NATIONAL GEOGRAPHIC

From the Editor

WHENEVER WE FEATURE an article concerning scientific evidence of evolution, I can be certain of two things: The story will represent the latest physical evidence presented by leading scientists in the study of early life—and my office will be deluged with letters from readers who reject evolutionary theory. Most of the critics object as a matter of scriptural principle; others say they have scientific evidence that calls evolution into question. This month's story about the origins of life will only add to that debate.

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Faith and science have at least one thing in common: Both are lifelong searches for truth. But while faith is an unshakable belief in the unseen, science is the study of testable, observable phenomena. The two coexist, and may at times complement each other. But neither should be asked to validate or invalidate the other. Scientists have no more business questioning the existence of God than theologians had telling Galileo the Earth was at the center of the universe.

NATIONAL GEOGRAPHIC's respect for faith, the core beliefs that stir billions of people around the world, is reflected in recent articles on Jerusalem, the Vatican, Palestinians, Galilee, Buddhist caves, and Native American powwows. Society President Alexander Graham Bell's vision of geography as "the world and all that is in it" echoes a line from Psalm 89.

Science is in a perpetual state of becoming. Yesterday's observations give rise to today's theories, which will be tested through painstaking research. Just as any good scientist must be ready to abandon a bad idea, he or she must stand by the results of unbiased empirical evidence and experimentation. The current studies of how life arose, most scientists believe, stand up to that scrutiny.

Bill Allen

BLUE REFUGES

U.S. NATIONAL MARINE SANCTUARIES

By DOUGLAS H. CHADWICK

Photographs by DAVID DOUBILET and FLIP NICKLIN

From the seat of a biplane a thousand feet above the Florida Keys, the sea seems a boundless place, tranquil but for the froth of breakers on coral reefs and the hues of mingling currents. Yet this blue veneer—like all the world's oceans—is critically threatened by overfishing, pollution, disease, and encroaching humanity. To help protect vital pockets along U.S. coasts, the government has created 12 marine sanctuaries, which include the waters of the Florida Keys. Each site in this living gallery of kelp forests, benthic canyons, coral gardens, and tide pools is a laboratory for the restoration of marine ecosystems—lifeblood of the blue planet.

STELLWAGEN BANK

A brazen band of herring gulls scramble to steal small fish that may leap from the baleen-fringed maw of a humpback whale feeding along Stellwagen Bank. One humpback may gulp a ton of fish a day from the nutrient-rich waters of the bank—a mass of glacially deposited sand in Massachusetts Bay that provides a critical feeding ground for endangered humpback, fin, and northern right whales.

Sanctuary staff work with the area's lucrative whale-watching industry and others to protect marine life. But large vessels, which must cross sanctuary waters to reach Boston, still pose a threat to migrating whales.

THE WIND WAS CLEARING OUT THE FOG; not lifting it so much as drawing it open in curtains. The edges grew incandescent. And then our boat was plunging through pure sunshine upon an azure sea off California. Dolphins appeared, hundreds upon hundreds of them, leaping together in groups. Some came to ride the ship's bow wave, effortlessly matching our speed with their own sleek hulls. They were joined by sea lions, which not only kept pace at the bow but began to leap through the air in synchrony themselves.

The birds called phalaropes came swarming in; scarcely the size of robins, they spend most of the year out on the open ocean, feathered specks in a storm-tossed immensity. The flocks were skittering over the chop, dabbing at food. Wilson's storm-petrels arrived—possibly the most abundant bird in the world, though they also spend so much of their life at sea that hardly anyone knows them. Two other seabirds joined them: Cassin's auklets and Xantus' murrelets. Good signs: The current must be full of plankton and the shrimplike crustacean known as krill. And krill meant. . . .

There! A geyser of fine mist nearly 30 feet high erupted to starboard. Behind, a great bulk arose, surfaced pale blue and dappled with sea-gray spots, and kept coming until it showed broad as the deck of a submarine. And kept on coming and rolling forward and rising higher and then slowly began to arc down again, bringing into view a tapered fin and after a while an enormous, flat tail that pressed down upon the water and was gone.

Animal life takes no larger form than the blue whale we had just seen slipping beneath the surface. Some reach a hundred feet in length and weigh as much as 190 tons, the equivalent of an entire elephant troop. Two more titans rolled behind the first. Not long afterward, we came upon four others and, passing a distant point of land, saw a minke whale leap almost completely clear of the water.

It felt as if I had voyaged into uncharted latitudes, but I was barely 25 miles from the mainland of southern California in the Channel Islands National Marine Sanctuary. The sanctuary extends from the high tidemark of five islands—San Miguel, Santa Cruz, Santa Rosa, Anacapa, and Santa Barbara—to six miles off their shores, taking in 1,658 square miles of Pacific Ocean. Nine other ocean reserves shine around the coastlines of the continental United States. One more stretches from Maui to several nearby Hawaiian islands. Another covers a patch of Fagatele Bay in American Samoa. Together, they make up the National Marine Sanctuary System. Managed by the National Oceanic and Atmospheric Administration (NOAA), this is perhaps the least familiar segment of our

federally protected lands and waters. Yet it has the greatest potential to reshape our view of the world, whose surface is, after all, nearly three-quarters salt water.

As Sylvia Earle, former chief scientist for NOAA, observed, "To understand what makes Earth different from any other place, and why life can thrive here, it would be logical to focus on the part of the biosphere that supports most of the action—that is, the sea, of course." America's oldest national park, Yellowstone, was established in 1872. A full century would go by before lawmakers turned to safeguarding the nation's maritime treasures. Even as technology was rapidly advancing our understanding of the underwater realm, it boosted the potential for offshore development, notably mining and drilling. Headlines about disastrous oil spills and vanishing whale populations were making people increasingly uneasy about modern civilization's impact upon the sea. Thus, the Marine Protection, Research and Sanctuaries Act joined a flurry of environmental legislation making its way through Congress in 1972.

Monitor National Marine Sanctuary was the system's first entry, put in place in 1975 around the wreck of that famous ironclad vessel from the Civil War, which lies in 230 feet of water off Cape Hatteras, North Carolina. The entire reserve covers less than one square mile. By contrast the 3,696 square miles of Florida Keys sanctuary encompass the world's third largest barrier reef. Then there is Monterey Bay sanctuary, running for more than 350 miles along the California coast and as much as 53 miles seaward. Its northern boundary adjoins the Gulf of the Farallones, a sister reserve that is connected in turn to the Cordell Bank sanctuary farther north.

In all, the 12 units of the system take in some 18,000 square miles. That sounds huge. But the U.S. claims jurisdiction over ocean acreage nearly equal in size to the 50 states; marine sanctuaries make up barely half of one percent of it. However, two more sites—Northwest Straits, in the Puget Sound area of Washington, and Thunder Bay, a freshwater reserve focused around a cluster of shipwrecks in Lake Huron—may be included in the near future, and many more are being considered.

Although resource protection is the major purpose, marine sanctuaries are by no means underwater parks. They are multiple-use areas, not surprising given that NOAA is a branch of the Department of Commerce. As a rule, you cannot drill, mine, dredge, dump waste in, or remove artifacts from a sanctuary, but shipping traffic is merely restricted to certain lanes to minimize the possibility of wrecks and spills. Commercial fishing, diving for edible species, and setting traps for crabs and lobsters are generally permitted. So are sportfishing, spearfishing, boating, and other types of recreation.

But sanctuary officials and visitors alike are beginning to wonder how many human activities may safely be allowed, and at what level, before they undercut the purpose of a marine reserve. On the other hand, at what point would tighter rules begin to strangle people's ability to wrest a living from the sea or simply enjoy traditional outings? What are the best uses of the natural resources that belong to every American, including the generations yet to come?

With more than half the U.S. population now living in coastal states, the young and growing sanctuary system inevitably finds itself being drawn into the kinds of debates that have long swirled around national forests and wildlife refuges. A key difference is that we have only a blurry idea of what's out in those salty depths, much less how their ecosystems work. Sanctuary managers list research as an urgent priority, for they are dealing with our planet's last and least explored frontier.

DURING THE YEAR I spent discovering the sanctuary system, I did a lot of my breathing through a snorkel and often headed deeper with scuba tanks. Water is 800 times as dense as air. The human sense of wonder can get multiplied by about the same amount beneath the waves. No matter how tidy and domesticated things may have become on shore, as soon as you stroke a few feet out, you are in wilderness. As in any good, untamed place, you also slip down the food chain a bit.

DOUGLAS H. CHADWICK, a wildlife biologist, took scuba lessons to prepare for this coverage. He is the author of *A Beast the Color of Winter* and *The Fate of the Elephant*. DAVID DOUBILET began making underwater photographs at age 12. This is his 44th byline in NATIONAL GEOGRAPHIC. A frequent contributor to the magazine, FLIP NICKLIN most recently photographed bearded seals for the March 1997 issue.

CHANNEL ISLANDS

Beneath the blush of dawn the Channel Islands curl like sleeping seals. Two of the isles—Anacapa and Santa Barbara—are key nesting sites for endangered brown pelicans. Creatures as tiny as tentacled green anemones (below) and as massive as blue whales thrive in the rich broth of sanctuary waters, a blend of warm southern and cold northern currents. Because marine sanctuaries also protect cultural resources, sanctuary staff work with Santa Barbara museums to find and preserve artifacts of the Chumash Indians—whose presence here dates back some 10,000 years. To teach children the ecological and cultural value of the sea, the sanctuary began Los Marineros, a program for Santa Barbara fifth graders. "We are the next century," says ten-year-old participant Aurora Fleur Gaines. "If we don't help the ocean, I don't think we have much chance of surviving."

A towering grove of giant kelp harbors grazing señorita wrasses and orange garibaldi—a protected subtropical fish that rarely ranges farther north than the Channel Islands. Giant kelp is the Jack's beanstalk of algae, capable of growing two feet a day to lengths of a hundred feet. Though harvested for algin (used in paints, foods, and makeup), kelp provides sustenance and shelter for so many forms of life that Darwin likened kelp forests to rain forests in their bounty.

DAVID DOUBILET

More than 20 kinds of sharks roam Channel Islands waters. Great whites in particular are drawn by one of the world's outstanding concentrations of warm, plump sausages with big eyes and long whiskers. Upwards of 150,000 California sea lions live and breed here. Harbor seals are everywhere. Northern fur seals travel between the islands and Alaska. A few rare Guadalupe fur seals, which barely escaped extinction by 19th-century pelt hunters, cruise up from Baja California. Northern elephant seals are among the biggest of all pinnipeds and the best divers, capable of descending nearly a mile. They, too, were nearly exterminated, by whalers who rendered their fat into oil. Today San Miguel Island is a rookery for more than 10,000.

The edge of Anacapa Island was furred with seals and sea lions as I jumped from the research vessel *Ballena* into the water behind Ed Cassano, the sanctuary manager. Expecting to feel exposed, I found instead that we were elaborately sheltered by fronds of feather boa kelp and giant kelp, *Macrocystis pyrifera*. I pulled myself from stalk to thick stalk toward the bottom and then paused to look up. Cathedral light splintered down through the congregation of branches. "Our redwoods," Cassano had called these underwater forests that flourish around the islands. The giant kelp can grow to a hundred feet. Yet in terms of sheer color and the variety of life, this seemed more like a tropical jungle.

Both red and purple urchins lay like bright globes on the bottom, mixed with sea stars and sea cucumbers. Stocky orange fish called garibaldi defended the algal gardens they graze. Sheepheads, which change from females to males as they age, swam alongside kelp bass, and a bat ray flared past into a cave.

Near the surface, the tangled kelp canopy becomes a sheltering nursery for juvenile fish. While I was trying to identify a school of fry from below, big bodies came hurtling toward me—sea lions, trailing bubble strings bright as pearls. Curious about the intruders in their neighborhood, they circled quickly and then again upside down for a closer look. I wanted to move like they did, as though the water held no resistance. All I could do was wave in slow motion as they shot by.

Inhabitants of subtropical waters flowing north from Mexico and residents of the cold currents coming from the North Pacific meet and mix among the Channel Islands. "The region's diversity of marine life is exceptional," Cassano later told me. "Something like 150 species new to science have been identified in the past few years." When the chilly, deep-running northern waters hit the islands, they are forced upward, and the nutrients they carry fuel rich plankton growth at the sun-warmed surface. This is the basis of the food chain that ultimately produces the area's bounty of seabirds, pinnipeds, and great whales—and feeds a fair number of fishermen.

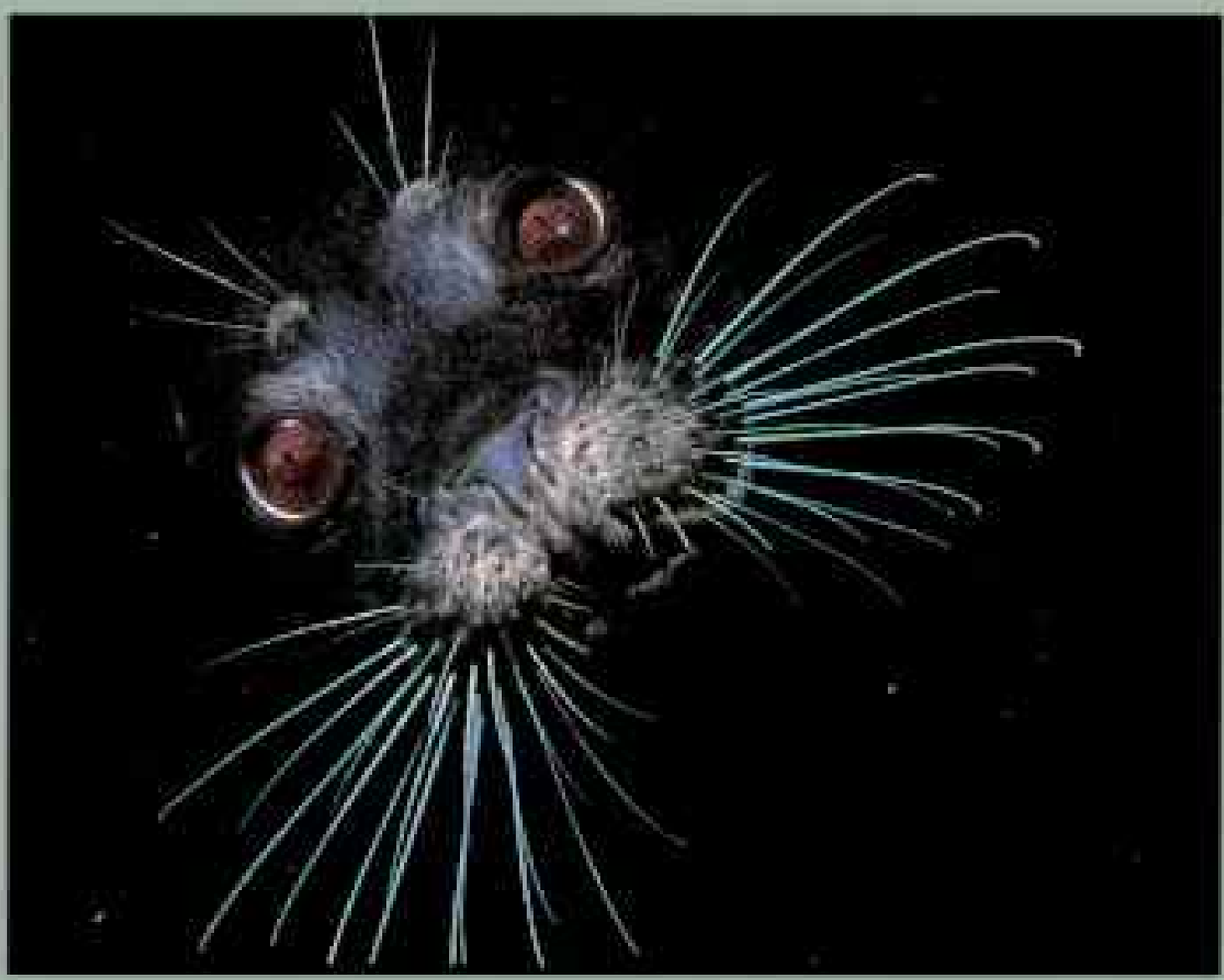
ONE OF THE TOP INDUSTRIES associated with the sanctuary these days is diving for red urchins, whose eggs are prized in Japan. Most of the harvest is by independent operators out of nearby Santa Barbara and Ventura. Although the creatures are prolific and the take is limited both in terms of season and the number of permits sold, urchin numbers have been in decline over the past five years. But a burgeoning squid fishery in the area is still unregulated. "I'll see 60 to 70 squid boats in the sanctuary at one time now," Cassano told me. "Squid are the bread and butter of a large part of the food chain. Some animals such as Risso's dolphins eat little but squid. What are the effects of removing such a large quantity? What nontarget species are being caught in the same nets? I'm organizing a meeting with other agencies to discuss these issues."

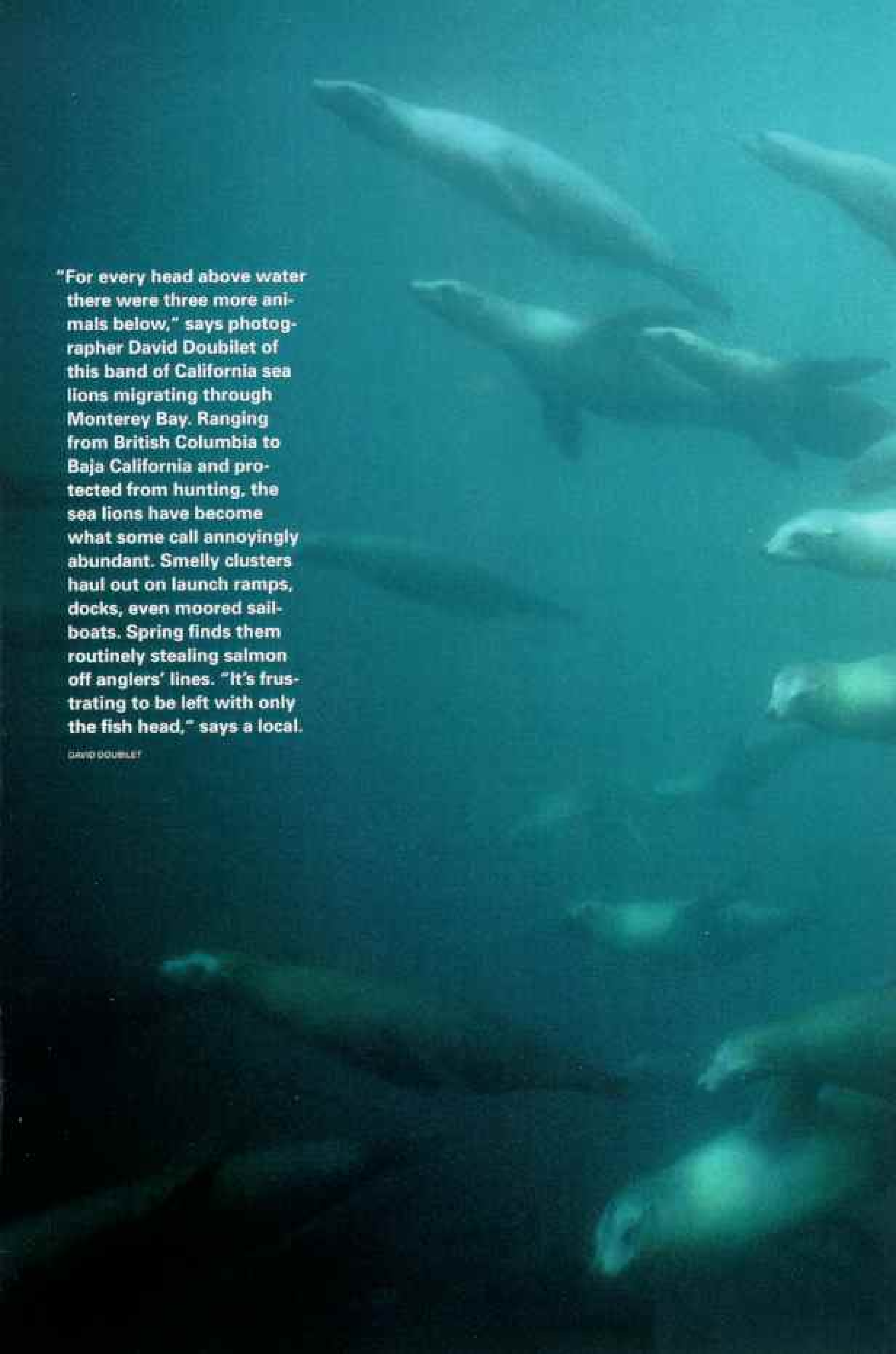
Sportfishing for bass and rockfish ranks high among the Channel Island industries, though tourism, from whale-watching to sea kayaking, is probably the fastest growing business of all. Meanwhile, a fleet of larger ships annually harvests more than 125,000 tons of the fast-growing (up to two feet a day) giant kelp from the area. Algin, the compound that gives kelp its flexibility, is used to help bind and gel some 70 different household products from toothpaste to ice cream. The average American is said to use kelp in one form or another about 15 times daily. Although you may never have heard about this sanctuary, chances are you have touched its forest.

Ultimately, decisions on the commercial use of marine life near shore are made by the state, while species that dwell farther off the coast or range more widely *(Continued on page 18)*

MONTEREY BAY

Surprise takes many forms at the nation's largest marine sanctuary—in the startled face of a harbor seal caught unawares underwater (below), in the bulk of an anchored aircraft carrier emerging from the mist (above), in the sheer size of the place. Spanning more than 350 miles of California coast and reaching as far as 53 miles offshore, Monterey Bay sanctuary holds the nation's greatest diversity of marine life and habitat as well as one of its largest ocean canyons, which cuts more than two miles deep. There scientists from the Monterey Bay Aquarium Research Institute are using a new remotely operated vehicle to film the depths, study water chemistry, and discover new species. "Because this sub is so quiet, we'll be able to get a more accurate picture of where animals live and how they behave," says biologist Judith Connor. "It's really exciting."





"For every head above water there were three more animals below," says photographer David Doubilet of this band of California sea lions migrating through Monterey Bay. Ranging from British Columbia to Baja California and protected from hunting, the sea lions have become what some call annoyingly abundant. Smelly clusters haul out on launch ramps, docks, even moored sailboats. Spring finds them routinely stealing salmon off anglers' lines. "It's frustrating to be left with only the fish head," says a local.

DAVID DOUBILET

FARALLON ISLANDS

Just 30 miles beyond the Golden Gate the granite spires of the Farallon Islands rise in jagged splendor. This wildlife refuge within the Gulf of the Farallones sanctuary hosts the largest concentration of breeding seabirds in the continental U.S. Petrels, puffins, auklets, and murres are among the quarter million birds that nest and burrow here. Along mainland bays and estuaries Caspian terns (below) forage and court. The male brings a fish to his intended mate. In winter a barrel-chested male elephant seal (left) lumbers onto an island beach to breed. Nearly wiped out by 19th-century hunters, the seals thrive here, though dozens of juveniles are lost yearly to great white sharks. A corps of volunteers helps track marine life—and death—in the sanctuary. Says volunteer Gordon Bennett, "Each bird that washes onto the beach is a little message from far offshore."

(Continued from page 12) fall under the control of regional councils and the National Marine Fisheries Service. It is the nature of fisheries to go after the maximum harvest that might be sustainable, yet sanctuaries are responsible for sustaining the ecosystem in all its complex variety for the public as a whole.

The two goals do not always match up. In most cases all the sanctuary staff can do is make suggestions, persuade other agencies into looking beyond single species with obvious economic value, and continue to build up information like an abalone adding pearly layers to its shell.

TO MAKE CONTACT with Flower Garden Banks sanctuary takes some work. You have to travel to the East Texas coast and then a hundred miles out into the Gulf of Mexico, where the seafloor is hundreds of feet deep and largely barren, until two salt domes suddenly bulge from the muddy sediments to within 50 to 70 feet of the surface. That's close enough for sunlight to support some 350 psychedelic acres of stars, brains, rainbows, and lace—the structures of the colonial animals we call coral.

Huge seagoing vessels once found the banks a conveniently shallow spot to anchor offshore. Many smaller craft attracted by the excellent fishing cast out anchors as well. Having seen the accumulating damage firsthand, scuba divers lobbied for years to protect these coral reefs, the northernmost on the continental shelf. An underwater videotape that featured the giant anchor of an oil-field boat ripping through coral heads finally focused political attention, and in 1992 Congress approved a 55-square-mile sanctuary around the two underwater summits. Another small unit, Stetson Bank, was added late in 1996 to protect a siltstone bank 30 miles closer to the coast.

By some estimates 10 percent of the world's coral reefs have been destroyed by human activities, and more than 70 percent may be gone within the next half century. The first step toward saving these complex communities is to get a better grasp of how they work, and a protected spot like Flower Garden Banks just might provide the laboratory to do that.

Once each year the main reef-building corals release sperm and eggs, usually during a very brief period and always at night. Steve Gittings, the sanctuary manager, had predicted that the spawn would begin eight days after the full moon in August at around 9:15. That, I reminded myself, was why I was about to jump off a perfectly sound ship into a black ocean with currents sweeping to faraway Mexico.

"Almost nine," Gittings called out. "Time to get under." I leaped, sank, and soon made out far below the clusters of glow sticks and flashlights carried by my fellow divers—sanctuary biologists, University of Texas researchers financed by the Gulf of Mexico Foundation and the sanctuary, and volunteers recruited through Oceanic Expeditions, an ecotourism group.

For a moment I thought I was looking at some busy underwater city of the future. Then I settled onto a sand patch 70 feet down and peered into a coral cave where tiny luminescent organisms twinkled within its recesses. Parrotfish slept protected in transparent cocoons woven from their own mucus. Squirrelfish with huge eyes peered back into mine, and long-spined urchins crawled along the ledges like walking pincushions.

At almost precisely 9:15, the star corals started "smoking," giving off white puffs of sperm. Within a few moments, the whole reef was shedding BB-size packets of gametes that floated toward the surface like clouds of pollen. Suddenly, all kinds of other creatures were spawning as well: sponges, tube worms that grew among the corals, brittle stars writhing in a mating dance. I swam on in my tunnel of lamplight through a broth of life in the making, surrounded by people with nets and bags gathering data from a landscape of dreams.

Two nights later we placed samples of the rapidly developing coral larvae on small sections of reef that researchers had scraped bare earlier and also on a pyramid of tile plates. Follow-up observations would reveal more about the conditions that allow these relatives of jellyfish and anemones to settle and start secreting protective limestone walls around themselves—information that could help efforts to restore damaged reefs elsewhere.

"Over the past 20 years I've seen coral reefs going downhill all over," said Fred Lagno, a bookbinder by trade and one of the diving volunteers who had been shuttling research supplies between boat deck and sea bottom. "I keep fish as a hobby. I wanted to learn more

about them and where they live. Going with scientists is great for that, and they can always use an extra pair of hands."

Marine sanctuaries don't just appreciate volunteer help; they could hardly manage without it. The entire system has an annual budget of only 11.7 million dollars—a sum, in effect, that reduces these sanctuaries to a state of poverty proportionately even worse than that of the National Wildlife Refuge System.* The typical marine sanctuary, therefore, must take care of an enormous area with a staff that could fit into a broom closet.

BRAD BARR is one-third of the total personnel for Stellwagen Bank sanctuary, which takes in 842 square miles of Massachusetts Bay beginning 25 miles east of Boston and three miles north of Cape Cod. I met Barr, the manager, at sanctuary headquarters in Plymouth, a couple of blocks from the spot where the Pilgrims settled in 1620. In those days, he told me, lobsters were so abundant that the settlers used them for fertilizer. An early labor contract protecting indentured servants forbade their masters from feeding them lobster more than three times a week.

Today Cape Cod is nearly out of cod. From flounder to haddock, many North Atlantic fish stocks are at all-time lows, decimated by relentless overfishing. Yet inside as well as outside the sanctuary, nets still seine the ocean day and night. Trawl nets bump along the bottom, tearing loose sedentary marine life. Draggers rake up scallops and clams, leaving stretches of the seafloor looking like freshly plowed fields. Some boats go after quahog clams with hydraulic equipment, sucking the sediment away. "Even the draggers worry about those guys," one fisherman told me.

In parts of South Africa and Australia, marine sanctuaries serve as replenishment zones—places where fish can prosper and multiply under full protection, helping guarantee a sustained supply for fisheries in neighboring waters. By comparison, temporarily closing a small part of Stellwagen to fishing in order to study the effects on fish populations doesn't seem especially radical. Yet when Barr floated that idea, it was greeted by jeers from many local boatmen.

Down on the Plymouth docks I watched the crew of the *Lady Di* unload bloody heaps of the small sharks called dogfish into shipping crates. Captain Dennis Cadorette finished tying up the boat and looked around wearily. "I'm 55 years old," he said, "and I've been out since four this morning. If I could sell this business, I'd do it tomorrow. All we're getting besides a few flounders is dogfish. We used to throw them overboard as trash. Now they're keeping us alive. Everybody understands you can't keep raping the place or there'll be nothing left, but who wants to deal with more regulations?"

But it's not necessarily about more regulations. Critics charge that sanctuaries rarely use their existing powers to control commercial uses. "A sanctuary's purpose is to protect resources, not somebody's ability to make a profit by exploiting them," says Jack Sobel of the Center for Marine Conservation.

Instead sanctuaries have made themselves clearinghouses for information about the ocean environment. While sanctuary staffers try to monitor some resources on their own, they mainly coordinate research by other agencies and institutions while reaching out through them to educate the public.

I was once on a boat bound for Stellwagen Bank when it suddenly listed to one side. Dozens of people had rushed to the rails to watch a humpback whale dive and move in a circle. The whale exhaled blasts of air that rose to the surface, forming a ring of bubbles. The center of this bubble net began to fill with sand lance, a type of small fish. Then the leviathan rose up through them. Fish leaped from the pool formed by its closing maw, only to be snatched in midair by swooping gulls and shearwaters. A hundred yards farther out, 70-foot finbacks, sleekest and fastest of the great baleen whales, steamed past, lunge feeding after the same silvery schools.

Over the ship's loudspeaker a naturalist explained how to identify different types of whales at a distance by the shape of the spouts they blow. Twelve-year-old Jessica Honeywell already knew. According to her parents, she had been talking and reading about whales for the past four years, ever since the family "adopted" a humpback by contributing funds to a conservation organization. This was her

*See "National Wildlife Refuges," by the author in the October 1996 GEOGRAPHIC.

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OLYMPIC COAST

Tide ebbs. Day fades. Spruces cling to a remnant of ancient plain (right), and a lone blood star gleams (above). Such is the raw beauty of Olympic Coast sanctuary, where remote tide pools remain untouched but for the occasional hiker or native tribes that gather shellfish. Each month rough offshore waters host thousands of vessels engaged in Pacific Rim trade. Sanctuary staff promote shipping safety and practice oil-spill response to keep waters pristine. Says education director Bob Steelquist, "We got here in time."

HAWAII Her pectoral fin a protective wing, a humpback swims with her young in Hawaii's humpback whale sanctuary—the only site dedicated to one species. For reasons still unknown nearly two-thirds of the estimated 8,000 North Pacific humpbacks mate and calve here, their only U.S. breeding ground. "From the office we'll hear a *whack whack* and think it's a loose shutter; then we'll see flukes smacking the water," says sanctuary liaison Allen Tom. "That's how close they are."

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first contact with the real thing. "Did you see the one that came right up to the boat?" Jessica asked me. "It was even bigger than I imagined. Everyone was screaming." She thought a minute. "I was screaming too but in a happy way."

In a good year, when sand lance abound, whale-watching in Massachusetts Bay may draw close to a million people and generate more than 20 million dollars. Compliance with laws against harassing the giants is spotty among private boaters. Stellwagen staff have turned to the International Wildlife Coalition and other groups to patrol in small craft and warn overeager viewers against getting too close. The presence of fishing gear causes more problems. Some whales become entangled in nets or lobster traplines every year.

Of all the great whales, northern right whales are the most endangered. Experts think fewer than 350 remain on earth. Because the animals swim slowly, skimming swarms of tiny crustaceans from the surface, they are especially prone to collisions with freighters and other large vessels. Stellwagen Bank is part of an important winter feeding area. Another vital wintering area, where the females give birth, lies within Gray's Reef sanctuary, a 23-square-mile reserve 20 miles off the coast of Georgia.

WHEN I ARRIVED on the coast near Gray's Reef, summer still held sway, and a different kind of imperiled species had come to produce another generation. Once again I headed out at night with a group of volunteers and specialists, but this time on solid ground, walking the beaches of the 9.5-square-mile Sapelo Island National Estuarine Research Reserve. (NOAA co-manages 22 such reserves in coastal wetlands, several of which have close ties with

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nearby marine sanctuaries.) We were trying to pick out dark shapes on the sand.

"We get a few green, leatherback, and Kemp's ridley sea turtles coming ashore to nest on Sapelo," said Brad Winn of the Georgia Department of Natural Resources, "but this is the loggerheads' time." Around two in the morning, we found tracks and followed them to a 300-pound reptile with a barnacle-encrusted shell shaped like a heart. Her head was broad and her jaws thick, designed for crunching shellfish. We watched in silence as she dug a deep pit with her rear flippers and filled it with more than 130 eggs, one moist white sphere at a time.

Slowly, methodically, the loggerhead buried her nest and tamped the sand smooth above it. She turned and cocked her head, as if taking a fix on the night sky or the glow of breaking surf a hundred yards distant. Then the turtle began dragging her heavy bulk back toward the water, pausing often to rest. At last, lapped by the glimmering waves, she became buoyant again and stroked for the open sea beneath a crescent moon.

At the nest site the team promptly dug up her eggs, reburied them higher up toward the dunes—where they would be safer from high tides and storm surges—and then placed wire over the new nest to keep out marauding raccoons and feral hogs.

The turtle was probably bound for Gray's Reef, an extensive hard-bottom feature on a part of the continental shelf mostly buried beneath shifting sediments. Earlier radio-tracking studies had indicated that female loggerheads may stay there to feed and rest after trips ashore for nesting.

When I dove to see the place for myself, I met loggerheads on their way to the surface to replenish their air and gulp cannonball jellyfish. Others 70 feet down snoozed in a cave.

Poking my nose into the next cave over, I was greeted by two olive-yellow eyes with vertical slits belonging to a nurse shark.

This was not the turbid, brown water of the coast or the blue water of the Gulf Stream but the green water in between, tinted by plankton and organic debris flowing out from the fertile estuaries. The particles seemed to coalesce before my eyes into cigar minnows, or round scad, so numerous that they almost formed a second reef layer. At one point they enveloped me like a tornado of glittering confetti. Amberjacks and barracudas passing by punched holes in the envelope's sides.

Because Gray's Reef is small and the hard-bottom community vulnerable to disturbance, prohibitions against seafloor trawling were agreed upon when the sanctuary was established in 1981. Today the staff—of three—is talking to divers and charter-boat operators about limits on spearfishing. The sport can quickly remove a reef's larger predators such as gag grouper, causing a cascade of effects down through lower levels of the food chain.

Spearfishing, collecting tropical species for aquariums, and using wire fish traps were among activities banned in America's very first underwater park: John Pennekamp Coral Reef State Park, established in 1960 near Key Largo, Florida. At that time state territory extended only two miles from shore. The most spectacular reef formations were just beyond. When treasure hunters insisted on digging there, Florida turned to the feds for help, and 1975 saw 135 square miles adjoining Pennekamp set aside as Key Largo sanctuary.

In 1981 another eight square miles of classic spur-and-groove reef formation farther south was protected as Looe Key sanctuary. But a host of other factors continued to threaten the area, including pollution, coral diseases, and overfishing. Booming boat use led to more damage from props and anchors and almost 500 groundings every year.

During 1989 three big vessels smashed into prime reefs within 18 days. That did it. The next year the U.S. gained a sanctuary that extended 220 miles from Biscayne National Park on the north to the pristine waters around Dry Tortugas National Park on the south, including part of Florida Bay between the keys and Everglades National Park.

There's your reserve, Congress told the new Florida Keys sanctuary staff. Now kindly write a management plan that will fix the reef, take care of the two other major marine ecosystems around the keys—sea grass beds and mangroves—and make everyone who uses the place happy. I showed up in 1996 to find a final plan of three thick volumes that had still not been approved.

"Is it true you've been burned in effigy?" I asked the sanctuary superintendent, Billy Causey, when we met in Key West.

"Naw," he replied. "Hung in effigy twice but never burned. It's one thing to set up a sanctuary way offshore. But this one completely encloses waterfront communities. Our problem is convincing people we're not part of the heavy hand of the federal government. The plan gives the state final say over much of our management, because two-thirds of the sanctuary is within state waters. Half our staff are state employees."

IN THE TOWN of Marathon, midway down the keys, I walked past cinder-block houses, hard-used fishing boats, and stacks of crab and lobster pots to the home of Jay and Michele Usher. They were helping organize resource users whose position was summed up by placards on their pickup trucks parked out front: SAY NO TO NOAA.

"Tell me," said Jay Usher, a salvage diver, "if the 22 federal, state, and county agencies we've already got here haven't been able to take care of the reef, how is one more bureaucracy supposed to be the answer?"

Michele added, "We believe the government's ultimate goal is to get rid of the historical economy and replace it with a national tourist park. It's catering to those cosmic yuppies who drive down in their BMWs with Save the Reef stickers on the bumpers. Us little guys who depend on these waters for our livelihood feel under siege."

The keys have more than 80,000 permanent residents, but more than 2.5 million tourists arrive every year. According to a recent survey, 900,000 snorkel and dive on the reef; 715,000 view wildlife; 525,000 sportfish. And nine out of ten say they are concerned about the environment. Tourism, which brings in 1.2 billion dollars a year, essentially is the local economy, and it depends on these waters.

Last year volunteers *(Continued on page 31)*

FRANKLIN & HOLLY BEDFORD | DOUG PERRINE

FLOWER GARDEN

The waters a hundred miles off the Texas-Louisiana coast look flat as a delta bayou. But beneath the surface two salt domes rise from the ocean floor and bristle with coral—northernmost coral reef on the continental shelf. This is Flower Garden Banks, where for a few nights each August the coral equivalent of Mardi Gras occurs: a riotous release of billions of gametes in a mass spawn that looks like an inverted confetti storm. One of many species here, hermaphroditic star corals release egg-sperm packets (above), which float to the surface. After fertilization, coral larvae will drift, then sink to reseed the reef. Because larval mortality exceeds 95 percent, researchers gather gametes from the spawn, nurture them, then transplant the larvae onto clay tiles (below). By learning to grow coral on artificial substrates, scientists hope to replenish damaged reefs worldwide.

Gliding like a stealth bomber, a manta ray is anything but evasive with snorkelers at Flower Garden Banks. Juvenile rays frequent the banks year-round, perhaps drawn by an abundance of planktonic foods. When swimmers remain unaggressive, manta rays often become curious and even nuzzle up to be stroked. "It's a magical experience," says marine biologist Jeff Childs.

FLIP NICKLIN

THE KEYS Snorkelers in the Florida Keys delight in weightless flight while ogling colorful fish and corals. But many are blind to the ills plaguing America's largest tropical reef: choking algae fed by waste, coral disease, overfishing, breakage from careless fingers and fins. People can ride waves, salvage treasure, hoist sails, and otherwise use marine sanctuaries. Yet this site has a comprehensive plan to protect its 220-mile arc of reefs. Mooring buoys prevent anchor damage to coral heads. Channel markers reduce groundings and prop damage to sea grass beds. And in 23 zones harvest of marine life is banned in hopes of replenishing stocks. Says manager Billy Causey, "The eyes of the world are watching what's happening here."

Miami
FLORIDA
Gulf
of
Mexico
Key
Largo
Tavernier
Atlantic
Ocean
Dry Tortugas
Florida Keys
NMS
Key
West
Marathon
Long Key
0
20
MILES

DAVID DOUBILET (NOTM)

THE KEYS

In 1987 the retired Coast Guard cutter *Duane* (right) was deliberately sunk in 120 feet of water seven miles off Key Largo. This 327-foot vessel, which served in World War II and Vietnam, is serving its country once again—as an artificial reef that lures divers away from fragile natural reefs and harbors life where none grew before. Algae now encrust its steel frame, providing food for parrotfish. Corals and sponges ornament the hull, and the wheelhouse shelters schools of grunts (above).

Naturalist Rachel Carson wrote that the marine life of the keys holds "dimly seen foreshadowings of the future." Sanctuary status may help ensure that the future teems with life.

(Continued from page 24) put in about 22,000 hours of work on behalf of the Florida Keys sanctuary complex. I went with two of them, Paul Silverman and Fred Tooker, who also volunteered his boat, into Florida Bay. Looping through a hundred miles of mangrove islands and sea grass flats where herons stalked silversides and tarpon flashed after mullet, we gathered water samples as part of a regular monitoring effort.

Silverman lowered a special disk into the water to measure its clarity. There was none. Storms had churned up the shallows. The effect was magnified now because the shoal, manatee, and turtle grasses that normally anchor sediments had been dying off. On top of that, the nutrients released by their decay seemed to be turning seasonal blooms of algae into year-round growths.

When we tied up back at port in Tavernier, I could smell raw sewage percolating out of some of the estimated 11,000 illegal cesspits in the keys. Silverman said he had seen a lobster crawl up on land to get out of one fetid stretch. Until lately Key West pumped its raw sewage directly offshore. It now treats the wastes to break down solid material, but the residue is still loaded with nitrogen that can fertilize algae that attach themselves to coral formations. They grow until portions of the reef become smothered, especially as overharvesting reduces populations of algae-grazing fish. The effluent also carries worrisome levels of cyanide and zinc.

Underwater visibility out among the corals used to average 80 to 100 feet. These days 40 to 50 feet is considered good. Dive-boat operators generally promise at least that much, but when I went overboard, I often couldn't see much farther than 20 to 30 feet.

Craig Quirolo of the private group Reef Relief has been finding new diseases eating away at the corals practically every year, most recently a bacterial "pox" decimating elkhorn coral and a fungus eating away at the soft corals known as sea fans. "Corals need a lot of light," the former charterboat captain told me. "The water may not be clear enough for them to thrive anymore."

The Florida Keys are nicknamed the Conch Republic. Old-timers call themselves conchs. The anti-NOAA group headed by Jay and Michele Usher is the Conch Coalition. Conch fritters and conch chowder are specialties on menus throughout the keys. But nowadays the conchs themselves come from the Caribbean. The locals took so many of the big spiral shells to sell as souvenirs and food that the state banned all harvest years ago. The Florida Department of Environmental Protection has been working with the sanctuary to restore them.

As many as 5,000 young queen conchs are produced annually at a state hatchery and released into the ocean. A crew led by a state biologist, Bob Glazer, has been studying their survival. The morning we steered for Sombrero Reef to carry out a count, the waves were coming at us four feet high. We passed a boatload of volunteers running back for shore but decided to dive anyway. Each young, peach-pit-size conch had been fitted earlier with an aluminum tag, and our research crew carried metal detectors. A good thing, for the wave surge made the bottom hopelessly murky and tossed us back and forth over it like laundry in a washing machine.

I felt that if people were willing to work this hard to help save what is basically a humongous snail, the keys had a fighting chance of making their waters fit again.

Early in 1997 both NOAA and Florida approved the keys sanctuary management plan. It moves closer to the concept implied by the word "sanctuary," calling for tighter regulations and for zones from which nothing may be taken—even though these "no-take" zones add up to only 1.5 percent of the sanctuary. People are beginning to grasp the idea that changes on the reefs are linked to changes in Florida Bay, which in turn reflect changes in the flow of fresh water through the Everglades due to urban and agricultural diversions upstate.

No one really knows how to manage an ocean or even part of one. We have to invent ways as we go along. Our marine sanctuary system remains a work in progress, gathering influences from near and far. Jay Usher's question—why one more bureaucracy when the others have failed to turn things around?—deserves an answer. Perhaps the sanctuary system's strength in educating people and encouraging cooperation will provide one. □

NAPLES

FOR SOULLESS *efficiency, go north to Milan, sneer proud Neapolitans. But for the "real" Italy of street smarts, passion, and* arrangiarsi*—the art of making do—come south to the clamorous world of Naples. In this gritty labyrinth of a city, crammed with churches and slums, notorious for crime and corruption, beauty somehow survives, as insistent as the red in a peddler's bouquet.*

UNABASHED

By ERLA ZWINGLE
Photographs by DAVID ALAN HARVEY

DOWN AT THE LOCAL TRATTORIA, *taxi driver Gianni Cozzolino and his wife, Luisa, exhaust the dinner hour, exemplifying what an observer calls Naples' "frank devotion to the pleasure of the table." Loyal to their savory city, the couple fear that the appetite for a better life will drive their two children away.*

RUSH-HOUR *choreography on Via Toledo, a center stage for shopping, involves a cast of hundreds, all moving—or trying to—to a cacophony of horns, curses, and crunching metal. Gridlock is legendary in one of Europe's most congested cities. A native's advice: To cross a busy street, follow after an old person.*

ROMANCING THE SEA, *a fisherman waits to haul in his net off the city coast. On a good day depleted waters yield only fistfuls of octopus and squid. The Mediterranean has fed Neapolitans since 600 B.C., when Greeks founded Neapolis, "new city," later a favored resort of Roman emperors.*

SOMETHING ABOUT NAPLES just seems made for comedy. The name alone conjures up pizza, plinking mandolins, and lovable, incorrigible innocents warbling "O Sole Mio"; a nutty little corner of the world where the id runs wild and the only answer to the question "Why?" appears to be "Why not?"

Naples: the butter-side-down of Italian cities, where even the truth has a strangely fictitious tinge. One day a car rear-ended one of the city's minibuses. The bus driver got out to investigate. While he stood there talking, his only passenger took the wheel and drove off. Neither passenger nor bus was ever seen again.

Then there was that busy lunch hour in the central post office when a crack in the ceiling opened and postal workers were overwhelmed by an avalanche of stale croissants. As the cleaners hauled away garbage bags of moldy breakfast rolls, the questions remained: Who? Why? And what else could still be up there?

But Naples actually isn't so funny. Italy's third largest city, with 1.1 million people, has a much darker side, where chaos reigns: bag snatching and mugging, four-deep double-parking at angles unknown to geometry, clogged streets of stupefying confusion, where traffic moves to mysterious laws of its own through multiple intersections whose traffic lights haven't functioned for months, maybe years—if they have lights at all. Packs of wild dogs roam the city's main park. Nineteen policemen on the antinarcotics squad are arrested for accepting payoffs from the Camorra, the local Mafia.

To many Italians, particularly those in the wealthy, industrialized north, none of this is surprising. To them Naples means political corruption, wasted federal subsidies, rampant organized crime, appallingly large families, and cunning, lazy people who prefer to do something shady rather than honest work.

Neapolitans know their reputation. "People think nothing ever gets done here," said a young professional woman. "Sometimes they say, 'Surely you come from Milan. You come from Naples? *Naples?*'"

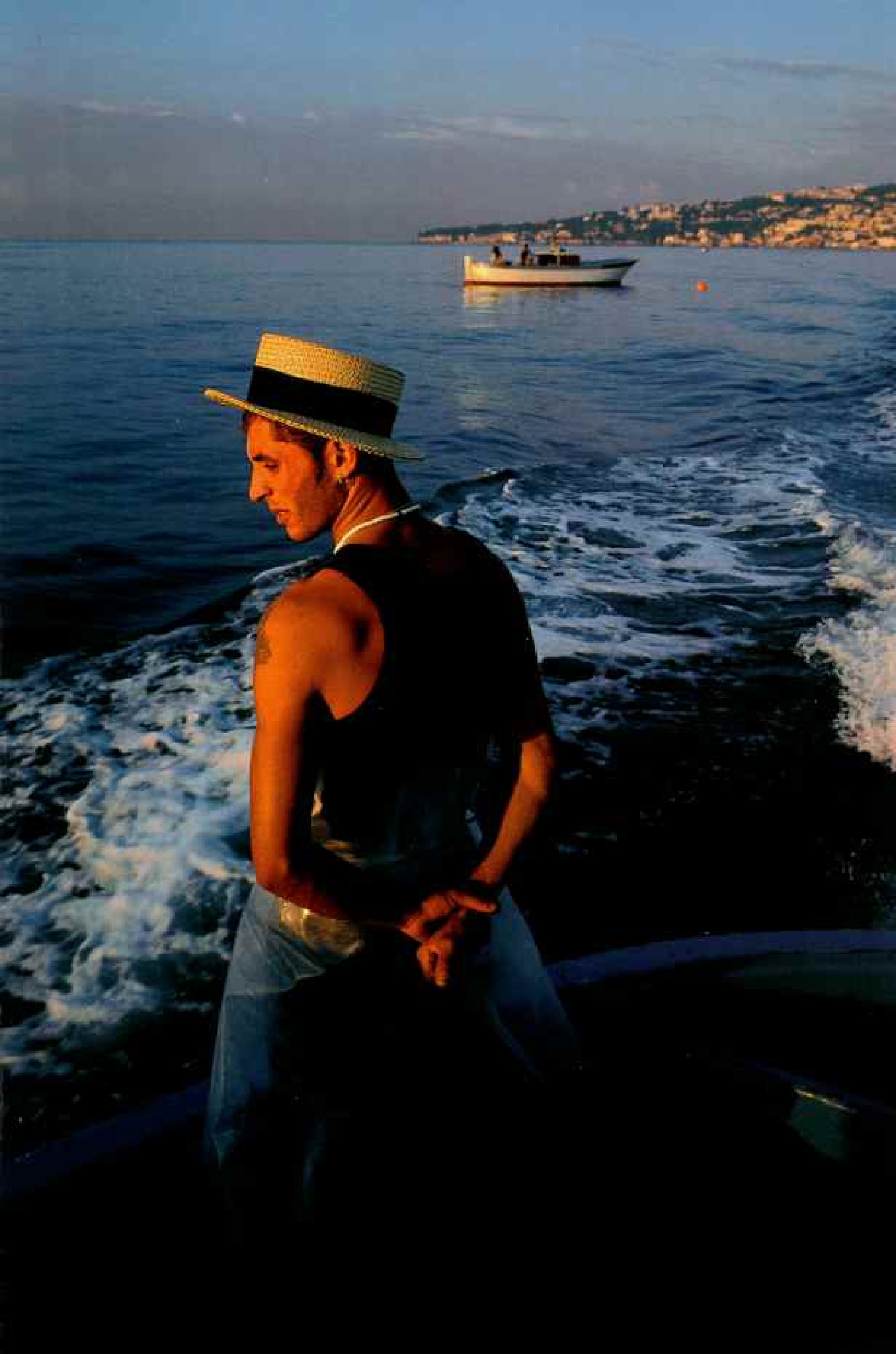
Giovanni del Forno, an insurance executive, told me about his flight home from a northern Italian city; the plane waited on the tarmac for half an hour for a gate to become available. "And I began to hear the comments around me: 'Well, here we are in *Naples*,'" he said with a wince. "These comments make me suffer."

Neapolitans may complain, but most can't conceive of living anywhere else. The city has the intimacy, tension, and craziness of a large but intensely devoted family. The people have the same perverse pride as New Yorkers. They love even the things that don't work, and they love being Neapolitans. They know outsiders don't get it, and they don't care. "Even if you go away," one woman said, "you remain a prisoner of this city. My city has many problems, but away from it I feel bad."

Therefore Neapolitans are just as quick to make cracks at their own expense (a T-shirt depicts this exchange between two men: "If a man bites a dog in Milan, it's news"; "If a man bites a dog in Naples, it's breakfast"). Neapolitans love to talk about how impossible they are. "If someone else says we're Bad Ten," one man remarked, "we immediately say, Bad Twelve, Bad Fourteen."

This is a city in which living on the brink of collapse is normal. Naples has survived wars, revolutions, floods, earthquakes, and eruptions of nearby Vesuvius. First a wealthy colony founded by the Greeks (who called it Neapolis, or "new city"), then a flourishing Roman resort, it lived through various incarnations under dynasties of Normans, Swabians, Austrians, Spanish, and French, not to mention a glorious period as the resplendent capital of the Kingdom of the Two Sicilies.

ERLA ZWINGLE, a former NATIONAL GEOGRAPHIC editor, lives in Venice, which she covered in February 1995. DAVID ALAN HARVEY has photographed 29 stories for the magazine.



LIVING DANGEROUSLY, *Naples continues to thicken and sprawl under the threat of 4,203-foot-high Mount Vesuvius, overdue for an eruption. Famous for burying nearby Pompeii in A.D. 79, Vesuvius last exploded in 1944. Some three million people live within an eight-mile radius of the temperamental crater.*

It was a brilliant, cultivated city that once ranked with London and Paris. The Nunziatella, the oldest military school in Italy, still basks in its two centuries of historic glory; the Teatro San Carlo remains one of the greatest opera houses in the world. The treasures of Pompeii grace the National Museum. Stretched luxuriantly between mountains and sea along the curving coast of the Bay of Naples, full of ornate palaces, gardens, churches, and works of art, with its mild climate and rich folklore, Naples in the last century was beloved by artists and writers. The most famous response to this magnificence was the comment by an unknown admirer, "See Naples and die."

Today that remark carries less poetic connotations. The bombardments of World War II were followed by the depredations of profiteers and politicians-for-rent who reduced the city to a demoralized shadow of itself, surviving on government handouts. Until five years ago city governments were cobbled together by warring political factions; some mayors lasted only a few months. A cholera outbreak in 1973 was followed in 1980 by a major earthquake. Its famous port has withered (though the U.S. Sixth Fleet command is still based just up the coast), industries have failed, tourists have fled, natives have moved out—it seems that only drug trafficking is booming. "Unlivable," the Neapolitans say. "Incomprehensible." "Martyred."

It seemed fated to remain all that. But four years ago a new mayor, Antonio Bassolino, began trying to get his battered city back on its feet. When the seven major world powers agreed to come to Naples for their 1994 meeting—the G-7 summit—he instigated a major refurbishment of the city's center that presented Naples in a dramatic new light, not least to the Neapolitans themselves. For a while at least that part of Naples was beautiful again.

Buildings got a quick face-lift; there were no traffic problems because most traffic was banned, no crime because police were everywhere, no garbage because special squads picked it up.

The city's focal point, Piazza del Plebiscito, was at the center of the G-7 set. Dominated on one side by the severe, imposing Church of San Francesco di Paola and on the other by the more elaborate, crimson facade of the former Royal Palace, it overlooks the cobalt sweep of the bay below. The piazza was, until Bassolino, a desperately congested parking lot. By banning cars, he returned the square once again to strolling lovers and frolicking families, not to mention what appears to be every bride south of Rome posing for wedding portraits even more stagey than the setting. Today Piazza del Plebiscito isn't merely a location; it has become a symbol of the mayor's determination to regenerate the city. "We never thought he'd be able to do it," marveled a professor.

Though life in large part has slid back into its old laissez-faire groove, having a mayor capable of the sweeping deeds of some epic hero has altered Neapolitans' view of their own possibilities. In many houses people prominently display a picture of San Gennaro, the city's patron saint. Lots of them add a portrait of soccer player Diego Maradona, worshiped by his legions of fans. Lately, some have begun adding a third image: Antonio Bassolino.

Neapolitans have seen what their city can be like when it's under control, and they like it. In many ways they have begun to awaken to a cautious new optimism, and something almost like pride.

"NAPLES IS BEAUTIFUL," I heard a million times, "it's the Neapolitans that are bad." I believe the reverse is true. Although the historic center of Naples—now a UNESCO world heritage site—has many architectural gems, most are

lost amid the general confusion, not to mention the uncontrolled sprawl that has buried the once gracious green hillsides under gray concrete ramparts. It isn't a city that solicits affection. But the Neapolitans themselves are irresistible.

One morning I went on a small exploratory walk through Spaccanapoli, the historic center of Naples. Here the grid plan remains from the original Greek settlement, with laundry-festooned streets barely the width of an average driveway. Lack of space has never presented any serious problem to the Neapolitan, who apparently accepts chaos theory as a practical reality: At any given moment there will be at least one car on the street, along with two motorbikes (coming from opposite directions), three girls walking arm in arm, and a family with a baby carriage, all of whom unaccountably manage to avoid collision.

The streets are lined with small, busy stores selling salami, housewares, gold jewelry, and coral pendants carved into the ancient good-luck piece called the *corno*, or horn, favored by the devoutly superstitious Neapolitans. There are also shops featuring miscellaneous religious items, from the countless ceramic figurines treasured as part of each family's Christmas Nativity scene to plastic Madonnas with crowns of small electric lights.

A few steps from the dilapidated Church of San Giorgio Maggiore, I came upon a small, robust man with buzz-cut gray hair and the only smile I ever saw that you could actually call beatific. Overhead his shop's faded sign announced: DOLL HOSPITAL. This is Luigi Grassi, the fifth generation in his family of doll doctors, and he may pass more time outside than

SEE AND BE SEEN: *Such are the stage directions for opening-night intermission at Teatro San Carlo. Playing the bloodied Cavaradossi in* Tosca, *tenor Luciano Pavarotti hams it up backstage with Mayor Antonio Bassolino, a political star who vows to make Naples once again a cultural capital. Since he was first elected in 1993 Bassolino has ordered the repair and reopening of churches and museums, made Piazza del Plebiscito in the city center safe for pedestrians, and, perhaps most popular, spent money to fix potholes and traffic lights.*

in, schmoozing with anyone willing to stop.

Luigi doesn't smile so much as gently beam, radiating a nimbus of goodwill toward men with just an edge of mischief. It's the air of Pulcinella, the classic Neapolitan Carnival character, a mix of court jester and peasant buffoon dedicated to puncturing pretension and having the last laugh. The prospect of talking with me seemed to strike Luigi as the most delightful thing that had happened that day, or possibly ever.

He politely asked Cristina, my interpreter, if she was Neapolitan.

"No," she replied, "I've only lived here five years."

He inclined ever so slightly toward her and gave a delicate little sniff. "Ah," he said gallantly, "one smells already the aroma of Vesuvius."

Inside the tiny shop dolls were lying, sitting, and standing everywhere. There was barely enough space for us, let alone his serene daughter, Tiziana, who works as his assistant.

"This is a happy hospital," he said, "because we don't have any mortuary. When you enter, you always leave cured."

One or two patients arrive every day, and not always in the hands of children. Nearly three-quarters of the customers are adults. "A husband may want to repair his wife's doll, as an anniversary present," he said. "Or a woman may say, 'I want to have this fixed for my daughter because my husband gave it to me when we were engaged.'" A doll was considered a good-luck token, Luigi explained. "Sometimes the mamma of the bride would put a doll on the newlyweds' bed for their return from the honeymoon."

As for the children, "They come crying," he

said. "They don't want to leave the doll, to let go. Then they call me to ask how it is." I smiled. "It's not as silly as it may seem," Luigi said quickly. "The sentiments remain in the soul. The soul is intangible, but these things remain like a tattoo. These memories travel with us and help us live."

Neapolitans are celebrated for their sentimentality, for fantasy; many of their songs positively pulsate with it. But when Luigi spoke, the emotions lost their melodramatic quality.

Apparently nothing dims his glow of good humor. Is it because the hundreds of dolls always seem to be smiling? Or is it perhaps because, at least in his little corner of Naples, everything always comes out all right.

"A doll always carries happy memories," he said. "You breathe again the air when we were good."

THE AIR OF GOODNESS is something many Neapolitan children have yet to inhale. Neapolitans often invoke the new generation as the source of new solutions. But the poor children already reflect their city's deep tensions, showing the difficulties of moving ahead.

The old Mercato area, which was once the major market, is now just one more struggling neighborhood in which drugs, crime, and the occasional shoot-out on the street are no news. The Sant'Eligio elementary school occupies part of a convent surrounding a weather-beaten Renaissance cloister. There are a few palm trees and a broken marble fountain.

Maria Pagnozzi, a dark-haired woman in her early 30s, spent most of one morning shouting at her class of 17 ten-year-olds. She had to; the commotion in the room was unnerving.

WELCOME *to your new world, a grandmother seems to say to her charge—a world with big families, flags of laundry, and whispered confidences between balconies that has changed little in generations. Of this poor, cramped area called Spaccanapoli, a neighbor says, "What there is a lot of is intimacy."*

Children talked, laughed, shouted, wandered around—it was normal street life moved indoors. And yet the children seemed oddly isolated. "I don't see much affection between them," Maria said. "And I don't believe they understand the value of friendship."

Suddenly two of the boys, Gennaro and Giuseppe, were scuffling wildly, grappling, kicking. She lunged to pry them apart.

"You can't be tender," she told me after she had them both seated again. "You have to be hard. In Naples, if you give them a finger, they'll take the whole hand. One glance is enough, and they start fighting."

We all sat in a circle, and I asked the children about their lives and their worries about their city. The replies tumbled out, the same replies I heard from adults: "Stealing." "Drugs." "Camorra." "Killing."

Many of the children had quick answers about how to make the world better: Don't dirty the city, don't pollute the forest, don't pollute the sea. By noon, though, the floor of the classroom was awash in discarded paper. The class seemed an almost perfect small replica of the city beyond, in one sense especially: "They don't recognize authority," Maria Pagnozzi said.

This may be the quintessential Neapolitan trait: a compulsive urge to go against the rules. Its everyday manifestation is called *arrangiarsi*, or "managing for oneself," a survival skill that Neapolitans have refined to an art form. "For many Neapolitans the law isn't seen as something that helps in daily life," said a young businesswoman, "but as something imposed on them. It's seen as someone who is taking away their liberty."

"It's absurd for a foreigner to try to understand our mentality," one Neapolitan said. Yet Biancamaria Fenzi, an archaeologist who moved here from Pisa, thinks the mentality is easy enough to understand—it's just hard to accept. "Here there's too much individualism," she said bluntly. "The idea is, 'If you allow me to do what *I* want, I'll allow you to do what *you* want.' You need *some* cleverness, but when *everybody's* clever, it's a damn mess."

Red lights, few as there may be, are the most obvious example of individualism in full flower. "If I see that my light is red," one man explained with the air of the simplest logic, "I know that the others will wait for me, even if they have the green light."

"If you stop at a red light," his wife added, "they all honk behind you."

Many Neapolitans attribute this lack of common civic sense to their centuries as a kingdom. "We were subjects," one man explained, "not citizens." Yet more than a hundred years have since passed. It's more likely that the true culprits were the rapacious politicians who

MEN IN RED *walk the Santa beat at Christmastime in Piazza Vittoria. For a fee they pose with children. Working the streets is common in Naples, where full-time jobs can seem as scarce as honest politicians. Many Neapolitans earn their first lira selling contraband cigarettes in the city's maze of alleys.*

PARADE-GROUND *warriors, third-level students at the Nunziatella, an elite military academy, don finery for opening-day festivities. On the battlefield of the streets, members of the Falcons, plain-clothes motorcycle police, keep uniforms simple and scruffy as they plan the next gun or drug bust. They rarely lack suspects, since dozens of organized crime clans, called the Camorra, rule the poorer neighborhoods.*

followed. As Guido Donatone, president of Naples' Italia Nostra, a national preservation group, put it, "There's a great, even complete, lack of faith in the political process. The culture of the public interest is lacking here."

UNTIL THAT CULTURE TAKES HOLD, complaining about their city and their fellow citizens may remain the Neapolitans' favorite pastime. I got into an elevator one rainy morning in Monte di Dio, an old, cramped, slightly seedy neighborhood. A damp, breathless, gray-haired woman got on too. We started down.

"You can't win in this city," she blurted out, without any prompting. "They put those metal guardrails in the street to prevent parking, so people park right in the middle of the street. Each person needs to have his own policeman, to make sure they do what they ought to. Not Neapolitan. Maybe German. And they should change every month. Otherwise the policeman would get used to it. That's the only way. Good day." The doors opened, and out she walked.

Unfortunately, the police already have too much to do. When I went to visit Bruno Rinaldi, the deputy police chief, he was overseeing an anticrime effort that clearly left him little time to sleep. His dark eyes were heavily circled.

Rinaldi was doing the typical work of most big-city police officers, except that it was complicated by the Camorra, which is deeply involved in every enterprise in which money can be made illegally. Every conversation about the city's political, economic, and moral health leads inevitably to organized crime. It's the breadth and depth of its activities that baffles and frustrates ordinary people and fuels their

suspicions about the power (or will) of the politicians to crush it. "Even Bassolino must have something to do with them," said one Neapolitan firefighter with a shrug. "Because unless the Camorra lets you, you can't do anything in this city." The mayor was outraged by this remark.

In 1996 police seized nearly eight times the amount of drugs as the year before. As for violent crime, homicides have decreased slightly, but the number of attempts has risen. Death dominates the headlines because it seems to take the cruelest, most random forms; stray bullets from clan shoot-outs have killed housewives and children. Last summer 500 troops were sent into Naples to free police for stronger patrolling. Yet theft is a bigger threat than guns. Police records show that you're nearly 20 times more likely to be mugged than killed.

Rinaldi, who speaks with a serious, thoughtful air, connects crime foremost with unemployment. In 1997 there were 184,000 people out of work, one-quarter of the employable population. The number has increased by 10,000 each year over the past five years. Some get by selling cigarettes and packets of tissues, which can actually net more than $1,200 a month. Others steal or mug. If they are successful, they move up the ranks.

To combat crime, two motorcycle squads of 120 men, the Kites and the Falcons, patrol the worst neighborhoods. The Falcons work in their street clothes and look like guys from a pool hall in South Philly. They have nicknames like Big Doll and Crazy. They ride big Enduro off-road motorcycles.

I couldn't persuade them to let me ride with one. Instead, for security, Cristina and I climbed into the back of a squad car with officers Carmine and Enzo for a Falcon's-eye view of Naples by night.

We cruised through ever tinier streets, through Forcella and the Spanish Quarter, where steep hillside streets crumpled up into stairways, and parked cars blocking the road were a firefighter's nightmare. Some streets were brilliantly illuminated, with small stores blaring light from their open doorways. Makeshift sidewalk stands sold fruit, clothing, pizza. Everyone was milling around, talking and shopping. The side streets were darker and emptier, with small clusters of people standing and watching. On some of these streets they were selling heroin.

BELIEVING IN MIRACLES, *a crowd presses into the duomo for a chance to kiss a vial of blood said to be from the martyred San Gennaro, patron saint of Naples. As often as three times a year the saint's dried blood inexplicably turns liquid amid a frenzy of prayer. A furious faith in demonstrations can also seize the masses. One week it's the jobless (right) making themselves heard. The next week it's marchers protesting higher taxes or demanding safe streets. The noisiest rallies, however, roar with the same message year after year: Napoli soccer rules!*

Enzo explained how these neighborhoods work: "You have a child, I have a child. They get married. They're all related here," he said. "So when there's an arrest, they all start fighting you." (On one memorable day the families formed a phalanx and blocked the street, preventing the police from entering.) A small group moved unwillingly from the middle of the street to let us pass. Someone called "Mariooooo." "It's probably a code word," Enzo said calmly. "Now everyone knows we're here."

We drove through micro-territories, deserted squares surrounded by dark tenements. Enzo recited the litany of local bosses: Giuliano, Mazzella, Tolanelli, Vastrelli. It's a Naples within Naples.

I asked if he ever feels vulnerable. "The Falcons are admired and feared," he replied, "because we have the desire to take risks. You can't have fear to live here, so the people here admire the courage of the person. It's the thing they admire the most. Only strength earns respect."

"WE HAVE TO GIVE criminals some alternative," Bruno Rinaldi, the deputy police chief, had insisted. "We haven't been able to give them the choice of work or crime. We haven't determined if someone would choose between them. But we need to get rid of the concept that here in Naples is the *tendency* to be delinquent."

There are, in fact, plenty of hardworking Neapolitans who belie the lazy, worthless image. I spent one morning with a few of them on a small fishing boat in the Bay of Naples, watching the city awaken. As the sun rose, it glowed ever more intensely behind the distant

summit of Vesuvius until it seared through the edge of the crater and broke free. The city from the sea is a jumble: undistinguished luxury seafront hotels, the austere medieval Castel dell'Ovo sitting heavily atop its own little island, the long red flank of the Royal Palace, the defunct Mobil oil refinery, and the stark silvery towers of the new Centro Direzionale, Naples' touch of Manhattan.

The few local fishermen who keep at it are no match for the megaboats working the deep ocean. By 7 a.m. the five men were yelling exquisitely musical curses at the passing boat that had just ripped up their net (the second such disaster of the morning) and gazing with disgust at the lone octopus that represented four hours of work.

Other Neapolitans have more to show for their labor. A larger airport is in the planning stages, and a rapid-rail link to Rome should be operating by the year 2000. Some entrepreneurs have proposed a major reorganization of the port to attract more cruise ships and other trade. Neapolitan goldsmiths—whose skill has been prized since the 13th century—have opened Il Tari, a consortium of jewelers that offers members state-of-the-art equipment and training. And an indomitable woman named Mirella Barracco, with her private Naples 99 Foundation, has reawakened Neapolitans to the beauty and importance of their city's monuments, churches, and works of art. Her adopt-a-monument program has involved scores of schools citywide and is now being copied in 140 other Italian cities, as well as elsewhere in Europe. The children are learning at least a few reasons to be proud of their city. "Our generation has been useless," she said.

"We have to aim at the young people through our cultural heritage."

Working just as hard is Antonio Bassolino, the city's undaunted mayor. "We have to go patiently," he told me in his palatial office, "day by day, step by step, one thing after another. The thing that counts is the patience and the obstinacy to keep working, every day." Then, half-smiling, he showed me his good-luck charms—a hunchback on a letter opener, a box of stationery decorated with coral "horns." Hard work can take you only so far, he seemed to suggest; after that, you can only hope that luck will kick in. Last November, it did: He was triumphantly reelected to a second term.

I WAS TALKING ONE DAY with a Neapolitan athlete named Davide Tizzano, who won a gold medal at the Atlanta Olympics in rowing double sculls. When I asked his thoughts about Naples, his face registered the usual mix of diffidence and hopefulness. "I hope this window you're opening on Naples will be different," he began. "No," he quickly corrected himself, "I hope it will be the truth."

But what could that mean, in a city where the possible and the probable are constantly at war? Where a vast reserve of talent and energy appears doomed to remain largely untapped because it seems that other people's rules will never work here? There is the active voice: "The Neapolitans will sacrifice everything if they know there will be a result," one woman said. And there is the passive voice: "*Metti il somaro dove vuole il padrone*," the saying goes: "Just put the donkey where the boss wants it."

Neapolitans don't bother to try to reconcile these contradictions. "With all the city's problems, the ties are too strong," said Enzo, the Falcon. "I wanted to raise my family elsewhere. I lived in Milan for eight years. But the ties were too strong."

All those millions who have had to leave, the generations of Neapolitans who emigrated to find work—in America, in northern Europe, in the factories of northern Italy—may learn how to stop at red lights. But their souls can't seem to find peace beyond sight of Vesuvius's looming presence. If the heart of Naples is its music, the heart of its music is an unfathomable yearning for its own place and its own people.

I felt this one evening, sitting by the grand piano in a spacious third-floor apartment just behind the Piazza del Plebiscito. The living room was full of people, crowded onto divans and motley chairs. The hostess, Bruna Gaeta Catalano, was an irrepressible 76-year-old woman with black hair and glowing dark eyes. She spoke in a vibrant voice with swooping, dramatic phrases; it made even her most mundane comment seem strangely thrilling. And in about eight seconds she had made me feel like some long-lost daughter who had miraculously returned: She flattered me, she held my hand, she gazed at me intently with kindness and fascination. For all her theatricality, she seemed startlingly sincere. In a word, Neapolitan.

MEDITERRANEAN LIGHT *seldom graces Via Pasquale Scura, a shadowy world cloistered by church, home, and tiny shops. On such streets across Naples, kids play, adults conspire, motorbikes whine, and so inhabitants endure in a tough old city with a gleam in its eye.*

Bruna is the daughter of E. A. Mario, one of Naples', and Italy's, most important composers, especially of songs in the Neapolitan dialect. As the keeper of his flame, Bruna has a seemingly infinite number of friends. This musical evening was the special request of a particularly elderly one. Bruna sat down authoritatively at the piano. Her daughter, Delia, stood nearby, ready to sing.

Delia's voice was dark and not highly trained, but she felt the songs deeply. The words were in Neapolitan, which in itself is almost a song. They were melodic, powerful evocations of loneliness, longing, despair; the core of the Neapolitan soul torn from its beloved Naples: "The Song of the Emigrant" and songs of tragic love—a drunken man stands beneath a window, serenading the woman he loves. At the end of his song he discovers that she's dead.

The white curtains fluttered in the evening breeze and the traffic below growled and honked. It felt like a reunion, the family of Neapolitans bound together by the music and by something no foreigner could touch. □

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THE RISE OF LIFE ON EARTH

Looking like a planet adrift in space, a tiny ball of carbon holds a world of meaning: Nestled in a cavity etched from 3.86-billion-year-old rock (colored here for contrast), it may be the oldest evidence of life on Earth. The specimen, found on what is now an island off Greenland, has lost all anatomical features, yet scientists believe its biochemistry was similar to that of every life-form that has evolved since.

MAGNIFIED 6,360 TIMES; STEPHEN J. MOJZSIS, UCLA

A scattering of stardust

Slamming to Earth some 50,000 years ago, a chunk of iron and nickel left a scar more than three-quarters of a mile wide—Arizona's Meteor Crater. Such collisions rarely occur now, but for hundreds of millions of years after the accretion of the planet 4.5 billion years ago debris bombarded its surface.

The largest objects may have vaporized oceans as they hit. Smaller ones could have survived impact, bringing with them organic material formed at the birth of the solar system.

Today a constant rain of microscopic interplanetary dust particles (above) delivers the same kind of compounds, which almost surely contributed to the primordial soup and the living things that arose from it.

(LEFT) D. DON BROWNLEE, UNIVERSITY OF WASHINGTON (ABOVE) ADRIEL HEISEY

By RICHARD MONASTERSKY
Photographs by O. LOUIS MAZZATENTA

HUNDREDS OF FEET above the Yellowstone River, Anna-Louise Reysenbach and I bound down the side of a ravine, our legs plunging knee-deep into the snow. Near the bottom of the gorge we leave winter behind and step into a steamy volcanic landscape.

The snow disappears and the ground feels warm, even through my insulated boots and two layers of wool socks. Along the riverbank a dozen steam vents hiss and roar like dragons. Trails of foul vapor rise into the gray sky, thickening the air with a rotten-egg stench.

Reysenbach, a microbial biologist at Rutgers University, holds up a wrist. "See how my bracelet is starting to tarnish? That's how I know there's hydrogen sulfide in this steam. When I work here all day, I get bad headaches."

However unpleasant for humans, this site in Yellowstone National Park is heaven for some unusual forms of life. Reysenbach sticks long tweezers into a pool of 190°F water and plucks out some black muck, which she drops into my hands. Warm and gooey, like well-chewed bubble gum, the dark glob harbors microorganisms adapted to the extreme temperatures. Called thermophiles, or heat lovers, these creatures are living fossils from Earth's earliest days. Along with other new discoveries, the Yellowstone thermophiles are helping scientists unravel how life first took hold on our planet.

RICHARD MONASTERSKY, a writer at *Science News* magazine, has pursued science stories on all seven continents. This is the 18th article that photographer LOU MAZZATENTA, a former senior assistant editor, has contributed to the GEOGRAPHIC. His fascination with life's origins evolved from his keen interest in ancient peoples.

Ever the teacher, Reysenbach uses her tweezers to draw a diagram in the mud. She scrawls three lines representing the main branches on the tree of life, all emanating from a central stalk. One branch holds eukaryotes—organisms made of cells with a nucleus. This is where we humans fit, along with all animals, plants, fungi, and algae. The second major branch is made up of bacteria. The third branch belongs to another group of single-celled organisms known as archaea.

In the bubbling ponds a few feet from the

BILL AND SALLY FLETCHER (ABOVE); ERIK X. TERRY BEVERIDGE, BOB HARRIS, AND ANDREW MOORE, UNIVERSITY OF GUELPH, ONTARIO

diagram, Reysenbach and others have discovered several thermophilic species of bacteria and archaea that can grow only in water hot enough to burn a human. Perfectly at home in their toxic surroundings, the single-celled creatures consume iron, sulfur compounds, and other nasty chemicals in the water. Though new to science, these thermophiles are some of the most primitive organisms known. On the tree of life they occupy lower limbs near

A highlight for scientists last year, comet Hale-Bopp revealed details about its contents: water, ammonia, formaldehyde, and hydrogen cyanide, which can react to form amino acids, the building blocks of proteins necessary for life.

When comets struck the young Earth, it may be that they not only seeded the planet but also sparked reactions critical to the creation of the first organisms. For three billion years life diversified but stayed about the size of the *Streptococcus* bacteria (pink) and archaea (yellow) on the tip of this needle—colored here for clarity.

the center of the diagram, not far from the unknown organism that spawned all three major branches.

"The Yellowstone microbes are the closest relatives to the original ancestor of life we've found so far," says Reysenbach. "And the interesting thing is that all the branches close to this original ancestor live in places with high temperatures."

That fact leads some scientists to suspect that life got its start in a scalding environment about four billion years ago, perhaps around volcanic hot springs on the ocean bottom. Those deep-sea geysers spew out superheated fluids laden with metals and with energy-rich compounds that can power some of the chemical reactions thought critical for evolving life. According to this idea, seafloor springs simmered the sterile primordial ocean, causing chemicals to join together in myriad ways to create totally new molecules. Over thousands or perhaps millions of years, those chemical kitchens cooked up the greatest dish ever prepared: life itself.

The father of prebiotic chemistry

Approximating conditions on the early Earth in a 1952 experiment, Stanley Miller—now at the University of California at San Diego—produced amino acids. "Once you get the equipment together it's very simple," he says.

The microscopic thermophiles warming my hands hark back to that distant time known as the Precambrian. Geologists like to think of Earth's history as a book, with the Precambrian the first and by far the longest chapter, taking up 88 percent of geologic time. This rambling prelude runs from the birth of the planet 4.5 billion years ago to the explosive evolution of animal life in the Cambrian period, a little over half a billion years ago.

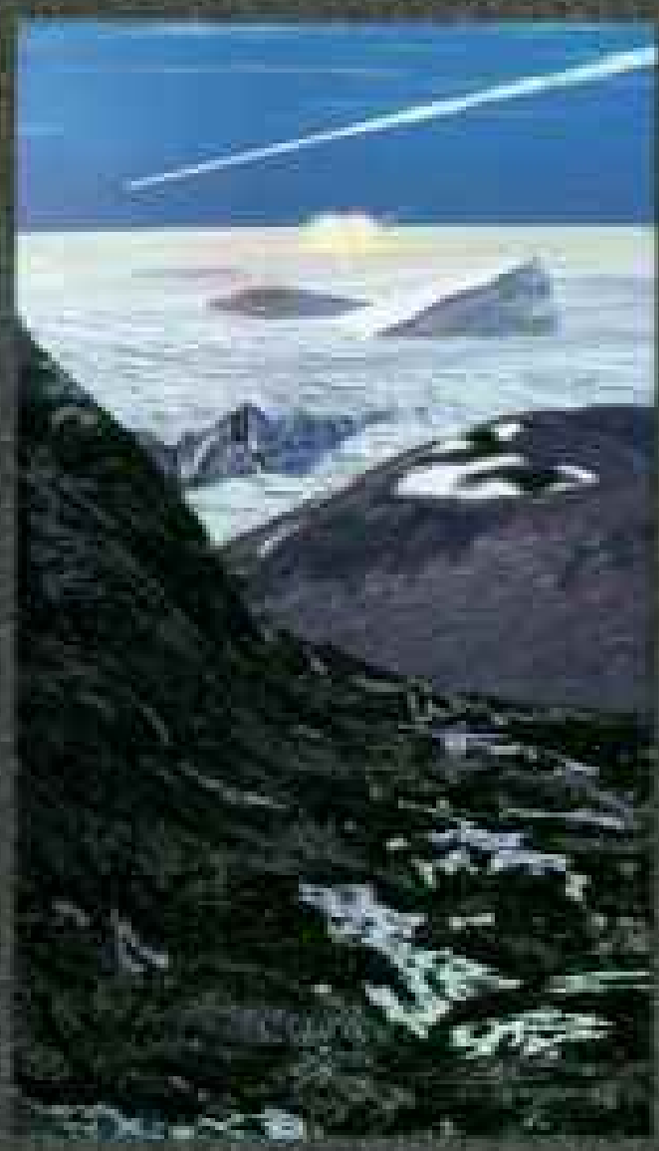
Coming long before humans, dinosaurs, or even snails entered Earth's story, the Precambrian can be called the age of microscopic life. Although the characters in this chapter were minuscule—billions could fit in a drop of water—they paved the way for all later organisms. They developed DNA and proteins, the basic molecules that sustain all living cells. They devised ways of harnessing sunlight to produce food. They gave rise to the oxygen we need to survive. They even invented sex.

THOUGH THE STORY of the Precambrian is carved in stone, geologic vandalism has torn out some of the best passages. Rain, that most powerful of natural forces, has eroded away almost every scrap of rock older than 3.5 billion years.

To reconstruct some of the missing events, Stanley Miller models one possible version of an infant Earth in his laboratory at the University of California at San Diego. Now semi-retired after a long career as a research chemist, Miller rocketed to scientific stardom almost 50 years ago with the first of these groundbreaking experiments, which simulate conditions on Earth before life arose.

A thin, balding man with large glasses and a grandfatherly demeanor, Miller ushers me toward an archaic-looking network of glass flasks and tubing. He turns out the lights and switches on a device that resembles an electric toothbrush—except that this machine generates 100,000 volts *(Continued on page 68)*

What kind of place was PRIMORDIAL EARTH?



FREEZING?

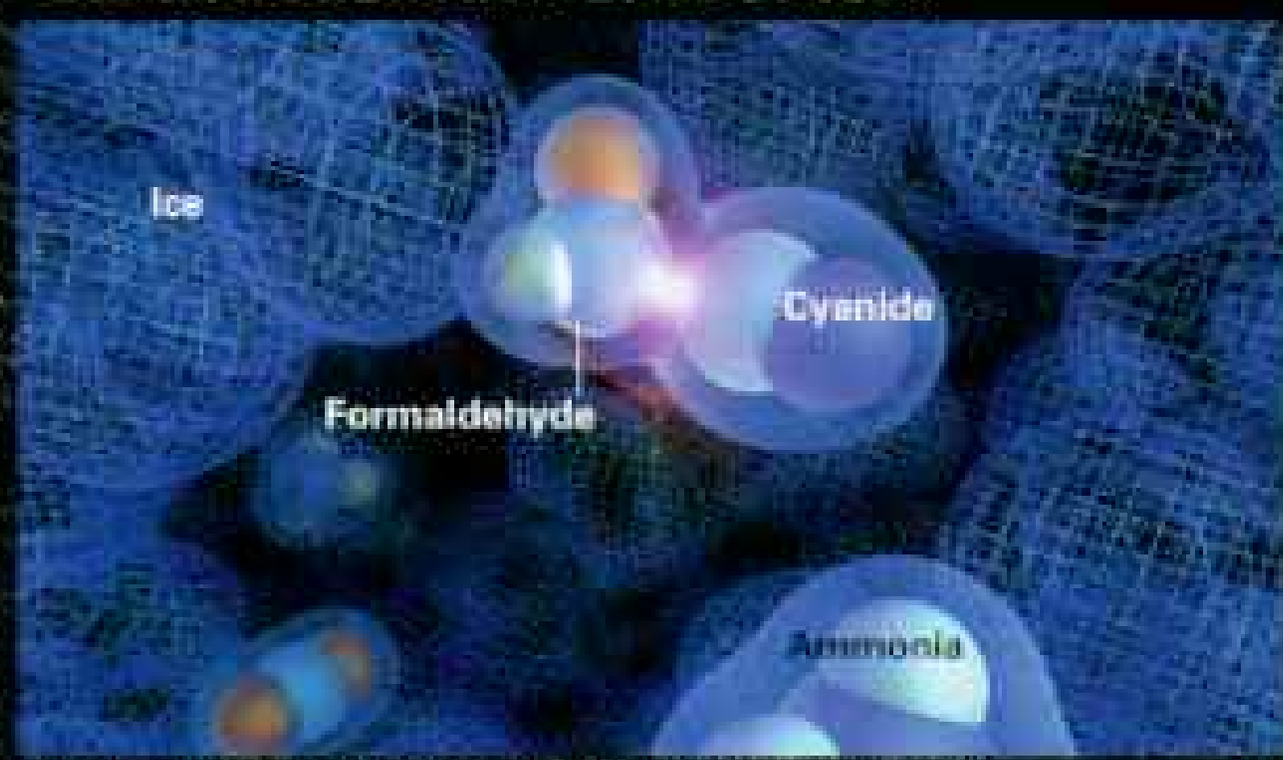
TEMPERATE?

STEAMY?

Four billion years ago. The young sun shone with only 70 percent of its present power. The atmosphere held no free oxygen. There were few sounds beyond the wind, the hiss of lava hitting water, the boom of meteorites. No plants, no animals, no bacteria, no viruses. From that starting point scientific opinion varies widely: No one knows exactly what Earth was like when life began. Rocks that may have held clues were deformed long ago by the movements of the crust. The following pages offer three possibilities for the cradle of life, reflecting the latest views of prominent scientists. Whatever the circumstances, they produced a momentous chain of events.

"Organic compounds organized themselves into something that was self-replicating," says Stanley Miller. "Once that happens, away you go. You've got Darwinian evolution."

DID LIFE BEGIN IN A BALL OF ICE?



1,000 feet of ice

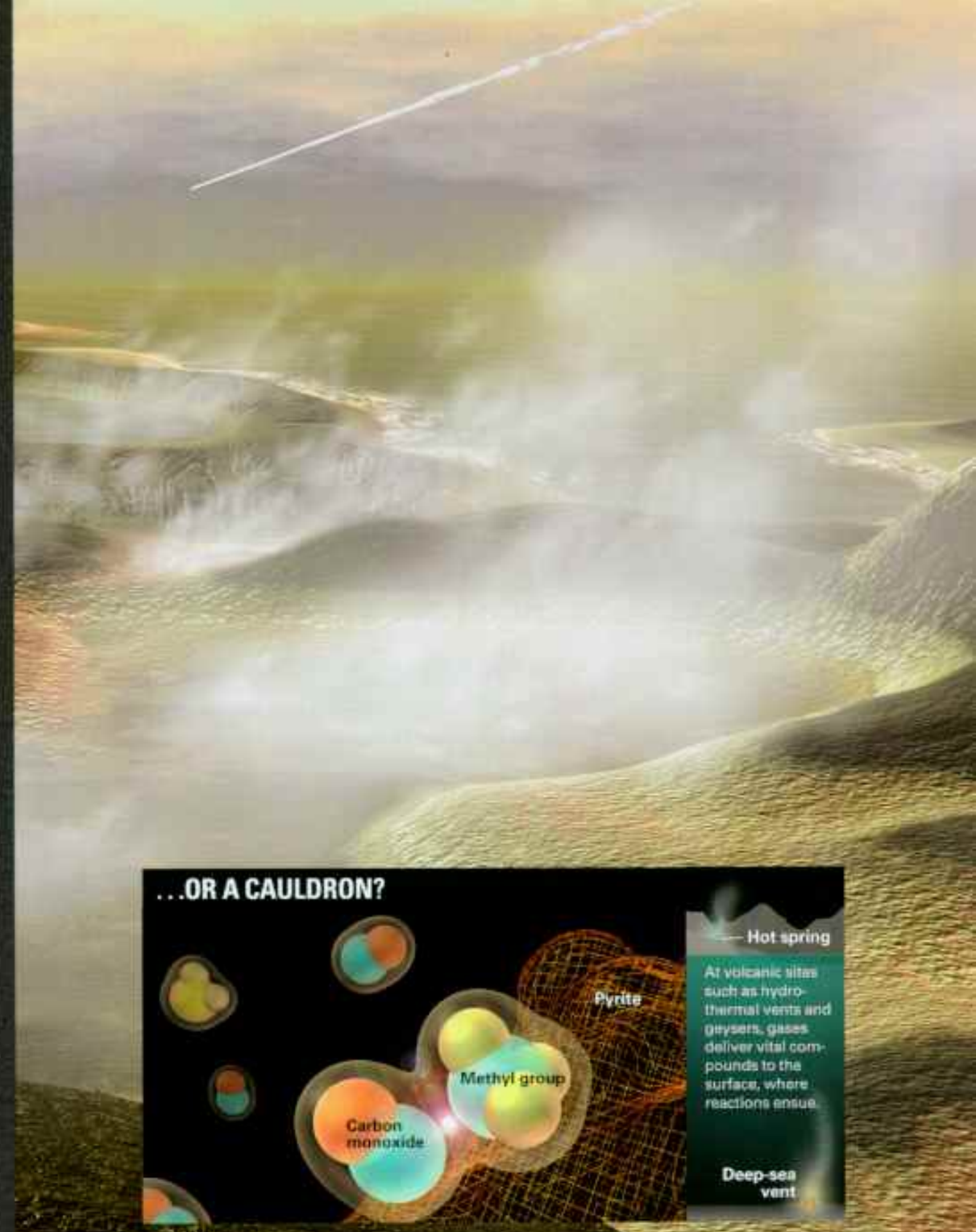
Ice caps the ocean and shields it from UV light. At the base of the ice, pockets of water bring organic compounds together for possible reaction.

Deep-sea vent

LANDSCAPES BY JONATHAN HERBERT; CHEMICAL REACTIONS BY KEN EWARD

Although many scientists believe carbon dioxide in the atmosphere kept the world warm, some envision a global winter. "I say, 'Let it freeze,'" says Jeffrey Bada, a biogeochemist at Scripps Institution of Oceanography in La Jolla, California. "The colder the temperature, the more stable the compounds." Interplanetary debris, hydrothermal vents, and atmospheric reactions could have provided compounds such as formaldehyde, cyanide, and ammonia. These then combine in water within a lattice of ice (above), a process that results in an amino acid called glycine. A huge meteorite impact ultimately could have thawed this frozen world.

Charles Darwin and his contemporaries imagined life evolving in a small body of water, perhaps a pond, an idea still viable today. "Runoff collected in a small volume is the most likely means of achieving the necessary concentration of ingredients," says Gustaf Arrhenius, a geochemist at Scripps Institution of Oceanography. The pond may have further concentrated compounds on the internal surfaces of sheet-like minerals, which attract certain molecules and act as a catalyst in the subsequent reactions. Two aldehyde phosphate molecules thus united (above) form a sugar phosphate, a possible precursor to RNA.



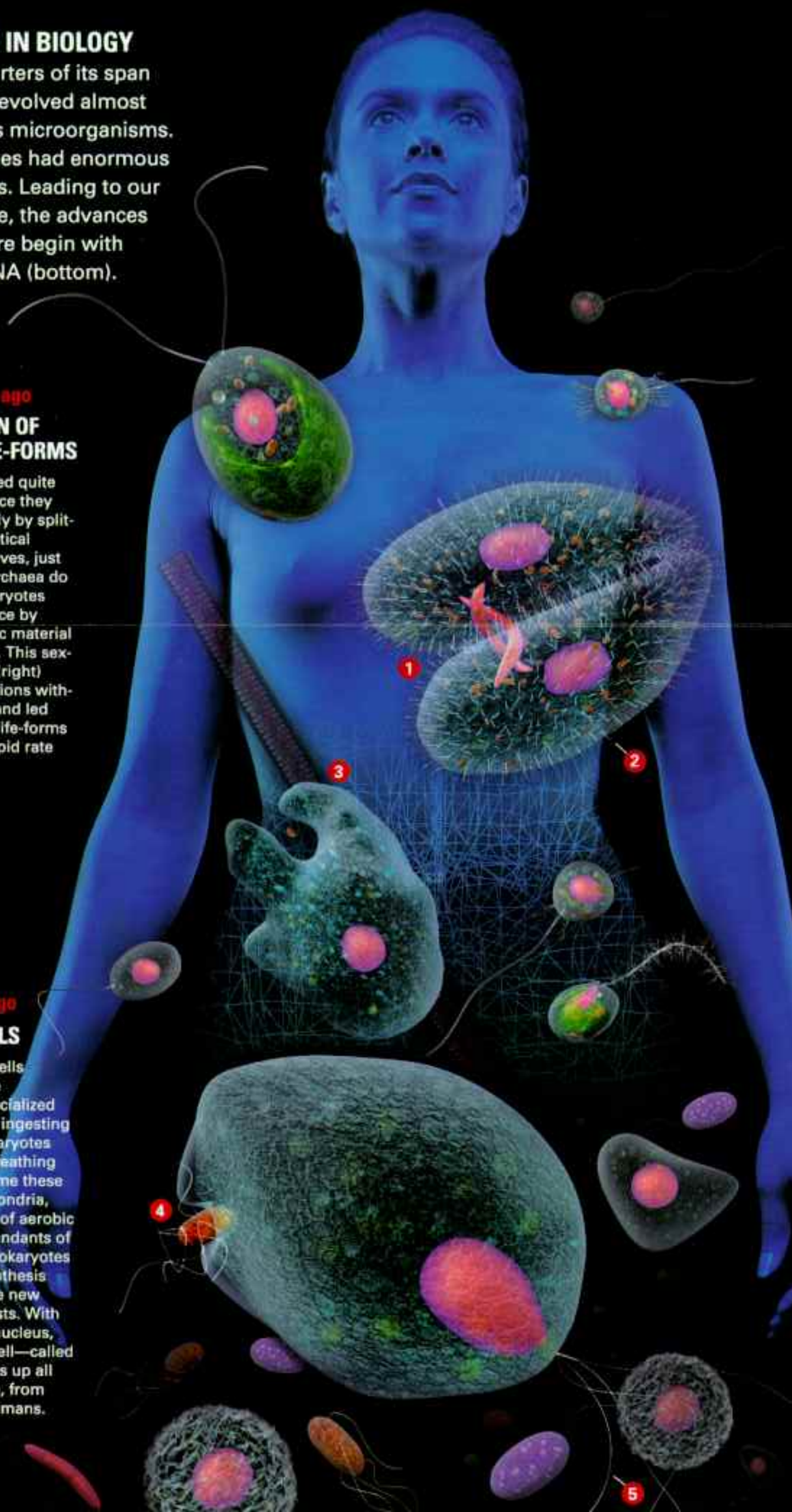
After accretion Earth may have been a fiery orb of magma. Even when it became somewhat cooler, the atmosphere would have shimmered with heat when life began. "It was volcanic everywhere," says Günter Wächtershäuser, a chemist in Munich, Germany. "Gases released from the molten magma would have been constantly seeping from the surface, leaching out vital compounds." Resting on a stabilizing surface of pyrite, carbon monoxide and a methyl group combine (above), one step in the formation of activated acetic acid, a crucial chemical for synthesizing other organic compounds.

OUR MICROBIAL ORIGINS

BIG EVENTS IN BIOLOGY

For three-quarters of its span on Earth, life evolved almost exclusively as microorganisms. Yet the changes had enormous consequences. Leading to our own existence, the advances presented here begin with primordial RNA (bottom).

ART BY KEN EWARD



1.2 billion years ago

AN EXPLOSION OF COMPLEX LIFE-FORMS

Eukaryotes evolved quite slowly at first, since they reproduced merely by splitting into two identical copies of themselves, just as bacteria and archaea do today. Later, eukaryotes began to reproduce by combining genetic material from two parents. This sexual reproduction (right) accelerated variations within the gene pool and led to a profusion of life-forms and a far more rapid rate of evolution.

2 billion years ago

COMPLEX CELLS

Over time some cells evolved into large assemblies of specialized parts, perhaps by ingesting free-floating prokaryotes (right). Oxygen-breathing prokaryotes became these new cells' mitochondria, the powerhouses of aerobic respiration. Descendants of photosynthetic prokaryotes carry on photosynthesis inside some of the new cells as chloroplasts. With its gene-bearing nucleus, this new kind of cell—called eukaryotic—makes up all other forms of life, from slime molds to humans.

A LIVING LEGACY

Many early cell structures and processes seem to have endured in a variety of evolutionary lines, including our own. The examples below pair a single-cell organism with a human feature that has inherited the same mechanism.

1 SEXUAL REPRODUCTION

Two specialized reproductive cells called gametes of the alga *Chlamydomonas reinhardtii* mate (above left), forming a unique individual with a mixture of genetic material from both parents. In strikingly similar fashion, a human sperm fertilizes an egg.

CHLAMYDOMONAS: 1,000 X, URSULA GOODENOUGH
SPERM AND EGG: 820 X, DAVID M. PHILLIPS, PHOTO RESEARCHERS

2 CILIA

A fringe of tiny oars, the cilia that cover a paramecium row it around to find food (above left). The rowing motion of similar structures that line the entire human respiratory tract, especially the bronchial tubes, sweeps out mucus and the foreign material caught in it.

PARAMECIUM: 1,500 X, KARL AUFDERHEIDE, VISUALS UNLIMITED
HUMAN CILIA: 700 X, LENNART NILSSON, ALBERT BONNIERS FÖRLAG

3 ENGULFING OTHER CELLS

An amoeba eats by surrounding its meal with a pseudopod, or false foot (above left), which forms as cytoplasm streams in the required direction. Fighting infection, an amoeba-like white blood cell sends out its own pseudopod to isolate a harmful bacterium, a process called phagocytosis.

AMOEBA: 100 X, M. ABBEY, VISUALS UNLIMITED
PHAGOCYTOSIS: 170 X, LENNART NILSSON, ALBERT BONNIERS FÖRLAG

3.9 billion years ago

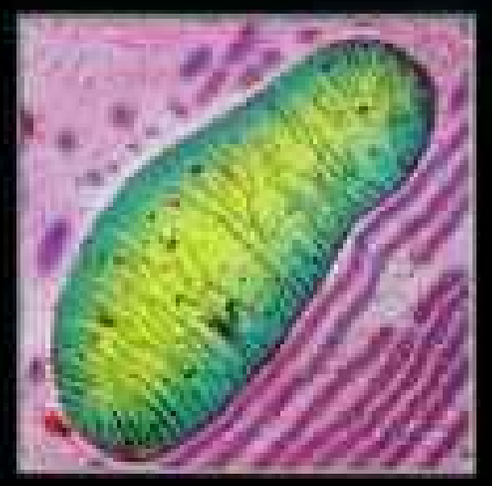
SIMPLE CELLS

How RNA came to be remains a mystery. The first real cells probably looked much like modern prokaryotes—bacteria and the newly designated archaea usually found in extreme conditions. Both ancient and modern prokaryotes have no nucleus and contain little more than genetic material and ribosomes in a jellylike cytoplasm. From their pill-shaped beginnings (right), prokaryotes have evolved a diversity of forms.

4 billion years ago

PRIMORDIAL RNA

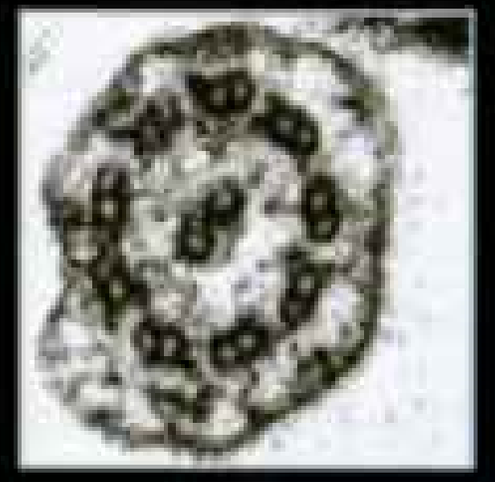
As organic molecules became ever more complex, they formed RNA molecules (right). Scientists believe these early RNA molecules were capable of replicating themselves, mutating, and undergoing natural selection. In modern cells RNA has given up to DNA the lead role for passing along genetic information, although RNA still plays a vital role by transmitting information to the ribosomes, where cells produce their proteins.



4 MITOCHONDRIA

Primitive eukaryotes probably acquired mitochondria by engulfing purple bacteria. Today almost all eukaryotic cells need mitochondria to survive. Though the body in *Reclinomonas americana* (above left) looks different from that in a human pancreas cell, it has the same purpose: burning fuel.

RECLINOMONAS: 30,000 X, D.H. HOPCROFT, R.J. BENNETT, C.J. O'KELLY
PANCREAS CELL: 11,000 X, K.R. PORTER, PHOTO RESEARCHERS



5 FLAGELLA

A long tail whips a human sperm cell along with amazing speed (above right). Other eukaryotic cells also have flagella, all with a similar internal structure. A cross section of a flagellum of the protozoan *Reclinomonas americana* displays that structure as one pair of microtubules surrounded by nine others.

CROSS SECTION: 90,000 X, D.H. HOPCROFT, R.J. BENNETT, C.J. O'KELLY
SPERM: 1,500 X, LENNART NILSSON, ALBERT BONNIERS FÖRLAG

(Continued from page 60) at its glowing tip.

"Although it has a very high voltage, it puts out next to no amps, so you can touch it," Miller says unconvincingly. He makes no move to demonstrate with his finger. My own hands have hidden themselves deep in my pockets.

When Miller touches the humming instrument to an electrode on one of the flasks, a bolt of purple lightning sizzles inside, conjuring up images of *The Bride of Frankenstein.*

Miller dreamed up this electrifying experiment back in 1952. To represent what he supposed was in the primeval atmosphere, he filled a glass flask with methane (natural gas), hydrogen, and ammonia. In a lower flask he placed a little pool of water as a stand-in for the early ocean. The electric shock mimicked the effects of lightning. By sparking the atmosphere, Miller hoped to generate new chemicals that would rain into the tiny ocean and react to form something interesting.

He got more than he bargained for. "I turned on the experiment one night at 10 p.m. Then I came back the next morning, and the water inside the flask had turned yellow. I knew I had something," Miller recalls.

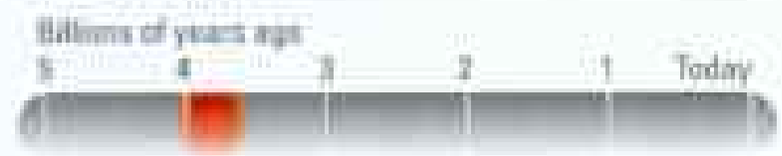
What he had was a rich broth of amino acids, used by all known creatures as the building blocks for proteins. Miller's experiment showed how easy it was to create these prime ingredients of life. All it took was an ocean, an atmosphere, and a little lightning.

Many scientists now suspect that the early atmosphere was different from what Miller first supposed. They think it consisted of carbon dioxide and nitrogen rather than hydrogen, methane, and ammonia.

That's bad news for chemists. When they try sparking carbon dioxide and nitrogen, they get a paltry amount of organic molecules—the equivalent of dissolving a drop of food coloring in a swimming pool of water. Scientists find it hard to imagine life emerging from such a diluted soup.

One solution to this problem could come from outer space. Asteroids, comets, meteorites, and even specks of interplanetary dust carry organic molecules, including amino acids or the ingredients necessary to produce them. Those extraterrestrial objects may have helped season Earth's primordial soup with enough critical chemicals to permit the first stirrings of life.

Life begins to self-assemble



Leafy veins of RNA, replicating in a colorized modern cell, follow the genetic plan supplied by the central strand of DNA. Primordial life, however, likely had no DNA. It may have relied instead on RNA with a genetic plan that enabled it to live and replicate by itself.

To understand how that RNA might have functioned, Gerald Joyce of the Scripps Research Institute is trying to create a strain similar to what once existed. Beneath a display of its nucleotide structure, a batch of evolving RNA glows in ultraviolet light—a sign that it is ready for the experiment's next stage. "Our aim is life in a test tube," says Joyce. "A molecular kind of life, nothing squishy."

DAVID C. MCCLELLAND, PHOTO RESEARCHERS (IMAGE LEFT)

To witness life in the making, I leave Miller's office and take a short drive along San Diego's coastal bluffs, home of the Scripps Research Institute. There, in a sterile white laboratory buzzing with students and whirring machines, a young biochemist named Gerald Joyce is attempting to manufacture life in a test tube.

Before Joyce shows off his experiments, I ask him a question that has been bothering me: "What does it mean to be alive?"

Dressed casually in khaki pants and looking no older than his students, Joyce gets antsy as he tries to respond. "You can't put forward a firm scientific definition of life. It's a term that really only has popular meaning."

Although scientists have offered many definitions of life, all fall short at some level. Some are so broad they encompass nonliving entities, such as fire or mineral crystals. Others are so narrow they disqualify mules, which are sterile. Joyce favors the definition of life as "a self-sustained chemical system capable of undergoing Darwinian evolution."

The last element—Darwinian evolution—is shorthand for a three-step process. First, a group of individuals have to be able to reproduce by making copies of themselves. Second, the copies must contain inheritable imperfections, or mutations, that introduce variation into the population. Last, there has to be a system of natural selection that favors the survival of some individuals over others.

As complicated as this sounds, Joyce and other scientists have managed to mimic Darwinian evolution in the laboratory. Joyce leads me through a vaultlike door into a sweltering room kept at 98.6°F—the temperature of the human body. He picks up a tiny test tube holding a drop of clear liquid. Inside that drop are a trillion molecules of RNA.

In modern cells DNA is the star that stores genetic information. RNA plays a supporting role: It copies the instructions from DNA and ferries them to the chemical factories that produce proteins, the workhorses of the cell.

The RNA molecules Joyce holds are special because they are evolving in his hands. By replicating, mutating, and undergoing natural selection, they are the closest scientists have come to creating life in the lab.

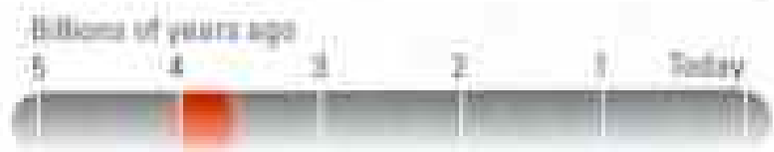
These RNA molecules aren't truly alive because they don't entirely control their own replication. Someday soon, though, Joyce and his colleagues hope to find a piece of RNA that can copy itself without any help.

Molecular biologists are spending so much time studying RNA because they believe its roots reach back close to the dawn of life. "If you look at what RNA is doing today," says Joyce, "it's involved in fundamental, ancient processes in the cell."

Before DNA and proteins evolved, before even the simplest bacteria appeared, life may have consisted solely of RNA molecules floating in the sea, replicating, mutating, and undergoing natural selection on their own. As DNA and proteins evolved, these more specialized molecules took over most of the critical work from RNA. At some unknown point life found a home inside a protective membrane, forming the very first cells. From these cells arose the three main branches of life—bacteria, archaea, and eukaryotes.

Like most aspects of Earth's earliest history, the timing of these events remains shrouded in mystery. For many years scientists thought that life couldn't have developed until large comets

Cells take form



"I imagine the start of life being a rather fragile thing requiring a benign environment," says David Deamer, a biophysicist at the University of California at Santa Cruz. "An ordinary tide pool, for instance." There, in the same way that mixing water with fatty molecules called lipids creates curling tubes in a lab (right), waves could have mixed water and lipidlike organic compounds to form cell-size versions of bubbles on a beach.

Deamer has found that under tide-pool conditions organic compounds from a meteorite plump up as capsules. Similar substances may have formed the first cells by encasing self-replicating molecules within membranes.

NIK S. WETTER ARMSTRONG AND DAVID DEAMER, UNIVERSITY OF CALIFORNIA

and meteorites stopped pummeling the planet about 3.8 billion years ago. Before then, conditions were thought to be too hellish to permit the evolution of fragile cells.

But some scientists now think that life didn't wait for the shelling to stop. According to Stephen J. Mojzsis of the University of California at Los Angeles, Earth's oldest sedimentary rocks, from southwestern Greenland, contain chemical fingerprints of complex cells at least 3.86 billion years old. If so, the first quickening of life must have happened millions of years before that, perhaps between the blasts of the cosmic fusillade.

Those missiles from space may, in fact, have played a central role in the origin of life. A few scientists suspect that bacterium-like cells evolved first on another planet and then journeyed to Earth on an asteroid.

Evidence supporting this outlandish theory lies inside a potato-size meteorite labeled ALH84001, which contains possible signs of life on Mars. Originally a piece of the Martian crust, ALH84001 was blasted into space 16 million years ago when a large asteroid slammed into Mars. The rock sailed on a roundabout journey through the inner solar system until it landed in Antarctica 13,000 years ago.

When meteorite experts studied ALH84001, they found tiny rods similar in shape to fossilized bacteria, suggesting that microbes may once have thrived deep inside the Martian crust. The debate over these potential Martian fossils will likely rage until NASA sends a probe to the red planet and brings back samples of the crust—a mission planned for 2005. If scientists can prove that microbes once populated Mars, then it's conceivable that life originated there and inadvertently journeyed to Earth on shards of flying debris.

WHETHER LIFE BEGAN on Earth, Mars, or somewhere even more distant, it probably had spread across our planet by the time of the Greenland rocks. Scientists will never know, however, what those early organisms looked like because the oldest sedimentary rocks hold no recognizable fossils.

The Greenland deposits and others nearly as

old are frustratingly vague because they were smashed by colliding continents and buried deep underground. The intense pressure and heat destroyed all fossils. Paleontologists call these rocks fubaritic—a term that stands for "fouled up beyond all recognition," says UCLA paleobiologist J. William Schopf.

A bespectacled man never far from his pipe, Schopf has spent much of his life searching for Precambrian fossils. In 1992 he unveiled his most impressive find—3.46-billion-year-old microfossils from the Apex chert, a remote rock formation in northwestern Australia. Drawing quietly on his pipe, Schopf describes their dilapidated state. "The material is by far the most difficult I've ever worked on. The fossils are so exceedingly old that they've been charred to black bits and pieces."

To find these microfossils, Schopf spent four months staring down the barrel of a microscope. On a typical day he would examine the rock for ten hours and find only one object recognizable as a fossil. With such a low success rate, he grew so familiar with individual fossils that he named them as if they were pets.

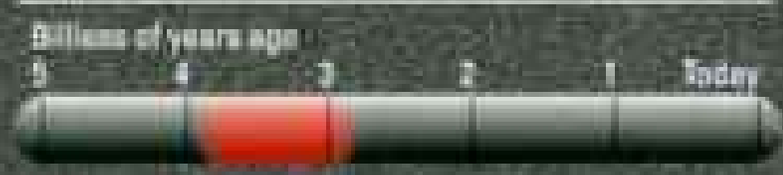
"This is a really nice one," Schopf says, pointing to a filament that looks like a segmented worm, except 20,000 times smaller. "I named it Willie after the jockey Willie Shoemaker, because it's very tiny."

Some of the Apex fossils seem spitting images of cyanobacteria, a type of bacterium found in pond scum. One of the hardiest forms of life today, cyanobacteria—formerly called blue-green algae—can inhabit environments that other organisms find unattractive, from the driest deserts to the Antarctic ice sheet to the cooling tanks of nuclear reactors.

A special attribute of cyanobacteria is their ability to use sunlight to convert carbon dioxide into energy-rich sugar, generating oxygen as a waste product. Such photosynthesizers anchor the food chain, providing sustenance for all higher organisms.

Because cyanobacterial photosynthesis is such a complex process, Schopf was surprised to find evidence that the oldest known microbes had already developed this advanced ability. "Before this discovery the assumption was that life got started and limped along for

Global gas warfare



Survivors of the first living communities, stromatolite reefs still flourish in Shark Bay, Australia, as they did throughout the globe 3.5 billion years ago. Taking up the top few inches, a velvety microbial mat grows in fine layers that include a crown of oxygen-producing photosynthetic cyanobacteria, a middle section of bacteria that can tolerate some oxygen and sunlight, and, at the bottom, bacteria that thrive only in the absence of oxygen and sunlight.

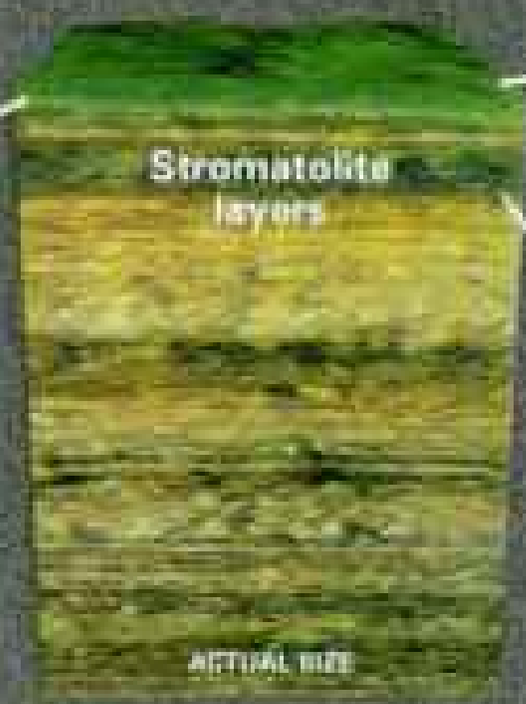
Sediments trapped in the mat bind with calcium carbonate from the water, constantly building up the solid rock base. To gain access to sunlight—and to keep from getting cemented in—the organisms move upward through the sediments.

Such communities are now rare. They survive in Shark Bay perhaps because the hypersaline water keeps out predators.

Evolving in an oxygen-free atmosphere, the first photosynthetic bacteria consumed and gave off other gases. Then mutant offspring began to produce oxygen, poisoning the parents. As the air became richer in oxygen, the offspring took over the surface; the parents retreated.

Where light is plentiful, oxygen-producing photosynthetic cyanobacteria coexist with oxygen-dependent microbes.

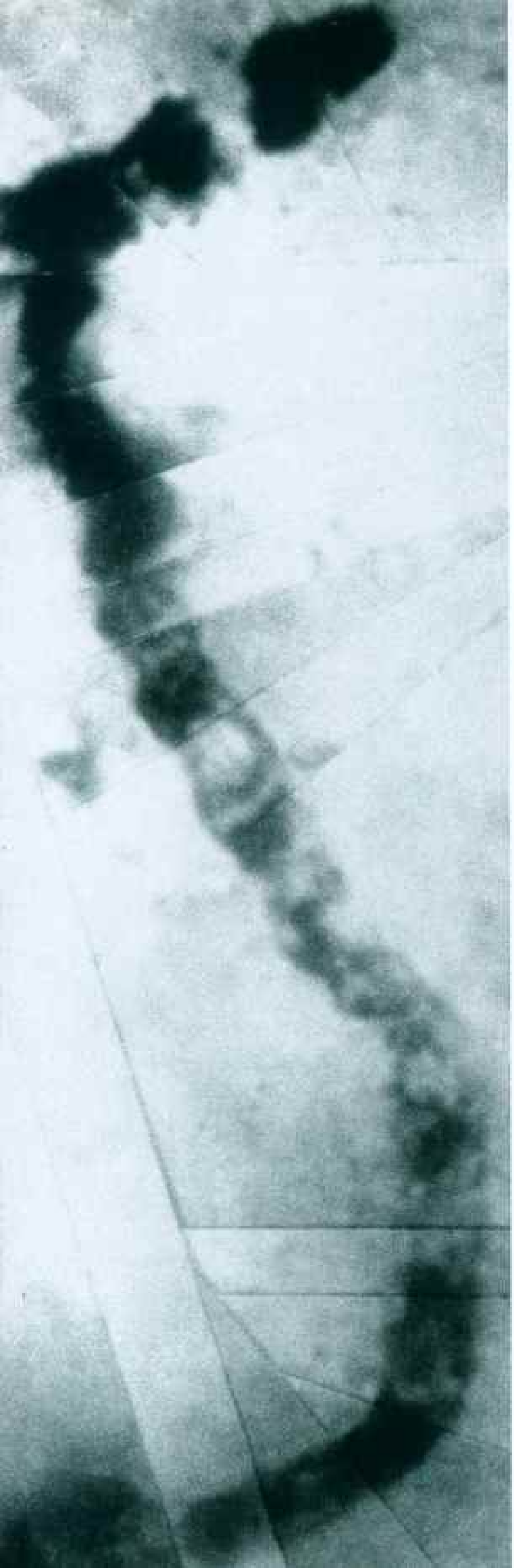
These microbes use oxygen that seeps from the surface or, when it is unavailable, switch to fermentation.



In the absence of oxygen, the only microbes that survive are those powered by fermentation.

A menagerie of species makes up a stromatolite. One square foot may contain half a billion individuals linked by symbiotic relationships that hold the community together. Microscopic views (left) show organisms under conditions at different levels.

ART BY KEN EWARD



eons before more complicated things evolved," says Schopf. "This deposit tells you that life evolved very far, very fast, very early."

AT THE TIME of the Apex fossils 3.46 billion years ago, Earth would have been almost completely unrecognizable to modern eyes. The planet was spinning so much faster back then that each day lasted less than 18 hours. A pale young sun hung in the sky, its glow noticeably dimmer than the more mature star we see today.

There were no continents, just archipelagoes of volcanic rock jutting above the waves. There were no buzzing insects, no rustling leaves, little but the sound of rumbling volcanoes and the wind screaming over barren peaks. Strange shapes—some as big as cars—littered the beaches and shallow water. Called stromatolites, these immobile objects could have passed for ordinary boulders, but they were actually alive with microbes; they were the most abundant form of life during the Precambrian.

Stromatolites still survive in such nutrient-poor environments as Lake Clifton, along Australia's southwestern coast. On a cloudy day in late summer I travel to the lake with Linda Moore, an Australian biologist, to see these Precambrian relics up close. The smell of thunderstorms hangs in the air as Moore wades into the warm water, trying not to let her tennis shoes get sucked off by the sludgy bottom. She comes back with a small stromatolite in her hand. I expect it to be as hard as stone, but the greenish brown exterior feels squishy.

"It's dead on the inside," says Moore. "The only living part is the outer surface."

Half dead, half alive, stromatolites represent a partnership between microorganisms and rock. The spongy coating is made of cyanobacterial filaments that secrete a sticky mucus. Grains of sediment get trapped in the mucus and stick together to form a crust of rock. As the filaments grow longer, they trap more sediment and add a new layer to the exterior. What's left on the inside is dead stone.

Amid the domes, I look out over the thousands of stromatolites speckling the shore.

"Standing here is like going back in time," says Moore with an air of nostalgia for the stromatolites' heyday. "They used to dominate, and now they're uncommon. The evolution of higher organisms ended their reign."

When algae and seaweed appeared more than a billion years ago, those faster growing organisms took over the shallow seas from the sedate stromatolites. Some 500 million years later the first animals sealed the stromatolites' fate by grazing on the bacterial filaments.

A replay of that assault is taking place at Lake Clifton today. With increasing development in southwestern Australia, sewage and agricultural runoff are pouring nutrients into the lake. Aggressive algae are now threatening to smother the stromatolites, says Moore, who has campaigned to save them. "Their fate is hanging in the balance," she said, returning the stromatolite to its niche. "If nutrients increase any more in the lake, the stromatolites could die. And once they're gone, they're gone for good. It's almost like watching their decline at the end of the Precambrian all over again."

Though stromatolites are struggling to survive today, during the Precambrian those ruthless bullies shoved aside their fellow microorganisms and took over by poisoning the ocean with oxygen, an extremely toxic gas to other bacteria and archaea. At first those life-forms didn't have to deal with this poison because the atmosphere and ocean held almost no free oxygen. Then cyanobacteria evolved and started waging the world's first case of gas warfare. The oxygen they produced through photosynthesis stunted the growth of other microbes, enabling the newcomers to capture the choicest sites in shallow water with the best exposure to the sun.

Eventually cyanobacteria started filling the atmosphere with oxygen, bequeathing a legacy

(LEFT) J. WILLIAM SCHOPF, UCLA (OPPOSITE); (RIGHT) WALSER, PHOTO RESEARCHERS (ABOVE LEFT)

Early oxygen producers

A collage of microscope images (opposite) reveals a 3.46-billion-year-old fossil from Australia—the oldest yet found. When alive, the now sinuous shadow likely resembled a strand of the photosynthetic cyanobacterium *Oscillatoria* (above left). Colonies of such organisms, growing in spots like this pond in front of Australian paleontologist Jim Gehling, were probably among the first to add oxygen to the air.

that makes our lives possible today. "The gas they produced changed the world," says Lynn Margulis, a biologist at the University of Massachusetts at Amherst.

A restless and combative scientist, Margulis can perhaps sympathize with the Precambrian cyanobacteria: Like those ancient organisms, Margulis mercilessly overturned the established order. She tossed aside standard ideas of evolution and forced biologists to change their views on the history of life.

As the self-appointed ambassador of the microbial world, she has worked tirelessly to improve our understanding of microscopic life-forms, which make up perhaps half the living matter on Earth.

"Most people's concept of nature is the same as my mother's," says Margulis. "There are plants, obviously. And there are animals, obviously. Everything else is a germ."

Tiny organisms don't get enough credit for their accomplishments, she argues. During the Precambrian, bacteria invented photosynthesis and fed the world. They transformed the atmosphere by adding oxygen. And some happened upon a method of dealing with the new poison in the environment by harnessing oxygen's burning power and using it to break down food.

Bacteria that use oxygen are turbocharged, generating energy far more efficiently than their oxygen-hating, or anaerobic, neighbors. While anaerobic bacteria produce only 2 units of energy by fermenting a molecule of sugar, aerobic bacteria use oxygen to squeeze 36 units of energy from the same molecule.

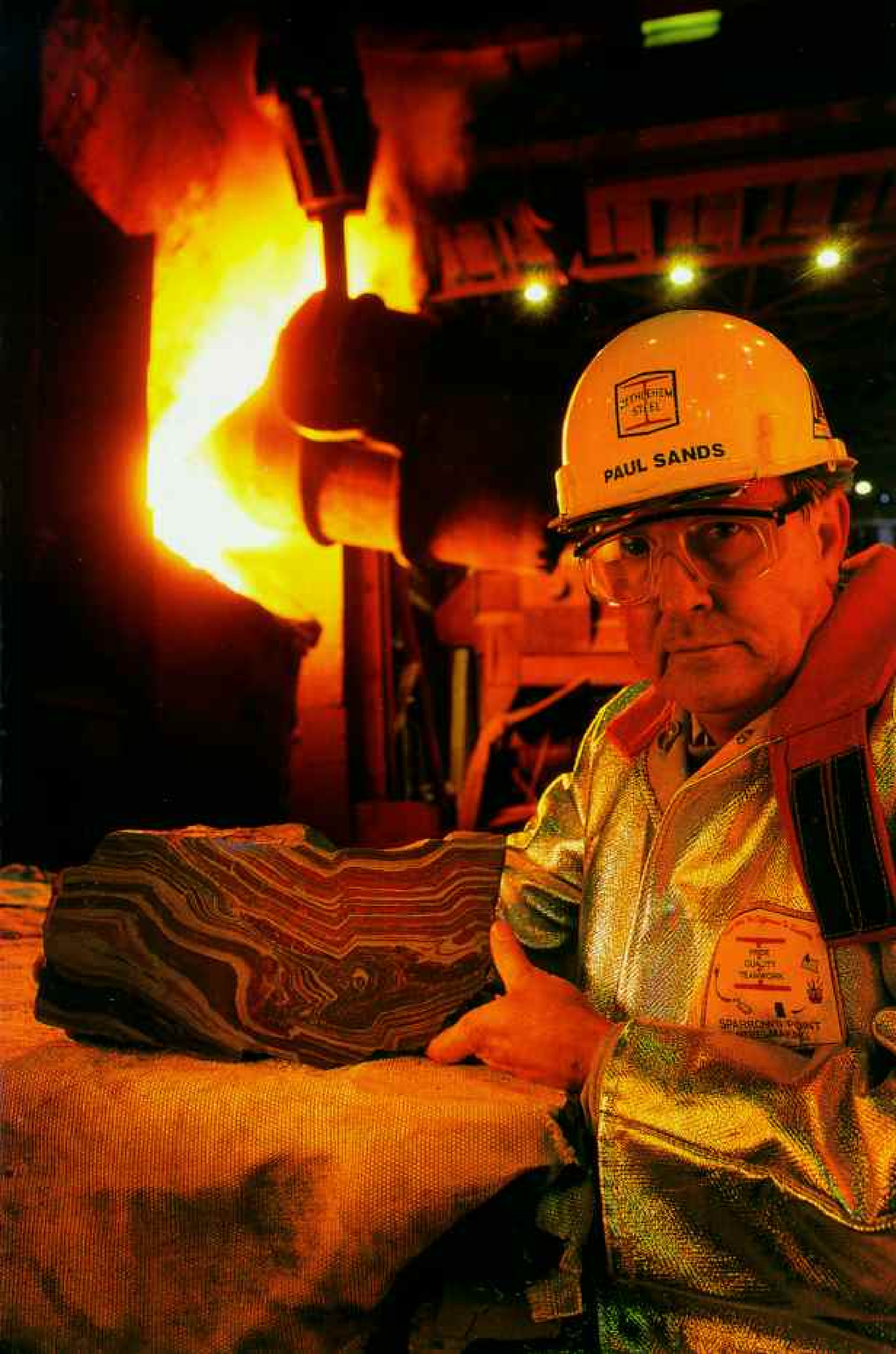
Margulis believes that we carry the descendants of Precambrian bacteria within our own bodies. So do petunias, paramecia, and almost all other eukaryotes. In our cells are tiny power plants called mitochondria, which burn sugar and oxygen to generate energy. Thirty years ago Margulis championed the idea that mitochondria are the remnants of oxygen-breathing bacteria that invaded eukaryotic cells perhaps two billion years ago and have stayed there ever since. That's why we need oxygen. With every breath we feed the descendants of predatory bacteria in our cells.

Plants harbor an additional stowaway. Their photosynthetic ability comes from former cyanobacteria that now reside inside plant cells as sunlight-powered factories called chloroplasts.

GRYPANIA SPIRALIS (ABOVE), BOTH ROCKS FROM THE SMITHSONIAN INSTITUTION

The triumph of oxygen

Why did it take nearly a billion years for oxygen to begin accumulating in the atmosphere? One reason lies at the bottom of the ocean. Seawater once contained dissolved iron. When cyanobacteria took hold, the oxygen they generated reacted with the iron, which precipitated as rust onto the ocean floor. Over millions of years this created deep beds of banded rock. At Bethlehem Steel's Maryland plant, a furnace casting its light on a 2.1-billion-year-old sample from such a deposit helps turn similar iron ore into steel. Our stoves and bridges, it turns out, are made of materials created by bacteria. Eventually all the iron in the oceans was oxidized, and atmospheric oxygen rose sharply, benefiting ever larger organisms like *Grypania* (above), whose fossil spirals in a 2.1-billion-year-old rock.


PAUL SANDS

A new perspective on life

Heated by fires as old as Earth itself, a steaming spring in Yellowstone National Park provides a sample of its inhabitants to Anna-Louise Reysenbach, a microbial biologist at Rutgers University. "It looks like slime now," she says, "but under a microscope it's a forest of organisms."

Such samples usually include archaea as well as bacteria. Very different life forms, they were once classified together. Beginning in the mid-1970s, however, advances in gene sequencing disclosed the great diversity of the microbial world. As a result, the five textbook kingdoms of life—with plants, fungi, and animals at the top, one-celled eukaryotes in the middle, and prokaryotes at the bottom—have been replaced with a tree of three

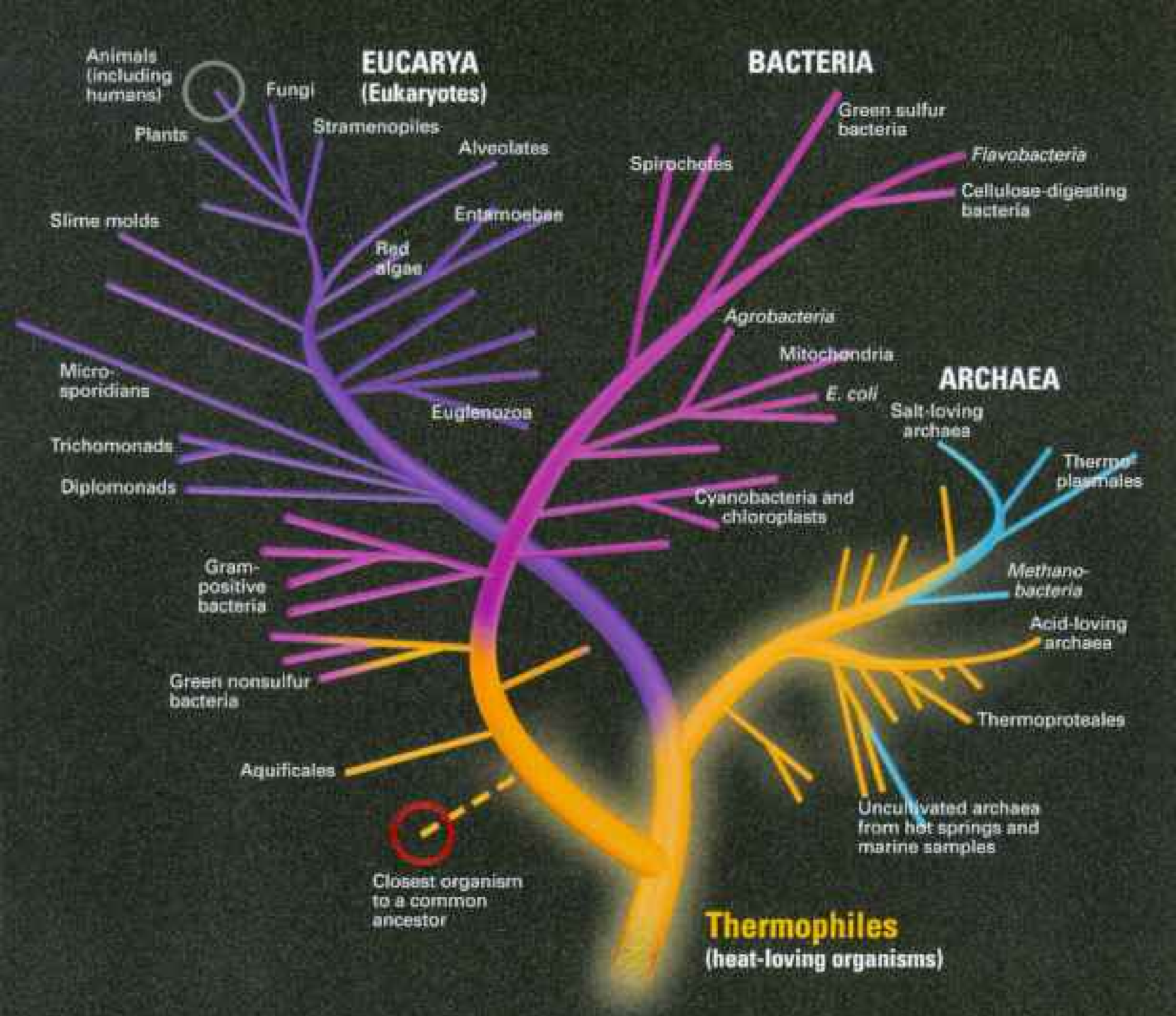
Billions of years ago

2

1.5

Oldest evidence of eukaryotes indicates that cell structure, including a nucleus, has evolved.

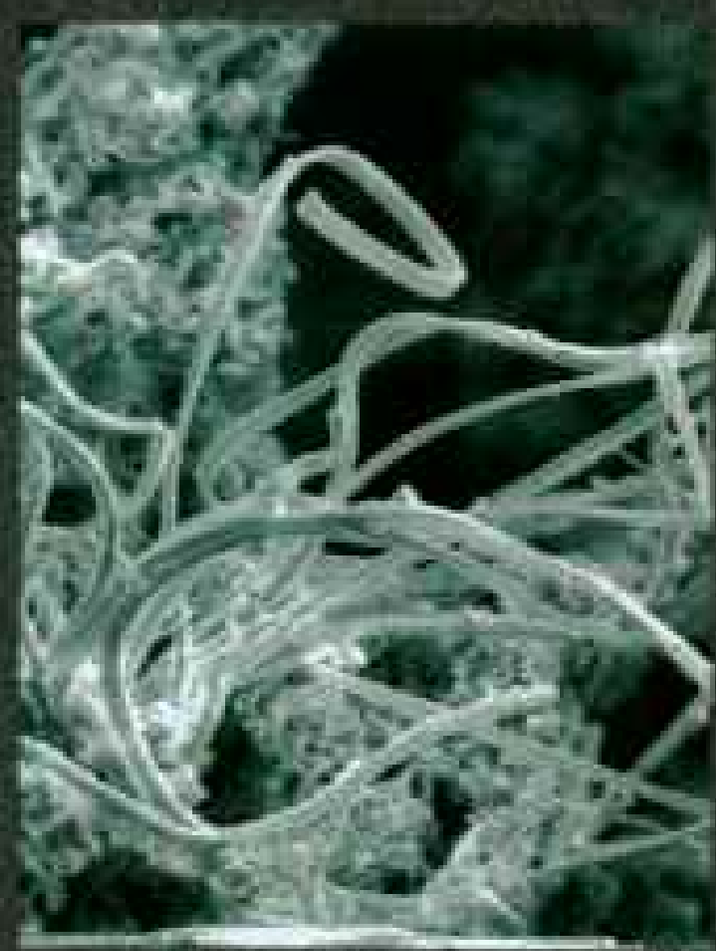
Mixing of genes through sexual reproduction leads to an explosion of life-forms among eukaryotes.



domains (above). Distance from the trunk indicates how far a species has evolved genetically from common ancestors.

Genetic comparisons have also shown that all the oldest known lineages thrive in heat. In another sample from Yellowstone—seen at right under an electron microscope—Berkeley graduate student Carrine Blank has identified what may be the closest organism yet to a common ancestor—circled in red above. Some scientists say this supports the theory that life began in a hot world. Others wonder if thermophiles were merely the sole survivors of searing meteorite impacts.

No matter what its roots, life's spreading canopy has only recently included beings such as humans.



3,500 X. SHERRY CADY, SETI INSTITUTE, NASA; ART BY KEN EWARD

"Everything that's alive today traces its ancestry back to the common bacteria," she tells me, pausing so I can consider my lowly origins. "We always think we came from the apes. But our cells really come from the bacterial world."

I SEARCH FOR HINTS of my bacterial heritage while inspecting a family portrait taken midway through the Precambrian. In the picture—a microscope slide of a slice of a Canadian stromatolite—I can discern filaments of fossilized bacteria the color of faded sepia photographs. Each filament is about 1/500 the length of an eyelash.

Andy Knoll, a paleobiologist at Harvard University, peers through the other barrel of the two-person microscope. As Knoll adjusts the microscope, different layers of bacteria swim into focus and then disappear. For a brief moment the fossils seem alive as they dance in the light of the microscope.

"They're just beautiful," Knoll marvels, even though he has viewed this slide hundreds of times. "I still find it exciting to think that two billion years ago these things were alive."

The residents of this stromatolite lived at a critical point: Oxygen was beginning to accumulate in the atmosphere, and eukaryotes were making their debut. These early eukaryotes left behind tiny one-celled fossils that look like saggy beach balls under the microscope. For hundreds of millions of years these eukaryotes remained smooth globes, with few new species appearing. Evolution seemed to be proceeding in slow motion.

Between 1.2 billion and 1 billion years ago the pace picked up dramatically as dozens of new species developed. Some had knobby coatings; others, slender spikes or stout horns.

One of the sparks for this biological revolution may have been the origin of sex. Before this period organisms reproduced asexually by making genetically identical copies of themselves. But advanced eukaryotes evolved a more complicated strategy: During sexual

An invader's vulnerability

Savage malaria parasites in a red blood cell (far left) start on a rampage. Each will invade another cell, suck it dry of hemoglobin, then produce a new infectious generation. Long before they began to attack warm-blooded hosts, however, malaria's ancestral cells lived like plants. Today each contains a relic from that time: a chloroplast, normally a center of photosynthesis, like the one shown in green in the colorized cell at left. What the chloroplast does for modern-day malaria is still unclear. Deprived of light inside a human body, it cannot photosynthesize. Yet scientists puzzling out this intricacy of life believe it plays an indispensable role and that someday one of history's most ancient scourges may be eliminated by something as simple as a herbicide.

(LEFT) DLOU K. LEMMART NILSSON, ALBERTI BONNIERS FÖRLAG; (FAR LEFT) DLOU K. GEORGE MARADICHA, BOTANY SCHOOL, UNIVERSITY OF MELBOURNE

reproduction parents mixed their genes together to produce new combinations.

The advent of such sexual reproduction kicked what had been a stately course of evolution into high gear, spurring the development of new types of organisms. "With the evolution of sex you get a lot of genetic recombination, a lot of possibility for change," says Knoll.

The effects of shuffling the genetic deck seem obvious as I hold my two-year-old son, Noah, who has drawn a full house of features from many members of his family. In him I see my big ears and furrowed brow woven together with his mother's smile, grandfather's cleft chin, and aunt's saucerlike brown eyes.

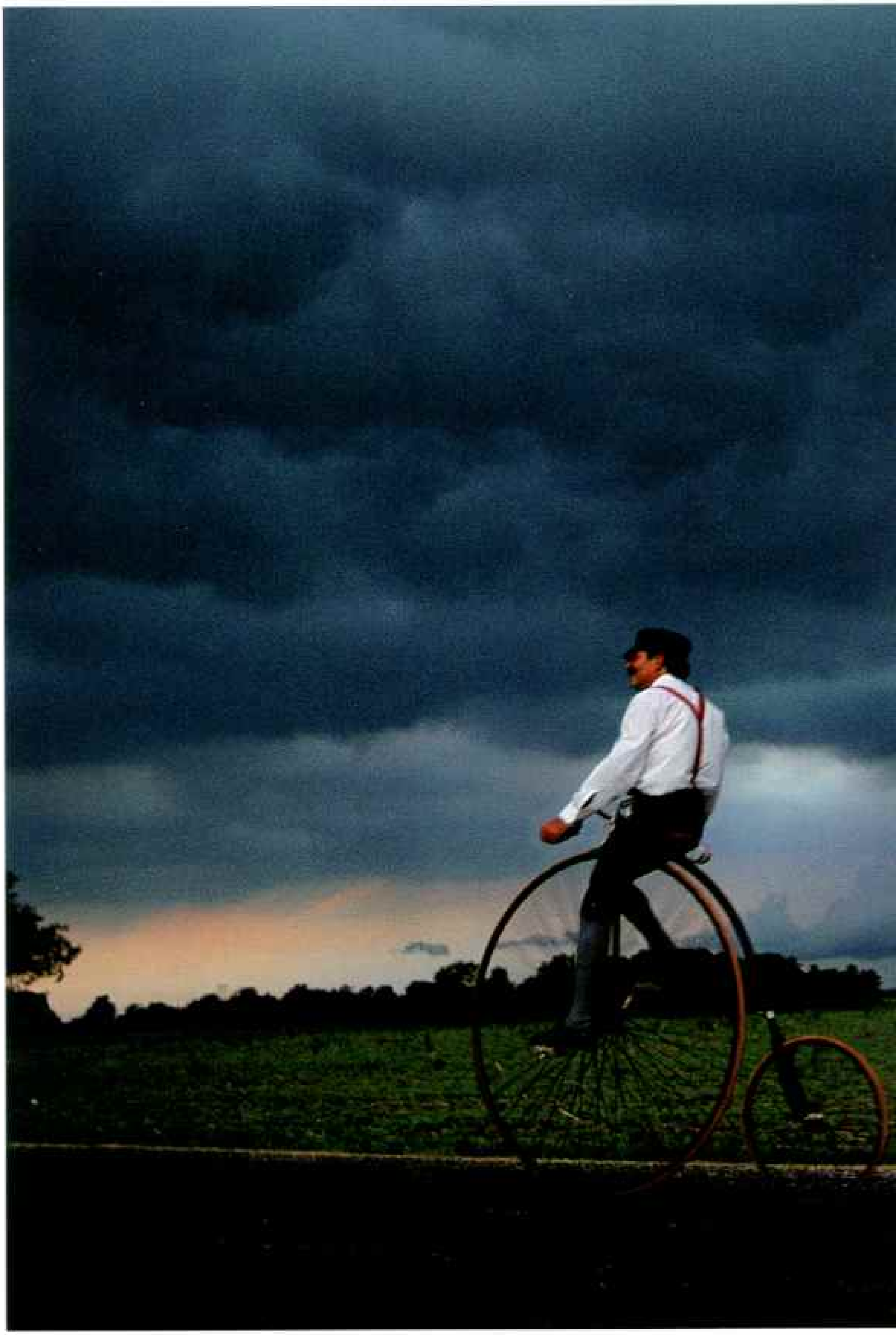
On this crisp April night we're standing outside watching comet Hale-Bopp light up the northwestern horizon, looking like a celestial exclamation point leaning to one side. Since before the Earth formed, Hale-Bopp has been wandering the skies, leaving behind a trail of organic molecules and other exotic chemicals. Its fuzzy tail is a reminder that similar comets may have seeded the early Earth with the building blocks of life.

Other Precambrian relics resonate across the world today—in our bodies and in almost everything we see. As I hold Noah, my arms begin to tire and burn. The muscle cells in my biceps have run out of oxygen and must temporarily revert to a fermenting lifestyle, just like that of the earliest bacteria.

In other parts of my body the descendants of Precambrian predators—the mitochondria—help generate energy from the supper I just ate. My cells bustle with RNA molecules that trace their ancestry to some of the earliest forms of life. And the grass under my feet contains remnants of the cyanobacteria that helped build stromatolites before the continents appeared.

I give Noah a squeeze and wonder if our descendants will be watching when Hale-Bopp streaks by 2,400 years from now, sprinkling the sky with the ingredients for new life. □

For more about the rise of life on Earth join our online forum at www.nationalgeographic.com.



America's First Highway

Looking west, an infant nation dared envision an overland link to its growing frontier. In its heyday the National Road teemed dawn to dusk with loaded wagons and livestock. It also conveyed an essential idea: that even as they spread across the continent, far-flung individuals could remain united.

By WILLIAM R. NEWCOTT
NATIONAL GEOGRAPHIC SENIOR STAFF

Photographs by MELISSA FARLOW

RECALLING 19TH-CENTURY NATIONAL ROAD BICYCLISTS, DON STEWART PEDALS AHEAD OF AN INDIANA THUNDERSTORM.

"DOES THE HORSE pull the cart or does the horse push the cart?" Holding the reins of his home-built covered wagon, Elam Bender turned to me and smiled as he repeated his question. I stared back, half considering the problem and half engrossed in his coonskin cap. I'd seen coonskin caps before, mind you. I had just never seen one with the coon's head attached.

"Absolutely, without a doubt," I guessed, "the horse is pulling the cart."

Bender turned his gaze back to the road. The 14-year-old horse, Queen, clip-clopped along the highway pavement, the top of her head bobbing in and out of view. Ahead of us was the lead wagon; behind us, some 20 more, a reenactment of the westering caravans that rumbled over this length of the National Road in Maryland during the early 1800s.

The wagon's wheels crept uncomfortably close to the edge of the road. "You're wrong," Bender finally said. "Old Queen up there is pushing against the harness with her shoulders. So as far as the horse is concerned, she's pushing the wagon."

At the moment, Queen was pushing us up a pretty steep hill near Keysers Ridge. It was already noon, yet the air was still cottony with fog. I watched Bender's hands at the reins, the hands of a retired dairy farmer and retired Mennonite minister, dark lined from decades of farmwork and God's work and everything that overlapped. Now, after 20 years participating in this annual pilgrimage, Bender seemed to know every twist and turn in the road. He pointed out each spot where the National Road's original path veered to the right or left of the modern highway that has replaced it. Queen turned her head longingly toward those byways, particularly when a tractor trailer rudely overtook us with a muffled *woomph*.

"The trucks get a little scary," observed Bender. "But I guess they're the reason the highway was put here in the first place."

The highway is U.S. Route 40. Since the 1920s that's been the official name the old National Road has borne for most of its 591-mile length through Maryland, Pennsylvania, West Virginia, Ohio, Indiana, and Illinois. The National Road was the first federal interstate, constructed in fits and starts from 1811 to 1838 with the goal of linking the great port of Baltimore with the wide Mississippi near St. Louis. Originally called the Cumberland Road, it's also been known as the Great Western Road, the Old Pike, the National Trail. The road commonly became Main Street as it passed through a town; some romantics got to calling it the Main Street of America.

The route has been repaved and straightened countless times, but motorists still roll over stone bridges built by hand 175 years ago, past centuries-old inns where wagon and stagecoach drivers once shook trail dust from their boots. West from Maryland, original

Weaving among the hills of western Pennsylvania near Scenery Hill, the National Road—today's U.S. Route 40—follows old Indian trails. In 1794 farmers of this region balked at paying an excise tax on liquor and took up arms. This so-called Whiskey Rebellion, and the threat of losing settlers' allegiance to British and Spanish influence to the north and south, strengthened President George Washington's resolve to establish a federal road to Ohio—a dream later championed by western Pennsylvania landholder Albert Gallatin, Thomas Jefferson's treasury secretary.

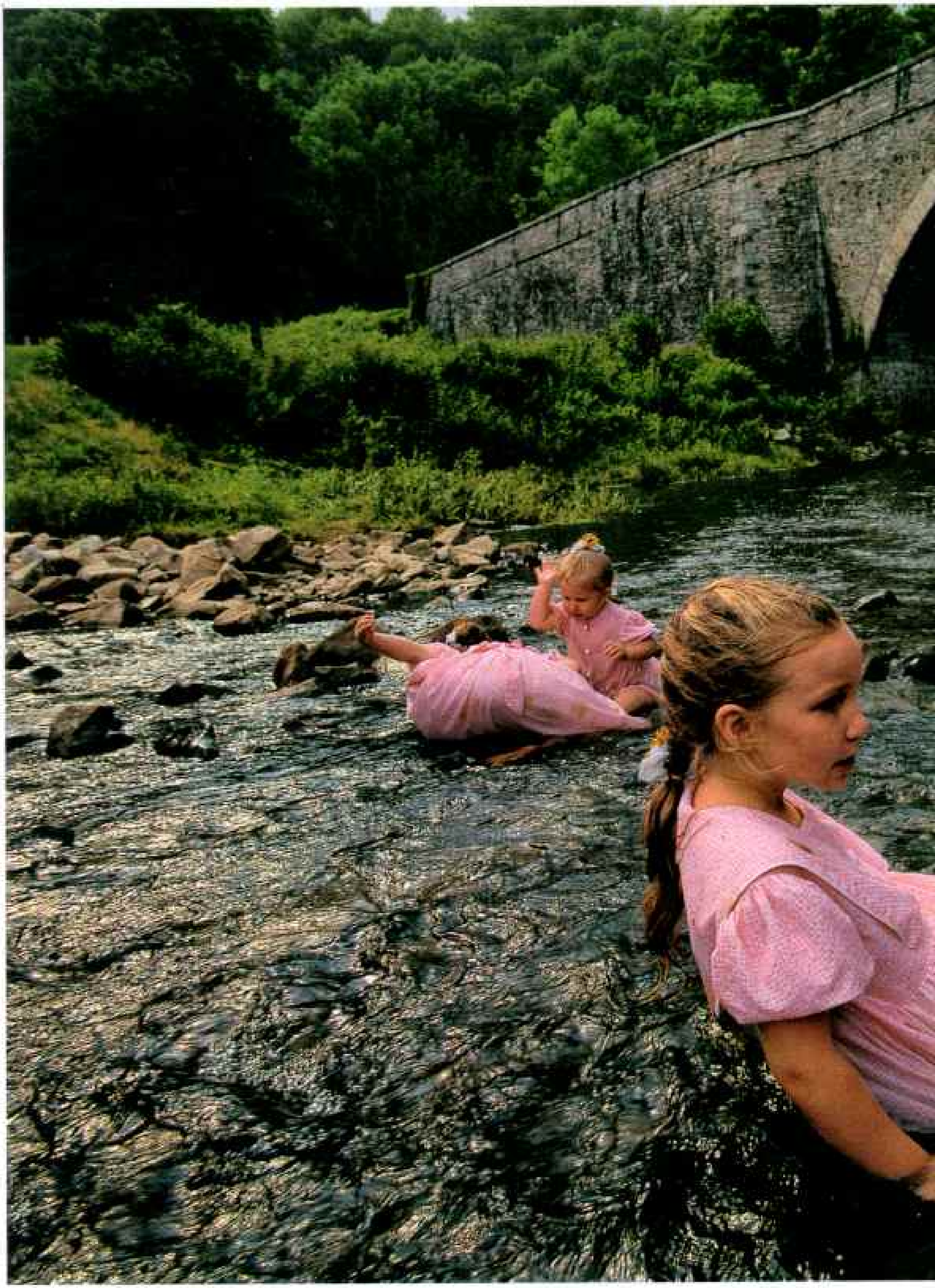
MELISSA FARLOW's photographs appeared most recently in the March 1996 article on the Hudson River. Covering this story brought back memories of her small-town girlhood home in Indiana—just a hop, skip, and a jump from the Old Pike itself.

mile markers still count down the distances to Wheeling, Columbus, and towns that no longer exist. And, in many spots, just a few feet beneath U.S. 40's pavement lie layers of rocks, each fragment hand-hewn when the nation was young.

I had set out on the road as the leaves began to turn, in a new rental car. It would have been nice to find an old Studebaker—made by the same company that once built covered wagons—but my sedan would prove to be worthy as I frequently urged it off the pavement to explore overgrown, abandoned stretches of the old road.

THE NATIONAL ROAD begins in Cumberland, Maryland. The city marks the western end of an old toll road from Baltimore and the end of the Chesapeake and Ohio Canal, which parallels the Potomac River for more than 180 miles from Washington, D.C. Today I-68 swoops down from the hills, skims on pylons over Cumberland's rooftops, and takes off again, like a barnstorming jet. Between descent and ascent, there's barely time to admire Cumberland's turn-of-the-century spires, made more impressive by their location on a hill close to the heart of downtown.

As with so many major human accomplishments, the National Road had its roots in the desire to make money. In 1751 the Ohio Company of Virginia hired a Delaware Indian named Nemacolin to blaze a path to its holdings near what is now Brownsville, Pennsylvania. Two years later, as a Colonial Army major, George Washington rode that same trail to demand that French commanders pull their troops from Pennsylvania—a request that was not only rebuffed but also touched



Sunday church dresses double as bathing suits for the Byler sisters below the Casselman River bridge in Grantsville, Maryland. Rising stone by stone in 1813 like a lone cathedral rib, the 50-foot highway arch was designed to clear a canal that never came.

off the French and Indian War. In subsequent years Washington widened the trail when he built, then surrendered, Fort Necessity and helped command a force that improved the route again when he served as an aide-de-camp to British Gen. Edward Braddock during a disastrous campaign against the French.

After the Revolution, Washington worried about the fate of the young country's western territories, which were still wedged between conflicting European powers. He feared the residents might align themselves commercially and politically with "the Spaniards on their right, or Great Britain on their left."

The solution, he declared, was to "open a wide door, and make a smooth way for the produce of that Country to pass to our Markets before the trade may get into another channel." The dream of a national road was born. Congress passed a bill to create the road in 1806, and Thomas Jefferson signed it.

There was no easy route across the mountains. The Appalachians form a considerable barrier from Georgia to Maine. But it didn't take long for planners to agree that the best route stretched west of Baltimore, at first roughly following the trail blazed by Nemacolin, aiming for the Ohio River at Wheeling, West Virginia.

WEST OF CUMBERLAND the original road crawled over Haystack Mountain, but I drove the route adopted just a few years later, around the mountain and through a streambed contained on both sides by high cliffs. Legend says an Indian maiden and an English trapper, forbidden to marry by her father, hurled themselves off the cliffs together.

It would have been quite a drop. They call this territory the mountain side of Maryland. Building a road here in the early 19th century wasn't easy. I could picture teams of laborers pushing through the forest: the first group blazing a trail, the next felling trees, another digging the roadbed. Workers—sometimes moonlighting farmers—sat at the roadside, hammers in hand, breaking native rocks to congressionally prescribed specifications.

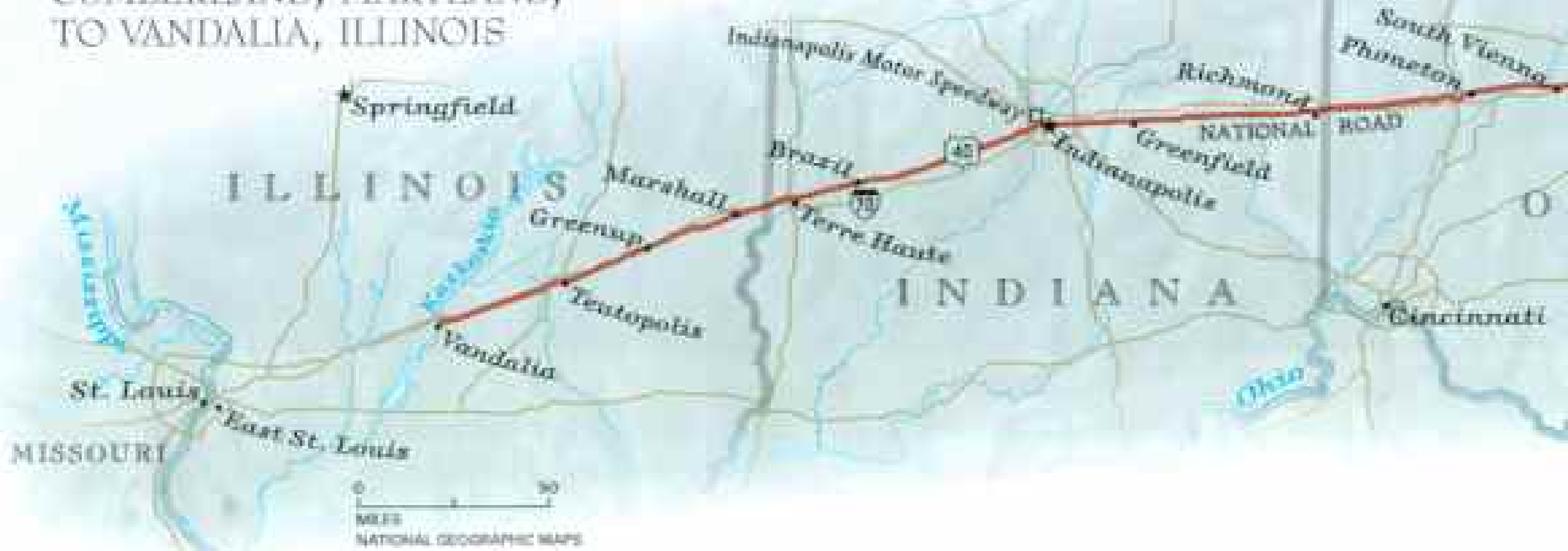
Up Chestnut Ridge from Great Crossings, Pennsylvania, I found Don and Eunice Shoemaker. They hadn't expected to stay long when they took over as managers of the Summit Inn in 1958. The road practically passed through the parking lot of the sprawling hotel, 2,400 feet up at the western rampart of the Appalachians.

The inn has a glorious history. It is a resort in the grand old tradition, with a sweeping covered veranda and a 30-foot stone fireplace in its cavernous lobby. Built in 1907 as a retreat for the wealthy coal barons of nearby Uniontown, the Summit rode the automobile craze of the early 20th century in a big way. Signing the Summit guest book with a flourish were such visitors as Henry Ford and Harvey Firestone. They and other tycoons tested their newfangled contraptions against the perils of the National Road, which a few yards west of the Summit dropped off the Appalachians at a 9 percent grade.

My feet were propped on the white-painted railing at the Summit porch west end. The rosy sun, low on the horizon, argued for bragging rights with the reds and oranges of early fall. Then the lights of Uniontown, a third of a

National Road

CUMBERLAND, MARYLAND, TO VANDALIA, ILLINOIS



"Let us conquer space," declared Congressman John C. Calhoun in 1816, arguing in favor of funds for the road, which ultimately reached from Cumberland, Maryland, to Vandalia, Illinois. A lifeline to growing cities like Wheeling and Columbus, the road gave birth to towns like Centerville, Pennsylvania (left), so named because it was halfway along the road between Uniontown and Washington, Pennsylvania. The old road fronts houses and the Centerville United Methodist Church; a bypass sneaks around back.

Wagons lined up 20 deep at Searights Tollhouse, one of six built in Pennsylvania when the U.S. turned the road—and its expense—over to the state in the mid-1830s. Designed by the Army Corps of Engineers, the buildings resemble lighthouses.

mile below, flickered on. Eighty years ago glowing coke ovens would have dotted the landscape.

I was sitting atop the last mountain on the National Road. Beyond this point spread the rolling hills and flatlands of America's Midwest. I could imagine those road builders, after two years of battling gravity in the Appalachians, viewing this landscape with a sigh of relief—then bracing for their plunge into that forest.

THE AMY C out of Tampa, Florida, was passing beneath my feet, heading south on the Ohio River. The barge was pushing nine huge bins lashed together with cables, six of them filled to their rims with coal. Behind the wheelhouse glass the pilot returned my wave as he disappeared under the 149-year-old Wheeling suspension bridge—once the world's longest—which carries the National Road toward Ohio. Wheeling marked the road's end until July 4, 1825, when construction resumed to the west. Jubilant locals turned out at the St. Clairsville, Ohio, courthouse to listen to speeches and watch the first spade of dirt turned.

As the road rose out of the Ohio River Valley, I could see its stages of history laid out side-by-side-by-side. To the north sits the original roadbed—concrete, brick, or gravel pushed up by grass—overhung by unruly trees. To the south roars I-70, four lanes of interstate highway that, with the pedal to the floor and a wallop of caffeine, will get a motorist to Utah in a couple of days.

In between lies U.S. 40, two lanes of blacktop that ease you between towns, then join the old route as it passes through alternately picturesque and shabby business districts. The most dismal ones pass namelessly. The more vibrant ones all seem to have a personal claim to fame: Cambridge (site of the Hopalong Cassidy Sidewalk), New Concord (childhood home of John Glenn, the astronaut and senator), Zanesville (birthplace of Zane Grey, the Western novelist who glorified the pioneers rolling through his hometown).

The original road groans back to life on its own in the less fortunate settlements that

Less than two decades after it stopped making covered wagons, the Studebaker company built this 1937 President coupe, still cruising the National Road in Columbus, Ohio. Cattle driven to town along the road helped give rise to the city's nickname: Cowtown.

have been bypassed by U.S. 40, which veers abruptly around them like a motorist trying to avoid a pothole. Whether the intention was to preserve the towns or simply speed the flow of traffic, the strategy of rerouting U.S. 40 often amounted to a municipal death sentence.

It is past Columbus, they say, that the Midwest truly begins. One thing is for sure: Beyond it the National Road begins to ignore the contours of nature and makes a beeline toward Indianapolis. At this point Congress was getting impatient with the cost of building the road. Surveyors were ordered to plot a route as straight (and cheap) as possible. Their dedication to the task is admirable. If not for a slight pull to the right on the front wheels of my car, I could have pointed straight ahead, closed my eyes, and let the cruise control take me to Indianapolis.

Of course, that would have meant missing West Jefferson, Ohio, home to the Western Hemisphere's one and only Krazy Glue distribution center, and South Vienna, where the corn ears painted in the middle of the road commemorate the annual Corn Festival.

I stopped in Phoneton, founded in 1893 by AT&T at the junction of three major phone and telegraph lines, to find a telephone. Naturally, there was no public phone in Phoneton. But there were ostriches. Two of them behind a fence, staring at me bug-eyed just as I was accelerating to head out of town.

"They're named John and Martha," said Jim Callahan, "and they'll kick the tar out of you."

Callahan and his wife, Letha, have been raising ostriches—and their flightless cousins, emu and rhea—practically on the shoulder of the National Road since 1982. "They're sold for meat and leather for boots and jackets," Callahan said, pouring some pellets for John and Martha's dinner. His dog, Holly, followed close behind, seemingly intent on keeping Callahan between herself and the birds. "A few years ago, I could get $10,000 for a year-old pair. Now it's more like $400."

Blithely unaware of the whims of market demands, Martha was this month laying an egg every two days. In a shed, Callahan showed me an incubator with four eggs in various stages of gestation. "Letha's scared to

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Some 40,000 train buffs a year pull out of Cumberland on a 16-mile scenic ride to Frostburg. Rail all but doomed the road when the Baltimore & Ohio line reached Wheeling, West Virginia, in 1852. A century later cars elbowed the train aside.

Prewashed produce is today's special at a roadside stand run by Robert Conway, sheltered by his assets during a western Pennsylvania rainstorm. Farmers were early beneficiaries of the National Road as they found markets beyond nearby towns.

death of ostriches. They've got these big claws on 'em. But let me show you what she does with the eggs. . . ."

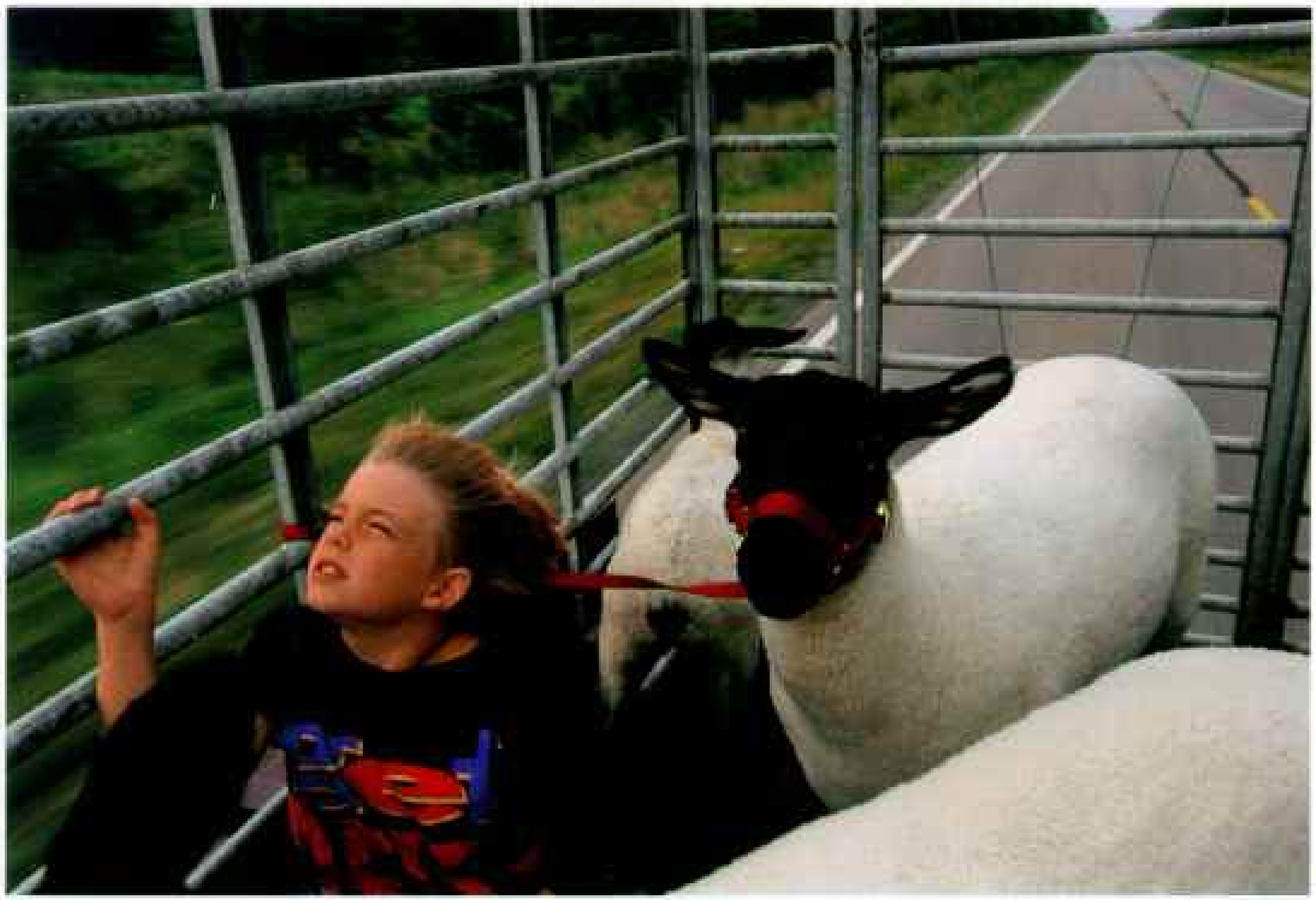
He led me into their modest house, through the screen porch to the living room. I stood in a folk Fabergé museum. Everywhere were ostrich eggs. Carved ostrich eggs. Decorated ostrich eggs. Hollowed out ostrich eggs with dioramas lovingly placed inside them. On one shelf an ostrich egg figurine held an ostrich egg parasol and wore an ostrich egg hooped skirt all decorated with pink beads.

I just knew that a mile away from here at the Wal-Mart along I-70 these things would fetch a pretty penny. But Letha wouldn't dream of it. "If I sold them, it would be labor," she said, straightening the parasol shell. "So I'm not interested in that."

WESTERN OHIO rolled past under my wheels. This is farm country. The land is sealike in its lightly swelling flatness, the sky arching over wide horizons. Barns rose darkly, like islands, skirted by bright gabled farmhouses. Fence posts and mile markers whizzed by. I was surprised to see tobacco barns, with their telltale slatted sides, among the scatterings of farm buildings. Then I remembered that the term "stogie" comes from the National Road's Conestoga wagon drivers, who enjoyed cigars rolled from Ohio tobacco.

Richmond, Indiana, puts a temporary stop to the farm idyll. This is a town that has something to prove. You sense it from the tourist flyers at the brand-new Wayne County visitors bureau, just across the state line. The town has several historic districts reflecting its history as a trading outpost, railroad depot, and manufacturing center. One of the Midwest's best preserved Victorian neighborhoods draws nationwide admirers who stroll along Richmond's sidewalks, peering past the wrought-iron fences at imposing homes with gingerbread trim.

But a few blocks away stands a monument to Richmond's darkest day. A brick wall bears the words: "In Memory of the Forty-one Persons Who Lost Their Lives in the Tragic Downtown Explosion April 6, 1968."



Washed and ready to show, nine-year-old Kenny Weaver's sheep head for the Cumberland County Fair in Greenup, Illinois. "He loves animals immensely," says his dad, Mark. "I think he'll stay on the farm when he grows up." A good start: Kenny won a blue ribbon.

I walked over to the Romanesque Wayne County Courthouse into the office of the county clerk, JoEllen Trimble. She knew all about the explosion. Her husband was one of the 41.

"Jim was an attorney," said Trimble, a woman with sparkling eyes that outshone her violet jogging suit. "It was Saturday, the week before Easter. A gas main ruptured, and there was a huge explosion. And then there was another explosion—it touched off a supply of gunpowder in the basement of a sporting-goods store."

Two city blocks of Richmond vanished.

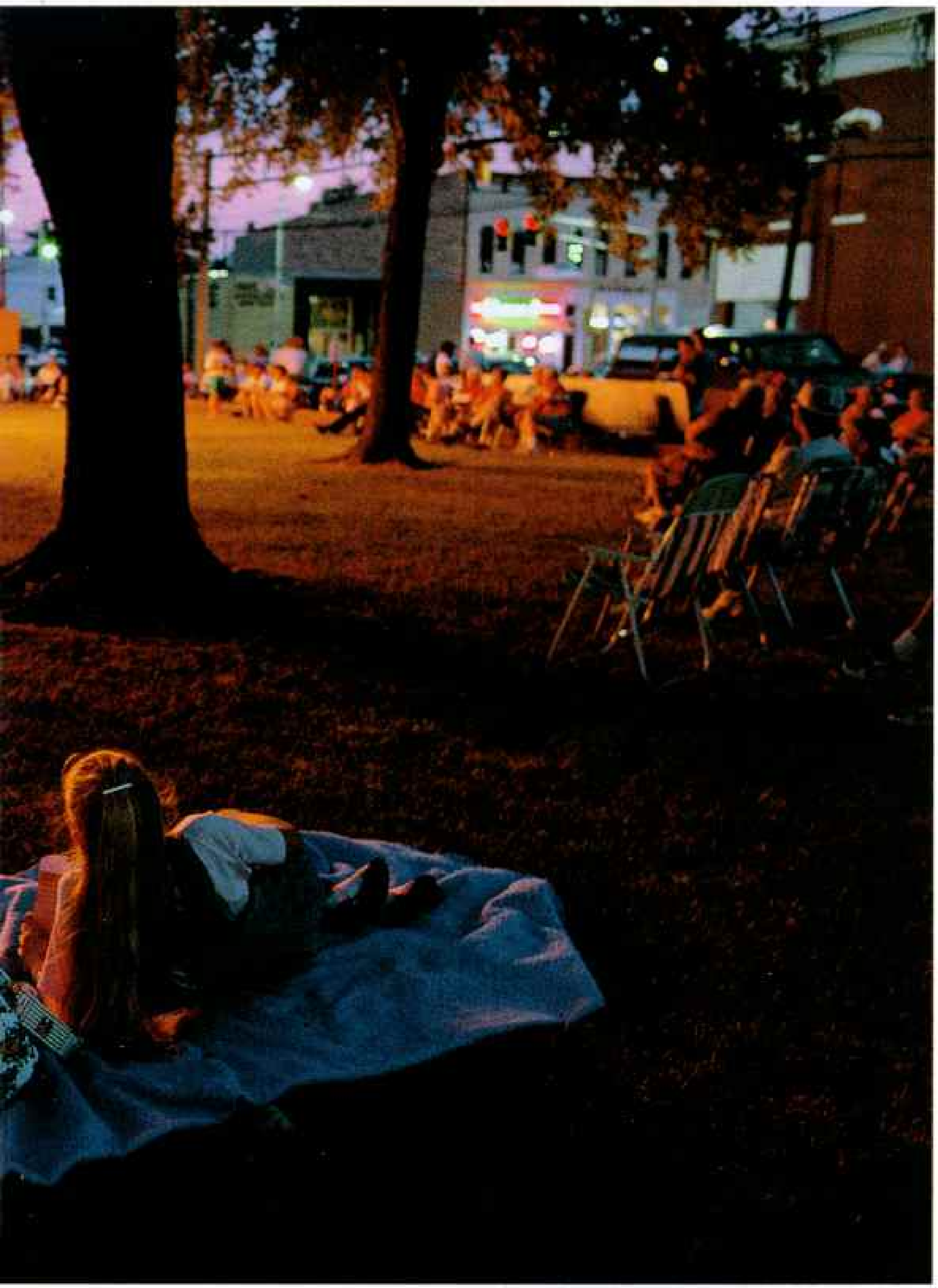
"I'd been out of town that day, and when I first heard about it, I wasn't worried about Jim," she said. We had left the courthouse and were walking past the blast site. It is occupied now by a department store. "It was a Saturday, and Jim didn't usually work on Saturdays. But that Saturday. . . ."

A wind blew up. Trimble pulled her jacket collar close around her neck. It occurred to me that for 29 years she'd been walking past this spot. So had scores of others who lost husbands, wives, and children on that day.

You might not remember the Richmond explosion of April 6, 1968. I had not, even though it should count as one of the great American tragedies of the 1960s. Two days before, in Memphis, Tennessee, Martin Luther King, Jr., was assassinated. Riots broke out in a hundred cities across the nation, leaving more than three dozen people dead. That dark weekend Richmond was just another American city in flames.

At the library I flipped through news photographs of Richmond residents, both black and white, running into collapsing buildings to save each other's loved ones. A multiracial group of volunteers, their determination showing, held a fire hose. In one account Lucy Robinson, a black mother of eight who was out of town that day, tried to call Richmond and, when she couldn't get through, was told by a telephone operator that there was probably a riot going on there.

"You may know telephone work," Robinson told the operator, "but you don't know Richmond, Indiana."



"The bandstand is 68 years old, and so am I," says Harold Ellshoff, director of the Marshall, Illinois, band, begun in 1875. Four generations of his family have performed in the band, which plays Friday nights all summer. Come early for the ice cream social.

It seems fitting that just a mile or two north of the National Road lies the most famous automobile racetrack in the world. The Indianapolis Motor Speedway was built right about the time that the pike, long left obsolete by railroads, awakened to a motor-age renaissance.

Beyond Indianapolis I thought I was driving past corn farms gone bust. The fields were sloppy landscapes of broken stalks surrounded by dead weeds. It took a patient fellow at a gas station near Brazil (birthplace of Jimmy Hoffa) to set me straight.

"We call that no-till farming," he said, talking slowly in the apparent hope that I might comprehend. "Don't have to plow after the harvest. Just plant the seeds underneath the stalks, and spray for weeds during the growing season." I asked if all that spraying causes any problems, like chemical runoff contaminating streams. "Nooooo," he said, speaking ever slower. "We're *real* careful."

Teutopolis, Illinois, introduces itself with an exclamation mark: The spire of St. Francis of Assisi Roman Catholic Church occupies a portion of the sky usually reserved for grain elevators. A quick look around confirms that St. Francis is not merely the most impressive church in town, it is the only church in town.

"This is the only church T-Town needs," I was informed by a woman hurrying out the church doors.

Indeed, Teutopolis—named for its heritage as a German Catholic settlement dating back to the 1830s—thrives as an island community of 1,400 that has stubbornly melded its historic, ethnic, religious, and political identities. Its streets are a neat grid of meticulously kept homes. Front-yard Virgin Mary statues outnumber the birdbaths. A ball field on the

Bypassed by time and the interstate, a five-mile stretch of original road links Claysville and West Alexander, Pennsylvania. A hilltop stand of maple and locust trees recalls the forests that greeted work gangs as they pushed through the wilderness. When they were done—a quarter of the nation and almost $7,000,000 in federal funds later—the road's completion in 1838 passed virtually unnoticed. Now preservationists aim to save stretches like this, before the Old Pike is obliterated by the very growth it created.

grounds of a former Franciscan seminary is still flanked by the school's large devotional statues. A home run could imperil a Blessed Virgin just beyond the right field scoreboard.

Now it was late fall, and the basketball season was about to begin. Teutopolis High School is fiercely proud of both its boys and girls teams. I expected to find the players hard at work in the high school gymnasium, but no one was shooting hoops.

I stopped in at the school's main office. "I'm sorry, the principal's not here today," a secretary told me. I waited for her to direct me to someone in charge. Finally she declared, "It's the first day of hunting season!"

It occurred to me that since arriving, I had not seen many males. There were women everywhere, but most of the guys, it turned out, were off stalking deer. I suspect that gender roles here haven't changed much since the days the road first came through, although the antler size of those deer, not the venison, may inspire more excitement today.

PAST A SUCCESSION of cornfields and oil wells, the old roadway dies in Vandalia, at the Kaskaskia River, where a covered bridge used to stand. Here, nearly 600 miles from Cumberland, a sheet-metal highway sign planted in the middle of the pavement declares, "ROAD ENDS."

Across the river I wandered through the halls of Illinois's old state capitol building. Abraham Lincoln served in the legislature and gave his first published speech here, opposing an investigation of the state bank. Out front is an 18-foot-high Madonna of the Trail monument, one of 12 erected nationwide in the 1920s by the Daughters of the American Revolution to honor pioneer women.

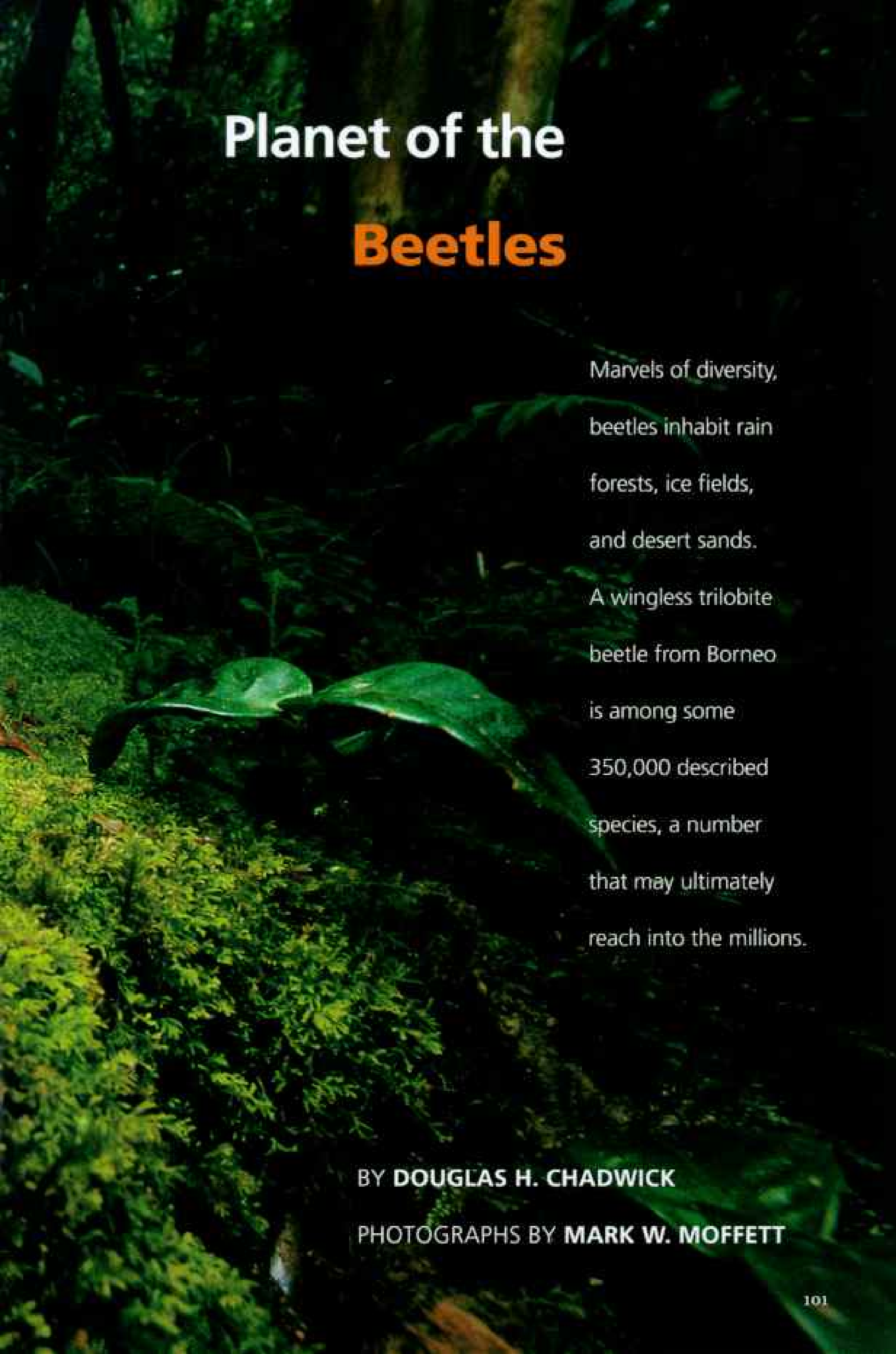
By the time the road reached Vandalia in 1838, the town was breathing its last as the state capital. Springfield would inherit the title the following year. The road was out of breath too, proceeding more from momentum than necessity. There were plans to continue it on to the Mississippi, but roads already went there from Vandalia—and besides, the railroads had all but obviated the road builders' aim to join East to West. So the old road ended ingloriously on this riverbank.

I drove on to St. Louis along U.S. 40. The original route of this highway from Vandalia ends in East St. Louis, near a Mississippi riverboat casino. Nearby, barges are loaded with corn for shipment downriver. Highway bridges leap toward the Gateway Arch, symbol of America's expansion to a West far beyond George Washington's wildest dream. I thought of Elam Bender's riddle. Did the road pull the nation west, or did the nation push the road west? A bit of both, I figured.

It was past sundown. For tens of thousands who had traveled this far in their wagons, there would be no more roads. The great trails of the West had no inns spaced along their lengths, no reassuring mile markers.

Many of the early travelers never got this far. They dropped out, settled down, started new communities here and there along the Old Pike. Nothing wrong with that. The most rewarding dreams aren't always realized at the end of a road. □

OUVIRCOLA SP.



Planet of the Beetles

Marvels of diversity, beetles inhabit rain forests, ice fields, and desert sands. A wingless trilobite beetle from Borneo is among some 350,000 described species, a number that may ultimately reach into the millions.

BY **DOUGLAS H. CHADWICK**

PHOTOGRAPHS BY **MARK W. MOFFETT**

As MORNING SUNLIGHT breaches the peaks and slants down through the forest, an oval shape near the tip of a branch begins to glow. The object has a gemstone hue that dances between emerald and jade, and one end is streaked with what looks like polished silver. They say Apache Indians and Spanish explorers both left plunder here in the mountains of southeastern Arizona. But this glittering bauble has a heartbeat. It is a scarab beetle, *Plusiotis gloriosa*, dining on juniper leaves. It is also, if you pause to look closely, a window into an extraordinary dimension of natural history.

North America holds nearly 1,500 different species of scarab beetles; the world has more than 30,000. And they make up just one family of beetles. More than 150 other beetle families exist, from pine-flower snout beetles to the clan called pleasing fungus beetles. In fact, about one of every four animal species known on Earth is a beetle.

We tend to assume that big, warm-blooded beasts dominate wildlife communities. Beetles, which splat on windshields and crunch underfoot, don't seem terribly significant by comparison. But the 4,000 different mammals and 9,000 birds on the planet add up to well under one percent of the 1.75 million species identified by science. Insects make up about 60 percent, and at least a third of them are in the order Coleoptera—the beetles. This group includes more species than the entire plant kingdom does, and scientists agree that many thousands, or even millions, more beetles have yet to be discovered.

When asked what his studies of nature had revealed about God, J.B.S. Haldane, the renowned British physiologist and philosopher, is said to have replied: "An inordinate fondness for beetles." My friend Michael Ivie, a Montana coleopterist, just says, "We like to think we are living in the age of

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Alien samurai, a long-horned beetle of French Guiana can exceed four inches in length. Though armed with serrated mandibles, it feeds mainly on liquids. Exactly how the world appears through beetles' compound eyes is unknown.

MACRODONTIA CERVICORNIS

man, but we are obviously living in the age of beetles." I figured the least I could do was learn a little more about them, both in their own right and as representatives of all the overlooked, small creatures that together run the ecosystems that sustain us.

Soon I had met beetles that move through water by walking on the underside of the surface as though it were a glass ceiling and beetles that jet ski on top with the aid of compounds spritzed from their abdomens; beetles that wander ice fields deep in caves, stilt-legged and blind; beetles that live in beaver fur and others high in falcon nests. I came upon beetles whose young rear up and chirrup, begging for food like baby birds, and dazzlingly iridescent beetles worn as jewelry.

There are beetles that resemble bird droppings, the better to catch flies; beetles that shape manure into balls and roll them along the ground to store as food; and smaller beetles that lay their eggs on those dung balls. I saw beetles so big that early collectors knocked them out of the air by firing shotguns loaded with sand and beetles so small they hitchhike on the mouthparts of bees. There are even beetles that make their way into museums and devour beetle collections.

Family reunion: Having fled the heat of the Arizona desert, ladybird beetles mass in the cool heights of Mount Lemmon outside Tucson. Also known as ladybugs, these beetles are voracious predators of aphids. Collectors sell them in bulk to gardeners for pest control. Beetles are both enemy and friend to agriculture. Some species devastate crops; others attack the attackers, reducing the need for chemical pesticides.

IN TERMS OF SHEER VARIETY, beetles may be the greatest success story in the long history of life. The obvious question is why, and the answer begins with their defining characteristic: the hard case known as the elytra that covers the wings and abdomen like two halves of a shell. Ancestors of beetles had two sets of wings, like dragonflies, and are thought to have lived mainly on the ground and under bark. Subject to constant wear and tear, the forewings evolved into thick covers for the rear pair, protecting them against abrasion and predators. Over time, these covers grew stronger and more streamlined until beetles became rambling fortresses.

As the wing covers evolved to fit together more compactly, they helped trap moist air around the wings folded underneath. This allowed beetles to expand into desert regions, where they have flourished ever since. The same ability to store air beneath their elytra lets other beetles live underwater.

We usually think of the Mesozoic in terms of dinosaurs. But the truly colossal event during that era, which occurred between 245 and 65 million years ago, was the origin and spread of flowering plants—an explosion of fragrance and color that transformed the globe. Beetles probably fueled it, for they were the premier pollinators among insects at the time. Then, as now, the majority of beetles relied on leaves, roots, wood, fungi, or plant debris for food. New forms of vegetation meant new opportunities, and these armored insects proliferated into a superabundance of forms.

This welter of different beetles confused me at first, but there still lives in me a ten-year-old glad for an excuse to chase the likes of toads and bugs again, the weirder the better. So I looked forward to stalking species in places like Panama, where I found myself in a lowland forest one night with several researchers. We

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DOUGLAS H. CHADWICK and MARK W. MOFFETT, both frequent contributors, often cover the world's wild places and creatures.

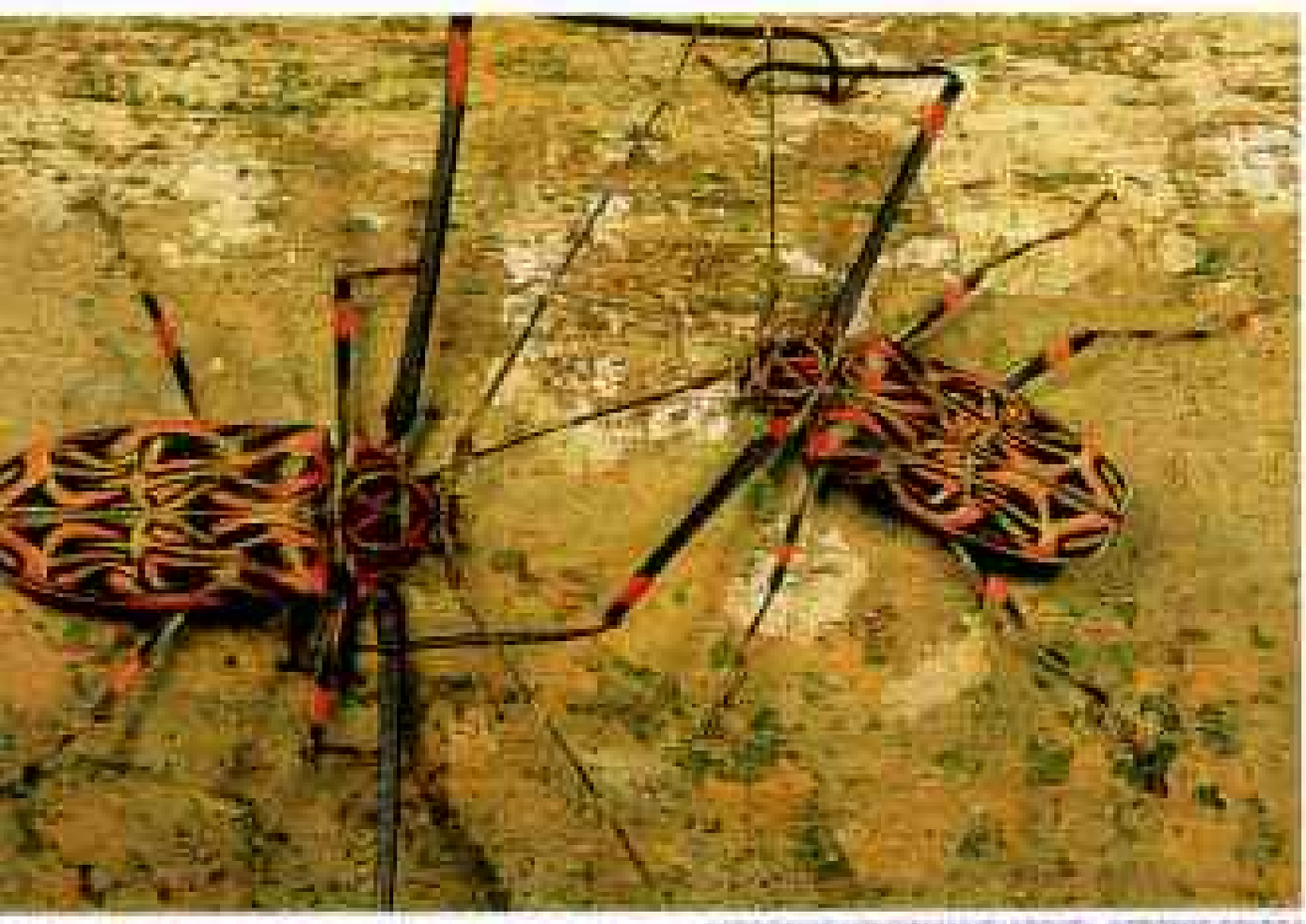
HIPPODAMIA CONVERGENS

were peering at slender little rove beetles writhing among green-glowing mushroom gills. In rotting logs nearby, we located social beetles called passalids that communicate through rasps and squeaks made by rubbing their wings against their abdomens. Every so often we would hustle back to see what had been drawn to our ultraviolet light, hung in a small clearing. Hoots greeted a boat-shaped, predatory diving beetle and an elephant beetle resembling a toy tank that settled among the soft flurry of tropical moth wings.

Suddenly an engine came crashing our way through thickly knotted jungle while a powerful light beam played wildly back and forth. It was a dentist from the midwestern United States, dripping sweat and vines, holding a portable generator in one hand and a searchlight in the other. "This is my idea of a dream vacation," said David Brzoska, who was after tiger beetles, a favorite among collectors. "I go to as many as half a dozen different countries each year. It's almost like I do dentistry to support my collecting these days."

Is it that some folks never quite grow up? Or did everyone else just give up after being told once too often: "Hey, those 'bugs' aren't really treasures"? Yet they are. Some tiger beetles on the hunt can run two feet a second. To cover the same amount of ground in proportion to its body length, a racehorse would have to hit 250 miles an hour. Some rove beetles gobble fly larvae and root-destroying worms, keeping their populations in check. Al Gillogly, who has studied passalids in Panama for years, believes those beetles may have value of a different kind. He had just shooed a snake from the entrance to a labyrinth of tunnels in a fallen tree where juvenile beetles had helped their parents rear new larvae. "These chambers seem to stay mold free for months after the passalids leave," he told me. "Apparently the

Romance begins at arm's length for two harlequin beetles, which gingerly check each other out with oversize limbs in a courtship ritual. Maternal instinct sounds an alarm in a tortoise beetle (opposite), prompting her to stand fast between her fledgling offspring and an approaching column of ants.



ACROCINUS LONGIMANUS (ABOVE); ACROMIS SPINICA

beetles produce something that blocks the growth of fungus. We might want to investigate that chemical for our own use."

HIGH ON A RIDGETOP farther north in Panama, I placed a half-foot-long male Hercules beetle on my arm to watch for a moment. Battles often erupt when two of these tree-dwelling titans meet. They commence the beetle equivalent of roaring—loudly rubbing their wing covers—at the mere sight of each other. Each has a long horn arching forward from its head and an even longer upper horn projecting forward from its thorax. Rushing forward, the beetle maneuvers to lift its opponent between the horns and toss it to the ground below. But when I tried to lift this Hercules off me, I lost. It pulled back harder, pressing the claws at the end of each foot more tightly into my skin. I had little choice but to let the monster wander at will.

Like most people, I find it easy and natural to ascribe human qualities to various animals. Not this one. It was too cold and brittle to the touch, too robotic in its movements. Too . . . *other.* Waving antennae with leafy packets of receptors through the air to gather stray molecules of scent, peering out through kaleidoscopic eyes, it probably didn't perceive the world in any fashion I would recognize.

My beetle looked like glazed porcelain. But no clay could be molded into such intricately curved patterns. Nor could I imagine any steel or modern plastic that could match the combination of strength and flexibility offered by that exoskeleton built of chitin, a polysaccharide similar to ordinary cellulose. Bronze tufts of sensory hairs sprouted from its underside and the upper parts of its legs, making some of the creature downright shaggy. As for the mouthparts beneath all that formidable battle gear, they proved to be wimpish, made for slurping soft fruit. By the time the beetle spread veined amber wings as long as a swallow's and whirred off into the jungle mists like a burly helicopter, I was beginning to hope it would stay awhile, if only as one stranger keeping another company in a vast, mostly inanimate universe.

Just how many other life-forms share the planet with us? When researchers first tried fogging the leafy canopy of tropical forests with insecticide, even the optimists were stunned by the number of unknown species that rained down. Most were very small, and most were beetles.

Terry Erwin, a biodiversity specialist from the Smithsonian Institution in Washington, D.C., counted the variety of beetles found exclusively on one Panamanian tree species, then multiplied that by the number of different kinds of trees within the tropics. The result bumped the estimate of insect species on Earth from one million to 30 million. "I wasn't trying to provide an absolute figure," Erwin explained, "so much as stimulate a healthy debate and more research into one of the most important subjects in biology."

Riding through Panama's forest canopy in a gondola dangling from a giant crane operated by the Smithsonian Tropical Research Institute, I helped a Norwegian entomologist, Frode Ødegaard, sample three of the largest beetle families: leaf beetles, long-horned beetles, and weevils. One of many scientists responding to Erwin's challenge, Ødegaard wanted to pin down the links between particular types of beetles and trees more closely. Is all the insects' food found on the host tree? Do the patterns vary from daylight to dark, from dry season to wet season? *(Continued on page 112)*

ECHOTISOPHA SP.

EUCHROMA GIGANTEA

CARABIDAE

ROVE BEETLE
As peripatetic as their name suggests, members of this family can be found among leaf litter, under rocks, and in the mud along waterways. Many prey aggressively on other insects.

SCARAB BEETLE
Essential to ecosystems, these beetles recycle plant matter and feces. Though some are brilliantly colored, it was a black dung beetle that ancient Egyptians revered as a symbol of rebirth.

DARKLING BEETLE
Beetles, many of them darkling beetles, make up a significant portion of desert fauna. Commonly eating dead, dry vegetation, this family lives in virtually every habitat, including rain forests.

METALLIC WOOD-BORING BEETLE
Often called jewel beetles because of their dazzling iridescence, this family is a favorite of collectors. Their feeding habits help speed the decomposition of wood in forests worldwide.

WEEVIL
Eight families make up the superfamily of weevils. Major crop destroyers, they chew into nuts, seeds, and plant stems. Among their vast number is the giraffe weevil of Asia.

GROUND BEETLE
A typically predaceous ground beetle prepares to use its elongated mouth to extract snail flesh from a shell. Most family members live on the ground, though some, in spite of their name, live in trees.

CICINDELA SP.

ELECOMARPA SP.

ATTELABIDAE, IN THE SUPERFAMILY CURCULIONOIDEA

CHRYSOMELIDAE

LONG-HORNED BEETLE
The antennae of many long-horned beetles, like this Asian species, approach or exceed body length. Recyclers of dead plants, some also have a taste for live vegetation.

LEAF BEETLE
Plant material, preferably living, is the diet of this family. Though some are destructive pests, others are used to biologically control noxious weeds. Many are important pollinators of flowers.

DASCYLLIDAE

A profusion of forms and functions

Small and mostly inconspicuous, beetles can nevertheless be viewed as evolution's biggest success story. About one-fourth of all animal species on Earth are beetles, an order that encompasses the bizarre, the destructive, the attractive, and the beneficial. The eight groups shown here account for two-thirds of all known beetles.

A key to the insect's adaptability is its elytra, a "shell" that is actually a pair of hardened wings. It protects and also serves as custom equipment, permitting some species to live in the desert by sealing in moisture and others to move underwater by trapping air.

Beetles fill critical ecological niches; their scavenging helps remove animal wastes, carcasses, and plant matter. As pollinators they aided the great explosion of flora in the Mesozoic era.

Disposal specialist, an African scarab beetle (below) rolls animal dung into balls, which are buried and fed upon by its larvae. A burying beetle (bottom) recycles a dead rat by laying eggs near its body, then feeding larvae bits of regurgitated carcass. Both of these beetles work in monogamous pairs, as do some bark beetles—though their work is less welcome. One species (opposite) riddles fir trees with channels where larvae will mature.

CINCILLIUM BACCHUS

Image Not Available

MICROPHORUS DARICELLUS (ABOVE); DENDROCTONUS PSEUDOTSUGAE

(Continued from page 106) Though Odegaard was addressing some big ecological questions, the fascination for me was in the details: the convoluted origami patterns in which chubby attelabid weevils rolled leaves to seal off their eggs from predators or the way some tortoise beetles clamped their transparent armor down onto a leaf like a limpet threatened by enemies. Some tortoise beetle parents guard their young for weeks, driving off parasitic flies and using the edge of their flattened elytra like a shovel to toss away ants.

An ordinary walk through an equatorial forest can reveal beetling multitudes, provided you bring along a kite-size white cloth stretched open by sticks. Collectors call it a beating sheet. Just stop every so often, hold it out, and club the hell out of the vegetation above to see what comes showering down. More often than not, you'll have lizards leaping off the sheet between shaggy, bright-eyed spiders and wasp-size ants looking to pay you back for their tumble. But you'll also have incredible beetles scuttling in all directions. And to identify them before they fly off, you have to reach into the hubbub and grab the big ones, jam them into containers, then whip out a special jar with tubing to suck up fully grown, elaborately sculpted marvels that may be no larger than this sentence's punctuation marks.

When I literally beat the bush for several weeks in the remote Congo Basin of equatorial Africa, two things happened. First, my attention focused down from the level of splashy butterfly wings to one where an odd freckle on a leaf might stop me cold. Bark became a terrain of hillocks and gullies, and I started seeing dirt as individual grains—all habitat for my quarry. Sifting through leaf litter, I gathered a number of slow, heavyset adult darkling beetles feeding on decaying vegetation. Uniformly dull black in color, they all seemed alike—until I noticed intricate patterns of pits, knobs, grooves, and ridges embellishing the wing covers. They made the darkling beetles as different from one another as the local gorillas were from their fellow primates, the chimpanzees, whooping in the distance.

The second thing that happened was that I came home with beetles unknown to science. Not that I was able to recognize them as such; Mike Ivie and his wife, LaDonna, did when I brought the collection to their entomology lab at Montana State University in Bozeman.

Mike later showed me one of the still unnamed new species under a microscope. He said, "We think it's a type of myrmecophile," literally, a lover of ants, in whose colonies a great and bizarre assortment of beetles have carved out niches. My beetle's antenna segments looked like toddlers' play blocks strung together—cone upon ball upon rectangle and cylinder. Yet it was Mike who also taught me that you don't need to trek to feverishly exotic places to find beetles stuffed in every cranny.

For several years following a 1988 wildfire, the Ivies surveyed beetle populations on the west side of Montana's Glacier National Park. "You might expect a northern conifer forest with snowcapped peaks to have a meager beetle fauna," Mike said, "but we came up with roughly the same number of species that we've recorded in the Virgin Islands"—over 1,200.

Hiking along a wolf-tracked floodplain, Mike paused at a charred pine and pointed out the pinhole-size borings of ambrosia beetles, which cultivate a wood fungus for food and carry its spores from tree to tree in special pockets on their bodies. Peeling back the bark exposed several ground beetles, which are typically voracious hunters. Many stalk caterpillars, in effect guarding woodland foliage from outbreaks of harmful moths.

Mike told me that 55 beetle species from this part of Glacier, including one genus so far found nowhere else in the world, showed up only in the old-growth stands. Wildlife managers in the Northwest have considered pileated woodpeckers and spotted owls indicators of healthy old growth. But accurate counts can take years, and the animals often visit other types of vegetation as well. By contrast, each stage of plant succession has a very distinctive community of beetles intimately bound to it. Sampling the beetles thus becomes a much more precise and efficient way to keep track of changes within forests—and most other kinds of environments. "These critters," said Mike, "are the ultimate indicator species."

For good or ill, some beetle species are chemical factories on legs. In Namibia the *Commiphora* tree is the host plant of this leaf beetle (below). When its larvae feed on the leaves, they produce a toxin—not found in the adults—which a Kalahari Desert Bushman squeezes onto an arrow tip. The poison on a single arrow can fell an adult antelope.

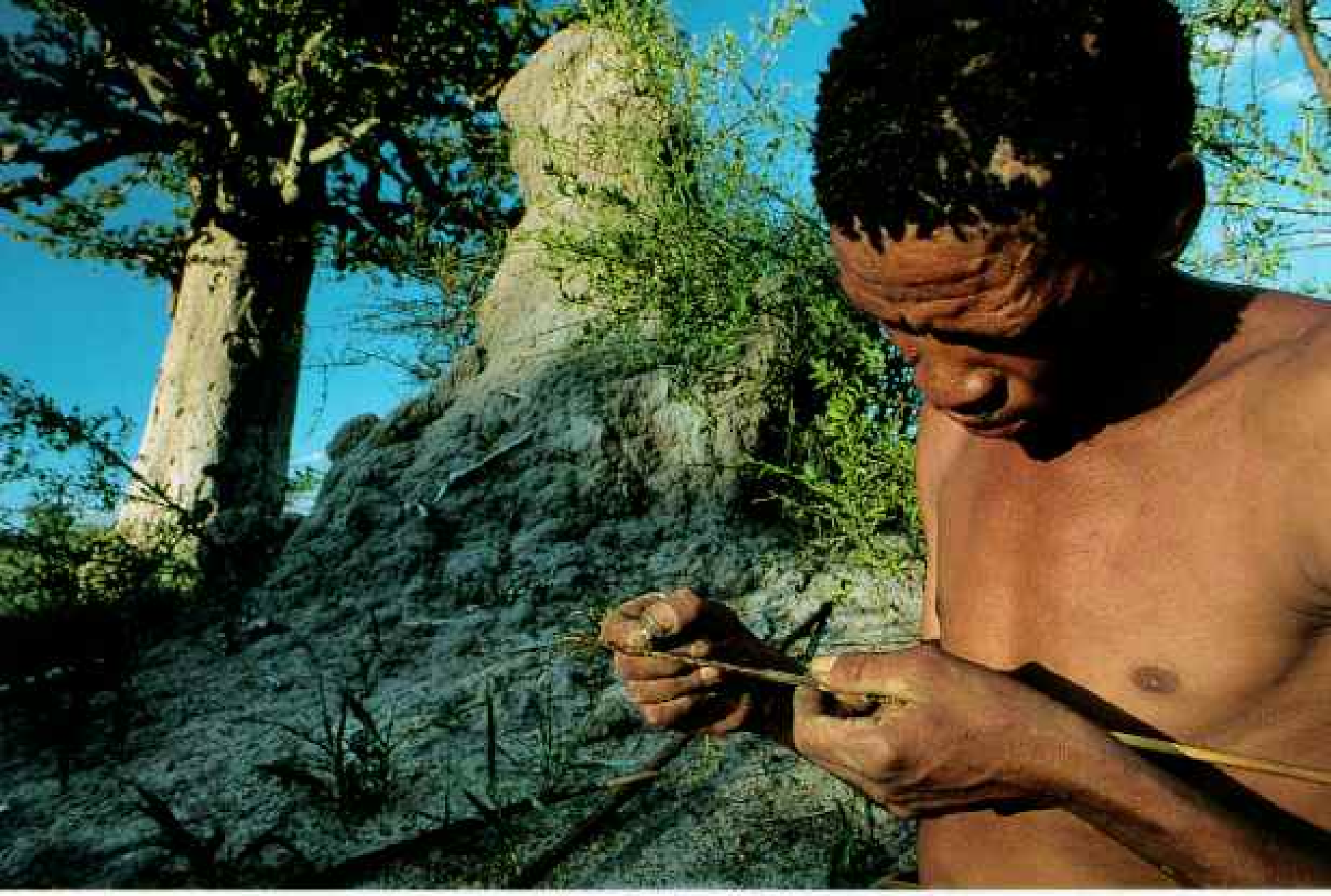
CHAMPYSSA NIGRICORNIS (?)

WHAT DOES IT MEAN, then, when a beetle is facing extinction? Nine U.S. beetles are on the threatened and endangered list. On Block Island, Rhode Island, dwell several hundred American burying beetles, *Nicrophorus americanus*. They constitute one of the largest single populations left of this orange-dappled, inch-and-a-half-long species once common across the eastern half of the nation.

Ancient Egyptians held another recycler, the dung beetle, to be a sacred symbol of rebirth, ever emerging from the ground. I wouldn't go so far as to worship beetles, but considering what our surroundings might smell like if those that consume carrion or animal droppings went on strike, I would definitely give thanks now and again. Among the legions of beetles that speed up decomposition and the recycling of nutrients through ecosystems, pairs of American burying beetles inter the carcasses of small mammals and medium-size birds to feed developing larvae. Where the ground is too hard, the male and female may lie on their backs underneath the body and push it along with their legs to softer dirt. They can lift animals 200 times their own weight and move them several feet.

Though no one knows for certain what caused the species' decline, some view it as an aftershock from the 19th-century slaughter that drove North America's most abundant bird, the passenger pigeon, to extinction along with the Carolina parakeet, heath hen, and other key food sources. Watching some of the scavengers in a Block Island field now protected from development, I thought of how far our society has come to bestow upon a gravedigging insect the same legal protection granted whooping cranes and humpback whales.

The most intriguing issue is not why some



beetles are in trouble but how the group as a whole continues to reign in such splendid profusion. I could hardly avoid the subject while high above Tucson, Arizona, on the summit of Mount Lemmon. The ground, tree trunks, and a growing portion of my body were orange with ladybugs, more properly called ladybird beetles. Entrepreneurs roam the countryside harvesting such mating congregations and deliver ladybirds by the bagful to companies that sell them as gardening supplies. By one estimate, the descendants of a single female can eat 200,000 aphids in one season.

Beetles have proved invaluable in the control of damaging insects and invading weeds, and they continue to be major pollinators. But some, like the boll weevil, which toppled the cotton economy of the American South during the early 20th century, are notorious munchers of crops, stored grain, or timber.

Back in the buffalo days a striped leaf beetle lived out on the Great Plains, contentedly eating buffalo bur, having mastered the trick of digesting the natural toxins that these plants in the nightshade family manufacture to defend themselves. Then settlers replaced the native prairie with solid rows of potatoes—also in the nightshade family—putting an obscure little critter on the road to big-time pesthood. By the late 1800s the problem had spread across the U.S. and was soon bound for Europe. We named it the Colorado potato beetle.

One of the first insects to come under broad attack from pesticides, the Colorado potato beetle was among the first to become resistant. Genetic variation, coupled with the insects' rapid rate of reproduction, kept yielding generations able to tolerate each new poison. The species is still thriving, costing farmers as much as $250 an acre in the latest chemicals.

Did the agrochemical folks really think they could brew up an easy way to erase organisms that have been reinventing themselves for 300 million years? There are blister beetles whose touch can start your skin peeling and bombardier beetles that shoot boiling hot mixtures from glands near their anus to repel enemies.

These creatures are like little chemical factories crossed with organic microchips crossed with Swiss army knives, able to add to their basic armored body plan the latest survival tool needed. Some beetles proceed through four or five dissimilar forms using separate habitats as they grow to adulthood. They are really several

Desert magician, a darkling beetle conjures moisture where there appears to be none. Even in Africa's harsh Namib Desert, dew forms at daybreak. As condensation forms on its shiny exoskeleton, the beetle tilts forward, sending water down its body and into its mouth.

DITMAR/BRUNDL/CLOREN

organisms in one, each subject to different natural selection pressures. This may boost the whole pace at which they evolve.

THE WORLD'S BIG WILDLIFE is under heavy siege, which makes being a nature lover seem more a burden than a joy at times. Yet as soon as I start poking around the plant stems in my backyard and turning over old boards or linger by the porch light on a midsummer night, the natural realm suddenly seems crowded again, wilder and more varied than ever, teeming with opportunities—the way it used to feel when we were children.

"As a boy, Dan was always vanishing when we went for walks in the fields," said his father, Don Schmidt, leaning on a tractor near Schuyler, Nebraska. "I'd turn around, and he'd have disappeared on his knees in the grass."

Dan, a slim, mustached man who raises pigs on his own place and helps his father with corn and cattle next door, laughed and said, "Like most kids I was crazy about dinosaurs. Then I discovered there are even stranger creatures underfoot. I became an avid insect collector."

As time passed and responsibilities grew, Dan dropped his hobby. A few years ago, however, he read a newspaper article by Brett Ratcliffe, a professor at the University of Nebraska in nearby Lincoln. Ratcliffe, a leading scarab beetle researcher, was asking people to help keep an eye out for the American burying beetle, recently rediscovered in the state. Intrigued, Dan visited the university, and Ratcliffe guided him through the museum's collections, rattling off information with infectious enthusiasm. I know, because Ratcliffe later guided me, pulling out drawers that included the most beautiful life-forms I had ever laid eyes on: weevils that were turquoise and amethyst mosaics; scarabs like thumb-size ingots of gleaming gold; rhinoceros beetles whose huge horned heads reminded me of *Triceratops*.

"I got excited about collecting again," Dan recalled. "I thought, I'm not the only crazy guy around—people actually do this for a living." At Ratcliffe's suggestion Dan concentrated on certain subfamilies of rove beetles that can be extremely difficult to tell apart. To gain a clearer understanding of the rove beetle family tree, taxonomists need to scrutinize the larval stages, but there had been very little luck rearing the larvae from eggs. Working in his home

The streamlined shape and shimmering scales of a New Guinea weevil would please any collector. Naturalists Joseph Banks and Charles Darwin were both avid beetle collectors even as children. With untold numbers of species yet to be identified, new discoveries promise more wonders for decades to come.

laboratory—a closet warren of shelves and jars next to the furnace room, plus a corner table in the living room—Dan devised a way to keep the larvae of one species thriving. The key? American cheese, which grows the fungi that feed the nematodes that Dan found the larvae require as food.

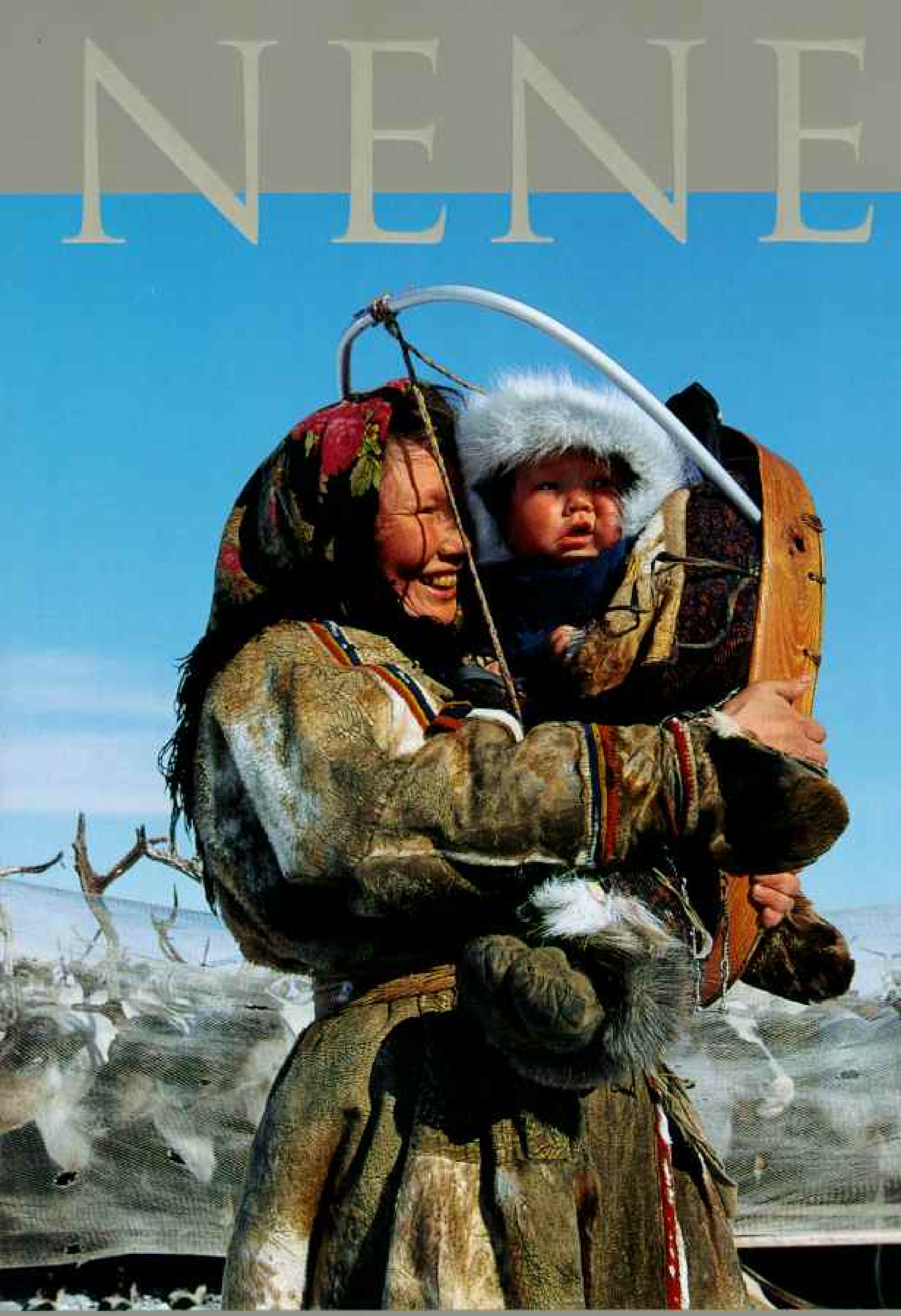
"Check out these guys." Dan set out a shallow dish of soil with rove beetle larvae and added primitive little insects known as springtails. Though nimble jumpers, springtails are wingless, and as they hopped about plump and pale, the beetle larvae came racing through the openings between clots of soil. Leaping and twisting, they impaled their prey between pincered jaws, shook them in the air, ripped them in pieces, and drained their vital juices. Staring through Dan's microscope, I was seeing cheetahs among antelope fawns, *Velociraptor* falling upon a herd of soft-bellied fellow reptiles.

"It's a fierce world down there," said my host, who has published three scientific papers and is preparing a fourth. Amateur naturalists have always made invaluable contributions to our knowledge about insects, especially beetles. Science sometimes seems intimidating, but, at heart, it is just about looking and asking questions. All you need is an advanced degree of curiosity. Read about Charles Darwin, an indifferent student but a fanatic beetle collector when young. Ask Dan, who corresponds with rove beetle specialists around the world.

The Schmidts invited me to dinner. It was the Fourth of July, and the table was crowded with relatives of all ages. By the time I left, night had fallen. I drove down the dirt lane past the corn rows with my car lights off, so I could see the show in the sky better. Skyrockets were bursting in the distance. Closer by, fireflies danced over low-lying fields dampened by recent rains. I thought they were more spectacular, for there were thousands of them: beetles becoming living explosions of light, ignited by their need to mate, to make more of themselves, to be alive. □

Eumolcus sp.

NENE



Surviving on the Siberian Tundra

As the pent-up energy of spring fills the air, a Nenets family prepares to follow its reindeer into the Siberian high Arctic. After weathering 70 years of communism, the Nenets now face the challenge of a capitalist energy boom on the Russian tundra.

By **Fen Montaigne**
Photographs by **Maria Stenzel**

A CARAVAN OF SLEDS glided over the snow-covered taiga of western Siberia. Near the head of the column Alexander Serotetta sat tucked in behind the muscled flanks of four reindeer. Steam rose from the animals' dun-colored backs, and their hoofs kicked snow into our faces. Serotetta's Siberian husky trotted beside us, his black head wreathed in frost. The only sound was of the sled, squeaking and crunching over the snow as we moved northward in the twilight.

Serotetta and the 18 members of his extended family in our caravan are Nenets reindeer herders. It was spring, and they were in the midst of their annual migration from the shelter of the northern forests, the taiga, to the treeless tundra of Russia's Yamal Peninsula 200 miles beyond (map, page 125). There, far above the Arctic Circle, the reindeer would calve, and the herd would find summer pasture.

Today about 10,000 of the 35,000 Nenets still move with the seasons, tending their reindeer. What's remarkable about these people is not that they are some ancient tribe just discovered in the wilds of the Russian Arctic but that they have survived the modern era—and communism—virtually intact. No other native group in the Arctic has hung on to its traditions as steadfastly. In Finland, for instance, the Sami now follow their reindeer in four-wheel-drive vehicles and on snowmobiles, and in eastern Siberia an overwhelming majority of the Chukchi and Koryak have ceased migrating in large family groups.

For nearly a week Maria Stenzel, a photographer with a penchant for high latitudes, and I had the opportunity to travel with the Serotettas. Accompanying us was Sven Haakanson, Jr., an Alutiiq from Alaska and a Ph.D. candidate in archaeology at Harvard, who was studying the Nenets for the Smithsonian Institution. Haakanson and the museum's Arctic Studies Center, co-sponsor of a program to document Nenets culture, had helped arrange our trip.

Visiting one of the Yamal's 50 Nenets brigades—an old Soviet term for herding groups that range from a dozen to more than 50 Nenets—is an experience in time travel. One morning in mid-April I was languishing in a small hotel in the Soviet-era petroleum boomtown of Nadym, an agglomeration of concrete high-rises grafted onto the taiga. That afternoon an Mi-8 Russian helicopter ferried me a hundred miles north into the wilderness,

FEN MONTAIGNE, Moscow correspondent of the *Philadelphia Inquirer* from 1990 to 1993, writes frequently about Russia. This is his first assignment for the GEOGRAPHIC. MARIA STENZEL is a freelance photographer whose coverage of the winter sea ice off Antarctica appeared in May 1996.

In thin forest just south of the tree line, a Nenets herder leads his reindeer across snow-covered pastures where lichens serve as winter fodder. Soon they will cross the Arctic Circle into the treeless tundra of the Yamal Peninsula, where the Nenets have been pasturing their animals for centuries.

and by evening I was perched on Alexander Serotetta's sled near the Arctic Circle, 40 miles from the closest village. As the reindeer moved at a trot across the frozen landscape, I surveyed a scene untouched by the modern world.

Serotetta, swaddled in a heavy coat of reindeer fur, was prodding the animals in front of him with a 12-foot birch pole.

"*Eeeeee-ohhhh!*" he hollered. "*Plah, plah, plah, plah, plah!*"

It was nearly nine o'clock, and an orange sun hung just above the horizon. That day's travel, an advance of six miles, had not begun until about seven in the evening, in part because the Nenets prefer to move when the bright spring sun is low, making it easier on their eyes. Nor do they like to rush. "Those who hurry on the tundra are in a hurry to die" is a Nenets saying.

Half a mile ahead of us was the sled belonging to Andrei Serotetta, 43, whose skill as a herder had earned him the position of

leader of his extended family group—Brigade 17. About 75 sleds were strung out more than a mile behind us, and the hundreds of reindeer in the caravan stirred up a faint white cloud of snow dust that hovered in the silver-blue light of the Arctic dusk.

AROUND 9:30 P.M. Andrei stopped for the night, jabbing his long birch pole into the crusty snow to mark where his *chum*, or tepee-like tent, would stand. With darkness falling, the rest of the brigade arrived, and the women unloaded wooden planks, iron stoves, handcrafted tent poles, and reindeer skins that form the chum walls. In no time they had assembled the chums and lit a fire in the stove in the middle of the floor.

Nenets women are responsible for the chum and everything connected with the domestic life of the family; the men handle the reindeer and everything to do with the tundra.

By midnight I was lounging on reindeer furs in Alexander Serotetta's warm chum, drinking tea and eating slices of raw, frozen sturgeon dipped in mustard sauce. Outside, the northern lights shimmered on the horizon. Shooting stars flamed out across the heavens as reindeer moved spectrally among the chums. Packed in with eight other people and eleven dogs, I fell asleep to the sound of reindeer

Women's work in the Nenets' nomad culture includes the assembly and disassembly of the family chum *(left), a tent made of larch poles and reindeer skins. Workers affiliated with Russia's giant energy conglomerate, Gazprom, live in barrel-shaped barracks raised above the permafrost at Bovanenkovo, a settlement in one of the huge gas fields underlying the Nenets' summer pastureland.*

pawing up the snow to get at the lichens below.

The remoteness of this place—along with the Nenets' sense of identity and cultural pride—has enabled them to operate at the fringes of the modern world without being swallowed up by it. "These are indeed people who live in a totally different dimension," says Andrei Golovnev, director of the ethnology section of the Ural Institute of History and Archaeology. "They do not want to be the same as everyone else. They just want to be what they are. The Nenets believe they're the best reindeer herders in the world. Such absolute certainty of their superiority, the belief that they are special people, allows them to survive."

At one of the herders' regular campsites a boy slumps on a chest filled with frozen food and topped with fresh meat. As the nomads move north across the melting snow of late spring, they will shift to lightweight summer sleds that their reindeer can pull across the fields of damp tundra grass.

Golovnev, who has spent years living with the Nenets, says they're willing to rub shoulders with the modern world, taking from civilization what they like, such as tea and transistor radios, and rejecting what they deem superfluous. "They're quite flexible," he says. "This ability to change when the times change is a tradition."

The Nenets may soon experience an extreme test from the outside. The Yamal Peninsula holds what may be the largest natural gas reserves in the world—about 300 trillion cubic feet. (United States reserves are estimated at just over half that.) Working out of Bovanenkovo and other settlements, more than a thousand shift workers are laying the groundwork of a new industry: the towering derricks of exploratory wells, clusters of prefabricated buildings, roads crisscrossing the snowy landscape, a railroad. Large-scale production is expected to begin early in the next century, and some Nenets worry that they'll be left with a despoiled tundra, shrunken grazing lands, and a minimal share of the huge profits expected from gas production.

"I think gas will get in the way, take up our land," says Vladimir Salinder, at 64 the brigade's oldest herder. "The drilling wells spoil the land. The reindeer get sick from all that dirt and trash. The railroad they are building is

STEN HAAGANSON, JR.

Inside their chum, where women sew clothing of reindeer hides, Nina Serotetta and her son drink spoonfuls of reindeer blood. Home to seven people and eleven dogs, the chum stays warm in subzero weather with the aid of an iron stove vented through a smoke hole above. Space and social life are highly regulated within the chum, and the sewing materials will be stored in a special area reserved for women.

no good for us either. There will be too many people, too many machines."

In the long run the greater challenge for the Nenets may come from the incursion of modern life. "I think they'll gradually be diluted," says Alexander Steshenko, a construction engineer in Bovanenkovo. "Do the Indians in America still live in wigwams? With time, everything passes."

ONE OF THE PEOPLE in my chum, Aleksei Serotetta, Alexander's younger brother, was the embodiment of the Nenets' timeless spirit. A sinewy 24-year-old with a copper-colored face, high cheekbones, and a scraggly mustache, Aleksei can lasso galloping reindeer with ease and make a sled from larch, without nails or modern tools, in less than a week.

After a day on the tundra Aleksei, who had served two years in the Soviet Navy, would entertain us by singing pop songs in tortured English and doing Michael Jackson's moonwalk. But Aleksei knew where he belonged. "Give me fresh air on the tundra, not the stink of gasoline in the cities," he told me one night after pursuing stray reindeer for four hours in a blizzard. "We should never forget about traditions."

At the heart of traditional Nenets life is the domesticated reindeer. Reindeer, also called caribou, are everything to the Nenets: their food, clothing, shelter, transportation, even their sense of identity.

"Man and deer become almost related," Andrei Golovnev wrote in his book *Talking Cultures*. "The first thing a newborn baby touches outside the womb is the deerskin in which it is wrapped by the midwife. A dead man is also wrapped in deerskins. And between these first and last encounters, a person lives with the deer [and] thanks to the deer."

A herder relies on the instincts of his lead reindeer. When lost in a blizzard with no hope of finding the camp, he'll look to the lead reindeer to show the way. If the animal hesitates, or perhaps sneezes, while attempting to cross a frozen river, the herder will turn back or look for a new crossing point. In Nenets mythology the fate of a hero can be foretold by what happens to his lead reindeer; if the animal is

At the annual spring festival at Yar Sale the Nenets test their reindeer's mettle with team racing. Soon the animals' homing instincts will be tested, as the deer follow ancient migration routes to the pastures of the far north—there to fatten until fall snows prompt them to return south.

shot down in battle, the hero too will soon die.

Nenets women depend no less on reindeer in their daily lives, making use of almost every part of the body. One morning I watched Anna Serotetta, the grandmother in our chum, using her teeth to separate a sinewy substance into strands, which she then rolled between her palms. The material came from a reindeer's tendons, and she was turning it into sewing thread. Anna and all the women spend many hours a week sewing reindeer skins to make boots, leggings, coats, hats, and other pieces of clothing. The garments are extraordinarily warm, offering protection from winter temperatures that routinely drop well below zero. The women also help butcher the reindeer, storing the meat in old wooden chests that serve as freezers.

Nenets women use the natural gifts of the taiga and tundra as well, drawing on knowledge passed down through the generations. One day Anna Serotetta scratched under the

snow and pulled up handfuls of a strawlike grass she used to insulate her boots. Another substance, a cottony pulp scraped from under the bark of birch trees, substitutes for toilet paper and is used for diapers.

These practices must have been around a long time. Archaeological evidence suggests that people were living on the Yamal Peninsula some 5,000 years ago, no doubt surviving by hunting sea mammals and caribou. People apparently began domesticating caribou on a small scale about 2,000 years ago, but the tradition of mass herding that Aleksei holds dear goes back no more than 400 years, when the Russian Empire was expanding eastward from Moscow. (The Nenets were then known as Samoyeds, which some historians interpret to mean self-eaters, perhaps because the Russians mistook their fondness for raw caribou meat and blood as cannibalism.) In the face of the Russian advance, other native peoples fled deeper into the taiga, encroaching on the Nenets' caribou hunting grounds. The Nenets reacted by switching to herding the caribou, a portable livelihood that enabled them to flee northward into the empty reaches of the Yamal Peninsula.

THE NENETS seem as stubborn as their land. During the 1930s Stalin executed and exiled dozens of their spiritual leaders and many wealthy reindeer herders. The communists forced Nenets children to attend boarding schools and organized the herders into state-controlled brigades, a collectivization program aimed at breaking down clans and separating the people into manageable units. The Soviet system propped up the reindeer economy with large subsidies to collectives. The Nenets played along with these changes, selling their venison to the state and outwardly accepting the brigade system. But their centuries-old migratory traditions and clan allegiances were stronger than a Moscow-imposed ideology. As many elders predicted, Nenets traditions outlived those of Marx and Lenin.

Today two-thirds of the reindeer are privately owned, and demand for venison has plummeted because it's too expensive to get it to market without state price supports. The herds are growing, and there are now more than 175,000 reindeer on the Yamal, which, some ecologists say, has enough lichens and other plants to support 120,000 at most.

"The crisis on Yamal is overgrazing," says Grigory Vilchek of the Russian Academy of Sciences. "You see the vegetation destroyed in some areas. In a few years this territory will be a real desert." As much as half the peninsula may already be overgrazed, and although Russian and Western scientists are studying the problem, little is being done, in part because some Nenets leaders refuse to accept that overgrazing is a serious threat.

During the trek to new pastures the chum offers a sturdy but movable haven. One morning I awoke and stared at the 40

ОКРУГА.

Nenets in Yar Sale catch up on the news while displaying their finest reindeer coats and boots. Though the Soviets collectivized the herds and introduced state schooling for the children, about a third of Russia's 35,000 Nenets have kept their nomad culture almost intact.

smoke-blackened larch poles that made up the skeleton of our chum, coming together at a small opening 20 feet above my head. The first sound I heard was that of grandmother Anna Serotetta stoking a fire in the iron stove. Dim light filtered through two thick plastic windows into the chum, which was about 18 feet in diameter. Lying with their feet to the fire, like the spokes of a wheel, were family members spanning six decades and three generations, and their two American guests. On my side were Alexander, his wife, Antonina, and their six-year-old son, Oleg. (Their four older children were away at boarding school at Yar Sale.) Across the chum were Alexander's brother and sister, Aleksei and Nina; Kostya, Nina's five-year-old son; and Maria Stenzel.

The family dogs—some tied to the chum poles, others sprawled over drowsing Serotettas—scratched themselves and watched attentively as the tent came to life. Nina and Antonina prepared tea, and our group ate a Nenets-American breakfast: raw, frozen fish from the Serotettas' supplies and peanut butter, chocolate, and dried fruit from ours.

Afterward I joined the entire brigade as the herders gathered under an enormous blue sky for the daily task of lassoing the reindeer needed for that day's work. About 250 of the brigade's 3,000 reindeer, those specially selected to

One state tradition still observed at a boarding school in Yar Sale, weekly cleanup at the bathhouse is not an elective. By law Nenets children spend much of the year in school. Bilingual in Russian and Nenets, these boys will face a choice: to follow the herds—now generally back in private hands—or to enter the Russian mainstream. For most the choice will be clear, as nomad tradition continues to exert a powerful draw on Nenets youth.

pull sleds, are kept close to the chums; the rest graze several miles from the camp. With whoops of encouragement, the brigade's five younger men lassoed reindeer as they trotted around the chums, then led them into a makeshift pen. The older men, women, and children, brandishing long poles, drove other animals into the pen. Some reindeer were harnessed for sled work, the others released.

Because several brigades were moving north at the same time, the search for fresh pastures was of the utmost importance. Clumps of white and pale green lichens buried under the snow are the staple food of the reindeer in winter and well into spring, and a 3,000-head herd can strip a lichen field in a day. Alexander Serotetta and two other men hopped on their sleds and, with Maria and me in tow, headed out to move the main herd.

We bounced across a gently rolling landscape of stunted birches, larches, and firs. About two miles from the camp the herders and their Siberian huskies began driving the reindeer off a hill and into an adjacent valley, the men leaning out of their sleds to prod recalcitrant animals with long poles. Twelve thousand hoofs crunching through the snow made a whooshing rumble, which was accompanied by the clatter of antlers. The animals seemed to move over the taiga as one, and the only sign of the 20th century was a white jet trail in the southern sky.

ANOTHER SUNNY AFTERNOON I was treated to a virtuoso herding performance. More than 200 of our brigade's reindeer had strayed into a herd of 2,000 animals belonging to a neighboring brigade. After visiting briefly, the Serotettas and five men from the other brigade traveled the several miles to the herd to winnow out the Serotettas' reindeer. With the help of their dogs, the herders ran the reindeer back and forth across a long hillside. Standing amid the stampeding animals, the men lassoed the strays as they thundered past. A herder would grab a snagged reindeer by the antlers, wrestle it to the snowy ground, then hobble it by tying its front and hind legs together.

Herders know their reindeer individually, either by notches cut into their ears or other identifying marks. Earlier I'd asked Vladimir Salinder, our brigade's elder, how they could possibly identify each reindeer.

"Do all people look the same to you?"

"No," I replied.

"Well," he said in a voice raspy from cigarettes, "neither do all these reindeer look the same to us."

The lassoing went on for hours, with the men laughing and needling one another whenever one of them missed an easy mark. Slowly the vagrant reindeer from our brigade began piling up on the hillside like casualties on a battlefield. Many of the females were pregnant and lay immobile, their abdomens distended and their black eyes wide with alarm.

The Arctic sky went from pale gold to pink

The nomadic life requires 75 sleds for the 19 people of Brigade 17, whose name is a holdover from communist times. The frigid April landscape is more secure ground for the Nenets than is their future, but their remarkable ability to coexist with modern culture may safeguard the Nenets' own.

to fiery orange as the sun set. Around 9 p.m., in the twilight, the men of the neighboring brigade guided the flowing gray mass of their herd away up the opposite hill. The Serotetta clan unbound the animals and sent them on their way with a slap or a kick. Heads high, the reindeer trotted at full speed toward the main Serotetta herd.

Although the men and women of Brigade 17 were willing—even eager—to share reindeer stories, they were reluctant to talk about their spiritual beliefs. Only one person in the brigade, Nina Serotetta, raised the subject of the spirit world with us, and that was after Maria Stenzel and I had unwittingly violated the Nenets' tightly prescribed rules of behavior. Maria had stepped across several of the men's sleds and driving poles, which is forbidden because the Nenets believe a woman can sap a man's strength or exert magical control over him by walking across his possessions.

Late at night in the chum Nina gently

admonished me for something else. "You know that we have these little people [dolls], these spirits whom we venerate," said Nina, an amiable, bespectacled woman whose features reflected an ancestry that seemed part Russian. "Someone told me that today you sat on the sacred sled carrying a box of these little people. That's not supposed to be done, and he wanted me to mention this to you."

The Nenets believe that the harsh surroundings of the tundra symbolize an unseen world where the forces of good and evil vie for control. Thus the sky god, Num, and the underground god, Nna, are forever at war, setting the rhythm of the seasons and influencing the weather. In summer the sky god triumphs, the sun is high, and the eagles soar. In winter, when the god of the underworld is victorious, darkness and cold descend on the tundra.

"For the Nenets, nothing is simply beautiful," Andrei Golovnev told me. "There is no such thing as a beautiful moon. The moon is a being that meddles in their affairs every month and dictates how they live. For them, beauty is the ABC of what makes the world tick."

Scattered throughout the Yamal are sacred sites where herders go to sacrifice deer to the gods, to bring them gifts of reindeer antlers and fox pelts, and to say prayers for the sick. When someone dies, his body is placed under an overturned sled, because the Nenets believe that it is sinful to bury a body in the ground.

ON OUR LAST DAY with the Nenets, we got a taste of the Yamal's fierce climate. We awoke to a blizzard, with the wind howling, shaking the walls of our chum. As the Serotettas came and went, opening and closing the entrance flap, blasts of snow followed them inside.

The brigade was now about 30 miles south of the Gulf of Ob, gateway to the Yamal Peninsula and the spring calving grounds. The men spent most of the morning outside, sitting in the snow, carving new sleds and poles. They held axes with their bare hands, and as they hewed away in the frigid air, the shavings piled up around their legs.

I was drinking tea in the chum when the helicopter came. Incredulous that anything was flying on such a day, I ran outside just as an orange-and-blue hulk smeared with engine soot landed near the chums, sending snow flying in all directions. I shook hands with the herders and walked up to Anna Serotetta, the grandmother who had observed me closely for a week but had scarcely said a word to her strange guest. I extended my hand. Anna Serotetta grabbed me by the shoulders and kissed me on the cheek. She was still smiling when Maria and I boarded the helicopter.

The aircraft rose slowly, hovering above the chums as the pilot turned south toward Nadym and the 20th century. The Serotetta clan stood and waved, and we waved back through the small windows. We rose higher, banked, and the Nenets of Brigade 17 disappeared in the swirling snow. □

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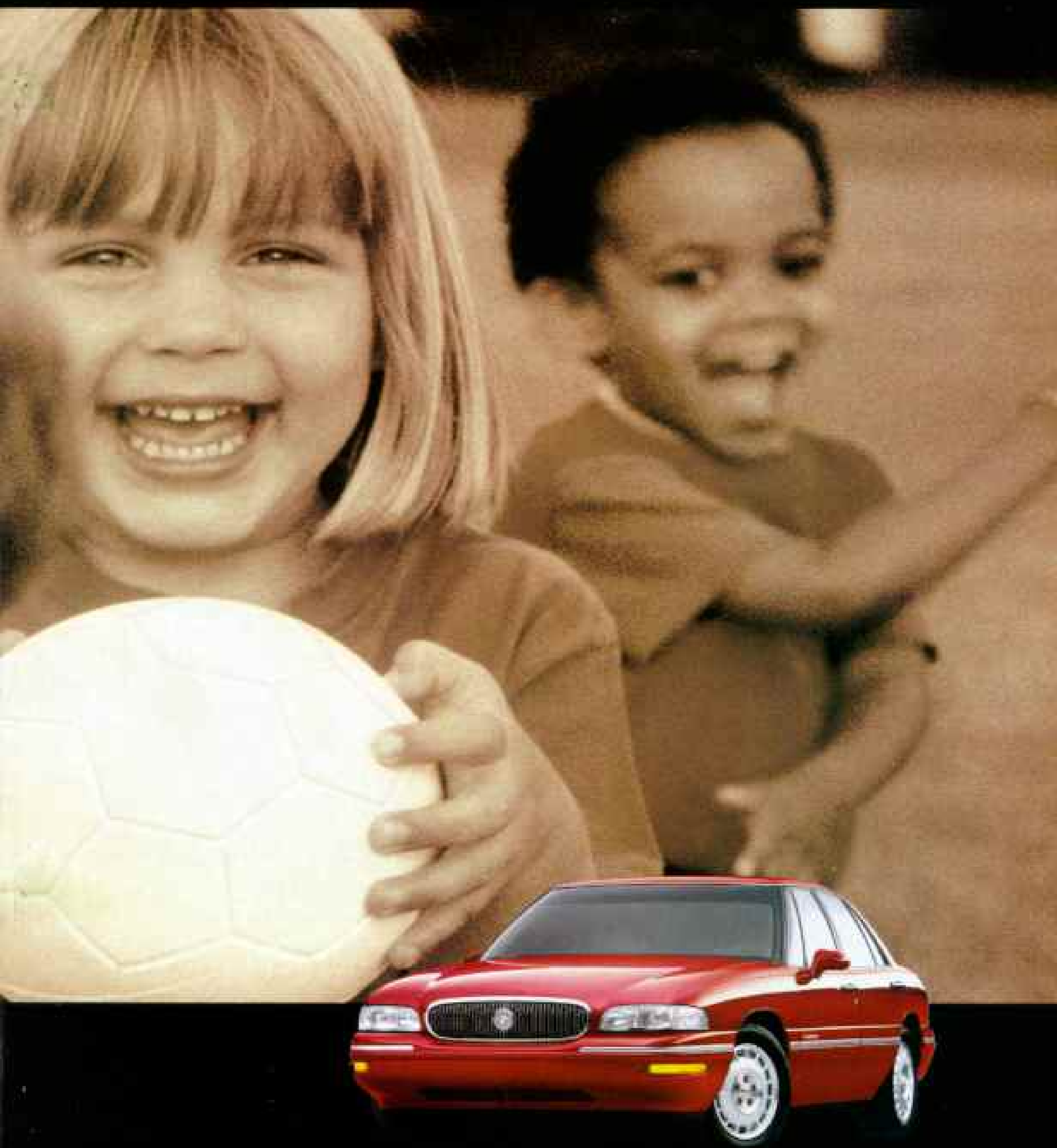
WILDLIFE



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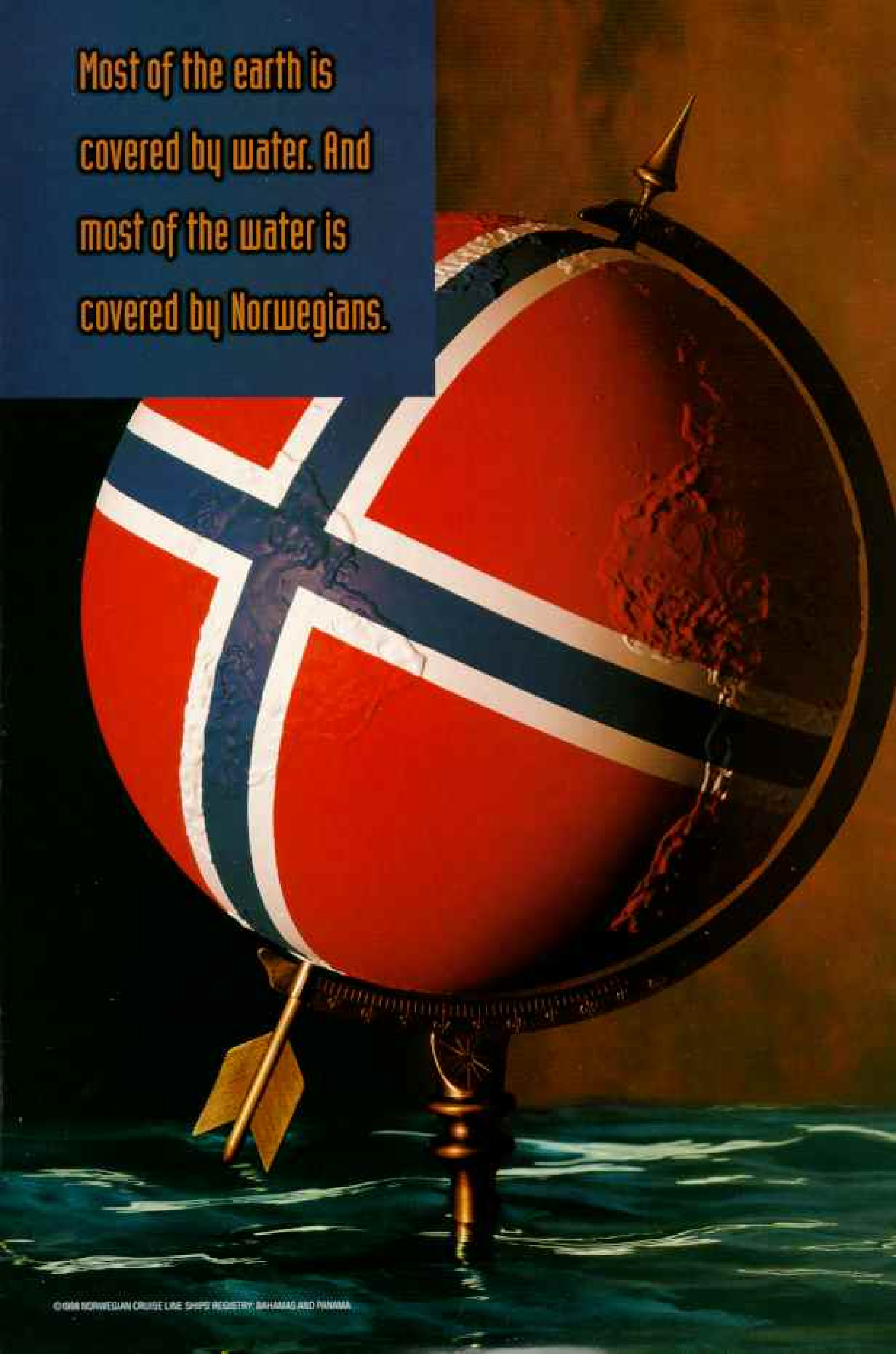

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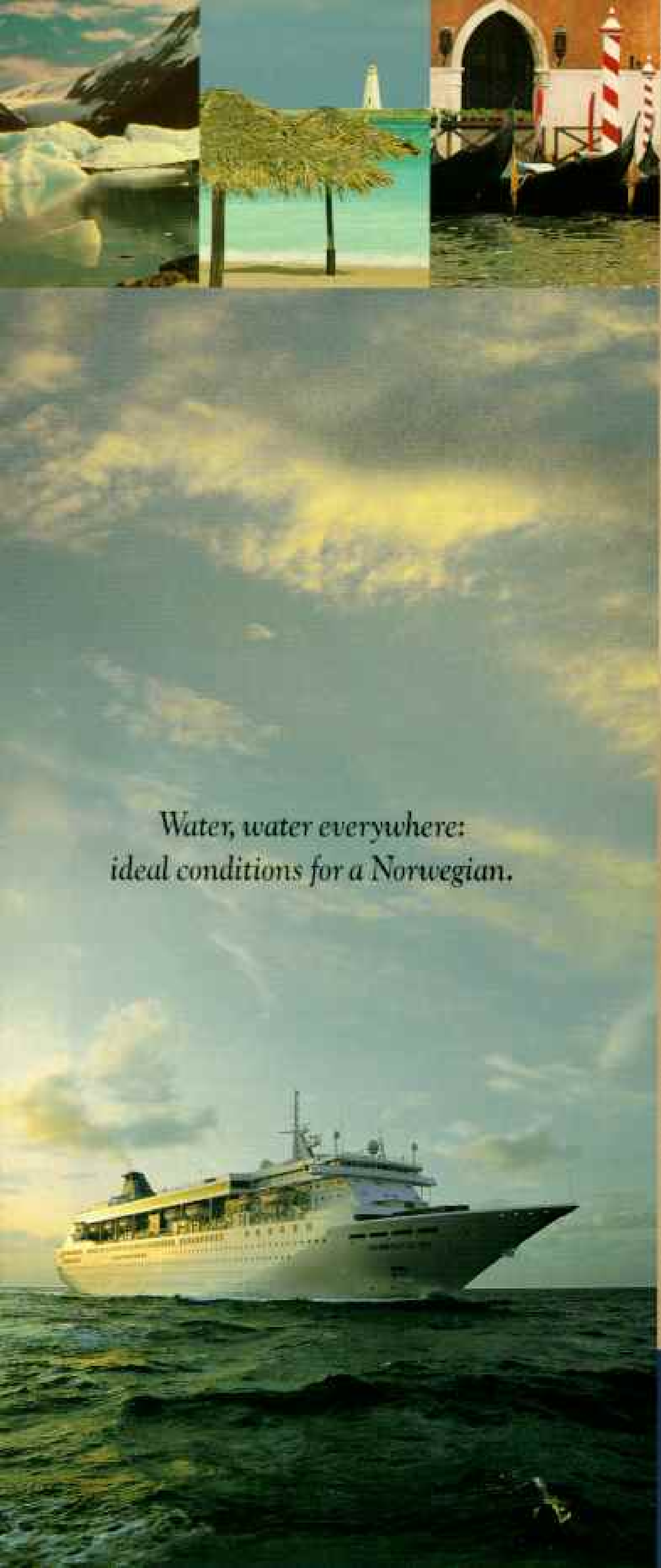

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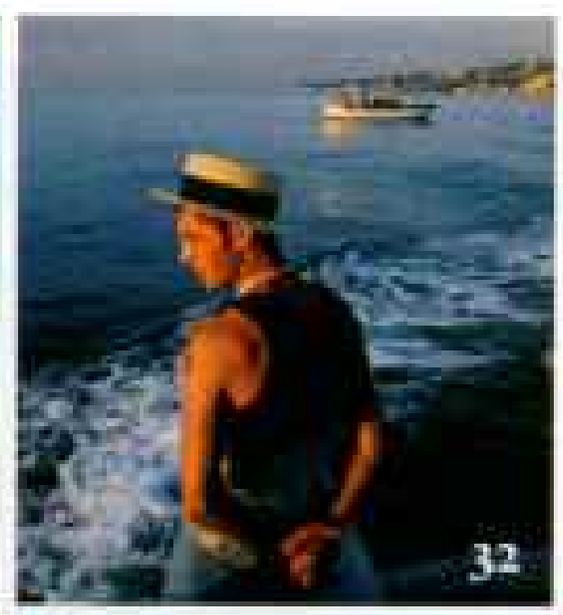

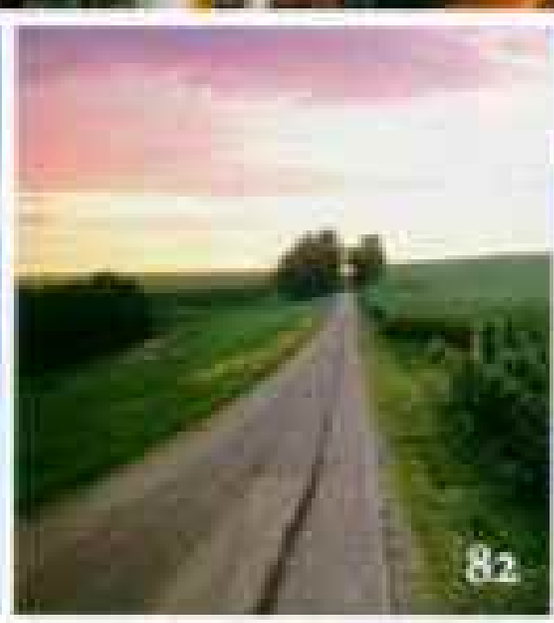

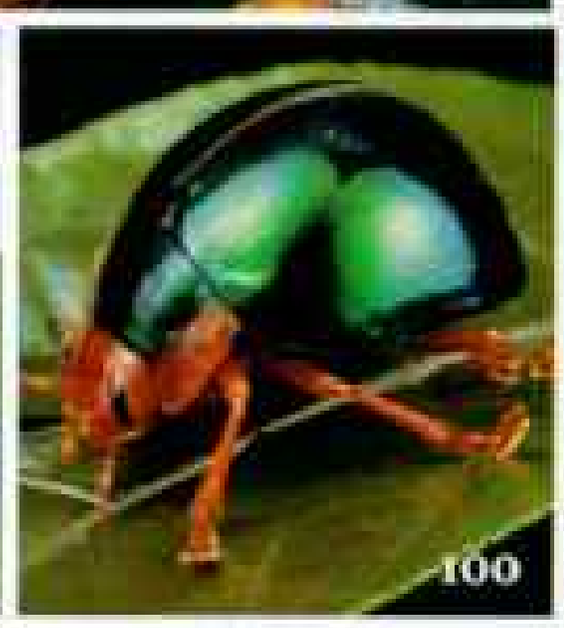

2 **Blue Refuges** *Charged with protecting U.S. ocean treasures, 12 national marine sanctuaries encompass 18,000 square miles of coral reefs, elephant seal rookeries, kelp forests, and whale feeding grounds.*
BY DOUGLAS H. CHADWICK
PHOTOGRAPHS BY DAVID DOUBILET AND FLIP NICKLIN

32 **Naples Unabashed** *A city schooled in passion, chaos, and the art of making do, the Italian metropolis embraces its virtues and grapples with its problems—without apology.*
BY ERLA ZWINGLE PHOTOGRAPHS BY DAVID ALAN HARVEY

54 **The Rise of Life on Earth** *Microscopic life-forms, our planet's pioneer inhabitants, bequeathed the oxygen we breathe, the DNA and proteins that drive our cells, and the photosynthesis that feeds us.*
BY RICHARD MONASTERSKY PHOTOGRAPHS BY O. LOUIS MAZZATENTA

82 **America's First Highway** *The National Road, part of today's U.S. Route 40, was built between 1811 and 1838 to connect the port of Baltimore to the Mississippi River.*
BY WILLIAM R. NEWCOTT PHOTOGRAPHS BY MELISSA FARLOW

100 **Planet of the Beetles** *From humble ladybugs to brilliant scarabs, beetles both help and bedevil us. A third of the world's identified insects are beetles, and they are everywhere.*
BY DOUGLAS H. CHADWICK PHOTOGRAPHS BY MARK W. MOFFETT

120 **Nenets: Surviving on the Siberian Tundra** *Having endured the communist collectivization of their reindeer herds, these nomads now face capitalist development of the huge gas fields underlying their pasturelands.*
BY FEN MONTAIGNE PHOTOGRAPHS BY MARIA STENZEL

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The Cover

Fierce appearance belies the harmless nature of this long-horned beetle, which inhabits the rain forest of French Guiana. Photograph by Mark W. Moffett

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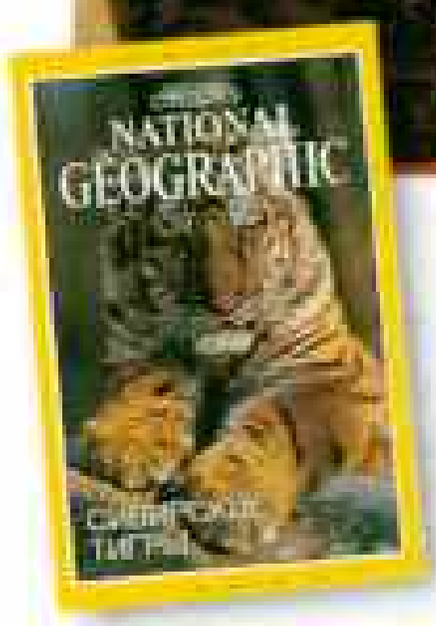
Behind the Scenes

CALLIE SHELL, THE WHITE HOUSE



Our Russian Tiger Tale

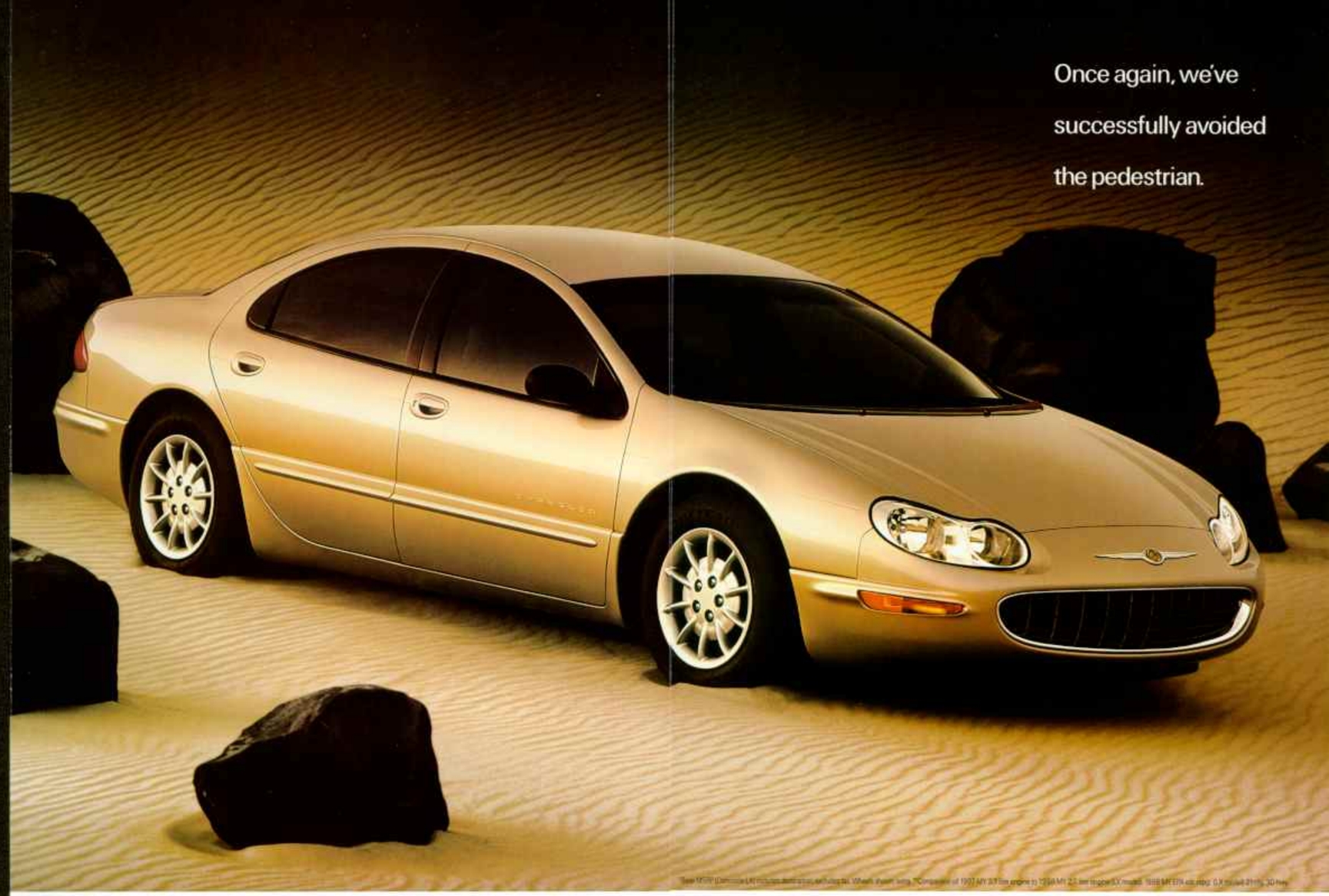
There was some extra reading for the Russians during last September's meeting of the Gore-Chernomyrdin Commission in Moscow. The group, led by U.S. Vice President Al Gore and Russian Prime Minister Viktor Chernomyrdin (above, at top center), convenes twice yearly to discuss mutual interests, including the environment. GEOGRAPHIC Assistant Editor Don Belt covered the meeting—he wrote our February 1997 article "An Arctic Breakthrough," which reported on some of the commission's work. Don brought along 2,000 reprints in Russian of our story on Siberian tigers (inset, above) from the same issue. Prime Minister Chernomyrdin recently helped push through federal protection of tigers in Russia. "We'll put these magazines to good use," he said, when Vice President Gore presented him with the reprints. The prime minister was right; at least one member of the Russian delegation got an early start.

DAVID ALAN HARVEY

She Who Hesitates Is Crushed

Longtime New Yorker Erla Zwingle thought she knew traffic, but the author of our Naples story hadn't yet seen Neapolitan drivers. Pedestrians cross streets without looking; cars don't stop. "It works somehow," she says. "But I was petrified."

We started with a clean sheet of pavement.



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If your eyes only knew what they were missing. Of course, the road can't go on forever (an equally regrettable fact, perhaps). But, although you may stop, the thrill need not. Simply look around you. The first thing you'll notice in the new Concorde LXi is room. You'll also notice how lavishly we appointed that room. Rich leather trim starts at your fingertips and continues down to the exceptionally comfortable seat of your pants. Instruments and controls are

Its exhilarating performance will have your eyes glued to the road.

Pity.

LXi interior

strategically placed to be where you want when you want them. Front seats are eight-way power adjustable for individualized comfort. A 240-watt sound system with nine speakers is designed to envelop you. There's even a temperature control system that automatically keeps the cabin at your preferred comfort level. To learn more, call 1.800.CHRYSLER or visit www.chryslercars.com. To be sure, there's much more we wouldn't want to overlook.

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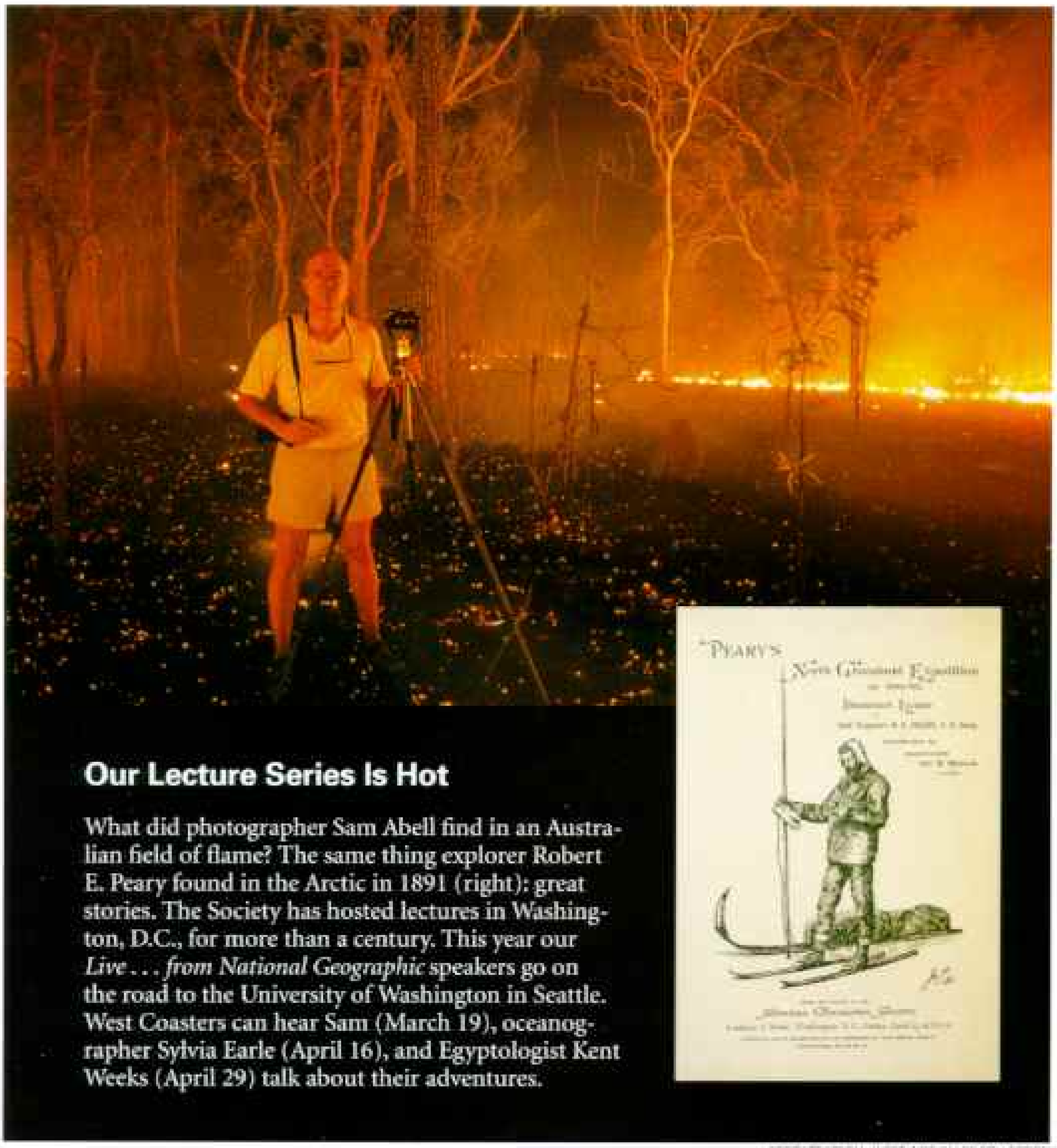
to a more passionate side.



KENNY TRAPNELL; INSET, NGS IMAGE COLLECTION

Our Lecture Series Is Hot

What did photographer Sam Abell find in an Australian field of flame? The same thing explorer Robert E. Peary found in the Arctic in 1891 (right): great stories. The Society has hosted lectures in Washington, D.C., for more than a century. This year our *Live . . . from National Geographic* speakers go on the road to the University of Washington in Seattle. West Coasters can hear Sam (March 19), oceanographer Sylvia Earle (April 16), and Egyptologist Kent Weeks (April 29) talk about their adventures.

She's on the Ball

Football players have heroes too. Jeff Lageman of the Jacksonville Jaguars nominated his former teacher Judy Miller, now at Virginia's Loudoun Valley High, as NFL Teacher of the Month. Graduate of two Society geography teachers institutes, Miller won $2,500 and a scholarship for Lageman's school.

TEXT BY MAGGIE ZACKOWITZ

MARK THIESSEN, NGS

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Forum

"North Woods Journal," an intimate photo essay in the November 1997 issue, drew fervent admiration as "a feast for the eyes" and for "sensing the moments when life and nature speak to one's heart." Although "Quebec's Quandary" generated complaints from a number of French Canadians, one wrote, "I could find nothing that wasn't factual."

Aging

In pursuit of eternal middle age or at least of a healthy longevity, any activity is certainly beneficial but especially that which defers to the ancient injunction, "If you wish to live long, live slowly."

LOUIS MICCIO
El Paso, Texas

Just because one ages, one doesn't have to act old, health permitting. Two years ago my daughter bought a Jet Ski, and it was love at first ride for me, a 72-year-old senior. The faster we go, the rougher the ride, the more I enjoy it. When her fiancé offered me a ride on his Harley, I said, "Why not?" and off we went. No, I am not ready to buy a leather jacket yet, but I did order a Jet Ski from Santa Claus.

JEANNE MOEDE
Milwaukee, Wisconsin

Rick Weiss's article brought both tears and laughter with each turn of the page. I was given not one point of view but several, which I can think about to create my own. I was given an inside look at some lives of the older generation, enough to gain my utmost respect.

ERIC BEELER
Austin, Texas

Well into my 80s, I find the most difficult part of aging is being left out of the exciting things of life. With age our bodies weaken and our minds slip. We seek comfort in old age, but not all of us are able to achieve it on the money we laid by. Doctors' remedies are very expensive. Scam artists in the financial world watch our every fumbling step. I agree with the adage: Old age ain't no time for sissies.

HARRIET FRYE
Hampton, Virginia

At 67 years of age, I thought I was healthy as a horse, but after reading your article telling me my brain is shrinking, lungs collapsing, arteries thickening, and that everything else in my body is going to hell because of aging, now I feel sick as a dog. Thanks a lot.

JOSEPH V. MELIDOSIAN
Belleville, Michigan

To subject rhesus monkeys to constant hunger in the name of longevity studies when humans have shown themselves incapable of restricting food intake is absurd. The monkeys go crazy grasping at their meager rations. What is the benefit?

There is already a large body of evidence proving that vegetarian diets low in fat reduce the risk of disease. This type of diet can be delicious and filling without the feeling of deprivation that a dramatic caloric reduction causes. Yet most humans in Western cultures are unwilling to make even that type of change in diet.

SHEILA COLSON
Fremont, California

The most significant hazard of reaching age 85 is dementia (Alzheimer's and related disorders). In the U.S. today more than four million people have dementia. By the year 2015 the number will increase to ten million. Their nursing home costs now exceed $72,000 a year in the New York City area.

STAN J. MARCEWICZ
River Vale, New Jersey

Quebec's Quandary

I am pleased that your article opened in the Saguenay Valley. The Saguenay Fjord is truly one of the great natural wonders of North America. My wife is from that area, and I have visited regularly. The isolation of the Anglophone community from the larger Francophone community and the resistance to accepting French as the official language of the province are a big part of Quebec's problem. I believe former premier of Quebec René Lévesque best articulated the political position of most *pure laine* Québécois when he said, "French Canada is a genuine nation and contains all the elements essential to nationhood. . . . without sovereignty."

SCOTT BLAIR
Rockville, Maryland

The nitty-gritty of the French-Canadian problem includes the fact that instead of keeping French in the province of Quebec, French Canadians have forced the rest of the country to become bilingual regardless of the cost. Yet in Quebec few English signs are provided. If Quebec separates, how will she handle paying her share of the federal debt and support her own police, military, customs, airline, etc.? What happens to all the Québécois who currently work in Ottawa? What happens to all the federal buildings in Quebec? I suggest that Quebec learn to live with the rest of a great country.

ROBERT V. GREENSHIELDS
Arcadia, California

If English speakers really see federal and provincial efforts to preserve a French identity for Canada as "appeasement" to nationalists and French culture only as colorful street parties, then it's no wonder that for many Québécois it is time to move out on their own.

SCOTT F. EATON
Manchester, New Hampshire

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Portrait of a Hutsul Village

A sincere thanks to author Lida Suchy for revealing the inhabitants of the Carpathian Mountains of Ukraine. Recalling my childhood memories from prewar times as a resident of Vorokhta, a resort in the Carpathian Mountains, I remember getting up on winter mornings and seeing the charm of this wonderland through my window. Snow, beautiful snow everywhere.

EDWARD KUCHAR
Howell, New Jersey

Being a first-generation Ukrainian American, born and raised in New York City, I traveled to Ukraine a few times with my father to learn about my roots. I was honored to stay overnight in a Hutsul family's home. The modern Hutsul family increasingly lives in a large, modern home and owns a car. Often an extended family builds next to parents' and grandparents' houses. Sometimes these new homes are rather palatial, in contrast to the old, yet sturdy and functional, log cabin homes.

OLEH PICH
New York, New York

Why in the world would NATIONAL GEOGRAPHIC publish this article with black-and-white photos? This is undoubtedly a beautiful and colorful area, whose people have colorful handiwork. Black-and-white photos belong in obscure art journals where they can be admired by people who like them. Your readers want to see the world as it is, in color.

MARGARET HINKLE
Arvada, Colorado

To me black-and-white photography is a much more satisfying way, emotionally and viscerally, to view the world. The opportunity to enter into an image is impeded by the use of color; colors do too much of the work. I hope you will try to use more black-and-white in future issues.

TOM M. THEOBALD
Peoria, Arizona

Black-and-white photography forces us to feel something. Can anyone visualize the great WPA Dust Bowl photographs in color?

ERIK SCHNACKENBERG
Fulmorville, New York

North Woods Journal

For years we casual photographers have comforted ourselves with the notion that professionals take hundreds of pictures to get a handful suitable for your pages. Then along comes Jim Brandenburg with his 90 consecutive frames on 90 days, each more breathtaking than the last. Photography is an art, and Mr. Brandenburg is an artist.

DEBORAH S. WEBER
Chicago, Illinois

I fell in love with art at a very young age. Later I worked hard in various classes to produce what I considered art in the field of photography, but I never lived up to my own expectations and shelved photography and moved on. Your presentation has renewed in me a passion for capturing the art I see every day—from the reddening pear trees on my way to school to the eyes of the people around me.

DOMINI HARRELL
Arlington, Texas

The Boundary Waters Canoe Area Wilderness, on whose edge Brandenburg lives and where many of his photos were taken, is threatened by congressional action that will weaken its wilderness protection. Two bills before Congress, S. 783 and H.R. 1739, would reopen three portages to motor vehicles in sections where they had been banned and prevent the final phasing out of motorboats on Sea Gull Lake. Without public outcry to save what little wilderness we still have, places like those in Jim's article will become a thing of the past.

PAM LESCHAK
Northeastern Minnesotans for Wilderness
Ely, Minnesota

It became obvious as I read the text and examined the pictures that the project had transcended its boundaries to achieve a philosophical significance that was astonishing.

GLENDA MALLETT
Boulder Creek, California

Flashback

Your photograph showed four boys and their cart dogs at Sainte-Anne-de-Beaupré, Quebec, and questioned whether they had been racing, hired to carry mail, or were available to give rides. My father took two photographs of me on a dog cart "on the road to Quebec" dated July 4, 1934. I was six years old and since then have often reminisced about our visit to Sainte-Anne-de-Beaupré.

HENRY Z. HORN
New Bedford, Massachusetts

My dad did the same thing in northern Maine: racing the dog. The glasses are blinders so the dogs can not see where they are going and get lazy and not go as fast. They were family dogs. The boys did it for bucks, cigarettes, and drink. Yes, that's the story Dad told me.

ERLENE PARNELL
San Diego, California

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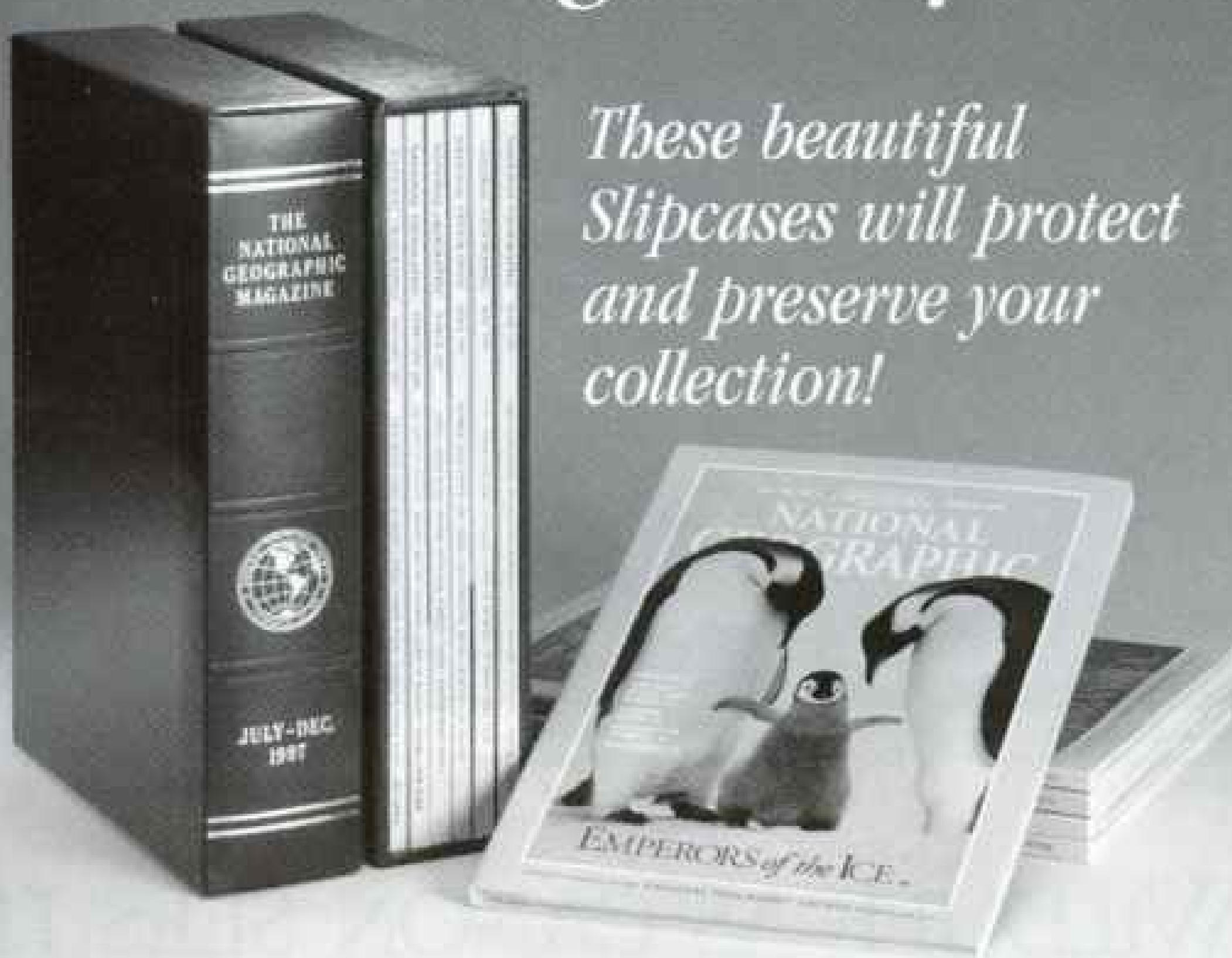

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Wrinkled Hornbill (*Aceros corrugatus*) **Size:** Length, 65-70 cm **Weight:** Approx. 1.2 - 1.5 kg **Habitat:** Lowland primary evergreen forest in Thailand, Malaysia, Indonesia, and Brunei **Surviving number:** Unknown

Photographed by Tim Laman

WILDLIFE AS CANON SEES IT

Wrinkled hornbills fly great distances over the rain forest canopy in search of fruiting trees. They travel an undulating flightpath, calling with soft coughing sounds while their wingbeats produce a loud rushing noise audible for over a kilometer. Monogamous pairs rear their offspring cooperatively. In a behavior unique to hornbills, the female seals herself inside a tree cavity prior to laying eggs. During the prolonged nesting cycle, the male delivers food to its mate through a narrow slit in the sealed entrance. Logging and agriculture are diminishing the wrinkled hornbill's habitat. As a global corporation committed to social and environmental concerns, we join in worldwide efforts to promote greater awareness of endangered species for the benefit of future generations.

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A Southwest Empire's Lengthy Shadow

Between A.D. 900 and 1150 the great complex at Chaco Canyon, New Mexico, dominated a 40,000-square-mile region of the American Southwest (GEOGRAPHIC, April 1996). The Chacoan, or Anasazi, influence is visible in dozens of more modest versions of Chaco Canyon's great houses and kivas—small round ceremonial buildings.

University of Colorado students working with archaeologist Catherine Cameron are excavating one of those sites (right) at Bluff, Utah, an outpost 125 miles northwest of Chaco Canyon. Since 1995 the team has found a great house surrounded by an earthen berm, typical of Chacoan settlements, a large subterranean kiva and three smaller kivas, and parts of a road linking the structures and pointing toward Chaco. Pottery indicates the Bluff site was occupied at the peak of Chacoan power.

"The masonry of the walls is not as carefully crafted as at Chaco Canyon, and the ceramics are not as beautiful," Cameron says. "It could be that the people who lived here saw a successful way of life and decided to emulate it."

KEN ABBOTT, UNIVERSITY OF COLORADO

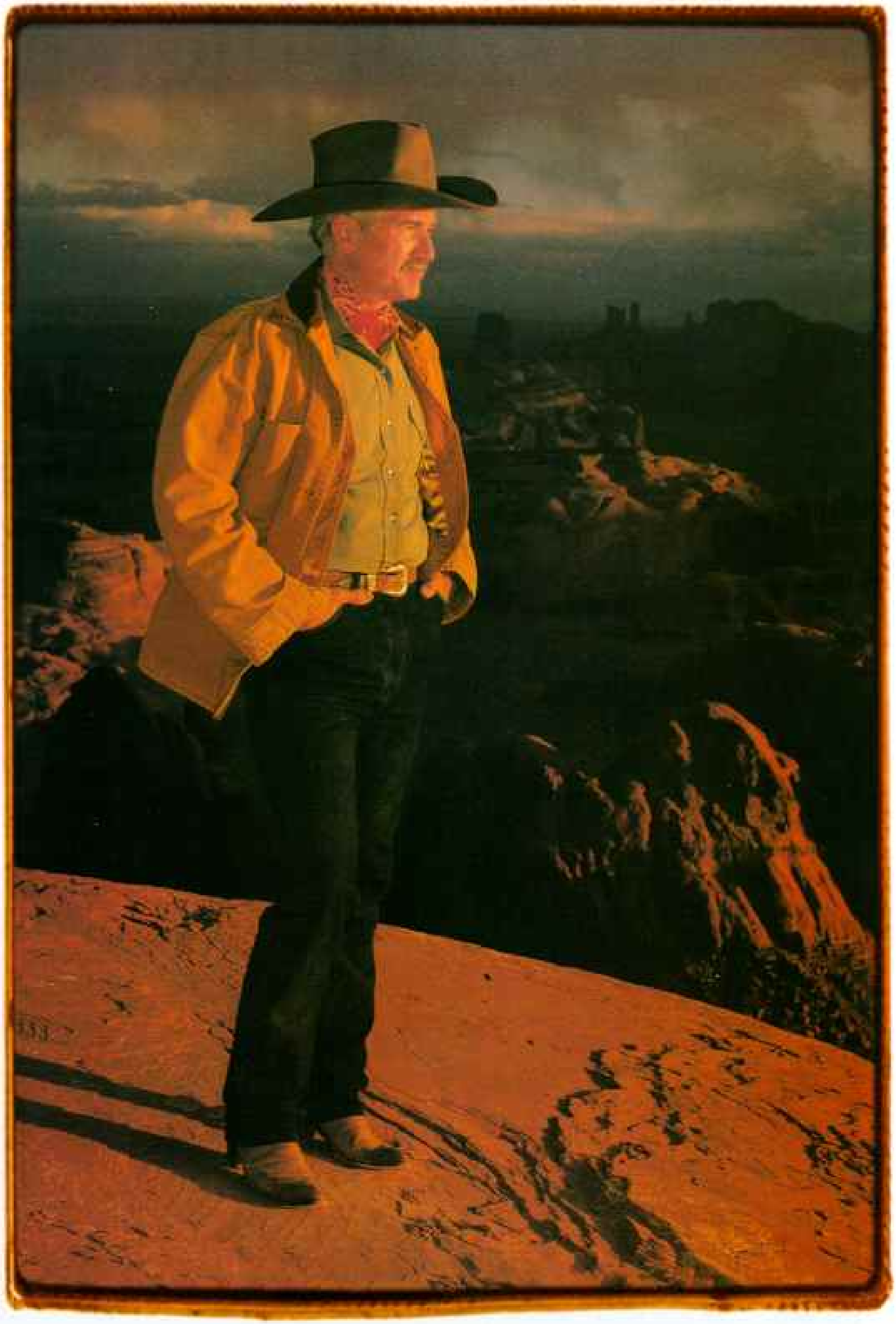
Little Fish With Big Appetites

A European anchovy weighs only a third of an ounce and measures about 4.5 inches long. But there's power, and importance, in its numbers: These fish, *Engraulis encrasicolus*, consume more than 20 percent of the zooplankton in the northwest Mediterranean, making them a vital link in the food chain.

Concerned about the long-term health of the heavily fished anchovies, Spanish researcher Sergi Tudela launched a study of their feeding behavior off Spain's Catalan coast, a major spawning area. He found that the unusual species feeds mainly between noon and sunset, not around the clock like most anchovies elsewhere.

They rise as much as 150 feet at night to lay eggs in shallow warm water, then return to colder deep water to feed. That way, Tudela says, they don't cannibalize their own eggs as other anchovy species do.

A. MARGIOCCO, ACQUARIO DI GENOVA



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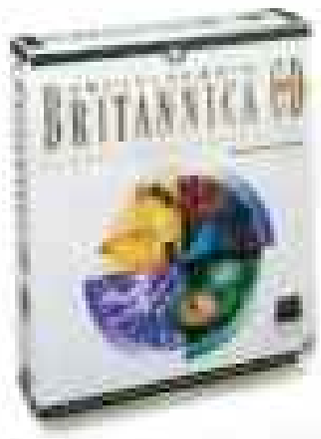

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Earliest Human Heart in Art?

This 4.5-inch-high ceramic figure holding a human heart, from about 1000 B.C., piqued the interest of amateur art historian Gordon Bendersky at an Olmec art exhibition at Princeton University. A cardiologist by profession, he was surprised that it depicts the aorta, on the right, the pulmonary artery, and both ventricles. Bendersky thinks it is the earliest anatomically accurate image of a human heart, though others cite older Egyptian hieroglyphs that show similar features. Not until the 16th century did artists again achieve such detail.

African Song Spans the Ocean, the Centuries

As a child on Georgia's rural coast, Mary Moran, now 76, learned "an African song" from her mother. In Sierra Leone, Baindu Jabati learned the same lyrics, a women's funeral refrain, from her grandmother. Now the two have met and sung it for each other, a connection a long time in coming.

Lorenzo Turner, a black linguist collecting folklore in African and Gullah dialects, recorded Mrs. Moran's mother's version in 1932. In 1990 anthropologist Joseph Opala and ethnomusicologist Cynthia Schmidt played the recording in Sierra Leone and heard Mrs. Jabati, a member of the Mende people, join in singing the same song. This bit of culture had crossed the Atlantic on a slave ship and, astonishingly, survived. Last year Mrs. Moran and her family flew from Georgia to Sierra Leone, where she was greeted, she says, as "something special" (below). "One slave girl brought that little five-line song with her," she muses. "They took everything she had but her dignity, and they couldn't take the song."

AUSTIN KIRK (TOP LEFT); PAUD PRODUCCIONES S.L.

Time Doesn't Stand Still for Cities on the Go

"Places, like people, have personalities," says Robert Levine, a psychologist at California State University, Fresno. Levine wanted to know which of 36 U.S. cities had the fastest pace of life. He found that Bostonians, here rushing by on a downtown street, topped the list, outhustling surprising runners-up Buffalo and New York. His study, *A Geography of Time*, charted walking speed, talking speed, how long it took bank clerks to make change, and the number of passersby wearing watches. New Yorkers led in watches, but the Big Apple placed third overall due to a 28th-place finish in talking speed. Fast-moving cities are more stressful but tend to be more productive economically than their slower moving counterparts, Levine discovered. At the bottom of the list: laid-back Los Angeles. People there talk so slowly that reading the 6 p.m. news would take them until 7:25 to report what residents of Columbus, Ohio, would finish by 7 p.m.

TEXT BY BORIS WEINTRAUB

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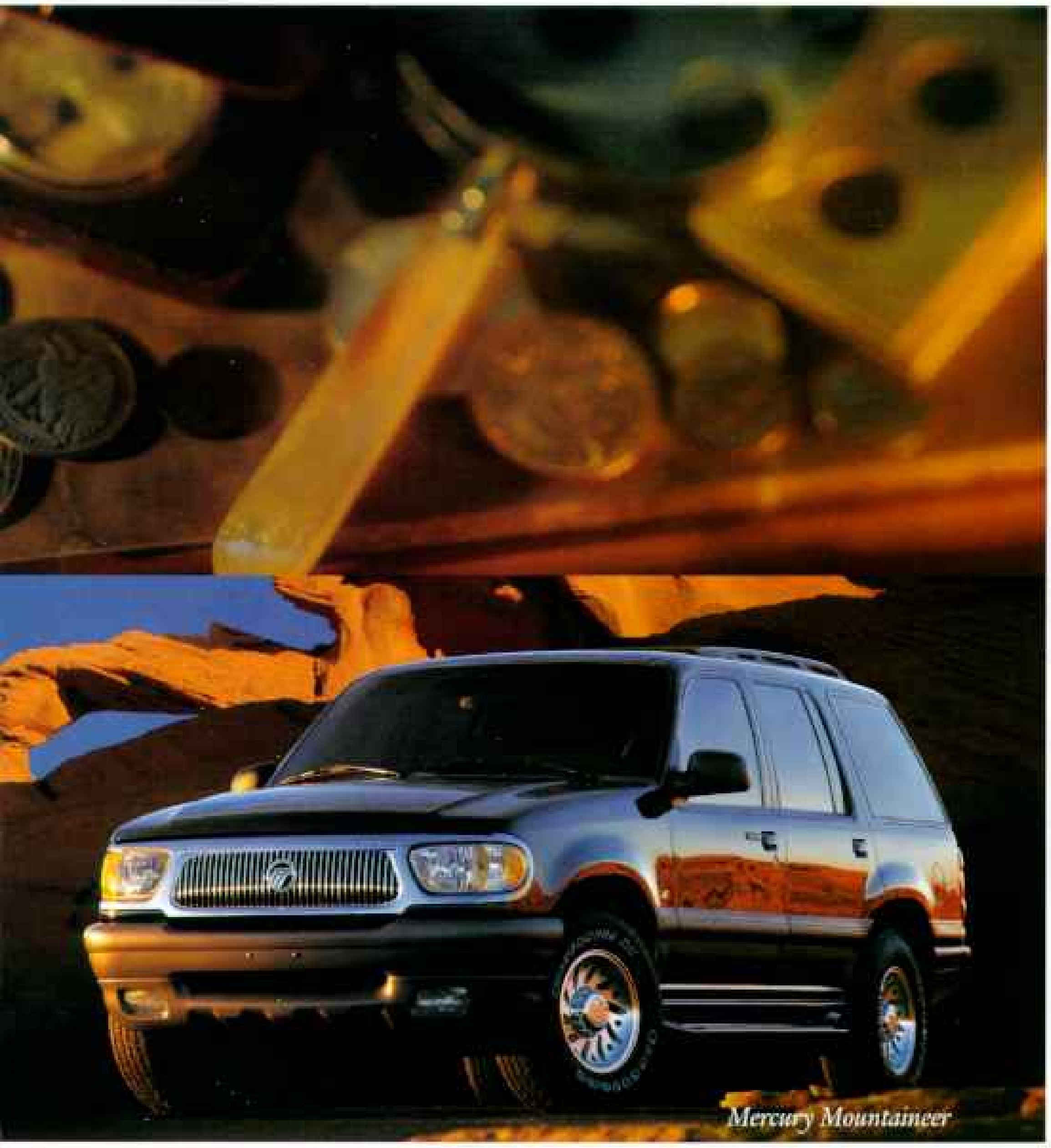

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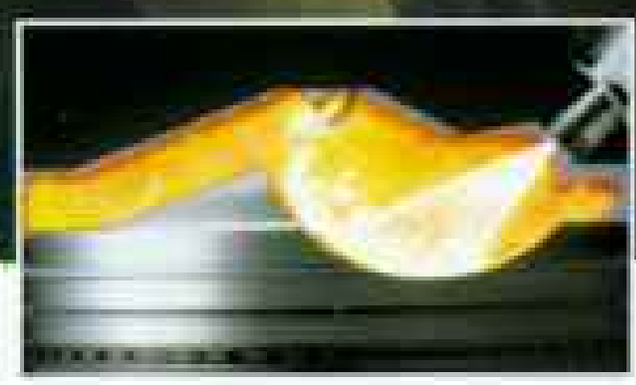

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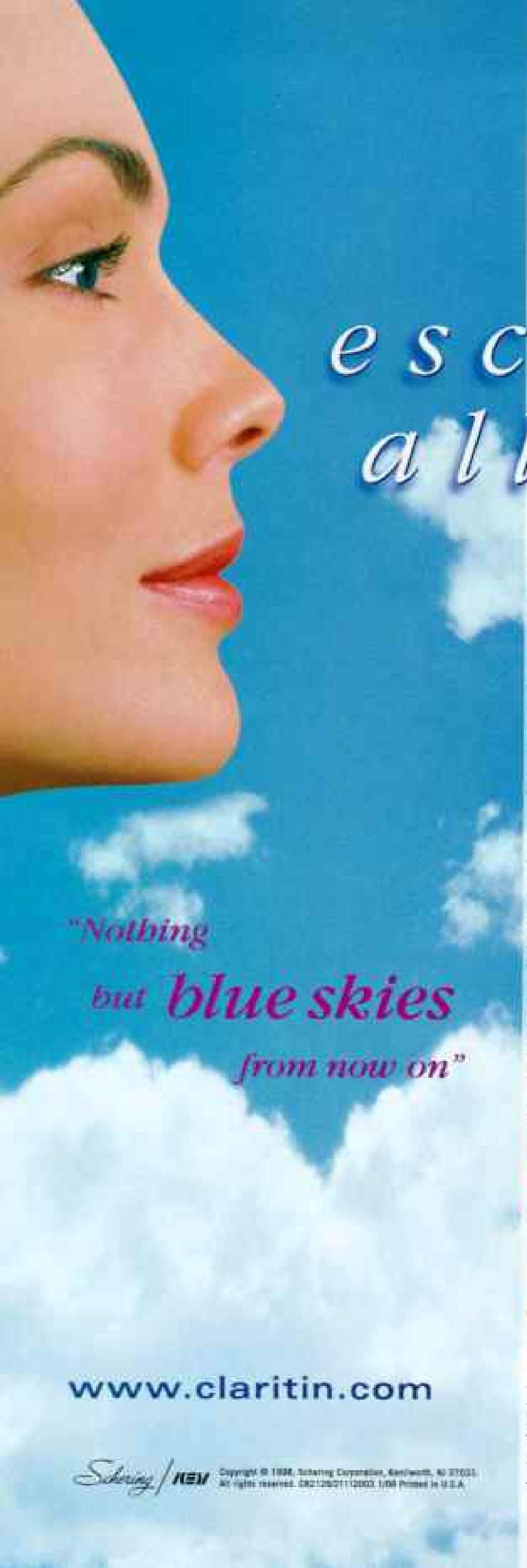

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brand of loratadine
TABLETS, SYRUP, and RAPIDLY-DISINTEGRATING TABLETS

BRIEF SUMMARY **(For full Prescribing Information, see package insert.)**

INDICATIONS AND USAGE: CLARITIN is indicated for the relief of nasal and non-nasal symptoms of seasonal allergic rhinitis and for the treatment of chronic idiopathic urticaria in patients 6 years of age or older.

CONTRAINDICATIONS: CLARITIN is contraindicated in patients who are hypersensitive to this medication or to any of its ingredients.

PRECAUTIONS: **General:** Patients with liver impairment or renal insufficiency (CrCl < 30 mL/min) should be given a lower initial dose (10 mg every other day). (See **CLINICAL PHARMACOLOGY: Special Populations.**)

Drug Interactions: Loratadine (10 mg once daily) has been coadministered with therapeutic doses of erythromycin, cimetidine, and ketoconazole in controlled clinical pharmacology studies in adult volunteers. Although increased plasma concentrations (AUC 0-24 hrs) of loratadine and/or descarboethoxyloratadine were observed following coadministration of loratadine with each of these drugs in normal volunteers (n = 24 in each study), there were no clinically relevant changes in the safety profile of loratadine, as assessed by electrocardiographic parameters, clinical laboratory tests, vital signs, and adverse events. There were no significant effects on QT_c intervals, and no reports of sedation or syncope. No effects on plasma concentrations of cimetidine or ketoconazole were observed. Plasma concentrations (AUC 0-24 hrs) of erythromycin decreased 15% with coadministration of loratadine relative to that observed with erythromycin alone. The clinical relevance of this difference is unknown. These above findings are summarized in the following table:

Effects on Plasma Concentrations (AUC 0-24 hrs) of Loratadine and Descarboethoxyloratadine After 10 Days of Coadministration (Loratadine 10 mg) in Normal Volunteers

	Loratadine	Descarboethoxyloratadine
Erythromycin (500 mg Q6H)	+ 40%	+46%
Cimetidine (300 mg QID)	+103%	+ 6%
Ketoconazole (200 mg Q12h)	+307%	+73%

There does not appear to be an increase in adverse events in subjects who received oral contraceptives and loratadine.

Carcinogenesis, Mutagenesis, and Impairment of Fertility: In an 18-month carcinogenicity study in mice and a 2-year study in rats, loratadine was administered in the diet at doses up to 40 mg/kg (mice) and 25 mg/kg (rats). In the carcinogenicity studies, pharmacokinetic assessments were carried out to determine animal exposure to the drug. AUC data demonstrated that the exposure of mice given 40 mg/kg of loratadine was 3.6 (loratadine) and 18 (descarboethoxyloratadine) times higher than in humans given the maximum recommended daily oral dose. Exposure of rats given 25 mg/kg of loratadine was 28 (loratadine) and 67 (descarboethoxyloratadine) times higher than in humans given the maximum recommended daily oral dose. Male mice given 40 mg/kg had a significantly higher incidence of hepatocellular tumors (combined adenomas and carcinomas) than concurrent controls. In rats, a significantly higher incidence of hepatocellular tumors (combined adenomas and carcinomas) was observed in males given 10 mg/kg and males and females given 25 mg/kg. The clinical significance of these findings during long-term use of CLARITIN is not known.

In mutagenicity studies, there was no evidence of mutagenic potential in reverse (Ames) or forward point mutation (CHO-HGPRT) assays, or in the assay for DNA damage (rat primary hepatocyte unscheduled DNA assay) or in two assays for chromosomal aberrations (human peripheral blood lymphocyte clastogenesis assay and the mouse bone marrow erythrocyte micronucleus assay). In the mouse lymphoma assay, a positive finding occurred in the noninactivated but not the activated phase of the study.

Decreased fertility in male rats, shown by lower female conception rates, occurred at an oral dose of 64 mg/kg (approximately 50 times the maximum recommended human daily oral dose on a mg/m^2 basis) and was reversible with cessation of dosing. Loratadine had no effect on male or female fertility or reproduction in the rat at an oral dose of approximately 24 mg/kg (approximately 20 times the maximum recommended human daily oral dose on a mg/m^2 basis).

Pregnancy Category B: There was no evidence of animal teratogenicity in studies performed in rats and rabbits at oral doses up to 96 mg/kg (approximately 75 times and 150 times, respectively, the maximum recommended human daily oral dose on a mg/m^2 basis). There are, however, no adequate and well-controlled studies in pregnant women. Because animal reproduction studies are not always predictive of human response, CLARITIN should be used during pregnancy only if clearly needed.

Nursing Mothers: Loratadine and its metabolite, descarboethoxyloratadine, pass easily into breast milk and achieve concentrations that are equivalent to plasma levels with an AUC_{milk}/AUC_{plasma} ratio of 1.17 and 0.55 for loratadine and descarboethoxyloratadine, respectively. Following a single oral dose of 40 mg, a small amount of loratadine and descarboethoxyloratadine was excreted into the breast milk (approximately 0.03% of 40 mg over 48 hours). A decision should be made whether to discontinue nursing or to discontinue the drug, taking into account the importance of the drug to the mother. Caution should be exercised when CLARITIN is administered to a nursing woman.

Pediatric Use: The safety of CLARITIN Syrup at a daily dose of 10 mg has been demonstrated in 186 pediatric patients 6-12 years of age in placebo-controlled 2-week trials. The effectiveness of CLARITIN for the treatment of seasonal allergic rhinitis and chronic idiopathic urticaria in this pediatric age group is based on an extrapolation of the demonstrated efficacy of CLARITIN in adults in these conditions and the likelihood that the disease course, pathophysiology, and the drug's effect are substantially similar to that of the adults. The recommended dose for the pediatric population is based on cross-study comparison of the pharmacokinetics of CLARITIN in adults and pediatric subjects and on the safety profile of loratadine in both adults and pediatric patients at doses equal to or higher than the recommended dose. The safety and effectiveness of CLARITIN in pediatric patients under 6 years of age have not been established.

ADVERSE REACTIONS: **CLARITIN Tablets:** Approximately 90,000 patients, aged 12 and older, received CLARITIN Tablets 10 mg once daily in controlled and uncontrolled studies. Placebo-controlled clinical trials at the recommended dose of 10 mg once a day varied from 2 weeks to 6 months' duration. The rate of premature withdrawal from these trials was approximately 2% in both the treated and placebo groups.

REPORTED ADVERSE EVENTS WITH AN INCIDENCE OF MORE THAN 2% IN PLACEBO-CONTROLLED ALLERGIC RHINITIS CLINICAL TRIALS IN PATIENTS 12 YEARS OF AGE AND OLDER

PERCENT OF PATIENTS REPORTING

	LORATADINE 10 mg QD n = 1926	PLACEBO n = 2545	CLEMASTINE 1 mg BID n = 536	TERFENADINE 60 mg BID n = 584
Headache	12	11	8	8
Somnolence	8	6	22	9
Fatigue	4	3	10	2
Dry Mouth	3	2	4	3

Adverse events reported in placebo-controlled chronic idiopathic urticaria trials were similar to those reported in allergic rhinitis studies.

Adverse event rates did not appear to differ significantly based on age, sex, or race, although the number of nonwhite subjects was relatively small.

CLARITIN REDITABS (loratadine rapidly-disintegrating tablets): Approximately 500 patients received CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) in controlled clinical trials of 2 weeks' duration. In these studies, adverse events were similar in type and frequency to those seen with CLARITIN Tablets and placebo.

Administration of CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) did not result in an increased reporting frequency of mouth or tongue irritation.

CLARITIN Syrup: Approximately 300 pediatric patients 6 to 12 years of age received 10 mg loratadine once daily in controlled clinical trials for a period of 8-15 days. Among these, 186 children were treated with 10 mg loratadine syrup once daily in placebo-controlled trials. Adverse events in these pediatric patients were observed to occur with type and frequency similar to those seen in the adult population. The rate of premature discontinuance due to adverse events among pediatric patients receiving loratadine 10 mg daily was less than 1%.

ADVERSE EVENTS OCCURRING WITH A FREQUENCY OF ≥ 2% IN LORATADINE SYRUP-TREATED PATIENTS (6-12 YEARS OLD) IN PLACEBO-CONTROLLED TRIALS AND MORE FREQUENTLY THAN IN THE PLACEBO GROUP

PERCENT OF PATIENTS REPORTING

	LORATADINE 10 mg QD n = 186	PLACEBO n = 262	CHLORPHENIRAMINE 2-4 mg BID/TID n = 170
Nervousness	4	2	2
Wheezing	4	2	3
Fatigue	3	2	5
Hyperkinesia	3	1	1
Abdominal Pain	2	0	0
Conjunctivitis	2	<1	1
Dysphonia	2	<1	0
Malaise	2	0	1
Upper Respiratory Tract Infection	2	<1	0

In addition to those adverse events reported above (≥ 2%), the following adverse events have been reported in at least one patient in CLARITIN clinical trials in adult and pediatric patients:

Autonomic Nervous System: Altered lacrimation, altered salivation, flushing, hypoesthesia, impotence, increased sweating, thirst.

Body As A Whole: Angioneurotic edema, asthenia, back pain, blurred vision, chest pain, earache, eye pain, fever, leg cramps, malaise, rigors, tinnitus, viral infection, weight gain.

Cardiovascular System: Hypertension, hypotension, palpitations, supraventricular tachyarrhythmias, syncope, tachycardia.

Central and Peripheral Nervous System: Blepharospasm, dizziness, dysphonia, hypertonia, migraine, paresthesia, tremor, vertigo.

Gastrointestinal System: Altered taste, anorexia, constipation, diarrhea, dyspepsia, flatulence, gastritis, hiccup, increased appetite, nausea, stomatitis, toothache, vomiting.

Musculoskeletal System: Arthralgia, myalgia.

Psychiatric: Agitation, amnesia, anxiety, confusion, decreased libido, depression, impaired concentration, insomnia, irritability, paranoia.

Reproductive System: Breast pain, dysmenorrhea, menorrhagia, vaginitis.

Respiratory System: Bronchitis, bronchospasm, coughing, dyspnea, epistaxis, hemoptysis, laryngitis, nasal dryness, pharyngitis, sinusitis, sneezing.

Skin and Appendages: Dermatitis, dry hair, dry skin, photosensitivity reaction, pruritus, purpura, rash, urticaria.

Urinary System: Altered micturition, urinary discoloration, urinary incontinence, urinary retention.

In addition, the following spontaneous adverse events have been reported rarely during the marketing of loratadine: abnormal hepatic function, including jaundice, hepatitis, and hepatic necrosis; alopecia; anaphylaxis; breast enlargement; erythema multiforme; peripheral edema; and seizures.

OVERDOSAGE: In adults, somnolence, tachycardia, and headache have been reported with overdoses greater than 10 mg with the Tablet formulation (40 to 180 mg). Extrapyramidal signs and palpitations have been reported in children with overdoses of greater than 10 mg of CLARITIN Syrup. In the event of overdosage, general symptomatic and supportive measures should be instituted promptly and maintained for as long as necessary.

Treatment of overdosage would reasonably consist of emesis (ipecac syrup), except in patients with impaired consciousness, followed by the administration of activated charcoal to absorb any remaining drug. If vomiting is unsuccessful, or contraindicated, gastric lavage should be performed with normal saline. Saline cathartics may also be of value for rapid dilution of bowel contents. Loratadine is not eliminated by hemodialysis. It is not known if loratadine is eliminated by peritoneal dialysis.

No deaths occurred at oral doses up to 5000 mg/kg in rats and mice (greater than 2400 and 1200 times, respectively, the maximum recommended human daily oral dose on a mg/m^2 basis). Single oral doses of loratadine showed no effects in rats, mice, and monkeys at doses as high as 10 times the maximum recommended human daily oral dose on a mg/m^2 basis.

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Kenilworth, NJ 07033 USA

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CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) are manufactured for Schering Corporation by Scherer DDS, England.

U.S. Patent Nos. 4,282,233 and 4,371,516.

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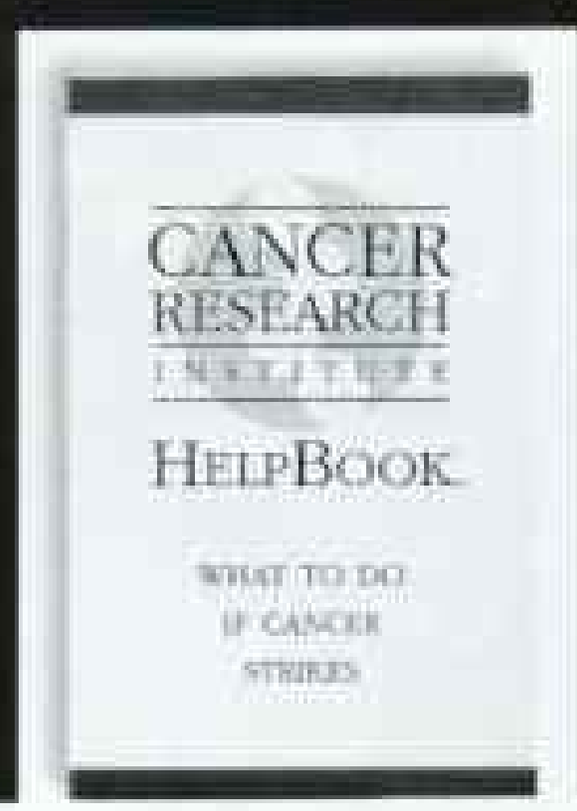

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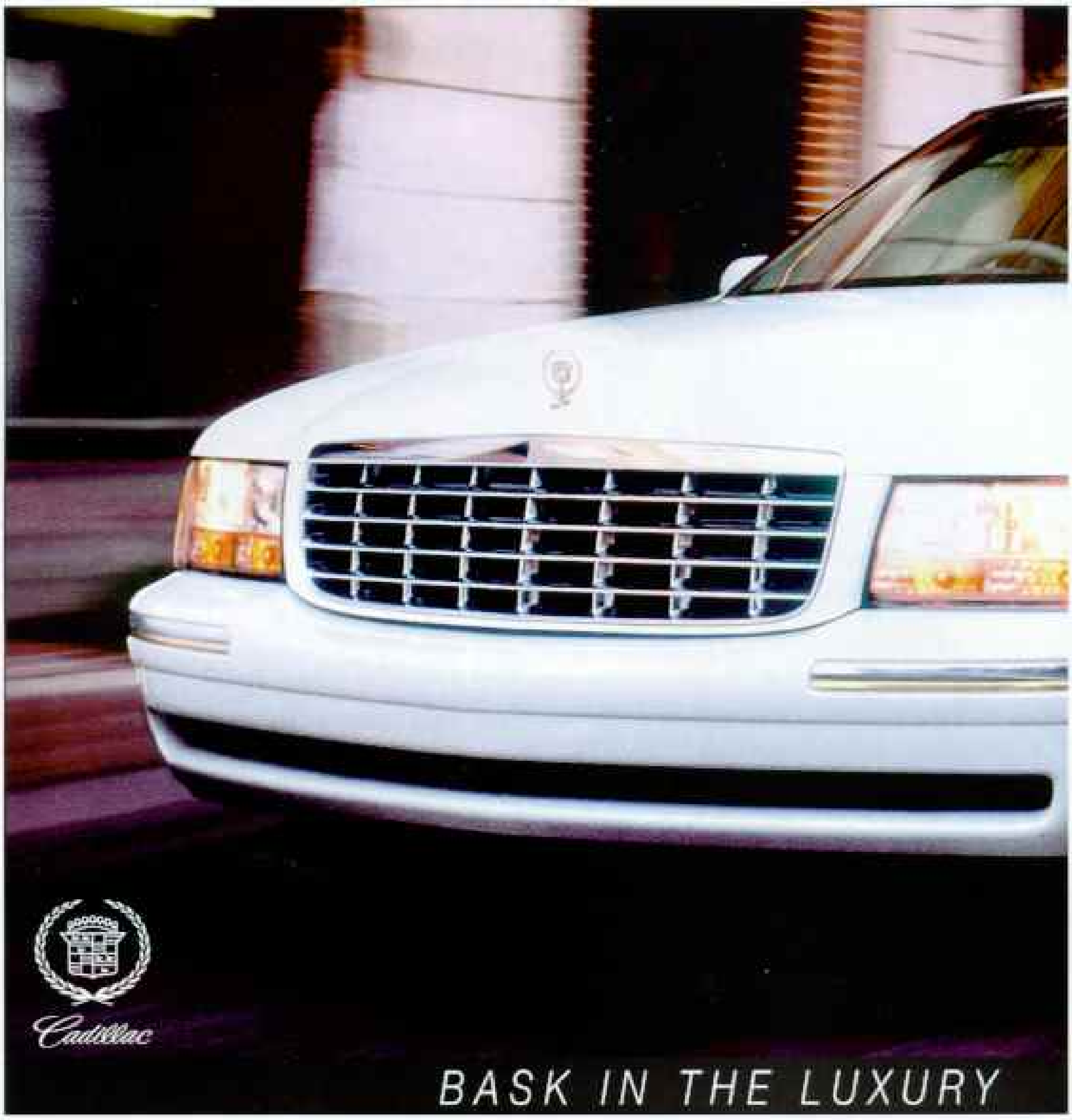

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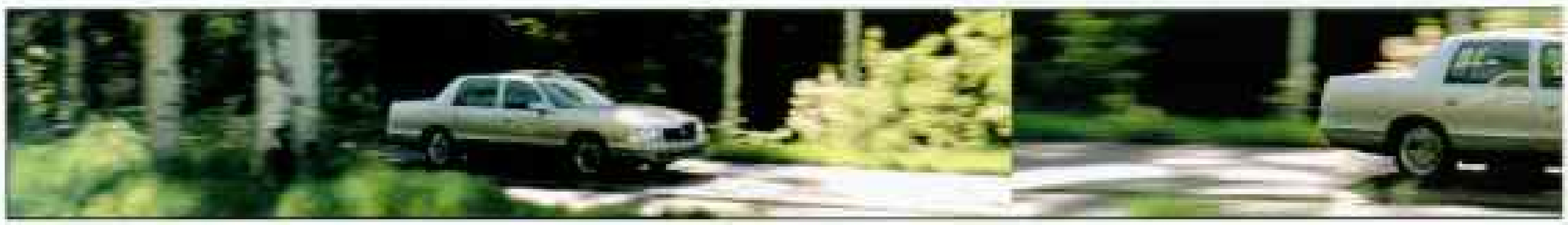

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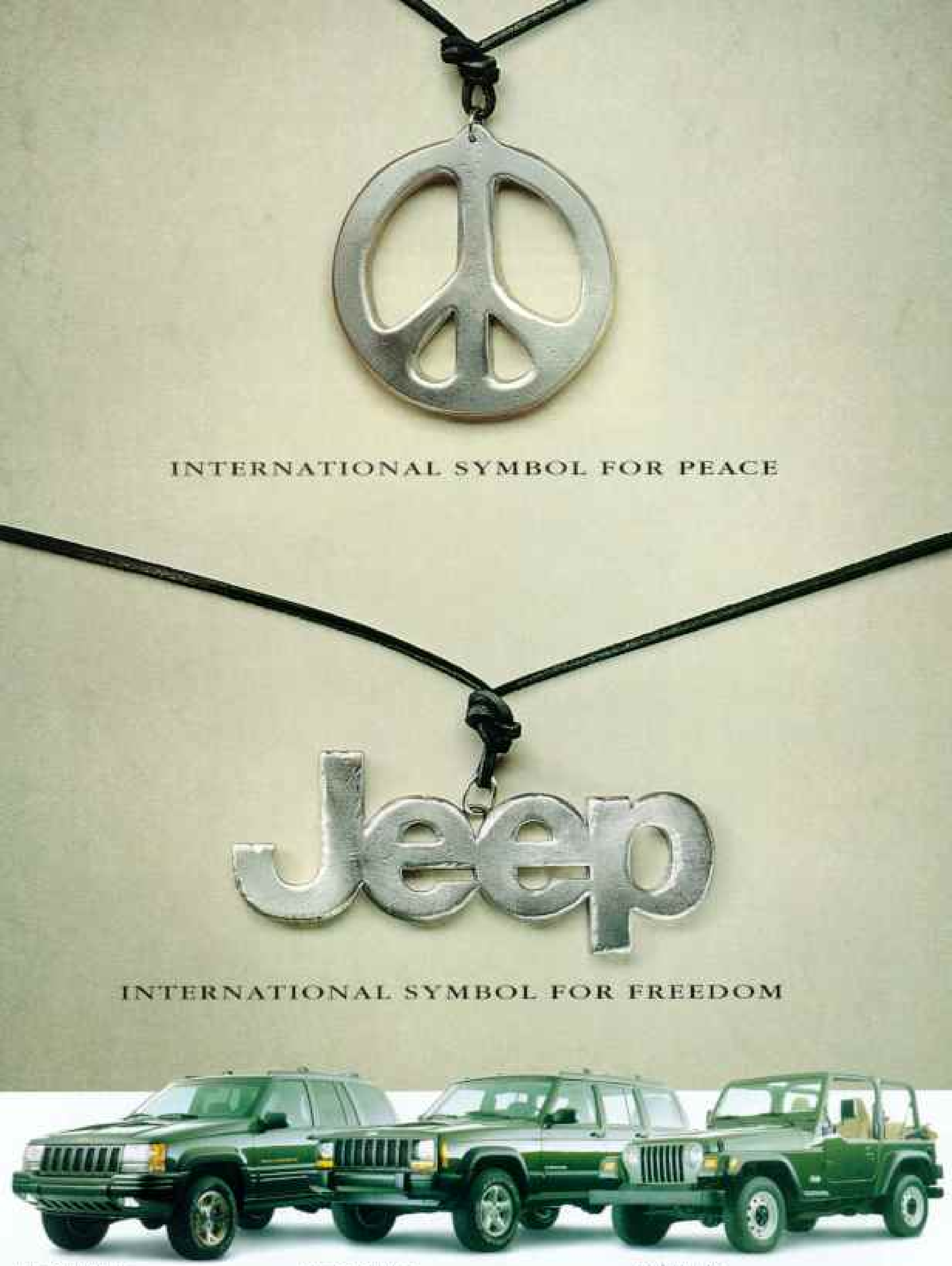

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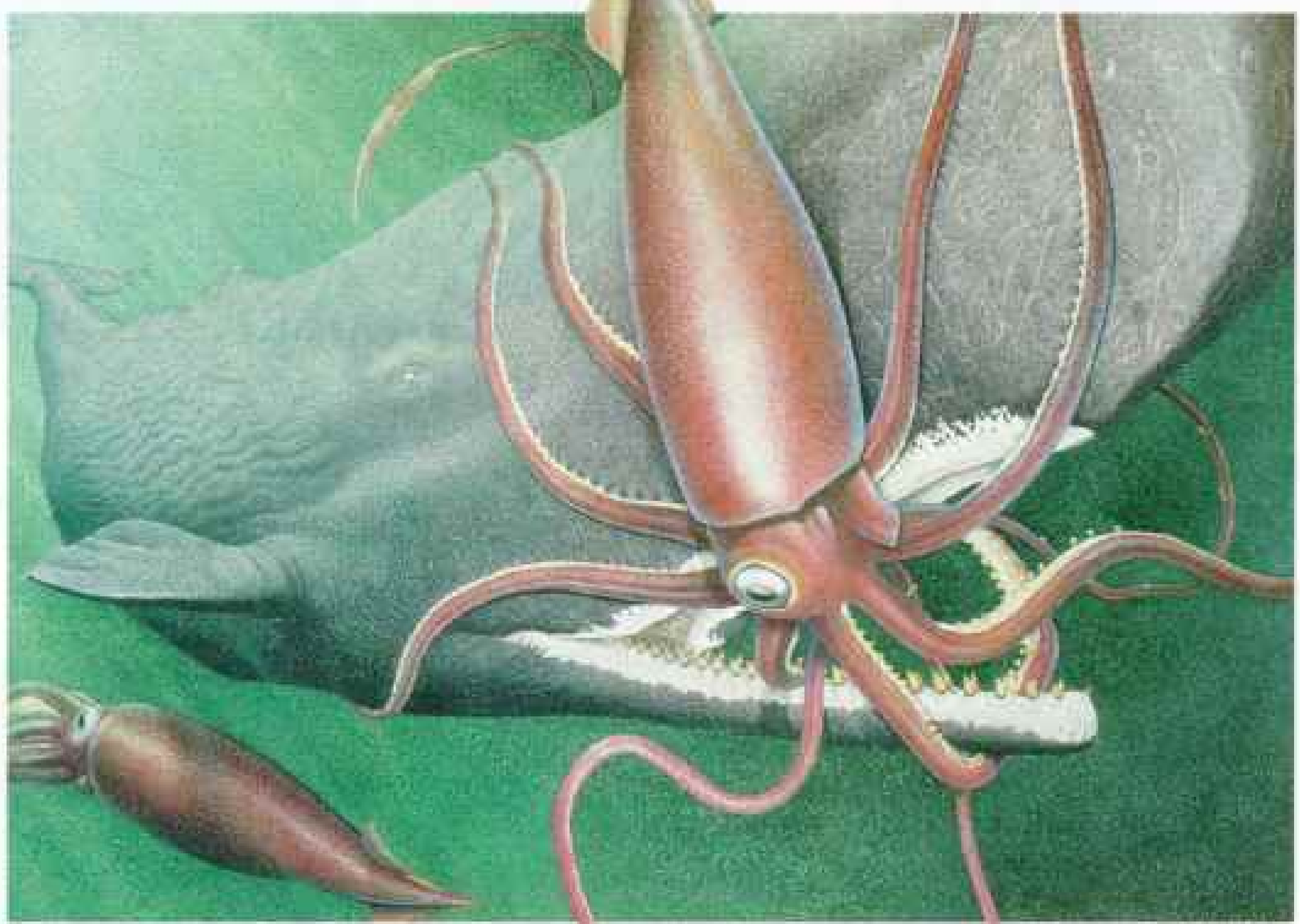
LEON DANIEL

■ FROM THE GEOGRAPHIC ARCHIVES

Remembrance of Things Pasta

Neapolitan spaghetti makers, untroubled by the restless volcano Vesuvius puffing in the background, air-dry pasta in 1934. Never published in the magazine, this photo was probably purchased for our September 1936 article "Sojourning in the Italy of Today," by Mrs. Kenneth Roberts, who had moved to Italy "to find a quiet and detached place in which my husband could write a series of American novels." She continued, "When one begins housekeeping in Italy with a vocabulary of 50 disconnected words and a dictionary, daily problems remain problems for some time."

On Television



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■ SPECIAL, FEB. 25, 8 P.M. ET

A Really Big Sucker

It grows to the length of a school bus or longer and has eyes as big as volleyballs. A razor-sharp, parrot-like beak, eight arms, and a pair of whip-like tentacles make it the perfect sea monster. But it has never been seen in its natural habitat—the deep ocean.

"For many young people today the giant squid has become the new dinosaur," says the world's leading expert on the creature, marine biologist Clyde Roper of the Smithsonian's Museum of Natural History.

The adult giant squid's only known predator is the even bigger sperm whale. Scientists have found squid beaks in the stomachs of sperm whales and circular scars on whale skins from desperate struggles. The

© BOB CRANDALL

National Geographic Special "Sea Monsters: Search for the Giant Squid" explores the relationship between sperm whales and both giant squid and the smaller Humboldt squid, whose sucker cup on a tentacle reveals a ring of sharp teeth (above).

To go where humans cannot, marine biologist and inventor Greg Marshall attached a crittercam, a video and data recording system, to the back of a sperm whale. Equipped to operate in low light, the device is built of titanium to withstand pressure of more than 3,500 pounds per square inch.

The National Geographic Crittercam Research Program makes the invention available to others for scientific projects. Since its first use, crittercam has made research assistants out of turtles, seals, and sharks.

■ PROGRAM GUIDE

National Geographic Specials
"Sea Monsters"
NBC, Wed., Feb. 25, 8 p.m. ET

National Geographic EXPLORER
TBS, Sundays, 7 p.m. ET

National Geographic Videos and Kids Videos Call 1-800-627-5162.

Programming information accurate at press time; consult local listings.

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A Secluded Haven for Canada's Grizzlies

"Confined space of salmon and bears"—Khutzeymateen—is the name that British Columbia's Tsimshian people give to a remote river valley on the Pacific coast. In 1994 the provincial government set aside about 110,000 acres as Canada's first sanctuary to protect grizzly bears. Densely concentrated, about 60 bears winter in mountain dens, then come down to the Khutzeymateen River and gorge on pink salmon in summer and fall.

"Access is strictly controlled," says area supervisor John Trewhitt. "Only about a hundred visitors a year can come by boat with one of two licensed guides."

A study in the early 1990s recommended against allowing logging, in part because conflicts with humans could prove fatal to bears. The Khut then became a model for Canadian conservationists. Some hope to build on its success by establishing a chain of preserves along the Pacific coast. Of about 25,000 grizzlies that roam Canada, perhaps 300 are legally shot every year.

CHRIS HARRIS

ART BY DENNIS DOHERNER

Tune In, Turn On to Whales

Talk radio will get an earful this spring in the Pacific Northwest when a new station begins broadcasting at 88.5 FM as ORCA—the voice of killer whales. Researcher John Ford of the Vancouver Aquarium has obtained a license for the station. He installed an underwater microphone off British Columbia's Johnstone Strait, where scores of orcas utter their distinctive calls. The calls will be featured in the aquarium and interpreted for its 850,000 annual visitors.

BUREAU OF LAND MANAGEMENT (BOTH)

Requiem for a Ruined Arch in Montana

It stood above the Missouri River for millennia, an 11-foot-tall sandstone arch called Eye of the Needle (above). Lewis and Clark passed beneath the sentinel, as did modern canoeists. Last Memorial Day weekend, history took a beating when vandals destroyed it (above right).

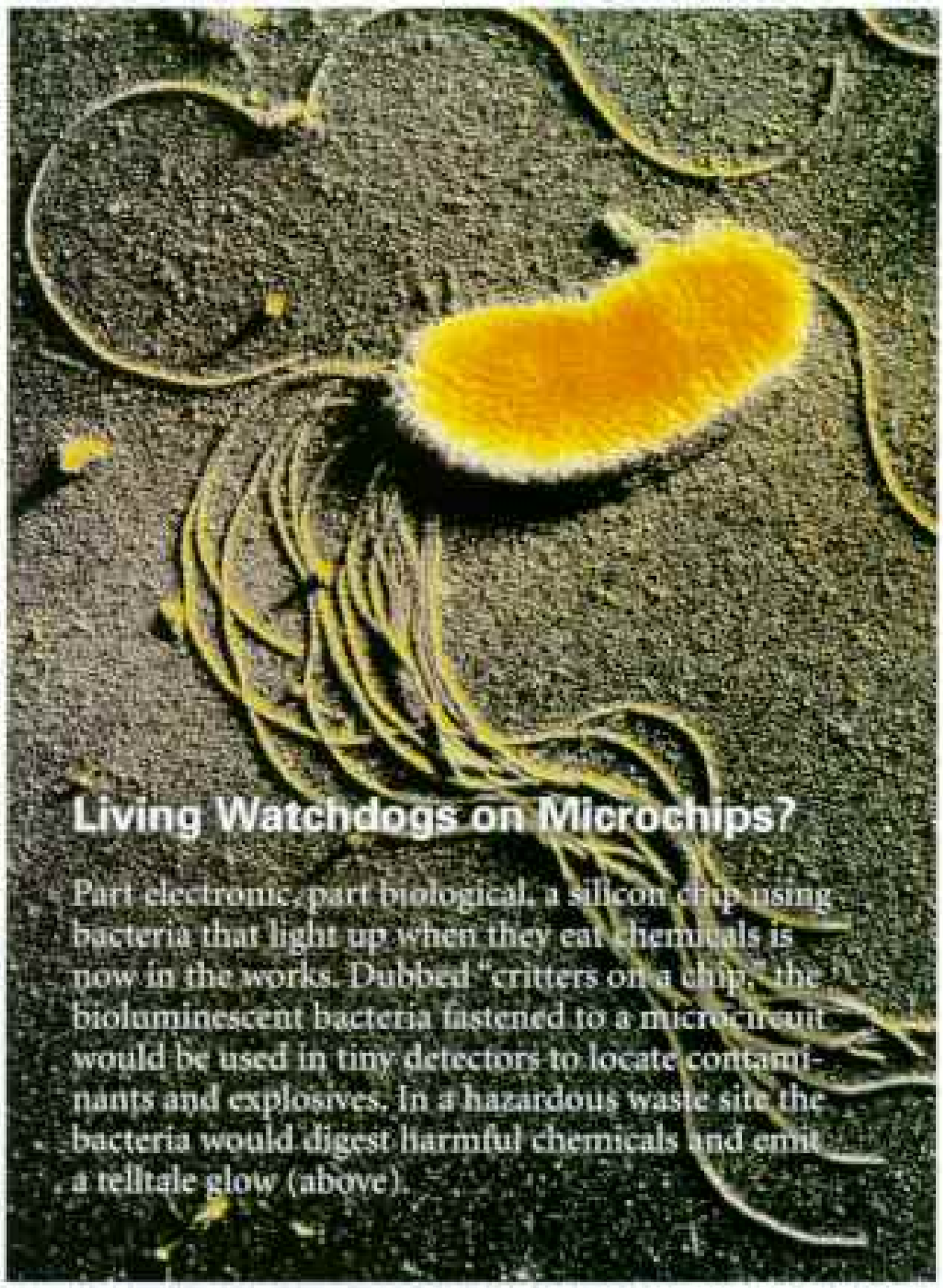
"I was in shock that this could happen on a wild and scenic river," says Chuck Otto of the Bureau of Land Management. No suspects have been arrested; the charge would be destruction of government property, a felony. A replica of the arch, made of the same White Eagle sandstone, is planned for the Lewis and Clark bicentennial celebrations in 2003 at nearby Fort Benton.

World's Rarest Parrot to Be a Family Man?

Marooned in northeast Brazil by habitat loss and collectors, only one wild little blue macaw remains. The lonely male (below) has taken a mate of a different species, a blue-winged macaw. None of her eggs have hatched; still, the two birds' bond is strong. Meanwhile, 40 little blues have been captive raised. Biologists hope to transfer fertile eggs from captives to the wild nest.

TEXT BY JOHN L. ELIOT

JOHN MAIER, STILL PICTURES



Living Watchdogs on Microchips?

Part electronic, part biological, a silicon chip using bacteria that light up when they eat chemicals is now in the works. Dubbed "critters on a chip," the bioluminescent bacteria fastened to a microcircuit would be used in tiny detectors to locate contaminants and explosives. In a hazardous waste site the bacteria would digest harmful chemicals and emit a telltale glow (above).

TONY BRAIN, SCIENCE PHOTO LIBRARY/PHOTO RESEARCHERS

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CHUCK CARTER

Cobalt water surging through towering cliffs—a natural wonder to preserve or an energy source to tap? That's a dilemma you will face when you visit Geoguide online. Squint through a surveyor's transit (right) to watch a river before, during, and after construction of a typical dam. Other digital field trips showcase the Nenets people of Siberia, featured in this issue, and tigers. Your departure gate is *www.nationalgeographic.com/resources/education/geoguide.*

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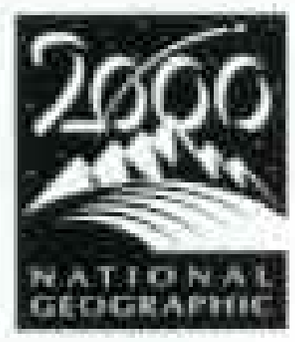

New York City's police force has retooled an old weapon for its anticrime arsenal—maps. Step inside the precinct house at . . . */features/2000.*

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TIMOTHY C. GREENFIELD-SANDERS

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NATIONAL GEOGRAPHIC

On Assignment

FRANKLIN J. VIOLA

■ MARINE SANCTUARIES

An Assignment That Was All Wet

Getting a feel for his story, writer Doug Chadwick snorkeled through the coral-breeding grounds at Flower Garden Banks sanctuary in the Gulf of Mexico. He recently learned to dive and says "it's a whole new frontier to write about." Doug has always enjoyed fieldwork; as a kid he spent summers helping his geologist-dad explore the backcountry in the West, then grew up to be a wildlife biologist. "But not enough people read scientific papers," says Doug of his career switch to journalism. "It's a better way to get the word out—and still get to be outside."

■ NENETS

A *Chum* of One's Own

Life in a ten-person deerskin tent, or *chum*, in Siberia wasn't so hard, says Sven Haakanson, Jr. (below, left), an Alaska Alutiiq and Harvard Ph.D. candidate. "All those people keep you warm." For three months he roomed with the Serotetta family, recording traditions for the Living Yamal Project of the Smithsonian Institution's Arctic Studies Center, which helped arrange our coverage. "The Nenets still have their culture, which we have lost at home. They have a sense of identity and know where they belong," says Sven.

MARIA STENZEL

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NATIONAL GEOGRAPHIC
Geoguide

Reindeer People on the Move

■ Much of everyday life among the Nenets remains traditional—especially for some 10,000 of the herders who still migrate with their reindeer and use them for food, clothing, shelter, and many other necessities of life. How many uses of reindeer can you find in the two photographs on pages 128-9?

Harnessed to a sled built for speed, reindeer whisk a Nenets herder across the frozen taiga of northern Siberia. Although most reindeer—both male and female—grow antlers, they shed them throughout the winter and spring. Under the scrutiny of adults, a Nenets child (below) learns such basic skills as woodchopping.

■ Even among the traditional Nenets, modern life is closing in. What things can you find in each photograph in the story that reveal how the Nenets are adopting Western culture?

■ To get an idea how far north the Nenets live, check the latitude of the Yamal Peninsula on the map on page 125. Then, in an atlas or on a world map, find places in North America at the same latitude. Do any major cities in North America lie that far north? How far north of your hometown do the Nenets live?

■ If you try petting a cat or dog, notice the fur. In most breeds it consists of fine, thin hairs. If you were to pet a reindeer, you would discover that its fur is coarse and bulky—because the outer hairs contain many air-filled cells. These hairs trap body heat and help insulate the reindeer from frigid Arctic air. Reindeer hides made into clothing keep the Nenets people warm by insulating them in the same way.

MARIA STENZEL (BOTH)

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