in red flower models. The remainder, eighteen beetles, were evenly distributed among the other colors. The researchers were also able to confirm their prediction that the beetles would be found in all of the red flowers of the poppy guild. *Amphiocoma* likely do most of the polli-

Crowned anemone
Bernd Heinrich

nating of these red flowers, since a visiting beetle carries away nearly 2,000 pollen grains (as opposed to a *Lasioglossum* bee, for instance, which carries, on average, only 110 pollen grains).

Red flowers probably have more to offer than food. Red color also advertises sex. Dafni and colleagues noted that the female beetles remained, on average, sixteen minutes in each flower they visited, whereas the males kept moving from flower to flower every three and a third minutes or until they found a female. Upon finding one, they immediately stayed to mate. Are the males searching for females in flowers?

The fuzzy, little, dark brown beetles with greenish or purplish thoraces are not always common. In one area near Jerusalem, I examined 1,548 *Anemone coronaria* flowers and found twenty-two that contained one beetle and eleven with more than one (primarily copulating pairs). Thus, only one in seventy flowers had a single beetle, whereas every flower with one beetle had a 50 percent chance of having another beetle. Put another way, a flower's chances of being visited again were thirty-five times greater if it already had a beetle in it.

I also noted numerous solitary bee males in the genus *Eucera* apparently sleeping in flowers. Indeed, under overcast skies, all of these bees stopped foraging and I saw up to six in a single flower. However, I never saw them copulating there. Their long antennae—almost as long as their entire body—attest that scent plays a large role in mate finding. In contrast, the antennae of the *Amphiocoma* beetles are microscopic in size. Although the beetles are nearly three-eighths of an inch long, the lamellae of their antennae are no larger than the dot a sharp pencil makes on paper. Their scent-organs seem almost atrophied, but their eyes are not: their attraction to red flowers finds them mates.

The sexes must meet somewhere. Why not while lounging at conspicuous, well-advertised places? And a female must lay up large protein stores to make eggs. For that she needs to eat pollen. Indeed, on two occasions during my brief survey, I saw male beetles land on flowers containing a beetle I was photographing, and in both instances the new beetle instantly attempted to mate with the beetle in the flower. Food rewards were apparently of only secondary concern for the males.

Thanks to fieldwork by Dafni and electrophysiological experiments by Randolf Menzel, of the Free University of Berlin, we know that these beetles (unlike most other insects, but like birds) evolved the capacity to see the color red. Once that occurred, the beetles could exploit the very conspicuous red signal of the flowers, resulting in enhanced mating success for them and for the plants they visited. Although we don't know for sure how the red flower guild serviced by beetles evolved, a likely scenario is that the plants imitated one another, and that many new products—like so many knockoffs of Swiss Army knives—entered the market, using the same distincive red signal in their advertising campaigns. In this case, the product being advertised was sex with breakfast in bed—a winning combination. And now the *Amphiocoma* beetles in the Judean desert enjoy the red carpet treatment, while we enjoy the show. □

The tremendous diversity of flowering plants in the Judean desert is partly the result of the region's drastic fluctuations in rainfall. In spring, the lush growth of flowering plants contrasts starkly with the treeless hills.
Aften Rokach

OPENING OF THE FOSSIL MAMMAL HALLS

The American Museum of Natural History launches its 125th-anniversary celebration with the opening of two of six new fossil halls on Saturday, May 14. Specimens in the Lila Acheson Wallace Wing of Mammals and Their Extinct Relatives include the mummified remains of a baby mammoth that lived 25,000 years ago, whose head, trunk, and leg were found "freeze-dried" in the Alaskan tundra; the ferocious bear-dog *Amphicyon*, shown running at full speed in pursuit of its prey, the antelopelike *Ramoceros;* a twelve-million-year-old early horse, *Protohippus*, which may have died trying to give birth; and a *Palaeocastor*, an early relative of beavers, shown where it was found at the bottom of an eight-foot-long spiral burrow.

Three Charles R. Knight murals and dozens of his smaller paintings have been restored and are displayed in the fossil mammal halls. In addition, for each of six extinct species, contemporary artist Jay Matternes has contributed three drawings depicting the fossil skeleton, the muscles and tendons, and how the animal might have looked in life. At interactive computer stations, visitors may take tours of evolutionary history with Museum scientists and see reconstructions of the fossil animals in their original habitats.

The new fossil mammal halls and the Museum's new library are part of a vast renovation plan still in progress. Two new dinosaur halls on the fourth floor will open in 1995. The project will be finished in 1996 with the opening of the Hall of Primitive Vertebrates and an Orientation Center.

Martyn Colbeck's prize-winning photograph
© British Gas Wildlife Photographer of the Year Competition

THE BIODIVERSITY CRISIS

The last three lectures in a series sponsored by the Museum's Center for Biodiversity and Conservation will be held this month. On Tuesday, May 3, and Thursday, May 12, Joel L. Cracraft, a curator in the Department of Ornithology and acting director of the Center, will discuss the scientific basis of current mass extinctions in the earth's species. On Tuesday, May 17, Michael J. Novacek, a Museum vice-president and dean of science, will talk about the challenges in dealing with the biodiversity crisis and the relationship of science to public policy. The lectures begin at 7:00 P.M. Call (212) 769-5310 for information.

CONSERVATION IN THE TWENTY-FIRST CENTURY

Richard Leakey, paleontologist and director of Kenya's Wildlife Service, will talk about environmental dangers that threaten us with extinction. He will draw upon material from his new book, *Origins Reconsidered: In Search of What Makes Us Human.* The talk will be given on Wednesday, May 18, at 7:00 P.M. in the Main Auditorium. Tickets are $29 ($19 for Museum and Learning Annex members). Call (212) 769-5310 for information.

THAR' SHE BLOWS

Kenneth A. Chambers, a retired Museum educator and lecturer in zoology and exploration, will discuss the turbulent history of whaling in a slide-illustrated talk on Tuesday, May 3, at 7:00 P.M. in the Kaufmann Theater. Tickets are $15. For additional information, call (212) 769-5310.

ASIAN AND PACIFIC-AMERICAN CELEBRATION

This month, Asian and Pacific-American cultures are the focus of the Education Department's year-long series on cultural diversity. On Sunday, May 22, choreographer Yoshiko Chuma and the School of Hard Knocks will present *A Night at the Millionaire's Club,* a contemporary work based on traditional Japanese concepts of space and time. On Sunday, May 29, the Pan-Asian Repertory Theatre will present scenes from *Wilderness,* the final play in a trilogy by Chinese playwright Cao Yu. The programs, at 2:00 and 4:00 P.M. in the Kaufmann Theater, are free with admission to the Museum. For a complete brochure of events, call (212) 769-5315.

AN UPCOMING ECLIPSE AND A COMET COLLISION

Weather permitting, the solar eclipse on Tuesday, May 10, can be observed safely through telescopes at the Planetarium. On Thursday, May 5, meteorologist Joe Rao will give a slide-illustrated lecture about this upcoming eclipse. In late July, Comet Shoemaker-Levy 9 is due to hit Jupiter. David Levy, a scientist at the Lunar and Planetary Laboratory of the University of Arizona and codiscoverer of the comet, will talk about the comet's collision course on Monday, May 23. Both talks will begin at 7:30 P.M. in the Sky Theater. For tickets and information about all Planetarium events, call (212) 769-5900.

RESTORATION OF THE KNIGHT MURALS

Charles R. Knight was one of the first painters to re-create prehistoric animals based on the study of fossils. In 1911, the Museum commissioned him to create a series of murals that portrayed saber-toothed cats, giant beavers, mammoths, mastodons, and other extinct creatures. The restoration of these murals, under the direction of paintings conservator Felicity Campbell, will be the subject of a talk on Friday, May 6, in the Kaufmann Theater at 7:00 P.M. Call (212) 769-5606 for information.

PHOTOGRAPHER OF THE YEAR EXHIBITION

A closeup of an elephant taking a dust bath won British photographer Martyn Colbeck first place in the British Gas Wildlife Photographer of the Year Competition. Organized by *BBC Wildlife* magazine and the Museum of Natural History in London, the competition is in its tenth year, and includes 11,500 entries from forty-two countries. Thirty-nine winning photographs will be exhibited in the Akeley Gallery from Friday, May 20, to Sunday, July 31.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

may calendar

S	M	T	W	TH	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

3 TUESDAY
"The Biodiversity Crisis and Its Causes" ✚
LECTURE (five-part lecture series exploring biodiversity and conservation), 7:00 p.m., Main Auditorium, $15.00 for single lecture, $40.00 for series

5 THURSDAY
"The Solar Eclipse of 1994" ●
LECTURE, 7:30 p.m., Hayden Planetarium, $6.00 members, $8.00 nonmembers

6 FRIDAY
"Restoration of the Charles Knight Murals" ■
LECTURE, 7:00 p.m., Kaufmann Theater, $6.00 members, $9.00 nonmembers

10 TUESDAY
Solar Eclipse Day ●
SPECIAL EVENT (viewing of solar eclipse, weather permitting), 11:30 a.m., Hayden Planetarium

12 THURSDAY
"The Biodiversity Crisis and Its Solutions" ✚
LECTURE (five-part lecture series exploring biodiversity and conservation), 7:00 p.m., Main Auditorium, $15.00 for single lecture, $40.00 for series

14 SATURDAY
Lila Acheson Wallace Wing of Mammals and Their Extinct Relatives
NEW PERMANENT EXHIBITION HALLS displaying the world's greatest collection of fossil mammals, Public Opening

17 TUESDAY
"Why Biodiversity is Important: Understanding and Saving the World's Species" ✚
LECTURE (five-part lecture series exploring biodiversity and conservation), 7:00 p.m., Main Auditorium, $15.00 for single lecture, $40.00 for series

18 WEDNESDAY
"Conservation in the 21st Century: An Evening with Richard Leakey" ✚
LECTURE, 7:00 p.m., Main Auditorium, $19.00 members, $29.00 nonmembers

21 SATURDAY
The Ice Age and Its Mammoth Hunters ■
PERFORMANCE FOR CHILDREN, 10:30 a.m., Kaufmann Theater, $6.00 members, $9.00 nonmembers

23 MONDAY
"The Great Jupiter-Comet Crash of 1994" ●
LECTURE, 7:30 p.m., Hayden Planetarium, $6.00 members, $8.00 nonmembers

29 SUNDAY
Wilderness: A Performance by the Pan Asian Repertory Theatre ✚
PERFORMANCE, 2:00 & 4:00 p.m., Kaufmann Theater

THROUGHOUT MAY

125th-Anniversary Celebration of the American Museum of Natural History
The Museum launches a 20-month celebration of 125 years as one of the world's preeminent science and research institutions.

Global Cultures in a Changing World: A Series Exploring Cultural Diversity ✚
LECTURES, FILMS, & PERFORMANCES in May celebrate Asia/Pacific American Heritage Month. Leonhardt People Center, 1:00 to 4:30 p.m., every weekend (except May 7 & 8)

Search for the Great Sharks ▲
IMAX FILM; daily showings, Naturemax Theater, $5.00 adults, $2.50 children

Space Places: A Photographic Exhibition
SPECIAL EXHIBITION, through May 15; and *Orion Rendezvous: A Star Trek Voyage of Discovery* ●
SKY SHOW, daily showings. Both at the Hayden Planetarium, $5.00 adults, $2.50 children

Photo: a 300-million-year-old mammal relative in the new fossil mammal halls.

■ Membership, 769-5606 ▲ Naturemax Theater, 769-5650 ✚ Education, 769-5310 ● Hayden Planetarium, 769-5900

American Museum of Natural History

Central Park West at 79th Street, New York City - For information, call 212-769-5100

Four Giants of Paleontology

by Edwin H. Colbert

In 1859, the year that *The Origin of Species*, by Charles Darwin, appeared, changing forever the way in which we think about ourselves, our origins, and our world, Henry Fairfield Osborn was just two years of age. This son of wealthy and loving parents, who was supposed to become an influential figure in the world of railroads and high finance (or so his father thought), was destined to become instead a leading authority on the evolution of backboned animals.

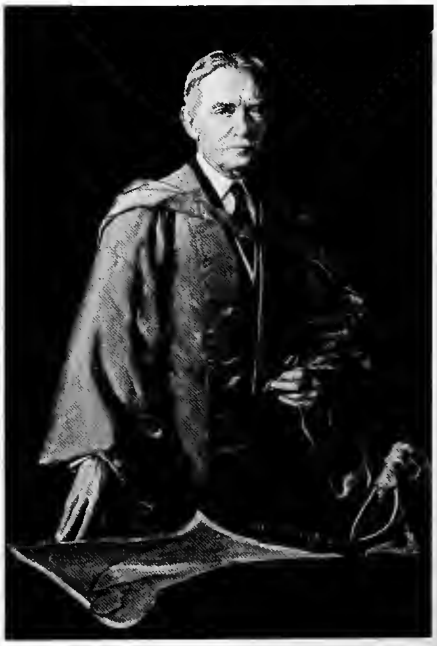
For many years Osborn was a dean and professor of zoology at Columbia University and, simultaneously, a prime driving force in the growth of an institution that has been at the forefront of evolutionary studies since the 1880s—the American Museum of Natural History. Osborn was appointed president of the Museum in 1908 and served for twenty-five years.

On May 14, 1994, the American Museum of Natural History launches its 125th-anniversary celebration by opening the LILA ACHESON WALLACE WING OF MAMMALS AND THEIR EXTINCT RELATIVES. Mastodonts, giant ground sloths, and other mammalian fossils from the Museum's collection will be on view.

In 1871, twelve years after Darwin's epochal publication, William Diller Matthew was born in Saint John, New Brunswick. Later, as a young man, Matthew gravitated to Columbia, where he came under the influence of Osborn, then presiding over the Department of Zoology. Osborn's passion for the study of vertebrate evolution was contagious. So at the age of twenty-four, Matthew, who had come to Columbia seeking a career in mining geology, headed instead for a paleontologist's life at the American Museum as a colleague of Osborn's.

Seventeen years after that fateful year of 1859, William King Gregory was born in Greenwich Village, New York City. Eventually he also attended Columbia. In 1899 he became Osborn's assistant, thereby initiating his own long and distinguished career at Columbia and at the American Museum, where he was one of those rare individuals on the curatorial staff—a native New Yorker.

For more than three decades the three men—the mentor and his two students—worked together at the Museum cataloging and trying to make sense of its rapidly expanding collection of fossil vertebrates. Each year, the Museum's famous bone collectors, such as Barnum Brown, would bring in thousands of specimens, newly freed from tons of rock. Osborn was interested in extinct reptiles and mammals, particularly mammals. Matthew was an internationally respected authority on mammalian evolution, and Gregory was



Henry Fairfield Osborn
AMNH

justly famous for his encyclopedic knowledge of all the vertebrates.

These three quite naturally developed different approaches to their evolutionary studies. Osborn was by training a biologist, so his interpretation of the evolution of extinct animals was dominated by his knowledge of related modern animals. In contrast, Matthew's view of evolution, particularly mammalian evolution, was based upon his broad background in geology and especially stratigraphy—the sequence of rock strata in which fossils are found. (Matthew's father, George Frederic Matthew, was a distinguished Canadian geologist, and young Matthew became further steeped in geology under another Columbia mentor, James Furman Kemp.) Gregory was primarily a comparative anatomist who extended his comparisons to vertebrates of all geologic ages. His scholarship was indeed comprehensive, for his view of the world reached across time, space, and phylogeny.

The three men—Osborn, Matthew, and Gregory—brought to the enormously complex subject of vertebrate evolution a powerful combination of different talents and outlooks that helped shape the discipline for decades to come.

They worked both separately and together, and their collaborative studies describing previously unknown fossil species led to the revelation of many new evolutionary facts. Important assemblages of extinct creatures were worked up for publication under the joint authorships of Osborn and Matthew, Osborn and Gregory, and Matthew and Gregory. As for their individual interpretations of evolutionary processes, most of those papers were signed singly because of their separate and sometimes divergent opinions.

Osborn, a large and forceful man, liked to formulate evolutionary "laws" to which he appended his own designations. Perhaps he fancied himself as a sort of evolutionary Jove, issuing edicts for the guidance of his followers. In his later years, Osborn became remarkably pompous and vain—a result of having occupied high positions in the scientific world, as well as in the social milieu of New York. But as Gregory pointed out, "Osborn himself was under no delusion as to the lack of enthusiasm with which his writings on the theory of evolution were received in many quarters." Osborn had a strong predilection for the concept of orthogenesis—the idea that organisms evolved inexorably in determined directions, like soldiers marching toward a defined objective. Furthermore, Osborn became obsessed with the idea of evolutionary parallelism—for him, animals separated at very early stages in their histories to evolve side by side along discrete, but similar, lines.

Osborn's view of evolution through time is nicely exemplified in his huge, two-volume monograph on the proboscideans (the mastodonts and elephants) in which the lines of all families are traced back to presumably ancient, unknown origins, and nothing seems to be ancestral to anything else. This concept of straight-line evolution prevailed in his earlier works, including his researches on fossil horses.

A similar story is seen in Osborn's studies of human evolution—in this case with Gregory doing much of the detailed research. In the end, Osborn wished to carry the origins of mankind far back in time, beyond anything justified by geologic evidence. Gregory claimed Osborn was "afflicted with pithecophobia—the dread of apes as relatives or ancestors." Although their views became irreconcilably divergent over this issue, they remained friends.

Despite several of his stubbornly held premises in approaching the material, Osborn made many outstanding contributions to vertebrate evolution, notably his work on the basic evolutionary relationships of reptiles, on the origin of mammals from mammallike reptiles, on the origins of mammalian molar teeth, and on the evolutionary histories of the perissodactyls, or odd-toed hoofed mammals—the titanotheres, rhinoceroses, and horses. While writing his massive monograph on the elephants, Osborn liked to revise his drafts *after* the work was set in type.

A personality such as Osborn's—overbearing, pompous, and vain—is apt to collide with the real world now and then. Once Osborn, accompanied by Fred Smythe, of the Museum's finance office, went to City Hall in New York, to see

William Diller Matthew
AMNH

Joseph McKee, president of the Borough of Manhattan. Osborn announced to the receptionist that "President Osborn is here to see Mr. McKee." Soon a flunky appeared to inform the visitors (much to the delight of Smythe) that "President McKee will now see Mr. Osborn."

Osborn was a typologist and a "splitter"; he thought that comparisons among specimens should be taken right back to the types on which the original descriptions of species were made. Matthew, allowing for variation within species, was a "lumper," who viewed population samples as a truer basis for determining species relationships. These divergent approaches, together with Osborn's orthogenetic ("straight line") concept of evolution, led to the abandonment by Matthew of their joint authorship of a massive monograph on fossil horses to which Matthew had devoted many years of research.

Far from being overpoweringly forceful in the Osbornian sense, Matthew was none the less a man of solid convictions, based upon the facts as he saw them in the fossil record. As Gregory wrote of his longtime friend,

> It may be said in brief that Evolution was the one theme about which he was always writing.... He never wearied of insisting upon the value of facts as compared with theories.... Scrupulous intellectual honesty was one of his outstanding characteristics.

Matthew was a firm believer in the close relationship between environments and the evolution of animals, a belief that found expression in his 1915 publication *Climate and Evolution*. This work, a milestone in Matthew's evolutionary studies, attracted universal attention and has been a point of reference, and a subject of debate, during the many years since its publication.

One of his first projects at the American Museum was a comprehensive synthesis of the Cenozoic strata in North America within which fossil mammals are to be found. With his background of geologic knowledge, Matthew saw the evolution of horses, for example, differently than did Osborn. Realizing that primitive horses were closely related to primitive rhinoceroses and tapirs, all of which are found within strata of the Eocene age (some fifty million years ago), Matthew studied the Cenozoic mammals as they were spread out in space, as well as over time. He was as concerned with the worldwide distribution of mammalian faunas as he was with the lines of descent of particular species.

Consequently much of Matthew's research was based upon the geologic formations of the western United States, with which he became thoroughly acquainted during successive seasons of fieldwork. His analysis of the fossils resulted in his early great monograph on the ancient carnivorous and insectivorous mammals of the Bridger Basin of Wyoming. His crowning work—a huge monograph on primitive mammals from the Paleocene strata of the San Juan Basin of New Mexico—was also based on assiduous fieldwork as well as Museum study.

Matthew was a witty person, who reveled in the world's absurdities. He was a great versifier, and wrote many ditties for the amusement of his colleagues, such as:

DARWINIAN THOUGHTS ON VIEWING A SKELETON OF ERYOPS

From Palaeozoic slime he rose,
Your ancestor and mine,
With webby toes,
Retroussé nose
And, I suppose, a lateral line.

Gregory's characterization of Matthew as a man of "scrupulous intellectual honesty" could well be applied to Gregory himself. Although he was an assistant to Osborn for many years, and although in 1910 he took over Osborn's position as professor at Columbia (in addition to his curatorial duties at the Museum), he did not submit to Osborn's overwhelming personality. He expressed his own opinions, particularly with regard to evolution, but he had the knack of doing so in a way that did not ruffle the Osbornian feathers. He would address a memo to Osborn "to our own imperial mammoth" or "to our great sulphur-bottomed whale," and Osborn loved it. Even in later years, when the two had their fundamental disagreements about the evolution of humankind, Osborn harbored no hostility toward Gregory. The same could not be said about the Osborn–Matthew relationship, however.

Gregory was a gentle and in many respects an unworldly soul. Aside from his anatomical studies, he never worked with his hands. I cannot picture him, for instance, using a hammer, saw, or screwdriver to fashion some useful object for his study. One day he was coming back to the American Museum from lunch (he lived nearby) thinking his thoughts, when suddenly he stumbled into a coal-hole in the sidewalk. Such apertures for delivering coal to the brownstone houses were common features on the old slate sidewalks of Manhattan. In this instance the workmen, after having delivered a load of coal, had failed to put the heavy cast iron cover back in place. Gregory scrambled out of the hole a bit soiled, and indignantly rang the doorbell of the nearby dwelling, planning to give the owner what for. But when a sweet old lady came to the door, Gregory forgot his wrath and wound up the situation by manfully replacing the dusty iron cover with his own hands.

In addition to his detailed, comprehensive knowledge of all the land vertebrates, or backboned animals, Gregory was a universally recognized authority on the evolution of fishes. He knew not only the primitive fishes as seen in the fossil record but also the myriad modern bony fishes. He was an authority on the mammallike reptiles, so abundantly represented in the fossil record of South Africa, as well as on the evolution and relationships of marsu-

William King Gregory
AMNH

pials, the pouched mammals so abundant in Australia's modern fauna. He had also devoted many years of research to the evolution of the primates, including humans, and his book *The Origin and Evolution of the Human Dentition* remains a classic. Alfred Sherwood Romer, one of Gregory's students who became a leading vertebrate paleontologist, once remarked to me that in his opinion, no one on earth had such intimate knowledge of the vertebrate skull as did William King Gregory.

In 1927 Matthew moved to California to assume the chairmanship of the Department of Paleontology at the University of California at Berkeley. His chosen successor at the American Museum was George Gaylord Simpson, born in 1902, who had recently earned his doctorate from Yale and who had spent a postdoctoral year at the British Museum (Natural History) in London. He was a worthy successor to Matthew, who by 1927 had established a towering reputation as a student of mammalian evolution. Paleontologist Stephen Jay Gould has written that "George Gaylord Simpson, in the impact of his ideas and by the power of his writing, both in style and substance, was the most important paleontologist since Georges Cuvier." This is not excessive praise; the man was a paleontological genius. One of Shakespeare's Elizabethan contemporaries said of the bard, "his mind and hand went together; and what he thought, he uttered with that easiness, that we scarce received from him a blot in his papers." So it was with Simpson; the massive output of his papers, monographs, and books began as flowing handwritten manuscripts, with scarcely a rewrite on their pages.

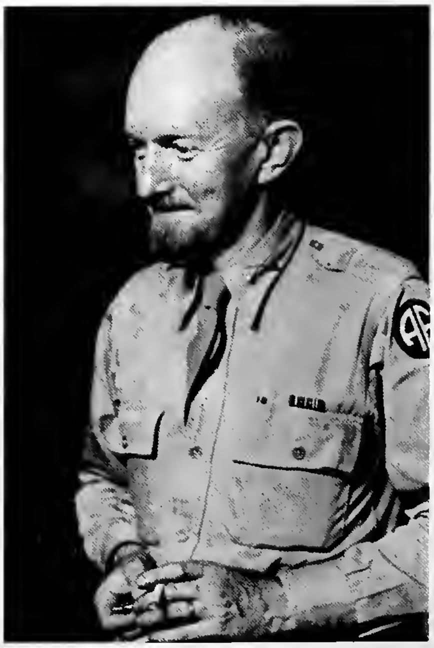
A small and unprepossessing figure, Simpson was not easy to know. On the surface, he was shy; underneath he was determined, even belligerent, as befits a person who is in complete command of his field. During the Second World War, Simpson was attached to Gen. George Patton's staff as a major. One day an order came down from the imperious general for Major Simpson to shave off his beard immediately. Simpson sent his respects and firmly pointed out that as long as he could get a gas mask on over his beard, there was no regulation that required him to shave. The general may have fumed in private, but Simpson kept his beard.

His work focused on the study and elucidation of mammalian evolution along the lines that Matthew had followed. Thus, Simpson was very much involved with extinct mammalian faunas, with their evolutionary relationships, and with the distributions of mammals through geologic time. He was, like Matthew, essentially a geologic paleontologist, but with a strong biological understanding of the fossils to which he devoted his attention.

Also like Matthew, he was a firm believer in the permanence of the continents. After the Second World War, however, when the geologic evidence for plate tectonics (the "drifting" of continents through time) became overwhelming, he finally gave in, but with great reluctance. He will be best remembered for his beautifully written and closely argued books, such as *The Meaning of Evolution, Tempo and Mode in Evolution,* and *The Major Features of Evolution.* Also of enduring interest is a book he wrote early in his career, *Attending Marvels,* a superb account of his first expedition to Patagonia, the land where Darwin himself had excavated fossils of a giant ground sloth.

Simpson was a leader, along with Ernst Mayr (who was for many years at the American Museum and is now at Harvard), in the movement known as evolutionary synthesis. During the late 1940s, this new interpretation of Darwinism attempted to combine the findings of modern paleontology, systematics, animal behavior, and population genetics into an integrated, or "synthetic," discipline.

Although he was a deeply contemplative thinker and a superb theorist, Simpson did not dwell in an ivory tower. He was very much a field man who spent many seasons in the fossiliferous badlands of North and South America, collecting the



George Gaylord Simpson
AMNH

fossils on which he based his descriptive research and his paleontological conclusions. Afterward, he spent untold hours in the laboratory, carefully studying the fossils that he and other paleontologists had collected.

Like Osborn and Matthew, Simpson wrote about the evolution of horses. But in contrast to Osborn's sweeping and relatively simple (unilineal) view of equid evolution, he delineated a complex history that involved several evolutionary lines, progressing from woodland browsers to high-plains grazers. As Simpson put it, "Evolution doesn't move in straight lines, but the minds of some scientists do." In developing these studies, he was in many respects following the path that Matthew had taken some decades earlier.

Two lines of research by Simpson deserve particular mention. One was exemplified in his two thorough monographs about all the Mesozoic mammals known at the time he was entering upon his remarkable paleontological career. His other research was his detailed study of the classification of all mammals—both living and extinct—a long-term project that established him as an authority on the rather legalistic subject of animal taxonomy.

Most of his scientific career was spent at the American Museum, but in 1959 he moved to Harvard. His final years were spent in Tucson, Arizona, where he was associated with the University of Arizona.

Today the study of organic evolution at the American Museum of Natural History is in its second century of research and the four men are now historical figures. The contemporary effort, involving modern, expanded techniques at paleontological sites around the world and modern sophisticated studies in the laboratory, is a projection of the seminal research by Osborn, Matthew, Gregory, and Simpson, who through three-quarters of a century established the Museum as a world center for evolutionary fact and theory. Theirs were lasting contributions to our knowledge of the history of life.

Edwin H. Colbert, for many years chairman of the American Museum's Department of Vertebrate Paleontology, knew and worked with the great paleontologists he writes about. (He began his career in 1930 as an assistant to Henry Fairfield Osborn.) Now curator of vertebrate paleontology at the Museum of Northern Arizona, he lives in Flagstaff with his wife, Margaret—the daughter of paleontologist William Diller Matthew.

Bonaventure Island, Quebec

by Robert H. Mohlenbrock

Flat-topped, sheer-sided Percé Rock protrudes into the Gulf of Saint Lawrence on the eastern edge of Quebec's Gaspé Peninsula. During high tide, it stands isolated from the mainland, but at low tide, one can reach it by walking across a 400-yard stretch of exposed, slippery rocks. Looming out of the water three miles east of Percé Rock is another landmass. This is Bonaventure Island, internationally known for its colony of nesting gannets.

Percé Rock lies off the eastern shore of the Gaspé Peninsula. Above, right: A gannet uses seaweed to build its nest on Bonaventure Island.
Victoria Hurst; First Light

Along with Percé Rock, it was designated a provincial conservation park in 1985 under the management of the Quebec Department of Recreation, Game, and Fish.

According to geologist H. W. McGerrigle, Percé Rock consists of layers of limestone deposited by the sea about 375 million years ago. Its seaward side ends in a low, wide arch that creates a huge window through the rock. Two hundred feet beyond is a separate pillar of rock, or "seastack." This pillar was also once connected to Percé Rock by an arch, but the arch collapsed in 1845. According to sailors' reports from about 1600, there once was a series of four arches. The one that remains should last a few hundred more years, according to McGerrigle.

Bonaventure Island is reached by ferry from the village of Percé, nestled beneath nearby mainland cliffs. Because of the severe winters and persistence of ice in the gulf long into spring, the ferry operates only from mid-June to mid-September. Traveling there in August, I was fortunate to visit Bonaventure Island accompanied by naturalist Lucie Lagueux, author of a popular booklet about the gannets. In a half-hour ride, the ferry crossed the three miles of open water from the mainland and then slowly circled the island in a clockwise direction before docking on the west side, facing Percé.

As the ferry passed the cliffs on the north and northeast sides of the island, countless seabirds filled the air above and in front of the rock. Most were gannets out for their morning fishing expedition, but we also saw black-legged kittiwakes, black guillemots, double-breasted cormorants, great black-backed gulls, herring gulls, razorbills, and common murres. A very small colony of common puffins also nests on the island, but we saw none on the day I was there. From the ferry we could see that every possible surface on the island's upper rocky terraces was covered by white, nesting birds. Lucie Lagueux estimated that there were about 21,000 gannet pairs, roughly 20 percent of the known world population of this species.

The ferry docks on the western side of the island, where the slope to the water is gentle enough for passengers to disembark. A fishing community was established here during the seventeenth century. A few abandoned buildings and other evidence of this settlement remain. Most of

Gerry Ellis

the area around the landing site has been cleared, and the vegetation consists of weedy plants introduced through human disturbance—milfoil, wild parsnip, burdock, vetch, and timothy grass.

All around the island is a narrow strip of open, rocky terrain with primarily arctic flora, known locally as the natural prairie. Most likely, these arctic species were driven southward during the last Ice Age and were left behind after the glaciers receded, about 10,000 years ago. They include a tiny whitlow grass mustard, three-toothed cinquefoil, the live-forever saxifrage, bistort, and a wild iris. While most of the island is covered by a boreal coniferous forest, the natural prairie survives because it is undisturbed and because there is not enough soil for forest trees to gain a foothold.

Several trails lead from the dock up through the moist, cathedrallike forest to the north-facing cliffs where the gannets nest. Balsam fir and white spruce are the dominant conifers, and they grow so densely that sunlight rarely reaches the moss-covered forest floor. Many kinds of wildflowers, all adapted to living in a poorly lighted and very moist environment, grow up through the carpet of mosses. Among them are goldthread, purple wood sorrel, twinflower, one-flowered wintergreen, bunchberry, and lady-slipper. Most have green leaves and use the sun's energy in photosynthesis. Some of the plants, however, such as Indian pipe and coralroot orchid, lack chlorophyll and live entirely off the rich organic matter that accumulates on the forest floor.

As we climbed the trail upward through the firs and spruces, the great commotion of nesting gannets became louder and louder. Suddenly the forest ended, and we were standing on a fifty-foot-wide grassy strip that was all that separated us from the rocky terrace at the edge of the cliff. On this terrace were the most birds I had ever seen in one place, with scarcely any rock

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For visitor information write:
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Quebec Department of Recreation,
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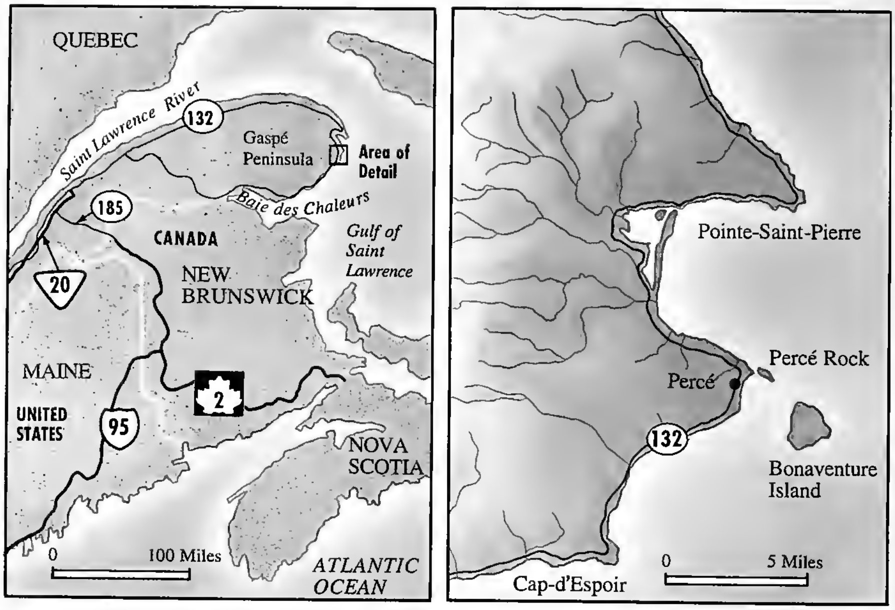
C. P. 310, Percé, Quebec G0C 2L0 Canada
(418) 782-2240

Joe LeMonnier



showing between adjacent nests. The park service permits visitors to come to a fence not more than six feet from the nearest nesting birds. There is also a sturdy, forty-foot-tall observation platform that provides an overall view of the spectacle.

Gannets are large, soft-looking birds with dark bills and legs. A patch of yellow-brown on the back of the head is all that marks the otherwise white, downy plumage. An adult gannet weighs about seven pounds. When spread, its wings span a little more than five feet. The birds I saw nesting were at least five or six years old, the age of sexual maturity for a gannet. Younger gannets congregate on the rocks at the base of the cliffs, practicing their diving and fishing skills and learning the techniques of social behavior that they will need when they are sexually mature.

The adults, which pair for life, arrive in early April from their wintering grounds in Florida and Mexico. They soon begin building their nests of grass on the bare rock. Each site is about twenty-nine and a half inches in diameter, separated from adjacent nests by no more than two inches. Mid-April is the mating season, and it begins with the art of fencing, in which a male and female carry out a ritual of crossing beaks.

Unlike most flowering plants, Indian pipe lacks green leaves for photosynthesis.
Thomas A. Schneider

The female lays a single white egg in early May, and incubation lasts for forty-three days, with the female and the male alternating shifts every thirty to thirty-six hours. When the parent that is incubating the egg wants to leave the nest, it signals its partner to return by pointing its beak straight up.

The egg hatches about the third week in June. The hatchling is black, naked, and blind, but within three weeks, it weighs two-thirds as much as the adult. At seven weeks, the chick actually outweighs the adult by two pounds. After exercising its wings, it takes its first flight from the cliff, landing in the sea. This action is so exhausting, and the young bird is so heavy, that it is unable to take off again for a few days. Instead, it swims away from the island, surviving on its excess fat and some fish. During this time some 60 percent of the fledglings perish.

Young gannets that survive the fledgling stage usually start on their migration south in September, before stormy weather sets in. Adults stay longer, feeding on the abundant fish and perhaps lingering over the late-hatching chicks (most of which are doomed to perish). The adults begin the long journey southward about the middle of October, and the last ones are gone a few weeks later. Interestingly, the adults leave Bonaventure Island as pairs, but the males overwinter on the Gulf Coast of Mexico, while the females generally go to the Atlantic coast of Florida.

The gannets' breeding cycle meshes with the seasonal distribution of the fish on which the birds feed. Gannets arrive at Bonaventure Island in the spring, precisely when large numbers of herring are spawning in the nearby waters. The hatching of the gannet eggs coincides with the spawning of another fish, the capulin. Adult gannets feed upon the capulin, then regurgitate some of the food for their young. They continue by feeding them on mackerel, which subsequently appear in abundance. Then, just as the young are fledging, a second large population of herring arrives.

During the late 1960s, the hatching success rate for gannets, normally 75 percent, fell to half that. Scientists from the Canadian Wildlife Service discovered that DDT, ingested by birds from contaminated fish, was being stored in the bird's fat and ultimately causing a calcium deficiency in the eggshells. Thus weakened, many of the shells would break. When DDT was eventually eliminated, the hatching rate returned to normal. Nonetheless, the large gannet colony at Bonaventure Island must always be monitored for oil spills, PCB contamination, and other environmental pollutants. A major disaster here could wipe out up to one-fifth of the birds' total population.

This month, Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, takes a northern holiday from his usual beat, the 156 U.S. national forests.

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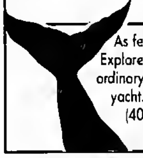

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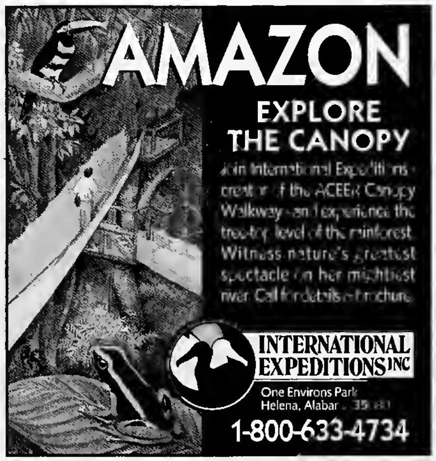

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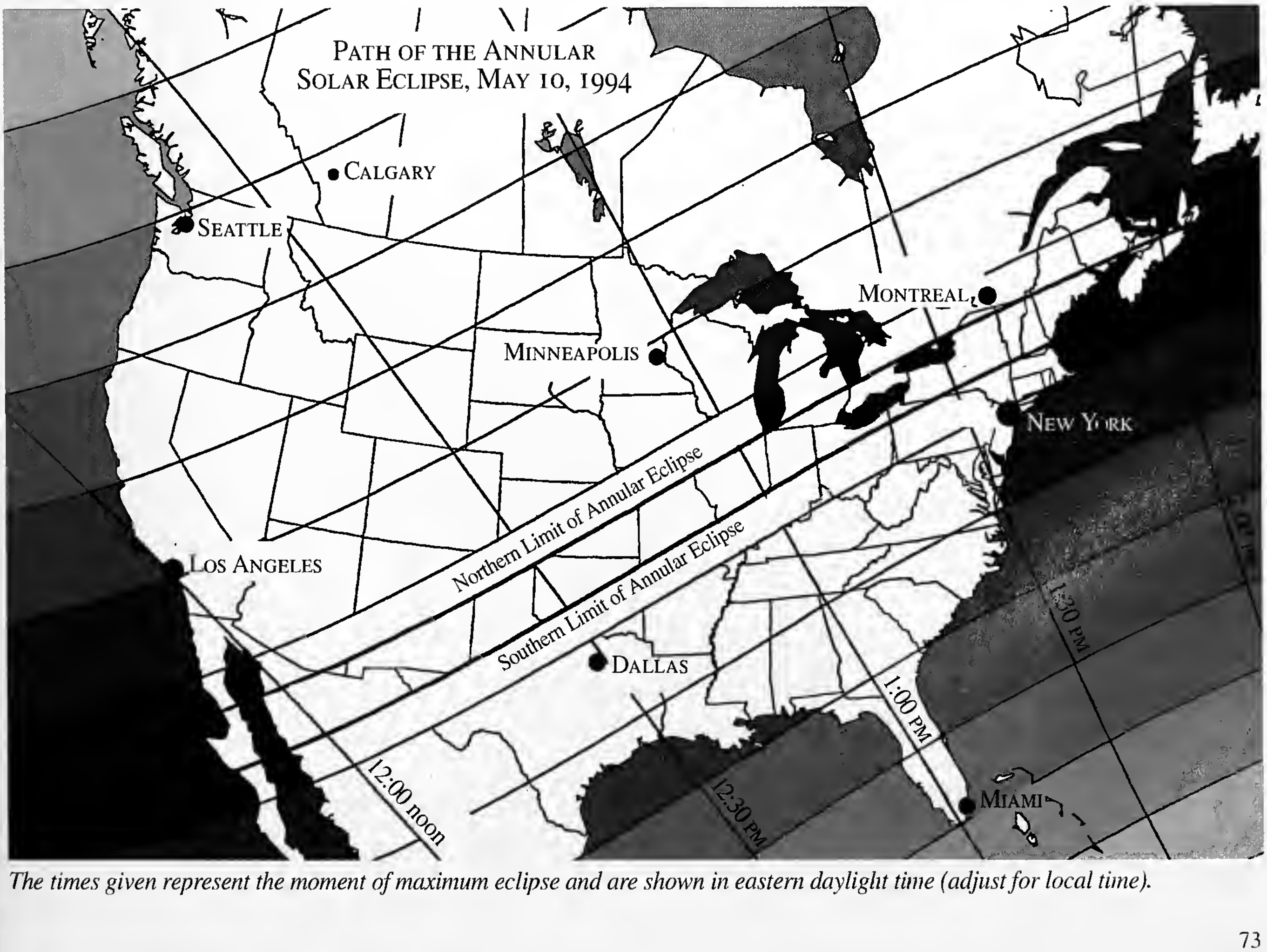
Ring of Fire

by Gail S. Cleere

A total solar eclipse is perhaps the most spectacular celestial event, but unfortunately, at any given location, it is very rare: the next one visible in the continental United States will occur on August 21, 2017. (In all of recorded history, the sun has never been totally eclipsed over Washington, D.C., where I write.) On May 10, however, the next best thing, an annular solar eclipse, will occur as the moon passes in front of the sun without completely covering it. The result will be a brilliant ring of sunlight surrounding the black disk of the moon. Starting in the Pacific Ocean, south of the Hawaiian Islands, the annularity will be visible along a 150-mile-wide swath, extending across the United States, from New Mexico to Maine, before it crosses the Atlantic and ends in Morocco.

Solar eclipses can occur only during the new moon, the only time of the month that the moon and the sun are in the same part of the sky. Solar eclipses do not occur every month because the orbits of the earth, moon, and sun are not in the same plane. The moon's orbit is tilted by 5° in relation to the earth's orbit around the sun, so during the new moon phase, the moon is usually slightly above or below the sun. Only rarely does it pass directly in front of the sun. A minimum of two solar eclipses (total, annular, or partial) occur every year; the maximum is five.

A further complication is that the moon's orbit is not perfectly round. When the moon is near perigee, its closest distance to the earth, its disk is just large enough to cover the entire sun. (By coinci-



The times given represent the moment of maximum eclipse and are shown in eastern daylight time (adjust for local time).

dence, the sun is 400 times farther away from us than the moon, but it is also 400 times larger than the moon, so that in the sky the two appear to have roughly the same diameter. This is what makes solar eclipses so spectacular.) During apogee, however, when the moon is farthest from us, its disk is not large enough to cover the sun completely, so a ring, or annulus, of sunlight escapes around the edges. Along one side, the ring is often broken up into bright points of light by mountains on the moon's surface.

During May's annular eclipse, the moon's disk will cover 88 percent of the sun. Even 12 percent of sunshine in the ring of annularity is still a lot of light, however, and although the sky will become darker, it won't be spectacularly so. At the height of the eclipse, the lighting will be equivalent to that of a heavily overcast day. What will be striking is that the edges of shadows will get sharper (because light is coming from a smaller source), and hundreds of pinhole images of the sun will be seen under trees as the image of the sun is filtered through the leaves.

This effect can be simulated by making a pinhole in a card and projecting the image of the sun through it onto a sheet of paper. This method is one way of viewing eclipses safely. To look at the sun during eclipses, you need special filters to protect your eyes from its direct rays, which can quickly cause permanent damage. Because all the bright photosphere of the sun is hidden by the moon in a total solar eclipse, during totality, observers can safely look directly at the eclipse with the naked eye. Annular and partial eclipses, however, can never be viewed safely because some of the solar surface remains exposed. If you must look directly at the sun, use a rectangular welder's glass of shade number 14, which can be purchased at hardware stores and welding supply firms. Welder's glass of lower shade numbers are not safe for solar viewing. Nor do gelatin filters, color film, photographic filters, smoked glass, or sunglasses offer any protection.

Viewers near the center of the eclipse path will see a symmetrical ring of sunlight around the moon, while those near the edges of the track will see the moon off center in the solar disk. At its best near Toledo, Ohio, the annular phase of the eclipse will last six minutes and thirteen seconds. The rest of the United States, as well as Canada, Mexico, Central America, Greenland, Iceland, the Arctic, and portions of Europe and Africa, will witness a partial solar eclipse. In Hawaii, the sun will rise partially eclipsed. For most of Europe, the sun will set eclipsed.

THE PLANETS IN MAY

Mercury is in the evening skies during the second half of the month and is in a good position for Northern Hemisphere observers just after sunset. On the 15th, Mercury is 8° above the red star Aldebaran in Taurus. On the 30th, Mercury reaches its greatest distance east of the sun for the year—a whopping 23° east of the sun. Now is the time to look for Mercury in the western twilight.

Venus shines at –3.9 magnitude just after sunset in the west. On the 4th, it will pass 6° north of the reddish star Aldebaran. On the 12th and 13th, look for Venus just above the very young moon. Those lucky enough to be in the path of annularity during the eclipse on the 10th should look for Venus about 30° to the left (east) of the sun as the sky darkens.

Mars remains difficult to spot, low in the southeast as the sun rises. On the 7th and 8th the waning moon passes nearby.

Jupiter continues to dominate the night sky. It rises a couple of hours before sunset in the southeast and travels across the southern sky, setting just before sunrise. On the nights of the 22d and 23d, the gibbous moon passes near Jupiter. All month long Jupiter vies for our attention with the bright star Spica, which is nearby in the constellation Virgo.

Saturn rises in the east several hours before sunrise. The planet is in the constellation Aquarius. Look in Pisces for the bright star Fomalhaut—from the Arabic, meaning "the fish's mouth"—just below Saturn, nearly matching the ringed planet in magnitude. On the 5th, look for Saturn near the waning crescent moon in the predawn skies.

Uranus and **Neptune** remain in eastern Sagittarius. Both are now in their apparent westward motion through the constellation—a function of the earth overtaking them in orbital speed (all the planets move in an easterly direction through the constellations in the sky). In dark, predawn skies, both planets can be found with binoculars and a detailed sky chart, just east of the dense river of stars forming the Milky Way. Facing Uranus and Neptune, you are looking toward the center of the galaxy.

Pluto's biggest day of the year occurs this month, at opposition in our nighttime skies on the 17th in Libra. It is as far from the sun as it can get for the year, so this is the best time for serious astronomers to try observing Pluto—the faintest planet in the solar system.

The **Moon** reaches last quarter on the 2d at 10:32 A.M., EDT; is new on the 10th at 1:07 P.M., EDT; and reaches first quarter at 8:50 A.M., EDT, on the 18th. The moon is full on the 24th at 11:39 P.M., EDT, and will produce the second eclipse of the month. This partial lunar eclipse begins at 10:38 P.M., EDT, when the moon enters the dark umbral shadow of the earth. Maximum eclipse will come at 11:30 P.M., EDT, when the lower quarter of the moon's disk is covered. The moon will leave the umbra at 12:23 A.M., EDT.

The Eta Aquarid meteors, a stream of frozen particles left behind in the path of Halley's comet, are best during the hours just after midnight on May 5. Unfortunately, moonlight will interfere. They are named not for the comet but for the place in the sky where they seem to originate (a dim star in the faint constellation Aquarius). We can expect to see twenty bright meteors per hour: some bright yellow; some leaving long, glowing trails. These meteors were first recorded by the Chinese in A.D. 401.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

Old Foods in the New World

by John R. Alden

Until a decade or so ago, no one thought about ancient societies as having cuisines. Cuisines were high culture, like haute couture and symphony orchestras. France had a cuisine; so did China. But that was about it. In the United States people lived on food like barbecue, baked beans, and corn on the cob, and certainly none of that qualified as cuisine. As for the ancient world, most of us figured those folks were just happy to have a mess of pottage.

Our perceptions have changed. Cuisines no longer follow formal repertoires of ingredients, recipes, and techniques. They are simply coherent styles of selecting, preparing, flavoring, presenting, and consuming food, and every culture, region, social stratum, and ethnic group is recognized as having a cuisine of its own. Fast-food is an element of modern American cuisine; so are corn flakes and, in parts of the country, corn dogs. Futhermore, ancient societies had cuisines too.

America's First Cuisines describes what three of the New World's most important aboriginal societies—the Aztecs, the Maya, and the Inca—ate and how they went about eating it. Sophie Coe, an anthropologist and food historian specializing in Latin America, chose these groups for two practical reasons. First, of all the New World's disparate cultures, these three made the greatest contribution to the cornucopia spilling from the shelves of today's supermarkets and filling the pages of today's cookbooks and restaurant menus. Second, says Coe, "that is where the information is." These societies are simply better known than other New World groups. Through contact period chronicles, Coe has reconstructed a fascinating picture of how these prehistoric Americans ate.

AMERICA'S FIRST CUISINES, by Sophie D. Coe. *University of Texas Press, $35.00 ($14.95 paper); 276 pp., illus.*

Prehistoric Mexicans made a protein-fortified bread by soaking and cooking maize, a process known as nixtamalization.

Coe begins with a summary of the ingredients available to each of her three groups. The list of domesticated animals is surprisingly short. In Mesoamerica it included only dogs, turkeys, honeybees, and Muscovy ducks. South America had dogs and Muscovy ducks, llama and alpaca, and the guinea pig. Wild animals were extensively utilized by all three New World cultures (game, remember, was also important in the cuisine of fifteenth- and sixteenth-century Europe), but in terms of foods they produced, these societies were mainly dependent on things that grew in the ground.

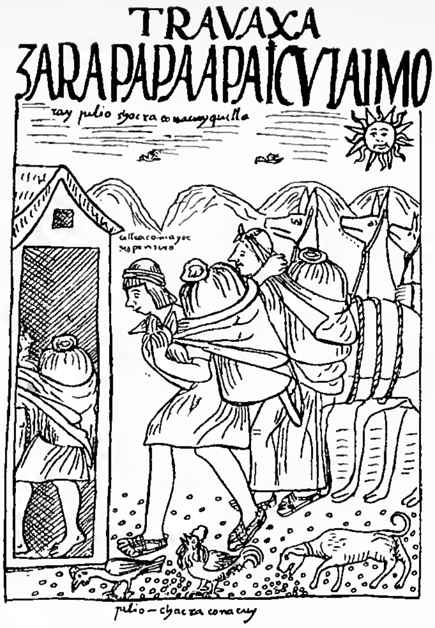
The New World's staple grain, grown from southern Canada all the way down to the southern reaches of the Inca empire in central Chile, was maize. Maize is just another name for what people in the United States call corn, but because *corn* is sometimes used to describe other cereal grains, the stuff that grows as high as an elephant's eye in the fields of Oklahoma is in Coe's book called maize. Whatever its name, this was the most important item in Aztec, Maya, and Inca diets. Infants were weaned on maize, and many aboriginal

Americans ate it virtually every day of their lives.

Maize was not the New World's only staple food. In the humid tropics, manioc (cassava root) was processed into starch and then made into a sort of bread. It was an everyday food in a good part of the Central and South American lowlands, although the Spanish were unimpressed with the product. ("He had a bit and gave it to us to try," wrote one chronicler, "and we thought it was terrible.") Potatoes and similar root crops—sweet potatoes, yams, oca, ullucu, maka, and llakhum—were staples in the highland Andes, particularly at elevations where maize didn't grow well. In all these regions, however, maize was the staple of choice.

An impressive variety of fruits, greens, seeds, and vegetables supplemented maize and root crops. Beans, squash, and tomatoes are the most famous of these New World products, but the original Americans also domesticated pineapple, passion fruit, avocado, jicama, peanuts, quinoa, and a host of less familiar foodstuffs. In addition, New World cuisines were the source of three of the modern world's most important flavorings: chocolate, vanilla, and chili peppers.

Although these pre-Columbian peoples produced the bulk of what they ate, they were also energetic gatherers. The Aztecs ate cactus fruits and the young pads of the nopal, or prickly pear cactus. They collected water bugs and their eggs, maguey worms, freshwater algae, and the maize smut fungus, *huitlacoche*, which despite its unappetizing name in English is actually quite tasty. According to one chronicler, the Maya would eat anything that didn't smell bad to them. The Inca were



The Incas used llamas to transport maize and potatoes to state warehouses.

also adventurous eaters: seaweed, toads, lupine leaves and seeds, caterpillars, nasturtium blossoms and roots, mayfly larvae, dried lizards, and so many kinds of greens that the chronicler Garcilasco de la Vega (1539–1616) declined to even list them.

Coe supplies fact or anecdote about many of the ingredients. "Columbus was the first European to eat a pineapple, which he did on November 4, 1493." "The word *tomatl* in Nahuatl, the language of the Aztecs, means something round and plump." Drinking cups have been found in Maya burials with the glyphs for "chocolate" written on the vessels' rims. During one of their festivals, the Aztecs spread turkey eggshells on the streets, celebrating "the goodness of the god who had given them that fowl."

The book is most interesting, however, when the author goes beyond the ingredients and talks about cuisines. She focuses her discussion on the features of pre-Columbian cuisines that are most unfamiliar to us. First, because the notion of a staple food has disappeared from our own cuisine, she repeatedly emphasizes the degree to which the Aztec, Maya, and Inca societies built their menus around maize. Maize was eaten green, ripe, and dried. It was soaked, crushed, ground, and fermented; baked, boiled, roasted, steamed, and popped. It may not literally have been used in every dish, but when it was available maize seems to have appeared in every meal.

A second characteristic of these cuisines is that almost everything was flavored with chili peppers. Readers who have traveled in Mexico or Peru will be aware of how important hot peppers are in these countries, but until you have watched people shake ground chile on coconut and pineapple, eat chicken or turkey in chocolate and chili pepper sauce, and chew up whole peppers that are too hot for you to even touch, you may have difficulty appreciating that simple truth. Even the statement that prehistoric Native Americans "ate nothing without them" seems inadequate. But Coe makes this point memorably by reporting that for the original inhabitants of highland Mexico "the simplest fast...was to abstain from salt and chili." The Spanish may have viewed chiles "as a mere condiment," but to pre-Columbians they were "a dietary cornerstone, without which food was a penance."

America's first cuisines, in contrast to the cuisines of Europe and to modern cuisines in general, were low in fats. Pre-Columbian diets included little meat (in the case of the Maya, so little that European observers "described Maya life as perpetual Lent"), and what meat the people got tended to be lean. Squash seeds, cacao beans, peanuts, and avocados are all good sources of vegetable oils, but these were dietary supplements rather than staples, and no pre-Columbian society seems to have extracted edible oils from such sources. In addition, the diets of conquered and conqueror alike were different from our diets today in that the conquest-era cuisines regularly included starchy liquids.

A "class of foodstuff that is extinct in our lives today," writes Coe about the starch-based drinks that the Aztecs called *atolli,* was "sold from shops full of jars large and small, on the street corners as well as in the market." She lists more than a dozen variants of this beverage, differentiated by how the basic maize was prepared and what kinds of flavorings or fortifiers were added. The Maya mixed soured maize dough with water to make *posolli*, and also made as many kinds of *atolli* as their highland neighbors. Andean peoples made maize-based drinks called *chicha* and drank such liquids almost exclusively. Of pure water, a seventeenth-century historian of the Inca Empire, Bernabe Cobo, commented that "there is no greater torture for [Andean Indians] than to make them drink it, a punishment which the Spaniards inflict on them occasionally, and which they feel more than blows."

Two other features of Aztec cuisines deserve to be mentioned here—cacao-based drinks and cannibalism. Coe argues persuasively that both were more important in ritual contexts than as regular dietary items. The case she makes is too wide-ranging to recapitulate in a few sentences, but two features of their preparation and use are striking. Among the Aztecs, only the men were allowed to drink chocolate. And *tlacatlaolli*, or human stew, was one of the only Aztec dishes not flavored with chili. This feature, Coe comments, "should signal to us that this was not an ordinary meal but a religious rite."

Coe does not use modern ethnographic or culinary studies in her reconstruction of the cuisines that existed in late fifteenth and early sixteenth century New World societies. This is a wise decision. Much can be learned from such sources, but distinguishing introduced patterns from indigenous ones is a difficult business. Important elements of the aboriginal cuisines have disappeared (chocolate drinks in the Aztec and Maya regions and wild greens in all three regions are the most obvious examples), and European ingredients and cooking techniques have spread into every cuisine in Latin America.

Still, I wish she had touched more upon the archeological evidence. Pictures of the more obscure fruits and vegetables and an appendix summarizing Latin, common, Spanish, and Indian names for the various foods and plants discussed in the text would have also been helpful.

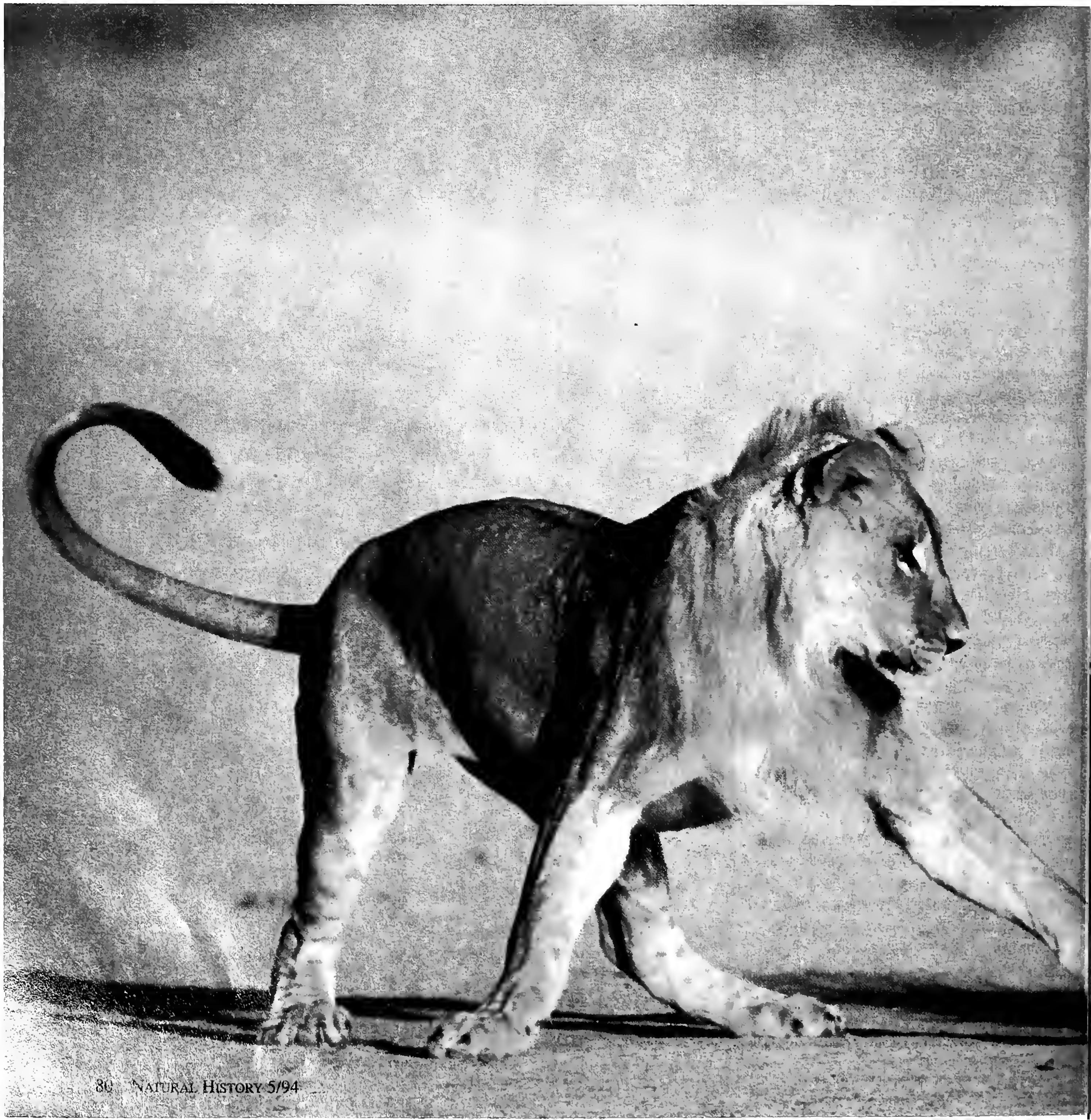
The strengths of *America's First Cuisines*, however, far outweigh any such complaints. This book is full of significant insights and interesting asides about the cuisines and cultures of the New World's three major indigenous civilizations, and it is as entertaining as it is informative. The European conquest of the New World was a catastrophe for the societies Coe discusses, a cataclysm so fundamental that it even changed the way they ate. But the changes went both ways. The barbecue, baked beans, and corn on the cob in our own cuisine were adopted or adapted from the cuisines of America's indigenous peoples, and understanding where these foods came from makes them even more enjoyable to eat.

A freelance book critic and enthusiastic eater, John R. Alden has done archeological research in Mexico, Panama, Peru, and Chile.

A Prickly Encounter

Photograph by Barrie Wilkins

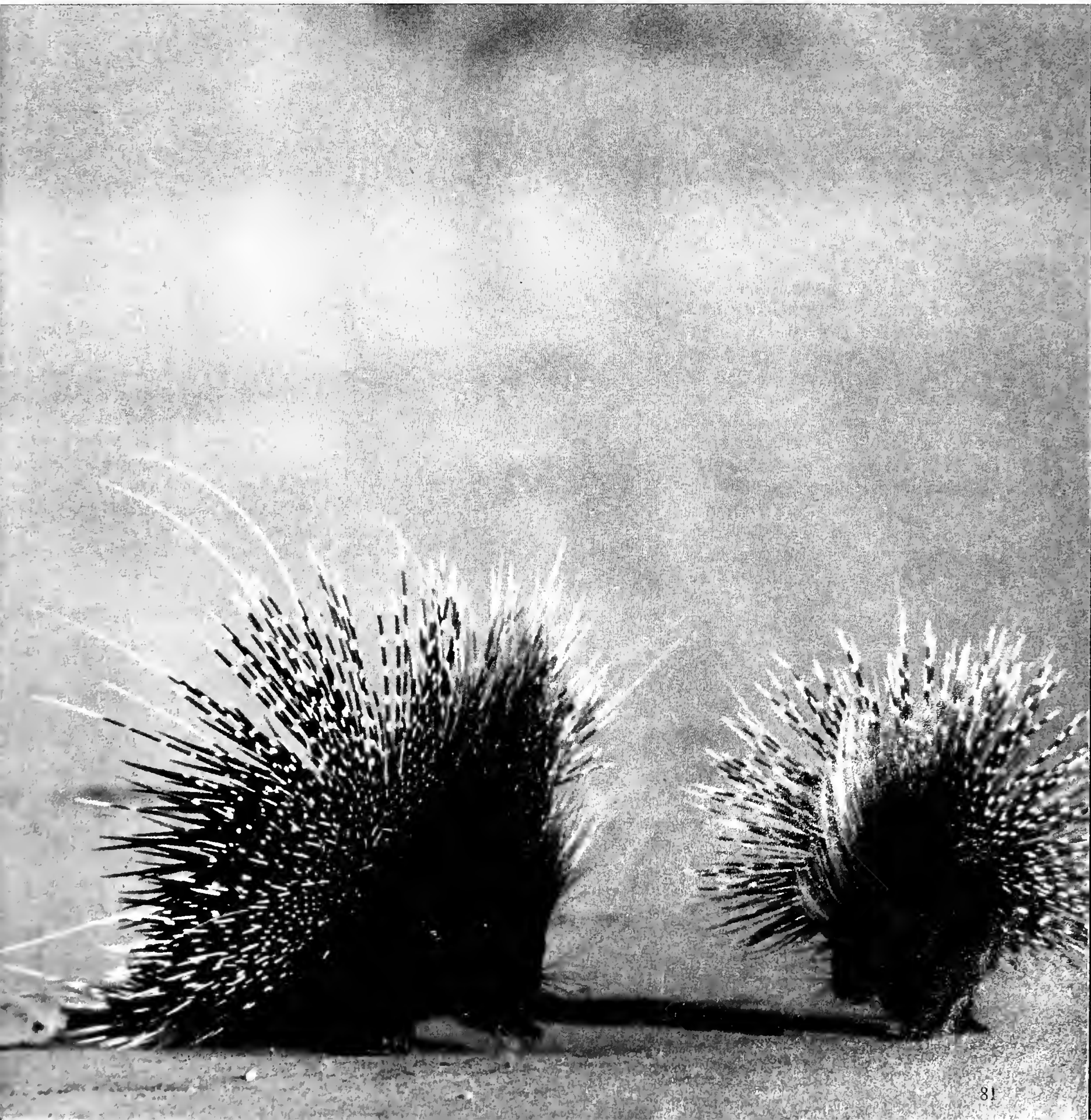
On one of his early morning drives through South Africa's Kalahari Gemsbok Park, photographer Barrie Wilkins encountered two adolescent lions worrying an African porcupine and her youngster in the dry bed of the Nossob River. Realizing that these burrow-dwelling porcupines are rarely active in the daytime, Wilkins concluded that the lions must have detained the pair all night, trying to get past the sharp, barbed quills to a tasty meal. He also noticed numerous tracks that had been made during scuffles and near-escapes. After observing and photographing the confrontation, he returned to camp. There, members of a research team confirmed that they had seen the animals



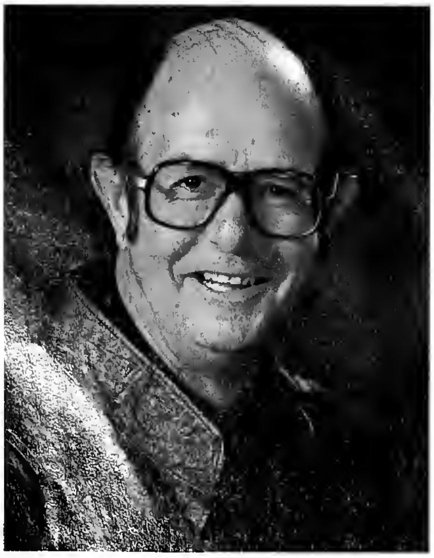
in the same place the previous night.

During the two hours Wilkins spent photographing them from his van, one of the young lions kept trying to flip the smaller porcupine so as to reach its unprotected belly. The porcupines, however, always managed to keep a row of quills pointed at the inexperienced lions, no matter which way they circled. (An older lion might have been able to distract one so that his partner could flip the other over.) Suddenly, the mother porcupine charged one of the cats, which jumped out of the way to avoid being stabbed. Then the standoff resumed.

The lions occasionally lost interest and strolled away, but whenever the predators had walked a few yards, the porcupines tried to escape across the river bed, and the lions charged back to reengage them. This game continued until midmorning, accompanied by roaring on the part of the lions, and grunting, hissing, and rattling of quills by the porcupines. Finally, with the lions tiring, the porcupines suddenly made a successful break and reached a safe burrow in the dunes.—*R. M.*



South African photographer **Barrie Wilkins** (page 80) has spent many years taking pictures in the Kalahari Gemsbok Park, which is renowned for its lions. He has exhibited his work worldwide and has twice garnered the Photographic Society of America's Medbury Award. The photo in this month's "Natural Moment" is itself a prizewinner, having taken a first place in the British Gas Wildlife Photographer of the Year Competition, organized by *BBC Wildlife* magazine and the Natural History Museum in London. Because the South African National Parks Board prohibits photographers in nature reserves from stalking their quarry on foot, Wilkins prowls the Gemsbok Park in a four-wheel-drive van, with special mobile camera brackets mounted on the window frame. "The vehicle acts as a blind, allowing relatively close access without disturbing the creatures," he writes. Although his first love is the Kalahari, Wilkins has traveled extensively throughout southern Africa and has also photographed Alaska's bears and Yellowstone's winter wildlife. In 1986, he coauthored *Kalahari Safari*, a photographic book on Kalahari wildlife. He continues to evaluate and record the influence of the seasons on the park's animals. The picture was taken using a Canon EOS with a 600 f4 EF L autofocus lens.



As a teen-ager, **Patricia Chapple Wright** (page 44) read Gerald Durrell's books about his adventures with animals, and after graduating from college in the late sixties, she acquired an owl monkey as a pet. Intrigued by its behavior, she was inspired to go to South America to have a look at owl monkeys in the wild. After that experience, primatologist Warren Kinzey convinced her to go to graduate school. Now an associate professor of anthropology at the State University of New York at Stony Brook, Wright is a MacArthur Fellow and international coordinator of a project to conserve the tropical rain forest in Madagascar's Ranomafana National Park. Her own fieldwork in Madagascar has included studies of three species of bamboo lemurs (*see* "Lemurs Lost and Found," *Natural History*, July 1988) and, for the past eight years, the ecology and behavior of diademed sifakas. For more on rain forests, she recommends John Terborgh's *Diversity and the Tropical Rain Forest* (New York: Scientific American Library, 1992). Terborgh has also written a book specifically about Peru's Cocha Cashu Biological Station: *Five New World Primates* (Princeton: Princeton University Press, 1984).

"You try to uncover the logic of nature, and that logic is always the same, wherever you find yourself," writes **Bernd Heinrich** (page 52), referring to the effect of insects on flower evolution. The idea that bees and other pollinators shaped the appearance and diversity of flowers first excited him when he was a graduate student researching insects in a Maine bog. Twenty years later, he relearned the evolutionary lesson when he saw the array of similar-looking red flowers—including a large red buttercup—blooming in the Judean desert near Jerusalem. A professor of zoology at the University of Vermont, Heinrich is a frequent contributor to *Natural History*. His latest book, *In the Maine Woods*, will be published by Addison-Wesley this fall.

When Peruvian police seized some treasures plundered from a prehistoric pyramid at Sipán, archeologist **Walter Alva** (page 26) was called in to evaluate them. Recognizing that a major tomb had been looted, he organized the subsequent scientific excavations that have so far revealed three intact tombs. A native of Peru, Alva, left, has participated in numerous excavations on that country's north coast and is the director of the Museo Brüning at Lambayeque. Coauthor **Christopher B. Donnan** is a professor of anthropology and director of the Fowler Museum of Cultural History at the University of California, Los Angeles. A specialist in Moche iconography, he participated in the Sipán excavations and worked to identify the priestly ranks of the tombs' principal occupants. Alva and Donnan described the discovery of the tombs and the nature of Moche culture in several articles that appeared in the October 1988 and June 1990 issues of *National Geographic*. They are the coauthors of *Royal Tombs of Sipán* (Los Angeles: Fowler Museum of Cultural History, University of California, 1993).

"I've always enjoyed spending time outside, so pursuit of a graduate degree in field biology seemed a logical way to combine my avocation with a possible vocation," says **Renée Godard** (page 36). Soon to be assistant professor of biology at Hollins College in Roanoke, Virginia, Godard became interested in the evolution of communication as a doctoral student at the University of North Carolina at Chapel Hill. By studying one species, the hooded

warbler, in the field, she began to realize the intricate role song played in the bird's biology. Most recently Godard has been studying a small population of Caribbean flamingos in the Galápagos Islands. Coauthor **Haven Wiley** earned his doctorate in animal behavior from The Rockefeller University in New York. A professor of biology and ecology at the University of North Carolina at Chapel Hill, Wiley has done extensive fieldwork in South America, particularly in Venezuela. But, he says, "In the 1980s, with a growing family, I decided to shift my field research closer to home—and discovered that hooded warblers were among the commonest songbirds in the bottomland forest near the university." This species proved to be an enlightening one in his study of animal communication. Readers can find further information on the behavior and nesting of warblers in Douglass H. Morse's *American Warblers* (Cambridge: Harvard University Press, 1989) and Hal H. Harrison's *Wood Warbler's World* (New York: Simon and Schuster, 1984). *The Selfish Gene*, by Richard Dawkins (Oxford: Oxford University Press, 1990) introduces some of the evolutionary problems associated with reciprocity.

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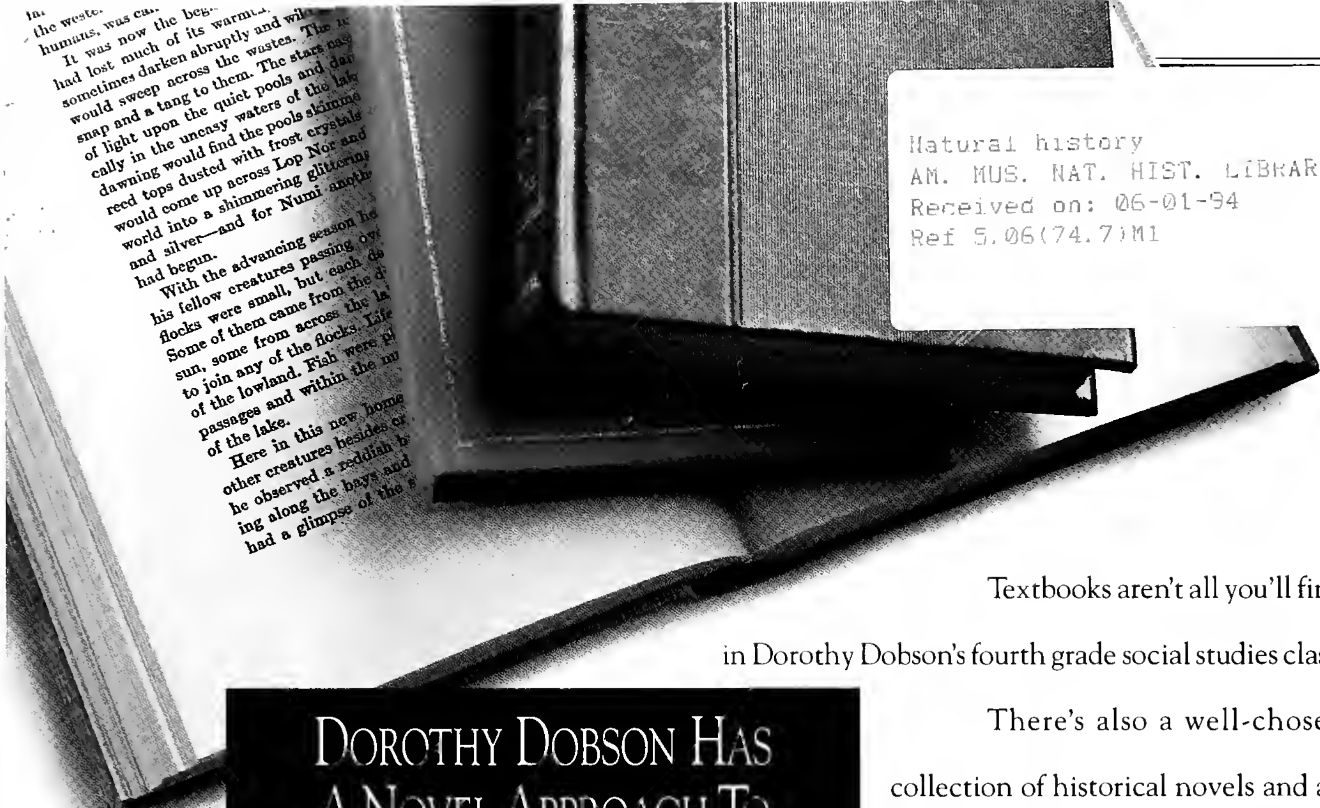
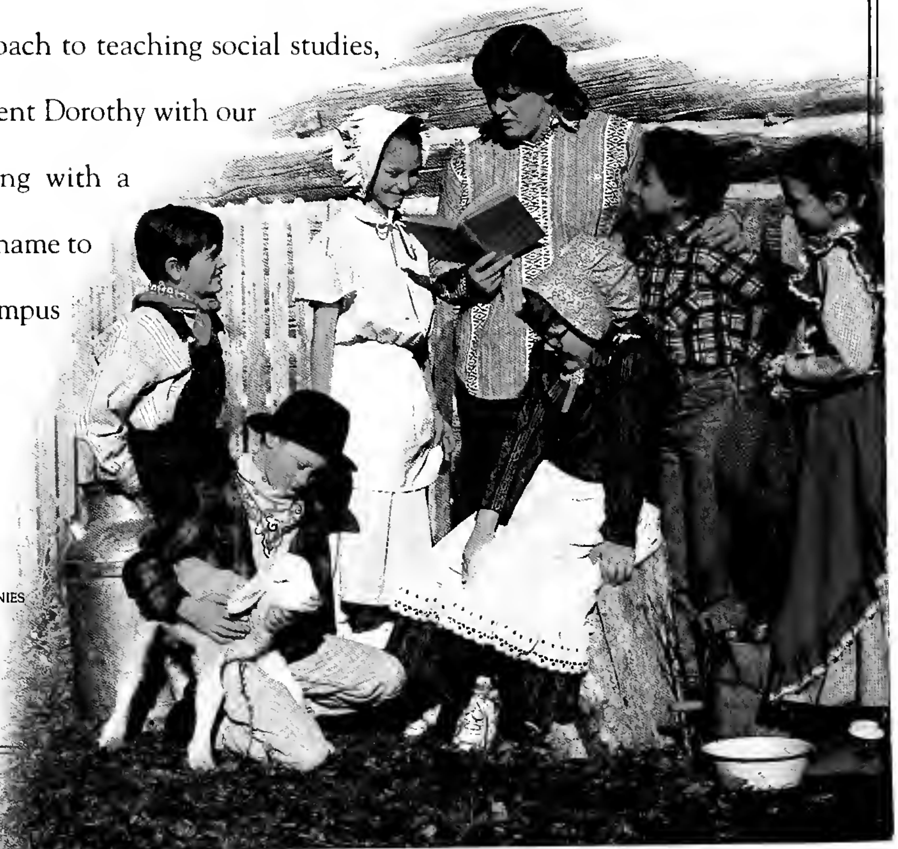


Dorothy Dobson Has A Novel Approach To Teaching Social Studies.

Textbooks aren't all you'll find in Dorothy Dobson's fourth grade social studies class. There's also a well-chosen collection of historical novels and all the space her young students need to bring history to life.

For Dorothy, "memorizing a lot of dates" isn't what's important. Instead, her students read novels that relate to the period of history they're studying. After that, anything can happen. From staged reenactments of important chapters to creating room-length murals that depict historic times and places. In short, any activity that helps them "experience" history.

For her creative approach to teaching social studies, State Farm is honored to present Dorothy with our Good Neighbor Award, along with a contribution of $5,000 in her name to Edith Bowen School on the campus of Utah State University.



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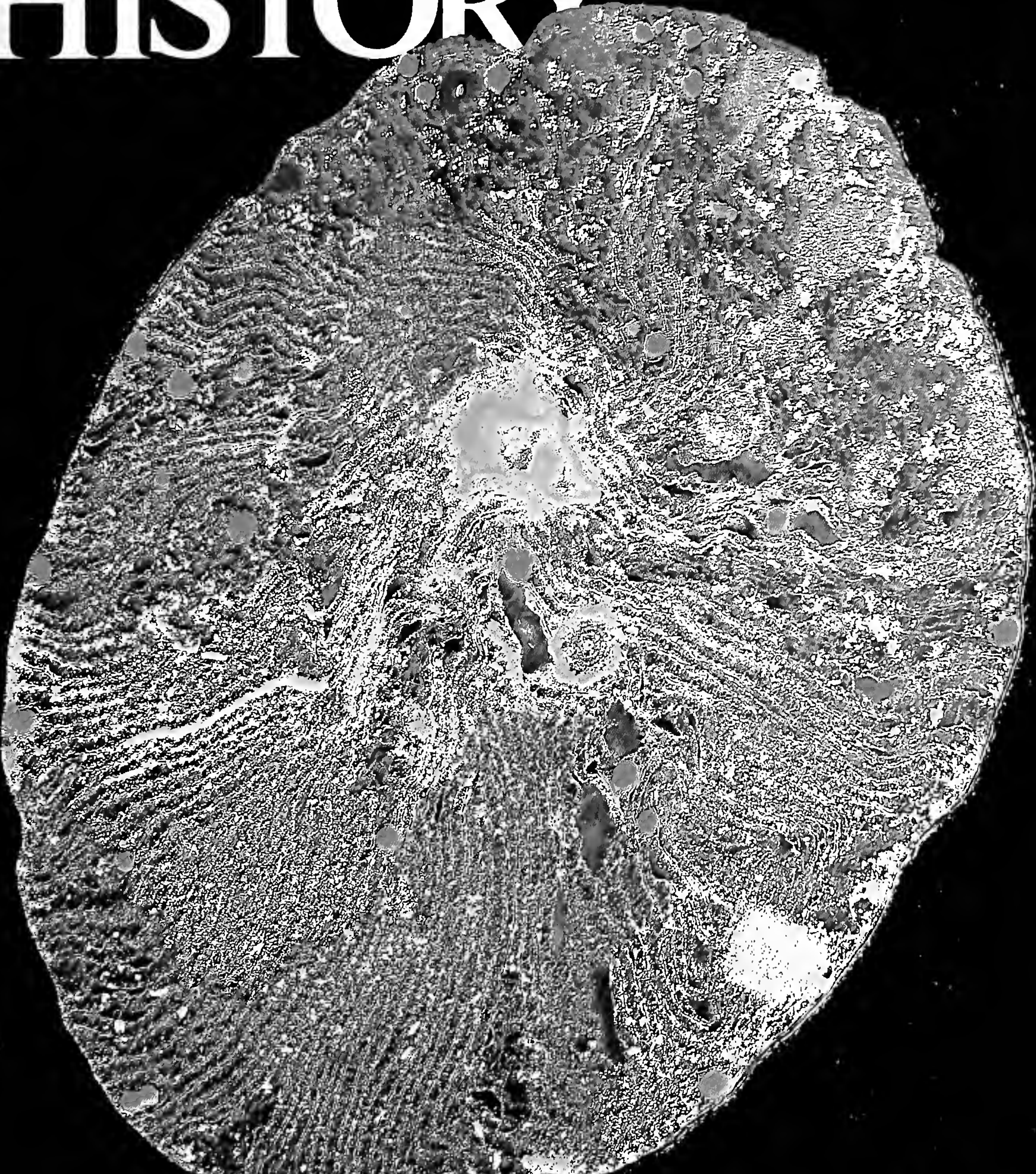

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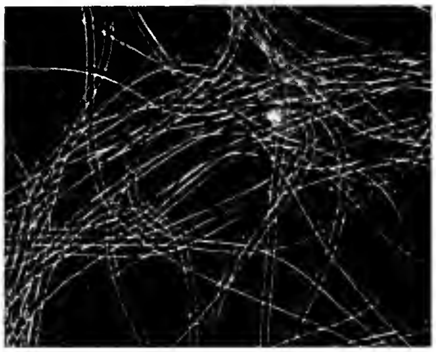
COVER: *A false-color electron micrograph of a single-celled cyanobacterium (magnified 31,000 times) shows the laminar membranes (wavy, parallel lines) in which photosynthesis takes place. These tiny organisms began releasing oxygen billions of years ago, thus kicking off the oxygen revolution. Story on page 14. Photograph by A. B. Dowsett; Science Photo Library; Photo Researchers, Inc.*



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Volume 103, Number 6, June 1994

125 Years of Q & A About Life's Story

The American Museum of Natural History, a major center for research and public education in New York City, is celebrating its 125th anniversary this year. The Museum shelters some thirty million specimens, forty-two display halls, a planetarium, two hundred research scientists, an active education department, and this magazine. The anniversary is being celebrated in many ways, including the publication of this special issue on evolution—a subject long and deeply pondered in the halls of the Museum.

Departments

Clyfford Still, *Untitled*. Private Collection, Courtesy C & M Arts, New York

The Cutting Edge of Evolution

A century and a half ago, Charles Darwin forged possibly the most powerful weapon ever handed to science: his theory of evolution. With this hard-edged sword, scientists cut away bonds of ignorance, superstition, and arrogance that had shackled human understanding of life for thousands of years. The sword has become sharper with use. Today, we better understand life's beginnings and its changes and expansion over millions of years. Biologists now appreciate the dynamic relationships organisms have with one another and with the ever changing environment. They are beginning to fathom the roles of molecules and the intricacies of the genetic code. The Darwinian perspective is changing medical research. It is also illuminating our place—and our fate—in the glorious venture called life. This special issue is a sampler of evolutionary insights and research in progress. It commemorates the 125th anniversary of the American Museum of Natural History, the magazine's soul and home in New York City. Since its founding, the Museum has been a beacon for public education and research on evolution.—*A. P. T.*

The Power of This View of Life

"We should never have sought either solace or moral instruction in Nature"

by Stephen Jay Gould

In the last sentence of *The Origin of Species,* Charles Darwin attributed multiple powers to life itself, but chose to designate the evolutionary perspective ("this view of life") as imbued with grandeur:

> There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

Darwin thus located evolutionary grandeur in a contrast between the repetitive motion of our planet's circuit about the sun and the fascinating narrative of life's history—a tale with a mysterious beginning, an enthralling unfolding, and an unpredictable end. The grandeur, in short, lies in the contrast between a well-oiled machine and an edifying story.

"This view of life" also emits power, for evolution represents the fundamental fact and central organizing concept of biological science, and Bacon proclaimed long ago that knowledge is power. Darwin clearly saw that his revolution included two distinct and separable components—establishing the fact of evolution (genealogical connections among all organisms, with life's history as a tale of physical "descent with modification," to cite Darwin's words) and proposing a theory (natural selection) for the cause of change. Darwin wrote in the *The Descent of Man*:

> I had two distinct objects in view; firstly to show that species had not been separately created, and secondly, that natural selection had been the chief agent of change...hence if I have erred in giving to natural selection [too] great power...I have at least, as I hope, done good service in aiding to overthrow the dogma of separate creations.

(Darwin's distinction was not only logically correct but also politically sound. The intellectual world had been ready for evolution's factuality, and had eagerly embraced Darwin's evidence, but his radical theory of natural selection found few takers during his lifetime and did not become a majority view until the 1930s. Darwin is buried in Westminster Abbey, literally at the feet of Isaac Newton, but he lies in hallowed ground for establishing the fact of evolution, not for proposing a theory about causes.)

Evolution surely stands first among the "outrages upon our naïve self love" that Freud identified as the cachet of all truly great scientific revolutions. I don't mean to downplay the mental adjustment required by the two other revolutions that Freud specified as paramount: changing our abode from the immobile center of a limited universe to a small peripheral hunk of rock subordinate to one star among billions, and altering our view of mind from a logical and moral instrument to a largely nonrational device buffeted or controlled by an "unconscious." Still, no demotion of hope can quite match the cancellation of our "particular privilege of having been specially created" (in God's image, no less) and our consequent "relegation to descent from the animal world."

Evolution therefore entered Western consciousness as the most threatening of all new ideas to our most fundamental social assumption and psychological hope for human uniqueness and centrality. Evolution in any guise had to pose a challenge and initiate a crisis. But many versions could have buffered the shock and sanitized the transition. The two components that Darwin identified—fact and theory—might have been formulated in a "friendly" fashion that challenged a minimal number of cherished assumptions. An instigator other than Darwin might, for example, have portrayed the pathway (the "fact") of evolution as inherently progressive and predictably leading to *Homo sapiens* as a pinnacle—the necessary result of a mechanism (the "theory") that conceptualized advancing neurological complexity as an ineluctable, internally driven property of living matter. In fact, most non-Darwinian theories of the nineteenth century did portray evolution in this more conventional and less threatening mode. (Our name for the process is a vestige of this search for comfort. *Evolution* comes to us, largely via Herbert Spencer, from an English vernacular usage meaning "progress." Darwin did not like the word and preferred "descent with modification." But most evolutionists did equate biological change with necessary progress, and Spencer's favored term stuck.)

Charles Darwin was a complex and contradictory man—an intellectual radical, a political liberal, and a social conservative. His personal wealth and his loving, protective home life allowed him to range freely (and dangerously) in the realm of ideas. Evolution, as argued above, would have been challenging enough to constitute Freud's greatest revolution in any guise. But Darwin's version cut right through the keystone of social convention and provided an ideologically radical account in the domains of both theory and fact. Auspicious beginnings often cascade to full achievements (and rolling stones gather no moss). Darwin started us well, but the transformation continues, and the surprises do not diminish. Perhaps we can only agree with the English biologist and writer J. B. S. Haldane that the universe is not only peculiar but "queerer than we can suppose."

The Radical Theory: Natural selection, as a theory about differential reproductive success and its consequences, could scarcely be less available for any hope that evolution might be either cosmically rational or just parochially directed toward the appearance of *Homo sapiens*. Natural selection is, first of all, a theory about adaptation to changing local environments, not a statement about "improvement" or "progress" in any global sense. Since environments alter in a meandering and unpredictable way through time, natural selection should not lead to any pathway of stately unfolding. (Darwin, as an eminent Victorian in a culture maximally committed to progress, did manage to smuggle predictable advance back into evolution via an ecological argument about competition in biologically crowded environments, but he remained committed to his radical proposal that the "bare bones" mechanics of natural selection permits no statement about favored directions for long-term change.)

Moreover, natural selection, expressed in inappropriate human terms, is a remarkably inefficient, even cruel process. Selection carves adaptation by eliminating masses of the less fit—imposing hecatombs of death as preconditions for limited increments of change. Natural se-

lection is a theory of "trial and error externalism"—organisms propose via their storehouse of variation, and environments dispose of nearly all—not an efficient and human "goal-directed internalism" (which would be fast and lovely, but nature does not know the way). Darwin certainly grasped this central irony of our being when he wrote to his best friend Joseph Hooker in 1856: "What a book a devil's chaplain might write on the clumsy, wasteful, blundering, low, and horribly cruel works of nature."

The Peculiar Pathway: We look at the paleontological pattern of life's unfolding, and we try to extract a story that suits our prejudices. We speak of an "age of invertebrates" followed by an "age of fishes, reptiles, and mammals," all capped by an "age of man." We draw our sequences of pictures and arrange our chapters in textbooks, so that trilobites come first and people last. But invertebrates have always dominated the world of multicellular animal life in numbers of species and prospects for long-term success, while *Homo sapiens* is one tiny twig on life's exuberantly branching bush. (I do not deny the unparalleled impact of our species upon the planet, but magnitude of result bears no relationship whatever to predictability of origin.)

This is not the "age of man"; it is not even the "age of insects"—a proper designation if we wish to honor multicellular animal life. As it was in the beginning, is now, and ever shall be until the sun explodes, this is the "age of bacteria." Bacteria began the story 3.5 billion years ago, as life arose near the lower limits of its preservable complexity. The bacterial mode has never altered; the most common and successful forms of life have been constant. Bacteria span a broader range of biochemistries and live in a wider range of environments; they cannot be nuked into oblivion; they overwhelm all else in frequency and variety; the number of *E. coli* cells in the gut of any human exceeds the count of all humans that have lived since our African dawn.

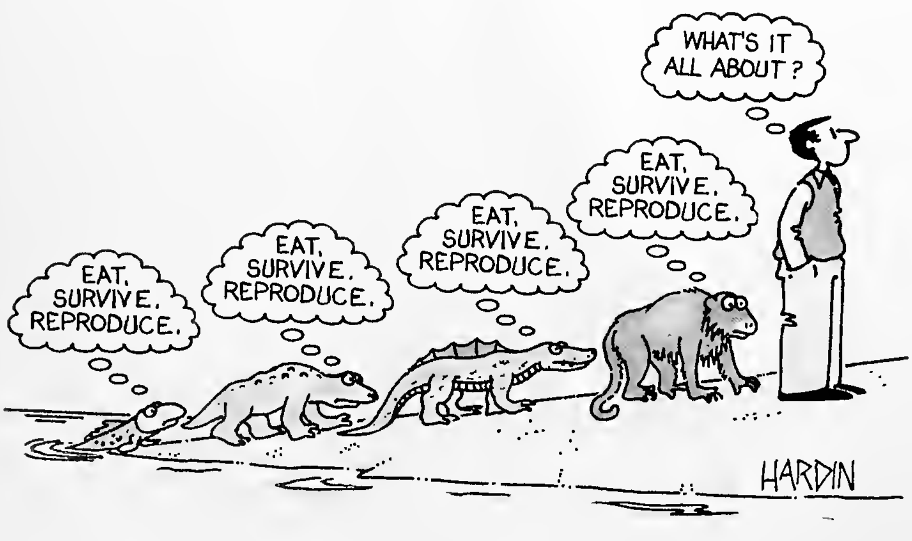
No trend of complexity or progress exists in the usual sense; the history of life features no upward thrust as a central tendency of evolution; the bacterial mode has persisted for more than three billion years. At most, every once in a while, a lineage or two tumbles into a domain of enhanced complexity, for this is the only open direction available (the numerous forms that evolve greater simplicity fall into a domain of overlap with creatures already existing). We focus upon this tiny tail in the distribution of complexity only because we reside there ourselves.

Moreover, the pattern of occupation for this small tail of complexity departs maximally from any notion of a predictably steady unfolding. With the exception of simple algae (a pathway unrelated to the genealogical story of animals), life remained unicellular for five-sixths of history. All but one phylum arose in a single geological whoosh, within some five million years or so, at the dawn of Cambrian times, 530 million years ago (the "lowly" Bryozoa, not our exalted chordate selves, form the single exception of slightly later origin).

In a basic anatomical sense, the history of life since then has been a tale of many variations on a few underlying themes. (I do not deny the unusual interest of some of these variations, including human consciousness.) The earth doesn't even permit exclusive evolution by the already messy and contingent rules of competitive natural selection. Mass extinctions punctuate the history of life, imposing regimes of death for reasons unrelated to Darwinian struggles of normal times. If a large extraterrestrial body had not struck the earth 65.3 million years ago, dinosaurs would probably still be dominating mammals, and no conscious being would have the privilege of pondering a world queerer than we can suppose.

How can Darwinism be exalting, and "this view of life" grand, if all our comforts be thus stripped away in favor of such messiness, contingency, and caprice in the details that matter (like the probability of our own evolution), with generalities confined to broad domains that offer so little solace (mass extinction as a recurring phenomenon; natural selection as a governing principle; invariance of the bacterial mode as a result). First, do not doubt the salutary effects of such a cold bath. We never should have sought either solace or moral instruction in Nature, who was not made for us, or even with us in mind, and who existed by her own rules for billions of years before we arrived. Better to learn a stern truth about marvelous multifariousness (and cosmic indifference to us) than to persist in a myth of warm cuddliness or intrinsic harmony that might channel proper attention from our own bodies and minds (true humanism) as the source of ethics and value.

Second, a world queerer than we can suppose must be, to anyone with a modicum of curiosity, so much more interesting a place than a planet crafted to feed our bovine complacency. Darwin's revolution remains incomplete, in Freud's crucial sense, until we face the cosmic insignificance that our own evolution truly implies—thus liberating us to grasp the deeply human meaning of our lives and most curious brainpower. We shall soon celebrate the two-thousandth birthday of a most interesting man who not only told us that the truth would make us free but who also spoke for all kinds of enlightenment in saying: "I am not come to destroy, but to fulfill."



Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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The Origin of Life

Which came first, proteins or RNA?

by Anthony Mellersh

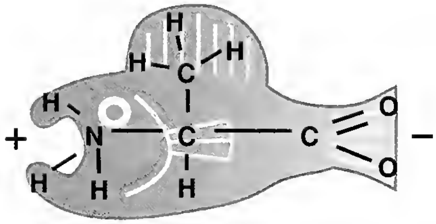
The origin of life remains one of the Great Questions. The presence of fossil bacteria in rocks 3.8 billion years old suggests that very soon after the earth cooled, life arose from the simple organic chemicals present in the primordial soup. But how did small molecules organize and begin to replicate, transforming a sterile planet into a living world? By necessity, the answers so far have been speculative, but we can make some educated guesses about certain steps in the early chemical evolution of life.

Underlying all living systems is a complex web of chemical reactions orchestrated by enzymes. These biological catalysts, almost all of which are proteins, deliver the right chemicals at the right time and at the right place, insuring that the energy and building blocks are brought together for each cellular function. These reactions, essential to life, would be unlikely to occur in the absence of enzymes. If we are to explain how the earliest organisms arose, we must figure out how these and other proteins can be made from scratch.

Proteins are long, unbranched molecules made up of subunits called amino acids. Amino acids and other small organic chemicals almost certainly came from a variety of sources. In 1953 Stanley L. Miller, a graduate student at the University of Chicago, found that by passing electric sparks through gases, he could create amino acids, but the conditions found around thermal vents at the bottom of the ocean could also have produced them. These simple chemicals are also present in many of the meteorites that fall to the earth's surface.

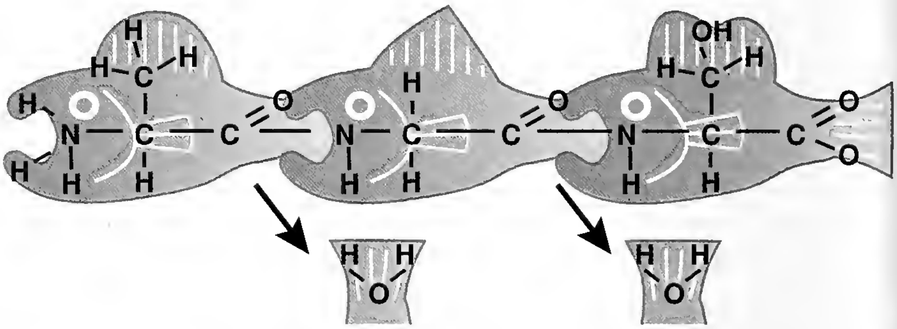
But getting from amino acids to proteins is another story, and one fraught with problems. Amino acids aren't likely to link up with one another—a problem related to their chemical construction. All are formed from a few elements and have the same central structure, a chain of three atoms. The first is a nitrogen (N), holding three hydrogens (H); the middle is a carbon (C), with one hydrogen and one variable side chain attached; the third is a carbon bound to two oxygens (O).

With a sideways squint, and a lot of imagination, we can see the molecule as a fish, an analogy that is useful for explaining how hard it must have been for amino acids to form proteins. To make a protein,



many "fish" must link up with one another in long chains. To do so, each must lose a molecule of water before the positively charged nitrogen atom at its head can attach to the negatively charged carbon-oxygen at another's tail. If the head (N) contributes two hydrogens and the tail an oxygen, water (H_2O) is released, the tails are shed, and the fish are linked together.

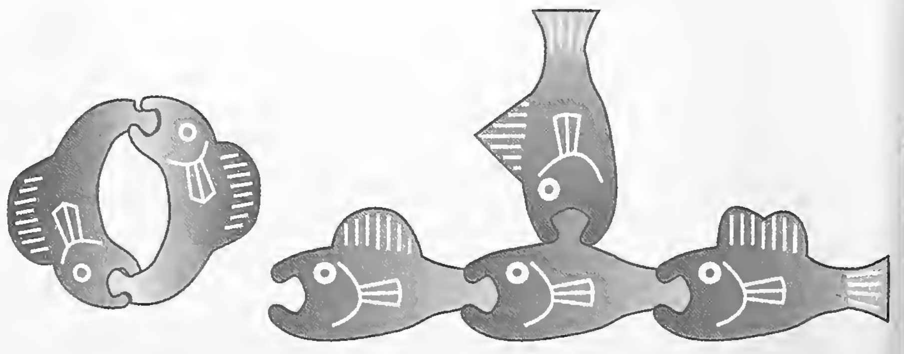
Amino acids aren't very likely to form such chains on their own. The hydrogen and oxygen needed to create the water are fairly tightly bound, so the reaction rarely happens spontaneously. If conditions are hot and dry enough, however, the water molecule is lost and amino acids can join together; but, following the path of least resistance, as soon as they join, the head of the first is most likely to bond with the tail of the second, forming a circle (below).



Another likely outcome is that the side chain will react with nearby molecules, producing a branched molecule (bottom, right). Neither of these reactions would be very helpful in the formation of proteins, which are long and unbranched.

The number of other, unwanted molecules that can react with a growing chain of amino acids further complicates the problem of protein synthesis. Just as there are a lot of different fish in the sea, there would have been lots of different amino acids in the primordial soup. Some may have had longer central chains or any of hundreds of possible side chains. And if that isn't complicated enough, most amino acids can exist in two forms, left-handed and right-handed; but only the left-handed one is used for building proteins. All in all, thousands of possibilities. Yet all proteins are made from only twenty kinds of amino acids. Add to the confusion any number of headless or tailless fish—miscellaneous, highly reactive molecules—that would have readily reacted with a free head or tail, preempting the chain formation required for protein synthesis.

Even if by some enormous stroke of luck, all these hurdles were overcome, and a single copy of an effective protein spontaneously arose, it would be a dead end. It could pass on this fortunate accident to posterity only if it could replicate itself, but proteins cannot.



Illustrations by Joe LeMonnier, after Anthony Mellersh

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the events and people behind the 1994 Collection

Adventure

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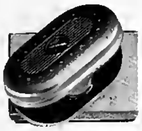

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Courage

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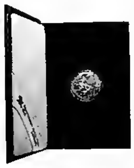

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Passages

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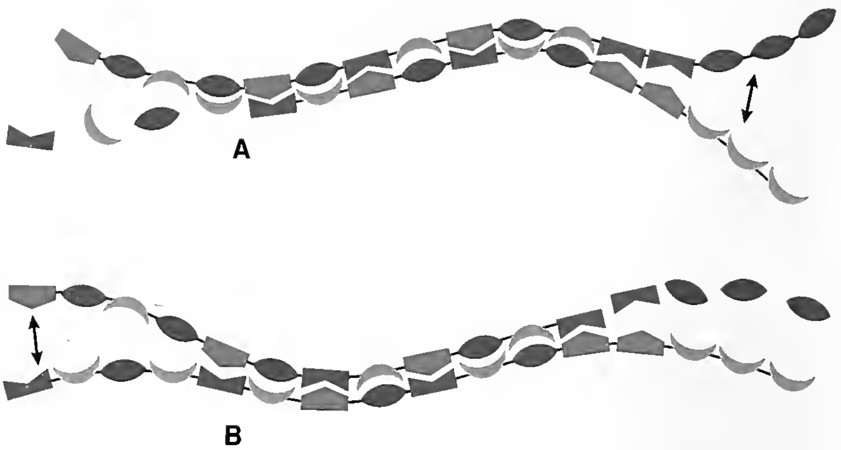
All this should be very disappointing to those who hold that proteins arose spontaneously, but proteins are so fundamental to life that the idea still has a few supporters. Another theory, superficially attractive, holds that life arose somewhere else in the universe—reaching this planet via comets or dust grains. This doesn't really solve the problem, however; it just shifts it elsewhere and creates new dilemmas. Any cometary debris that might have borne the seeds of life would have been subjected to extremes of temperature, and the all-important enzymes are very temperature sensitive, only working in a narrow temperature range from about –14° F to 212° F and being irreversibly destroyed at higher temperatures. Proponents of this theory must explain not only how life arose but also how it operated at the extremes of temperature found in space. And how did it then adapt to the earth, where the majority of proteins function most efficiently at about 80° F? The more ambitious theorists would have life arising around other planets or even stars. But to escape, the primitive organism would have had to overcome a gravitational force so strong that only the fiery impact of a large comet or asteroid could blast it into space—an event also likely to destroy it. Scientists proposing that life arose either on other planets or in other solar systems must explain not only how the chemistry to form life happened but also how it got here.

Back with our feet firmly on the ground, we need to look again at the origin-of-life problem. The "protein first" argument fails primarily because even if proteins did manage to assemble themselves successfully, they had no way of copying themselves so that their success could be recorded and amplified. (The order in which the amino acids are strung together is crucial because it determines how the chains will fold and twist into the three-dimensional shapes of individual proteins.) Only one group of biological molecules can copy themselves. These are the two slightly different nucleic acids, ribonucleic acid (RNA) and deoxyribonucleic acid (DNA). Like enzymatic protein molecules, nucleic acids are long and unbranched, formed from subunits. The building blocks are called nucleotides and, like amino acids, can be assembled fairly easily from simple, inorganic molecules. The nucleotides also have side chains, or "bases," but there are only four common ones and they are divided into two pairs, each of which has a special affinity for the other. As the bases in a chain of RNA attract their partners from solution, a complementary chain is built that separates from the original (A). When this complementary chain attracts its own complement, a copy of the original RNA sequence emerges (B). The really exciting thing that points to RNA as the first "living molecule" is that not only does it replicate but it can also act as a catalyst.

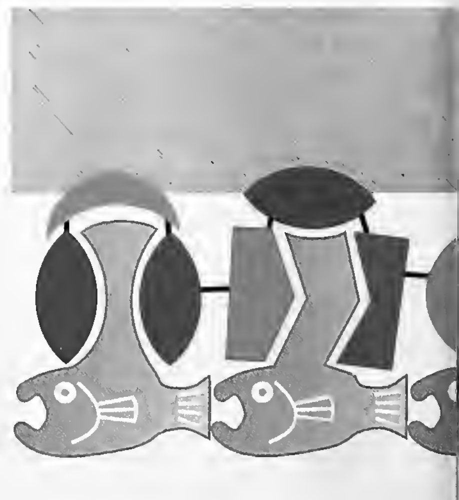


The majority of scientists working on the origin of life now believe that there was a time when RNA was the only biological molecule. But the range of reactions that RNA can accelerate is small and usually involves only the joining or splitting apart of RNA molecules. Such a "living" system is extremely limited. It has not overcome the hurdle of protein production, which would extend the range of RNA so that a much broader range of reactions can occur. The solution offered by the "RNA world" proponents is that small segments of RNA—called adapter molecules—go off and find the correct amino acid and bring it back to the parent RNA for assembly into a protein. This is really an enormous logistical exercise, and one that introduces a lot of problems. How, for example, do the little RNA molecules recognize an amino acid? How do they join to it? Why do they come back "full" and not "empty"? How do they give up the amino acid to growing protein chains? But the solutions to these questions make the system more and more complicated.

One of the guiding principles of science is Occam's razor, which suggests that the most likely explanation is the simplest. Making functioning proteins requires both the information that specifies the sequence of amino acids and the amino acids themselves. The information is encoded on RNA (there is no other plausible candidate) and is carried in sequences of three bases. The simplest theory would be that three bases on the RNA recognize the amino acids. This was investigated by some biologists in the 1960s. The researchers put short segments of RNA of known base sequence in solution to see if they could capture specific amino acids. The results were negative, so the theory gained little support, and the more complex theories became popular.

But did those early experiments give the simplest theory a fair shake? Let's go back to the fish analogy. If you wanted to catch fish, you could use a net. But if you just throw a piece of loose netting into the sea, you will probably fail. Similarly, free-floating RNA molecules cannot capture the amino acids in a solution, because the RNA will be buffeted by all sorts of forces and will drift about wrapping itself up randomly, just as loose netting would. To succeed in catching the fish, the net needs to have a rigid support.

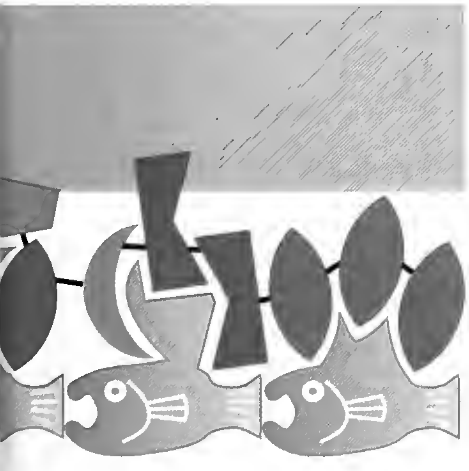
In the past forty years, the nucleic acids have been studied intensively. One of the most exciting techniques has been "gene probing," which involves extracting nucleic acids and attaching them to a variety of solids by their backbone, so that the



bases are pointing away from the surface and can be recognized by a complementary sequence, in a similar manner to the RNA (left). The technology for determining the exact shape the nucleic acid would take on the surface of such a solid is not yet available, but by applying the basic rules of chemistry, a model can be made. Such a model suggests that it is undulating, folding back on itself every three bases, forming a series of clefts. Each cleft has a negative charge on one side and a positive charge on the other, and these are just the right distance apart to capture a "head" or a "tail" of one of the twenty amino acids that form proteins. The side chain of the amino acid projects into the space between the bases, which differs for each of the three bases. Each cleft will accept only a particular molecule—that is, the fish with a head and tail the right distance apart and with the correctly shaped dorsal fin. When RNA is supported like a fixed net (below), it can capture fish, and different fish in each bit of the net.

This model yields more. The fish are already oriented head-to-tail. A "condensing agent," which is a molecule that can remove water, such as polyphosphate, aligns with the amino acids. When conditions become dry and the condensing agent removes the water, the fish automatically join up in a line and separate from the RNA template. They can't get at the wrong tail or the dorsal fins, so no circles or branched chains are made. Exactly the same protein is synthesized each time, with no half proteins or double ones.

For years, scientists debated whether proteins or RNA came first. Was it the chicken or the egg? With RNA attached to a solid, a compromise emerges: RNA and proteins came together, and together they lit the spark that resulted in all the wonderful things that we call life.



Evolution

Life's Expanding Realm

Every living organism rests on a microbial foundation formed billions of years ago

by Andrew Knoll

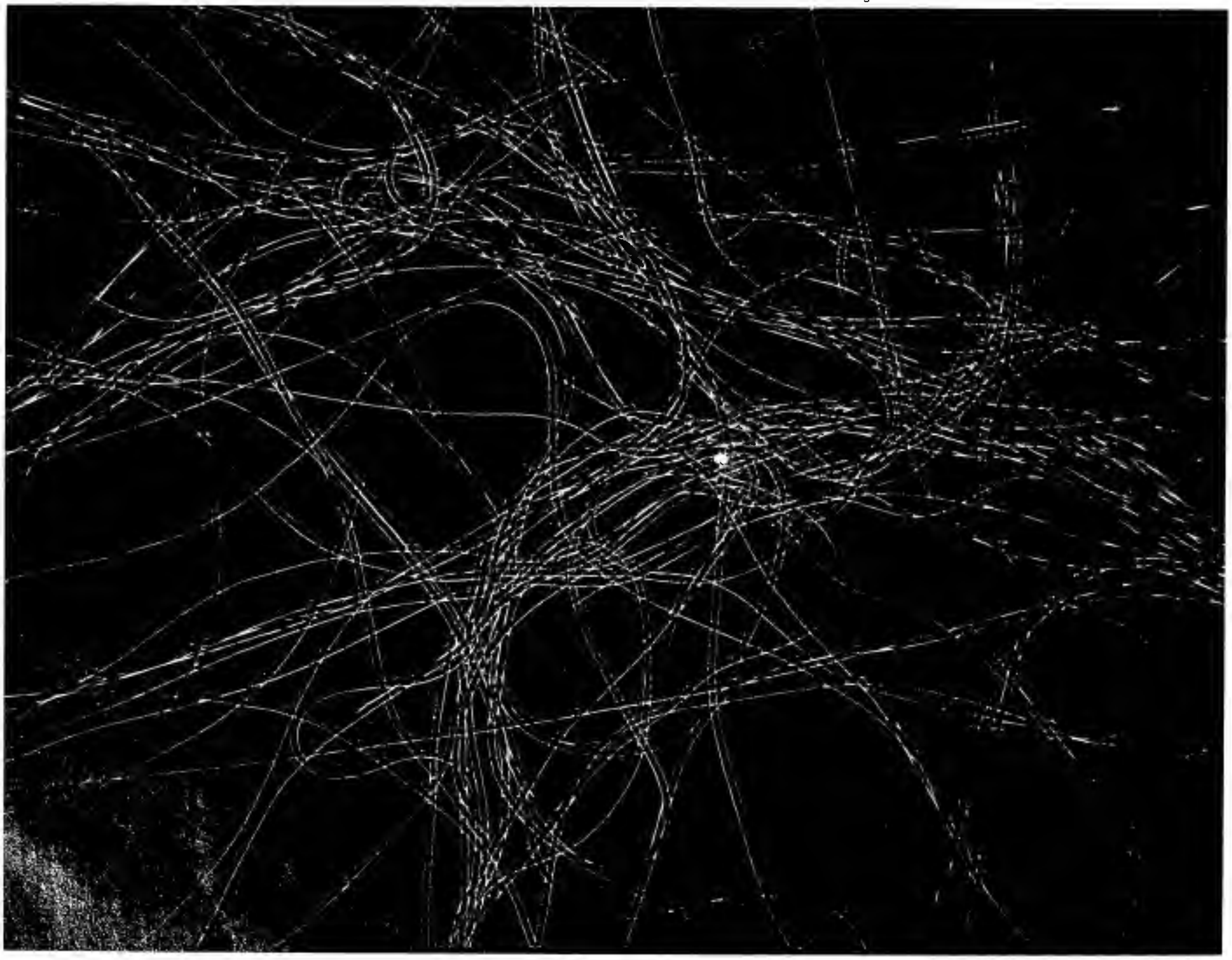
We live on an ever changing planet, where stability—as much as humans might yearn for it—has no place. With every change may come disruption, or even extinction, for some forms of life. For others, however, change may mean opportunity. The result of all this dynamism has been more than just a constantly changing cast of characters. Environmental change, along with the opportunities it brings, has created an expanding Earth, not literally a growing planet but one where the range of environments available for colonization has increased enormously over time and where beneficiaries of one change have been the progenitors of the next.

To appreciate the biological importance of the expanding environment, one must take the long view of evolution, looking at how ecosystems have developed over the full extent of the earth's history. Wanting to see what this planet might have been like four billion years ago, and lacking a time machine, I took a trip to the North Pole. The trip was hot, dusty, and bone-jarringly bumpy; only skillful driving prevented collision with the kangaroos encountered en route, for this particular North Pole is in the remote outback of western Australia. There, in the hills beyond an isolated sheep station, are 3.5-billion-year-old chert and lava formations. The sediments they contain help us put together a picture of the primordial earth.

Then, as now, oceans covered the globe, a gray green expanse broken by small continents and broad volcanic platforms that rose out of the sea, as Iceland does today. The North Pole sediments tell us that the chemical content of seawater was determined not so much by erosion from the land, as it is today, as by the circulation of water through vents in the ocean floor; the atmosphere contained abundant carbon dioxide and very little oxygen.

On such a planet, humans couldn't survive for an hour, but other organisms could—and did. Direct evidence of these early organisms exists in fossils of bacteria preserved in chert and in stromatolites (distinctively layered, often dome-shaped

Once cyanobacteria (here a living form magnified 100 times) began producing oxygen as a byproduct of photosynthesis, more than a billion years passed before the atmosphere contained enough of the precious element to allow the evolution of oxygen-dependent organisms.
Dwight R. Kuhn




"I got the take home size."

About 2.8 billion years ago, cyanobacteria formed the distinctive layers visible in this stromatolite from the Nullagine Range in Western Australia.
Reg Morrison

structures formed by cyanobacteria and other microbes). Indirect evidence of life exists, too. Carbon atoms come in two stable forms that differ by a single neutron. Because photosynthetic organisms preferentially incorporate the lighter form, they have a chemical signature that can be read even in the carbon preserved in North Pole rocks. This view of early life on Earth, although fragmentary, is enough to show that three billion years before trilobites first graced the oceans, life existed in the form of complex microbial communities.

Some of the organisms that evolved in our planet's long infancy are still with us. In the damp mud of swamps, deep in the Black Sea, at the mouths of hydrothermal vents and elsewhere in the oceans, and even in our own digestive tracts, oxygen-free environments harbor bacteria whose physiologies evolved to exploit the ancient North Pole habitats and other primeval seas. Those survivors from a bygone world suggest that the earth's very earliest biota comprised bacterialike microbes that lived in hot, oxygen-poor environments and derived their energy from chemical reactions or the fermentation of organic molecules. Early on, some lineages evolved the ability to use energy from sunlight to drive the formation of organic matter from carbon dioxide dissolved in seawater. This innovation—photosynthesis—was ecologically liberating and enabled life to cover the globe.

Most photosynthetic bacteria rely on hydrogen sulfide and similar molecules for the electrons needed in photosynthesis; but one lineage, the cyanobacteria, learned to use a much more common substance—water. As a result, cyanobacteria, the blue-green scum in birdbaths and ponds, became the most abundant producers of organic matter on the planet. And because they produce oxygen as a byproduct of photosynthesis, these tiny organisms set a new course for the earth's environmental history, paving the way for the many kinds of creatures, including humans, with oxygen-dependent, or aerobic, metabolism.

But the oxygen revolution didn't happen quickly. Cyanobacteria may have begun releasing oxygen into the atmosphere as early as three and a half billion years ago (at the time of the North Pole sea), but signs of atmospheric change first show up in soils formed about 2.1 billion years ago. By that time atmospheric oxygen had passed a crucial threshold, from less than about 1 percent of present-day levels to 10 percent or more. The implications of this change are enormous: Above 1 percent of today's level, the atmosphere contains enough oxygen to allow the evolution of aerobic organisms. Also at the higher levels of oxygen, stratospheric ozone (itself a form of oxygen) effectively shields the earth from lethal ultraviolet radiation.

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oxygen-enriched atmosphere are evident if one examines evolutionary trees that depict the genealogical relationships among living organisms. Lower branches of the tree of life are populated by organisms that cannot utilize oxygen in their metabolism; in fact, for many, oxygen is toxic. Species higher up on the tree of life are able to use oxygen in respiration, the energy-yielding process in which organic molecules are broken down into carbon dioxide and water. In the new environments created by the oxygen revolution, bacteria diversified to form many of the aerobic lineages that are ubiquitous on the modern earth. More ancient, anaerobic microbes retreated along with their environments, from which they continued to play a central role in the cycling of carbon and other elements through ecosystems.

The earliest organisms were prokaryotic—simple cells whose genes do not reside in a membrane-bound nucleus. But at some point, other kinds of organisms evolved. These newcomers were eukaryotes, organisms with a clearly defined nucleus. These nucleated organisms—which now include protozoans, algae, fungi, plants, and animals—evolved before the oxygen revolution took hold, but were probably only a minor part of early communities. Oxygen got eukaryotes started on the road to ecological prominence, not because they evolved respiration themselves, but because they swallowed bacteria that had. Some aerobic bacteria became symbiotically incorporated into nucleated cells, in time evolving into mitochondria (energy-producing organelles in the cells of most modern eukaryotic creatures). In China, North America, and Australia, fossils and distinctive biomolecules in ancient rocks, from 1.9 to 1.7 billion years ago, document that eukaryotic organisms had become significant participants in marine ecosystems.

The oxygen revolution expanded the range of terrestrial environments enough to accommodate eukaryotic protozoans and algae, but not enough to support the biology of our own kingdom, Animalia. Animals, and their tracks and trails, are conspicuously absent from the geological record until about 600 million years ago. In 1959, J. R. Nursall, of the University of Alberta, suggested that animals appeared so late in the evolutionary day because until then there was not enough oxygen to support their metabolism. Only in the last few years have we accumulated geological evidence to evaluate his idea.

At oxygen concentrations significantly

above those reached 2.1 billion years ago, fossil soils do not provide a firm guide to atmospheric composition, and thus we are unable to measure oxygen levels directly. Fortunately, however, we can look for evidence of environmental processes capable of affecting the amount of oxygen in the atmosphere. Principal among these is the burial of organic matter in the sea floor by sediments. When organisms die, they decompose. Normally, the amount of oxygen produced in photosynthesis is balanced by the amount of oxygen consumed by respiring organisms, including decompsers. Burial, however, shields organic remains from respiring organisms, thus disrupting the balance of oxygen production and consumption and—if enough organic matter gets buried—tipping the balance toward production. Second is the conversion of sulfate ions (abundant in seawater) to oxygen-free forms of sulfur that accumulate in sediments as pyrite, also known as fool's gold. Every time a sulfate ion combines with a metal in seawater to produce a sulfide ion, two molecules of oxygen are freed. The geological history of these processes is written in the language of isotopes, the variants in atomic composition exhibited by individual elements.

A decade ago, my colleagues and I chanced on a telling fragment of this record near the other, better-known North Pole. Limestone from the Arctic island of Spitsbergen contained distinctive isotopic compositions of carbon and strontium that hinted at large-scale global change between 750 and 550 million years ago. Since then, we have sampled sediments from around the world, and they all tell a consistent story. Just prior to the radiation of large animals, tremendous amounts of organic matter (the remains of dead organisms) were buried beneath shallow seas. The high rates of organic carbon burial are related to rapid sediment accumulation, as shifting tectonic plates built both major mountain chains and new ocean basins. Recently, Gerry Ross, of the Canadian Geological Survey, has shown that the balance of the sulfur cycle shifted at the same time, depositing unusually large amounts of pyrite in deep-sea sediments.

As a result of these events, the environment must have expanded once more, adding a richly oxygenated surface layer—the atmosphere—in which the manifold physiological needs of large animals could be met. The Phanerozoic eon—the age of visible animal life that continues to the present—was ushered in. The first animals to appear in the fossil record include the relatives of such simple modern creatures as sea anemones and jellyfish, as well as unusual forms not easily related to living groups. Bilaterally symmetrical organisms—simple worms—are also represented by thin trails preserved in the sediments. By the beginning of the Cambrian period 545 million years ago, these early faunas had been superseded by diverse associations of complex animals that included the trilobites, mollusks, annelid worms, and invertebrate representatives of our own phylum, the Chordata.

Over the past 545 million years, the earth's repertoire of physical habitats has remained relatively constant. Environmental diversity, however, has continued to grow, and ever more rapidly. This time, the driving force has been not physical but biological: life itself has become an increasingly dominant aspect of environments. Cyanobacteria, by producing oxygen, may have provided new environments for future organisms; in the Phanerozoic, one organism can actually become, or create, the environment for another. The colonization of dry land by plants, for example, created a broad range of new habitats, making possible the emergence of diverse terrestrial communities (*see* "One Giant Step for Life," page 22). Vegetation provided both food and shelter for arthropods and, later, vertebrates. Novel compounds synthesized by the plants supported new types of bacteria and fungi, including those that digest wood. Many insects evolved in symbiotic partnership with flowers, while mammals and birds developed features that enabled them to harvest fruits and seeds. Jonathan Swift's doggerel proclaiming that "a flea hath smaller fleas that on him prey" is apt, as evolving animals have supplied food and living space for a panoply of other creatures. In our own case, these include the mosquitoes that extract our blood, the tapeworms and bacteria that reside in our intestines, and the protozoans that cause malaria and other scourges of our species.

In the conventional view, which emphasizes individual lineages of plants and animals, evolution appears to be a process of replacement. New species evolve in succession, each occupying a particular habitat and persisting until something comes along that can do the job better or (more commonly) until environmental disruption brings extinction.

The long view of evolution, however, persuasively argues that biological diversity is cumulative. The earth and its biota have evolved in concert, with environmental expansion repeatedly engendering biological novelty. New species do not simply replace old ones. Rather, new types of organisms depend directly or indirectly on those that came before, and even the most intricate ecological edifices of the modern world rest on a microbial foundation formed billions of years ago.

Animals, such as this 565-million-year-old Inkrylovia *from Russia, evolved relatively recently (compared with bacteria, which have a 3.5-billion-year-old history). They could not appear until the atmosphere contained enough oxygen to meet their metabolic needs.*
Andrew Knoll

One Giant Step for Life

Simple, law-abiding plants led the invasion of hostile lands

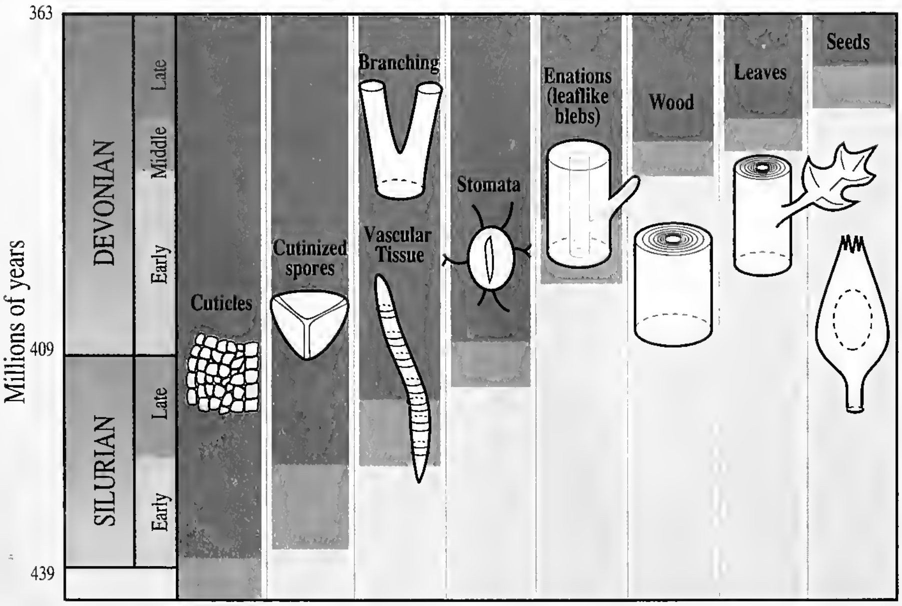
by Karl J. Niklas

In H. G. Wells's 1895 tale *The Time Machine,* a scientist travels into the future to a near-lifeless earth slowly circling a dying sun and finds "intensely green vegetation...the same rich green that one sees on forest moss or on the lichens in caves: plants which...grow in a perpetual twilight." Ironically, this melancholy description of life's closure adequately describes the earth when life first colonized the land some 440 million years ago. Plants were the very first forms of life to migrate onto land, and by providing food and creating a more humid and sheltered environment, they paved the way for the later colonization of land by animal life.

Although all life began in the oceans, the first land plants came from freshwater environments. The transition from water to land was long and complex and one of the greatest adaptive events in the history of life. The fossil record shows that the transition involved two phases that collectively lasted about 75 million years.

The first phase got under way about 439 million years ago, when comparatively small and structurally simple plants, resembling today's algae, began to colonize the land. During this time numerous adaptations evolved. Among the most important was the capacity to produce a cuticle, a layer of waxlike material coating the external surface of the plant body. The cuticle is not required for life in water, but it is the sine qua non of a land plant. Pores, or stomata, in the cuticle were another essential development, since plants need atmospheric gases for respiration and photosynthesis. (Neither nature nor the best chemists have invented a material that is both permeable to oxygen and carbon dioxide yet impermeable to water.) Flanking the stomata on most land plants are highly specialized cells that can change their size and shape depending upon the availability of water. By regulating the diameter of stomata, they can control the rate at which water vapor is lost from plant tissues to the air. The oldest currently known fossil land plants with cuticles, stomata, and guard cells are from very ancient rocks dating as far back as 410 million years. Another important adaptation was the evolution of plant spores with cutinized walls that reduced water loss and afforded mechanical protection as well.

The second phase of land-plant evolution started about 410 million years ago with the appearance of larger, more complex plants with tissues made up of cells that conduct water and sap throughout the plant body. Vascular tissues are the anatomical hallmark of the majority of the plants most familiar to us—ferns, pine trees, and the flowering plants.



Requirements for Leaving the Water: For plants, life in air first demanded cuticle, stomata, and—as they became larger—vascular tissue.
Diagrams: Karl Niklas and Joe LeMonnier

All these modern plants, no matter how complex, trace their evolutionary history to the very first vascular plants, and their diversity is the consequence of a remarkably rapid evolutionary specialization. Within only fifty million years, or approximately 12 percent of the entire history of vascular plant evolution, virtually every major plant group currently represented in modern world floras evolved.

This great taxonomic explosion, rivaling that of the Cambrian explosion of animals (*see* "Life's Expanding Realm," page 14), occurred during the Devonian. Flowering plants, which dominate today's world floras, had not yet appeared by the end of the Devonian, about 360 million years ago. Comparative latecomers, they made their first appearance in the fossil record only 125 million years ago, during the Cretaceous period.

That the initial colonization of the land by plants took longer than the subsequent radiation of vascular plants is not surprising. In many ways, life on land presented huge difficulties for aquatic organisms. It meant giving up unlimited access to water, essential for the growth and reproduction of every type of organism. It also meant coping with the compressive effects of gravity on body mass. (Water is roughly a thousand times denser than air and affords aquatic plants and animals a "mechanical cushion" against the force of gravity.) Indeed, we may well wonder why the land's surface was colonized at all. Although we may never know the answer to this question, applying a little physics and chemistry provides some clues.

Two simple facts tell us that plants had something to gain by leaving the water. First, water absorbs and attenuates sunlight, upon which all plant life depends. Second, the need for carbon dioxide and oxygen—the basic metabolic requirements of plants—is better met on land than in freshwater.

A basic law of physics—Bouguer's law—shows that the intensity of light decreases exponentially as light passes through a column of water. That is, if 50 percent of the available light energy is absorbed by the first centimeter of water, then it is weakened yet another 50 percent by the second centimeter, and so forth. Also, the quality of light changes as it penetrates the water column. Because wave-

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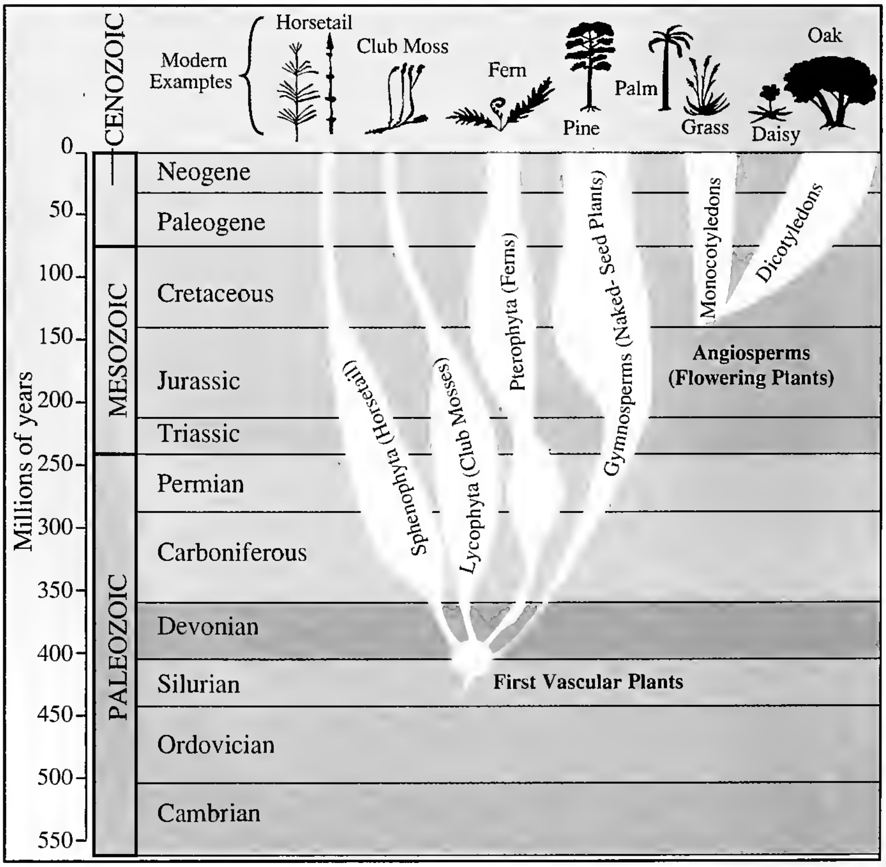
lengths in the red end of the spectrum diminish more quickly than others, the efficiency of photosynthesis is reduced. This limits the depth to which plant life can sink before the rate of photosynthesis fails to match the rate at which plants consume the foods they manufacture from sunlight and raw chemicals. This equilibrium, known as the compensation point, varies among plant species, thereby permitting different types of plants to grow at different depths in oceans and deep lakes.

Yet another physical law demonstrates that life in freshwater is harder than life on land. Fick's law shows that the rate at which carbon dioxide and oxygen diffuse into cells depends upon a physical property called the diffusion coefficient. The higher the numerical value of the coefficient, the greater the rate of diffusion. Importantly, the diffusion coefficients for carbon dioxide and oxygen dissolved in water are significantly lower than they are in the air. Thus, all other things being equal, carbon dioxide and oxygen take a longer time to enter the cells of plants in freshwater than to enter those on land.

Fick's law and a few rules of elementary geometry also tell us that since gases don't diffuse well into aquatic plants, the best shape for a plant is one that will maximize its surface area in relation to its volume. In other words, to get enough gases for its internal needs, an aquatic plant needs either to remain very small in size or to adopt "high surface area" shapes. Examples are long, cigar-shaped plants or broadly flattened, leaf-shaped plants, such as sea lettuce.

Finally, all these lessons about the physical properties of water and gases can be used to construct a scenario for the colonization of the land by plants. Their small size (dictated by Fick's law) conferred ecological and evolutionary advantages on aquatic plants. Small organisms grow and reach sexual maturity more rapidly than their larger counterparts. Therefore, they can live in ecologically changeable habitats. Also, small organisms, with their comparatively rapid life cycles, tend to have higher mutation rates and, as a very general rule, evolve more rapidly than larger organisms. Thus, small plants growing just below the surface of ancient freshwater lakes or water-saturated soils likely multiplied rapidly and had high mutation rates—features that conferred many advantages when water levels periodically dropped. Only those plants capable of enduring short-term water deprivation and brief exposures to the air could survive



The Great Plant Explosion: The diversity of today's land plants is the result of a remarkably rapid period of diversification in the Devonian.

and serve as the source for future genetic variation and evolutionary innovation.

Continued genetic "trial and error" eventually led to adaptations permitting plants to survive longer and longer periods of exposure to the air and culminating in plants with cuticles, stomata, and cutinized spore walls. This scenario also explains why these early, nonvascular land plants are not often found in the fossil record. Not only are small organisms likely to be overlooked; they are also not likely to be preserved, particularly in dynamically changing freshwater habitats, such as those proposed here as the cradle for early land plant evolution.

When the second, rapid phase of land-plant evolution began with the appearance of vascular tissues, it was attended by an overall evolutionary increase in plant size and height. Larger plants are not only more efficient at conserving water on land; they also can produce more spores and elevate their reproductive and photosynthetic organs above shorter neighboring plants that are competing for the same resources (water, sunlight, and space).

The increase in plant size and height was likely the outcome of a biological arms race in which the weapons were extensive root systems to absorb water, a canopy of leaves to intercept all the available sunlight, and tall, robust stems capable of elevating and dispersing reproductive organs far above, and away from, the interference of neighboring plants. This increase in plant size required vascular tissues through which water and other nutrients are rapidly transported from one part of a plant to another. And because vascular tissues are very strong and comparatively light in weight, their mechanical properties are ideal for building very tall structures. Indeed, many biologists tend to forget that the largest organisms that ever lived are trees. Built of vascular tissue—wood—the largest modern sequoia is taller (longer) and more massive than any whale or dinosaur!

Although they do not have access to H. G. Wells's time machine, evolutionists can draw on a wonderful fossil record—documenting more than three billion years of biological history—for an understanding of the mutability and adaptiveness of life in response to the physical challenges posed by constantly changing environments. They also benefit from knowing that the outcome of evolutionary experiments must comply with the laws of physics and chemistry, as well as the rules of geometry.

Evolution

A Spinal Column

Who's winning: Big, smart humans? Small, dumb mice? Or chiropractors?

by Roger L. Welsch

Folklorist Henry Glassie quotes the Appalachian mountain man who, when asked about the history of his region, responded, "First there was the dinosaurs...and then Daniel Boone...and here we are!" The breadth of that view is hard to beat, but paleontologists at the American Museum of Natural History hope to meet the challenge. Between now and 1996, the Museum will open six exhibition halls filled with fossils that illustrate the evolution of vertebrates, or animals with backbones. This is a massive undertaking, even if it excludes Congress. According to a new Museum guidebook, vertebrates include, for example, sharks, salamanders, lizards, kangaroos, and horses. Phew, imagine the surprise of the kangaroos when they show up at their 500-million-year family reunion and get a look at those relatives!

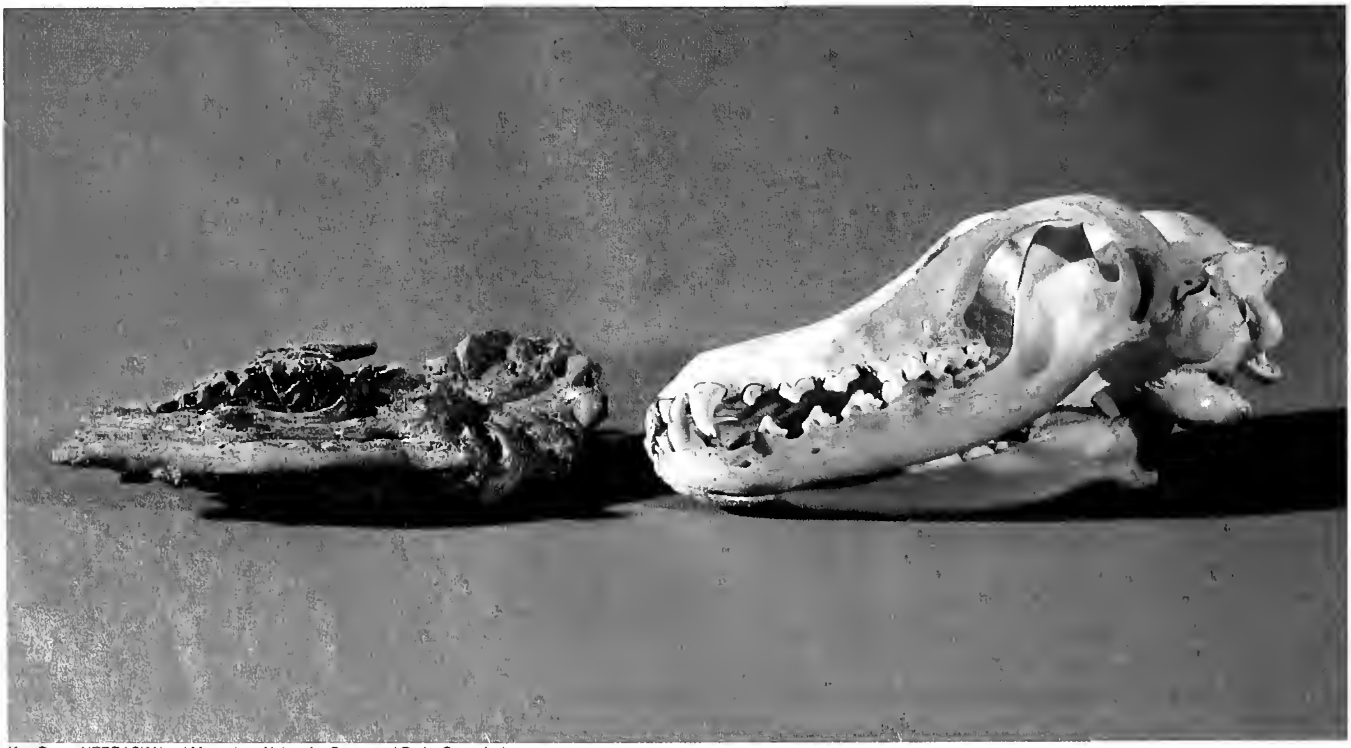
The first two halls that are opening, states the guidebook, "feature the group to which humans belong, mammals and their extinct relatives." To my mind, those tacked on words—"and their extinct relatives"—represent the most mysterious branches of the evolutionary tree. Why did some family lines continue and change, while others died out?

I don't keep up with the finer points of the biological sciences beyond what I read on the front cover of the *National Enquirer* while I am waiting at the grocery store checkout counter ("Stranded Alien Fathers Child of Zsa Zsa Gabor!"). But it's my impression that trying to find logic or pattern within the processes of natural selection is right up there with following a teen-age daughter's explanation of why she missed her curfew.

Turtles make sense to me. Years ago, a friend of mine who operated a gravel-pit pump came roaring into my yard, excited because he believed he had dredged from his Pleistocene glacier rubble a petrified human brain. At first glance I recognized that what he held in his hand was not a brain but a turtle, turned to limestone millenniums ago. I could even recognize what kind of turtle it was—a Blandings or some mighty close relative. Turtles represent evolution at its best, a creature built to last. I've watched coyotes and cows paw at closed turtles and tortoises without damaging them. Flood, drought, fire, famine, isolation...turtles take them all in slow but steady stride. Little wonder that turtles have survived.

Now, explain to me how the opossum has made it this far, right along with the Blandings turtle. The moment the first possum fainted away in terror upon encountering a coyote, the possum should by all reason have become extinct. But not ten days ago, Lovely Linda came in to tell me some savage creature was asleep in the chicken house, and when I went out to investigate, there he was—ol' possum, terrified into a coma by a rooster. Pink-nosed, pink-toed, and utterly defenseless, he was a generous lunch for anyone so inclined.

The fossil skull of a coyote (left) was found crushed beneath the bones of a mammoth. The coyote may have been standing too close to the dying mammoth when it fell or when its carcass shifted. A modern skull (right) is intact.



Ken Bouc, *NEBRASKAland Magazine;* Nebraska Game and Parks Commission

No pattern or logic there in that survival.

Another example is one of my favorites among the paleontological treasures at the University of Nebraska State Museum. I was fascinated by the specimen when I first saw it thirty years ago, and just last month I stood before it again, no less awed. The central element of the exhibit is the fossilized remains of two gigantic mammoths. Their huge tusks locked in eternal battle, the great creatures died staring into each other's eyes. They stood there in their last moments, magnificent creatures to the end. And, as such things go in biology, they were not alone.

A coyote watched as the drama unfolded. From experience, he knew what was happening. I have tried to imagine what must have gone through that coyote's mind: "Never again will I have to eat a grasshopper or mouse. There is enough meat in these two beasts to last me the rest of my life. I'll just eat my way into one of the carcasses and spend the rest of my life in there eating and sleeping, sleeping and eating. Is this going to be great or...."

At this point, however, the unfolding drama took a twist. The great mammoths staggered a little too quickly, a little too far in the wrong direction and fell—right on the coyote. And there the coyote's fossilized skull is squashed flat, right under the bones of the mammoths.

Dead mammoths, dead coyote. But consider this: the coyote—puny and eminently squashable—persists right here on the same Plains where his ill-fated ancestor died, while the mammoth has become extinct, along, so far as I can tell, with cheap electricians and reliable plumbers. The mammoth is gone and the coyote thrives. It makes no sense.

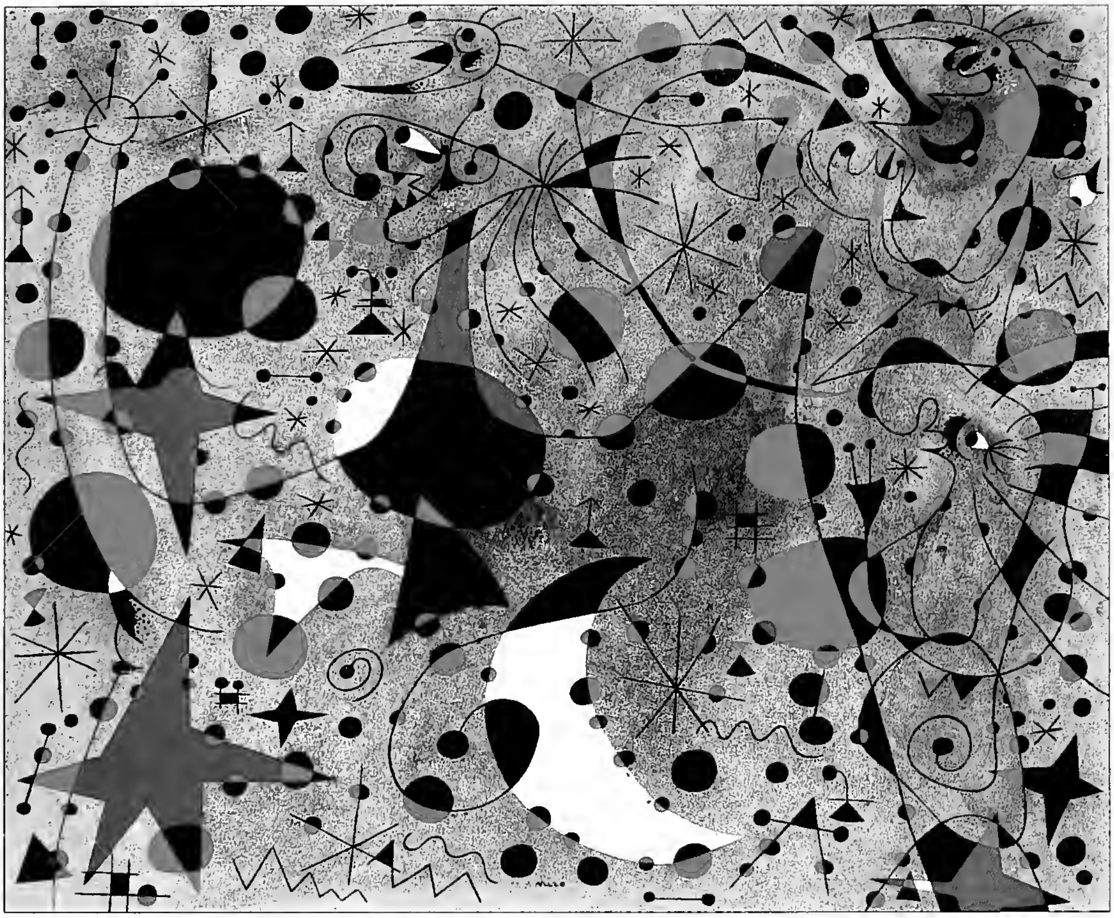
I think of that mystery every time I see a road-kill coyote along the highway: "Wow, if things had gone the other way around, this would definitely be a good place to own an auto body shop!"

Horses were here, and then horses were gone, and then horses were here again. What's that all about? We're big and smart, mice are little and dumb, mosquitoes are even smaller and even dumber. So who do you think is winning the evolutionary survival game within that trio? See? It makes no sense at all. The brightest and biggest—whales, elephants, rhinoceroses—are all threatened; the dumbest and most humble of us are apparently doing just fine (there was another possum in the chicken house this morning).

And yet there is change, there is cause and effect, there are valid conclusions. There is, for example, within the family tree of vertebrates, evidence of the workings of evolution. Vertebrates, we can safely say, unquestionably gave rise to chiropractors.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

The Games Species Play



Joán Miró, *Le Chant au Rossigne à Minuit et la Pluie Matinale;* © 1994 Artist's Rights Society; Perls Galleries, New York

In the good old days—say a century ago, give or take a few decades—scientists had a clear understanding of the evolution of life. Inspired by Charles Darwin's view of the role of natural selection, they argued learnedly about the survival of the fittest and the immutability of species. These radical ideas even moved into social and political realms—sometimes with ugly consequences. But life, in all its complexity, doesn't follow the clear-cut rules we are inclined to draw up for it. And good science never stops looking, questioning, learning, and challenging even its most sacred concepts. Scientists, with tools of high technology (as examples, they can now decode a gene, watch a cell battle an intruder on its membrane, trace an element through a complex food chain) and aided by the vast accumulation and circulation of knowledge (the electronic information highway is the latest gimmick, but universal postal service, fast printing presses, and cheap photocopiers weren't shabby innovations, either) are indeed making progress in understanding how life works. The following studies (selected from thousands of equally intriguing possible topics) reveal some of that progress and the continued significance of the Darwinian perspective. They also show that biological science is still the most exciting game on the face of the earth.

Evolution

Feminist Bacteria of Ladybird Beetles

A dose of antibiotics can clear up many problems, including a biological puzzle

by Gregory Hurst and Michael Majerus

Like humans and many other animals, the two-spotted ladybird beetle tends to produce sons and daughters in approximately equal numbers, sex being determined by the genetic constitution of the father's sperm. Fifty years ago, however, Ya Ya Lus—a Russian scientist breeding ladybirds in the attic of his house—noticed that some females produced mainly daughters. Intriguingly, these females also laid many eggs that simply failed to hatch. Lus performed an analysis of this odd phenomenon and showed that the mother, not the father, was apparently responsible for the plethora of daughters and that the dearth of sons was due to the death of male embryos early in their development. Unfortunately, with the information available to him, Lus was unable to determine how this strange state of affairs came about.

The story of male ladybird mortality was recently taken up in the United Kingdom, where field research into the mating preferences of these beetles had turned up similar skewed sex ratios and where breeding experiments in the lab had determined that, as in Lus's attic, females were behind the superabundance of daughters. And, as Lus had also noted, only certain ladybird "families" were involved. To find out more, we began our real detective work.

Genetic material in the nucleus of a cell comes from the mother and father in equal proportions, but there is far more to an organism than its nuclear genes. In fact, the vast proportion of any new individual is made up of cytoplasm, all the protoplasm in a cell outside the nucleus. This cytoplasm also contains genetic material. In most kinds of organisms, a new embryo is formed following the fertilization of an egg cell (which contains large amounts of cytoplasm) by a spermatozoon (which contains very little). The genes in the new organism's cytoplasm thus come almost exclusively from its mother.

Cytoplasm genes are less numerous than nuclear genes, but they may be of many types. Some, such as mitochondria, may be essential to such basic cell functions as energy production. Other genes may come in the form of viruses, protozoans, or bacteria that live and reproduce in the cytoplasm of their host cells and are passed along with the rest of the genetic material in the reproductive cells of their host.

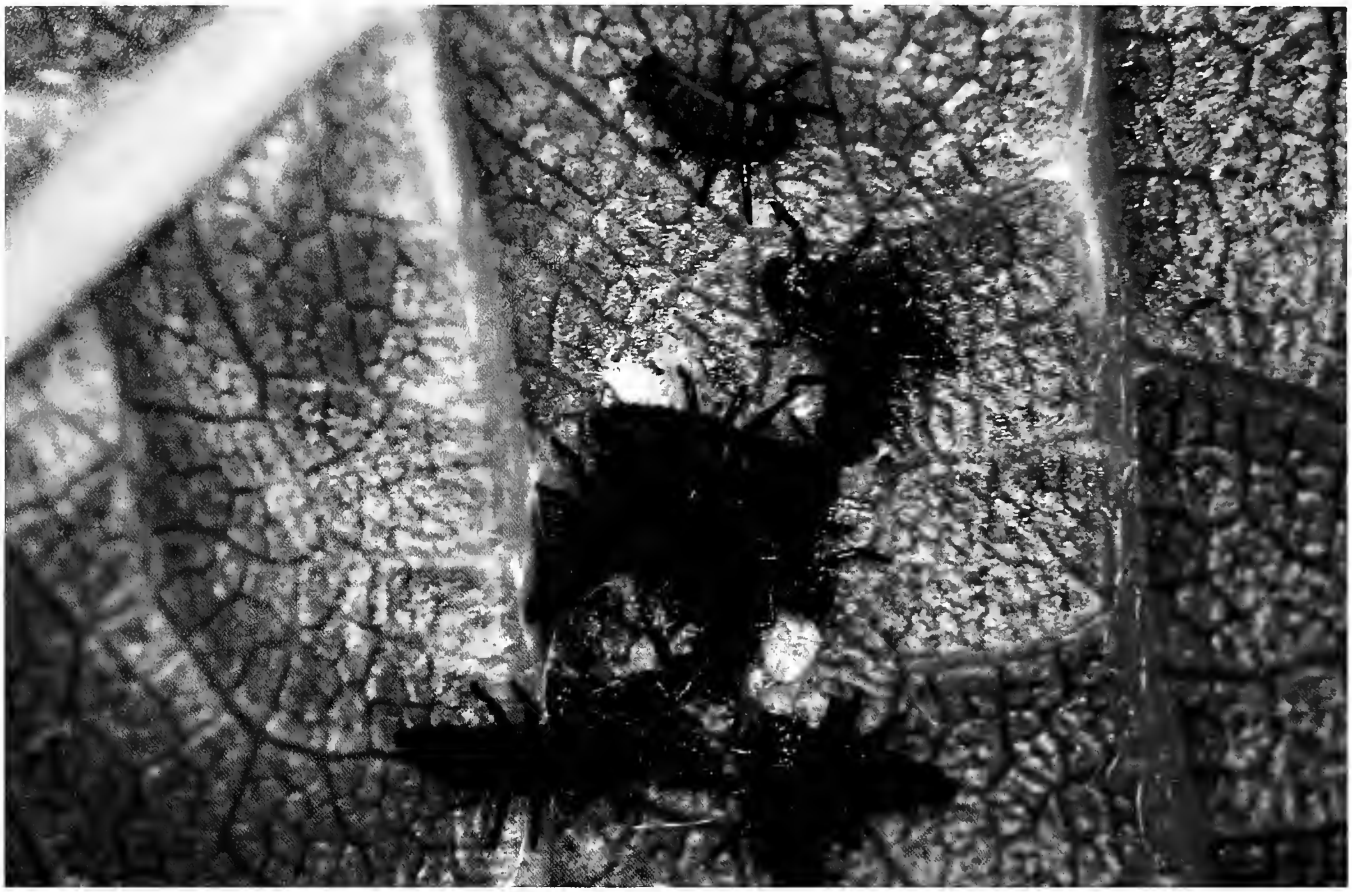
As we set out to track down the killer of our male ladybird embryos, we followed the scientific dictate, "Do easy, cheap experiments before difficult, expensive ones." And since previous work by others had turned up male-killing bacteria in other situations, we adopted an approach familiar to physicians: "If there is a suspicion that the problem is caused by bacte-

The typical two-spotted ladybird beetle is a rich red with two black spots. Dark individuals, however, are not uncommon and are as successful as their more traditionally colored conspecifics at finding food and mates.
Michael Majerus

ria, treat with antibiotics." Therefore, we fed our female ladybirds tetracycline in syrup (the best way to get ladybirds to take medicine).

Our frugal approach paid off. Almost immediately, the hatch rate of eggs laid by the treated females increased, suggesting that males were now surviving. And indeed, when we examined the offspring produced by these females, we found roughly equal numbers of each gender. Our killer appeared to be a bacterium. Microscopy subsequently corroborated this analysis, and further work by Jack Werren, of the University of Rochester, produced molecular confirmation: a bacterium, passed down from mother to daughter, had killed the sons.

Like any other organism, this bacterium should be trying to reproduce, to perpetuate itself. But in killing the males, it appears to be committing suicide. So what does the bacterium have to gain by such misandrous behavior? A great deal, suggests ladybird ecology. By killing male embryos early in their development, a bac-



As young larvae of the two-spotted ladybird disperse from their egg batch to seek aphids, they leave behind a jumble of egg debris. The yellowish remains are unhatched eggs that have been cannibalized.
Michael Majerus

terium may help insure the continued survival of its relatives, all genetically identical to itself.

Ladybirds lay clutches of about fifteen eggs, which hatch over a period of two to three hours. Any eggs that have not hatched within this time are eaten by siblings that emerged earlier; 5 to 10 percent of all ladybirds may die this way. The bacterium's actions reduce this cannibalism, at least on female embryos. Male embryos killed by the bacterium no longer pose any threat as cannibals and instead serve as food for their female siblings. They may even provide some protection for late-hatching females, which are less likely to be cannibalized when there are so many perfectly nutritious dead male eggs lying around for the taking. And anything that increases the survival of females—which, unlike males, can transmit cytoplasmic material—is, of course, also good for the bacterium.

The death of male ladybird embryos may have other, even more potent effects on female survival, however. Sibling egg cannibalism is common in ladybirds, probably because getting a meal early on in life greatly increases the likelihood that a ladybird larva will survive. The larvae are small (no more than 2 mm long) and born with scant energy reserves; without food, they will not live much more than a day. Newly hatched larvae feed on aphids, which they search out primarily by touch. If they do happen to bump into an aphid, their chances of capturing it are poor. The aphids are two to three times their size and have several defense mechanisms: they may kick the larvae away, run away themselves, or drop off the host plant to avoid capture. Many larvae die without obtaining their first aphid meal.

Cannibalism boosts energy reserves at this vulnerable stage, and any larva that gets a highly nutritious egg meal is more likely to last long enough to catch that first, crucial aphid. Having lots of dead male embryos around is an additional advantage; in such clutches, every female has, on average, at least one dead brother to feed on. Again, the dead males' sisters are not the only ones to benefit; the set-up is also advantageous to the bacterium living in them, for with the death of the males, the survival and propagation of the bacterium depends totally on that of the female ladybirds.

The bacterium thus seems to have worked matters out quite nicely: by killing males, the sex through which it cannot be inherited, it enhances the survival of females, the sex through which it can. But why has the ladybird beetle not died out for lack of males? After all, while the female beetles may not need many males to reproduce, they cannot do without them entirely.

As it turns out, uninfected individuals are being produced all the time, for a couple of reasons. For one, the bacterium is not perfectly transmitted from generation to generation: 10 percent of daughters are free of the infection. For another, a bacterium residing within a female inevitably uses some of its host food reserves for its own metabolism, thus reducing her fecundity and longevity. This, too, slows down the rate of bacterial transmission. Bad for the bacterium in the short term, this imperfect transmission is necessary for its survival over the long term. A completely successful bacterium, like a predator that wipes out all of its prey, would be doomed to follow its host to extinction.

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L E N O X. S I N C E 1 8 8 9.

Genetic Invasion of the Insect Body Snatchers

By controlling sex and survival, some parasites can turn their hosts into new species

by Jack Werren

My first encounter with a jewel wasp in the wild occurred along a roadside in the mountains of Utah. I had stopped to investigate a porcupine that had been run over several weeks previously. Flies had long since arrived and done their handiwork. All that remained of the original animal was skin, bones, and quills. Beneath the skin, thousands of fly larvae had pupated and were metamorphosing into adults. But another organism was doing to the flies what they had done to the porcupine. This was the jewel wasp, *Nasonia vitripennis*.

Small (about 3 mm long) and gnatlike, the jewel wasp is unremarkable to the naked eye, but seen through a microscope, it is a beauty. Its finely faceted body shimmers with iridescent colors that change with the angle of light. A female jewel wasp seeks out fly pupae and kills them by injecting them with venom. She then lays twenty to forty eggs in each fly puparium. The eggs hatch into larvae one to two days later and begin to devour the meal provided by their mother. In about two more weeks, the adult wasps emerge. The short-winged, flightless males mate and die in the patch of fly pupae they were born in. The newly emerged winged females fly off immediately after mating in search of fresh fly pupae in which to lay their eggs.

What originally attracted me to these creatures was the female's ability to control the sex of her offspring. In wasps, bees, and ants, males develop from unfertilized eggs and are haploid (that is, they have just one set of chromosomes, inherited from the mother), whereas females develop from fertilized eggs and are diploid (with two sets of chromosomes, one from each parent). After mating, the female jewel wasp stores sperm in a special organ called a spermatheca. This organ resembles a balloon with a strawlike tube at one end; attached to the tube is a muscle that can either straighten out and allow sperm to pass to the egg (resulting in a daughter) or can crimp the tube and block the sperm (resulting in a son). How many daughters a female produces depends on a number of factors, including whether she is the first wasp to lay eggs in a fly pupa (in which case she'll lay mostly daughters) or the second (in which case she will lay more sons).

Despite the female's impressive ability to influence the sexual identity of her progeny, her control is far from complete. The jewel wasps, like the porcupine and the fly larvae before them, are themselves victims of parasites. They harbor an assemblage of genetic parasites that can alter an insect's reproductive system for their own advantage.

The jewel wasp is not alone in this. As scientists have discovered over the last decade, virtually all organisms carry genetic parasites that perpetuate themselves at the expense of their host. Some of these parasites are bacteria "inherited" from one generation to the next through the host or-

These minute jewel wasps, seen here against grains of sand, are parasites that are themselves victims of parasitic bacteria and parasitic DNA.
Ed Bridges

ganism's eggs (*see* "Feminist Bacteria of Ladybird Beetles," page 32). Others are actual pieces of DNA that reside in the host organism's chromosomes. For example, in most organisms small, mobile pieces of DNA called transposons make and insert extra copies of themselves in the chromosomes of their hosts. Humans have hundreds of thousands of copies of a transposonlike element called Alu that makes up more than 5 percent of our DNA. This parasite is relatively benign, although every once in a while it causes a harmful mutation by inserting itself in the wrong place. Other organisms, such as mosquitoes, mice, and fruit flies, have parasitic chromosomes that are able to insure that they end up in all the host's reproductive cells, rather than just half, as would normally occur during meiosis.

What makes the jewel wasp unusual is the variety of genetic parasites it harbors and the severity of their effects. Not all individuals are infected with all these parasites at any given time, but among those commonly found are bacteria that kill male embyros; a second element (which we have not identified yet) that is transmitted only through eggs and that causes the wasp to produce nearly 100 percent daughters; and a bacterium called *Wolbachia* that prevents the development of hybrid offspring engendered by the mating of jewel wasps with wasps of closely related species. But the most remarkable piece of parasitic DNA found in the jewel wasp is the paternal sex ratio chromosome, PSR for short.

PSR is a killer chromosome. Diminutive—about one-fifth the size of a regular chromosome—it is found only in some males of the species. PSR hitches a ride in the spermatozoon along with the other chromosomes. Just as picking up human hitchhikers can sometimes be dangerous, sharing a sperm with PSR is fatal for its fellow travelers.

After an egg is fertilized, PSR destroys all the other paternal chromosomes, causing them to condense into a mass, which is eventually lost during development. PSR alone survives to join the maternal chromosomes within the egg. Without the fratricidal action of PSR, the egg would have been diploid, and the fertile embryo would have developed into a female. With PSR on board, the fertilized egg will remain haploid and produce a male. This sex change is advantageous for the parasite because PSR in male wasps is transmitted to 100 percent of the spermatozoa (and thus to the next generation). But PSR stuck in a female tends to get lost during meiosis and reaches significantly less than 50 percent of her eggs.

PSR is not only a killer of chromosomes; it is also a serial killer. In each generation, it becomes associated with and destroys a new set of chromosomes, converting females into males. Because this chromosome is so deadly, inevitably eliminating all the chromosomes with which it is associated, generation after generation, it is considered the most extreme example of parasitic DNA so far identified from any species.

Genetic parasites such as PSR challenge our basic concept of what an organism is. For example, PSR is part of the jewel wasp's DNA, but it is harmful to the rest of the genetic material. We now know that most organisms contain a variety of parasitic DNAs. Certainly an organism's genome is not a completely cooperative unit, as we used to think. There is conflict within the genome.

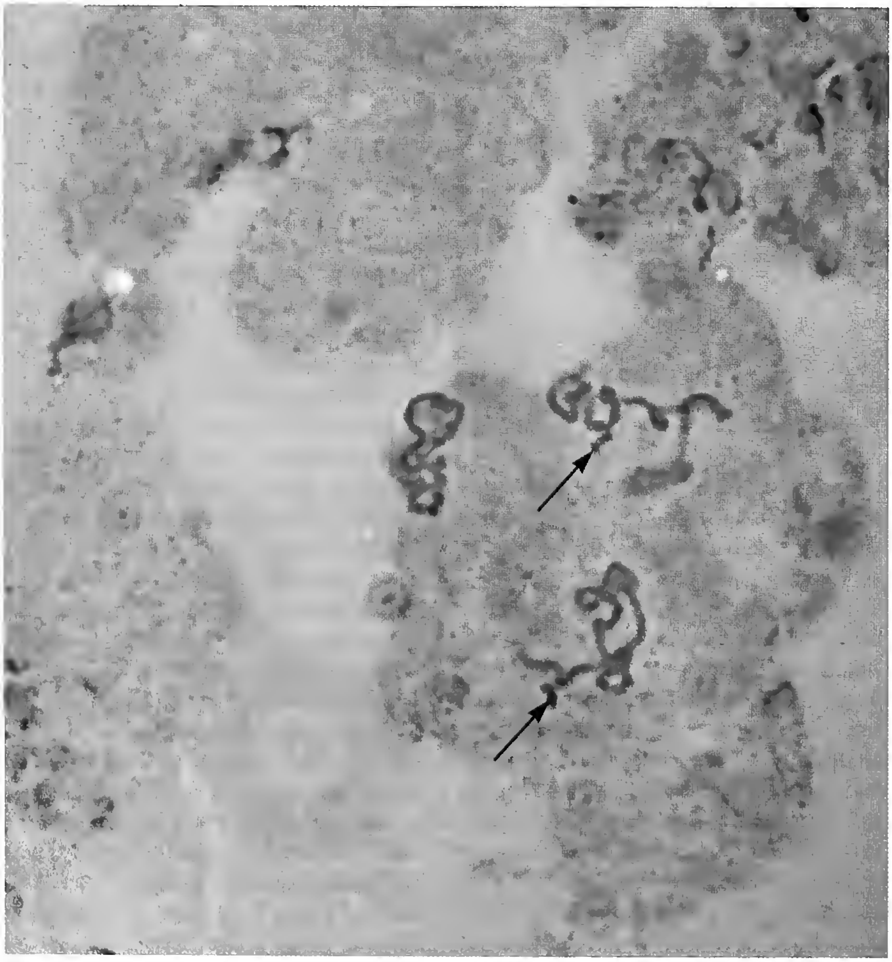
How does such genetic conflict begin? For instance, where did PSR come from? Trying to answer such questions brought me back, somewhat circuitously, to *Wolbachia*. All the jewel wasps I have collected from the wild carry these intracellular bacteria, which reside in cells of the male and female reproductive tract. The bacteria can be quite numerous: jewel wasps typically harbor one to two thousand in every egg.

At first glance, *Wolbachia* would appear to be simply going along for the ride. However, when we cure insects of the bacteria by treating them with antibiotics or arrange matings between insects carrying different strains of *Wolbachia*, we find that the bacteria exercise considerable control over the insects' reproduction. *Wolbachia* bacteria in a male's testes cannot be transmitted via the sperm, but they do modify his chromosomes, probably by producing proteins that bind to the sperm's DNA. Unless bacteria of the same strain are also present in the egg to undo this modification, the sperm-delivered chromosomes will fragment and be destroyed in the fertilized egg. For most insects, this results in the death of the embryo. In the jewel wasp, the outcome is less than lethal: it results in (haploid) males.

The bacteria benefit indirectly because eliminating the daughters of females who do not have the same bacterial strain actually increases the frequency of that strain in the population. By this mechanism, infected females can eventually predominate, as is seen in populations of jewel wasps and many other insects.

Some scientists have speculated that control by *Wolbachia* over the insects' reproduction may be important in the evolution of new species. A key step in speciation is reproductive isolation of populations, which allows them to evolve in divergent directions. If bacteria cause reproductive incompatibility between populations that once interbred, bacteria may also promote speciation.

In these developing jewel wasp sperm cells, the stubby, darkly stained PSR chromosomes (see arrows) lie next to the larger, lighter chromosomes that they will ultimately destroy.
Jack Werren



The situation in jewel wasps suggests this may indeed happen. *Nasonia vitripennis*, which lives throughout the world, has two close relatives in North America: *N. longicornis*, in the west, and *N. giraulti*, in the east. The cosmopolitan *N. vitripennis* overlaps with the two others in some places, making hybridization between them a real possibility. In our lab, we have found that while the three different species of jewel wasp will mate with one another, no hybrid progeny result. Closer examination reveals that chromosomes from sperm are chopped up into little pieces in the fertilized egg. However, when we cured the wasps of their *Wolbachia* infections and repeated the crosses, true hybrid progeny developed. In other words, reproductive isolation is "curable."

What does all this have to do with PSR? Occasionally in incompatible crosses a piece of chromosome survives the fragmentation process and is passed on to the next generation. Bryant McAllister, a graduate student in my laboratory, has found that DNA sequences on PSR are much more similar to DNA from *N. longicornis* than to DNA of the jewel wasp, indicating that PSR is an "alien chromosome" that came from the former species during an incompatible cross. One of the pieces of PSR DNA that McAllister has studied is itself a transposon, which makes it a piece of parasitic DNA on a piece of parasitic DNA, generated by a parasitic bacterium within a parasitic wasp. PSR may owe yet another debt to the *Wolbachia*—its ability to destroy chromosomes. We are now testing the possibility that PSR acquired the relevant genetic material from *Wolbachia* by genetic exchange during formation of the chromosome.

Wolbachia are turning out to be quite common in insects. During one trip to the rain forests of Panama, for example, I collected and examined more than a hundred species and found that more than 5 percent were infected with *Wolbachia*. Extrapolating to the global insect fauna, which is currently estimated to be at least five million species, an amazing 250,000 species may be infected with *Wolbachia*. Only time will tell whether these reproductive parasites are important in the evolution of new species, but the possibility is tantalizing. At any rate, I have had to give up my conception of an organism as a strictly cooperative unit. When I peer through a microscope these days, I am no longer even certain where one organism ends and another begins.

Bacteria Break the Antibiotic Bank

Drug-resistant genes are leaping across species boundaries

by John Maynard Smith

The brief era in which such infectious diseases as pneumonia, tuberculosis, and gonorrhea could be effectively controlled by antibiotics may be nearing its end. Strains of disease-causing bacteria resistant to penicillin and other antibiotics have rapidly evolved, and—even more unsettling—such resistance can often be passed from one type of bacterium to another.

Penicillin, for example, kills bacteria by binding irreversibly to enzymes (called penicillin binding proteins, or PBPs for short) that normally help bacteria manufacture cell walls. The penicillin bond puts the PBP enzymes out of action and thus prevents bacteria from synthesizing new cell walls. As a result, the bacteria die.

But bacteria can evolve resistance to penicillin in two ways. The first and most common method is for bacteria to arm themselves with ß-lactamase, an enzyme that breaks down penicillin before it can do any damage. The gene that codes for ß-lactamase is not actually part of the bacterial chromosome; it is carried on an accessory piece of DNA known as a plasmid. Plasmids, which are self-replicating circles of DNA, can travel from one bacterium to another, and from one kind of bacterium to another, across very wide taxonomic boundaries.

Almost all bacteria carry plasmids, which confer a wide variety of properties on their hosts, including the ability to metabolize unusual nutrients, to resist heavy metal ions and toxic substances, and to resist attack by viruses. Plasmids that encode for ß-lactamase probably originated a long time ago. Penicillin has been around for many millions of years, although its clinical use is new. It is manufactured by some soil fungi, presumably because it helps them to compete with soil bacteria. Most likely, a plasmid that permitted the production of ß-lactamase first evolved in a soil bacterium, and it and its host then proliferated because of the protection it conferred.

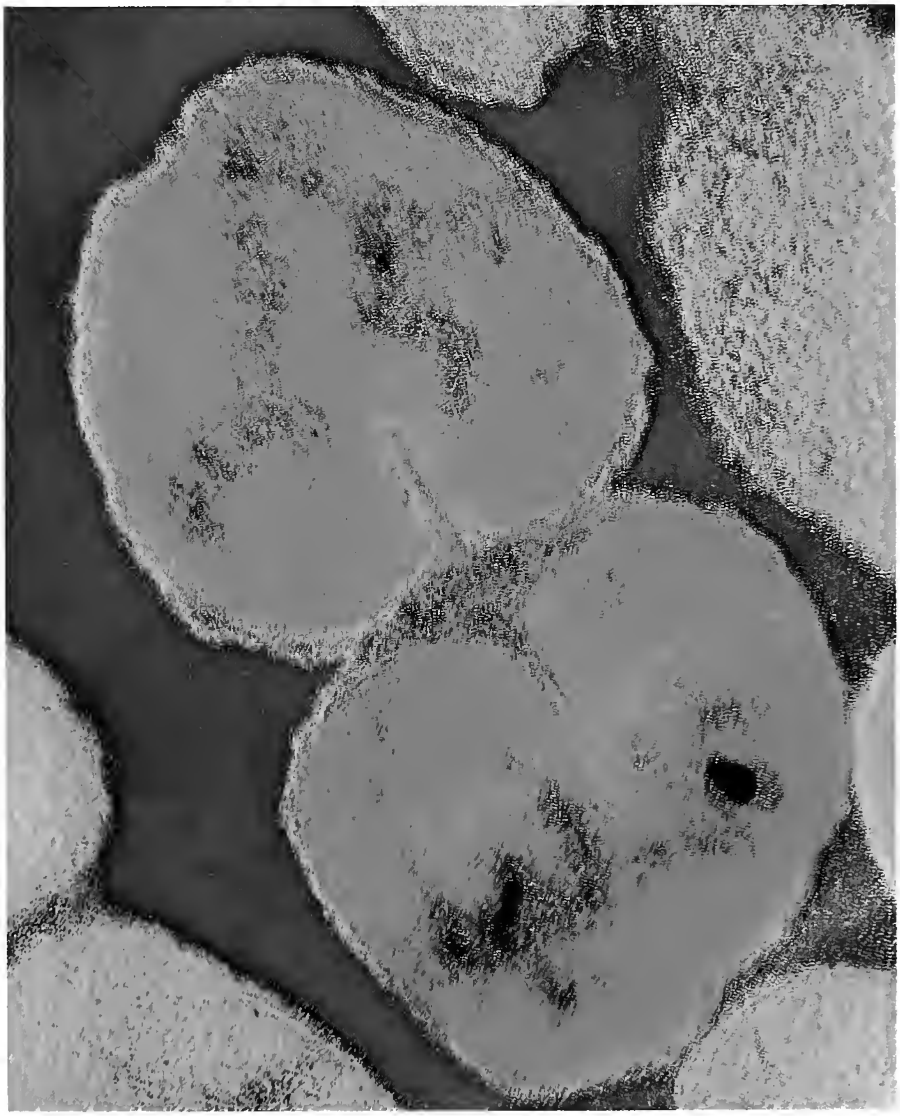
During the last fifty years, as a result of the widespread use of antibiotics, plasmids with the gene for ß-lactamase have been incorporated in most of the bacteria that live in humans. Acquiring plasmids that carry the genes they need is one way bacteria can evolve and become adapted to changed circumstances—in this case the increased exposure to penicillin. This is similar to the process of symbiosis, whereby higher organisms sometimes acquire new abilities by linking up with a partner—such as a bacterium, fungus, or alga—that has the necessary genes.

For example, the roots of peas and beans have bacteria that provide them with nitrogen in usable form, and heathers have fungi associated with their roots that enable them to live on nutrient-poor, acidic soils. Similar symbioses enable termites to digest wood and some animals to live in deep-sea vents. The difference between these examples and plasmids is that the symbionts of higher animals and plants were once capable of a free-living existence, and often still are, whereas plasmids are mere circles of DNA that could never have multiplied outside a cell. They apparently originated as pieces of bacterial chromosomes.

Most bacteria have evolved the ability to resist penicillin by acquiring a partner, a

Complicating the treatment of gonorrhea, some strains of the bacterium Neisseria gonorrhoeae *are no longer vulnerable to penicillin and certain other antibiotics. They have acquired their resistance by incorporating bits of DNA from other bacterial species—a process known as genetic transformation.*

Photographs CNRI/Science Photo Library; Photo Researchers



plasmid, that has the necessary gene. Plasmids that confer resistance to many other antibiotics are also now widespread. Some plasmids even carry genes that enable them to confer resistance to more than one antibiotic.

Other bacteria have followed a different route to penicillin resistance: they have changed their PBP enzymes so that penicillin will no longer bind to them. This is true of *Neisseria,* a genus that includes the causative agents of gonorrhea and of some cases of bacterial meningitis.

The gene coding for the PBP2 enzyme (the most important of the penicillin binding proteins) was analyzed for several penicillin-sensitive strains of *Neisseria meningitidis* and for a number of resistant strains. The sensitive strains were all very similar to one another, and their differences had little effect on the sequence of amino acids (protein building blocks) in the PBP2 enzyme. The genes belonging to the resistant strains, however, differed significantly. Each gene was a mosaic, consisting of DNA pieces that were very similar to the corresponding pieces in the gene from the sensitive strains, along with pieces that differed in about 20 percent of their bases (the chemical units in DNA that determine what amino acids will be inserted in the protein).

The variant pieces must have been acquired from another bacterium. We know that *Neisseria* cells actively take up bits of DNA from their surroundings, preferring DNA similar to their own. The DNA is broken into pieces, and some of the pieces are slotted into the bacterial chromosome, replacing those that are already there. This process of "transformation" is analogous to sex in higher organisms: it is a means whereby genetic material from two ancestors is combined in a single descendant. The difference is that in the sexual process, the new individual gets half its DNA from each parent, whereas in transformation, the recipient cell gets only a small fraction of its DNA from a donor. But from an evolutionary point of view, the two processes have similar consequences: favorable mutations occurring in different ancestors can combine in a single descendant.

In the case of *Neisseria,* we know where the introduced blocks of DNA come from. The genus includes not only the bacteria causing meningitis and gonorrhea but also a number of harmless species found in the human throat. Some of these are naturally resistant to penicillin, and were so before the clinical use of antibiotics began. The introduced blocks are almost identical to the PBP2 genes found in one or the other of two harmless species, *N. flavescens* and *N. mucosa.* Thus *N. meningitidis* evolved resistance to penicillin by acquiring DNA from related species that were already resistant. The same is true of *N. gonorrhoeae.*

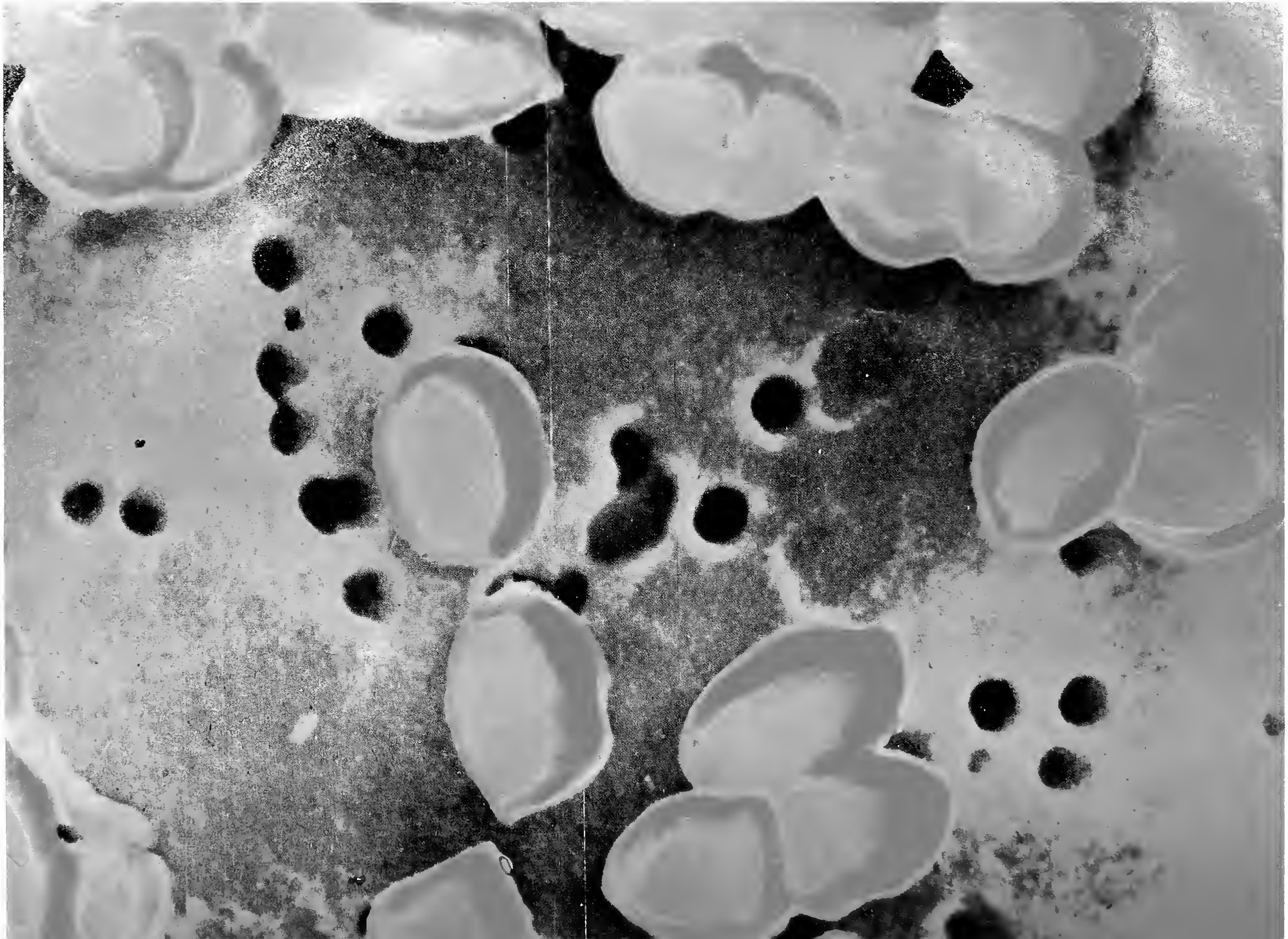
The PBP genes in resistant *Streptococcus pneumoniae,* an important cause of respiratory disease, also show a mosaic structure, and we are confident that they too were acquired by genetic transformation. The donor species, however, has not yet been found. (*S. pneumoniae,* incidentally, was the bacterium in which bacterial transformation was first discovered by F. Griffith in 1928. Oswald Avery then demonstrated that the transforming factor was DNA, and this led James Watson and Francis Crick to study the structure of DNA. So began the molecular biology revolution.)

Does transformation play a comparable role in other bacteria now developing resistance to antibiotics? We cannot be sure. Many bacteria, including the geneticist's favorites, *Escherichia* and *Salmonella,* do not actively obtain outside DNA—they are not, to use the jargon of microbial genetics, "competent for transformation." But even these bacteria can acquire DNA from other cells. For example, bacteriophages (viruses that live in bacteria) sometimes carry bacterial DNA into a new host cell by accident.

These and other forms of bacterial evolution, with the consequent spread of antibiotic resistance, are undermining our ability to treat infectious diseases, including the infections that can wreak havoc with any form of surgery. Further cause for concern is the increasing use of bacteria in industrial processes. If genetically engineered organisms are released into the environment, the genes in those organisms are unlikely to remain where we put them. We therefore have to ask not only whether the released organism is harmless but also whether the genes it contains are harmless.

Genetic transformation has enabled strains of Streptococcus pneumoniae, *which cause respiratory disease, to resist many antibiotics. The bacteria (within the globules) also combat the body's natural immune defenses by enveloping themselves in capsules of secreted material.*

Evolution



Evolution

On Darwin, Snow, and Deadly Diseases

An evolutionary approach to disease control could vastly improve public health

by Paul W. Ewald

The other passengers on the London train must have dismissed me as another mental casualty of twentieth-century urban life. I had looked out of the train window, let out a "Ha!" and then chuckled, nodding my head as though I had just been told a joke by an invisible friend. But I didn't care. I had just made a connection between disciplines that was symbolized by what I saw through the window.

The day began like most that summer of 1984. I entered the library of the London School of Hygiene at opening time, holding a plastic shopping bag filled with about a thousand note-covered index cards. Surviving a probing glance from the front desk, I scaled a flight of stairs and hustled to a secluded table sandwiched between floor-to-ceiling shelves of old medical journals. I removed half of my cards and a thermos of coffee that I had hidden in the bag, leaving a hand-width passageway to a cache of cookies, which would fuel me until the library closed. I concealed the cup with the bag and stowed the thermos below the table, out of the librarian's line of sight, to avoid the wrath I incurred when my operations were less clandestine. I then set to work.

I was trying to find out why some diseases are so dangerous and others merely annoyances. My interest had been sparked several years earlier when I read *Man Adapting,* by bacteriologist René Dubos. I was surprised by his statement, "Given enough time a state of peaceful coexistence eventually becomes established between any host and parasite."

I saw no reason why natural selection would always lead to peaceful coexistence, although it might do so in certain circumstances. Consider a population of viruses living within a human host. What if one variant in this population is more adept at exploiting the host's body? Replicating more rapidly, it would win the evolutionary race with its viral competitors and become the predominant variant in the population. It would also make the host sicker and more contagious.

But if the long-term survival of such a virus depends upon its being transmitted directly from host to host, as is the case with the virus that causes the common cold, then the rapid reproducer may pay a high price for its virulence. If the illness is severe enough to immobilize the host, contact with new hosts will be drastically reduced. A more slowly reproducing, milder virus—perpetually being transported by a mobile host to new contacts—would be more likely to prosper.

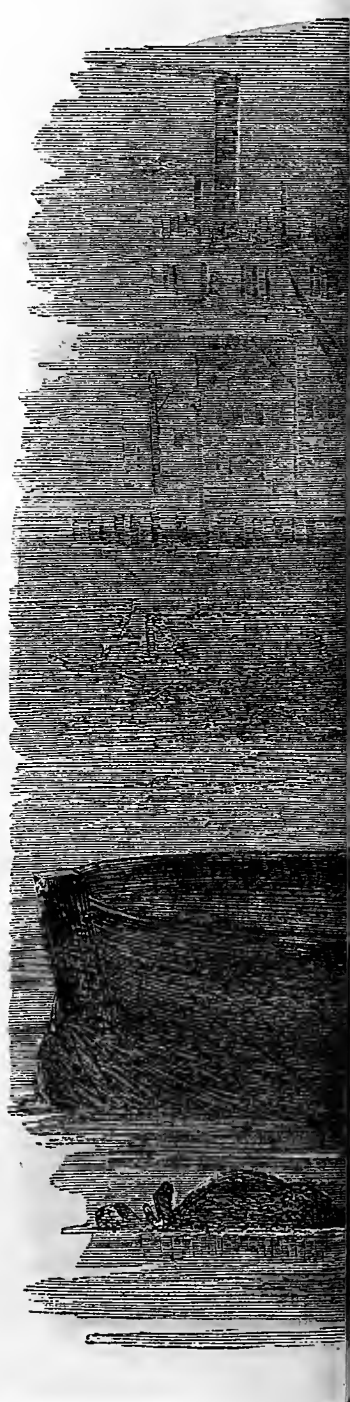
If host–pathogen relations always followed this scenario, Dubos's generalization would be reasonable; viruses would evolve toward a relatively mild state of coexistence with their hosts.

But, I reasoned, what if the pathogen could be transmitted even when the host was immobilized? Then the more rapidly replicating, abusive organism might get the competitive advantages of high reproduction at a bargain price. This seemed to be the case with *Plasmodium falciparum,* a pathogen that causes malaria. Even when its host is immobilized, this protozoan is still easily transmitted to other people by mosquitoes. Generalizing from this argument, I predicted that disease organisms transmitted by biting arthropod vectors should be more severe than those transmitted directly from person to person. I searched the epidemiological literature and found that the prediction passed the test. Vector-borne pathogens like *P. falciparum* and the yellow fever virus are significantly more severe than such host-borne viruses as the common cold.

Evolution may involve long spans of time, but it can be rapid if generations are short and the culling of competitors is intense. Use of antibiotics, for example, can cause staphylococcus bacteria in hospitals to evolve high levels of resistance within a few weeks. If our technology can accelerate the evolution of a bacterium, couldn't other human activities also cause pathogens to evolve rapidly? My attention was drawn to diarrhea.

Each year millions of people die from diarrheal diseases, but the organisms that cause diarrhea are not equally culpable. Some cause deadly diseases like cholera, typhoid fever, and dysentery, but others rarely kill. Are the classic killers maladapted organisms that will eventually evolve toward peaceful coexistence, or are they severe because our activities have made them severe?

This was the question that brought me to the London School of Hygiene. On that summer day, punctuated by surreptitious



An 1858 Punch *cartoon depicted pollution on the Thames. The skeleton is facing the residential area where John Snow completed his classic study of cholera-laden water supplies.*
The Granger Collection

sipping of coffee and covert crunching of cookies, I was reading John Snow's book *On the Mode of Communication of Cholera*. Snow was a dedicated, lonely workaholic who spent many years during the mid-nineteenth century trying to understand how cholera was transmitted. He focused on a middle-class residential area of south-central London; the northbound Thames bends sharply to the east and then arcs to the south around the area. Cholera battered the residents in 1849. Snow was looking for risk factors: activities or environmental exposures that could explain why cholera attacked some people and not others. His initial observations made him suspect the water. In one severely affected area he found that

slops of dirty water, poured down by the inhabitants into a channel in front of the houses, got into the well from which they obtained water.... Owing to something being out of order, the water had for some time occasionally burst out at the top of the well, and overflowed into the gutter or channel, afterwards flowing back again mixed with the impurities; and crevices were left in the ground or pavement, allowing part of the contents of the gutter to flow at all times into the well; and when it was afterwards emptied, a large quantity of black and highly offensive deposit was found...evacuations [from cholera cases] were passed into the beds,...the water in which the foul linen was washed would inevitably be emptied into the channel.

Water in this area was supplied by the Lambeth Company or the Southwark and Vauxhall Company. When one of Snow's colleagues examined the water, he "found in it the hairs of animals and numerous substances which had passed through the alimentary canal." He concluded that the water from these companies "is by far the worst of all those who take their supplies from the Thames."

Before the cholera epidemic of 1853, the Lambeth Company moved its water intake to a purer source. Snow realized that a vast experiment had been set before him. Scattered among the houses receiving contaminated water from the Southwark and Vauxhall Company were houses receiving purer water from the Lambeth Company. If water transmitted cholera, the residents served by the Southwark and

Vauxhall Company should have suffered from cholera more than residents served by the Lambeth Company. They did. Snow found that the risk of cholera among Southwark and Vauxhall customers was nearly ten times greater in 1853, even though it had not been greater in 1849, when both companies delivered contaminated water. By showing that cholera could be waterborne, John Snow had established the field of epidemiology.

From an evolutionary perspective, the transfer of the "foul linen," the movement of contaminated sewage into water supplies, and the delivery of contaminated drinking water acted like a horde of mosquitoes transmitting pathogens from immobilized patients. Might such waterborne transmission be responsible for the great variability in harmfulness found among diarrheal pathogens? A quick look at the literature cannot resolve this question because most diarrheal organisms can sometimes be transmitted by water and sometimes not. My task, therefore, was to determine from the literature whether severe organisms tended to be waterborne more often than were milder organisms.

By the time I looked out of the train window, I was a few years into this task. A pattern was taking shape: the lethality of the various diarrheal bacteria correlated almost perfectly with their tendencies to be waterborne. The correlation explained why cholera, typhoid fever, and some kinds of dysentery were so severe. It also suggested a new dimension for disease control. If waterborne transmission favors the evolution of increased harmfulness, then water purification should do the opposite—transform severe pathogens into milder ones. Indeed, records indicate that this transition has happened. Policy makers, however, have recently diverted investments from clean-water programs because field studies did not show a large reduction in frequencies of infection. But frequencies are only part of the story, the epidemiological part, the part that Snow was investigating. The severity per infection is the other important part, the evolutionary part. If the next generation of precise tests shows that water purification transforms severe organisms into mild ones, then we will have a powerful evolutionary tool for taming diarrheal disease.

These ideas forge a link between epidemiology and evolutionary biology, between John Snow and Charles Darwin. Although Snow and Darwin were long dead, I felt as though I had been meeting with them—their printed words had launched their insights through the intervening century. When I looked out of the train window I was aloft with these thoughts, but just as I was coming back to earth, I left it again when I saw a sign at the train station: Vauxhall! Until then the places in Snow's book had just been markers for keeping track of disease outbreaks. But at that moment I realized that I was having both an intercentury tutorial from Snow and a tour

London's Lambeth Company opened a new waterworks in 1852. Its customers therefore received relatively pure water and largely escaped a cholera epidemic that ravaged the city the following year.
The Granger Collection

THE LAMBETH WATER COMPANY'S NEW WORKS.

OPENING OF THE NEW WORKS OF THE LAMBETH WATER COMPANY, SEETHING WELLS, DITTON.

of the places that he had methodically canvassed to establish the field of epidemiology. I later realized that I had begun this tour by walking out of the library.

Snow moved to London in 1836; Darwin in 1837. In the early 1840s Darwin was living on Gower Street, a block north of where the London School of Hygiene would be built. He was, in his words, "collecting facts bearing on the origin of species." At that time John Snow was working on his degree at the University of London, which was across the street from Darwin's apartment. But Darwin and Snow apparently never met and may not have even been aware of each other's earth-shaking contributions. Although Snow was four years younger than Darwin, he died of a stroke in 1858, at the age of forty-five, one year before the publication of *Origin of Species*. Each time I went to the library that summer, I walked down Gower Street, where Snow and Darwin must have walked separately many times during the early 1840s. Chance had put me in the same place, and the printed words in the library had removed the barrier of time, allowing a linkage between Snow's epidemiology and Darwin's evolution.

Isaac Newton paid homage to scientists such as Galileo and Copernicus by writing, "If I see farther than other people, it is because I stand on the shoulders of giants." The rest of us also have the chance to see farther if we do a little giant climbing. As for me, I was teetering with one foot on Charles Darwin's shoulder and the other on John Snow's. We cannot predict precisely what new views will come from the merging of epidemiology and evolution, but we can see many possibilities. A better understanding of the evolution of virulence should allow us to identify interventions that will not only reduce the spread of infections but also force pathogens to evolve to milder states by making harmfulness too costly for them. Diarrheal pathogens may be forced into a benign state by water purification. Vector-borne pathogens may be similarly transformed by the installation of mosquito-proof housing that prohibits transmission from severely ill people. I expect that scientists at the end of the twenty-first century will find it curious that today's health scientists were so skilled at recognizing the importance of molecular biology and biochemistry, but that it took more than a century after the birth of evolutionary biology, epidemiology, and microbiology for us to realize the importance of using evolution as a tool for controlling disease.

Evolution

Behind-the-Scenes Role of Parasites

The fates of mushrooms, flies, and parasitic nematodes are intricately intertwined

by John Jaenike

As every mushroom picker knows, many of the mushrooms that spring from the earth after a summer rain are crawling with insect larvae. Cut open the stalk of a bolete or an amanita and you may find hundreds of tiny, white larvae tunneling through the fungus. In addition to humans and other mammals such as deer and squirrels, numerous insects compete for the mushroom's flesh. In turn, these insects are eaten by beetles, ants, and toads that visit the mushrooms. By drawing nutrients from the surrounding trees and soil through a network of mycorrhizae, mushrooms form the base of a small, but complex, food web.

In the 1970s, I became interested in mushroom-feeding fruit flies while conducting fieldwork on an island off the coast of Maine. All around me, the tiny flies were busy laying eggs on hundreds of mushrooms that would provide food and shelter for the developing larvae. Because they were in the same genus as *Drosophila melanogaster,* the workhorse of laboratory genetics, I realized that these flies would be ideal for studying ecological relationships. Later, when I learned that two of the most common mushroom-feeding fruit flies, *D. falleni* and *D. putrida,* can be infected by a parasitic nematode worm called *Howardula aoronymphium,* I wanted to learn whether this microscopic parasite affected the relative abundance of the flies.

Traditionally, ecologists studying why one species tends to be more abundant than another will focus solely on such factors as competition or predation. Increasingly, however, we are realizing that the parasites an organism harbors can be equally important in determining a species' place in the larger ecological community and, ultimately, in its evolutionary history.

Some parasites may evolve with a particular host for millions of years, presumably in a state of equilibrium. The chewing lice that parasitize pocket gophers, for example, are so genetically different from related lice that their association with the gophers must be a long one. Although some host–parasite associations are long-standing, many other parasitic relationships are quite ephemeral—at least on an evolutionary time scale. The *Howardula* nematodes are internal parasites of various arthropods, including flies, beetles, thrips, and mites. Such a broad range of hosts suggests that the worms can occasionally shift from one host to another.

The worms enter the fruit fly larvae by piercing their outer cuticle when they are feeding within the mushroom. The nematodes thrive inside the developing flies, which as adults spread the parasites to other mushrooms. The major deleterious effect that *H. aoronymphium* has on some fruit fly species is that it makes the females sterile. Nematodes, therefore, could have drastic effects on susceptible fruit fly populations. The parasites don't eliminate their hosts, however, because if the fly populations fall too low, transmission rates decline, so fewer flies become parasitized, thus allowing the fly populations to recover.

Recently, I observed just how fleeting

A stinkhorn mushroom, left, attracts fruit flies by the dozen. These mushrooms can often be smelled before they are seen. A trio of Amanita muscaria *mushrooms, right, push up through fall leaves. As they age, they will attract a host of insects and their parasites.*
J. L. Lepore; Photo Researchers, Inc.

Evolution

Ted Nelson, Dembinsky Photo Associates

the relationships between *H. aoronymphium* and their fruit fly hosts can be. Several years ago, after determining that wild strains of the nematodes can infect both *D. falleni* and *D. putrida*, I began to maintain one strain in the laboratory using *D. falleni* as the host. (At that time, I found it easier to keep the parasite strain going in this host species.) A couple of years later, in the course of doing some other experiments, I discovered that these nematodes could no longer infect *D. putrida*. (Whether the parasite lost the ability to recognize the fly as a suitable host or whether it lost some specific ability to penetrate the fly larvae's cuticle remains a mystery.)

Just to be sure of my observation, I tested two other strains of *H. aoronymphium* that I had obtained from the wild more recently. These nematodes infected about two-thirds of both species of fruit fly. My original laboratory strain could still infect *D. falleni* with the same frequency as these wild strains, but it had completely lost its ability to infect *D. putrida* after being isolated from it for fifty generations. Because a fruit fly generation is only two weeks in the laboratory, fifty generations is but a blink of an eye on an evolutionary time scale. Presumably, the ability to infect a fruit fly host can be reacquired in a comparably short time.

How does the parasite's ability to shift rapidly from species to species affect the evolution of its hosts? Consider a case in which the outcome of competition between different host species is mediated by a shared parasite species. If, for instance, a nematode infects one fruit fly species more frequently than another, that can tip the scales in favor of the less-affected species. But if this less-affected host becomes more abundant, the parasite may respond by becoming specialized on it, thus reducing the host's competitive advantage. In this manner, a rapidly evolving parasite may enable competing host species to coexist—as in the case of *D. falleni* and *D. putrida*.

A parasite's ability to rapidly shift hosts might have large effects on island populations. Suppose that on the mainland, a nematode like *H. aoronymphium* parasitizes two competing fruit fly species, such as *D. falleni* and *D. putrida*. An island may be colonized by one of these host species and later—or simultaneously—by the nematode. Given my laboratory results, I would expect the newly arrived nematodes to quickly become specialized on the island fruit fly. When the other host eventually colonizes the island, it will be at a competitive advantage because the resident nematode can no longer parasitize it.

Finally, the *Howardula* results may be relevant to the evolutionary enigma of sex. The ability of a parasite to exploit a particular host, and the response of that host to the parasite, can depend on the specific genotypes of the players. For instance, monocultures of crop plants, often bred to be genetically identical, are particularly susceptible to epidemics of parasites adapted to specific crop genotypes. Such observations have led to the hypothesis that parasites favor the maintenance of sexual reproduction in their hosts because sex serves to reshuffle the genetic deck every generation, preventing any one genotype from becoming especially common, and thus vulnerable.

Parasites of one kind or another have managed to invade almost every organism, from the mushroom-dwelling fly larva to the human body. And although they will never be apparent to most people who stroll through the woods, their effect is great. Interacting with other species, they play an important role in balancing ecological communities.

A fly and insect pupae cling to the underside of a broken mushroom cap.
Joy Spurr

Overhearing Cricket Love Songs

Some flies bear an eary resemblance to their victims

by Daniel Robert and Ronald R. Hoy

For 200 million years, on any warm evening, male crickets have been eagerly rubbing their forewings together, "singing" to attract mates. Early on, they were pioneers, inventing new ways to advertise their presence to their fellow crickets. But about forty million years ago, their serenades began to attract some eavesdropping newcomers—tachinid flies. For crickets, this was bad news.

Tachinid flies are parasitoids, parasites that use an animal host as a food source for their young, although the adults are free-living. The female tachinid fly, a tiny creature, deposits her eggs or larvae on or near a host insect, typically a species much larger than herself, such as a beetle or a caterpillar. The larvae then burrow inside and gorge themselves on the host's generous muscular mass or other tissues. After a week or so, they emerge to pupate. This strategy is very successful, judging by the abundance of tachinid fly species (8,000 have been identified worldwide, 1,000 in North America alone). The family Tachinidae is the second largest in the order of true flies, Diptera, after the very diverse Tipulidae, or crane flies. Another successful, large family of parasitoids is the Sarcophagidae, or flesh flies, which counts some 2,000 species worldwide.

As far as we know, the vast majority of tachinid flies (like nearly all flies) are deaf to high-pitched sounds, such as the chirping and trilling of crickets, and find their hosts by sight and smell. But a few species of tachinid flies have evolved the ability to home in on a cricket's chirp, getting the drop on their victim, no matter how well it may be concealed by vegetation or the darkness of night.

Among them is the fly *Ormia ochracea,* which lives along the gulf coast from Florida to Texas, preying on the southwestern or southeastern field cricket. Diving out of the night sky, the fly deposits one or more tiny maggots on or near a chirping male cricket and takes off. The active maggots latch on to the cricket and penetrate it. (They may even end up parasitizing a female cricket attracted by the same song.) By the time the maggots have matured and are ready to emerge, the cricket is at death's door.

As biologists interested in the evolution

After feasting for a week to ten days on the muscle mass of a living cricket, a larva of the tachinid fly Ormia ochracea *emerges to pupate.*

Marie Read; Cornell University

of sensory systems, we wanted to know how—and how well—this species of tachinid fly could hear the field crickets. In the course of their lives, both the female cricket and female fly face the same reproductive problem: finding a male cricket singing in the dark. The female cricket uses her sense of hearing not only to detect and locate singing male crickets but also to recognize those that belong to her own species and, possibly, to assess the adequacy of the male by the quality of his song. For the fly, the task is also to find a cricket of the right species. The possibility that a female fly also assesses the quality or health of her host before entrusting her brood to him seems slim, but cannot be ruled out.

Our probing of its anatomy reveals that the hearing organ of *O. ochracea* is composed of a pair of very thin membranes situated on the front of the thorax, near the neck and just behind the head. These membranes act much as human eardrums do, converting sound energy into mechanical movements. Each membrane is backed by an air chamber and attached internally to a vibration sensor. The ear appears to have evolved from a chordotonal sensory organ, a type of "mechanoreceptor." In nonhearing flies this organ serves as a sort of strain gauge that senses stresses around the neck region and probably helps monitor the movement and posture of the head and front legs.

Although an exceptional anatomical development among flies, the tiny ears resemble those found in various other insects, including crickets. In all cases that have been studied, insect ears seem to have evolved from such chordotonal organs. In crickets, for example, ears evolved from sensors situated on the tibia of the front legs, which originally functioned merely to detect low-frequency ground vibrations. Various lines of evidence suggest that the original sensory structure was duplicated, and that this duplicate gained a separate function, the sensing of air vibrations. As in other insects with ears, these structures have nothing in common with the feathery antennae that enable some insects (mosquitoes, for example) to detect low-pitched sounds, such as the buzzing of other insects, at close range.

The fly's ear resembles the cricket's not only in structure and sensory origin but also in sensitivity. One way to understand a fly's sensitivity to sound is to measure the electrical activity of the sensory nerves leading from its ears to its central nervous system. To determine which pitches *O. ochracea* is most sensitive to, we inserted tiny recording electrodes into the thorax, at the base of the auditory nerves, and tested the reaction to computer-generated simulations of the cricket's song.

Our experiments have demonstrated that this tiny fly is most sensitive to sounds at the frequency of five kilohertz (a little above the highest pitch on the piano), a pitch close to the frequency that dominates the cricket's song. This is a striking example of a phenomenon known as convergent evolution, where superficially similar structures evolve in distantly related organisms as adaptations to similar requirements or circumstances.

The fly's sensitivity—and especially that of the female fly—even surpasses the cricket's. We estimate that a female cricket can detect a male cricket from at least twenty yards away, while the fly can hear it from twice that distance. (Humans we tested are even more sensitive, discerning the cricket song at sixty yards—but they are not as quick and precise at locating it in the grassy meadows, perhaps for lack of practice.)

In field experiments using loudspeakers, we have shown that the flies are attracted by the sound of the cricket and require no other cues, such as smell. If the flies' ears are damaged, they cannot locate the sound. On the other hand, preliminary observation suggests that they may be reluctant to deposit their larvae unless they actually find a cricket at the source of the sound. In contrast, entomologist Tom Walker and his colleagues at the University of Florida, Gainesville, have observed that a related species from Brazil, *O. depleta,* will readily deposit from one to eight maggots right on a piece of paper covering a loudspeaker.

So far, six members of the genus *Ormia* are known to have ears for detecting their insect hosts, an ability they must have inherited from their common ancestor. In addition to field crickets, their specific hosts include some katydids and mole crickets. Two genera of flesh flies have also evolved, independently, a remarkably similar hearing organ to listen for the singing of cicadas.

To be a successful bacterium, fungus, animal, or plant depends on detecting crucial features of the environment. Survival often requires diverse sensory capacities. From an evolutionary perspective, there is always a potential advantage in doing something a little differently. When some parasitoid flies gained ears, a whole new sensory world became accessible to them. They reaped the advantage of locating a dispersed, concealed host. Other flies could find crickets by sight or smell, but might miss some that are easily located by sound. The hearing flies filled a new niche, where competition was reduced and resources lay untapped.

Guided by her acute sense of hearing, a female fly has located a cricket host for her brood.
Daniel Robert; Cornell University

Despite the advantage hearing has conferred on certain species of parasitoid flies, the phenomenon is not widespread. Shelley Adamo, of Cornell University, who studies the effects of parasitism on cricket behavior, physiology, and reproductive success, has concluded that at least in North America, relatively few singing insect species have bodies large enough to support a tachinid infestation. Probably more remain to be discovered in the tropics, where singing insects are numerous—and often large.

Many questions remain to be explored in the relationship between ear-equipped tachinid flies and their hosts. What effect do the parasitoids have on the cricket population as a whole? How detrimental is infestation to a male cricket's ability to leave offspring? And will the cricket's tendency to chirp eventually be eliminated by natural selection?

Some cricket species have lost their ability to sing, and we and others suspect that parasitism played a key role in this loss. Males of the species *Gryllus ovisopis,* whose common name is the taciturn field cricket, lack a long-range call, although they conserve enough of the sound-producing wing anatomy to scrape out a short-range courtship song if a female wanders into range. According to Tom Walker, who has studied them, they do not seem to have evolved any other long-range signals, such as chemicals. An entirely mute species (which has also lost its ears) is *Larandeicus bicolor* of southern Africa. Unlike its singing relatives, it attracts a female's attention with its brightly colored wings. Crickets may never regain the freedom of action they lost when tachinid flies arose forty million years ago. But if the going gets too tough, they may evolve some new tricks of their own.

Evolution

TECHNOLOGY UPDATE

500 miles from nowhere, it'll give you a cold drink or a warm burger...

NASA space flights inspired this portable fridge that outperforms conventional fridges, replaces the ice chest and alternates as a food warmer.

By Charles Anton

Recognize the ice cooler in this picture? Surprisingly enough, there isn't one. What you see instead is a Koolatron, an invention that replaces the traditional ice cooler, and its many limitations, with a technology even more sophisticated than your home fridge. And far better suited to travel.

What's more, the innocent looking box before you is not only a refrigerator, it's also a food warmer.

NASA inspired portable refrigerator. Because of space travel's tough demands, scientists had to find something more dependable and less bulky than traditional refrigeration coils and compressors. Their research led them to discover a miraculous solid state component called the thermo-electric module.

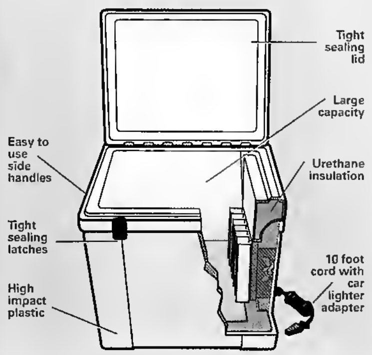
Aside from a small fan, this electronic fridge has no moving parts to wear out or break down. It's not affected by tilting, jarring or vibration (situations that cause home fridges to fail). The governing module, no bigger than a matchbook, actually delivers the cooling power of a 10 pound block of ice.

From satellites to station wagons. Thermo-electric temperature control has now been proven with more than 25 years of use in some of the most rigorous space and laboratory applications. And Koolatron is the first manufacturer to make this technology available to families, fishermen, boaters, campers and hunters– in fact anyone on the move.

Home refrigeration has come a long way since the days of the ice box and the block of ice. But when we travel, we go back to the sloppy ice cooler with its soggy and sometimes spoiled food. No more! Now for the price of a good cooler and one or two seasons of buying ice, (or about five family restaurant meals), all the advantages of home cooling are available for you electronically and conveniently.

The refrigerator from outer space.

The secret of the Koolatron Cooler/Warmer is a miniature thermo-electric module that effectively replaces bulky piping coils, loud motors and compressors used in conventional refrigeration units. In the cool mode, the Koolatron reduces the outside temperature by 40 degrees F. At the switch of a plug, it becomes a food warmer, going up to 125 degrees.



Think about your last trip. You just got away nicely on your long-awaited vacation. You're cruising comfortably in your car along a busy interstate with only a few rest stops or restaurants. You guessed it... the kids want to stop for a snack. But your Koolatron is stocked with fruit, sandwiches, cold drinks, fried chicken... fresh and cold. Everybody helps themselves and you have saved valuable vacation time and another expensive restaurant bill.

Hot or cold. With the switch of a plug, the Koolatron becomes a food warmer for a casserole, burger or baby's bottle. It can go up to 125 degrees.

And because there are no temperamental compressors or gasses, the Koolatron works perfectly under all circumstances, even upside down. Empty, the large model weighs only 12 pounds and the smaller one weighs just seven. Full, the large model holds up to 40 12-oz. cans and the smaller one holds six.

Just load it up and plug it in. On motor trips, plug your Koolatron into your cigarette lighter; it will use less power than a tail light. If you decide to carry it to a picnic place or a fishing hole, the Koolatron will hold its cooling capacity for 24 hours. If you leave it plugged into your battery with the engine off, it consumes only three amps of power.

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The versatile Koolatron is available in two sizes. The P24A holds 30 quarts and the smaller P9 holds seven quarts. An optional AC adaptor lets you use them in your rec room, patio or motel room. They plug into any regular outlet.

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Koolatron (P24A) holds 30 quarts	**$99**	$12 S&H
Koolatron (P9) holds 7 quarts	**$79**	$8 S&H
Optional AC Adapter (AC 10)	**$39**	$6 S&H

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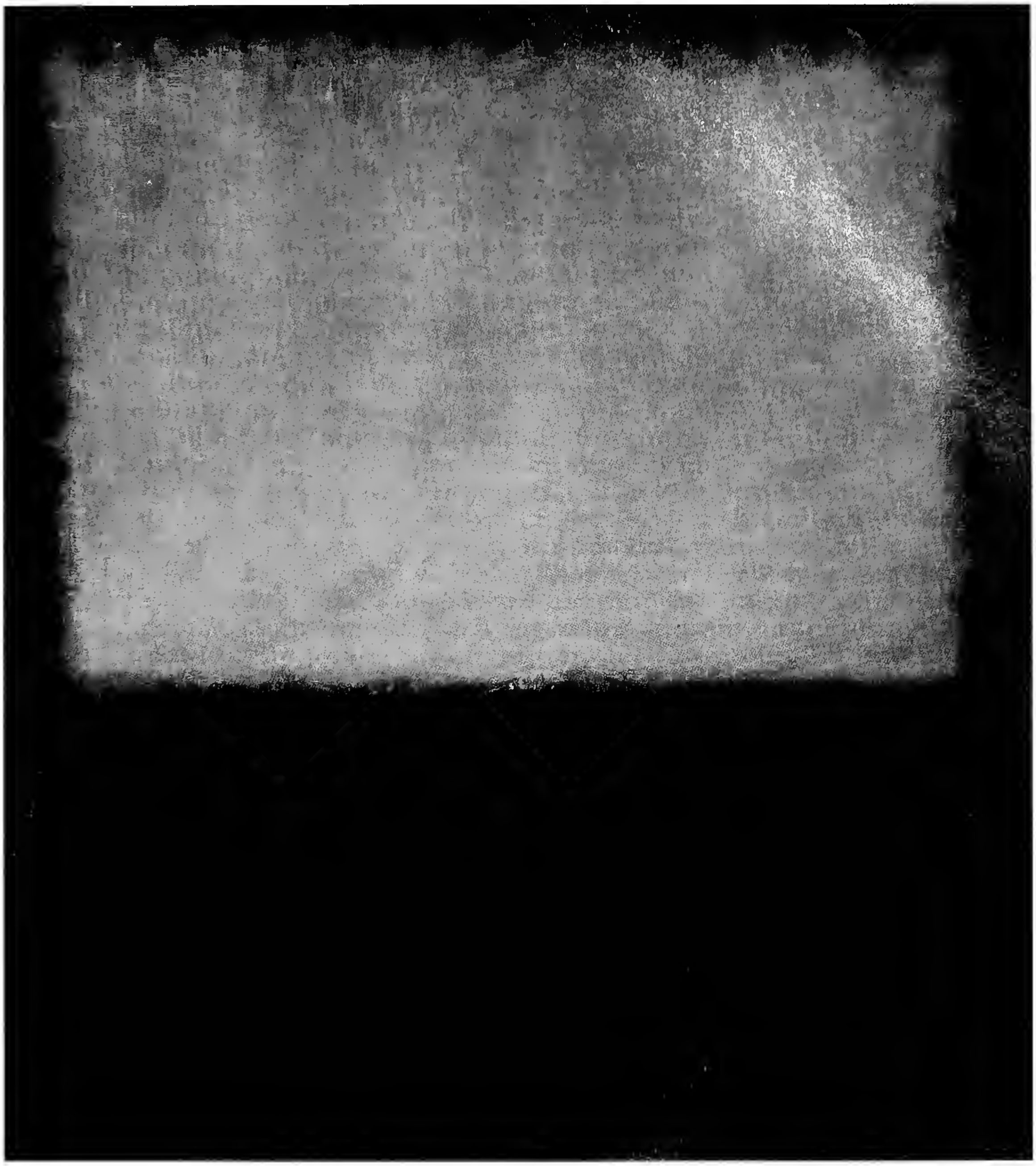
The Hard Evidence



Mark Rothko, *Light, Earth and Blue;* © 1994 Artist's Rights Society; Courtesy of C & M Arts, New York

The awe-inspiring story of the evolution of life on earth is hidden in layer upon layer of sedimentary rocks. Over millions of years, sediments settled into these massive formations, which were compressed and then twisted and deformed by the immense forces of plate tectonics. The fossil evidence of life that survived these processes is rare and fragmentary. But when—with hard, diligent field and laboratory work, and luck—scientists do piece together a chapter of life's odyssey, the tale it tells rings true because it has the undeniable weight of deep time on its side.

Evolution

On the Importance of Nothing Doing

An exhaustive study of tiny bryozoans supports the idea of punctuated equilibrium

by Jeremy Jackson and Alan Cheetham

From Charles Darwin's day until about twenty years ago, biologists imagined that the evolution of new species was a slow and gradual process. The record of the rocks, however, has always told a different story. While some lineages can be seen developing in a series of transitional species over the ages, most fossil species appear abruptly—without intermediate forms—and survive apparently unchanged for millions of years. Darwin attempted to dismiss this problem by invoking the fragmentary and incomplete nature of the fossil record. Trying to interpret it, he said, was like trying to read a book that was missing many of its pages and even whole chapters.

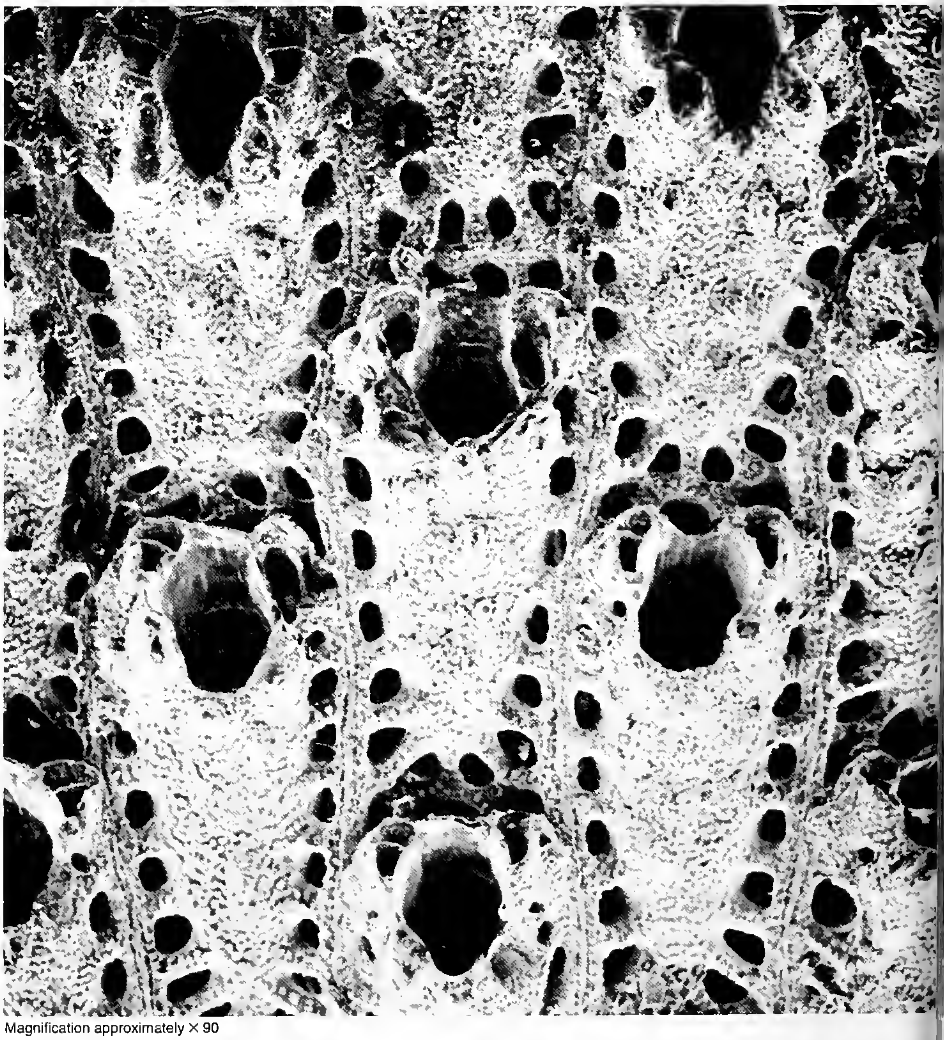
This explanation was widely accepted until the 1970s, when paleontologists Niles Eldredge and Stephen Jay Gould noted that, contrary to Darwin's expectations, a century of fossil discoveries had confirmed a pattern of stasis and abrupt change. Why not, they urged, accept the story told in the fossil record at face value? Long periods without change in organisms and relatively abrupt appearances of new species (punctuated origins) must be incorporated into any valid evolutionary theory. The Gould–Eldredge notion of "punctuated equilibrium" set new limits on how speciation usually occurs.

Amid the resultant controversy, paleontologists set out to see if they could disprove punctuated equilibrium. Some thought that by measuring the anatomical details of an extensive sampling of fossil organisms, they could confirm that speciation is gradual. When they attempted such studies, however, they found that most species (by about ten to one) show punctuated origins and then remain so stable that specimens differing by millions of years in age are visually and statistically indistinguishable.

Still, skeptics believed that long periods of species stability (stasis) were only occasional occurrences and doubted that similar-appearing organisms, separated by millions of years in the fossil record, could really be considered the same species. Within fossil skeletons, they suggested, dwelled subtly different species. (Examples of such "cryptic species" exist among some groups of living animals. Even experts cannot distinguish among a dozen kinds of black flies or certain salamanders without the aid of molecular genetic tests. One discovery has documented two species of apparently identical African elephant-nosed fish that are distinguishable only by the electrical pulses they produce.) The question of whether skeletons alone can be used as species markers is thus fundamental to accepting the fossil record as evidence of evolution. Only if a creature's skeleton is highly correlated with its genetics can paleontologists study its evolution with some confidence.

We addressed this question using both living and fossil cheilostome bryozoans. These common but little-known animals live in colonies in the sea and are superficially similar to corals. While the individual creatures are microscopic, one sees them in the aggregate attached to sea bottoms, tide pool rocks, and even aquatic plants. These colonies can resemble a mossy covering on an undersea rock or a clump of miniature trees about three to four inches high. The hard-shelled body is topped by a soft, circular feeding organ, the lophophore, composed of ciliated tentacles surrounding the mouth. The moving cilia create a current of water that directs plankton—microscopic algae, bacteria, and flagellates—into the mouth.

Bryozoans are not only among the most abundant, well preserved, and diverse marine fossils, they also provide a fine case study of evolutionary patterns because their evolution is punctuated in the extreme. Cheilostomes—a major group characterized by a lidlike structure that covers the aperture through which the lophophore protrudes—first appeared about 140 million years ago, and some



Magnification approximately × 90

forms similar to the first-known species persist unchanged today. The first 40 million years of their fossil record shows little change, but during the past 100 million years, hundreds of genera diversified. In each well-studied case, however, the new species appeared relatively abruptly, then remained remarkably stable over vast amounts of time.

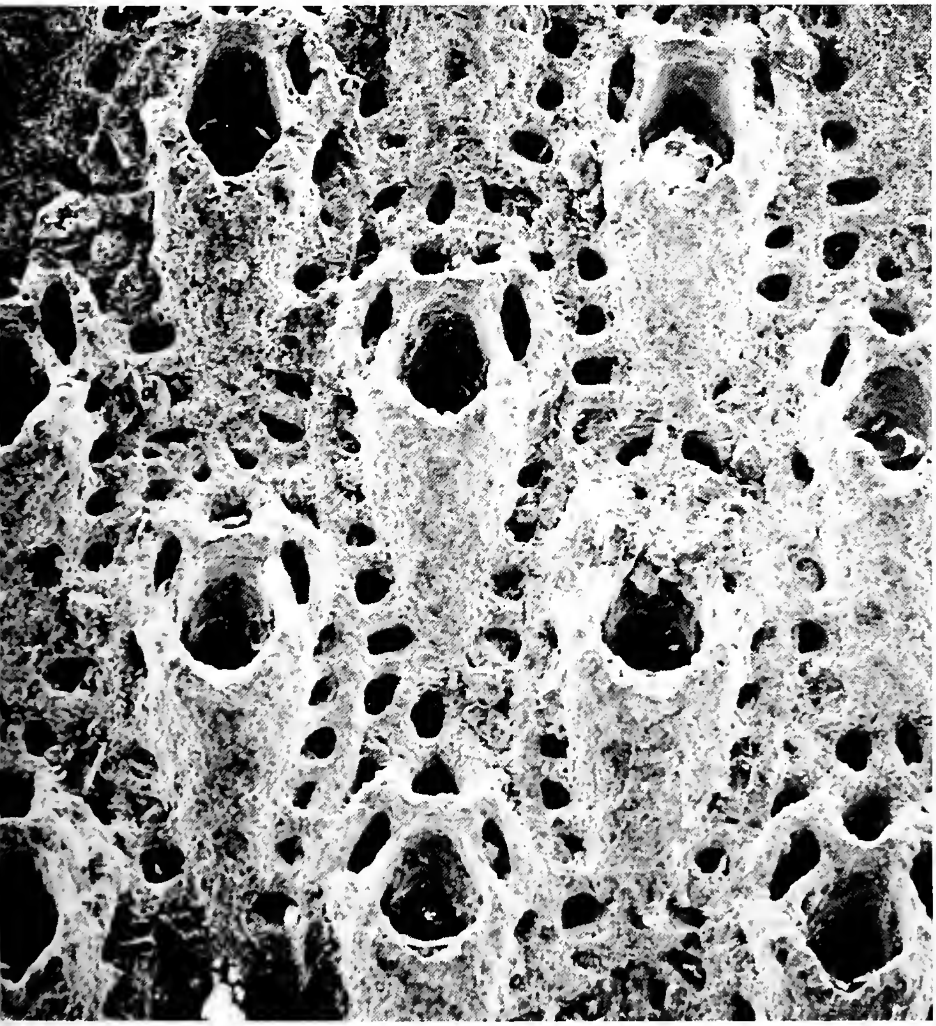
Our research strategy was to begin with hundreds of samples of modern bryozoan skeletons, and assign each to various species by measuring their structures and ranges of variation—a tedious statistical procedure. Next, we tested the reality of the "species" our measurements had defined. Would they match up with species defined by breeding experiments and tests of their genetic biochemistry? We foresaw three possible results. First, as some skeptics suggested, skeletal features might be too uninformative to be useful in distinguishing species. Second, environmental differences might produce very different external characteristics in colonies of the same species, creating "false" species. The last possibility—the one we suspected was true—was that skeletons are reliable, environmentally stable definers of bryozoan species, equivalent to genes in their precision. But to support our case, we needed a very high level of agreement in the species markers, by several different means of measurement.

We first studied three distantly related genera of bryozoans that live in the San Blas Islands and elsewhere along the Caribbean coast of Panama, each very different in its skeletal complexity. We would compare them with fossil bryozoans based only on skeletal measurements. Among the features we measured were the dimensions of the apertures, the shape of the calcareous modules that encase the body, and the comma-shaped structures (the avicularia) that are used to protect the oral opening. Some species' skeletons had relatively simple shapes that were easy to describe in ten measurements, while the more complex types had additional structures that required as many as forty. We needed to know whether the number of traits we measured was influencing our results. In all cases, we found the statistical differences in the measurements of twenty-two species held up, whether based on a few anatomical features or many.

Next, we needed to check on the stability of the species in differing environments. We collected colonies from different reefs and raised their offspring in the shallow seawater adjacent to the Smithsonian's laboratory in the San Blas Islands. After we had successfully raised two generations there, we began to study the offspring. Nearly 500 had grown big enough for morphological analysis before the experiment was terminated by a hurricane. The results were clear. All offspring in all three genera closely resembled their parents, despite having been transplanted to a new environment. No false species or environmental variants appeared.

We then used a biochemical procedure called protein electrophoresis to study variation in enzymes that are coded by the bryozoan's DNA. This is a relatively old and not particularly sensitive technique that first came into general use during the 1960s, and has since been supplanted by DNA comparisons. But electrophoresis has the advantage of rapidly and cheaply screening genetic variation in large numbers of animals. We examined more than 400 colonies of eight species. Again the results were unambiguous: no genetic evidence for undetected, or "hidden," species and clear genetic differences between all species tested. So far, the numbers pointed overwhelmingly in a single direction: we had the ability to detect true bryozoan species in the fossil record from their calcareous skeletons alone.

Finally, we extended the study to include more than one hundred Caribbean and western Atlantic populations of the genus *Stylopoma*, which is one of the three bryozoans that we had first looked at. We chose this genus because it is abundant today, it has many different species, and its fossil record seems complete enough to help reconstruct the evolutionary relationships of all known species in the genus.

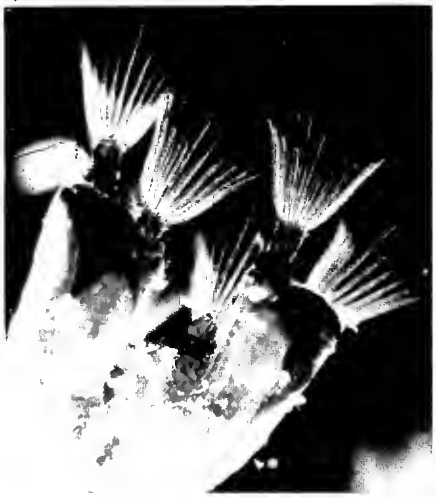


Fossil skeletons of the bryozoan Metrarabdotos auriculatum, *found in the Dominican Republic, show how little the species changed over eons. The Pliocene species, left, is 3.4 million years old and the Miocene species, far left, dates from 7.3 million years ago, yet their structural details are virtually identical.*
Photomicrographs by National Museum of Natural History; SEM Laboratory

Charles Seaborn, Odyssey Productions

About the size of a golf ball, a Caribbean bryozoan colony, right, attaches itself to the sea floor in waters more than one hundred feet deep. Species closely related to it are abundant in the fossil record and go back at least 100 million years. Below: A living cheilostome bryozoan extends its lophophores, which waft food particles into a few of the colony's many mouths.

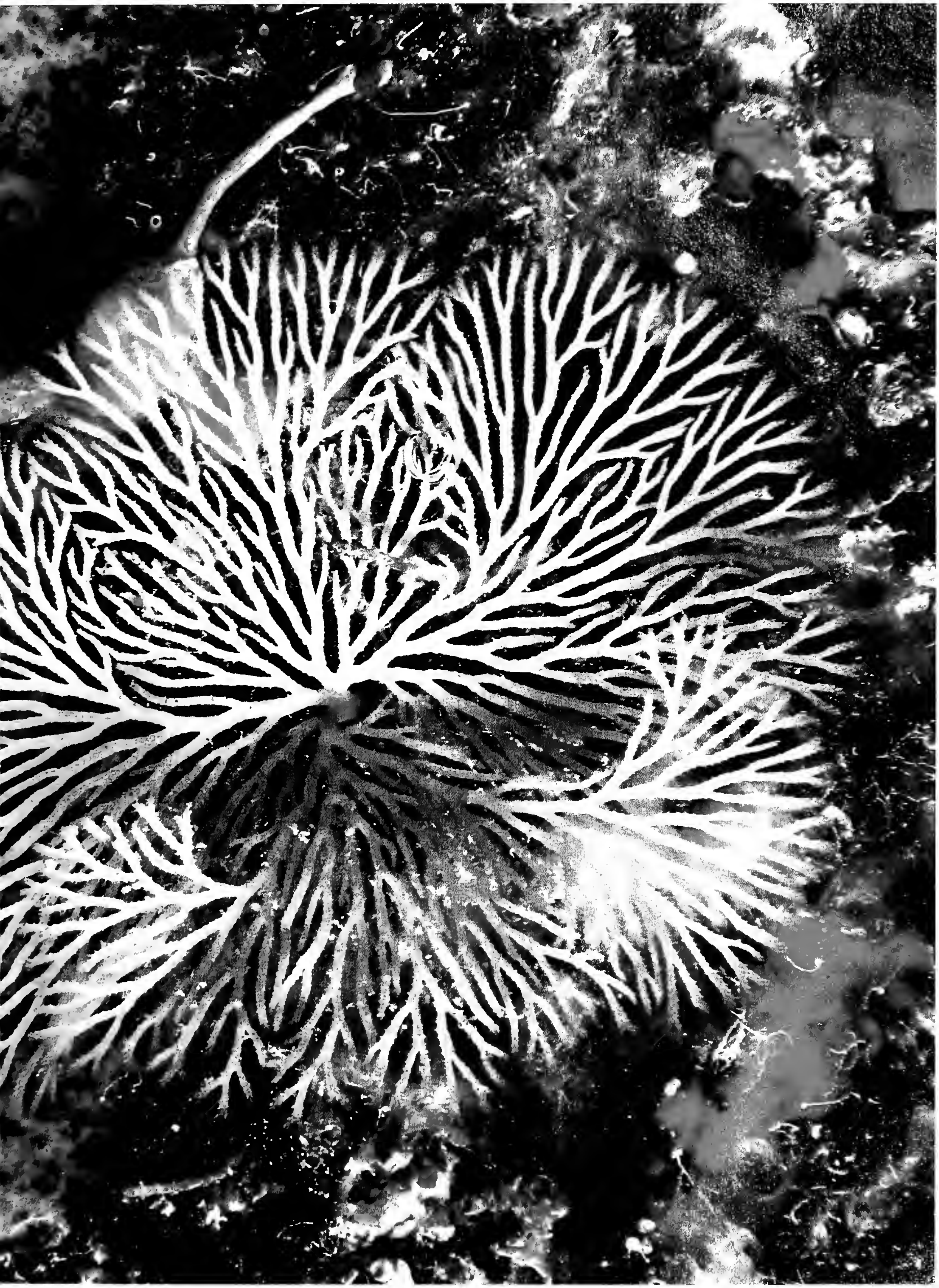
Kjell B. Sandved; Visuals Unlimited



We identified both fossil and modern species by their skeletal features, as before, and used these measurements to construct our hypothesis of relationships.

We then looked at the genetic chemistry, using *Stylopoma* from Panama and some from the island of Curaçao, which are far enough apart (about 600 miles) to contain quite different faunas. According to the genetic tests, only one of the 237 colonies we had classified by skeletons was proved to be incorrectly identified. Even more striking, each pair of species we compared showed about the same magnitude of genetic differences, skeletal differences, and the presumed distance of their phylogenetic relationship.

The excellent agreement among all these different methods and measures of relationship means that skeletal characters hold up as a valid method of defining bryozoan species. In studying those species through millions of years, we can trace the same patterns: relatively abrupt appearances, followed by enormous periods of unchanging sameness. Because our results have been consistent across three distantly related genera, our studies support punctuated equilibrium as a measurable reality. So far as living and fossil bryozoans can tell us, patterns of punctuation and stasis—rather than slow and steady gradual evolution—really do exist in the history of these ancient colonial creatures.



Evolution

Evolution

Survival of the Smallest

When Pleistocene seas rose, diminutive island deer gained a competitive edge...temporarily

by Adrian M. Lister

Islands have long been favorites among biologists for the study of evolution. Because the number of species is low and the habitats relatively simple, islands are ideal for thorough surveys of both ecology and genetics. They also provide a perfect model for one of the most popular theories of how species come into being: a small population of plants or animals, isolated from the main range of the parent species, can rapidly evolve into a new form. The widespread phenomenon of endemic species, plants or animals found only on particular islands or island chains, testifies to the power of this process.

A common island phenomenon is the evolution of unusual body size in mammals. Small mammals, such as dormice, shrews, and hamsters, often grow larger than usual, while larger, herbivorous mammals tend to become smaller than the norm. A living example of the latter can be seen in the Florida Keys, a chain of narrow islands off the southern coast of Florida. Key deer are miniature versions of the common white-tailed deer of mainland North America.

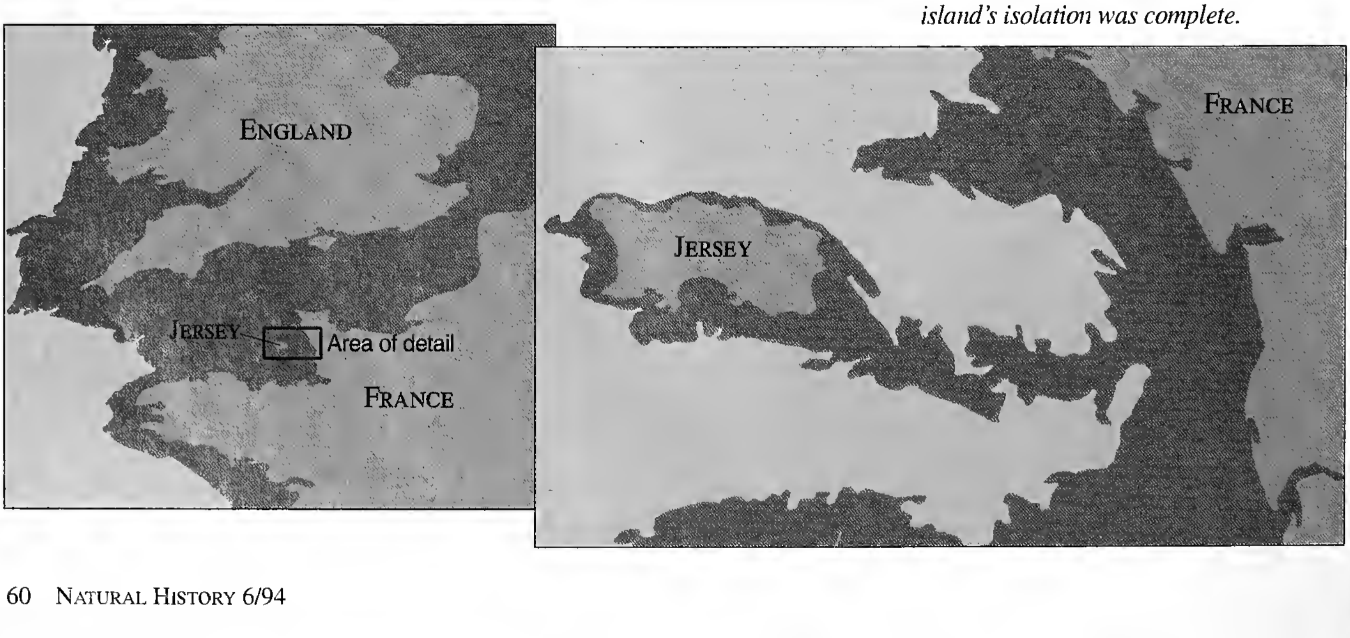
Further examples of dwarfing come from the fossil record, particularly from the Pleistocene, the period that lasted much of the last two million years and included the ice ages. During this time, many islands in the Mediterranean were home to dwarf forms of deer, elephants, and hippos. Dwarf stegodons, which were mastodonlike proboscideans, lived in Indonesia, and dwarf mammoths inhabited islands off California and northern Siberia.

For the past six years, I have studied fossil deer from caves on Jersey, an island politically affiliated with Britain but geographically close to the coast of northern France. The recent work there is the continuation of excavations first begun in a cave at Belle Hougue on the northern coast of the island in 1914; a second cave with deer remains was discovered nearby in 1965. Anatomical studies show these bones to be closely related to *Cervus elaphus*, the red deer common today in Europe and Asia, and differing only slightly from the North American elk. The bones from Belle Hougue belonged to animals that, fully grown, stood less than two and a half feet at the shoulder and weighed eighty pounds, only one-sixth the body weight of red deer from other Pleistocene fossil deposits in mainland Europe.

Dating of the Belle Hougue deposits, by analysis of uranium isotopes, indicates that the dwarf deer lived about 120,000 years ago. However, at another site on the island, La Cotte de Saint Brelade, older red deer fossils have been discovered in deposits spanning the period from about 230,000 years ago to shortly before those of Belle Hougue. These older remains are much larger than the bones from Belle Hougue; indeed, they are the same size as bones of red deer on the mainland. Jersey, then, was once home to ordinary-sized red deer. How and why did the transition to dwarf deer on Jersey occur? The clue comes in the climate of the Pleistocene.

For much of the time represented by the older La Cotte deposits, global climates were colder than those of today, and ice covered the higher latitudes. So much of the world's water was locked up in the expanded polar icecaps that global sea levels fell to as much as 300 feet below present levels. Even today, the seaway between Jersey and France is relatively shallow—only about thirty feet deep at low tide. But during the ice ages, this sea floor was exposed, and Jersey became part of a broad plain connecting Britain and France across the dry Channel. The large red deer recovered at La Cotte were therefore part of a widespread mainland population free to roam over a broad range and walk between present-day France and Britain.

About 125,000 years ago, the climate warmed up, the icecaps melted, and as sea levels rose, Jersey became an island. The dwarf deer bones from Belle Hougue, which date from this period, are embedded within a deposit of pebbles and seashells above the reach of modern tides. Now fossilized, these deposits were a beach when sea level was a few yards higher than it is



Left map: Some 150,000 years ago, sea levels were about 300 feet lower than today's, and the coast of Europe (dark green) was farther west. Britain, France, and the island of Jersey were part of one land mass. Map at right: As sea levels rose about 125,000 years ago, Jersey was joined to the mainland only by an isthmus. By 120,000 years ago, the island's isolation was complete.

Red deer stags congregate on an estate in northern England. Native to Eurasia, modern red deer vary in size, but all are larger and heavier, and the males have more elaborately branching antlers, than the Pleistocene dwarfs of Jersey.
Leonard Lee Rue III, Bruce Coleman, Inc.

today. Almost certainly, the isolation of Jersey, which cut its population of deer off from the deer on the mainland, set the scene for the dwarfing process. Then, as now, about fifteen miles of seaway would have separated the island from France. Red deer are good swimmers—they have been known to cross four miles of open water—but the greater distance from Jersey to the mainland would have insured their genetic isolation and allowed the dwarfing process to commence. We know from studies of fossil beaches and deep-sea cores that the temperate episode lasted about 11,000 years, and that for the central 6,000 years of this period, the sea was high enough to isolate Jersey. This gives us a maximum time span of just 6,000 years for the evolution of the dwarf deer.

In a paleontological context, 6,000 years is a very short interval. Red deer—of normal, large size—have lived in Europe for about the last 600,000 years, so the Jersey dwarfing represents only one percent of the species' duration. On a geological time scale, the dwarfing process qualifies as a very rapid evolutionary event. Biologically, however, 6,000 years represents about 2,000 generations of deer—plenty of time for the accumulation of genetic changes leading to size reduction. To an observer, this process probably would have appeared as a gradual generation-to-generation transition. The perception of evolutionary change as rapid or gradual is therefore subjective and dependent on the time scale.

The tendency of large mammals inhabiting islands to become dwarfed has given rise to much theorizing, but most researchers agree that it is related to restricted food supplies and the absence of mammalian predators. In the limited land area of an island, food is at a premium, and small-bodied individuals that can make do with less have a better chance of surviving and reproducing. Small size would be a particular advantage during times of winter shortage, since island inhabitants cannot migrate to richer feeding grounds, as can their mainland counterparts. In addition, large carnivores are usually absent, as small islands often cannot support the numbers of herbivorous mammals that predators need to exist. In the absence of wolves, bears, or large cats, one of the adaptive advantages of large size—defense and escape from predators—disappears. Also, in the absence of predators, herbivore populations expand to the point where individuals must compete for food, adding to the premium on frugality and small size.

What became of the Jersey dwarfs? About 115,000 years ago, the climate again cooled as the last ice age began. Sea levels dropped, Jersey once again was connected to the mainland, and the dwarfs disappeared from the fossil record; all the later remains of Jersey red deer are large. With the reemergence of the bridge to the mainland, the dwarfs would have come into contact with normal-sized red deer. We do not know if the dwarfs had, in 6,000 years, become a separate species or even if they were on their way to achieving their own mating cues, which would ultimately have isolated them genetically from mainland deer. If they had not reached this point, they may have been subsumed into the population of mainland red deer by interbreeding. In either case, the dwarfs would have had to compete with mainland red deer and would have become easy prey for large mainland carnivores. Adapted to island life, the Jersey dwarfs perished when, no longer isolated, they roamed into a new land of relative giants.

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The Turtle's Long-Lost Relatives

Its ancestors evolved many turtlelike traits before they acquired shells

by Michael Lee

A prominent zoologist once quipped that the only thing turtles have done since the Triassic, some 200 million years ago, is survive. This assessment seems a bit harsh, however, considering the variety of environments that they have conquered. Today, turtles thrive in oceans, rain forests, and deserts. Yet underlying this ecological diversity is a surprising degree of anatomical uniformity. No one has any difficulty recognizing a turtle; in all turtles the body is encased within a rigid, bony box. No other animal has a body architecture that is even remotely similar.

But where do turtles come from? The oldest fossil turtles (along with the earliest dinosaurs) appear abruptly in Triassic rocks, fully developed and without any obvious precursors. Details of their skull suggested that they evolved from a group of primitive reptiles, but none could be readily identified as turtle ancestors. Despite more than a century of research, the origin of turtles remains a major enigma.

Such "morphological gaps" are invariably seized upon by creationists as evidence against evolution. Scientists, aware of the vagaries of the fossil record, attach little importance to such negative evidence—the transitional forms may have once existed, but simply have not yet been discovered. Mere ignorance of something does not demonstrate its nonexistence. One is reminded of the crack about the atheist who couldn't prove that God didn't exist—and so took it on faith. Indeed, recent paleontological finds have plugged some of the most embarrassing and persistent gaps in the continuum of life: *Acanthostega* from Greenland, transitional between fishes and amphibians; *Ambulocetus* from Pakistan, a seallike link between whales and their terrestrial ancestors; and *Eoraptor*, the most primitive dinosaur yet discovered.

Stunning finds by intrepid field parties collecting in exotic locations aren't the only way such "missing links" become known to science. Sometimes a careful reappraisal of known forms can yield major surprises. For more than a century, the origin of birds remained a matter of conjecture, until John Ostrom, a Yale paleontologist, pointed out that certain small bipedal, carnivorous dinosaurs closely resembled *Archaeopteryx*, the first bird—so closely that a specimen of *Archaeopteryx* had been mistakenly cataloged as a dinosaur by museum workers. In a similar vein, I think that I have identified a group of animals, the pareiasaurs, that bridge the huge morphological gap separating the oldest turtles from primitive, lizardlike reptiles.

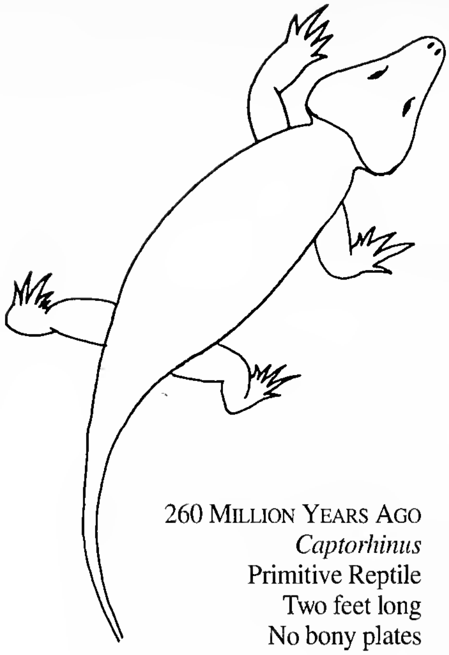
Pareiasaurs have been known to science since the mid-1800s, but their true significance went largely unappreciated. Their fossils have been recovered from Upper Permian rocks (about 250 million years old) in Russia, South America, China, and Europe. Most specimens, however, have come from South Africa, where farmers in the dusty Karroo Basin often stumble across bony remains weathering out of exposed rocks. The local Afrikaans name for them, *handjietand dier* (which is every bit as annoying to spell as *pareiasaur*), refers to their distinctive dentition and means "animal with teethlike little hands."

Pareiasaurs were among the largest animals of their time, but resemble nothing alive today. Imagine a fat hippopotamus with a thick tail. Shave off all its hair and cover its back with little armor plates. Now, stick some grotesque knobs all over its skull. Finally, make it drag its belly along the ground, with its legs sprawled out sideways, like a lizard's or a turtle's. The end result wouldn't look totally unlike a pareiasaur. Aesthetically challenged to say the least, these ponderous herbivores have long been neglected by paleontologists, dismissed as an inconsequential evolutionary dead end. (A colleague of mine, Des Maxwell, branded them "history's ugliest reptiles" and promptly switched to working on dinosaurs instead.) Even their name, pronounced "pariah-saur," seems to invite such scorn.

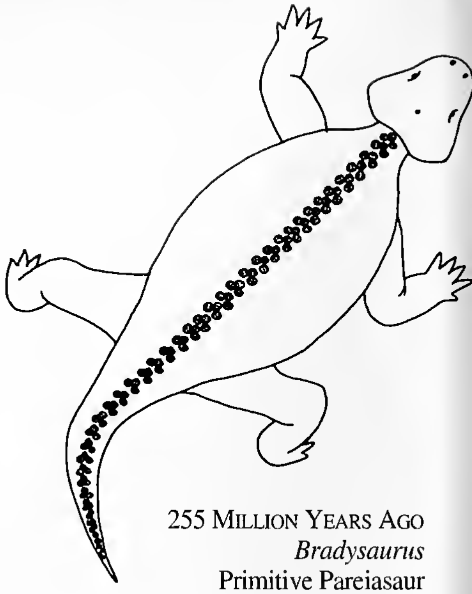
As a less-discriminating, first-year graduate student, however, I persisted in studying pareiasaur anatomy in more detail. I discovered that although they resembled bloated, oversized lizards in many respects, pareiasaurs had already evolved many of the characteristics of turtles. For instance, all primitive reptiles completely lacked body armor. Early pareiasaurs, however, had tiny bony plates embedded in the skin over the backbone; in later forms these plates spread out over the sides and belly, and enlarged and fused with one another to form a rigid carapace—just like a turtle shell. Also, most early reptiles had long, slender bodies, with twenty-five or more vertebrae in the neck and back. Early pareiasaurs had short bodies, with twenty vertebrae; later forms were even shorter, with nineteen; and turtles are stubbier still, with eighteen. Finally, moving from primitive reptiles to early pareiasaurs to late pareiasaurs, the shoulder, pelvis, and limbs also became more and more turtlelike. The message was clear: turtles evolved from advanced pareiasaurs.

If a pareiasaurian ancestry of turtles was so obvious, why hadn't anybody else proposed it? Perhaps I had overlooked some fatal weakness in the argument. As it turned out, I wasn't the first person to come up with the idea after all. William Gregory, a curator at the American Museum of Natural History and one of this century's paleontological greats, had proposed the same idea almost half a century ago, but his discussion of the supporting evidence was vague. For instance, he failed to emphasize that the similarities shared by pareiasaurs and turtles were found in no other primitive reptiles. His views, therefore, were largely forgotten.

What about more recent research? People have long asserted that the turtle's bizarre body plan is so highly modified that all evidence of its ancestry has been effectively obliterated. Therefore, many recent workers assumed that only skull features could reveal where turtles came from. Thus, they overlooked all the striking similarities between the bodies of pareiasaurs and turtles. Scientists are no more objective than other people; what we see is heavily constrained by what we expect to see. My ignorance of established dogma proved a godsend. Furthermore, I was fortunate to have access to critical information unavailable to most previous workers. The year before I began my studies, Eugene Gaffney, another curator at the American Museum of Natural History and an expert on fossil turtles, published a detailed description of the 200-million-year-old *Proganochelys*, the most primitive turtle yet discovered. Knowing what this turtle looked like was vitally important in trying to figure out what its immediate ancestors looked like. *Proganochelys* retained many features inherited from its



260 Million Years Ago
Captorhinus
Primitive Reptile
Two feet long
No bony plates



255 Million Years Ago
Bradysaurus
Primitive Pareiasaur
Ten feet long
A row of small, unfused
bony plates

pareiasaurian forebears. These evolutionary holdovers—clues to the ancestry of turtles—were later lost in more advanced turtles. Nevertheless, a forty-million-year gap, spanning almost the entire Triassic, still exists between the last pareiasaurs and the earliest-known turtles. When turtles first appear in the fossil record, in the late Triassic, they are represented by at least four distinct lineages, suggesting that the group evolved and radiated slightly earlier.

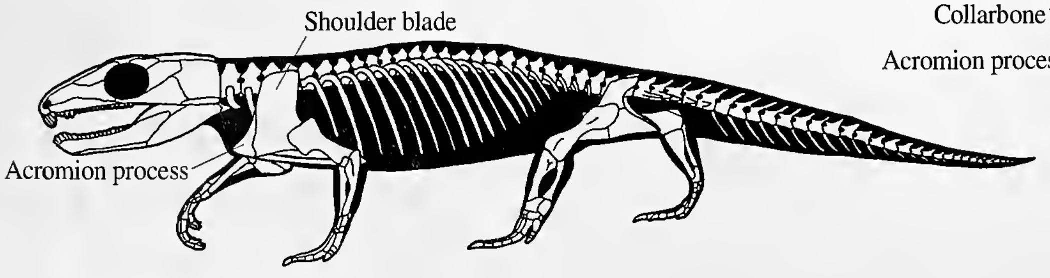
A pareiasaurian ancestry helps explain how and why the bizarre turtle body plan evolved. The turtle shell is an adaptive marvel. It forms an organic strongbox, into which the extremities can be retracted out of harm's way. It also supports the turtle, whose backbone is fused to the rigid shell and whose shoulder girdle is anchored to the shell by ligaments (other animals need muscles to keep these elements in place). Finally, the shell forms a thick, insulating layer, which confers thermoregulatory advantages. Compared with other reptiles of the same size, turtles overheat more slowly on hot days and cool down more gradually on cold nights.

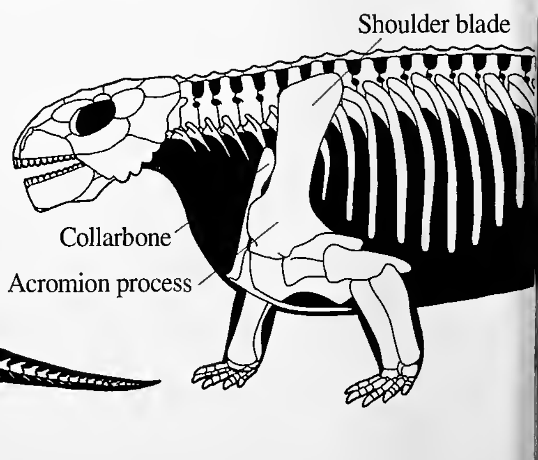
But which of these demands favored the evolution of the shell? Pareiasaurs supply the answer. Early pareiasaurs possessed a row of bony plates above their backbone—the first hint of a shell. Recent work by Dino Frey, a German morphologist, suggests that these plates helped the pareiasaur stop its backbone from sagging. Thus, the precursor of the turtle shell that evolved in the large, heavy pareiasaurs, initially served a supporting function. Only in later pareiasaurs and turtles did these plates spread out over the body and provide protection and insulation. All the earliest turtles were found in terrestrial deposits alongside dinosaurs and possessed stout legs adapted for walking, not swimming. So it seems safe to say that they, like pareiasaurs, were land animals. For a long time people had assumed that turtles must have evolved in the water, because of support problems created by the heavy shell. Yet, not only did turtles evolve on dry land, but initially the shell probably served for support.

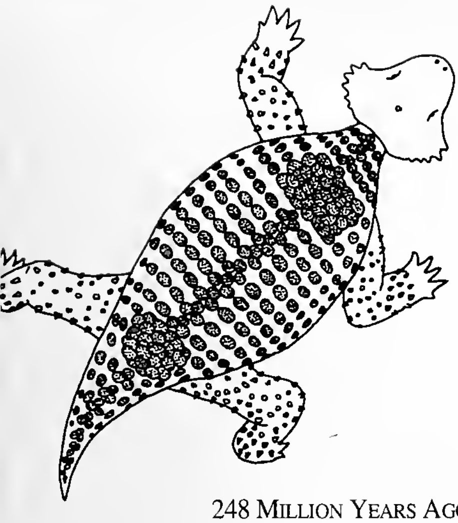
Many other distinctive anatomical traits of turtles appear to be, in one way or another, adaptations for life in the shell. A straightforward deduction might be that these traits evolved at the same time as the shell, or immediately afterward, and served their function right from the very beginning. Surprisingly, this isn't the case. Consider the turtle's stout body, for example. It appears to be adapted to fit into the shell. The wide, short shell of turtles is difficult for predators to overturn or get their jaws around. Furthermore, a shell of this shape is easier to maneuver than a long, skinny one (imagine how much difficulty a lizard encased in a rigid tube would have getting around). But this body shape actually arose in the pareiasaur ancestors of turtles long before the shell appeared. The earliest-known pareiasaurs lived in southern Africa, which at the time had only just drifted northward out of the Antarctic circle. The climate then was cool. Because short, fat animals lose heat less rapidly than long, thin ones (which is why many animals, ourselves included, curl into a ball when cold), the stout bodies of pareiasaurs probably helped them conserve precious body heat. Thus the short body of turtles first served a thermoregulatory function and initially had nothing to do with life in a shell. The body dictated the shape of the evolving shell, not the reverse.

Another example concerns a bony process on the turtle shoulder blade, the acromion process, which helps connect the

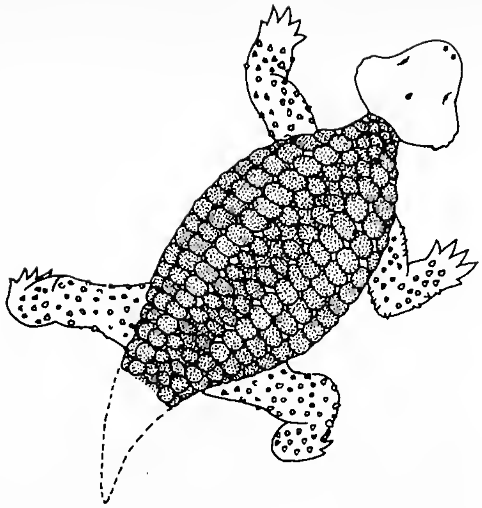
The elongated, lizardlike skeleton of Captorhinus *is typical of primitive reptiles. It had five neck vertebrae, twenty back vertebrae, and a shoulder girdle lying outside the rib cage.*
Illustrations by Michael Lee



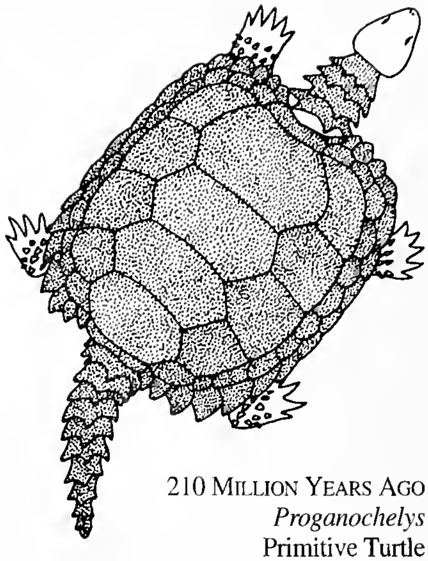




248 Million Years Ago
Scutosaurus
Intermediate Pareiasaur
Ten feet long
Fused bony plates over shoulder and pelvic areas. Unfused plates spread laterally



248 Million Years Ago
Anthodon
Advanced Pareiasaur
Three feet long
An interlocking mosaic of plates covered its back and sides

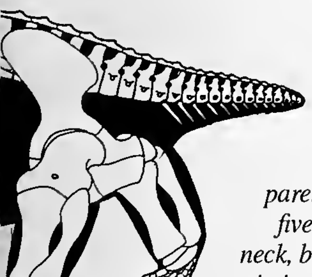


210 Million Years Ago
Proganochelys
Primitive Turtle
Three feet long
Looked like a modern turtle; shell completely enveloped its body

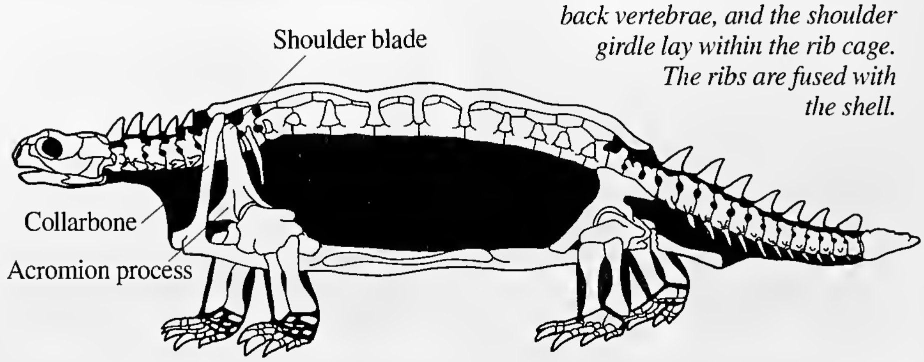
shoulder to the shell. Again, this structure first arose in early pareiasaurs and must have initially served a different function—one that is clarified by comparison with therapsids (primitive ancestors of mammals). Therapsids, which are totally unrelated to pareiasaurs and turtles, had independently evolved a similar structure, and research suggests that the acromion process improved the flexibility of the shoulder region. In primitive reptiles, the shoulder blade and collarbone are rigidly connected to each other along their entire length. In therapsids, the shoulder blade meets the collarbone only at the acromion process, and the two bones can move with respect to each other. The acromion process undoubtedly served a similar function in pareiasaurs. Thus, the acromion process initially evolved in pareiasaurs as a mobile articulation between the shoulder bones, and initially had nothing to do with anchoring the shoulder blade to the shell. Not surprisingly, in the most primitive turtle, *Proganochelys,* the acromion process retains the old function, and meets the collarbone, not the shell. Only in more advanced turtles did it shift position and come into contact with the shell.

The highly distinctive body plan of turtles, therefore, did not arise in one huge evolutionary leap. Rather, traits that were evolutionary holdovers from their pareiasaur ancestors were modified and integrated with one another. The shell started out as merely a supporting row of bony plates in pareiasaurs. Later, in turtles, these were co-opted to form the basis of a rigid protective, insulated box. Similarly, the short stubby body, the acromion process, and many other turtle traits (such as the tall, columnlike shoulder blade and oddly shaped arm and thigh bones) are often thought to have arisen purely as adaptations to life in a shell. Yet they appeared first in pareiasaurs, long before the shell appeared.

All this illustrates once again the serendipity of evolution. Natural selection favors what's best now—which is rarely what's best in the long run. Usually, this means adapting an existing organ to perform some new role tolerably well, instead of going back to the drawing board and evolving a completely new structure that does the job perfectly. (Vertebrate history is full of such makeshift expediency: our arms are really only modified forelegs, and our ear bones arose from bits of gill and jaw.) Traits that originally served other purposes in their pareiasaur forebears became modified in turtles to serve functions related to life in a shell. And so well have they been integrated into their new roles that it is difficult for us to imagine them as having evolved to do anything else.



Anthodon, *a pareiasaur, also had five vertebrae in its neck, but only fourteen in its back. In front of the wide, barrel-shaped rib cage, there was a narrow shoulder girdle. Shifting the girdle three vertebrae farther back into the rib cage would result in a turtlelike arrangement.*



Proganochelys, *the most primitive turtle known, had eight neck vertebrae and ten back vertebrae, and the shoulder girdle lay within the rib cage. The ribs are fused with the shell.*

A Tale of Two Seas

When North and South America collided, some close families were divided

Evolution

by Nancy Knowlton

Panama, the country where I now live, once lay beneath the sea. North and South America were separate continents, and the waters and marine animals of what are now the Pacific and the Caribbean mingled freely over the submerged land that would become the Central American Isthmus. The movements of the earth's crust and the resultant collisions of plates—which eventually led to the joining of the continents and the separation of the oceans—were gradual. They began some fifteen million years ago and by about three million years ago, the land bridge was complete. These events set into motion one of the world's greatest natural experiments: while land animals migrated north and south into new realms, the now separated inhabitants of the two oceans began to travel along separate evolutionary pathways.

Today, the closest relatives of many Caribbean fishes, sea urchins, snails, and shrimps are still to be found in the eastern Pacific. Even experts may have a hard time figuring out which ocean a particular animal comes from. Nevertheless, of the few attempts at mating animals from opposite sides of the isthmus, most have failed; even if we can't tell the difference, the animals can. Once members of a single species, these organisms were separated geographically after the isthmus arose, becoming over time what scientists refer to today as transisthmian sister species.

My colleagues and I investigated this evolutionary phenomenon by studying a single, but highly diverse, group, the shrimp genus *Alpheus*. These crustaceans look superficially like miniature cold-water lobsters, and they inhabit shallow, tropical seas, where they tend to hide in crevices, burrows, and shelters provided by other organisms, such as corals, sea anemones, and sponges. Rarely seen but often heard, *Alpheus* are commonly called snapping, or pistol, shrimps for the sound produced when they rapidly close the larger of their two front claws during aggressive interactions. We began by simply trying to identify the snapping shrimps from both coasts of Panama. With a little experience, we could readily recognize which ones were probably sister species by similarities in external form and in color patterns.

We wanted to find out if these apparently related, look-alike shrimps were still enough alike genetically to interbreed. Following geographical isolation, even the signals that animals use to recognize potential mates can change, so our transisthmian sister species provided an elegant model for studying the process of behavioral and genetic divergence that leads to the creation of new species. We paired snapping shrimps from the same and opposite sides of the isthmus and then

Before plate tectonics forged the land bridge between North and South America, marine creatures such as the snapping shrimp Alpheus armatus *moved freely between what are now the Caribbean Sea and the Pacific Ocean. Today this species is found only in the Caribbean.*
Alex Kerstitch

watched for any signs of reproductive compatibility. Because so few studies like this have been done, we didn't know exactly what to expect.

Snapping shrimps are good candidates for such a matchmaking experiment. They breed year-round, and when pairs are incompatible, they tend to be aggressive, so we could look at both behavioral interactions and fertility. Under experimental conditions, almost none of the transisthmian pairs produced eggs. Some of our look-alike pairs were quite tolerant of each other, but others were extremely aggressive, snapping repeatedly and sometimes pulling off claws. We were able to show that these behavioral incompatibilities were also reflected on a molecular level.

The evolutionary theory of the molecular clock holds that certain kinds of molecules change at a regular rate and thus provide a timepiece for dating the moment at which lineages leading to different organisms first separated. The rough regularity of the rate is due to the steady accumulation of errors; the process of copying DNA can lead to mutations, just as the copying of manuscripts by hand can lead to changes in a text. To estimate how far apart the pairs of species had drifted genetically, we looked for differences in the sequence of the four DNA nucleotides on a part of the circular DNA molecule found in the mitochondrion (the energy-producing engine of the cell). We also looked for differences in proteins that are determined by DNA in the nucleus of the cell.

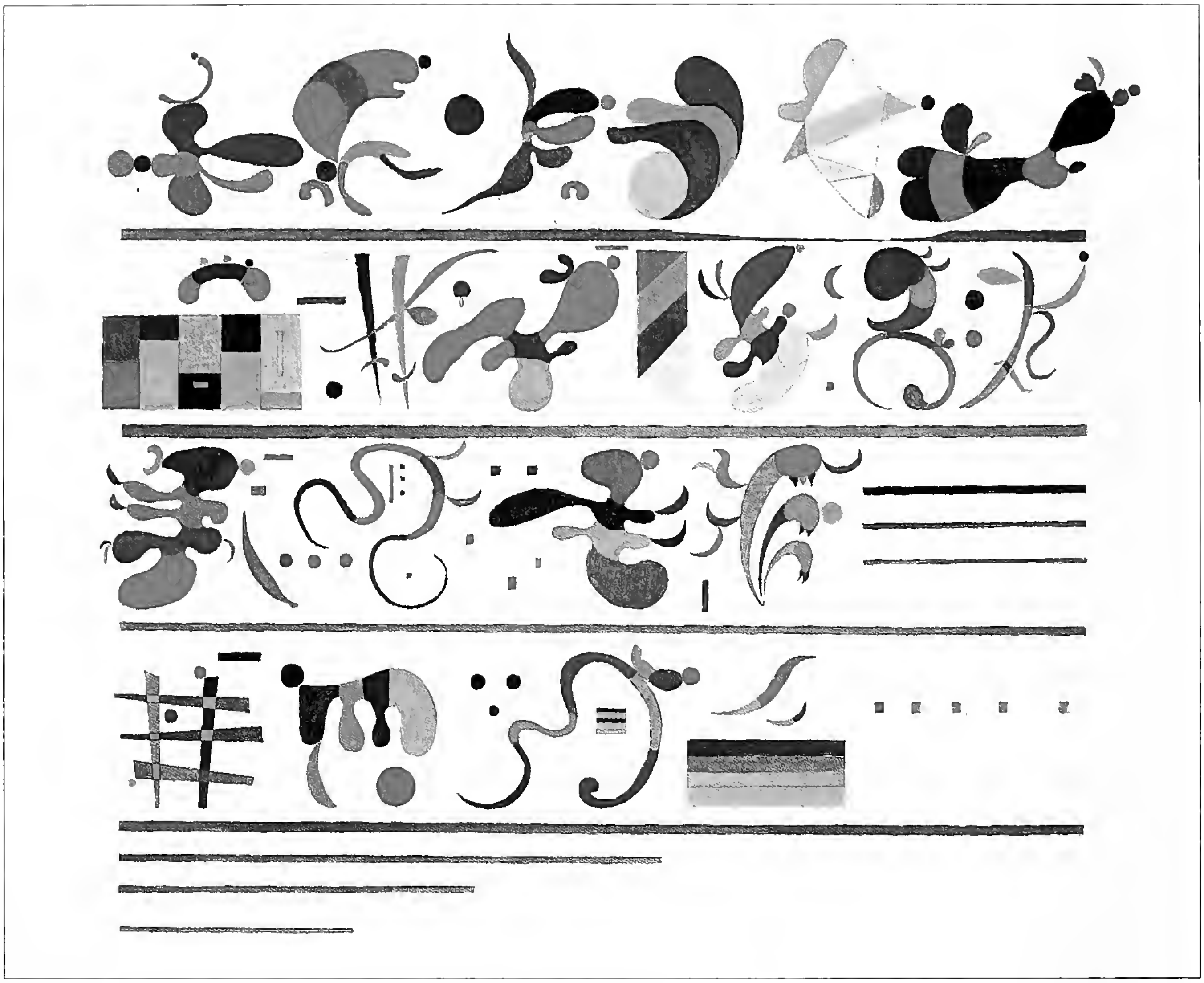
When we combined our data from the behavioral and molecular studies, we found a clear pattern. The shrimp pairs that were least aggressive to each other had the most similar mitochondrial DNA and nuclear proteins, while pairs that fought vigorously showed much greater molecular divergence. What could account for some sister species being more closely related to their transisthmian counterparts than others?

Ecological differences among the various shrimps—especially the kind of habitat they prefer—suggest that not all pairs parted company at the same time. The most closely related, and thus the most recently separated, species were those that inhabit shallow, turbid waters—exactly the kind of conditions that would have characterized near-shore habitats immediately preceding the final emergence of the isthmus and the closing off of any connection between the Pacific and Caribbean. The more divergent pairs, however, both in behavior and in their mitochrondrial DNA and proteins, were those typically found in slightly deeper water or in the clearer waters of offshore islands, perhaps indicating that they had already moved away from the turbid edge of the emerging isthmus before the land barrier was complete. How long before? Molecular divergence rates and paleontological evidence suggest that the four most closely related pairs of snapping shrimps were separated about the time of final closure of the isthmus, some three million years ago; five were isolated four to six million years ago; and two were separated at least seven million years ago.

Judging from the combination of behavioral tolerance and infertility demonstrated by the most similar males and females from opposite sides of the isthmus, three million years appears to be just adequate for the creation of new species of snapping shrimps. A study of closely related, but geographically isolated, fruit flies resulted in a similar estimate of the amount of time required to create new species. In both cases, the separated organisms remained almost identical in outward appearance. In contrast, during the same length of time, the transition from *Australopithecus* to our own extremely different species, *Homo sapiens,* took place. The isthmus, and the sibling species on either side of it, give us one measure of the background rates of routine evolutionary change against which great evolutionary developments can be compared.

A Pacific species of snapping shrimp, Alpheus sulcatus *inhabits coastal waters from western Mexico to Peru. Snapping shrimps wield their enlarged claws in territorial battles; when rapidly closed, the claw makes a sound reminiscent of corn popping.*
Alex Kerstitch

The Naked Ape's Bit Part



Wassily Kandinsky, *Succession;* © 1994 Artist's Rights Society; The Phillips Collection

Even the smallest single-celled organism probably would be obnoxiously self-centered if it had the means and time to think about itself. And *Homo sapiens,* who by definition are thinking animals, certainly have worried their big brains more about the details of their own evolution than any other species. But humans have played, at best, only a bit part in the four-billion-year drama of life on earth. *H. sapiens* barely deserve mention in this special issue. Furthermore, *Natural History* has treated them extensively in the past (see the section on human evolution in the April 1993 issue as an example). Yet knowing (and sharing) our readers' human foible of narrow self-interest, we end this issue with three evolutionary essays on human diseases, our body plan, and the global genetic diversity of our species.

Evolution

A Brave, New, Healthy World?

By accident, we may be entering an era of unprecedented genetic good health

by Steve Jones

The study of human genetics began with a fear for the future. Frances Galton, Charles Darwin's cousin, argued in his book *Hereditary Genius* (1869) that people of innate merit—the geniuses of his title—were having too few children, and that, as a result, the human race was on the edge of decline.

Many utopian and antiutopian novels trace their vision of the future directly to biology. Aldous Huxley's *Brave New World* owes much to his family's scientific ambiance—his brother was the biologist Julian Huxley, and his grandfather Thomas Henry Huxley was known as "Darwin's Bulldog." H. G. Wells—whose utopia appeared in *The Shape of Things to Come*—himself wrote, with Julian Huxley, a textbook on evolution; and George Bernard Shaw, author of *Back to Methuselah,* appeared on public platforms with Galton.

In true Victorian style, no sooner was the idea of evolution accepted than there was a call to interfere with it, in this case by controlling human mating. Nobody needs reminding of what the eugenics movement led to. Many of Hitler's crimes were part of a misplaced attempt to control the biological future of the human race.

Geneticists' views have changed greatly over the last century. Galton's sweeping concerns about the future have been replaced by a more realistic focus on the risks of inborn disease. The last few years have seen many triumphs in the diagnosis and treatment of genetic illness, and there is the promise of many more to come.

But with these advances has come a new concern. Perhaps our ability to interfere with our genes may—as the eugenicists feared—change the evolutionary outlook for the worse. Are such anxieties justified; and was Galton right?

Most human biological evolution, like that of any other species, depends on mutations that can occur as genes pass from parents to offspring. Some of these are better than what went before and become more common; others are worse and fail to survive. This process, natural selection, is the driving force of adaptive evolution.

Another important—but often neglected—agent is genetic drift, or evolution by accident. Particularly in small and isolated communities, genes become common or rare at random, as those who carry them have, by chance, more or fewer children than average and are hence more or less successful in passing on their genetic heritage.

It is hard to predict just what the forecast for mutation or natural selection might be. One thing, though, is sure. Barring some disastrous reduction in the number of people around, evolution by accident no longer has much force. Twenty thousand years ago, there were only as many people in the world as there are in New York today. Society was based on small bands or isolated villages, and marriages were within the group. For most of history, everyone had to marry the girl (or the boy) next door, because there was no choice.

Few people now live in small or isolated communities. The change began thousands of years ago and will take thousands more to complete (although it has accelerated during the past century). This will have not only a long-term effect on our biology but also an immediate influence on genetics—not on the number of geniuses, but on the incidence of disease.

Inherited disease is certainly common enough. About two out of every three people reading this article will die for reasons connected to the genes they carry. Many of the genes involved—including those connected with cancer and heart disease—kill later in life, after the reproductive years and too late for natural selection to have much effect.

About one person in thirty, though, is born with a gene that takes its toll relatively early. Such problems have become more important, in the West at least, as infectious diseases are controlled (*see* "Bacteria Break the Antibiotic Bank," page 39, and "On Darwin, Snow, and Deadly Diseases," page 42). The genes that underlie many inherited diseases are recessive; they show their effects only when a carrier has two copies, one from each parent.

The commonest inborn diseases among people of African and of European ancestry—sickle-cell anemia and cystic fibrosis, respectively—are of this kind. Others are more local, but are painfully familiar to people from the affected regions. In Cyprus, for example, one inherited blood disorder, beta thalassaemia, or Cooley's anemia, is so common that treating all the children involved is likely to soak up half the entire health budget within ten years. As treatments are developed for other diseases, many societies will face the problem of paying for them.

Both cystic fibrosis and sickle-cell anemia can now be treated, and those affected may survive to have children of their own. Tests to determine whether a fetus is at risk of genetic disease are now used in many parts of the world, so that the number of children born with these conditions is dropping. But not everyone has access to the tests, and some choose not to terminate a pregnancy even when the test is positive. What will the balance be between the increased numbers of damaged genes passed on by survivors and those lost by selective termination of pregnancy? Are we meddling with biology without realizing what we are doing?

Perhaps, but the effects of genetic technology pale before those of social change. We are in the middle of one of the most dramatic events in evolutionary history: the human race may be entering an era of unprecedented genetic good health—a biological utopia reached by accident.

At the heart of this new age is a change in mating patterns. Frances Galton himself showed what this can do to genes. He looked at a simple inherited character, the surname. Just like a gene, a surname is passed down through generations (albeit through only one parent) and, also like genes, names do odd things in small populations.

In Switzerland, for example, everyone in a mountain village may have the same surname, while everyone in another village a few miles away shares a different name. This is not because Schmidts survive in one place and Eisens in another. Instead it happens at random. Within each hamlet there has, over the years, been an accidental loss of names as some men have no sons. Eventually, different names take over in each place. The process is inevitable: even if each of the villages started out (as they probably did) with a slightly different set of names, the effects of random loss mean that the differences

between villages are quickly amplified.

Shared names mean shared ancestors. If one of those ancestors carried a single copy of one or another harmful recessive gene—as nearly everyone does—then his or her descendants in the village, choosing their mates from a restricted pool, are at increased risk of having a child with two copies of the gene.

The danger is a real one. Finland, with its impenetrable forests, has lots of isolated and inbred populations—and many local centers of inborn disease. Some are almost unknown elsewhere, while others represent isolated clusters of widespread but generally rare illnesses.

Social barriers can be just as effective as distance. In Britain, many children of Pakistani immigrants marry among themselves. Nearly half are married to a cousin. Although only about one British birth in fifty is to this group of closely related parents, these children represent about 5 percent of all inborn disease. Certain religious communities, such as the Amish, are natural laboratories for genetic disease because they are so inbred. Ellis-van Creveld syndrome, an inherited abnormality of the skeleton, is commoner among the Pennsylvania Amish than in any other group of people. Every sufferer traces his or her ancestry to Samuel King, a founder of the community.

Even outside such closed communities, most people have traditionally chosen to mate with those who live close to them. Now this pattern is changing quickly. The tens of thousands of surnames in New York—and the distinct ethnic groups to which many of them are attached—show just how mixed up the world's population is becoming. And cities are not the only places where the pool of potential mates is growing. Even on the Lipari Islands off the coast of Italy, where in the 1920s a quarter of marriages were between first or second cousins, only about one marriage in fifty is between cousins today.

A crude but effective way to measure how related one's ancestors may have been is to ask how far apart they were born. For nearly all the people reading this article, the distance between the places where they and their partners were born is greater than that separating their parents' birthplaces. And their parents were, in turn, likely to have entered the world farther apart than did their grandparents. In parts of nineteenth-century New England, the distance between birthplaces of marriage partners was less than twenty miles. Now the average in the United States is several hundred, and most couples are completely unrelated.

Bruce Plotkin

The mixing will not be complete for a long time, if ever—with as much as five hundred years needed to even out the genetic differences between England and Scotland alone. But even if global homogeneity is a long way off, increased movement and outbreeding will certainly work to decrease the numbers of children born with two copies of a defective gene.

One example of the genetic benefits of outbreeding—albeit one that has its roots in an abhorrent period of history—can be seen in the United States. On average, about a quarter of the genes of North American blacks were contributed by white ancestors—a result of interracial mating during the days of slavery (usually between white males and black females, who had little say in the matter).

Since the recessive gene for cystic fibrosis is unknown in Africans and that for sickle-cell anemia unknown in whites, the child of a black–white mating is safe from both diseases. One piece of advice that might be given to someone concerned that his or her child might suffer from genetic disease is to marry someone with a different skin color. Some geneticists believe that some of the general increase in child health seen in the West over the past century or so is due to such increased outbreeding.

Any benefits that genetic mixing will bring cannot last forever. In time the mixed populations of the world will reach a new equilibrium. Many of the genes hidden in the descendants of mixed marriages will reappear.

This new uniformity also means that no longer will there be much chance—as there was among the Amish—for small and isolated populations to diverge genetically by accident. One of the most important agents of evolution has lost its power.

Speculating about what is to come—particularly for a species like our own, so prone to social, political, or ecological disaster—is dangerous, but because so much of human evolution has involved random change in small groups, the loss of this agent of change probably means that the biology of the future will not be very different from that of the past. Humans may even be almost at the end of their evolutionary road. If so, we are as near to our biological utopia as we are likely to get, although it has been reached in ways not dreamed of by Galton.

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Evolution

Best Size and Number of Human Body Parts

We function well with one kidney, so why do we have two?

by Jared Diamond

When a routine medical test performed on me recently detected an unsuspected kidney cancer, my first thought was how to spend my final year of life, in case that proved to be all the time left to me. But after my diseased kidney had been removed and the other one proclaimed healthy, I grew reaccustomed to the expectation of a normal life span. I began to wonder instead how my life style would be affected, now that I had only one of what was originally a pair of vital organs.

Gradually, the answer emerged: There seems to be no effect. Having just returned from an even more demanding than usual New Guinea expedition, I can't detect any limitation on my capacity for exercise or for digesting food. As a physiologist and evolutionary biologist, I am left to wonder: Why did we evolve to have at least double the necessary mass of kidney, which ounce-for-ounce is the most energy-guzzling organ of our body to operate?

Actually, people can survive on only part of a single kidney, and our combined kidney mass has to drop by more than two thirds before it affects our life style. Hence we have a surfeit of kidney tissue, at least three times what we need. The outcomes of surgery on other organs show that, similarly, our intestine is approximately double and our pancreas a remarkable ten times the necessary size. As a result of that enormous excess of pancreatic tissue, one friend of mine who had the misfortune to develop pancreatic cancer felt no symptoms until 90 percent of his pancreas had been destroyed, by which time he was within a few months of death.

Why have we evolved to build and maintain such excesses in vital organs? Or—to reverse the question—if some excess is good, why don't we maintain even more? Fifty pounds of kidney would, of course, be too heavy, would fill too much space, and would require too much energy. But why are our kidneys the particular size that they are, 3 times, rather than 50 or 1.1 times, their necessary size?

This question is part of a broader problem in biological design. In addition to the puzzle of "how big," there is an analogous puzzle of "how many." For example, why are we endowed with two breasts, rather than with one or sixteen? (Some mammal species do have sixteen breasts). At the molecular level, why does each of our enzymes exist in its particular number of copies, rather than in some higher or lower number? Like clamshells and spider webs, our bones pose a third obvious, analogous puzzle of "how strong." Why didn't evolution result in our having stronger bones that would break less often?

Of course, you'll say, the answer has something to do with natural selection, which adapts each species to its particular life style and environment. For example, grass-eating cows, but not meat-eating tigers or humans, evolved a big rumen to digest cellulose. Similarly, Northern Europeans dependent for millenniums on drinking fresh milk as adults evolved to retain the milk-digesting enzyme lactase beyond childhood, but most peoples in the rest of the world did not.

Alas, most evolutionary reasoning remains at that qualitative, gee-whiz level and hasn't progressed since Darwin's day. (As a frequent author of such qualitative accounts myself, I'm not blaming other scientists for failings of which I claim to be innocent.) Rarely do biologists tackle the problem of adaptation quantitatively. We still lack a quantitative theory of biological design to predict numerical outcomes and to explain their variation in nature. We have yet to identify the selective pressures that keep our kidneys, breasts, and bones the size, number, and strength they actually are.

Exactly the same questions arise in connection with structures that we ourselves engineer. Such questions are now much on my mind and on those of my fellow earthquake-shocked Angelenos as we try to understand why some of our houses and freeways fell down while others didn't. Engineers analyze such questions by means of a well-developed framework that could serve as a model for biologists.

Like biologists, engineers have to deal with such questions as: How big? How many? How strong? Typical questions for them include: How strong should this house or bridge be built? How big should a hot-water heater be for a house expected to hold six occupants? How many emergency exits should be designed for a 12-passenger commuter prop plane or for a 500-passenger jumbo jet?

Engineered structures are qualitatively adapted to their "life styles," as are biological structures. For example, a bridge intended to bear the traffic of Sherman tanks is built more strongly than a bridge intended only for pedestrian traffic. But engineers go further than these qualitative analyses by calculating a "safety factor," that is, the ratio of a structure's capacity to its actual expected load. The cable supporting a fast passenger elevator, for example, is built with a safety factor of 11, meaning that the cable could actually support eleven times the maximum legal payload specified in the sign posted inside the elevator. Safety factors differ among engineered structures: for instance, 7 for slow freight elevators, but only 5 for hotel food elevators (dumbwaiters).

Why do engineers build with safety factors exceeding 1.0? Obviously, the answer is that actual capacities, as well as loads, are somewhat uncertain or variable, so that elevator cables with a safety factor of exactly 1.0 would often snap. Capacities vary because even batches of steel or concrete manufactured from the same mold differ in strength, and because strength deteriorates depending on age and use. Loads also vary unpredictably because one cannot be sure how many sumo wrestlers will try to crowd into an elevator at once or how many big trucks will simultaneously be driven across a bridge.

Actual safety factors are set depending on the expected magnitude of variation in capacities and loads, as well as on the costs and benefits of excess capacity.

That's why cables of passenger elevators have higher safety factors than those of dumbwaiters: the liability judgment against the elevator company will be much higher if a snapped cable kills hotel guests than if it just drops their room-service breakfasts. Structures made of wood have to have higher safety factors than those made of steel because wood's strength is initially more variable and deteriorates faster with time. Safety factors are set high enough to minimize the risk of structural failure, but low enough to avoid unnecessary expense or size. That is, safety factors reflect an optimization decision, based on trade-offs between costs and benefits.

Engineers used to make those decisions empirically and often unconsciously. For example, in New Guinea's Star Mountains, from which I returned a few months ago, people still cross mountain torrents over bridges that they build out of lianas and saplings. Falling into the torrent would mean certain death, so they build their bridges strong enough to make collapse unlikely, but they also don't make unnecessary work for themselves with overbuilt bridges. Those principles of bridge design evolved by natural selection, through experience with bridges that did or did not collapse.

In industrial societies, safety factors are instead calculated from physical principles and are written by law into design codes. However, those conscious decisions are still ultimately framed by a process of natural selection, where the arena is the marketplace of competing manufacturers and the selective agent is consumer choice. Builders presumably cease to buy elevators from companies whose cheap cables snap. They also cease to buy from companies whose overdesigned elevators cost double the price of already-safe, competing elevators.

Biological safety factors similarly evolved through natural selection, but the process is always "unconscious," and the

codes remain largely undeciphered in our genes. The biological arena in which natural selection operates is life itself, with its myriads of competing individuals and species. Yes, if all other things were equal, we would be better off with larger kidneys, more breasts, thicker bones, and more enzymes. But one cannot ignore the price of those benefits. All biological structures incur direct costs of biosynthetic energy and indirect costs of space occupied. Energy in the form of ATP is required not only to make a molecule or organ in the first place but also to maintain and operate it. Big organs incur further, indirect operating expenses because of the weight that has to be lugged around, as anyone who has been overweight or pregnant knows.

But the food energy available to an animal is finite. Space is also finite, as you may have appreciated when you saw all those organs packed closely together inside the body cavity of the frog that you dissected in introductory biology. Since available energy and space are limited, any resource devoted to one organ or enzyme comes at the expense of another. Thus, an economically designed animal will tend to outcompete not only an underequipped animal but also an overequipped one, profligate in one organ and necessarily shorted on some other.

The potential disadvantages of biological underdesign are obvious. Small bones break when overstressed, and small kidneys on which you dump too many toxins can't protect you against poison. As for the potential disadvantages of biological overdesign, they're reflected in the evolutionary loss or reduction of organs that become unnecessary because of an evolutionary change of life style. For example, why is it that so many birds on remote, predator-free islands have small wings or no wings, when flight seems so obviously advantageous? The hundreds of flightless bird species that evolved on Hawaii, Mauritius, and other islands testify to the advantages of getting rid of expensive and heavy flight muscles, which account for up to one-quarter of a bird's mass, when they are no longer needed to escape predators. Other analogous examples include the loss or reduction of eyes in cave-dwelling animals, and the loss of nutrient-synthesizing enzymes in bacteria grown in mediums providing those nutrients without cost.

For humans, the disadvantages of overdesign become clear whenever food availability is limited, as it has been for most people throughout human evolutionary history. One tragic example is the ill-fated Donner party of California pioneers, who became trapped by snow with little food during the winter of 1846–47. Half of the males but only 5 percent of the females in the age range from five to thirty-nine died. Women can stay alive with less food than men can because women are smaller. In another tragic example, the first man to collapse and die on Scott's disastrous trek to the South Pole was the biggest, Edgar Evans, starved by Scott's democratic division of his limited food supply into equal portions for each of his men regardless of their differing weights.

Selection against too much as well as too little biological investment results in the fine-tuning of our design, depending on the demands of our natural lives. Consider, for instance, the fine-tuning of breast number, which proves to be correlated with the natural variation in litter size. Most mammal species have a teat number double the number of pups in their average litter, and equal to the number of pups in their maximum natural litter. That is, mammalian teat design has a safety factor of 2 for normal operation. We fit that rule: we have a safety factor of two breasts for our usual litter of one; we're prepared for our occasional twin births, which account for as much as 5 percent of births in some human populations; but we make no provision for triplets and larger birth numbers, which were vanishingly rare before modern fertility drugs. For all but those rare mothers of triplets, four breasts would merely add to our weight and operating costs. The occasional appearance of supernumerary teats in humans and other mammals reveals our genetic potential for more breasts, a potential that is evidently reined in by natural selection.

Innumerable other examples testify to the ubiquity of such fine-tuning. Males of those species that have slightly higher expected frequencies of copulation have slightly larger testes. (That's why men have bigger testes than gorillas but smaller ones than chimpanzees). Birds and mammals with higher metabolic rates have slightly bigger hearts and kidneys than related species with lower metabolic rates. Such fine-tuning affects every aspect of our design, from the molecular level to the level of the whole body.

Physicists, and even many biologists, scorn evolutionary biology as a descriptive science, full of just-so stories and devoid of predictive power. An oft-quoted example of this prejudice is a notorious remark by the physicist I. D. Rutherford, to the effect that you don't understand something until you can express it numerically. While this remark is in many respects wrong and ignorant, the critics still have a valid point. Granted, it's harder to identify and measure the numbers underlying biological safety factors than those underlying safety factors of elevator cables. But we evolutionary biologists deserve much of the blame ourselves for not even trying.

The major challenge that I see for evolutionary biologists in the coming decades is how to convert a qualitative science into a quantitative one. That requires estimating such factors as the costs of building, maintaining, and operating a kidney; the variation in our kidneys' preprogrammed waste-excreting capacity, depending on damage and deterioration with age; and our normal rates of production of wastes to be excreted by the kidneys. Gathering all that information is at least conceivable in principle, even though it won't be easy. But the prize for success is big. It's nothing less than a quantitative understanding of biological design.

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Evolution

Putting Human Genes on the Map

With decades of data and big computers, scientists are beginning to visualize the complexities of human diversity

by Christopher Wills

Back in the late 1970s, I had the pleasure of visiting the laboratory—or perhaps more properly the lair—of Arthur E. Mourant. It was hidden away in the far recesses of the British Museum of Natural History in London. Mourant, a genial man who looks rather like Mr. Punch, presided over a large room lined with cabinets filled to overflowing with papers. For decades, he and a few devoted co-workers had kept track of our growing knowledge of the human gene pool, summarizing the work of thousands of scientists in huge compendiums. He had provided scientists working on human evolution and variation with a distillation of studies that had been written in a dozen languages, in a hundred parts of the world. We spent a couple of fascinating days going over some of the reams of data that he had collected and speculating about their meaning. Among other things, he showed me the proofs of a new book he had just finished on human genetic variation and disease.

THE HISTORY AND GEOGRAPHY OF HUMAN GENES, by Luigi Luca Cavalli-Sforza, Paolo Menozzi, and Alberto Piazza. *Princeton University Press, $175; 1,032 pp., illus.*

The gray columns of figures in this book were a treasure trove. The first connection between stomach cancer and the ABO blood groups had been published in 1953. By the time Mourant summarized the literature in 1978, an astonishing 5,000 studies had looked for connections between ABO blood groups and virtually every major disease. About 15 percent of them showed an association.

Other gray columns of his figures told about another, less-known human blood group called MN, which is confined to the surface of our red cells. So minor is it that it is usually ignored by our own immune system and, unlike ABO blood groups, it is not important in transfusion or tissue rejection. Strenuous efforts by many researchers have not been able to detect any association between the MN blood groups and disease.

Yet virtually every human population has the M and N forms of this trait in varying proportions. Why are both so pervasive, and why is not our entire species type M or type N? Is it simply accidental or are selective forces at work? And what does the distribution of these and other variant forms of genes tell us about the history and current state of our species? What indeed *can* it tell us if all the genes that have been discovered turn out to be as different as ABO and MN?

A new book by Cavalli-Sforza and his collaborators, as massive as anything put together by Mourant, attempts to answer some of these questions. It is an immense and laudable undertaking that pulls together the information on many genes that, like the ABO blood group gene, are polymorphic—that is, they exist in the population in a variety of types called alleles. Much of the data had been gathered in raw form by Mourant, with later additions by Mourant's co-workers and by Cavalli-Sforza's group. More than 75,000 allele frequencies, measuring the prevalence of various alleles in nearly 7,000 human populations, are summarized—not in the gray columns of Mourant's compilation but in the form of maps and statistical analyses that make trends in the data far more obvious and accessible.

The book begins with a survey of the methods used in analyzing the data and then moves on to an overview of the genetic and cultural histories of our species on a worldwide scale. Succeeding chapters deal with each continent in turn. The book is nothing less than an attempt to relate the physical appearance, language, and culture of the far-flung members of our extremely variable species to the evidence of the genes. In the course of this titanic enterprise, the book summarizes how much we have learned and shows how far we still have to go.

What are the many controversies that the book hopes to cast light on? One is the origin of our species itself. Did we arise within the last one or two hundred thousand years in Africa and spread throughout the rest of the Old World, sweeping all the poor hominids already resident there into the ash heap of history? Or did we arise from our immediate ancestor, *Homo erectus*, in a series of parallel events in various parts of the Old World, aided perhaps by puzzling and highly specific flows of genes conferring human rather than prehuman characteristics on our diverse ancestors? While admitting that all the evidence is not in, the authors come down on the side of a single origin.

A second question that the authors spend a good deal of time on is the matter of races. While our species is highly diverse both physically and genetically, the patterns are so complex that it is impossible to divide us into races in any consistent way. For example, an earlier generation of anthropologists classified the Ainu of northern Japan as Caucasian because of the abundant hair on their bodies, the lack of an epicanthic fold on the upper eyelid, their wavy brown hair, and pale skin. But their genes place them squarely among the peoples of eastern Asia. The San (Bushmen), at the other end of the Old World, in southern Africa, have flattened faces of rather Asian appearance—though again without an epicanthic fold—and yellow rather than dark skin. Yet the frequencies of their various alleles, although unusual in some respects, resemble those of their African neighbors.

The authors do not attempt an explanation. But I suspect that since our species is blessed with an abundant variety of alleles of genes that contribute to outward appearance, a little mixing, matching, and sorting out would have been quite enough to have produced—anywhere on the planet—the relatively trivial differences in appearance on which we put so much weight when we classify people into races.

A third question concerns the various patterns of migration our recent ancestors

took as they roamed over Africa, Europe, the Middle East, and far Asia. Can the traces of these migrations be detected by looking at allele frequencies, or does the spread of culture overwhelm the spread of genes? A striking cline—or regular gradation—of frequencies of alleles of some genes, such as ABO, extends across Europe and correlates in space and time with the spread of farming from its source in the Middle East. A likely explanation is that farmers, able to multiply in numbers faster than their neighboring hunter-gatherers, overwhelmed and mixed with them. This new, slightly mongrelized group of farmers repeated the process as farming spread to the north and west. On the other hand, a much more recent spread of Bantu-speaking peoples accompanied by agriculture in southern Africa has not left such obvious traces on the genes.

And finally, is there any correlation between the traces of migration seen in some of our genes and the spread and history of human languages? Sometimes. Again, a fairly striking correlation is found in Europe. In Australia, however, no correlation can be seen among the genes of the aboriginal populations, the distribution of their languages, and the fairly simple patterns of colonization from Australia's north that we know must have taken place starting some 60,000 years ago.

The book is unlikely to settle any of these controversies and, indeed, is certain to stir some because of its unabashedly idiosyncratic methods. The authors state at the outset that they are going to concentrate on their own methods of interpreting the data, because giving full justice to the approaches of others would make the book far longer than its current thousand or so very large pages. The authors are to be commended, however, for laying out all the data, warts and all, showing how they analyzed it, and hedging virtually all their conclusions with the caveats that imperfect data demand.

The first problem with this compilation, impressive as it is, has to do with the immense span of time for which we have no genetic data. Because our genetic portrait of humankind is necessarily based on recent samplings, it is unavoidably static. Historical records of human migrations cover only a tiny fraction of the history of our species, and we know surprisingly little about how long most aboriginal peoples have occupied their present homes. Language, too, is so labile and so easily overwhelmed by history that it can only take us, at the most, ten or twenty thousand years into the past. We are pretty close to the position of a viewer who tries to infer the entire plot of the film *Queen Christina* from the few final frames showing Garbo's rapt face.

Once we have looked as far back as we can—to the invention of agriculture and a little way into the Neolithic—how much more of our distant history can we infer from the present-day distribution of alleles? Very little, I think. As the authors acknowledge throughout the book, the distribution of genes has as many explanations as there are genes themselves.

Take the Duffy blood group. One allele of this gene confers absolute immunity against a particular type of malaria. This allele is present in sub-Saharan Africa because of malaria—not migration—and may have made its appearance only tens of thousands of years ago. The ABO polymorphism, on the other hand, is millions of years old, and therefore probably far more complex than that of Duffy. Even though we have known about it for the better part of a century, we have still not managed to discover the major reason that we (and our close relatives the great apes) have this polymorphism.

Many of the maps in *The History and Geography of Human Genes* were constructed with a technique called principal component, or PC, analysis, which sounds—and is—dauntingly statistical. To construct one of the maps, eighty-two genes were examined in many populations throughout the world. Each population was represented on a computer grid as a point in eighty-two dimensional space, with its position along each dimensional axis representing the frequency of one of the alleles in question. The line, rotated through all the dimensions, that best fits all the points is called the first PC. It can also be understood as the measure that best summarizes all the variables. Other PCs can be obtained that summarize the leftover data.

Suppose that all our genes behaved the same way—that is, they all had alleles with a high frequency in Africa, intermediate frequencies in Europe and Asia, and even lower frequencies in Australia. Then the first PC would account for all or most of the information in the data set. It is just such a pattern that the eighty-two-gene map appears to show. This is misleading, however, because the first PC accounts for only about a third of the data, and the other two thirds are made up of conflicting trends. Which, if any of them, do we believe?

Unfortunately, the authors tend to search through the various PC maps until they find one that supports the argument they are trying to make at the moment. I rather wish that they had played around with the data a little more in order to see how robust the maps are. For example, how much does a PC map change if one important allele like the Duffy variant is dropped from it? The authors emphasize migration, and while they sometimes suggest that selection for or against particular alleles and combinations of alleles in different regions may have played a role in shaping these maps, my guess is that such selection will turn out to be at least as important as migration.

The book closes with a plea to gather irreplaceable genetic information from indigenous peoples before they are killed, die of starvation and disease, or melt anonymously into the *favelas* of Third World cities. At times, the argument sounds uncomfortably like science-at-all-costs, a plea for "immortalizing" the white blood cells of peoples on the brink of extinction as the peoples themselves fade away. But such efforts should not, I think, be supported unless they form a part (a small part) of efforts for cultural preservation and political empowerment of the kind espoused by the Cambridge-based group Cultural Survival, and of efforts to shift priorities at the World Bank and among the Third World governments directly concerned.

The ABO blood groups were discovered in the year 1900. *The History and Geography of Human Genes,* arriving nearly a hundred years later, gathers together much of the information that has since been gleaned about human diversity and allows us to see, however dimly, a small part of our evolutionary heritage. The book summarizes this exciting story well, but the really exciting discoveries are still in the future. In the next hundred years we will find the genes that distinguish us from the great apes and perhaps discover how some of them work. And we will, I feel confident, finally be able to determine which one of the many conflicting theories about the evolutionary history of our unique species is correct.

Christopher Wills is a professor of biology at the University of California, San Diego. His books include Exons, Introns and Talking Genes: The Science Behind the Human Genome Project *and, most recently,* The Runaway Brain: The Evolution of Human Uniqueness.

Making Time

by Gail S. Cleere

By 1370, King Charles V of France had had enough. He was tired of hearing the church bells of Paris ringing at irregular intervals. He ordered a uniform time for the city, making the clocks synchronous with the master clock in the tower of the Palais Royal. Charles's edict established the first "time service," comparable to the universal system we have today.

Timekeeping has since become a lot more sophisticated, but uniformity is still the goal. On June 30, in keeping with the decision of the International Earth Rotation Service in Paris (a location Charles would consider only fitting), a "leap second" will be officially inserted into our clock time to keep it precisely matched to solar time, or the rotation of the earth. Only a year after the last adjustment, Coordinated Universal Time, usually shown as UTC—and formerly known as Greenwich Mean Time, or GMT—will be retarded by one second between the last second of the day, and the first second of the next.

Why do we do this? "Because the earth actually rotates irregularly on its axis," explains Bill Klepczynski, an astronomer at the U.S. Naval Observatory's Time Service in Washington, D.C., where the nation's master clock is housed. "Our clocks must be adjusted to stay in pace with the earth's rotation if we want to continue to see the sun in the daytime hours, and the stars at night."

The mechanics of the earth's motion on its axis are still not completely understood. Tidal friction and the "sloshing" of the earth's fluid core seem to play the largest role in rotation, but atmospheric conditions may also be a factor. Even El Niño, which pushes warm ocean currents up against the west coast of South America and wreaks havoc with the world's weather, can affect the speed of the earth's spin.

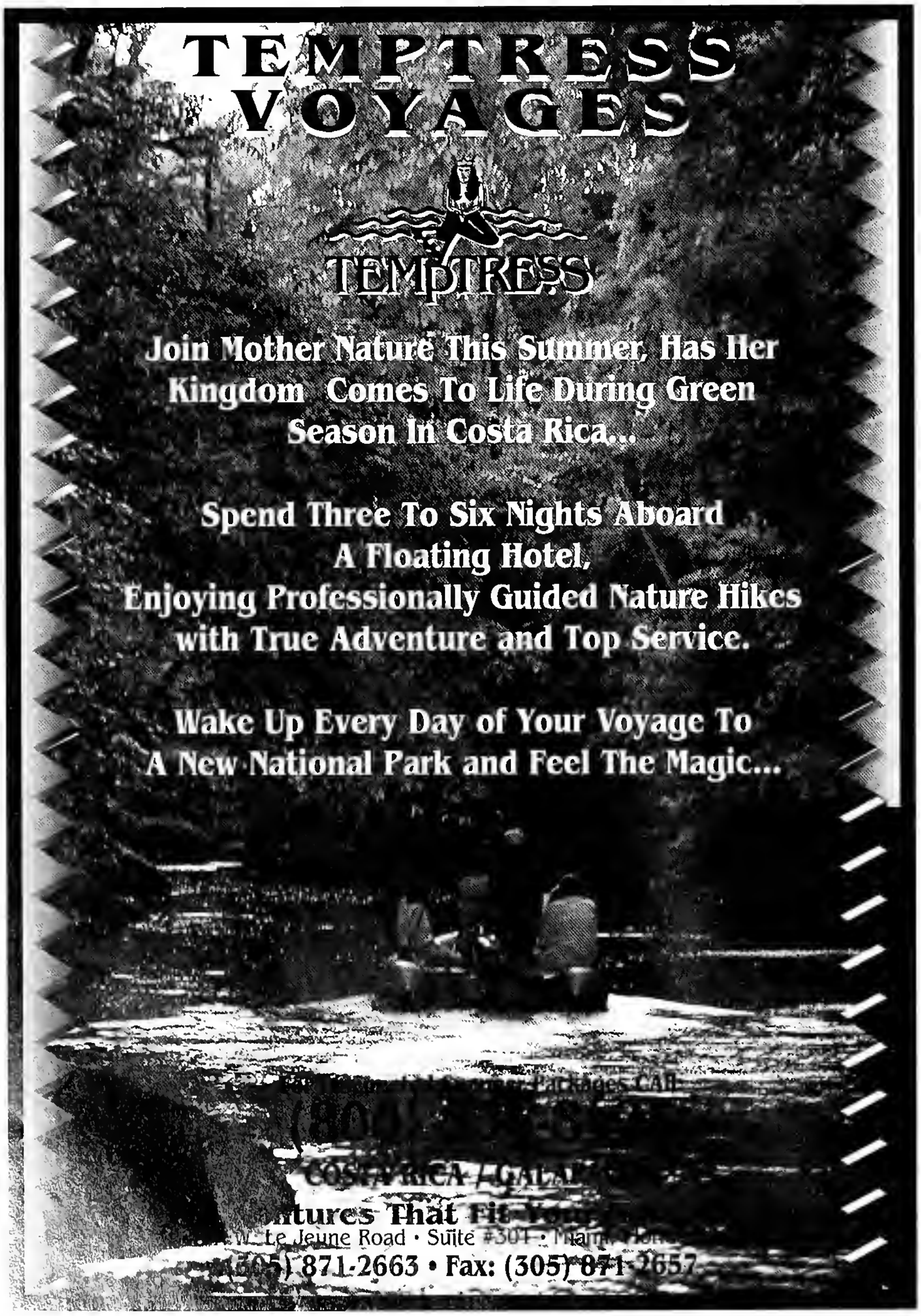
Over time, such fluctuations add up. Even though our days are roughly twenty-four hours long, that has not always been the case. When dinosaurs roamed the earth, the days were about an hour and a quarter shorter than they are today. Ever since the earth coalesced out of the gases and dust of the primordial cloud and began its orbit around the sun, its spin has been slowing down.

We used to use the earth's rotation as the standard for our clock time, setting the clocks by observing the regular passage of the stars overhead. The job of determining time was thus up to the astronomer, which is why it remains the bailiwick of the Naval Observatory today. Precise and coordinated time is necessary to determine longitude at sea. It was the Naval Observatory's job to adjust the fleet's chronometers before placing them aboard ships bound for the high seas.

As first our pendulum and then our quartz crystal clocks improved, and as our methods of observing distant astronomical objects became more precise, the discrepancies between the clocks and the earth's rotation became more and more apparent. Then, in the late 1940s the first atomic clocks were developed; by counting the regular oscillations of atoms, they allow time to be measured with unprecedented accuracy. Since 1967, the international second of time has been defined as

9,192,631,771 oscillations of a cesium atom, and the rotation of the earth has ceased to be the standard for time.

This may seem a bit esoteric if all you want is a three-minute egg, but June's leap second is heady news in the world of communications and navigation, where nanosecond accuracy is needed. "In electronic navigation, a time error of a millionth of a second can produce a position error of about a quarter of a mile. Get your celestial timing wrong and spacecraft will sail past planets, missiles can fall in the wrong places, and jets can land short of the runway," explains Klepczynski. "Leap seconds are the earth's way of keeping us on our toes."



THE PLANETS IN JUNE

Mercury is visible in the early evenings, low in the southwest at the beginning of the month, before slowly fading from view. The planet reaches inferior conjunction (between the earth and the sun) on the 25th.

Venus bedazzles us this month, shining in the western evening skies at a brilliant –4 magnitude (more than seventeen times brighter than Sirius, the brightest star in the sky). On the 10th, Venus passes the first-magnitude star Pollux in Gemini, and on the 12th passes by the waxing first-quarter moon.

Mars rises a couple of hours before the sun in Aries and can be spotted in the southeast just before sunrise. On the 6th, watch as the old crescent moon passes just a few degrees above the ruddy planet. NASA has recently announced that it will continue its exploration of Mars by launching a small orbiter in 1996 to study the surface of the planet. The spacecraft will carry half the science payload that flew on the *Mars Observer,* which was lost last August.

Jupiter is nicely placed in Virgo. It is visible as a very bright, silvery-white "star," well up toward the south at sunset, and sets after midnight. On the 18th, the giant planet can be found just north of the waxing third-quarter moon. The refurbished Hubble telescope's new images of Comet Shoemaker-Levy—due to crash into Jupiter next month—show that the comet is continuing to break up. The largest of its fragments appears to measure 2.5 miles in diameter.

Saturn rises about midnight among the faint stars of Aquarius and is well placed in the southern sky for observing until dawn. On June 1, and again on the 28th, look for Saturn well below the moon—a pretty sight on a warm summer morning.

Uranus and **Neptune** are the two blue green worlds that can be seen with binoculars and the help of a detailed sky chart just east of the teapot-shaped constellation Sagittarius, rising one and a half hours after sunset.

Pluto is not far from Jupiter, just above the star that marks the north "claw" of the scorpion (now part of the constellation Libra), but it is impossible to see without a large telescope.

The **Moon** reaches last quarter on the 1st at 12:02 A.M., EDT, and again on the 30th at 3:31 P.M., EDT. The moon is new on the 9th at 4:26 A.M., EDT, and reaches first quarter at 3:56 P.M., EDT, on 16th.

The summer solstice occurs at 10:48 A.M., EDT, on the 21st, marking the beginning of summer in the Northern Hemisphere. The sun at noon reaches its highest point in the sky for the year and then begins its relentless march south. Although the earth is almost at its farthest distance from the sun, it is tilted so that the Northern Hemisphere most directly faces the sun.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

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Chincoteague Refuge, Virginia

by Robert H. Mohlenbrock

Paralleling the Atlantic Coast from Long Island to Florida, a string of barrier islands shelters the mainland from the ravages of periodic storms. Composed of sand brought up by wave action from the gently sloping ocean floor, these windswept islands are continuously being reshaped. One is slender Assateague Island, which stretches thirty-five miles from southern Maryland to Virginia. The mainland areas it protects include salt marshes, freshwater marshes, bays, ponds, creeks, and inlets. These coastal wetlands, as well as those on and along the island itself, are important to wildlife, especially the migratory birds that pass through in the fall and spring. Along with a bit of adjacent Chincoteague Island, the entire Virginia portion of Assateague Island is managed by the U. S. Fish and Wildlife Service as the Chincoteague National Wildlife Refuge.

A ridge of sand up to forty-seven feet high edges the ocean side of the island. Built up by the wind and the constant ebb and flow of the tide, the ridge is too unstable to support the growth of many kinds of plants. The principal one that grows there is beach grass, able to anchor itself by much-branched, deeply penetrating rhizomes. Even the beach grass is often wiped out during violent storms, and the Fish and Wildlife Service replants plugs of grass to reestablish some cover as quickly as possible.

Just behind the sand ridge lie a variety of wetlands that attract shorebirds and waterbirds. Gulls, egrets, herons, ospreys, swans, glossy ibises—some 250 species in all—can be observed from the refuge's roads and trails.

Some of the wetlands are salt marshes, shallow places where there is an inflow of seawater. The plants found in them are adapted for survival in saltwater and are not found in any other type of habitat. One

Connie Toops

salt marsh that is easily accessible by trail lies near the southern end of Assateague Island, north of Toms Cove.

As one gazes across the salt marsh, from very shallow to deeper water to the open water of Toms Cove, one is impressed by a sea of grasses. The shortest grass, less than one foot tall, is salt grass, while other species range from about two feet to nearly ten feet tall. They include Virginia dropseed and several species of cordgrass. The grasses form a continuous cover because their aerial stems are connected to a network of underground rhizomes. All are able to take up saltwater and exude excess salt. If you were to rub your finger over a blade of salt grass and then lick your finger, you would get a very salty taste.

Scattered throughout the salt marsh are various wildflowers that have also developed one or more mechanisms to survive the salty conditions. Some have succulent stems that store water for use when freshwater is scarce. Probably the most unusual-looking of these is glasswort, or pickleweed. This nearly leafless plant has a swollen, jointed stem about eight inches tall. Its tiny greenish flowers, formed in conelike structures during the summer, are inconspicuous, but in the autumn, the stem may turn bright red. A similar-looking plant with showier, pink flowers is sea purslane. A third species with a succulent stem is sea rocket, a member of the mustard family, whose flowers have four white-to-lavender petals.

Other plants store freshwater in their

Cordgrass, left, grows abundantly in a salt marsh along Assateague Island. Right: Virginia thistle
Anne Heimann

A wild pony roaming amid the cordgrass is a descendant of domesticated horses first allowed to graze on Assateague Island centuries ago.
Fred Siskind

fleshy, succulent leaves. These include seaside goldenrod, sea oxeye (a species of daisy), and narrow-leaved aster. Despite their thicker leaves, these species have flower heads that look very much like those of their more common relatives.

Some plants have very small leaves so that little delicate leaf tissue is exposed to the caustic action of saltwater. One example is sea lavender, a small, somewhat wiry wildflower with equal branching and tiny leaves. Its small lavender flowers have paperlike petals, which retain their shape and color for many weeks.

At the edge of the salt marsh farthest from open water, where the sand is dry for most of the year, the cover consists of colonies of red fescue, interspersed with a few other species, such as sand evening primrose and a surface-hugging sand spurge. Red fescue is the grass species that has given rise to several popular strains of lawn grass, but the original variety is this sand-loving plant that inhabits the edges of salt marshes. If the sand in this dry zone gets too salty, the fescue is replaced by better-adapted grass species, wildflowers, and such shrubs as groundsel tree and salt marsh elder.

A special attraction at Chincoteague National Wildlife Refuge are the wild ponies that may be glimpsed as one drives or hikes along. About 130 of these ponies, owned by the Chincoteague Volunteer Fire Company, are allowed to graze by permit on the refuge, while another 40 live on the Maryland side of Assateague Island. They are the descendants of domesticated horses that were allowed to graze on the island perhaps three hundred years ago. Slightly smaller than a typical horse, they have exceptionally furry coats, which no doubt help them survive the winter weather and hordes of summer insects.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of natural areas, especially the 156 U.S. national forests.

Chincoteague Refuge

For visitor information write:
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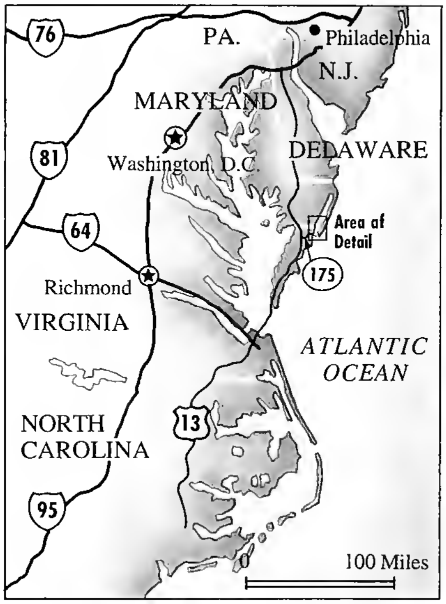

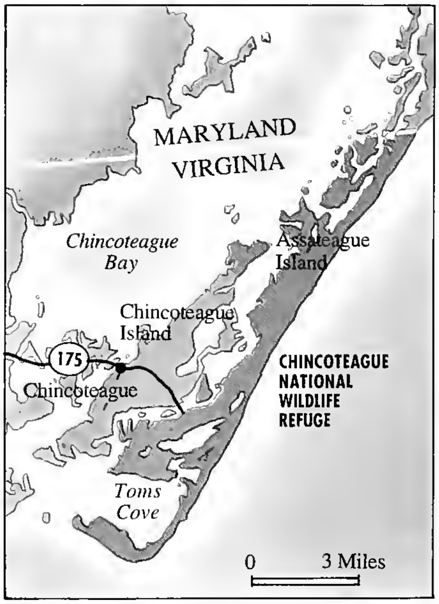

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125th-Anniversary Cultural Festival

The American Museum of Natural History will commemorate 125 years of expedition, exploration, and discovery on Saturday, June 4, with a day-long festival celebrating cultural diversity. Among the festival's features will be performances of traditional music and dance, foods of the world, and demonstrations and workshops. Visitors are also invited to bring artifacts, bones, fossils, minerals, and other natural objects (no gemstones, please) for identification by Museum scientists. General admission to the Museum, as well as to the Naturemax Theater and the Hayden Planetarium, will be waived. For further schedule information, call (212) 769-5100.

Peruvian Treasures

The exhibition "Royal Tombs of Sipán" will feature gold, silver, and gilded copper objects of the Moche, a people that flourished from A.D. 100 to 800 in northern Peru. The tombs, discovered by archeologists in 1987, are the richest ever excavated in the New World. The treasures include a two-foot-high gold-and-silver scepter, gold armor, elaborate headdresses, and a selection of jewelry. The exhibition will open in Gallery 3 on Friday, June 24, and run through January 1995. Admission is $5 ($2.50 for children) and includes an audio tour narrated in English or Spanish.

Walter Alva, the chief archeologist at Sipán and co-curator of the exhibition, will give a lecture in Spanish (with simultaneous translation into English) on Monday, June 20. Co-curator Christopher B. Donnan will speak on Friday, June 24. Both talks will begin at 7:00 P.M. in the Kaufmann Theater. The lecture series costs $25 and includes a special preview of the exhibition on June 20 from 5:00 to 6:45 P.M. Call (212) 769-5310 for information.

The Earth as a Peppercorn

The "planet walk" through the solar system will take place on the Museum's grounds on Sunday, June 12, at 1:00 P.M. A special evening tour will also be given on Saturday, June 25, at 8:00 P.M. Developed in 1969 by astronomer Guy Ottewell, the walk follows a thousand-yard-long model of the solar system. Volunteer guide Robert Campanile will lead the tour, which is free and begins on the Planetarium's front steps on 81st Street. Call (212) 769-5566 for information and reservations.

Update: The Universe

Black holes, new planets, colliding galaxies, and the quest for extraterrestrial life will be explored in the Planetarium's Sky Show *Update: The Universe.* Opening Thursday, June 16, the show incorporates many of the discoveries made by the Compton Gamma Ray Observatory, the European ROSAT, and the recently overhauled Hubble Space Telescope. Call (212) 769-5100 for show times, prices, and other information about Planetarium events.

The Natural History of Love

Poet and nature writer Diane Ackerman will discuss her latest book, *The Natural History of Love,* on Thursday, June 9, at 7:00 P.M. This nonfiction narrative draws on history, science, psychology, and social customs. The program will take place in the Kaufmann Theater. Tickets are $20. For information, call (212) 769-5310.

The Quark and the Jaguar

Murray Gell-Mann is a theoretical physicist and winner of the 1969 Nobel Prize for his discovery of quarks. Now at the Santa Fe Institute, he works on a range of theoretical issues with other scholars and scientists. Among the topics he will speak about on Thursday, June 16, at 7:00 P.M., are the connections between elementary particle physics and the process of natural selection. Tickets are $20. Call (212) 769-5310 for more information.

The Wonders of Metropolitan New York

The history of New York's water supply system and the area's billion-year-old geology will be the subjects of two talks by Sidney S. Horenstein, geologist and coordinator of environmental public programs at the Museum. The Thursday-evening lectures will be given on June 9 and 16 at 7:00 P.M. in the Kaufmann Theater. Tickets are $25.

Horenstein will also be conducting two 3-hour sunset cruises. The first, on Tuesday, June 7, will survey the geological features of the Hudson River, the southernmost fiord in the Northern Hemisphere. The ecology and origins of the river and the Palisades are among the topics covered on the trip. The second boat tour, on Tuesday, June 14, will examine some of New York's surrounding waterways, including Newtown Creek, Buttermilk Channel, and Gowanus Bay. The cruises will run from 6:00 to 9:00 P.M. Tickets for each are $25 ($22 for members). Call (212) 769-5310 for information.

Calling All Hippos

The social organization and underwater behavior of hippos will be the subject of a talk by William Barklow, a professor of biology at Framingham State College in Massachusetts. Barklow's 1989 fieldwork in Tanzania documented the vocal repertoire of hippos, including underwater signals similar to those of dolphins and whales. The slide-illustrated lecture will be presented on Thursday, June 30, at 7:00 P.M. in the Kaufmann Theater. For ticket availability and information, call (212) 769-5606.

Field Trip to Sterling Hill Mine

Joseph J. Peters, a senior scientific assistant in the Museum's Department of Mineral Sciences, will lead a tour of the last operating zinc mine in New Jersey on Saturday, June 11, from 9:30 A.M. to 5:00 P.M.. The group will visit underground tunnels and view mineral displays in a natural environment. The trip is limited to thirty-six adults and costs $50. Call (212) 769-5310 for reservatons and information.

Storytelling

Folk tales, myths, and personal stories will be told by master storytellers Gioia Timpanelli and Diane Wolkstein on Wednesday, June 8, at 7:00 P.M. in the Kaufmann Theater. Gioia Timpanelli won the Women's National Book Association Award for her work on oral traditions and has just compiled a book based on Sicilian folk tales. Diane Wolkstein is the author of seventeen books and teaches storytelling at Bank Street College. Call (212) 769-5606 for ticket availability.

Origami Theater

Using minimal props—her hands and sheets of paper—Marieke de Hoop, an origami expert from Holland, will tell a story about the figures she creates as she transforms the paper into a swan, a fox, a peacock, or a star. This presentation, which she calls *Orikadabra,* will take place in the Linder Theater on Wednesday, June 15, at 3:30 P.M. Call (212) 769-5606 for ticket availability.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann and Linder Theaters are located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

june calendar

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12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

4 SATURDAY

125th-Anniversary Cultural Festival: A Gift to the Public
SPECIAL EVENT.
Commemorating 125 years of expedition, exploration, and discovery, the Museum opens its doors to the public with a day-long festival celebrating cultural diversity. 10:00 a.m. to 9:15 p.m. Admission waived.

Wonderful Sky ●
SKY SHOW FOR CHILDREN, Hayden Planetarium, 10:30 & 11:45 a.m. Admission waived.

6 MONDAY

"The Jupiter-Comet Collision of 1994" ●
LECTURE, Hayden Planetarium, 7:30 p.m., $6.00 members, $8.00 nonmembers

8 WEDNESDAY

"Favorite Stories: Folk Tales for Grown-Ups" ■
STORY-TELLING, 7:00 p.m., Kaufmann Theater, $8.00 members, $12.00 nonmembers

9 THURSDAY

"The Natural History of Love: An Evening with Author Diane Ackerman" ✚
LECTURE, 7:00 p.m., Main Auditorium, $20.00

16 THURSDAY

Update: The Universe ●
SKY SHOW, Hayden Planetarium, shown daily, $5.00 adults, $2.50 children. Public Opening

"The Quark and the Jaguar: An Exploration of Physics and Natural Selection" ✚
LECTURE, 7:00 p.m., Main Auditorium, $20.00

20 MONDAY

"Royal Tombs of Sipán: The Discovery and the Mystery" ✚
LECTURE, (a two-part lecture series with the discoverers of the royal tombs in Peru), 7:00 p.m., Main Auditorium, $25.00 for the series, $15.00 for single lecture. Program continues on Friday, June 24.

24 FRIDAY

Royal Tombs of Sipán
SPECIAL EXHIBITION.
A glittering array of gold and silver objects from the richest tombs ever excavated in the Western Hemisphere. The exhibition explores the culture of the Moche, a pre-Inka civilization that dominated Peru from A.D. 100 to 800. Special admission: $5.00 adults, $2.50 children. Public Opening

Peruvian Highland Music and Dance ✚
PERFORMANCE, Kaufmann Theater, 2:00 & 4:00 p.m. Repeated Sunday, June 26.

28 TUESDAY

Peruvian Marriage Reenactment ✚
PERFORMANCE, Kaufmann Theater, 2:00 & 4:00 p.m.

THROUGHOUT JUNE

125th-Anniversary Celebration of the American Museum of Natural History
The American Museum of Natural History celebrates 125 years as one of the world's preeminent science and research institutions.

Lila Acheson Wallace Wing of Fossil Mammals and Their Extinct Relatives
NEW PERMANENT EXHIBITION HALLS displaying the world's most extensive collection of fossil mammals. Now open.

Search for the Great Sharks ▲
IMAX FILM; a round-the-globe expedition to observe one of the world's most misunderstood creatures, daily showings, Naturemax Theater, $5.00 adults, $2.50 children

Man on the Moon: The Apollo Adventure
SPECIAL EXHIBITION, a giant scale replica of the Apollo 11 lunar module is erected marking the 25th anniversary of the first moon landing. Hayden Planetarium.

*Photo: A miniature gold and turquoise ornament from the exhibition **Royal Tombs of Sipán**.*

■ Membership, 769-5606 ▲ Naturemax Theater, 769-5650 ✚ Education, 769-5310 ● Hayden Planetarium, 769-5900

American Museum of Natural History

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Terror in the Tide

Southern elephant seals and sea lions colonize the beaches on Valdés Peninsula in Patagonia, Argentina, where they produce hundreds of pups each year. In April, during the austral autumn, many young sea lions leave their mothers to take their first ocean swim—a venture that is fraught with danger. Immature sea lions face not only the mundane hazards of tides and rocks, but also predacious killer whales attracted to the vicinity each year at weaning time.

In their pursuit of sea lion pups, whales make spectacular lunges that sometimes leave them temporarily stranded in the shallows. Although they occasionally take young elephant seals, the whales prefer the sea lions. The powerful cetaceans typically toss the pups in the air and may kill and eat them right away. Frequently, however, they throw the dazed little sea lions around before eating them, just as cats toy with mice. Marine mammal specialist John K. B. Ford, who studies whale vocalizations, snapped this picture just as a female killer whale snatched a pup from the beach.

This female is well known to researchers, who have been observing the area's whales for more than fifteen years. She constantly travels with four younger whales, presumably her offspring, and does all of the hunting. After capturing a sea lion pup, she usually turns it over to her brood. In this instance, the young whales played with their captive for several minutes, then killed it and shared the meat.—*R. M.*

Photograph by John K. B. Ford
Ursus

AUTHORS

Anthony Mellersh (page 10) first became interested in life's earliest chemical evolution as a student at the University of Sheffield, where he earned his medical degree in 1979 and lectured from 1981 to 1986. A member of the Royal College of Pathologists, Mellersh is currently a consultant microbiologist at Derby City Gen-

As a college student, **Andrew Knoll** (page 14) couldn't decide whether to concentrate on geology or biology. Upon reading Lynn Margulis's early works on the evolution of eukaryotic cells, he realized that he didn't have to choose: by studying the early earth, he could learn how our planet and its biota evolved together. His fieldwork, in search of ancient rocks and the signs of early life they may contain, has taken him to Spitsbergen, Siberia, and other parts of the Arctic, as well as to China, Australia, and southern Africa. Back in the United States, where Knoll is chairman of Harvard's Department of Organismic and Evolutionary Biology, he continues his investigations in the laboratory. In the future, he hopes to go back to Siberia to learn more about what went on during a major interval of biospheric change about one billion years ago. For a popular account of the intertwined histories of the earth and its life forms, Knoll suggests E. G. Nisbet's *Living Earth* (New York: HarperCollins, 1991).

A native New Yorker who grew up on the pavements of lower Manhattan, **Karl J. Niklas** (page 22) says his juvenile experience with plants went no further than the salads and vegetables on his dinner plate. Later, as a math major at the City College of New York, Niklas took a botany class from Larry Crockett, whose lectures made him aware of the "intrinsic geometrical beauty of plant shapes." Inspired to enter a new field, he went on to

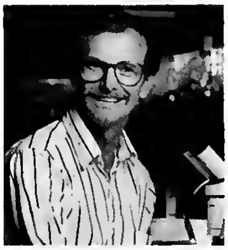
get higher degrees in botany at the University of Illinois, Urbana. Now a professor of botany at Cornell University, Niklas still looks at

Gregory Hurst (below) earned a Ph.D. in 1993 from Cambridge University, where he is now a junior research fellow at Christ's College, which Darwin attended. Hurst (page 32) says that although he has long been fascinated by insects and "peculiar" genetics, he was first intro-

duced to the odd sex ratios of ladybird beetles, and the shenanigans of the bacteria that reside in them, by coauthor **Michael Majerus** (a. k. a. "the boss"). The two-spotted ladybug continues to provide windows into the evolutionary genetics of parasites; Hurst and Majerus are currently investigating sexually transmitted disease in that species. Majerus, a university lecturer and fellow at Clare College, Cambridge, dates his interest in insects back to when he was four years old. He has been doing fieldwork ever since. His new book, *Ladybirds,* will be eral Hospital in Derby, England, and a clinical lecturer at Nottingham University. Among his avocational interests are the history of India and fly-fishing. For more on the origin of proteins, see Mellersh's article in the journal *Origins of Life and Evolution of the Biosphere,* vol. 23 (1993).

plants from a biomechanical perspective. For the last twenty years his abiding interest, applying engineering principles to plant form and function, has resulted in two books and more than 150 research papers. "When you look at a plant shape, you are compelled to think mathematically," he says. An avid cellist, operagoer, and gardener, Niklas considers teaching an avocation because it gives him such great pleasure.

published in July by HarperCollins. In the future, Majerus plans to do "more of the same" and to study "anything else that I cannot understand that I think I should be able to."



After completing a Ph.D. in insect reproductive strategies, **Jack Werren** (page 36) served for four years in the Army, where his job involved testing water for contaminating bacteria. The task gave him a real appreciation for what bacteria can do to their hosts, and he returned to academia with a new focus for his research. Currently an associate professor of biology at the University of Rochester, Werren hopes to continue investigating genetic parasites and to learn more about the distribution of *Wolbachia* bacteria and their effects on the insects they inhabit. For a discussion of

John Maynard Smith (page 39) began studying bacterial evolution fairly recently, when a colleague researching antibiotic resistance started asking him questions about evolution. He is principally concerned with the role of sexual processes in bacteria. Professor emeritus of biology at the University of Sussex, England, he is also currently investigating the evolution of animal signals used in mate choice and in conflicts. Maynard Smith has explored the causes of aging and the origins of sexual reproduction and has influenced many fields, including population genetics and ecological theory. He was the first to discuss the contrast between kin and group selection. Among his books are *The Problems of Biology* (Oxford: Oxford University Press, 1986) and *Did Darwin Get It Right: Essays on Games, Sex and Evolution* (New York: Chapman and Hall, 1989).

As a boy, **Paul W. Ewald** (page 42) did his first "fieldwork" in the many vacant lots of the not yet completed Chicago suburbs. Collecting and identifying insects, he took most delight in seeing beautiful saturniid moths attracting their mates at dawn in early summer. Toward the end of college at the University of California, Irvine, and in graduate school at the University of Washington, he studied territoriality in hummingbirds, a subject he eventually wrote on for *Natural History* (August 1979). Ewald began thinking about the evolution of pathogens in 1975, when a bad case of diarrhea started him wondering whether his body was trying to flush out the offending microorganisms or whether they were trying to assure their own survival by making themselves more transmissible. Nowadays, when chairing Amherst College's biology department is not claiming his time, Ewald tries his hand at maple sugaring and attempts to keep his house, built in 1760, "from falling apart." His book, *The Evolution of Infectious Disease,* was published by Oxford University Press this year.

Swiss biologist **Daniel Robert** (page 49) began investigating hearing in tachinid flies when he became a research associate in coauthor **Ronald R. Hoy**'s laboratory at Cornell University. "While observing some of these parasitic flies at night in Florida," he recalls, "I felt my own connection with the pattern of nature—the mosquitoes were eating me alive." Robert (right) has previously done research on hearing in moths and locusts and on acoustic communication in wild chimpanzees of the Ivory Coast. Hoy, a professor of neurobiology and behavior, has studied hearing and acoustic communication in species of *Drosophila* and praying mantises, as well as in crickets. For additional reading they recommend "Of Cricket Song and Sex," by William H. Cade (*Natural History,* January 1978), and "Sex for a Song (Dinner Included)," by Scott C. Sakaluk (*Natural History,* January 1991).

how natural selection acts on genes in an organism, he suggests Richard Dawkins's *The Selfish Gene* (Oxford: Oxford University Press, 1989). Werren also recommends R. R. Askew's book *Parasitic Insects* (London: Heinemann Educational Books, 1973), which provides fascinating life histories of the many species that, like the jewel wasp, live at the expense of their hosts.

Jeremy Jackson (page 56) is director of the Smithsonian Institution's Center for Tropical Paleoecology and Archeology at Balboa, Panama. Ever since earning his doctorate in geology at Yale University in 1971, Jackson has been studying bryozoans, mollusks, and corals in the waters off Jamaica, Panama, Costa Rica, Venezuela, Guam, and Truk. Before joining the Smithsonian in 1984 as a senior scientist, he also served as professor of ecology at Johns Hopkins University. An expert on living as well as fossil invertebrates, Jackson has documented the effects of oil spills and other "anthropogenic" damage to the oceans. This month's article had its genesis when Jackson read coauthor **Alan Cheetham**'s manuscript about punctuated equilibrium of bryozoans. "I wondered to him out loud whether or not the 'species' he created by his statistical hocus-pocus had any biological validity," Jackson recalled, "so we wrote a grant proposal together to put his career on the line." Cheetham (below), whose doctorate from Columbia University (1959) is in paleontology, is currently a senior research geologist at the National Museum of Natural History in Washington, D.C. During forty years of work on the systematics of bryozoans in the United States, Scandinavia, England, and France, he has sought methods of inferring patterns of evolution from the fossil record. Cheetham's hobby is woodland gardening near a small tributary of the Potomac, where he grows such native plants as "May apple and yellow violets, which, like bryozoans, grow in modular aggregates."

Armed with only a net, **John Jaenike** (page 46) is ready to catch some fruit flies. Unlike the famous lab insect *Drosophila melanogaster,* Jaenike's quarry are wild and seek out mushrooms on which to lay their eggs. He first began studying these mushroom-loving flies while conducting fieldwork on a small island off the coast of Maine (his favorite place to work). Jaenike earned his B.A. in biology at Amherst College in 1971 and his Ph.D. in biology at Princeton University in 1975. He is currently a professor of biology at the University of Rochester. Jaenike enjoys a host of outdoor activities such as hiking and windsurfing, but his favorite pastime is playing with his sons, Peter and David.

"I first became interested in snapping shrimps as a beginning graduate student at the University of California at Berkeley, when I went to look for octopuses in Baja California," recalls **Nancy Knowlton** (page 66). "I found hundreds of shrimps and almost no octopuses, leading me to believe that the former might make a more practical subject for my doctoral dissertation." Now a staff scientist at the Smithsonian Tropical Research Institute in Panama, Knowlton continues to study shrimps, as well as corals. In the future, she plans to investigate diversity in corals and their symbiotic algae. She says that for twenty years, she found herself working on projects that incidentally turned up previously unrecognized species, and she has now turned to the problem of marine biodiversity full time: "I think that when nature tries so insistently to tell you something, you should listen. Hence my current interest in marine biodiversity and systematics generally." For further reading on the biological history of the Isthmus of Panama, Knowlton recommends G. J. Vermeij's article "The Biological History of a Seaway," *Science,* vol. 260 (1993).

The strange case of the Jersey dwarfs caught the attention of **Adrian M. Lister** (page 60) in the early 1980s, while he was a doctoral candidate at Cambridge University in England, studying the evolution of Pleistocene deer. Now a research fellow in the Department of Biology at University College London, Lister continues to study Pleistocene mammals, especially deer and mammoths. His fieldwork has included the excavation of four mammoth skeletons in Shropshire, England, and he has been a visiting scientist at the Hot Springs Mammoth Site in South Dakota. Lister's interest in mammals extends beyond fossils to living animals, particularly to the preservation of the Asian elephant. He recently toured reserves in Nepal and India for a look at the problems of elephant conservation in those countries. For more information on Pleistocene fauna, including the discovery of frozen mammoths, readers can refer to Antony J. Sutcliffe's book *On the Track of Ice Age Mammals* (Cambridge: Harvard University Press, 1985) and for more on the phenomenon of dwarfing in island mammals, readers can consult Paul Y. Sondaar's article "The Island Sweepstakes," in *Natural History* (September 1986).

Michael Lee (page 63) was born in Malaysia and grew up in Australia. Lee says that he, like many children, acquired an interest in dinosaurs and natural history at a young age, but unlike most he never grew out of it. He earned his B.S. in zoology at the University of Queensland and is now finishing his Ph.D. at Cambridge University. His current interest is the study of primitive reptiles (those living before the age of dinosaurs) and pareiasaurs in particular. Lee's fieldwork (which includes "excavating" specimens from museum drawers) has taken him to Russia, South Africa, and Australia. He plans to return to Australia, where he will be at the University of Sydney working on the evolution of monitor lizards—the only large terrestrial reptilian carnivores alive today. For more details on similarities between pareiasaurs and turtles, see Lee's article "The Origin of the Turtle Body Plan: Bridging a Famous Morphologic Gap" in *Science,* vol. 261 (1993).

Steve Jones (page 72) is a professor in the Department of Genetics at University College London. These days, he writes, his hobby is doing research; his present vocation, being chairman of the department. He does manage, however, to continue his investigations into the ecological genetics of snails and slugs and the molecular mechanisms of human mutations. In the future, Jones hopes to concentrate more on his "hobby," studying the snails and slugs surrounding his "very modest" house in France. For more on human genetics, he recommends *The Code of Codes: Scientific and Social Issues in the Human Genome Project,* edited by D. J. Kevles and L. Hood (Cambridge: Harvard University Press, 1992). Jones's book *The Language of Genes* will be published by Anchor Doubleday in August.

For the past fifteen years, **John K. B. Ford** (page 98) has studied the social behavior and underwater sounds of killer whales and other cetaceans. A marine mammal specialist at the Vancouver Aquarium, Ford says his research on killer whales led to his interest in photographing these largest members of the dolphin family. He first photographed the natural markings on their dorsal fins as a means of identifying and keeping track of individuals and later began documenting their activities as well. His doctoral dissertation at the University of British Columbia, where he is now an adjunct professor of zoology, describes the existence of regional dialects among these creatures (*see* "Family Fugues," *Natural History,* March 1991). Hiding in a blind on the beach, Ford snapped this month's "Natural Moment" with a Nikon F-801, 300-mm f4 lens, and Kodachrome 64 film.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