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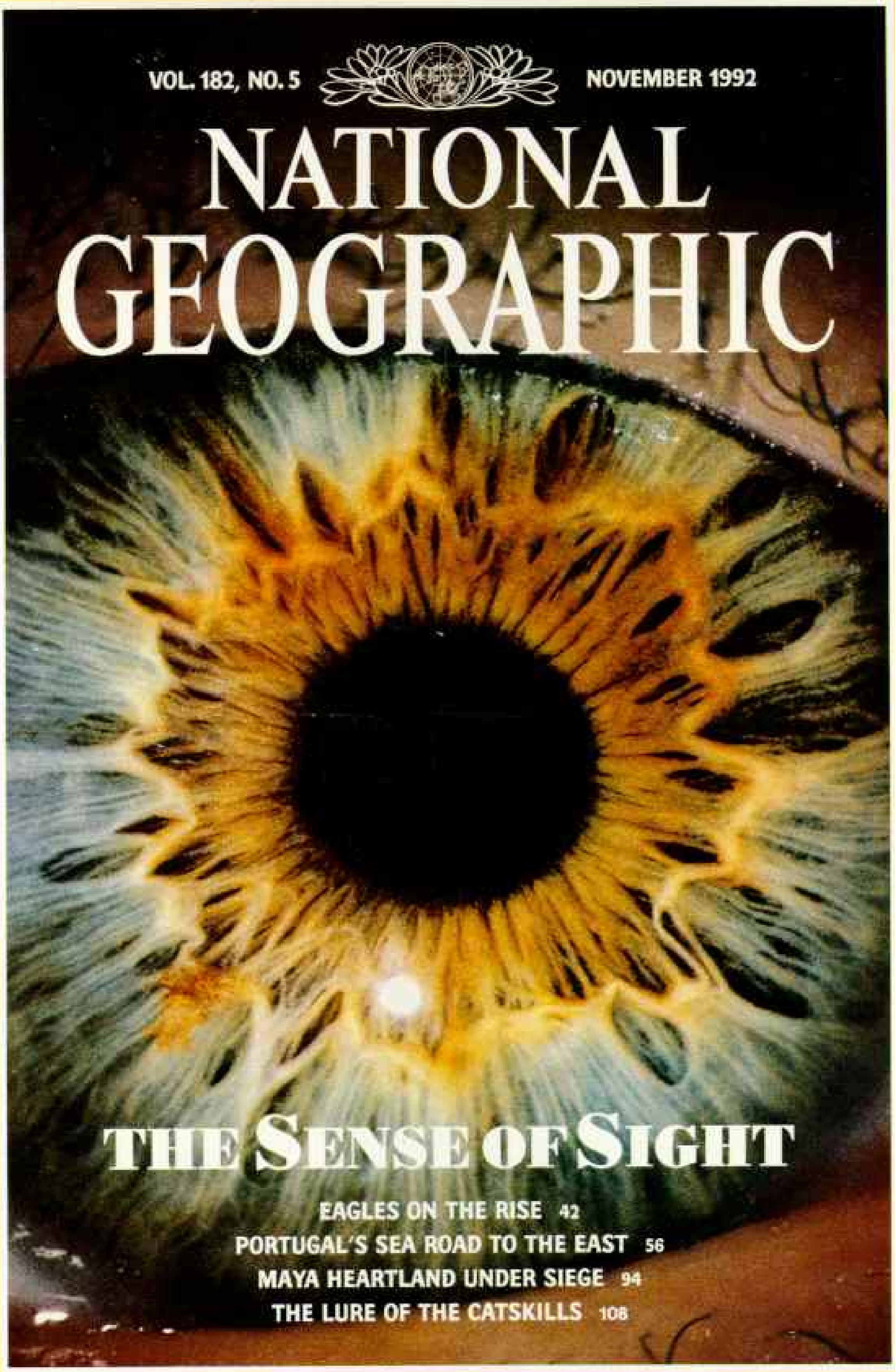

THE SENSE OF SIGHT

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COVER: The human eye reveals its extraordinary intricacies in a close-up usually seen only by ophthalmologists. Photograph by Joe McNally.

Cover printed on recycled-content paper.

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Photographs by JOE McNALLY
SYGMA

The SENSE of SIGHT

In the twinkling of an eye—mere trillionths of a second—the latest surgical lasers cut through tissue to restore sight, the magical sense that translates light into the colors and shapes of our surroundings.

Precious in function, gemlike
when magnified, this complex organ
drives a visual system that makes
billions of calculations every second.

JOE McNALLY WITH DENNIS THAYER, JULES STEIN INSTITUTE

A millimeter can make the difference
between sight and blindness
during microsurgery inside the eye
at Johns Hopkins Hospital.

THE LIGHT coming closer to my eye is piercingly bright, brighter than the white-hot ingots I'd tonged in an Ohio steel mill 40 years ago. The voice behind the light is that of Harry A. Quigley, an ophthalmologist at the Wilmer Eye Institute in Baltimore, Maryland. A blend of efficiency and empathy, Quigley maneuvers the light—called a slit lamp in his profession—to illuminate the interior of my right eye, then the left.

I have asked him for this eye examination, explaining that I haven't had one for years and that it would be a good way to begin research for this story on human vision that you are now reading. But I don't tell Quigley the truth: I am concerned because I have spent the day watching him minister to patients with glaucoma—a disease caused by excessive pressure within the eye, like too much pressure inside a tire. For the first time in my life I have been in the company of people whose ability to see is severely impaired.

From behind the light Quigley observes an abnormality on my retina, the thin sheet of neural tissue at the back of the eye. He makes a phone call, and I am on my way upstairs to see Susan B. Bressler, a retina specialist. Again the light. Bressler's diagnosis stuns. I have a disease called macular degeneration.

Bressler characterizes this as a deterioration in a tiny circular area in the retina called the macula. At the bull's-eye of this circle—the fovea—lies a tightly packed array of specialized photoreceptor cells that provide us with the fine-tuned central vision essential for everyday life. With foveal vision we are able to recognize the faces of friends or foes, write a letter, drive a car, watch TV, or read books, newspapers, signs, or recipes. Without it, having to rely on our much less acute peripheral vision, we can do none of the above and are legally blind.

Thus macular degeneration is the leading cause of blindness in people older than 50 in the Western world. In its "dry" form, the kind I have, for which there is no treatment, the disease could lead to a gradual, inexorable loss of central vision over the years. The gradualism is the good news.

Bressler cautions that I have a risk of the disease progressing to the "wet" form, in which rogue blood vessels erupt under the macula, degrading vision in a matter of days. Begun promptly, laser treatment can retard vision loss in half the cases, at least temporarily. But when vessels erupt beneath the fovea, loss of central vision is inevitable.

A recent strategy, as yet unproven, might reverse this frightening scenario in the future. Henry J. Kaplan, head of ophthalmology at the Washington University School of Medicine in St. Louis, envisions surgery to remove the scar tissue left by the invasive vessels. Then, in a procedure pioneered by neurobiologist Martin S. Silverman of the nearby Central Institute for the Deaf, tissue from the rear of the eye would be transplanted to nourish the photoreceptors.

As I leave the Wilmer in the darkening fall afternoon, I focus on the faces of people queued for taxis. I realize that my sight, once good enough for me to join that band of aviators who operate from aircraft carriers, is a temporary gift now up for withdrawal with what seems to be a roll of the dice.

The fear of that withdrawal, the loss of our sight, is a primal fear. According to polls sponsored by Research to Prevent Blindness, an organization in New York City that promotes eye research, Americans dread blindness more than any other disability. To be blind is to lose access to the most significant part of our perceptual world.

As much as a third of the highest level of our brain, the cerebral cortex, is devoted to visual processing. Our eyes funnel two million fibers into the optic nerves, while the auditory nerve, the conduit for hearing, carries a mere 30,000 fibers. Sight mediates and validates the other senses; when we hear, smell, or touch something, we usually turn to see it also. Before we eat food, we inspect it.

In a profound and mysterious alchemy, sight combines with memory to energize the will. After his return from more than six years of captivity in Lebanon, American hostage Thomas Sutherland related that he had tried to commit suicide three times, but that each time, "The vision of my wife and three daughters appeared before me," and he could not follow through.

Sight is the sense most intensely studied by brain researchers and the best understood. But any of them will tell you they are still on the ground floor of a building that may be tens of stories high. Try this where you're sitting: Look at an object and then turn away so you do not see it. Reach out and you will, most likely,

be able to touch it. The manufacturers of industrial robots would like to impart this ability to their creations, but neuroscientists do not understand it.

Nor do they fully understand blindsight, the rare ability of certain people blinded by brain damage to act on visual information. In tests some distinguished between colors, without being able to explain how. Apparently their optic fibers bypassed the primary visual cortex to communicate with other areas.

Sight enlivens our language. We celebrate poets for their "insight." The politician we acclaim today for "foresight" may tomorrow, in "hindsight," be abhorred. For the skeptic, "Seeing is believing." For the forgetful, "Out of sight is out of mind."

And blind people, who have lost this precious gift, become the most poignant reminders of our fear.

In pursuing this story, I have learned that most blind people have surmounted that fear, and many are busily building careers. In the course of months of research from San Francisco to Moscow, I have also glimpsed the many-faceted dimensions of our visual universe: How nature devises different solutions to the task of seeing, how the brain transforms photons of light into the images we see, how visual illusions deceive us, how the developing world is stricken with eye diseases that we in the industrialized world cannot imagine.

I also learned that important medical breakthroughs are forthcoming. Looking to the year 2000, Carl Kupfer, director of the National Eye Institute, part of the National Institutes of Health in Bethesda, Maryland, predicts advances in several areas, including:

- Cataracts, lens opacities that prevent light from reaching the retina. New drugs will slow the development of these opacities that are the leading cause of blindness worldwide.
- Retinitis pigmentosa. Researchers are now beginning to unravel genetic clues to this family of diseases that ravage photoreceptors. As understanding advances, strategies will develop to retard the disease.
- Optic-nerve regeneration. The stunning ability of proteins to regenerate damaged spinal nerves in experimental animals has also been demonstrated in the optic nerve, typically affected by glaucoma and other diseases.

As founding director of the National Eye Institute, which funnels most of our federal tax dollars that support eye research, Kupfer looks back with satisfaction at recent clinical trials that have resulted in a 90 percent reduction in blindness in diabetics and 50 percent in premature infants. Plus the development of the scanning laser ophthalmoscope that maps the retina in three-tenths of a second.

What would Georg Bartisch have done with all this technology? In Renaissance times Bartisch and other itinerant surgeons traveled

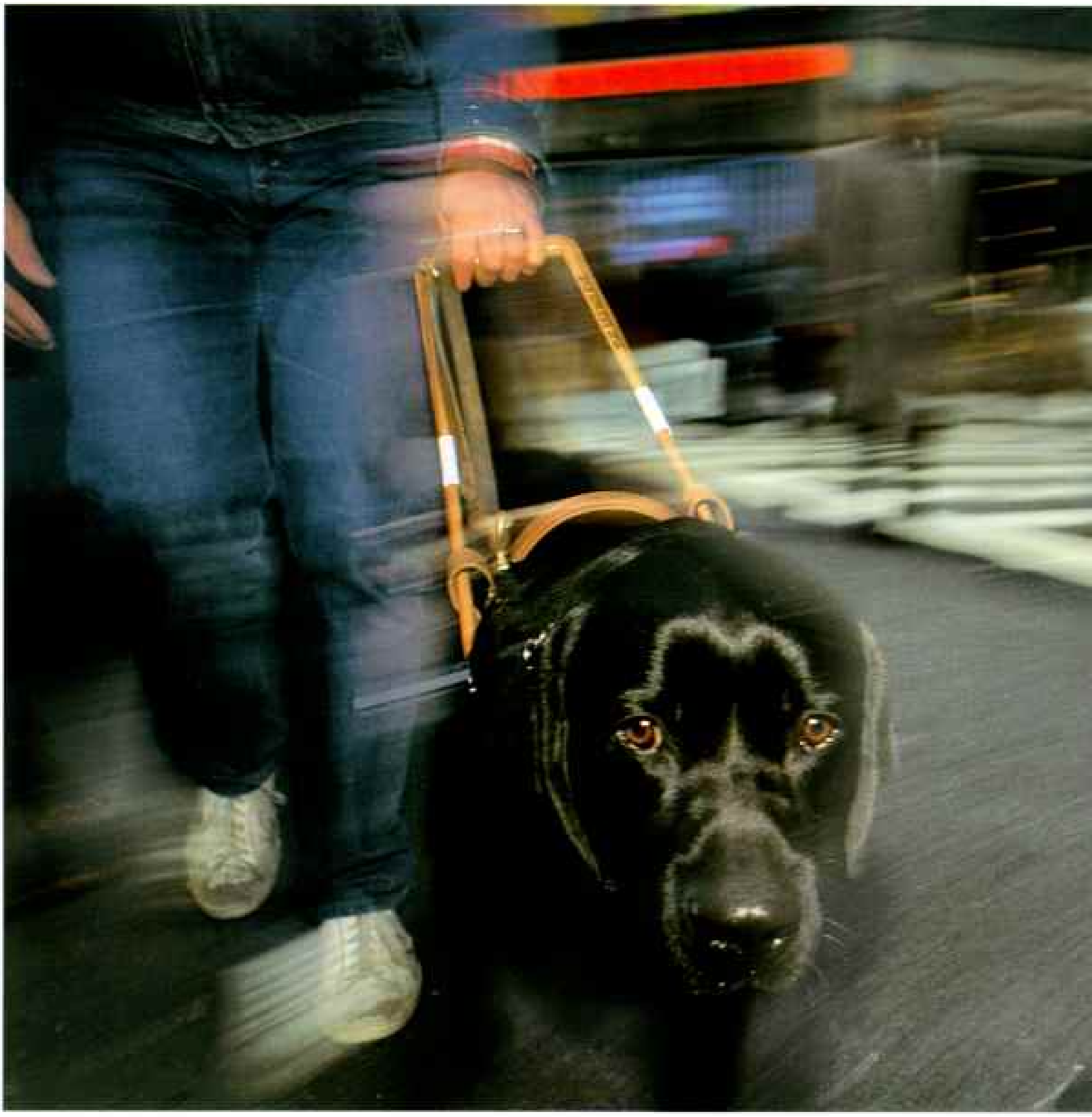
With a delicate touch Denis Lee, director of medical illustration at the University of Michigan, adds a lash to a prosthesis for a woman who lost her eye to cancer. After shaping features in silicone to match the undamaged side of his patient's face, Lee paints them like a portrait. "Without this kind of help a lot of people would just sit in their bedrooms for the rest of their lives," he notes.

Germany treating cataracts by jabbing the eye with a pencil-like instrument, a procedure that might sometimes jar the lens from the protective capsule surrounding it and restore some vision but always generated intense pain. Bartisch published a compendium of ophthalmology in 1583 that contains a woodcut illustrating the state of anesthetics—a patient's arms and legs are tied to a chair.

In the modern, virtually painless method, a needle inserted behind the eye deadens and immobilizes it while the patient remains conscious. At the Wilmer Institute I watched Harry Quigley anesthetize Esther Morse of York, Pennsylvania, for cataract and glaucoma surgery. Her right eye, magnified 30 times by the surgical microscopes, assumed the dimensions of a small planet. I felt like a visitor from Lilliput as Quigley made tiny incisions to create a trapdoor-like flap on the white of her eye near the upper eyelid, perforated the tissue beneath the flap to relieve the pressure of glaucoma, and sutured the trapdoor with wisps of nylon thin as eyelashes.

To remove the cataract-marred lens, Quigley made another tiny cut. "Now with a little pressure I'll pop it right out," he said to me, and the jelly-bean-size lens, brown with age, slid out.

"Take the wrinkles too, doctor," said the attentive Mrs. Morse. Promising to do his best, Quigley inserted a new plastic lens.



THE EYE FUNCTIONS like a camera to focus light rays on the retina. The rays are bent first by the cornea, the thin transparent tissue covering the iris, the diaphragm that gives the eye its distinctive blue, brown, or other color. The iris expands or contracts to regulate the amount of light transmitted through the round aperture at its center, the pupil.

Then the rays are bent further by a protein-rich crystalline lens behind the iris; this completes the focusing task.

Unfortunately for a hundred million Americans—who have to wear glasses or contact lenses—nature gets it wrong a significant amount of the time. If the light rays are not bent enough to focus on the retina, you are farsighted. If the rays are bent too much, you are nearsighted, or myopic, a much more common condition. A focal point even a millimeter in front of the retina results in significant myopia, the plight of at least a quarter of the human race, including 70 million Americans.

Though scientists have long known that myopia is often associated with persons of high income, education, IQ, and status, they do not know its cause. A five-year study, sponsored by the National Eye Institute, employs sophisticated measuring devices to track eye development among schoolchildren in Orinda, California, and may yield clues, says Anthony J. Adams, dean of the School of Optometry at the University of California at Berkeley. "This is the first study to measure every optical component of the eye and track it over a period of time," he explains.

Though conclusions about the cause of myopia are years away, surgical deliverance is at hand, according to Russia's Svyatoslav Fyodorov, perhaps the world's leading exponent of an operation to correct myopia called radial keratotomy.

In this procedure a surgeon makes tiny spokelike incisions deep in the cornea, which flattens a bit and focuses light rays more correctly on the retina.

"I guarantee beautiful sight," Fyodorov told me at the Eye Microsurgery Institute, his clinic on the northern edge of Moscow. "Four to 12 incisions. After 48 hours, some tears, then beautiful. For 99 percent of patients, I can guarantee 20/20."

But his crusade, joined by many U. S. practitioners, has produced skeptics as well as believers. In 1980 the National Advisory Eye Council declared radial keratotomy an "experimental" procedure and expressed "grave concern" until careful research validates its safety and effectiveness.

The National Eye Institute commissioned a study that *(Continued on page 23)*

Meeting Manhattan head on, Sherman puts his Seeing Eye training to the test as he guides his partner, 35-year-old Jeff Wiegers. "When I'm with Sherman, I don't feel like I'm blind," says Jeff, diagnosed with retinitis pigmentosa as a child.

The world through blinded eyes

Blindness does not always mean darkness. A number of eye disorders can block critical parts of vision without dropping a curtain across the whole view.

A person with normal sight perceives a New York City street much as the photograph at right depicts it. As the eyes scan the scene, images fall on the fovea, a small spot on the retina that provides our narrow, central field of focused vision. The brain integrates these images, thereby creating the impression of a wide, clear picture.

Retinitis pigmentosa, a genetic deterioration of the retina, gradually tunnels the visual field (below). The late stage of glaucoma constricts vision similarly.

Disease, injury, or age may cause degeneration of the macula, the area around the fovea. A person with this condition sees with only vague peripheral vision (below, center). Macular degeneration is the leading cause of blindness in the United States.

Someone with cataracts, a clouding of the lenses, sees through a haze (below, right). Bright sunshine creates an aggravating glare.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Practicing to deceive

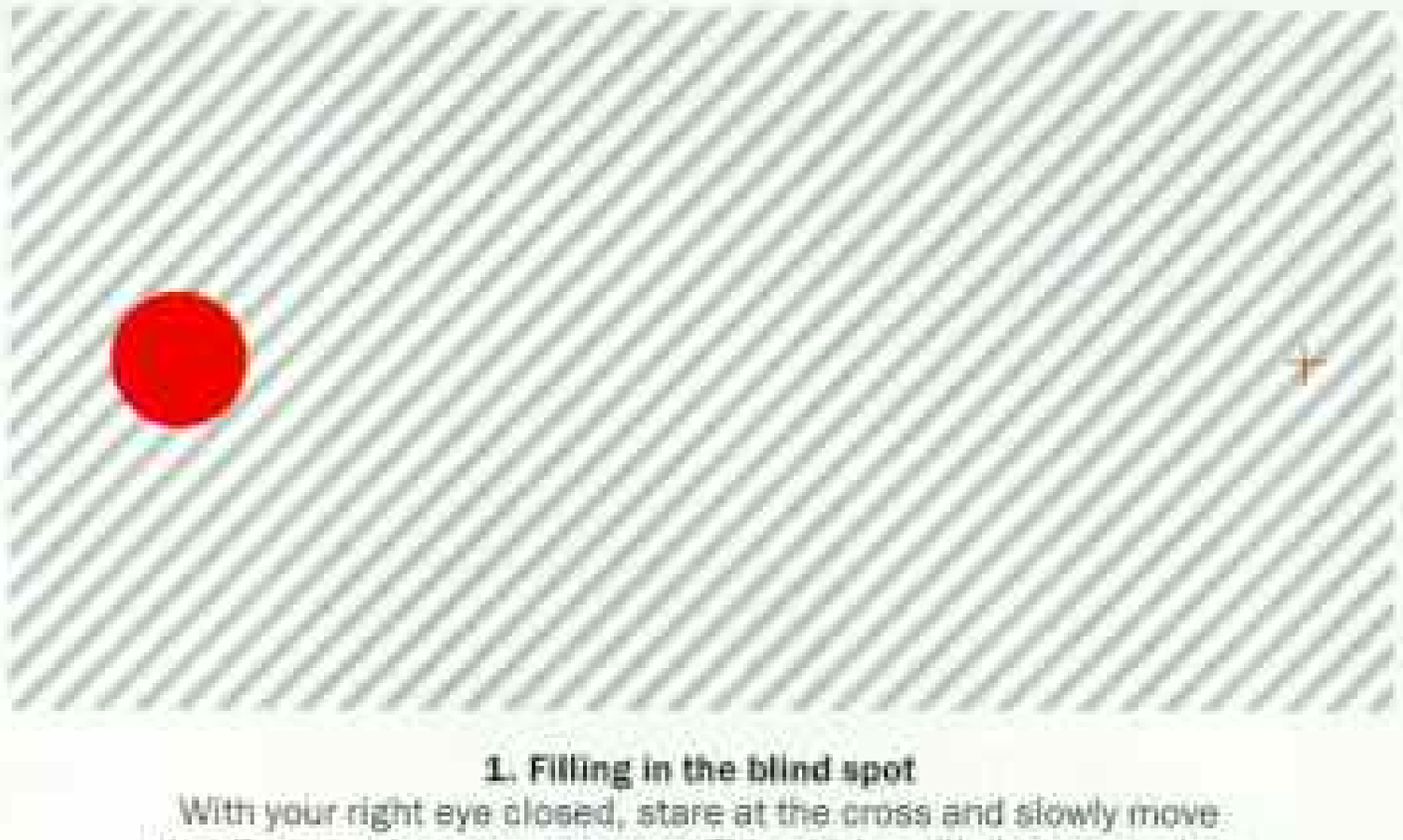
"People often think visual illusions are only curiosities. That's a misconception," says Vilayanur S. Ramachandran, professor of neuroscience at the University of California at San Diego.

"It's important to study illusions because they teach us how the visual system works, what its ground rules are."

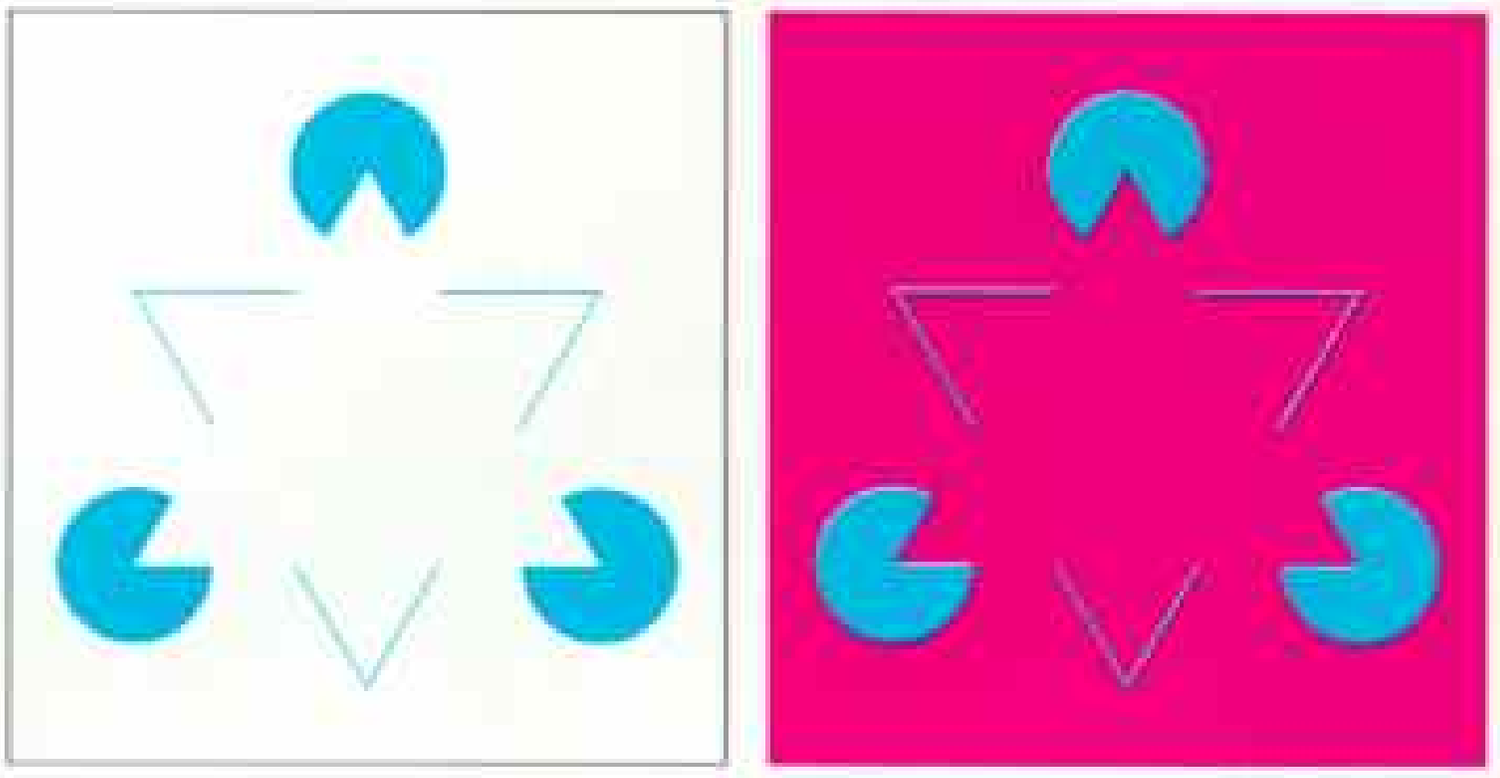
Normally we do not experience illusions in our everyday, three-dimensional world, which offers multiple cues to help our brains interpret images. When these cues are selectively reduced in a two-dimensional world, the brain can be fooled.

In illusion 4, Ramachandran says, we are forced to respond exclusively to the cue of shading. Our brains, accustomed to light from the sun overhead, assume objects are lit from above. Rotate the diagram. The brain keeps to its assumption and creates a new perception of the scene.

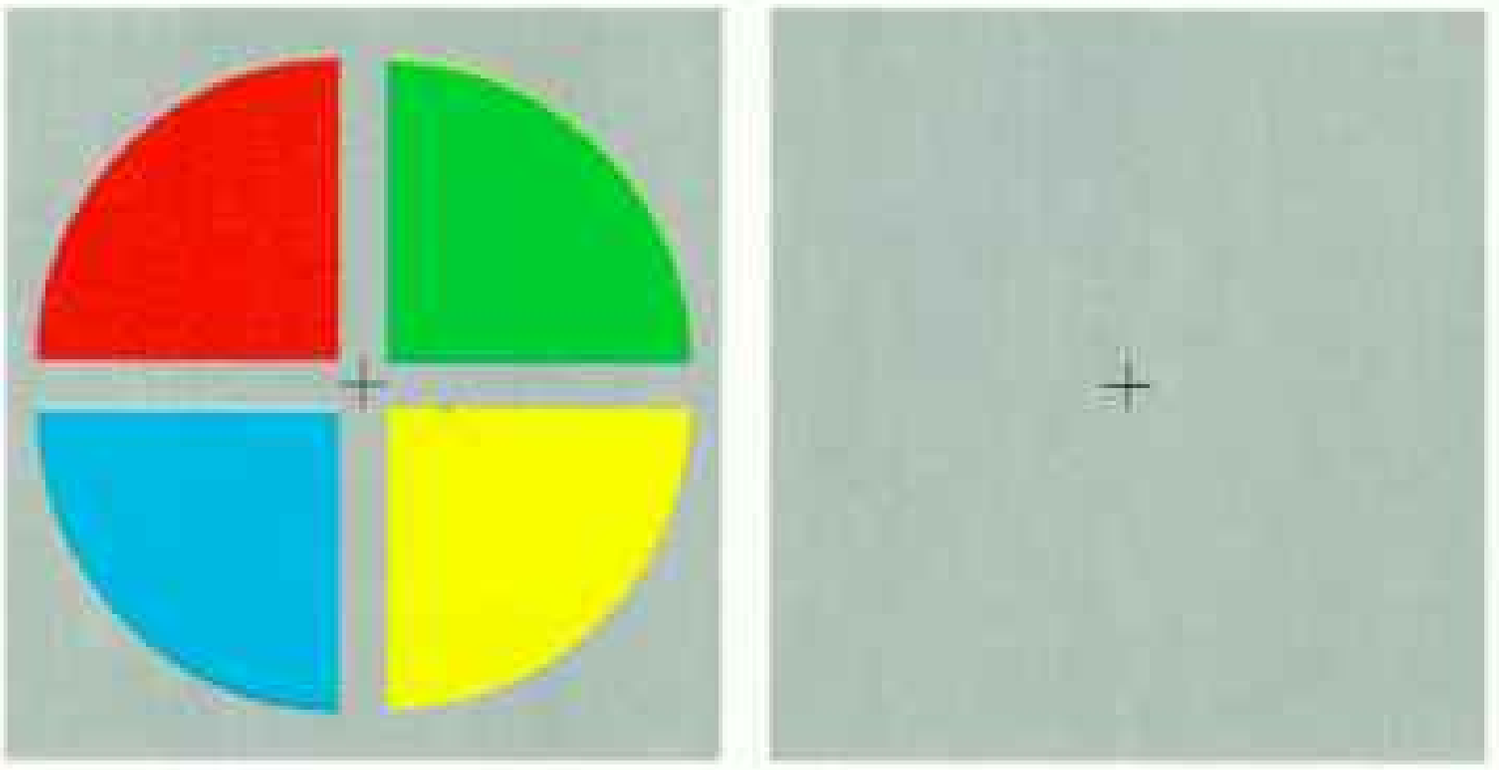
Illusion 2 shows how the brain is primed to construct outlines from incomplete data. A useful capability, says Ramachandran, if you ever need to recognize a tiger lurking in tall grass.



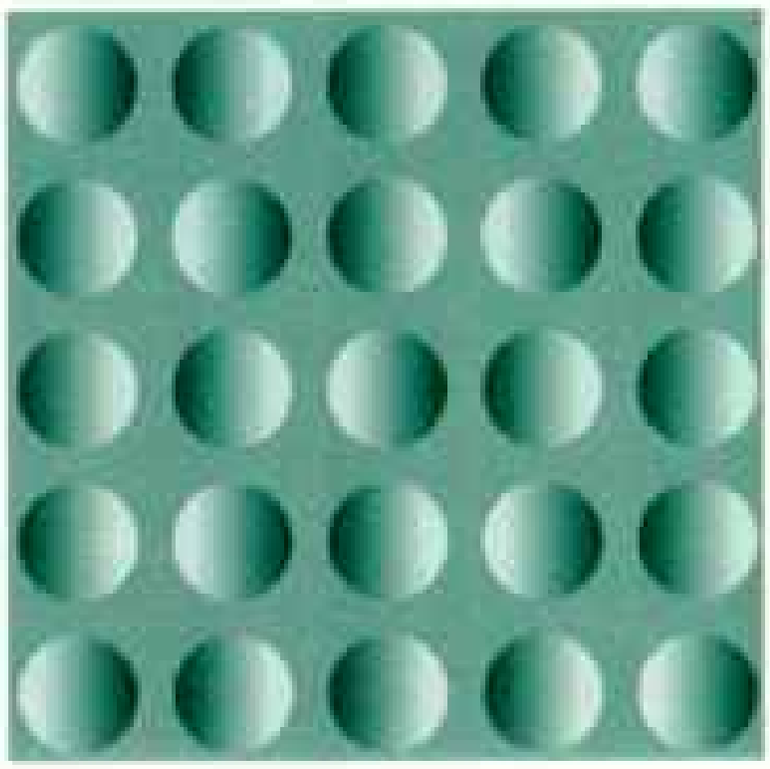
1. Filling in the blind spot
With your right eye closed, stare at the cross and slowly move the diagram closer to your eyes. The red dot will disappear when its focused image on your left retina covers the optic nerve head, called the blind spot because it has no photoreceptors. However, using data from adjacent receptors, the brain improvises, filling the void with slanted lines from the surrounding area.



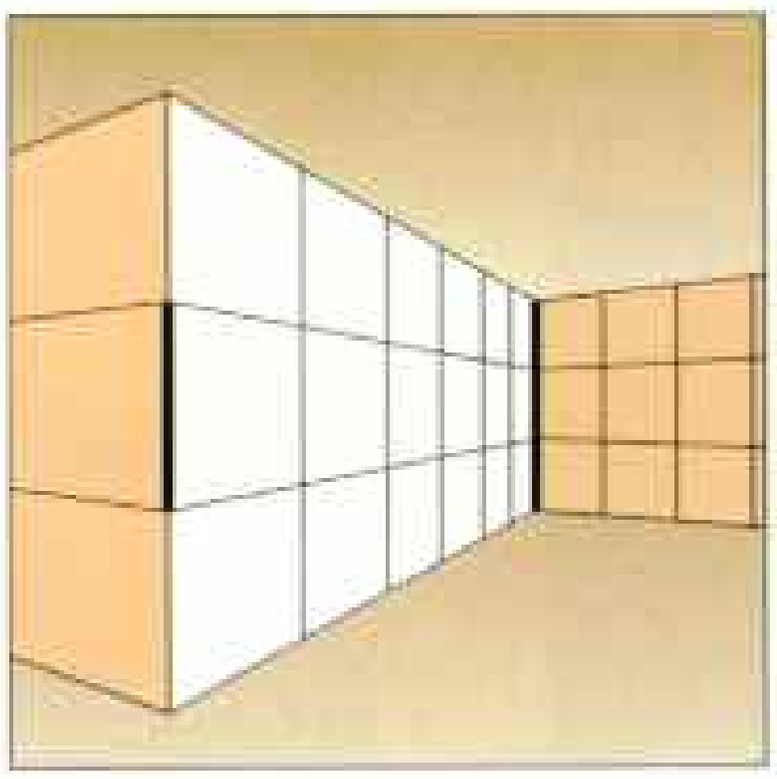
2. Illusory triangles
The white triangle (above left) seems superimposed on the blue-sided triangle. But upon study, the sides of the white triangle disappear: Its brightness is the same as that of the surrounding white. The illusion doesn't work for most people when blue and magenta are shown at equal luminosity, perhaps because the brain's contour-detecting cells are partly color-blind.



3. Afterimages
Stare at the cross in the color pie for a minute or so, and then shift your gaze to the blank square. Patches will appear in colors complementary to the original hues. Clockwise from upper right, red, blue, yellow, and green replace the original colors. Possible explanation: When neurons sensitive to one color become fatigued, antagonistic neurons produce its complementary color.



4. Shape from shading
Residents of a sunlit world, we assume light comes from above and use shading to determine shape. This pattern becomes an X of concave circles if you rotate it 90 degrees to the left. Turned to the right, it becomes an X of convex circles.



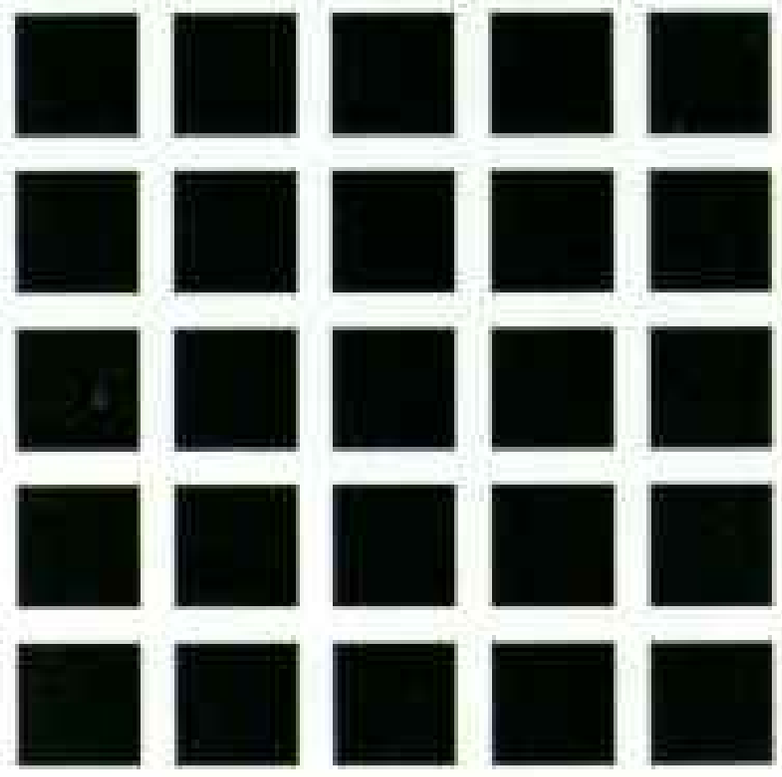
5. Is one line longer?
Measure to convince yourself: The two dark lines in this corridor are actually the same length. The perspective tricks the brain into perceiving the near line as shorter. Even when we know this, our visual system is still confounded.

6. One or two grays?
The color of the two small triangles is identical. It appears different to most people because the yellow and blue colors of the large triangles affect perception. When interpreting colors, the brain takes the larger scene into account.

KAISER PORCELAIN, JUDY COUSINS

7. Faces or vase?
We see two faces or a vase. But we cannot see faces and vase at the same time, because our brain recognizes an object by separating it from its background. Here both perspectives are equally plausible, so our perception reverses again and again.

8. Divergent or parallel?
The short hash marks confuse the brain cells that gauge orientation, and we interpret the longer lines as diverging. To negate this effect, tilt the diagram and look across it from the lower left corner. The divergent lines are in truth parallel.

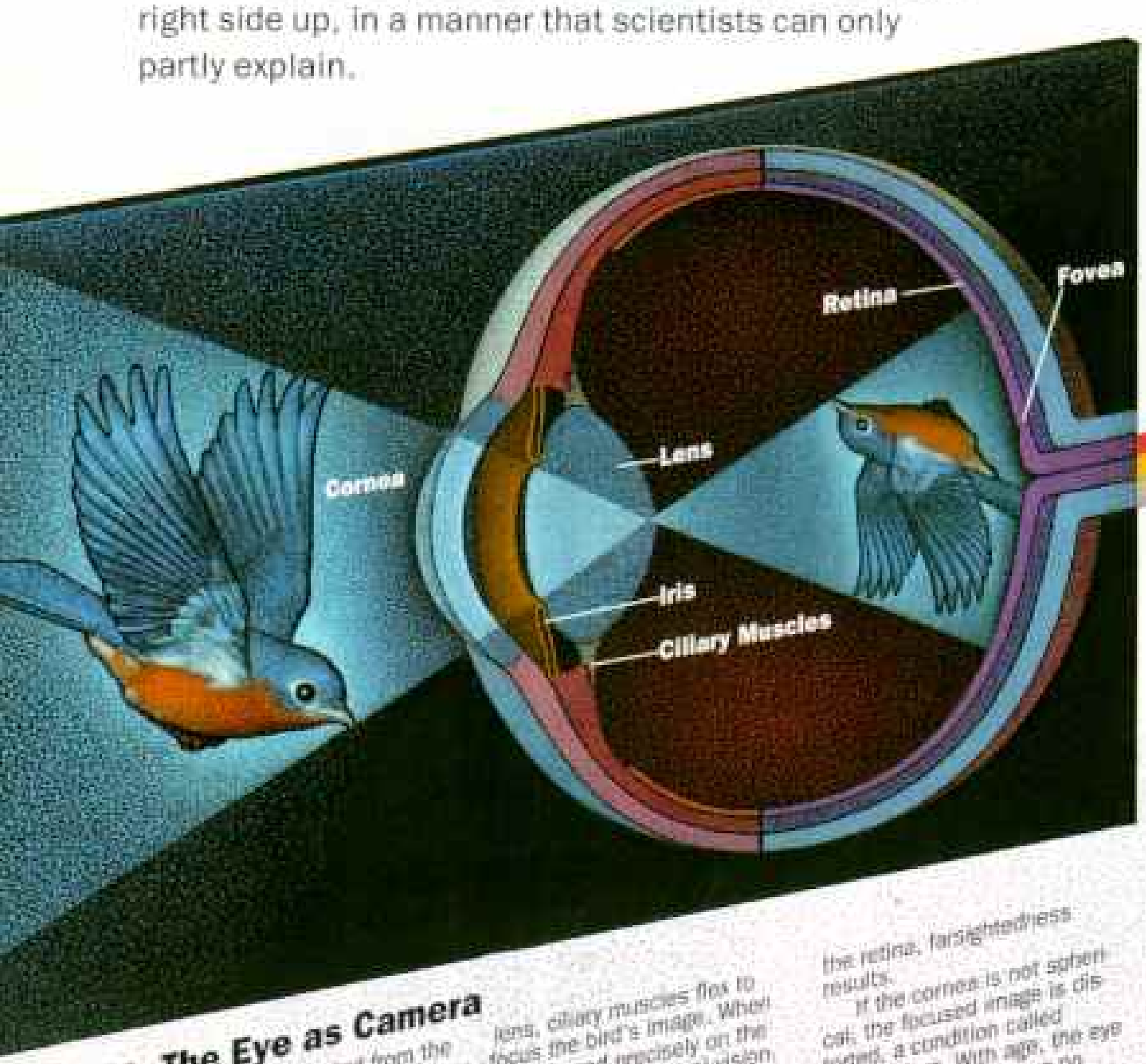


9. Whence the gray spots?
Where the white bars cross, dark spots pulse, induced by the way retinal cells react to light in this geometric scene. The contrast between black and white selectively excites or inhibits the response of these cells, thereby creating the illusion.

Pathways to perception

The act of seeing a bird on the wing (below) begins as our camera-like lenses focus the image, upside down, on the retina at the back of each eye. Within this sliver of neural tissue, millions of photoreceptor cells parse the image into an array of components. The bird's colors, shape, and motion—each flick of feather and glint of eye—are received as photons of light and coded into tiny electrical impulses.

In a feat of computation that far exceeds that of any computer, the impulses are channeled to the cortex, where they are analyzed and interpreted. Finally, the brain creates our perception of the bird, instantly and right side up, in a manner that scientists can only partly explain.



1 The Eye as Camera

Light waves reflected from the bird are bent first by the cornea, the eye's fixed outer lens. The iris, whose pigment gives an eye its distinctive color, contracts in bright light and expands in dim to regulate the amount of light entering the pupil.

Deployed around the inner lens, ciliary muscles flex to focus the bird's image. When it is focused precisely on the retina, we have normal vision. But if the focus falls even slightly short of the retina, we are nearsighted—near objects are clear and distant ones blur. When the focus is behind the retina, farsightedness results.

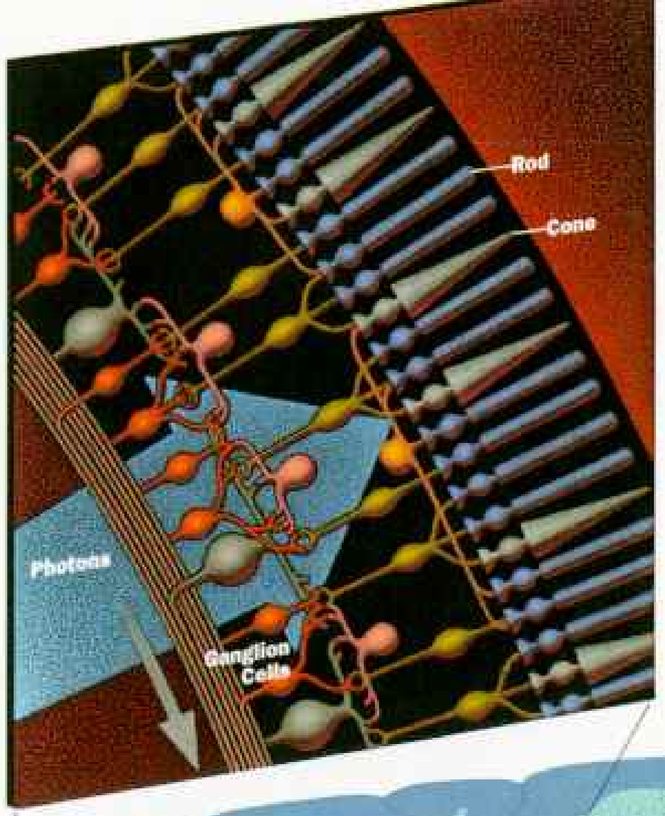
If the cornea is not spherical, the focused image is distorted, a condition called astigmatism. With age, the eye loses its ability to focus on near objects, creating the need for reading glasses.

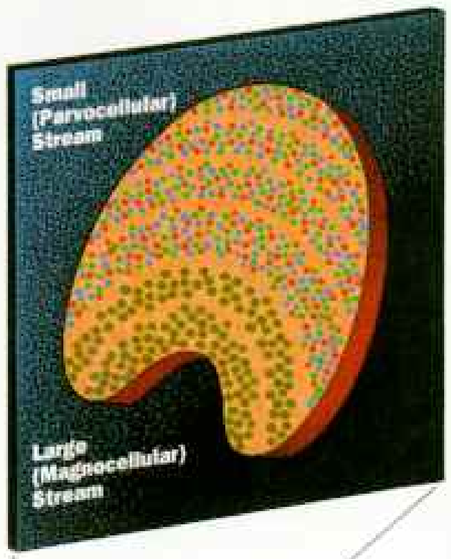
2 The Retina

Photons of light from the bird (right, large arrow) flood the retina to activate photoreceptors, called rods and cones because of their shapes. Cones specialize in bright light and are concentrated in a central patch of retina called the fovea, which provides our acute central vision, rich with color.

Spread through the retina's periphery, the sensitive but color-blind rods enable us to see in dim light. Each can be activated by a single photon.

Signals from the rods and cones are processed by banks of other cells and forwarded to the cortex. Large ganglion cells seem to specialize in data such as the bird's motion and outline. Small ganglion cells attend to the bird's color and fine detail. Messages from these cells leave the eye (right, small arrow) and enter the optic nerve.





4 The Switchboard

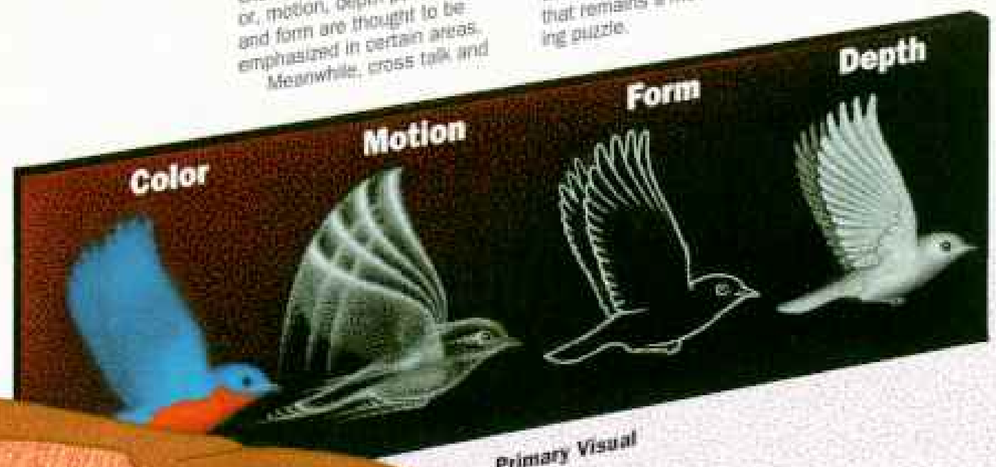
Like cables in cross section, six rows of cells in the geniculate body receive and pass on neural information. The two lower rows transmit data about the bird's motion and overall features. The four upper rows transmit impulses related to color and fine detail. Thus the brain continues its segregation of visual information into parallel streams for further processing.

5 Putting It Together

The parsing of information continues in the primary visual cortex and dozens of other visual areas in the brain. For example, the specifics of color, motion, depth perception, and form are thought to be emphasized in certain areas.

Meanwhile, cross talk and overlap occur among these areas and with other regions of the brain whose functions are not known.

If the brain takes the bird apart, why do we see it whole? For vision scientists that remains a most tantalizing puzzle.



Right Hemisphere of Brain

Right Lateral Geniculate Body

Primary Visual Cortex

Optic Chiasm

Optic Nerve

Left Lateral Geniculate Body

3 Left and Right

Certain channels of the optic nerves (colored yellow, at left) carry signals from the left half of the retina of each eye. Other channels (red) funnel information from the right half of each retina.

At the optic chiasm the nerves split, distributing input from each eye to way stations in the thalamus called geniculate bodies (figure 4, above). From the geniculates other neural pathways relay the messages to the primary visual cortex and higher regions of the brain. This circuitry enables us to see the bird even with one eye.

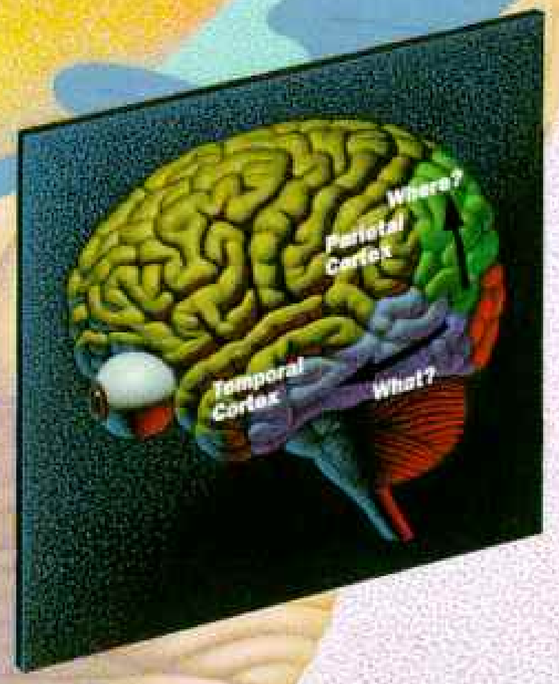
Left Hemisphere of Brain

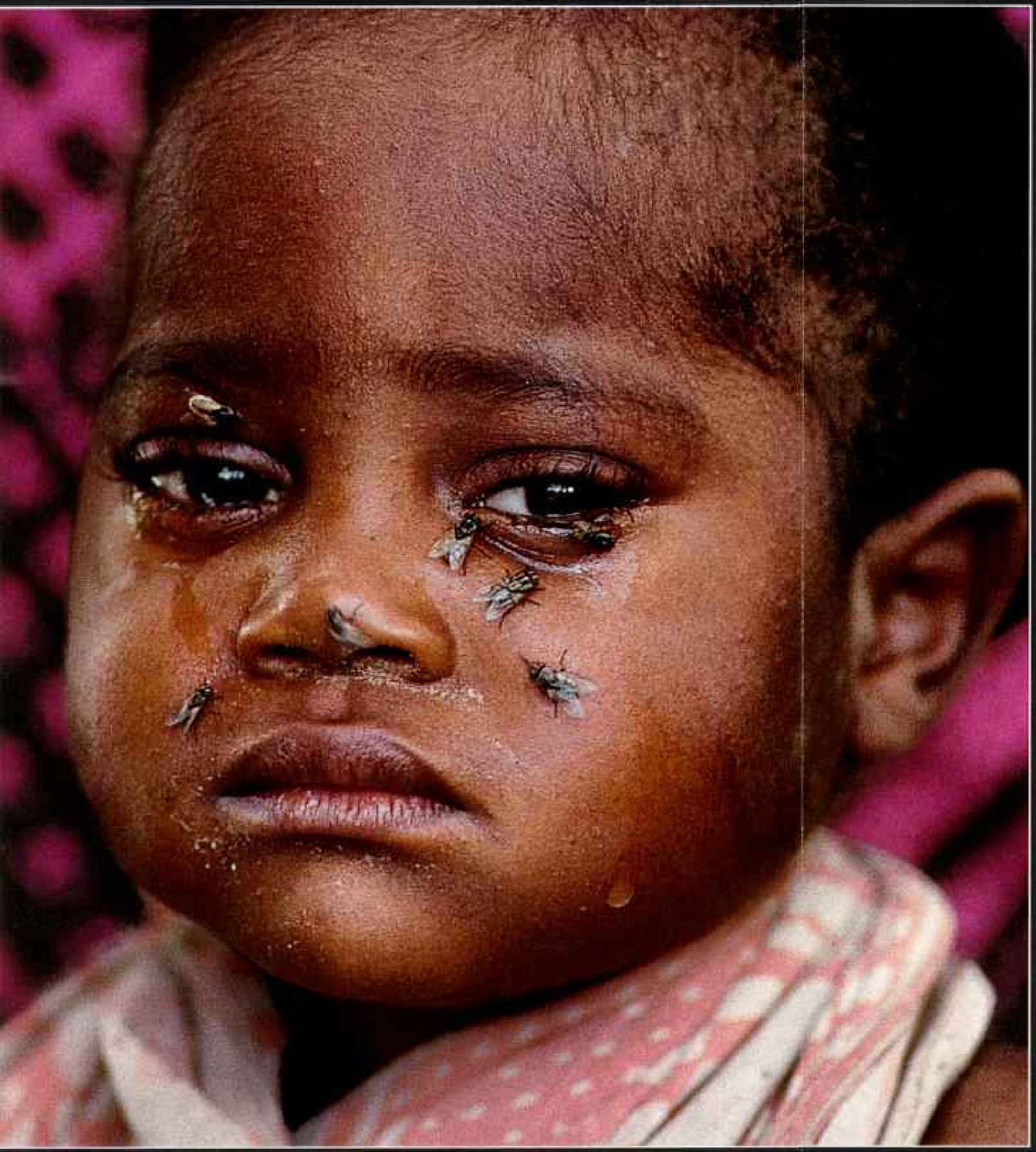
Cerebral Cortex

6 What? Where?

A visual area in the temporal cortex, whose neurons are sensitive to shape, identifies the bird as bird. People with damage to this region can lose the ability to recognize faces, even their own.

An area in the parietal cortex is sensitive to position: locates the bird in space. Damage to the right parietal cortex inhibits the ability to locate objects in the left visual field.





Africa: battling

Using the simplest tools, nursing officer Sidney Katala wages war against eye disease in central Tanzania. With a flashlight and magnifiers he examines a woman in one of the villages he visits (above).

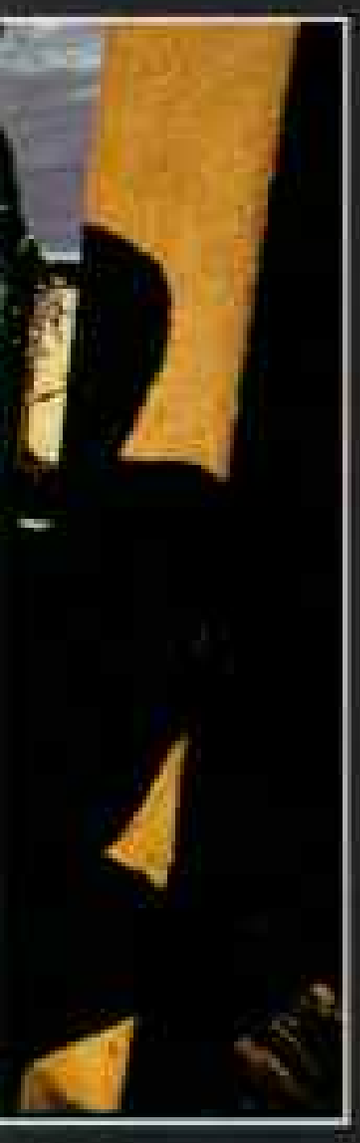
A Ministry of Health worker with training in ophthalmology, Katala has joined U. S. and Tanzanian colleagues in a

eyelashes across the cornea. Painful corneal disfigurement brings blindness.

At his clinic in Kongwa, Katala goes beyond persuasion to open the reddened eyes of a frightened child (below). Chances are he will find signs of trachoma: Six of every ten children in the region are infected, passing the disease among themselves as they play. A child's tears attract flies (far left), which may also transmit the infection.

The study has discovered that washing the face once a day (bottom, center) helps stop the cycle of infection. Village volunteers are now teaching parents to keep children's faces clean despite the scarcity of water.

blindness



study of trachoma, the world's leading infectious source of blindness. An inflammation caused by the *Chlamydia* microorganism, trachoma strikes in hot, dry places with poor sanitation. Repeated infections scar the inside of the upper eyelid, which turns under in some cases and eventually scrapes the

Blind since birth, Cortney Glonka listens for echoes of her clicker to navigate the halls of her Detroit school. The metal lockers, tiled walls, and recessed water fountains give off different sounds.

A trip down a Munich escalator is a trial for Gisela Leibold, unable to see motion since a stroke in 1978.

(Continued from page 11) monitored 435 patients who had the surgery. Carl Kupfer summarizes the results after four years: "Roughly two-thirds of the patients are corrected and do not need glasses. The others are either overcorrected or undercorrected. So you have a 67 percent chance of getting rid of your glasses. And then there are the long-term effects of the procedure to consider. We just don't know yet."

Meanwhile a laser vies to replace the scalpel in reshaping myopic eyes. With the ability to ablate corneal tissue a trillionth of an inch at a time, the laser's exquisite precision is now undergoing scrutiny by the Food and Drug Administration, which has the responsibility to establish the safety and effectiveness of new surgical devices in the United States.

WHEN THE ROLL of eye diseases is called in the developing world, the scourges themselves respond: as many as nine million people blinded by trachoma; one million blinded or severely impaired by onchocerciasis, or river blindness; 350,000 new cases in children each year of xerophthalmia, blindness from a systemic deficiency of vitamin A.

In Geneva, Switzerland, Bjorn Thylefors, World Health Organization program manager for blindness prevention, reports progress in some areas. Ivermectin, a new drug, fights the parasite that causes river blindness. The disease draws its name from the fact that the blackfly, which transmits the parasite through its bite, breeds in fast-flowing rivers. The effectiveness of the treatment is tempered by the difficulties of distributing the drug among rural populations.

In Indonesia and Guatemala, programs to fortify food so children get the needed amount of vitamin A have met with some success. But "more must be done in other countries or the disease will likely increase," said Thylefors.

Though such antibiotics as tetracycline can dispel trachoma, this disease inevitably returns through poor hygiene. With trachoma, caused by the *Chlamydia trachomatis* organism, repeated infections scar and tighten the inner eyelid. Over the years, the eyelashes are pulled under the lid, producing trichiasis. Each time a person blinks, the ingrown lashes scrape the cornea like a garden rake.

The hot, dusty area of central Tanzania is a notorious breeding ground for trachoma because of poor hygiene and the scarcity of water. To fight the disease at its roots, Sheila West of the Wilmer Institute and Tanzanian medical officer B.B.O. Mmbaga constructed an audacious hypothesis: If mothers can be encouraged to wash their children's faces, especially the eyes, at least once a day, transmission might be interrupted.

This was easier said than performed in a region where adolescent girls must walk miles to wells to fill a small water gourd that they bring home atop their heads. Yet initial results from two test sets of villages are "surprisingly good," in West's words.

Even if trachoma is conquered, Tanzanians will have plenty of other eye problems to cope with. One morning at the clinic in Kongwa, I watch Sidney Katala, an ophthalmic nurse, prepare for surgery. His patient, Sebiga

Mtochezi, a Masai tribesman sentenced to prison for cattle thievery, stands in a blue robe with the half-closed eyes that bespeak trichiasis. "He is in continuous pain," says Katala. "He will be blind in six months."

A tall man of kind face and demeanor, Katala asks him to recline on an ancient mahogany table nearby. Mtochezi's thigh muscles bulge as the anesthetic needle pierces his eyelid. Katala cuts the lid lengthwise just above the lashes and sutures the incision with sufficient tension to unfurl the lashes to their normal position. The operation is called a tarsal rotation and takes about ten minutes for each eye. Not many American ophthalmologists have seen it, certainly not performed by flashlight and without running water. Katala learned it during a fellowship at the Kilimanjaro Christian Medical Centre in Moshi.

Katala's practice encompasses 100,000 residents of 44 villages. Though he refers glaucoma and cataract patients to medical officer Mmbaga at the Dodoma hospital, Katala performs other surgical procedures such as enucleating, or removing, diseased eyes, perhaps five a month.

Face taut with concern, a young mother enters his office bearing an infant whose eyelids ooze pus. "Bacterial conjunctivitis," Katala murmurs. He encourages the mother to lean the boy backward to place the child's head between his knees. Katala chuckles reassuringly as he maneuvers the eyelids apart and administers an antibiotic. Immediately the boy flies to his mother's breast and proves he can nurse and cry at the same time.

I watch as Katala ministers to a woman with a damaged lens in her right eye—she had been beaten by a drunken brother; to an old man who lost an eye to a thorn pierce while gathering firewood; to a boy with a lacerated cornea; to an old woman recovering from a cataract operation.

One man requires a painkiller injection near the optic nerve for relief, Katala decides, but when the man sees the long needle he demurs, and it takes minutes of gentle suasion to get him to recline on the mahogany table. With great patience Katala slips the needle beneath the left eye and pushes the plunger. The man gets up and grins because, it seems, the needle didn't hurt as much as he had expected.

Katala supervises a program in which several blind residents of Ibwaga village learned to walk with canes and grow a modest crop of peanuts. He stops his truck on the road to Ibwaga, and we walk across a field where four blind women and a man await under a spreading tree. From his hunker, 65-year-old Mwaluko Magawa, whose eyes bear the scars of trichiasis, tells me he is proud to be able to plant and harvest a crop. Katala shows me a small mud hut where the crop is stored. It is necessary to place thorns across the entrance, he says, to dissuade sighted villagers from stealing the crop.

It is time to go. With blind Magawa in the lead, the little troop tap their canes from side to side in the maroon soil and file onto the dusty road. Katala follows along, showing compassion to these people on the road to Ibwaga as surely as the Good Samaritan showed compassion to his fellowman on the road to Jericho.

THE BLINDNESS that afflicts 100,000 Americans each year leaves eight out of ten with at least a sense of light and shadow and even measurable vision. People are legally blind, thus eligible for government services, when the diameter of their visual field is not greater than 20 degrees or when acuity in their better eye, with glasses, is not more than 20/200. This means they can recognize the top letter on an eye chart—usually an E—from 20 feet. A person with normal vision can see it from 200 feet.

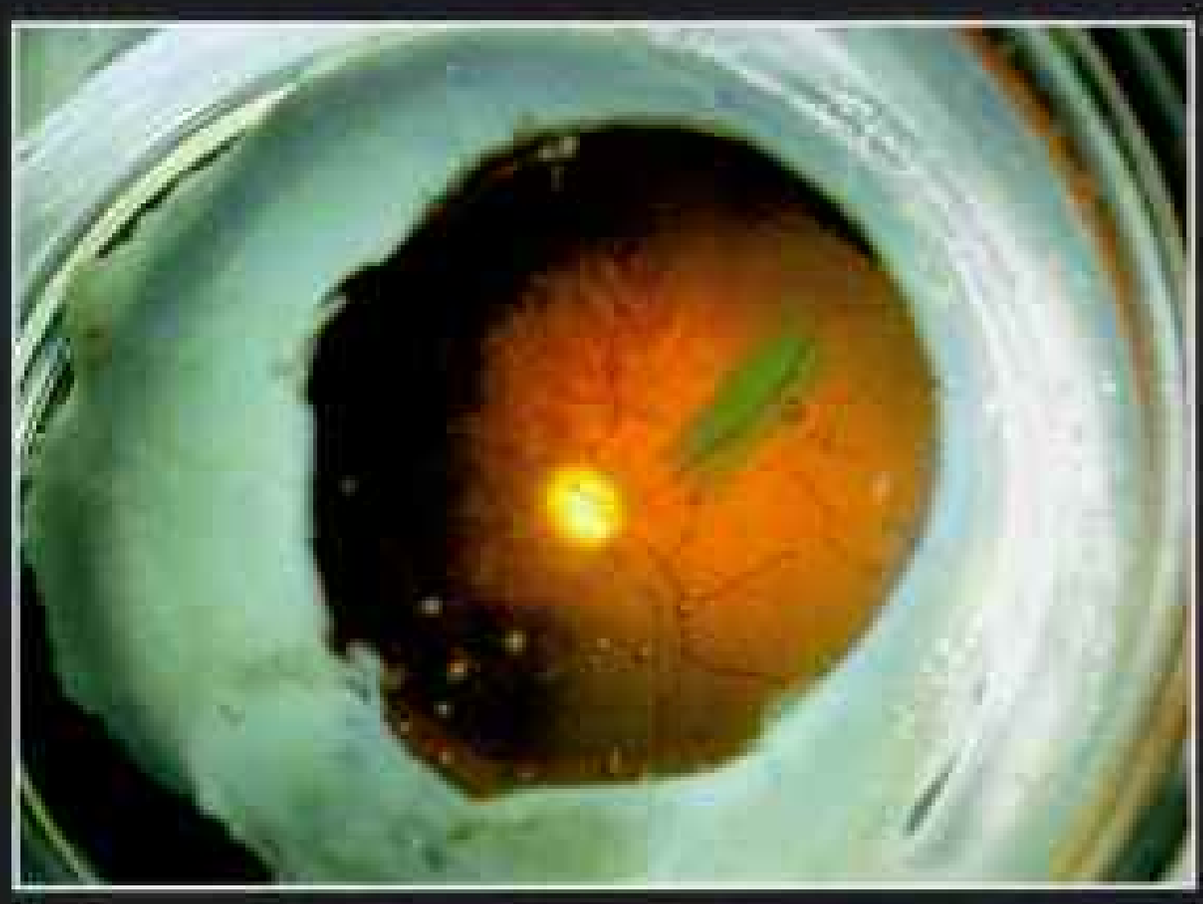
At Western Michigan University in Kalamazoo, men and women master skills to help visually impaired people adapt. They blindfold themselves to experience the deficit of blindness, learn to walk with a cane, to dress, to communicate with Braille and computers, to cook food and eat it arrayed in clock positions around their plates—for example, meat at 12 o'clock, vegetables at 4, beans at 7.

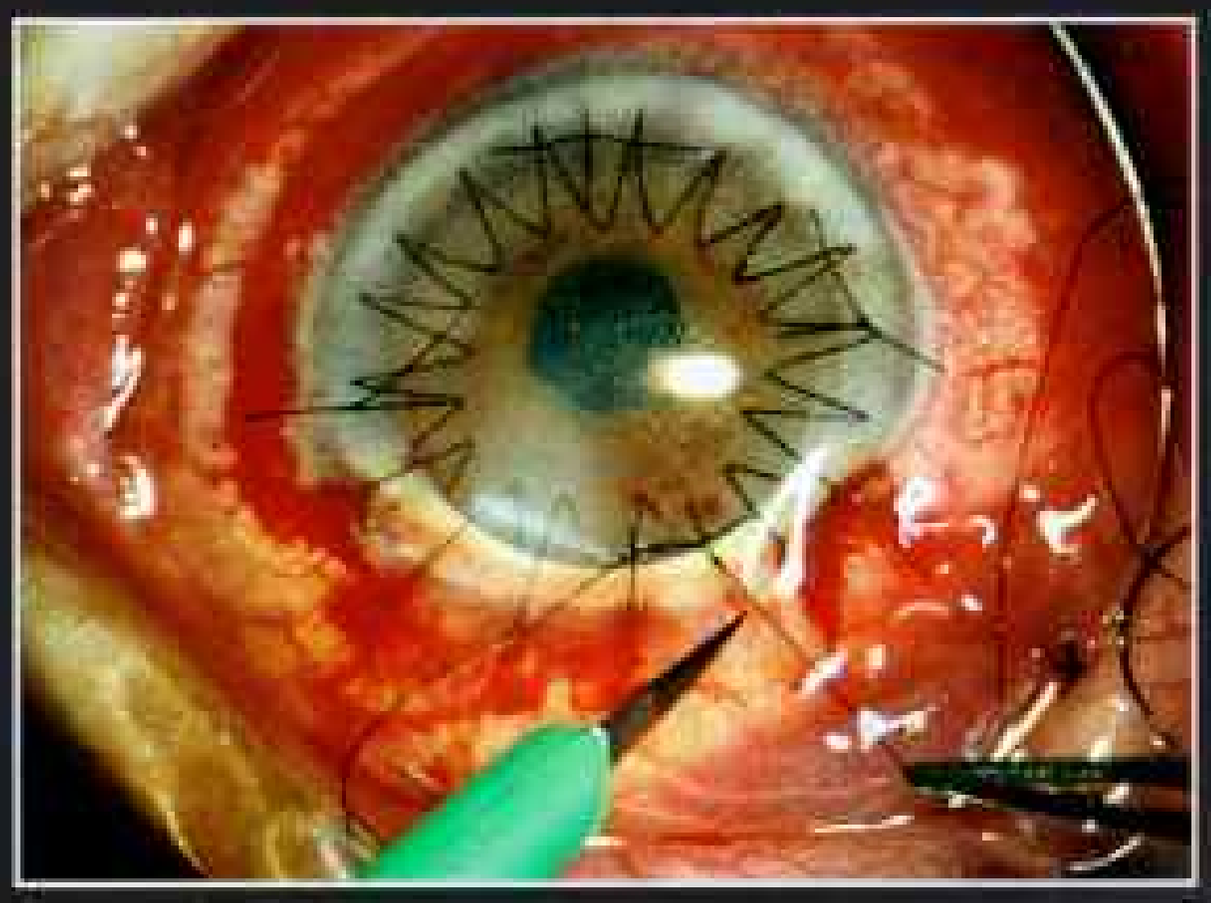
Professor William R. Wiener blindfolds me for an introduction to the art of the cane. Tapping the ground with side-to-side swings of a light aluminum cane, I can distinguish grass from concrete on a sidewalk but wind up in the middle of the street. The dip in the curb, designed to help people in wheelchairs, fools me as it can fool the visually impaired. Susan Ponchillia invites me to her classroom and patiently coaches me through grilling a peanut butter sandwich. The critical task is judging when to turn the sandwich as well as keeping it in the frying pan. "You'd make a good blind person," she says.

Susan's husband and fellow professor, Paul

At the cutting edge

Focused on his work, Henry Kaplan of St. Louis's Washington University removes scar tissue from the back of the eyeball through an incision in a patient's retina. To demonstrate another promising path to the space behind the retina, his colleague Martin Silverman has successfully shoehorned a green marker behind an intact baboon retina (center). Both men are applying their techniques to retinal cell transplant experiments in monkeys, hoping one day to be able to repair human retinas. Revolutionary just a generation ago, a corneal transplant (bottom) is now routine.





Vision factory

The Henry Ford of ophthalmology, Moscow's Svyatoslav Fyodorov (center) pioneered surgical correction of nearsightedness—and created an assembly-line procedure that dismays many U. S. physicians.

Eight patients at a time lie on tables in Fyodorov's clinic (below). When the five attending surgeons each finish their specialized portion of the surgery, the tables rotate for the next step. Each doctor's activity is monitored on TV screens over the surgical arena (above).

Fyodorov was inspired to invent his turntable approach in 1986, when the Soviet government agreed to pay him on a per-surgery basis. "This way I became immediately rich," declares Fyodorov, who is searching for even more ways to automate. "Our main task now is to exclude the doctor from surgery, because he is the

main cause of mistakes."

Many U. S. doctors now perform a similar procedure, charging patients roughly $3,000 for the chance to throw away their glasses. According to an ongoing study, they can do so in only 67 percent of cases, far below the 99 percent success rate Fyodorov claims.

Ponchillia, himself blinded at the age of 30 in a hunting gunshot accident, tells me that imparting the skills of daily living to visually impaired people is the easy part. The problem is teaching them to cope with sighted folks.

"THE WORLD SEES BLINDNESS as the ultimate bad news," Paul explains. "If you become blind, we can rehabilitate you in a few months, and your self-image comes back. Then you go home and discover that people—even your spouse—may look at you as a lesser person because they feel you are not capable; they feel sorry for you. That's the number one problem of being blind—dealing with the public perception of it."

Later I meet people who are dealing with it successfully:

• Jeffrey J. Moyer directed a staff of 40 at the Cleveland Sight Center in rehabilitating visually impaired persons and now works as a consultant on their rights in the workplace. Legally blind at 11 from retinitis pigmentosa, Moyer at dinner replaces one pair of dark-tinted glasses with another, explaining that the glare of room light reflected off the tablecloth hurts his eyes.

Moyer is slowly losing what remains of his vision. "There is a certain peace about it," says this man who does not take himself too seriously. "I am easily amused. A streetlight can be the moon." When Moyer first arrived at the University of California at Berkeley, where he graduated Phi Beta Kappa, he told his wife he thrilled at the sight of the "purple mountain's majesty" of the Berkeley Hills. "She told me I was looking at the roof of the International House Of Pancakes," he recalls.

• James Perley Storer, retired in Perry, Ohio, after a career in radio broadcasting, invites me into his study. Blinded by a chemical accident as a youngster, he extracts a disk from his computer and exclaims: "Nine . . . million . . . words!" He recites the contents of another: a complete Shakespeare, two editions of the Bible, *Walden*, *The Call of the Wild*, *Leaves of Grass*, *The Adventures of Tom Sawyer*, the Constitution and Declaration of Independence, the speeches of Winston Churchill and John F. Kennedy, Lincoln's Gettysburg Address, and perhaps some others that I miss.

Seeing how we see

A vision-processing center glows red at the rear of Caltech researcher John Allman's brain (opposite) in a computer image that has been superimposed on his head.

The red shows increased blood flow to the region, activated by focusing on a small object, like the primate brain Allman holds.

At Boston's Schepens Eye Research Institute (left), Rob Webb looks into a device that projects a laser pattern—here the word "research"—onto his retina. He sees the image, which along with a picture of his retina is shown on a TV. Watching the screen and listening to a patient's description of what is visible, a doctor can locate diseased retinal areas.

"I can access what I want and print it out in Braille or listen to it," Storer tells me. "For the first time in my life I do not have to rely on sighted people."

• Nikolai Stevenson, returning my call to his New York City office, calls me "Alice" and hastily apologizes—"I misread the secretary's note," he says. I understand when we meet later at a restaurant, and he brings the menu very close to his eye. Stevenson was a successful businessman when macular degeneration robbed him of his foveal vision. He now counsels people with retinal disease with the same esprit he displayed as a U. S. Marine Corps company commander on Guadalcanal in 1942. As we leave, he warns that he won't recognize me if we meet again. "I can't see your face," he says.

IN THE REFECTORY of a grand, red-brick building outside of Morristown, New Jersey, I breakfast at Seeing Eye, Inc., the oldest of a handful of schools in the U. S. that provide dog guides for visually disabled people. Under nearby tables sprawl 18 Labrador retrievers and German shepherds, one for each blind person finishing the meal. The men and women arise and, harnessing their dogs, file out of the room for another day of trekking around Morristown.

One blind person and dog and one watchful instructor to a team, they walk through streets, shopping malls, and supermarkets; negotiate escalators and elevators; visit the station to practice getting on and off the train, and stop for a muffin at Dietworks, whose doors open early just for them. Dogs are trained to be intelligently disobedient, to disobey a command that would put a blind person in danger.

Trainers have been doing this at the Seeing Eye since founder Dorothy Eustis returned from Europe in 1929. Eustis had observed German shepherds serving as guides for blinded soldiers, and she was intrigued with the idea of training dogs to help blind people become truly independent. Her idea blossoms again with each new class.

For a token fee of $150, which has not changed since 1929, a blind person gets the following: airfare to and from Morristown from anywhere in the U. S. or Canada, room and

SUPERIMPOSED BRAIN IMAGE BY BASSEM MORA AND GEORGE CARMAN

board, four weeks of training with a specially bred dog that has itself completed 12 weeks of training, plus a virtual lifetime guarantee on the animal. If a problem develops that can't be taken care of by telephone, Seeing Eye flies an instructor out to rectify it. Seeing Eye taps interest from a hundred-million-dollar endowment, mostly from bequests through the years, for 70 percent of its eight-million-dollar annual budget. The rest comes from general fund-raising.

I ask Douglas S. Roberts, director of Seeing Eye programs, if he will allow me to experience a walk, blindfolded, with a dog in nearby New York City. Doug agrees and picks a feisty young female black Lab named Jade, just graduated from training, who introduces herself with a kindly lick of my hand.

On a Morristown street Doug puts Jade's harness handle in my left hand and gives me basics: "The go command is 'Jade, forward.' . . . Wait for the pull and step out. . . . Think through your left hand. When she stops, extend your foot and find out why, probably the curb. . . . 'Forward,' again and wait for the pull. . . . She'll hesitate at the other curb, you raise your foot, contact the curb, and off you go. It's like dancing."

We train along a sidewalk. "Rough pavement here," Doug cautions. "Point your toes up inside your shoes so you don't trip." It works. "The traffic and noise in Manhattan can stress out a dog real quick," he says. "You need an eager animal." Feeling Jade's zestful tug, I agree she qualifies.

In Manhattan the next day, Doug handles Jade as we walk down Eighth Avenue. At a curb a man pushing a trolley loaded with dresses barrels toward the wheelchair ramp at the corner, directly at Jade. Doug stands coolly; the trolley keeps coming. Jade nudges Doug to the right, out of harm's way as the trolley rolls over the spot she has vacated. Doug explains he likes to take advantage of "real-life training opportunities."

At Madison Square Garden, Doug blindfolds me, and Jade and I begin to dance, heading north on Eighth Avenue with Doug riding shotgun behind me and to the right as Seeing Eye instructors do. Jade begins weaving—to avoid pedestrians, I suppose—and I lose the sense of straightaheadness that sighted people have, and I nearly panic. I know I have to trust Jade or take off the blindfold.

After a successful street crossing, I relax and step-to behind this eager dog guiding me along a sidewalk estuary fed by rivers of sound and smell. I hear women's heels clicking, smell pretzels warming and the sensuous aromas of grilling meat. On the left, traffic lows like cattle. On the right, rock music blares in a crescendo that signals the approach to a stereo store. Pedestrians clear throats, cough, and sneeze, but I hear few voices and have little sense of being in a crowd.

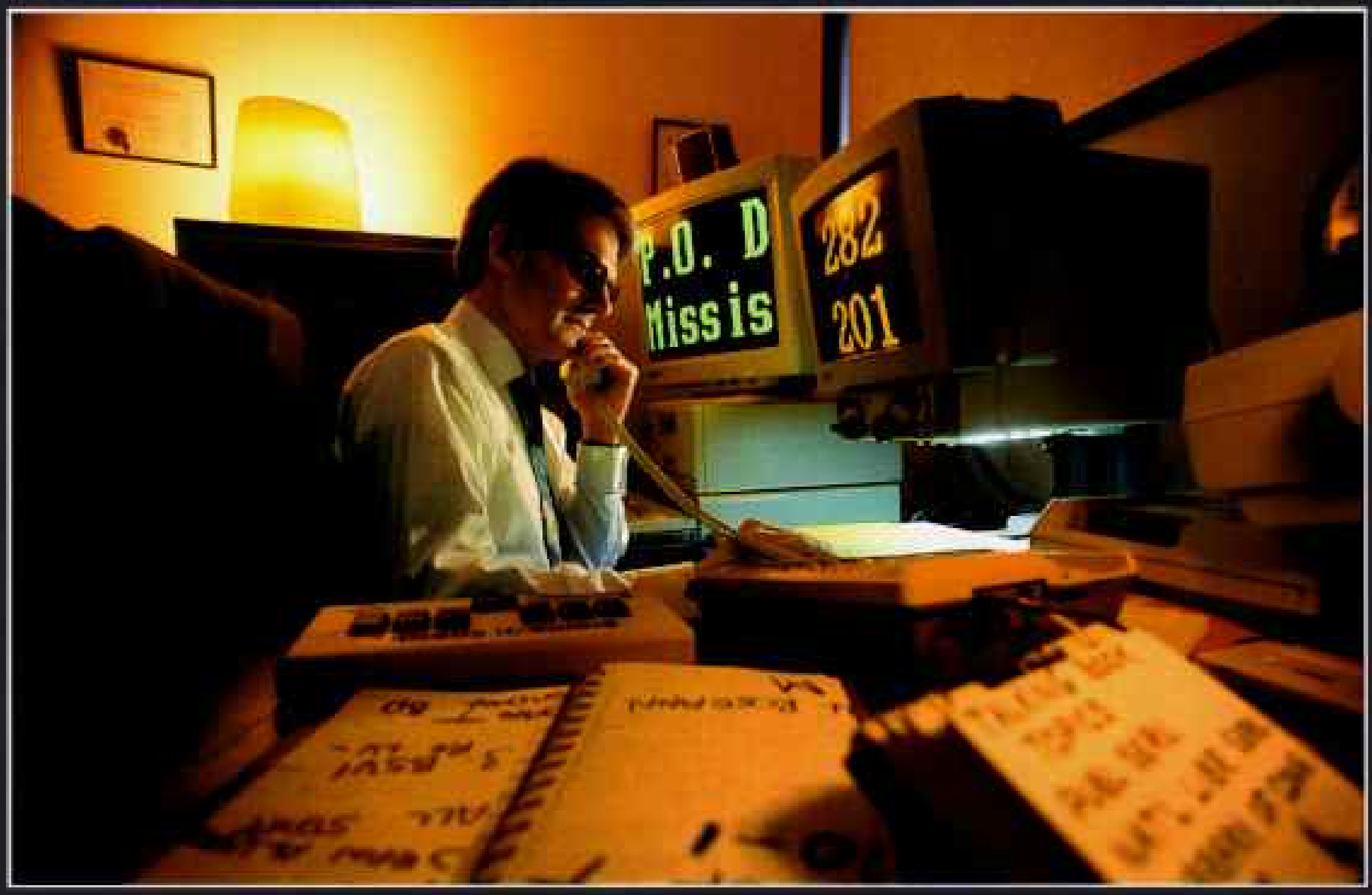
Doug tells me to turn right, and the river of sound goes dry—it is West 40th Street. Jade stops suddenly and moves decisively backward to jerk me to a halt. Raising the blindfold at Doug's behest, I see a red sports car that has just crossed the sidewalk in front of me to enter a parking garage. I lean down and congratulate Jade for good work.

We turn left on Broadway, negotiate more street crossings, and I feel Jade tugging me to the right. Doug takes the harness and asks me to raise my blindfold. Little toy dogs wound up by a sidewalk merchant prance up and down and have attracted Jade's attention. Doug takes time-out for some more real-life training, using the German expletive *"Pfui!"*—a clipped, explosive *"Fwee!"* that a proper Seeing Eye dog well understands as "No!" Jade's still a dog, she's not perfect, Doug explains.

At another curb I command a left turn, but after a few steps Jade stops and then orients me to the right. I raise my blindfold to find that she has prevented me from walking into a parked telephone truck whose driver is asking me in breezy Manhattan fashion what I am doing. I crouch to congratulate Jade again and get my face licked.

We retrace the route with Doug holding the harness, and Jade ignores the wind-up dogs. Though I had no sense of being in a crowd on Eighth Avenue, I now see we are amid a sea of pedestrians. A scuffle takes place, youths run, and a Hispanic voice shouts a challenge for a fight on equal terms—*"mano a mano."*

ONE OF NATURE'S earliest solutions to the challenge of seeing was the compound eyes of the trilobite, a tiny crustacean-like creature that began to ply ancient seafloors about 550 million years ago. Incredibly, their fossilized calcite lenses still work, according to Smithsonian Institution geologist Kenneth M. Towe. He used one in conjunction with a microscope to photograph a Justice Department building



Stay the darkness

"I have intellectualized the hell out of the fact that I am losing my sight, but I'm also grieving," says consultant Jeffrey Moyer (above), former director of rehabilitation at the Cleveland Sight Center. Magnified text on TV monitors dominates his office.

Others cope as they can: Loss of central vision demands nose-length dialing for Nikolai Stevenson in Manhattan (below left). Detroit high schooler Domekia Flennoy, legally blind like many albinos, scans the blackboard with a telescope (below).

A world of sensation surrounds Anna Cannings of England, born blind. "You feel for raspberries in the middle of the bush," reports Anna, 11. She also adores the plunge of a roller coaster.

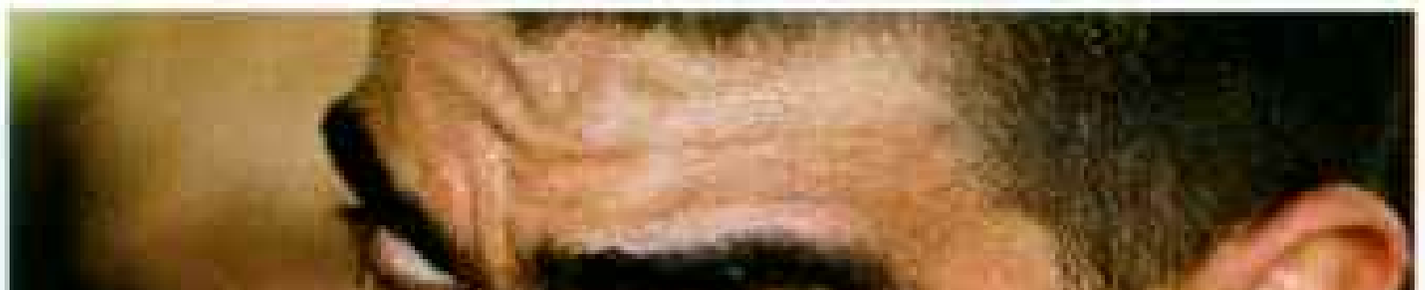
across the street. "Fuzzy, but you can recognize the building," he said.

The eyes of most insects and crustaceans hold hundreds, even thousands, of lenses, while most vertebrates—including fish, birds, and mammals—employ an adjustable single lens and retina system similar to our own.

For coverage and acuity human vision takes a backseat to that of birds. With men on base, a baseball pitcher has to crane his neck to check base runners and his catcher's signal before delivering the pitch. An American woodcock on the mound could see all the bases, home plate, the entire outfield, and the entire stadium, including most of the ceiling of an astrodome—without moving its head.

A human reads letters one by one on the appropriate line on an eye chart from 20 feet. "Eagles can see the entire line from at least 80 feet and perhaps much farther," declares Ivan Schwab of the University of California at Davis. Eagles' eyes have two foveae linked by a chain of photoreceptors to achieve greater acuity and a much wider field of view than human eyes.

But acuity alone takes an organism only so far. "The eye is an optical device for focusing light on the retina, where neural circuitry begins," says Robert H. Wurtz, chief of the sensorimotor laboratory of the National Eye Institute. "To analyze vision from that point on, you have to address the brain."



"Eyes without speaking confess the secrets of the heart," wrote St. Jerome. Pupil dilation and changes in muscles around the eyes may say come hither (top) or run for your life (bottom).

THERE ARE TENS OF billions of neurons in the human brain, each one networking with thousands of others, notes Wurtz, past president of the Society for Neuroscience. "The technology is available to count them as it is available to count snowflakes," he says, "but I'm not sure I want to do that." The question—how we use this apparatus to see—is bewildering.

The ancient Greeks, who had a way with complex questions, explained the mystery of sight by declaring that perception occurs when "internal fire" from the eye mixes with "external fire" from an object. They were half right—external fire is now called a photon, the basic particle of light energy emanating from all light sources.

Sight begins when even a single photon from a distant star enters your eye and splashes down on one of a thousand raftlike cellular disks stacked in a rod photoreceptor in the retina. On this tiny stage molecules seem as big as boulders. The photon hurtles through a swirl of protein in the disk until it collides with a

kinked sliver of a compound chemically akin to vitamin A.

In a quadrillionth-of-a-second twitch, the sliver straightens, much as you straighten your leg, precipitating a biochemical cascade throughout the photoreceptor. The tiny footprint of the photon is amplified thousands of times to alter by mere millivolts the electrical signature of the photoreceptor. Thus light energy is changed into electrical energy, the hard currency of neural exchange. The signal now enters the cellular network of the retina for relay to the many higher processing centers in the brain.

Analyzing vision deficits in soldiers shot in the brain, researchers by the 1920s had pinpointed an area in the rear of the brain, about the size of a credit card, as the primary seat of vision. At Johns Hopkins Hospital in 1958 young David Hubel looked at a microscopic slice of this visual cortex, noting its "millions of cells packed like eggs in a crate," and wondered "what they all could conceivably be doing."

Hubel and his colleague Torsten Wiesel determined to find out. They monitored the effect various stimuli have on individual neurons in the cortices of cats and monkeys, whose visual systems bear great similarity to our own. While earlier studies had shown that neurons in the retina react to tiny spots of light, Hubel described the neurons in the brain's visual cortex as "fussy." They reacted only to linear stimuli—lines, bars, and edges of light.

Moreover, individual cells fired only when a line of light was presented at a certain angle. Change the angle more than 20 degrees and the cells stopped firing, while other cells began. Change the angle another few degrees and another batch of cells fussy to this orientation took over. Other cells responded only to moving lines of light but retained their fussiness as to the line's angle and direction. The scientists also discovered that cells of a certain orientation preference cluster in columns.

These finds galvanized the research community and eventually won Hubel and Wiesel a share in the Nobel Prize in Physiology or Medicine in 1981. Hubel and Wiesel had revealed that the cells of the visual cortex disassemble the image transmitted by the eyes into its millions of constituent parts. Then a process of reassembly or integration, embodying the mathematical precision of a topographic map, takes place. To explain this process is the holy grail of vision research, a conundrum that continues to torment the experts.

MAKEUP BY MICHAEL GONDLAZ; CONTACT LENSES COURTESY NARCISSUS EYE RESEARCH FOUNDATION

Catlike contact lenses work a feline transformation on performance artist April Thompson. The human iris opens in a circle; cats' eyes widen like sliding doors. Both function to limit or increase light to the retina.

Even the biggest boys cry in a chamber filled with tear gas during Marine boot camp at Parris Island, South Carolina. Chemicals inflame the eye's mucous membranes as soon as gas masks are doffed.

MEANWHILE, researchers were discovering more maps in primate brains—and outside the primary visual cortex. In 1968 John Allman and Jon Kaas at the University of Wisconsin began monitoring cortical cells in owl monkeys. Now professor of neurobiology at the California Institute of Technology, Allman remembers, "We marched right through a mysterious area of the brain where people thought inputs from various senses somehow associated with one another and showed that most of it is made up of about a dozen pretty straightforward topographic visual maps."

The search for maps continues, with David Van Essen of Caltech reporting a "bewildering array of higher visual areas." He now counts 32 in macaque monkeys. "Many of us thought we could look at a wiring diagram of the brain and understand its function simply by knowing who talks with whom," says Van Essen. "That was naive. The system is awesomely complex. We presume the different areas have different functions, but in most cases we don't know what the functions are."

At Harvard University in 1968 Charles G. Gross got a clue when he waved good-bye to a monkey after a stimulus session. The cell under observation "fired like crazy," recalls Gross. After a frenzy of experimentation he and his colleagues announced the discovery of cells apparently dedicated to hands or faces in a region of the cortex called the temporal lobe.

People who have damage to this lobe can lose the ability to recognize familiar faces including their own. Some researchers theorized that so-called "grandmother" cells are dedicated to recognizing the faces of individuals—including one's grandmother—a notion that seems to impose an impossibly discriminatory task on a single cell.

"This would lead to the sort of problem Little Red Riding Hood had when her grandmother cells failed to discriminate the wolf's grey fur, sharp white teeth and heavy breathing from her grandmother's normal benign appearance," wrote Michael P. Stryker, a neuroscientist at the University of California in San Francisco.

At the Free University of Berlin, Otto-Joachim Grüsser told me how some people with schizophrenia misperceive faces. When one 23-year-old woman confronted the face of a stranger, "Suddenly the face would get a Dracula expression with bulging eyes, flaring nostrils, dilated pupils, and canine teeth protruding from the mouth. The woman would hear hissing coming from the eyes," said Grüsser. He feels that the Dracula legend and the depiction of the devil in medieval paintings may have arisen from this rare condition.

The unusual case of Gisela Leibold, a middle-aged widow in Munich, Germany, teaches us about the map in our brain that registers motion. Because of brain damage,

Gisela's ability to see motion has been all but destroyed. After a stroke in October 1978, Gisela seemed to recover, but whenever she poured coffee it seemed frozen, and she did not know when to stop. Traffic became a frightening succession of freeze-frame images, and she could not cross the street without assistance.

"I was always terrified," Gisela said as we sat at a table with Josef Zihl at the Max Planck Institute for Psychiatry, where Gisela had come in desperation. A neuropsychologist, Zihl discovered that the stroke had damaged a bit of cortical tissue—about as big as a thumbprint—responsible for analyzing movement.

With Zihl's help Gisela has adapted. Now she paints a dark line near the top of her teacups, and when the tea obscures the line, "I know it's time to stop pouring," she says. When I spoke to Gisela, I noticed she always looked away. Zihl explained, "When she does that, your lips do not confuse her."

Though an escalator is still a frightening experience, Gisela has learned to use the subway. "I feel comfortable if I can stand next to a wall, so people are moving on only one side of me," she said. As she progressed, Zihl suggested a test, cooking dinner for those who had helped her. "She did wonderfully," he said as Gisela beamed. "There was one ground rule—everybody had to stay in their chairs and not move around!"

A VISUAL ILLUSION teases the mind. In illusion 7 on page 15 we may see first a vase, then two faces. "The brain is like a judge confronted with two witnesses with equally strong evidence," says psychologist Stuart Anstis of the

University of California at San Diego. "They can't both be right, so the judge believes first one witness, then the other."

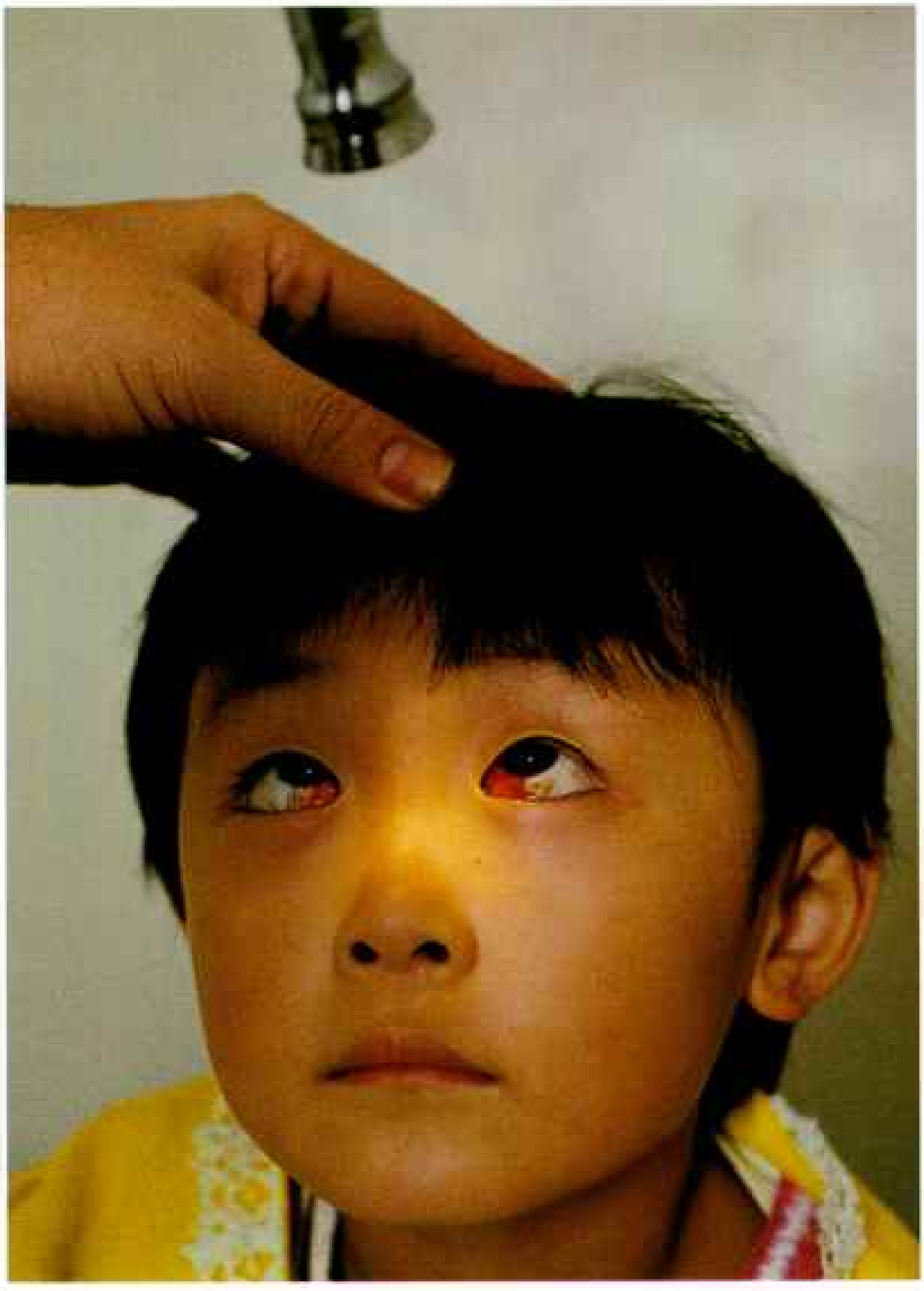
The "waterfall" illusion, described by Aristotle in the fourth century B.C., presents ambiguity related to motion. If you stare at a waterfall for a minute or so, then shift your gaze to the surroundings, the new scene appears to drift upward, opposite to the direction of the falling water. The neural basis of this phenomenon seems to be a yin-yang relationship among neurons—when those fussy for the direction of motion of the falls become adapted or fatigued, antagonistic fellow neurons take over, moving the scene in the opposite direction.

All very academic, but in the world of air combat, illusions can serve a more serious purpose. In October 1987 Air Force pilots from an F-16 squadron at Cannon Air Force Base in New Mexico returned from a bombing run over other F-16s at an outlying field. Actually, no real bombs were dropped in the training exercise; pilots merely indicated which airplanes they had chosen to attack.

Debriefing the pilots after the raid, Capt. Robert N. Kang, USAF, and Gregg E. Irvin of Science Applications International Corporation dropped their own bomb—nine of the eleven pilots had attacked cloth dummies instead of real F-16s. Asked to choose between black-cloth silhouettes plastered on the white tarmac and the actual jet fighters, they chose the high-contrast cloth versions.

"The pilots wouldn't believe it," recalled Irvin. "One of them threw his chair across the room in anger."

The results confirmed months of laboratory simulation at Wright-Patterson Air Force Base near Dayton, Ohio. Using a miniature



The cockpit of a DC-8 flying eye hospital doubles as a waiting room for Huang Xi Yu, four, and her mother (above) in Changsha, China. Xi Yu is among 12,000 people in 61 countries treated since 1982 by the volunteer group Project ORBIS. The day after surgery for "crossed eyes"—strabismus—her eyes were aligned (right).

Hospital room with a view lets Huang Yan, four, test her eyes after surgery on the ORBIS plane. Continuing courses for local doctors, funded by ORBIS, mean she can hope for a life of clear vision.

airfield they dubbed "Struddelheim," Irvin, Kang, and Lt. Col. William Marshak had tested a hypothesis: As Marshak put it, "The best decoy is not necessarily a replication of the real. It's the image on the retina that counts."

Using a trolley-like apparatus, they had simulated attack runs on Struddelheim and convinced themselves that a pilot's brain would accept a distant two-dimensional black cutout as a real F-16.

Later Marshak and Capt. Michael Dowler took me to the top of the sensor evaluation tower at Wright Pat to evaluate my vision. On the grass 200 feet below was an F-16. When we got back to the ground, however, I saw that it was another decoy—this one an F-16-size piece of fabric decorated in broadbrush style with wings, canopy, and landing gear. I helped my deceivers roll up the "airplane" and put it on a truck; then I cautioned myself that things are not always what they seem when we try to exercise our wondrous sense of sight.

AFTER MY JOURNEYS and conversations, I thought back over all I had learned. I had been impressed with the elegant work of scientists probing the mysteries of sight, with the progress made in overcoming disease, and with the many riddles still to be solved. But I had observed also that most of us regard sight as natural, normal—we just see. And so we take our most precious sense for granted.

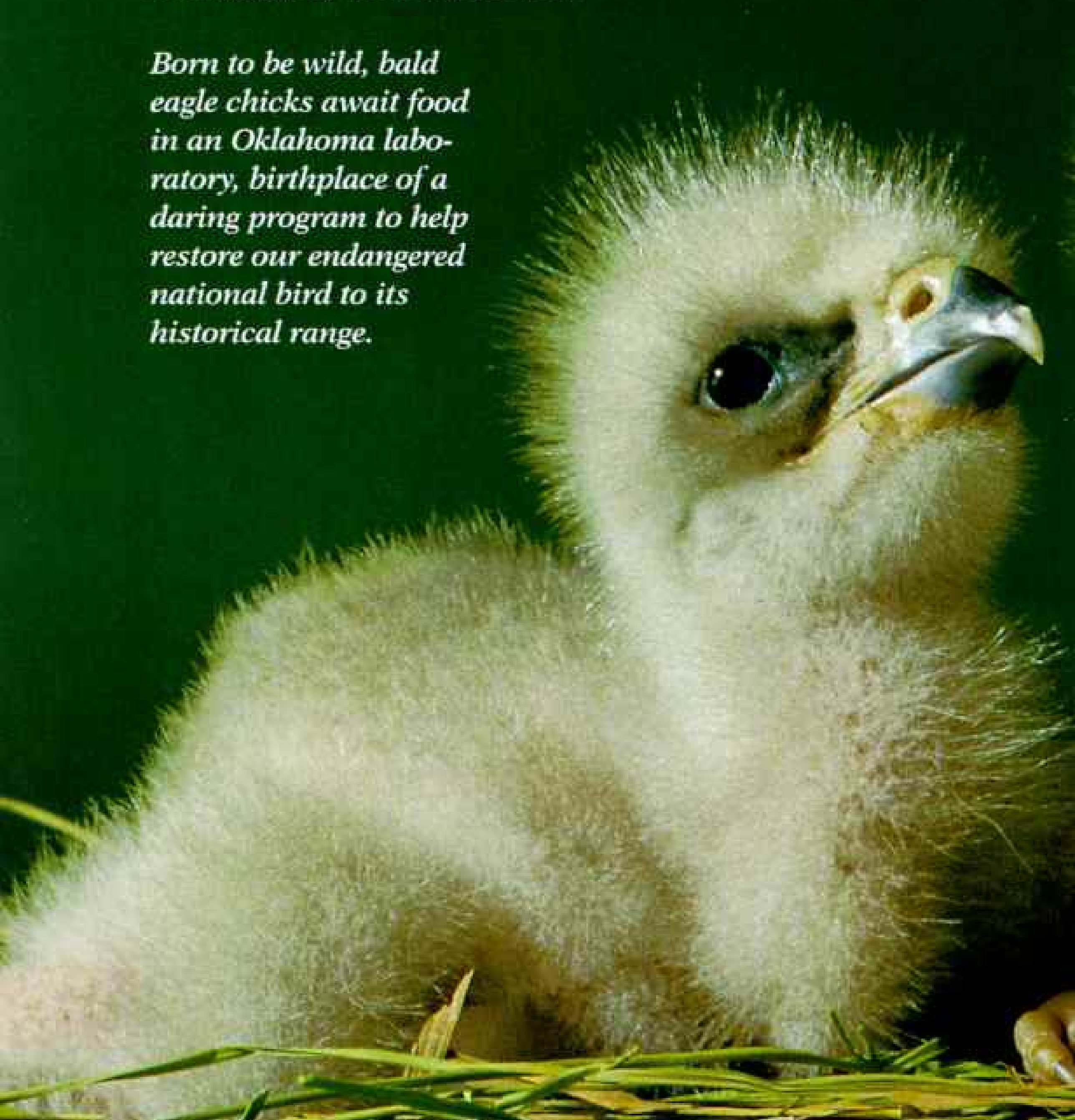
I did too until that darkish afternoon at the Wilmer Institute when Susan Bressler told me I had a traveling companion called macular degeneration that was capable of taking my sight in a trice.

Along with this stiff shot of reality Bressler also gave me a piece of paper with a grid of vertical and horizontal lines, like a schoolboy's graph paper. She told me to look at it once a day and—if the straight lines ever looked wavy—to call her immediately. I looked at it this morning. The lines were straight. It was my gift for the day. □

Eagles on

By PETER L. PORTEOUS
NATIONAL GEOGRAPHIC EDITORIAL STAFF
Photographs by JOEL SARTORE

Born to be wild, bald eagle chicks await food in an Oklahoma laboratory, birthplace of a daring program to help restore our endangered national bird to its historical range.



the Rise

TREE SURGEON Wayne Norton goes out on a limb to retrieve an eagle egg from a 75-foot pine near Orlando, Florida (right). He wears a surgical mask and glove to protect the egg from contamination as it begins a remarkable journey. Flown by jet to Oklahoma, it will be hatched, and the chick will be raised by biologists as protective as any parent eagles before being taken to a release, or hacking, tower in Alabama, 500 miles from its original nest. At the tower the eagle will learn to fly and hunt before it begins its northern migration. If all goes well, it will return to the area of its release to rear its own young.

"To be where no other humans are allowed is a powerful experience," says Norton, who has visited some 150 nests. "It reminds me I'm a small cog in a very big wheel. The word 'honored' isn't strong enough."

Norton makes his climbs in December, as part of a team led by the George Miksch Sutton Avian Research Center in Bartlesville, Oklahoma. One of several eagle recovery efforts in the country, the Sutton center has pioneered the technique of taking eagle eggs rather than chicks from the wild. The team knows that if it removes the entire clutch, usually two, the parent birds will lay another clutch, or "recycle."

That doesn't mean the parents welcome the intrusion. Although the birds rarely attack climbers, "I've had adult eagles dive to within ten feet of me," Norton says, "close enough to hear their beaks clicking."

With the parents out of the nest, Norton quickly places the egg in a plastic-foam container and lowers it to the ground. Exposed to the sun, the egg would soon overheat, killing the embryo. Team members record the egg's location and load it into a portable incubator (bottom left). Elapsed time: less than 15 minutes. Then they rush it to a more reliable incubator aboard an RV, which serves as base for two climbing groups. On the way to the team's apartment, technician Traci Darnell cushions the cargo and checks a thermometer for any variation from 99.25°F (bottom right). Every three hours she will help rotate the eggs, as eagle parents do, to prevent the embryos from sticking to the shells.

Although it has been illegal to harm or possess bald eagles since 1940, the birds nearly disappeared from the contiguous United States, where they once numbered perhaps 50,000. They fell to shootings and lost habitat but mostly to the pesticide DDT, which caused them to lay thin-shelled eggs that broke before they could hatch. By the time the U. S. restricted DDT use in 1972, only about 800 breeding pairs could be found.

Protected by the Endangered Species Act of 1973, the bald eagle has made a steady recovery. While the battle is not yet won, breeding pairs have increased to at least 3,000, and the number of hatchlings per nest is up. More than a thousand eagles have been released to the wild, nearly a third of them—275 to be exact—raised in captivity by the Sutton project.

ACEY HARPER AND JOHN MOORER (TOP); ACEY HARPER

AIRBRUSH before mealtime helps a newborn chick (facing page) retain body heat by fluffing its fine down. In the wild a chick's rubbing against siblings and parents has the same effect.

Hatched 30 minutes earlier, the chick was cut from egg membranes (right) and placed between a hot-water pad and a towel to dry. The day before, the hatchling had used the tiny egg tooth atop its beak to peck an air hole in its shell and begin its ordeal. Nearly all chicks hatch unassisted, but this bird needed help. To prevent it from drying out in the warm air of the hatcher, the staff applied Tegaderm, a covering used on human burn victims.

Eight hours after hatching, chicks receive their first meal—bits of lean quail raised on the premises. "The idea is to hold it loosely and let them grab it," says assistant Marcus Koenen (below), noting that eagles don't eat quail in the wild. He uses a puppet to feed a day-old chick, so that it imprints on eagles, not humans, as a food source.

When the chick can see better—at one week—it will graduate to the chick lab and be fed fish, quail, and other meat via a wall chute. For the next two months the staff thinks of little else but feeding eagles: Each chick consumes the equivalent of 800 quail before it leaves.

Draped crusaders, biologists move eaglets to a barn for two weeks of adjustment to outside temperatures. The six-week-old birds, not yet able to fly, also learn to interact

with other eaglets. During their first month the tubs prevent the birds from killing one another in fits of sibling aggression, behavior that claims some wild chicks.

FROM SCRUFFY to imposing, the look of the bald eagle changes entirely during its first four to six years (right). Achieved by annual molts, the adult plumage, with snowy white head and tail, indicates sexual maturity and may aid in attracting mates. Yellow beak, eyes, and legs complete the majestic profile. The mottled feathers of immatures may signal their nonthreatening status to territorial adults.

Bald eagles remain relatively plentiful in Canada and in the state of Alaska, but that is cold comfort to residents of the lower 48. One reason, explains Sutton director Steve Sherrod, is that bald eagles "nest near the area where they first learned to fly and hunt. They are less likely to colonize a new area as adults—they must be reintroduced."

While northern states successfully transplanted eagles from Canada and Alaska, attempts to introduce them into the South often ended in fiasco, with the northern eaglets dying of avian malaria. Fortunately the bald eagles of the southern states, which many biologists consider a separate subspecies, are resistant to the disease. And so, the team realized, the only hope for repopulating the Southeast lay with the eagles already nesting there, 90 percent of which live along Florida's waterways (map, facing page).

Less migratory than their northern cousins, southern bald eagles usually travel north and return only in their first few years. As older birds they remain in the South year-round to defend their nesting territories.

In 1983 Sherrod approached Don Wood of the Florida Game and Fresh Water Fish Commission with his plan to collect eggs, something that had never been tried with bald eagles. With a zeal for raptors and a doctorate in biology from Cornell University, he had the experience for such an undertaking. Still, there were plenty of doubters.

"First, there were those who didn't think the eagles in Florida would recycle when we took their eggs," he says. "Second, they didn't think we could hatch the eggs. Third, they didn't think we could raise the young without their being imprinted on humans for food. And fourth, they thought the eagles would end up hanging around human establishments because they were hacked off towers."

Since then—helped by Florida and five other states, along with the University of Florida, the U. S. Fish and Wildlife Service, the U. S. Army Corps of Engineers, and the National Park Service—Sutton has proved the doubters wrong.

Preparing an eagle for shipment to a release site, Sutton's assistant director M. Alan Jenkins (facing page, at right) measures its foot to determine its sex. As in nearly all birds of prey, females grow larger than males and are as much as seven pounds heavier. Calmed by former lab manager Alan E. Beske, the bird offers little protest.

"It feels like graduation," says Jenkins, who finishes the ceremony by attaching one of Sutton's white plastic leg bands. The aluminum band registers the bird with the Fish and Wildlife Service.

THREE DAYS

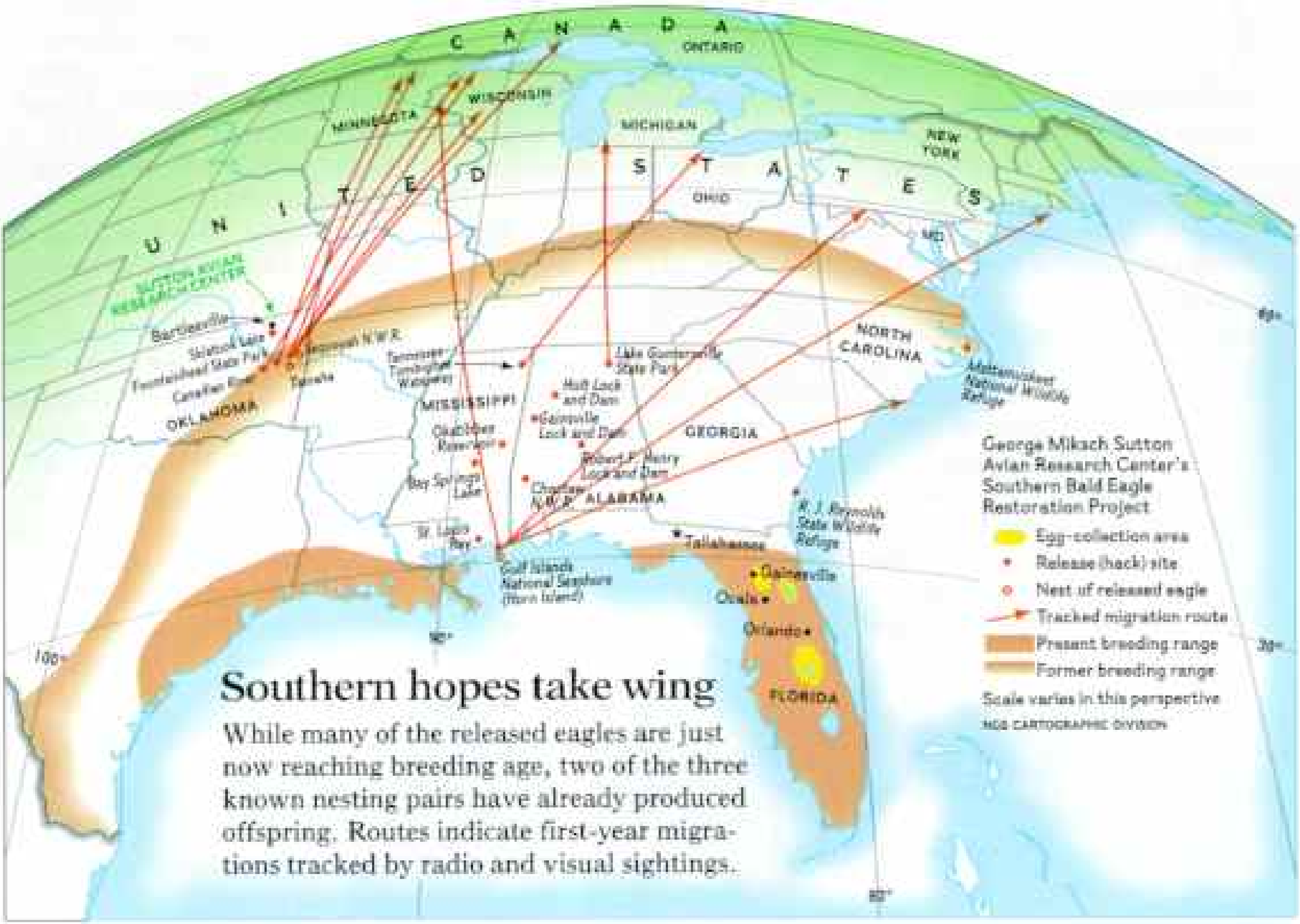
EIGHT WEEKS

ONE TO TWO YEARS

THREE YEARS

FULLY MATURE

FRANK OBERLE



Southern hopes take wing

While many of the released eagles are just now reaching breeding age, two of the three known nesting pairs have already produced offspring. Routes indicate first-year migrations tracked by radio and visual sightings.

CENTER STAGE at a hacking tower on the Alabama River, immature eagles balance on perches (below right). A room in the back of the 12-by-24-foot tower allows Sarah Gale and Marcus Koenen—who uncrated 13 birds weeks earlier (below)—to remain unseen as they feed and observe the eagles. They will do so for the next three months, rising before dawn to scatter the deck with whole fish and chunks of road-killed deer. There is no need to wean the eagles; instinct drives them to scavenge and hunt on their own.

Two weeks after the birds' arrival the bars come down, and the birds—part of last year's crop of 54—test their wings, hopping between perches and flying to nearby trees. Bleach marks, like the one on the left wing of the bird below at far right, enable team members to identify individuals from an observation blind. Many flights, like a first bike ride, end in crash landings or tumbles to the ground. That is no place to linger, though, given threats like stray dogs and alligators, which claimed three eagles in 1989.

One day the eagles will leave for good, beginning their northern migration. Only about half will survive the trip and the ensuing winter. Yet many of those that do will return to within a hundred miles of their release sites; all five release states have reported sightings.

More lasting evidence comes from Mississippi's Horn Island (right), where a six-year-old eagle brings fish to its nestling. The adult and its mate, both Sutton birds, have had offspring the past two years. Their nest was the first on the state's barrier islands in some 50 years.

Mated for life, the pair will build up the nest each breeding season, forming a structure so large it could eventually weigh two tons. Bald eagles, capable of living 30 years or more, create some of the world's biggest nests. Oklahoma also has, for the first time this century, two active nests of southern eagles.

BATES LITTLEHALES AND JOSEPH STANCAMPIANO, ROD (ABOVE AND TOP); BATES LITTLEHALES

WITH A SUBLIME AIR, an adult bald eagle sweeps over a youngster, which presents its talons as if grasping for food. Two other adults stay close, ready to pirate prey if given a chance. Heartened by similar displays across the Southeast, where a steady supply of released birds now approaches breeding age, Sherrod and his staff ended their eagle-release program this year. They have already begun fieldwork on their next project, a study of songbird declines in prairie habitat and the human role in that ecosystem.

Beyond their optimism for the eagles lies another reason for stopping the releases. "It's an expensive process, even with a species as glamorous as our national bird," Sherrod declares, noting that the center's $750,000 annual budget comes primarily from private donations.

Riding a wingspan of six feet or more, the bald eagle has risen to icon status, symbol of wilderness and freedom. Native to North America, it has benefited from a concerted conservation effort, and its numbers have grown impressively, despite the continuing threats of illegal shooting, use of some pesticides, and especially the loss of its wetlands habitat. The full recovery of the bald eagle is a prospect years away but now at least in sight. □

FRANK OBERLE

Reassurance for early navigators, the high bluffs of Cape Espichel greet the landward eye 20 miles south of Lisbon. Until advances in celestial navigation enabled Portuguese

voyagers like Vasco da Gama and Pedro Álvares Cabral to strike out into open seas, such landmarks were vital for coast-hugging forays along Africa's western shores.

Portugal's SEA ROAD TO THE EAST

A small medieval nation—isolated from the Mediterranean and facing the Atlantic—set sail on the vast unknown of the high seas and into the modern age. Spurred by Prince Henry the Navigator (above), the Portuguese discovered what Columbus was seeking: the fabled Indies. They also charted new sea-lanes halfway round the globe to Japan, where an artist depicted one of their square-rigged carracks (overleaf).

By MERLE SEVERY

Photographs by JAMES L. STANFIELD
NATIONAL GEOGRAPHIC PHOTOGRAPHER

KOBE CITY MUSEUM (ABOVE); BIBLIOTHÈQUE NATIONALE, PARIS

THE CHARMED EYES on our bow kept wary watch over the reef gnawing at waves on our port side. To starboard, miles of glistening beach edged the green coast of Kenya. A breeze filled the baggy lateen sail as our dhow, similar in size and rig to the Portuguese caravels of discovery, rode forth from the Lamu archipelago to breast the swells of the Indian Ocean.

Between frenzies of handling sail, the crew slumped against bulwarks or on deck to chat or to nap. Portuguese pathfinders would have known lean, leathery men like these.

"Jambo!—Hello!" the captain greeted me.

"Jambo!" I replied, exhausting my knowledge of Swahili. In the 16th century we would have negotiated in Portuguese, the lingua franca around the Indian Ocean rim, eastward through the Indonesian archipelago, northward from the Strait of Malacca to Japan.

In this quincentennial year, when all eyes are focused on Columbus and America, I have traveled in the opposite direction, following the paths of Portuguese pioneers and tracing the astonishing empire they built. Men like Dias, da Gama, Cabral, Albuquerque, Magellan, and others less renowned but no less bold. They braved seas no European had sailed before to reach and exploit the Indies, the Spice Islands, Japan, and China—precisely the shimmering goals Columbus sought, and died believing he had found.

For a century and more these men of Portugal held in

Evoking the burden of redemption, a bruised Christ presides over the Convent of Christ north of Lisbon at Tomar, home for centuries to the Order of Christ. Portuguese successor to the Knights Templar, this wealthy order helped finance the 15th-century voyages of discovery planned by their grand master, Prince Henry.

their grasp the rich seaborne trade of the East. And long after their chain of Asian colonies—the first global empire—had crumbled into history, I would find their living imprint across half the world, from Morocco to Macau. As now this creaking, leaking wooden vessel of timeless lineage, coasting East Africa in the wake of Portuguese mariners, took me toward nearby Malindi.

There on a headland a pillar marks the reef-sheltered roadstead from which Vasco da Gama set out across the Indian Ocean to Calicut five centuries ago, completing a voyage of 12,000 sea miles from Lisbon.

Below da Gama Point stands a humble Portuguese chapel. Here in 1542 Francis Xavier, sainted Apostle of the Indies, whom I would follow to far China, buried a Portuguese voyager—one of thousands who lie in such alien soil. Truly, it has been said, "God gave the Portuguese a small country as a cradle, but all the world as their grave."

Their story always entranced me. As a boy I relished tales of Prince Henry the Navigator crusading against the Moors, shaping wooden caravels for his iron men and sending them down the unknown coast of Africa, the Red Cross of Christ emblazoned on their sails.

Avidly I read of the quest for Prester John, the fabled priest-king. The Portuguese dream was to outflank Islam and join with his mighty Christian army to reconquer Jerusalem. They sought him up the Senegal and up the Congo. His kingdom lay somewhere to the east.

Bartolomeu Dias caught my imagination with his daring break from the coast-hugging tradition down Africa. In 1487, checked by wind and current, he took a great leap southwesterly into the unknown in hope of favorable winds. Then Dias turned east. Only empty sea. North. Finally, fighting fearsome tempests, he raised land. Following the wooded coast until it trended northeastward, he realized he had rounded Africa (map, pages 66-7). But his crews forced him to turn back. "He had seen the land of India," said a chronicler, but, like Moses and the Promised Land, "he did not enter it."

Another loop through the unknown—the longest open-ocean voyage yet—distinguished Vasco da Gama's 1497 passage through the South Atlantic. From the Cape Verde Islands off Africa's bulge to near its southern end, he spent 93 days out of sight of land. (Between the Canary Islands and the Bahamas in 1492, Columbus was only 33 days.)

Pushing up Africa's east coast, da Gama found an Arab pilot to guide him across 2,000 miles of Indian Ocean. He anchored near Calicut, richest of the chain of trading ports along the verdant Malabar Coast of southwestern India, on May 20, 1498. The Indies at last!

TO TELL THE STORY of Portugal's nearly 600-year global encounter, which changed the world we live in today, I first made a pilgrimage to Lisbon's spacious harbor, where the Tagus mingles its fresh water with the sea. Here galleons set forth amid the roar of cannon, the braying of trumpets, and the bittersweet farewells of shoreside crowds.

Here, in the Jerónimos Monastery, rest three giants of Portugal's golden 16th century: da Gama, who died in 1524 as Viceroy of Portuguese Asia; his patron, King Manuel the Fortunate, blessed with the richest, widest spread oceanic empire in the Renaissance; and the poet

Lonely and uninhabited, the Atlantic shores of Pico Island—where the volcano Pico looms over fields of lava—were first seen by the Portuguese when they discovered the Azores about 1430. Here

Former Assistant Editor MERLE SEVERY has written on historical subjects as diverse as Martin Luther, the French Revolution, and "The World of Süleyman the Magnificent," which appeared in the November 1987 NATIONAL GEOGRAPHIC. During his 38 years at the Society, he also edited 20 books.

Luís de Camões, who transmuted da Gama's voyage to India into *The Lusiads*, the national epic.

and in the Madeira Islands, the Portuguese planted their first colonies.

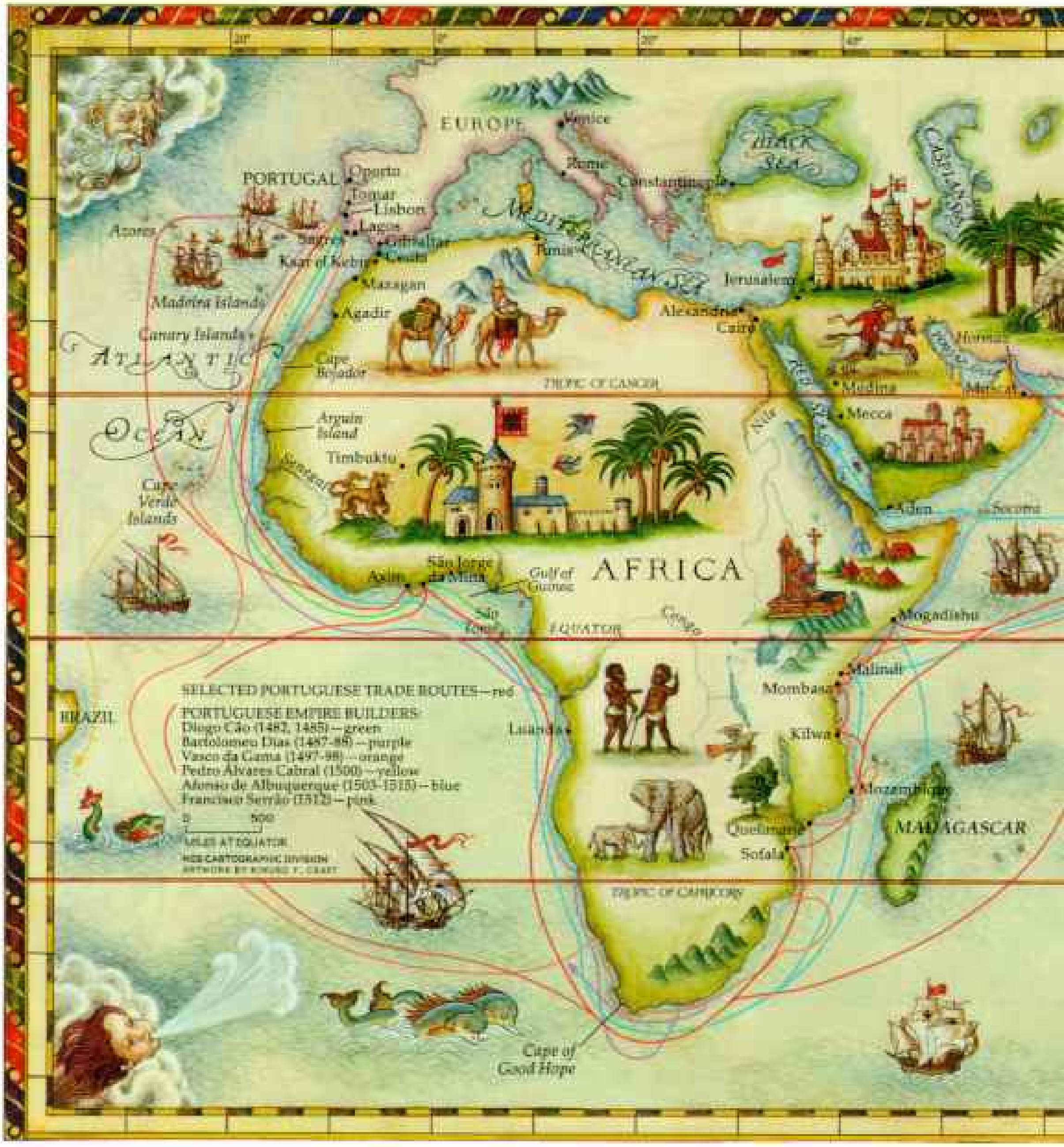
A thousand miles out, the Azores became a supply stop for ships returning from Africa, Asia, and the New World.

Seventy miles north at Tomar, I strolled the monastic corridors where Prince Henry, later celebrated as the Navigator, headed the Order of Christ; its revenues supported forays down the African coast. And standing at the end of Europe on Cape St. Vincent near Sagres, I heard in the pounding of Atlantic combers the call of distant lands.

While many of these explorers are household names in the West, too few know of Afonso de Albuquerque, empire builder of the East, whose feats led his countrymen to call him Afonso the Great. First sailing east in 1503, this soldier and strategist capped the Portuguese discoveries with an empire that wrested Indian Ocean trade from the Muslims and controlled gateways to the lands of Columbus's desire.

It was Albuquerque who in 1510 conquered Goa in western India —the river-moated city on a fine centrally located anchorage that he made the kingpin of Portuguese Asia.

Next came Malacca, key to eastern Asia, where the Indian Ocean funnels to the China Seas and eastward to the Spice Islands.



"Whoever is lord of Malacca has his hand on the throat of Venice," proclaimed the chronicler Tomé Pires. Albuquerque achieved both: He seized Malacca in 1511, and spice prices soared on Venice's Rialto.

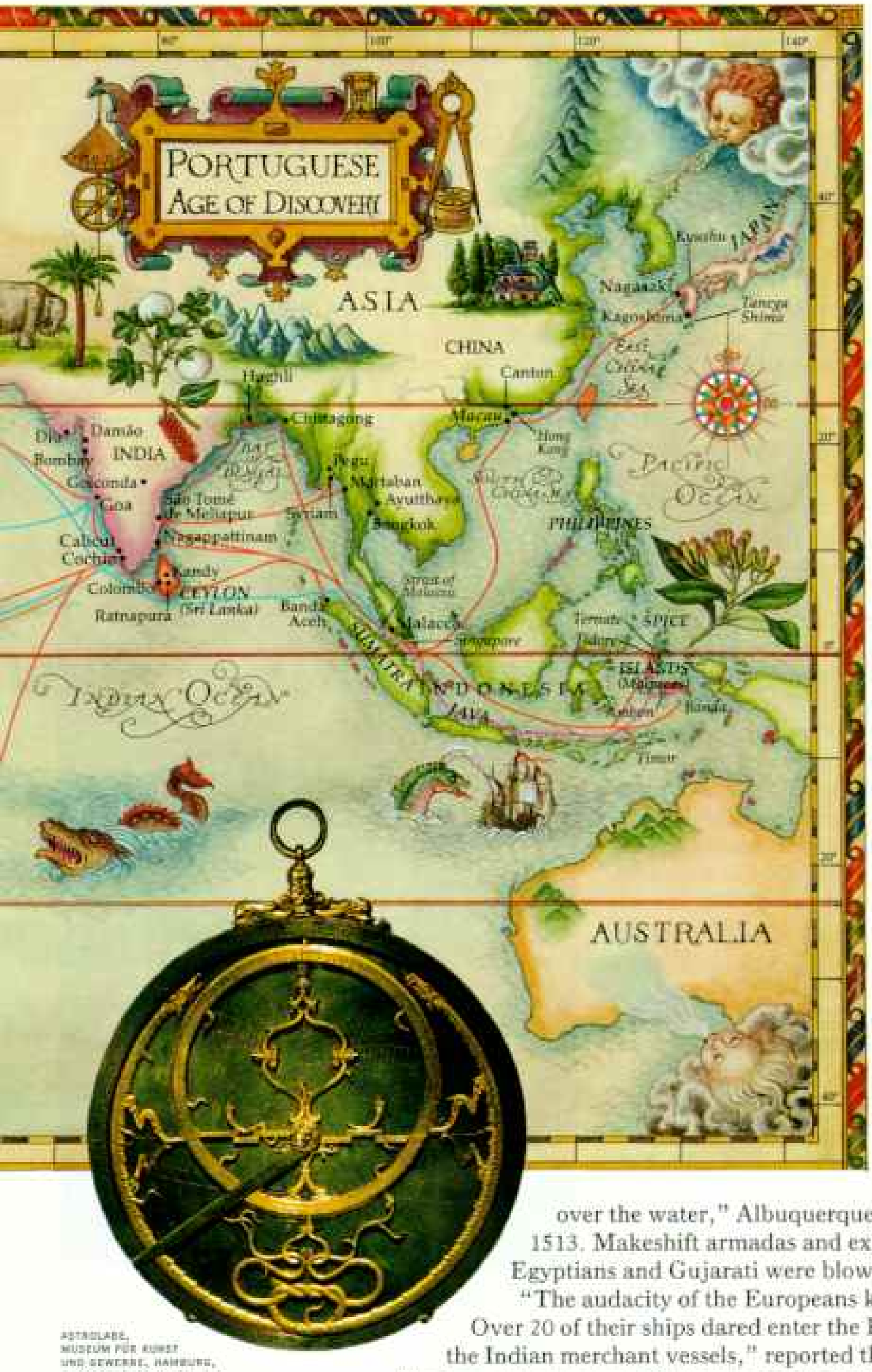
From Malacca, Albuquerque sent Francisco Serrão, possibly with his friend Fernão de Magalhães—Magellan—to discover the source of spices in the Moluccas. Then he sent embassies to Siam and to China.

In 1515, after repeated attacks, Albuquerque took Hormuz, the great emporium and choke point of the Persian Gulf.

Muslim traders now found two gates to the Indian Ocean slammed shut. The third—crag-circled Aden guarding the reef-strewn entrance to the Red Sea—was still ajar. Albuquerque's assaults in 1513 failed.

But the Portuguese already had control of the seas. "At the rumor of our coming the ships all vanished and even the birds ceased to skim

Key to the southern seas, the astrolabe (right) enabled ships' pilots to calculate latitude by the sun and stars. Thus freed from the danger of being lost, Portuguese sailors of



ASTROLABE, MUSEUM FÜR KUNST UND GEWERBE, HAMBURG, PHOTOGRAPHED ON EXHIBIT AT THE NATIONAL GALLERY OF ART, WASHINGTON, D. C.

THOUGH HISTORY CREDITS PRINCE HENRY AS ITS CATALYST, PORTUGAL'S AGE OF DISCOVERY BEGAN IN EARNEST UNDER JOHN II (1481–95). ONCE THE CAPE OF GOOD HOPE WAS ROUNDED IN 1488, AN ASTONISHING PERIOD OF EMPIRE-BUILDING ENSUED—NOT TO END UNTIL THE DUTCH AND ENGLISH CHALLENGED MODERN EUROPE'S FIRST COLONIZERS IN THE 1600S. THE PORTUGUESE USUALLY CONTROLLED THEIR EMPIRE THROUGH STRATEGIC COASTAL FORTRESSES AND PORTS RATHER THAN BY DOMINATING THE HINTERLANDS.

the late 1400s rode the favorable winds and currents of the open ocean.

over the water," Albuquerque wrote to his king in 1513. Makeshift armadas and expeditionary forces of Egyptians and Gujarati were blown out of the water. "The audacity of the Europeans knows no bounds. Over 20 of their ships dared enter the Red Sea, attacking the Indian merchant vessels," reported the Cairo chronicler Ibn Iyas. "It was very difficult to procure turbans and muslin veils in Egypt."

Depriving Cairo of turbans and veils was not what Albuquerque had in mind. He planned to seize the Prophet Muhammad's body at Medina. And to starve Mamluk Egypt by digging a canal to drain the Nile into the Red Sea. The sultan, for his part, had threatened to destroy Christ's tomb in Jerusalem.

SUCH RELIGIOUS FEROCITY was fired in the crucible of Morocco. I sought its origins across from Gibraltar in Ceuta, where Prince Henry won knighthood in the city's conquest from the Moors. Ceuta, 1415. Portugal's first foothold on another continent. It split the Portuguese personality: Some wanted to crusade close to home, plundering Morocco's cities, intercepting trans-Sahara caravans; others fixed their gaze beyond the horizon. Prince Henry embraced both causes.

I inspected the 15th- and 16th-century Portuguese forts that march down the coast to Agadir. I could see the temptation: to smite the Moors nearby, recover once Christian Roman and Byzantine Mauretania, seize booty and the bounty of a land four times as large as Portugal. Why go down forbidding coasts to an unknown fate?

At Mazagan (El Jadida today), I emerged from the vaulted cistern that slaked the thirst of the often besieged Portuguese garrison to blink in the blazing sunlight. Glistening Berber boys cannonballed from the mighty ramparts, splashing in the sea moat below. The Portuguese held the city against the Moors till 1769.

Morocco offered a training ground to Portuguese men at arms. Albuquerque and other governors of Portuguese Asia campaigned there. Magellan was lamed for life. Camões lost an eye. The great fortress at Diu in India was patterned on the citadel at Mazagan. But Morocco also threatened the push eastward by draining precious manpower: King Manuel threw 18,000 men against Moroccan Azemmour in 1513, while Albuquerque could muster only 3,000 against Aden in Arabia.

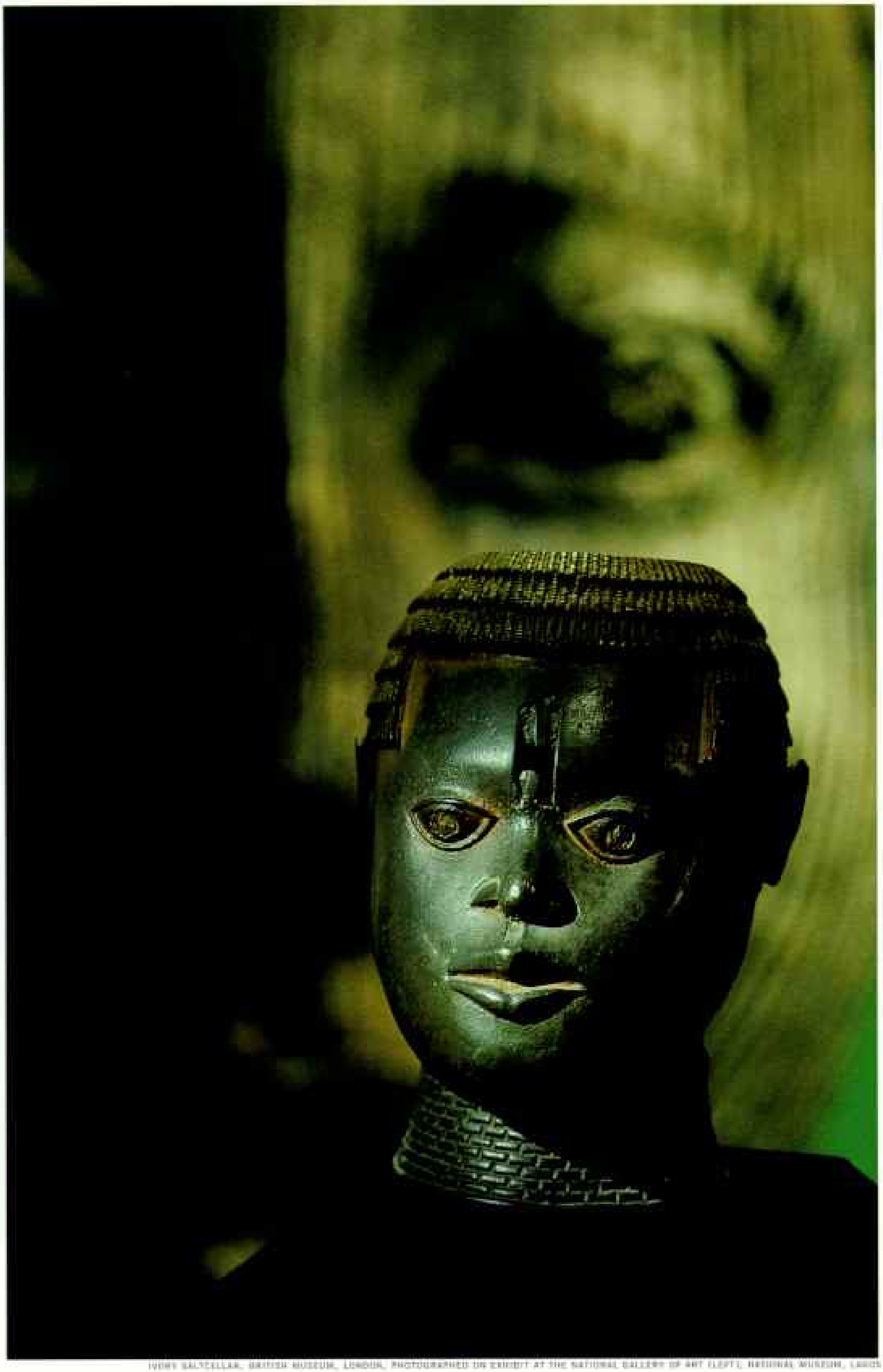
That momentous push to the East was prefaced by half a century of probing to the south—coastal African explorations for which Henry the Navigator has long been given credit. Too much credit, some believe.

"Henry's explorations? Mostly corsair and slaving voyages," Professor Luís Adão da Fonseca told me. We were at lunch in the university city of Oporto, overlooking the Douro River not far from the Casa do Infante, the somber-stoned customhouse that tradition pegs as Prince Henry's birthplace. Henry's aristocratic *fidalgos* (sons of somebody), setting out from Ceuta or Lagos, were more inclined to plunder and ransom captives than to explore. His captains were loath to leave sight of land; Henry himself never sailed on a voyage of exploration.

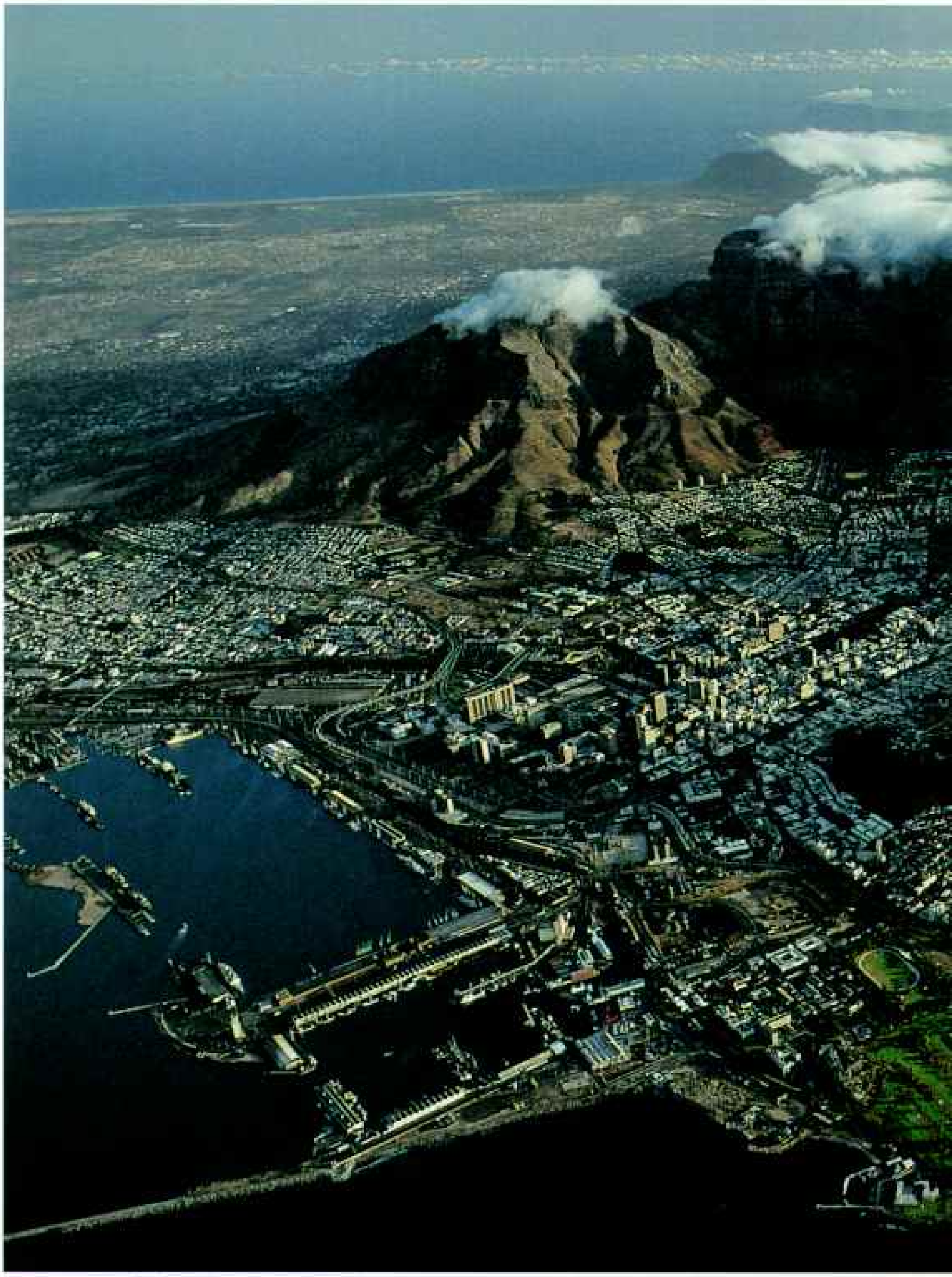
Henry licensed more African voyages than he organized himself. At first few cared to venture beyond Cape Bojador, with its leagues of empty sand. Then the first slaves and gold dust came back. From 1444 to 1446 he licensed more than 30 voyages to Guinea. He set up a "factory" on Arguin Island along its coast—a mid-15th-century prototype for fortified trading posts throughout the empire.

"Every year," reported the Venetian entrepreneur Alvise da Cadamosto, "the Portuguese take from Arguin 1,000 slaves." Here was

Benin bronzes, like the head of this ruler (right), testify to the high state of West African culture when Diogo Cão furthered Portugal's presence along the Gulf of Guinea in the 1480s. An ivory carving depicts a Portuguese warrior—seen through the eyes of an African—with cross and lance on a mission for God and king.



IVORY SALTCELLAR, BRITISH MUSEUM, LONDON, PHOTOGRAPHED ON EXHIBIT AT THE NATIONAL GALLERY OF ART (LEFT); NATIONAL MUSEUM, LAGOS



• *Mantled by clouds, the Cape of Good Hope lies beyond Cape Town, South Africa. After 70 years of exploring Africa's west coast, the Portuguese, under the helm*

of Bartolomeu Dias, discovered this long-sought seaway to India in 1488—nearly five years before Columbus reached what he thought were the Indies.

labor for the underpopulated Algarve and for Henry's plantations, which put Madeira sugar and wine on Europe's tables.

In Prince Henry we glimpse not the ascetic visionary with a "grand design" to double Africa to reach the Indies but an ambitious power broker collecting his order's tithes and petitioning for monopolies in soap manufacture, tunny fishing, or Madeira produce. He seems less interested in exploration than in a regal slice from those who raided and traded with his license. His captains only reached Sierra Leone, a third of the way down Africa, before his death in 1460.

"WHAT OF THE ADVANCES in navigation made by Henry's circle of scholars at Sagres?" I asked Luís de Albuquerque, esteemed historian of science, in Lisbon. "There was *no* 'School of Sagres,' " he replied. "Astronomical tables, improved instruments, charting the ocean—all of these came after Henry. Celestial navigation, Portugal's major contribution to opening the world, developed with the *volta da Mina*, the return from Mina."

São Jorge da Mina, a fortified trading post that stands to this day on the coast of Ghana, tapped the Timbuktu gold and the Guinea slave and ivory trade that fueled the expansion.

Because of contrary currents and winds the return voyage from Mina around Cape Verde was so difficult that mariners swung westward into the open Atlantic and then, picking up the westerlies at the Azores, looped back to Lisbon. Their only signposts were the Pole Star or the sun, and Portuguese seafarers (as well as Columbus,* who sailed with them to Mina) had to learn how to calculate their latitude in empty ocean.

It was John II—like Prince Henry, head of the Order of Christ—who truly launched Portugal's great age of exploration. In 1482 and again in 1485 he sent his courtier Diogo Cão southward along the coast of Africa, where he discovered the mighty Congo River.

In 1487 John dispatched Bartolomeu Dias to round Africa in search of a route to the East. Hedging his bet, the king also invited Columbus to Lisbon to discuss his "enterprise of the Indies." In one of history's great ironies, Dias returned in triumph just when Columbus arrived. Aware that he now held the route to the Indies, King John dismissed the would-be Admiral of the Ocean Sea.

Columbus's own successful voyage in 1492 prompted a papal bull

*Eugene Lyon wrote of the "Search for Columbus" in the January 1992 issue of NATIONAL GEOGRAPHIC.

Mother and child on the island of São Tomé and an old slave warehouse in Mozambique recall the bitter legacy begun by the Portuguese when they took their first captives off the West African coast in 1441. By the mid-1800s perhaps 12 million slaves had survived shipment to the New World.

Under a blistering sun, a woman in the southeast African port city of Mozambique keeps her face moist with a cream made from ground bark. Smitten by the women of this island, many 16th-century Portuguese mariners took lovers—as they did in all corners of their empire, where Portuguese names still abound. Way station en route to India, Mozambique was also a graveyard for hundreds of Portuguese victims of malaria and scurvy.

dividing the globe between rivals Spain and Portugal. But the Portuguese protested that the pope's line left them too little Atlantic sea room for their voyages to India. The line was shifted 270 leagues westward in 1494 by the Treaty of Tordesillas. Thus, wittingly or not, the Portuguese gained Brazil and gave their language to more than half the people of South America today.

On India's Malabar Coast a Chinese fishnet rises over Cochin harbor, as one might have in 1498 when da Gama first sighted these shores. Trade, not conquest,

FASCINATED BY THE SHIPS OF DISCOVERY, I went to Lisbon to see the man who had built one to reenact Bartolomeu Dias's epochal voyage on its 500th anniversary.

"Was your caravel a faithful copy of the one Dias sailed around the Cape of Good Hope?"

"Not quite," replied Rear Adm. Rogério d'Oliveira, president of Portugal's Marine Academy, a wiry, energetic man.

"Outwardly, in hull and rig, as authentic as possible. Inside, we had

brought the Portuguese to India. With shipboard artillery they wrested control of the eastern sea-lanes from Muslim traders, then dominant in the Indian Ocean.

radio, navigational gear, toilet, refrigerators, a small emergency engine. We used ancient tools but designed it with the aid of a computer.

"Actually, the ships Prince Henry sent to Bojador were *barcas*, one- or two-masters with square sails," the admiral said. "We have no record of a caravel before 1441. But this new Portuguese ship—light, shallow in draft, with lateen rig so it could beat to windward—was ideal for coastal voyages and probing bays and rivers."

By contrast, the *nao*—great ship—used on the Lisbon-to-Goa route in the 16th and 17th centuries was a giant. Broad-beamed, multidecked, high in bow and stern, these square-rigged carracks or galleons were open-ocean cargo carriers routed to sail before the wind.

Appealing to the eye, appalling to experience, these great ships on their 24,000-mile round-voyage promised 18 months of hardship and peril. Crowding, foul food and water, filth, dysentery, scurvy, and raging fevers.

Fewer than half of da Gama's men returned home. Half of Pedro Álvares Cabral's fleet, which touched Brazil in 1500, never made it to India. "If you want to learn to pray, go to sea," runs a Portuguese proverb.

Everyone was a trader, from the king (who held the monopoly on pepper) down to the grummet, or apprentice seaman, who to compensate for meager pay could load a duty-free "liberty chest." Crates and bales were stacked everywhere, blocking access to cannon needed to repel pirates; pepper from sodden, burst sacks clogged the pumps. Ships left homeward listing and leaking. One capsized before getting out of port.

Life aboard ship mirrored society ashore in Lisbon and Goa. The nobility in the poop were shielded from the stench of the commoners crammed between decks; privilege reigned, even in shipwreck. On marches along a desolate shore, some fidalgos insisted on being carried on litters by slaves. At the bottom of the social heap were the *degredados*—convicts with sentences commuted to exile—expendables to be given life-threatening missions. Like reconnoitering ashore.

The first man from da Gama's fleet to set foot in India was a degredado—João Nunez, a "new" Christian, a converted Jew who knew a little Arabic. Calicut boatmen took him to two Muslims from Tunis, in North Africa, who could speak Castilian and Genoese.

"May the devil take you! What brought you here?" they asked.

"We have come in search of Christians and spices," Nunez told

them—Christian allies against Islam, coveted riches of the East.

I came to bustling Calicut in search of Portuguese. Gondola-like boats choked the beach, for there is no port. Fishermen pulled in nets offshore; others sorted and basketed the catch. Odors spoke not of spices but of fish drying on the hot sands. After I found the Portuguese landing site up the coast, I asked locals, "Who was Vasco da Gama?" "Probably an American." "He came by ship and went." A shrug. "A businessman." "A very old Indian king, ruling in Trivandrum." "He ruled long ago but was not an old man," corrected a bystander.

Perhaps as sublime a state of ignorance as da Gama's, who insulted the mightiest king of Malabar by presenting trinkets as royal gifts (no gold but six washbasins) and violated Hindu taboos. Cabral's arrival two years later led to clashes with Muslim merchants and bombardment of the town. Thus not Calicut but Cochin, a rival kingdom down the coast, became the first capital of Portuguese India.

The odor of spices did hang heavy in the air as I explored Cochin's marts to the thud of sacks of pepper on warehouse floors, the craning of 15-ton containers on wharves, the gossip of women squatting in

Evangelical zeal of the 16th-century Portuguese comes alive each year in Goa, India, as the faithful flock for blessings during the Feast of St. Francis Xavier. Patron saint of Asia Portuguesa,

the tireless Jesuit missionary carried his faith to India, Ceylon, Malacca, Indonesia, and Japan. Center of Portugal's Asian enterprises, Golden Goa remained in Portuguese hands until 1961.

circles to sort nutmeg and ginger, and the jousting of brokers on several telephone lines at once.

The Portuguese found the spices they sought firmly in Muslim traders' hands, where land-based Hindu rulers profited in leaving them. So the struggle for spices quickly turned into holy war, with sacking and slaughter. Da Gama himself burned a huge Calicut ship jammed with pilgrims returning from Mecca.

"PORTUGUESE GALLEONS MAXIMIZED the advantages of Europe's gunpowder revolution and artillery," historian K. N. Chaudhuri told me. "With an added deck and gunports, the galleon became a floating fortress and a floating warehouse. Harnessed to the land fortress and the factory, or trading post, it could control coasts and waters thousands of miles from the home country."

After the discoverers became conquerors, they learned it was more profitable to keep Muslim trade and regulate and tax it. Declaring formerly open seas a Portuguese preserve, they decreed that Indian Ocean ships had to put into Goa, Hormuz, or Malacca to get a permit and pay duty. Ships sailing without one would be confiscated or sunk.

"Portuguese expectations also changed," Calcutta scholar Ashin Das Gupta told me. Instead of spices and the fabulous diamonds of Golconda carried via the cape to Lisbon, the Portuguese took their biggest profit from inter-Asian trade—selling Arabia's stallions to warring Indian princes, carrying cotton textiles around the Bay of Bengal and Timor's sandalwood to China, and bartering China's silks for Japan's silver. "India has a way of taking in people and changing them."

"The Portuguese also changed India," countered John Correia-Afonso of Bombay's Heras Institute. "They contributed corn, tobacco, pineapple, papaya, sweet potato, cashew, and other plants. They introduced the printing press, orphanage, bettered the lot of women."

From neighboring Ceylon (Sri Lanka), the Portuguese extracted the tear-shaped island's cinnamon, pearls, ivory, dyes, and gemstones. In 150 years of dominance they left a legacy of Portuguese family names and words and a major port city, Colombo, Sri Lanka's capital. Near Ratnapura I saw sweating men emerge from pits in the earth with baskets of gravel containing sapphires. In a jeweler's in Kandy I priced an alluring blue sapphire—$23,950—and left empty-handed.

Ultimately the Portuguese became part of the fabric of Eastern culture. "The secret of their survival was accommodation and collaboration. They were realistic, pragmatic—whether putting a Portuguese name on a Muslim cargo to get a permit, then sharing the profits, or in intermarriage." My informant was Professor Dejanirah Couto of the Sorbonne in Paris. Her darkly handsome features melded Portugal, India, and the Levant.

Albuquerque encouraged *soldados*, bachelor soldiers, to become *casados*, married settlers, to stabilize his empire. To high-caste Hindus intermarriage was a disgrace, but to low-caste Hindus and many Muslim women it meant improved status. Their descendants are all over the East, Portuguese in name, Portuguese words embedded in their speech, Portugal's Catholic faith in their hearts.

As trade and revenues flowed into Golden Goa from the expanding empire, fortunes were lavished on palaces and mansions, elegance and ostentation. The common soldier—subject to certain danger and uncertain pay—had no part of this, and with Portuguese fighting skills

and knowledge of weaponry in high demand, desertions were endemic.

"You see Portuguese mercenaries serving Indian princes, the king of Siam, everybody. This gave them money, food, a way of survival. They had to make their own retirement plan," Dejanirah Couto said.

REALM OF THE GODLY and the ungodly, the low-lying shore of the Bay of Bengal was a frontier where fortunes were to be made and souls to be saved. Portuguese began filtering in while crown and viceroy were occupied elsewhere. "Alongside the official *Estado da India* we see emerging a 'shadow empire,' far more influential than numbers would indicate," Professor George Winius of the University of Leiden in the Netherlands told me.

So great was their prowess at arms that Portuguese mercenaries often swung the balance in battles. Rising to become military advisers to kings, some sought to be kings themselves. Their initiatives led the Portuguese crown into attempts to conquer Burma and Cambodia.

Some, after they made their fortunes in trade or plunder, chose to return to the official empire. How could they get back into the graces of Goa after flouting its authority?

"Goa changed governors every three years; you paid your bribe and were let in," explained Professor Charles Boxer, British doyen of Portuguese empire scholars. "The viceroy wouldn't bother you—but the Inquisition might, after it came to Goa in 1560. They'd claim you had converted to Islam or Hinduism; they wanted your money. So you'd go to the raja of Cochin's realm, or to China. The Chinese never allowed the Inquisition to establish a branch in Macau."

Spices the Portuguese found on the Malabar Coast. Christians they would find on the other side of India. Following merchants, mercenaries, fugitives, and padres who joined them, I climbed the spice-rich slopes of the Western Ghats and descended to a vast green mat of rice fields laced by waterways that led me eastward to the harbor-stingy Coromandel Coast on the Bay of Bengal.

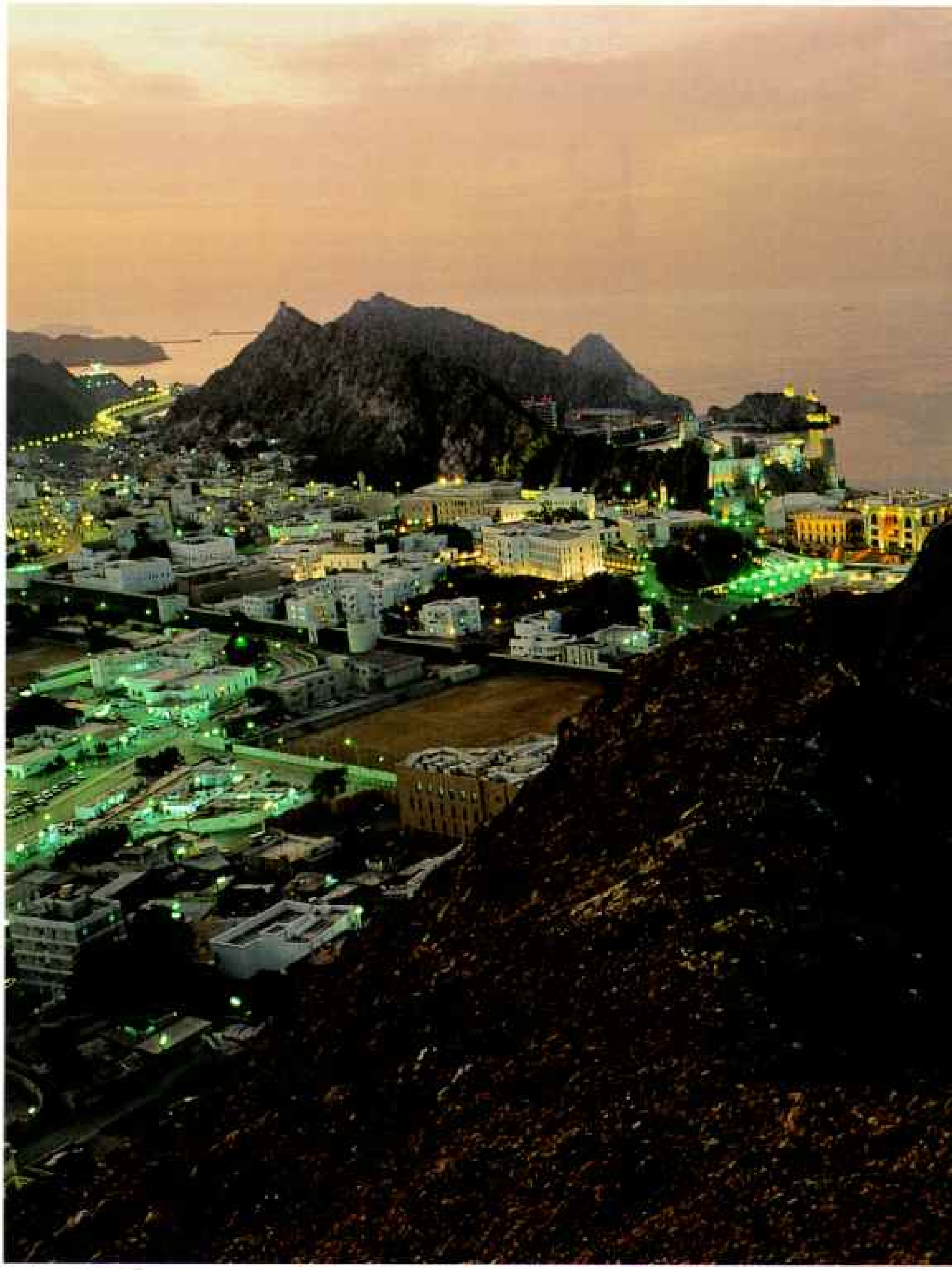
At Nagappattinam, where Portuguese traders had set up beside Hindu and Muslim merchants, scores of fishing boats snugged in a sand-barriered inlet. Offshore a Bombay freighter unloaded not Ceylon's war elephants and pearls of yore but phosphate fertilizer from the Black Sea into lighters towed to a dock. There a human chain shouldered and trotted the burlap bags into a warehouse.

With a Tamil priest, Father Xavier, whose namesake preached along this coast in 1545, I visited nearby Vailankanni, a beachside Lourdes thronged daily by thousands of Tamil pilgrims. They stroll amid stalls of crosses, rosaries, and religious images, make offerings recorded in ledgers, and jam the great white Basilica of Our Lady of Health to give thanks for her cures and her salvation of Portuguese mariners facing shipwreck on these sands.

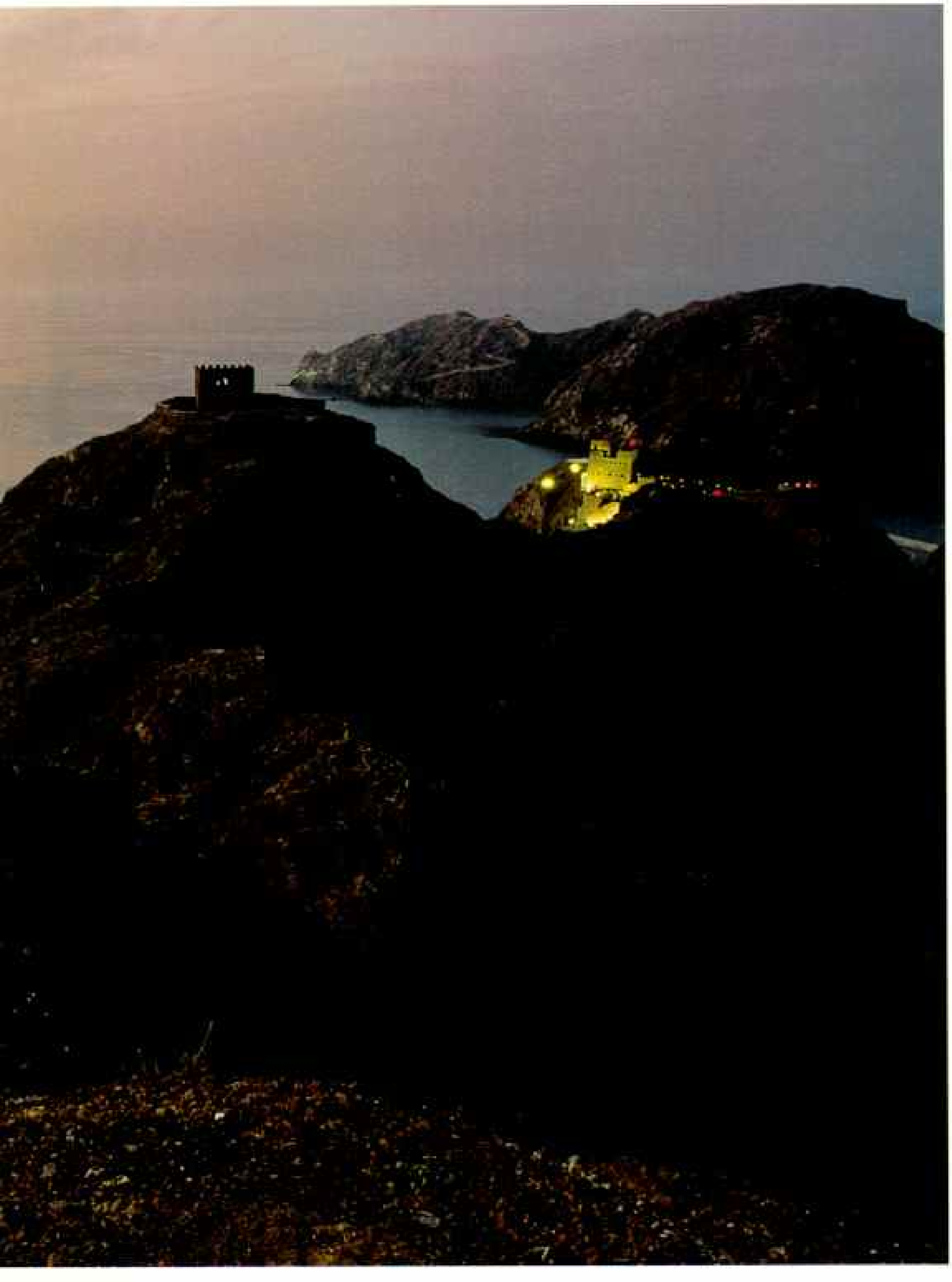
From Nagappattinam, Francis Xavier, the second Apostle of the Indies, went afoot on a pilgrimage 160 miles up the coast to the shrine of the first, Christ's Apostle Thomas. Thomas is said to have preached and met martyrdom at São Tomé de Meliapur (today in Madras). Revering his memory, Syrian Christians had long lived here. The Christians da Gama had sought!

Flying to Chittagong in Bangladesh, I crossed over the broad Ganges-Brahmaputra delta at the head of the Bay of Bengal. I looked down on river channels writhing through prongs of marsh, a gentle

Stewpot of the spice trade, a market in Cochin known as Jew Town is the scene of traditional under-the-towel bidding (below) for betel nuts, a popular stimulant. Dried in the hot sun, gingerroot is one of dozens of spices that drew the Portuguese here in 1502.



Sentinels of a lost empire, forts and watchtowers overlook the Omani capital of Muscat and the Gulf of Oman, where Portuguese and Muslims clashed for supremacy



in the spice trade. Seized by the Portuguese in 1507, the city was theirs until 1650, well after the fall of their strategic entrepôt of Hormuz.

land that opens to the savagery of cyclone and flood. The curving inlets and myriad passages made an ideal lair for pirates when the Portuguese came in 1518. And they still do: News accounts told of some 250 pirate raids on fishing boats in the weeks before my arrival.

In Chittagong I paused in St. Mary's churchyard to read the roll call of Portuguese names . . . Serrão, Costa, Pereira. . . . Walking through the Portuguese quarter, down to where Portuguese ships anchored, suddenly I was engulfed in chanting, cheering crowds. Honking vehicles, trishaws, bicycles, torrents of humanity swept me along behind palanquins bearing garlanded images of the demon-slaying Hindu goddess Durga to be immersed in the sunset waters. Memories of this Durga Puja, greatest of Bengal festivals, which celebrates the triumph of good over evil, accompanied me around the Bay of Bengal in the path of pirate and padre, merchant and mercenary.

I CAME to Ayutthaya, the old capital of Siam (now Thailand), many times besieged by the Burmese. For four centuries it was one of Asia's greatest cities, its million people and 4,000 war elephants dominating an exotic empire put on the popular map by Yul Brynner in the movie *The King and I*.

Strolling the Portuguese quarter of the river-girded city, I studied skeletons in the excavated church, one identified as Father Jeronimo da Cruz, his skull the worse for wear from a doctrinal dispute with Muslim traders.

That evening in traffic-choked Bangkok, 50 miles down the Chao Phraya River, I relaxed in the oasis of the Portuguese Embassy, oldest diplomatic residence in Thailand. "In 1516, five years after the Portuguese arrived, Portugal and the king of Siam signed the first treaty of alliance and commerce," my host, Ambassador Sebastião de Castello-Branco, said. "In return for Portuguese gunnery and soldiers, the king gave permission to set up trading posts in his realm and freedom to practice their religion."

After the Burmese finally sacked Ayutthaya, the kingdom was reestablished downriver. For their long and loyal service, the king granted the Portuguese land in the new capital. Into the 19th century Portuguese was Siam's language of diplomacy.

Far down the Malay Peninsula in neighboring Malaysia, Malacca—crossroads of Portuguese Asia—again seeks the world's eye, by trading on its history with restorations, museums, and a sound-and-light show.

"We have a Portuguese quarter, St. Paul's church where Francis Xavier was buried, remains from each period in the last 600 years," Tan Sri Rahim, Malacca's state minister, told me. "More, we have peoples of different races, cultures, religions living harmoniously. To make Malacca a showcase of peace and concord—that is my dream."

I sauntered along Malacca's Street of Harmony, past a mosque with a pagoda-shaped minaret, a Christian church, a shrine shared by Buddhists, Taoists, Confucians. A shop was stacked with boxes picturing

From the gem pits of Sri Lanka, where miners still toil by candlelight, 16th-century Portuguese traders reaped some of their tidiest profits. The island, then known as Ceylon, also exported cinnamon, pearls, and elephants. Cut and polished treasures, including several sapphires and a large topaz, are displayed among aquamarines by a jeweler in Colombo.

appliances. I hefted a microwave oven; the box was empty.

"I burn a box on my grandfather's grave on his death date," a customer told me. "He gets the appliance instantly and knows I am thinking of him. Last year a television. This year an air conditioner."

I spotted a packet of checks, a credit card, and a passport for otherworld use and bought them—just in case.

WHEN YOU DESCEND by small Indonesian airliner to the fabled Spice Islands of Ternate and Tidore, they are unmistakable: Twin volcanoes thrust from the sea across a narrow strait under the hollow eyes of Portuguese forts. Cloves, mace, and nutmeg are spread to dry beside the narrow road that rings each island. Framers of the Treaty of Tordesillas didn't know whether the islands were in the Portuguese or Spanish orbit: The line ran 370 leagues west of the Cape Verde Islands on the Atlantic side of the globe. But on the reverse?

The main goal of Magellan's effort to circumnavigate the globe was to settle this question. Yet even after his ship *Victoria* had reached the

Deporting himself in regal fashion past black-robed missionaries, a wealthy Portuguese merchant travels by litter in a late 16th-century Japanese Namban

KOBE CITY MUSEUM

screen called "The Arrival." The elephant, perhaps a gift from India for a warlord, shows that the Portuguese in the Far East had become intra-regional traders.

islands, the answer wasn't clear. Emperor Charles V solved the problem. Needing money, he gave up Spain's rights, in the 1529 Treaty of Saragossa, for 350,000 crusadoes from Portugal, a huge sum.

Ironically, after the development of the chronometer in the late 18th century made it possible to measure longitude precisely, it was determined that the Moluccas lay on the Portuguese side of the line. The Portuguese had bought what they already owned!

Not that the treaty stopped the Spanish from the nearby Philippines from interloping. The sultans of Ternate and Tidore were deadly rivals. The Portuguese played a dark game between them, which enabled the Spanish to establish themselves on Tidore. Then in the early 1600s the heavy hand of the Dutch fell. They chopped down clove trees in the Moluccas to limit production and hike monopoly prices.

From Banda Aceh at the tip of Sumatra I crossed Indonesia, 2,300 miles of almost unbroken Muslim dominance, to Ambon, capital of the Moluccas, to find its stores festooned for Christmas.

"Yes, half the people here are Christians," the affable Bishop Andrew Sol told me. I looked up at a statue of Francis Xavier, who

"I'm the last ghost of Macau," says 80-year-old resident Father Manuel Teixeira, who plans to stay on at St. Joseph's Seminary even after Portugal's last colony reverts to Chinese rule in 1999. A Jesuit scholar, he

has written extensively on Macau's 400 years of Portuguese history.

Itself a ghost, the facade of St. Paul's, once acclaimed as the grandest Roman Catholic church east of Rome, is glimpsed in a shop window.

had missionized here for nearly two years. "In one hand he holds the cross, in the other the Bible. Both are here today."

I had been following Xavier from East Africa to India, around the Bay of Bengal to Malacca, and across Indonesia. Now I followed him to Japan, landing as he did at Kagoshima, with its great volcano smoking over the long, magnificent bay at the southern end of Kyushu. Churches and a monument mark Xavier's ministry, which in 1549 initiated Japan's "Christian century."

On Tanega Shima, a small island 65 miles south of Kagoshima, I visited the cape where the first "southern barbarians" to land in Japan—three Portuguese merchants on a Chinese junk—were blown by a typhoon in 1543. So startling was the effect of their muskets that the local lord had his smiths reproduce them. But the copies were faulty and blew up. In the island's gun museum historian Takeaki Hirayama showed me one of the Portuguese muskets and another made locally. Graciously, he refrained from any test-firing.

Japan was embroiled in feudal wars. Rival daimyos—regional lords—coveted Portuguese weapons; they came to tolerate and even

embrace the Roman Catholic faith. Firearms and Christianity spread, rocking the political and religious boat. The shoguns kept one and tried to suppress the other. With new firepower, they unified the country.

A living landmark of the Portuguese in Japan is mighty Nagasaki itself; they chose its site in 1570 on the invitation of the daimyo of Omura, a Christian convert. A Christian settlement grew around the port, which became a hub of the rich Goa-Macau-Nagasaki trade. Portuguese-flavored in speech and food as well as faith, Nagasaki was a conduit for Western influence on Japan, from medicine to maps.

Conversions mounted. In 1638 the shogun Iemitsu stamped out a rebellion, massacring 37,000, mostly Christians. The Portuguese, who had opened Japan to the world, were expelled. For two centuries Japan turned in on itself, reverting to Shinto and the samurai sword.

Long before, Francis Xavier, fired with a desire to Christianize China, had died of a fever on a small island near Macau while seeking entrance to the mainland in 1552. Buried on that lonely doorway to China, then transferred to Malacca, he was finally enshrined in Goa. The Apostle of the Indies was sainted in 1622.

Europe's first major port in Japan, the city of Nagasaki was founded in 1570 by Portuguese seeking a harbor for their ships. After Christianity was banned, Japanese followers sustained their faith with covert images.

WHY DID THE EAST not discover the West? Why did Ming China, largest, richest, most powerful nation on earth, wait for little Portugal to come to its door? In the 15th century the Ming emperor sent awesome fleets—30,000 men on nine-masted "treasure ships" far larger than any ship Europe had—on great expeditions over 28 years through the Indian Ocean and down the coast of Africa. Why did they not sail around Africa and into the Tagus at Lisbon?

"The Ming had no need of the West, no desire to explore or expand trade," explained Professor Wang Gungwu, who heads the University of Hong Kong. "But the West needed the East. The Muslims controlled the old routes for Asian goods craved by Europe since the Crusades and Marco Polo's day, so Europeans sought a new route."

When the Portuguese arrived on the southeast coast of China in 1513, they were viewed as "just another bunch of pirates—people with beards, large eyes, long noses," said Professor Wang. "No real threat. Eventually the Portuguese were allowed to set up shop at Macau and trade at Canton's twice-yearly fairs."

Macau, an hour by jetfoil across the broad mouth of the Pearl River, is home to the Orient Foundation. This organization sponsors archaeological, restoration, cultural, and scholarly projects throughout Portuguese Asia. Its elegantly restored 18th-century mansion sits between Camões Garden, honoring the poet, and the Old Protestant Cemetery with its poignant reminders of premature death in fever-ridden tropics. Nearby looms the facade of ruined St. Paul's with its saints, Chinese dragon, and Portuguese galleon. Above, the Monte Fort commands the two harbors of the peninsular city—bullion broker of Asia long before the rise of Hong Kong and Singapore.

Hong Kong reverts to China in 1997, Macau two years later.

"Macau is already a Chinese city. It looks Portuguese, but it speaks Cantonese," Carlos Monjardino, the foundation's chairman, told me.

"Do you believe the mainland Chinese when they say they will leave the capitalist system alone for 50 years?" I asked.

"The Taiwanese do. They're investing heavily in Macau's new airport." But unease shows in the scramble for Portuguese passports and documents proving long residence.

"Will the foundation stay on in 1999?"

"Yes. There's much to do."

I spent many rewarding hours with Father Manuel Teixeira of St. Joseph's Seminary; its 16 professors and 70 students dispersed during the turmoil of China's Cultural Revolution. "Now I am all alone," the octogenarian said wistfully. Alone with books and documents encapsulating more than 400 years of the Portuguese presence in Macau and the Orient. Echoing corridors. Empty rooms.

He brightened with, "Where would you like to go today?" And the sprightly white-robed, white-bearded living encyclopedia, whose sandals know every cobblestone in Macau's six square miles, would trot me down yet another lane of Macau lore. Perhaps to the shrine of the Chinese sea goddess from whom Macau derives its name. Perhaps to a shipyard where we'd climb over piles of teak to watch junks take venerable shape amid the anachronistic snarl of power saws. He showed me a monument to the bloody defeat of child-stealing pirates in 1910. He told me of rival pirate gangs priests paid off to ensure safe arrival of casks of altar wine to a mission church.

In St. Francis Xavier Chapel on Coloane Island, I examined bones

of martyrs. "And St. Francis?" I had read that a relic of his upper right arm bone was hallowed here.

"It was here temporarily for an anniversary of the chapel," Father Teixeira said with an impish smile.

Returning to the seminary, he took me into the church, the marvelous acoustics resounding to our footsteps. He unlocked a case and placed in my hands a heavy, ornate reliquary. In the midst of its sunburst of silver I clearly saw, to my surprise, the enshrined bone.

"Finally you have met the saint you have been following."

PORTUGAL'S WORLD EMPIRE BEGAN, and its resplendent days ended, with crusades in Morocco, only a few miles apart. At Ksar el Kebir, 163 years after Prince Henry the Navigator won his spurs at Ceuta, King Sebastian, obsessed with quixotic dreams of knight-errantry, died with his army—leading to the takeover of his kingdom by his uncle Philip II and 60 years of "Spanish captivity." Portugal emerged with its manpower sapped by Spain and much of its empire snatched by the Dutch and English enemies of imperial Spain.

Yet Goa, last vestige of da Gama and Albuquerque's Portuguese India, held out until 1961. When Macau's turn comes, the first colonial power in Asia will be the last to go.

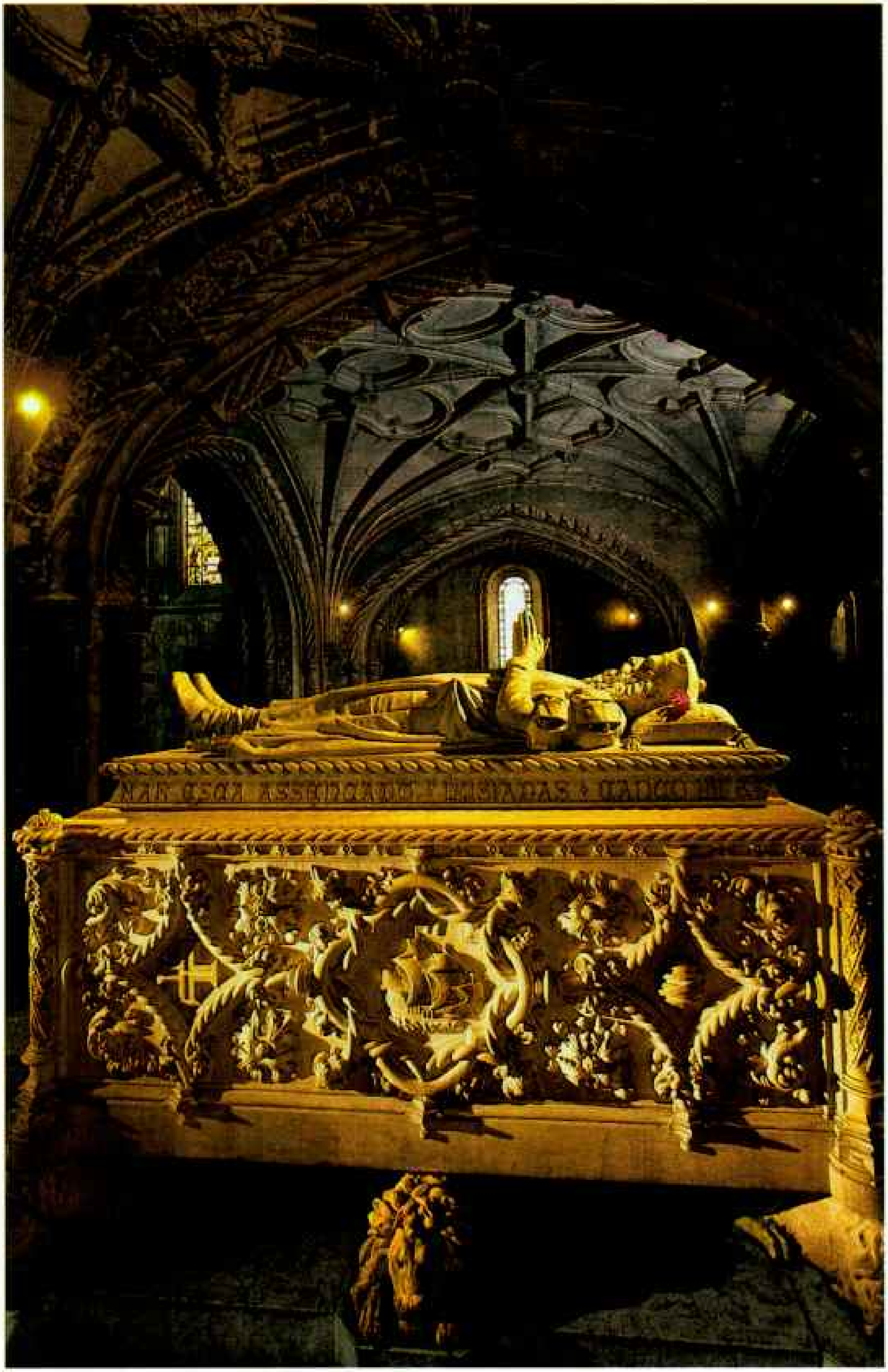
I recalled my evening with the Portuguese ambassador in Bangkok. He had noted the incredible feats of Portugal's empire builders, the shrewdness of her inter-Asian traders. "We were so few—only a million or so, with just thousands spread around the world." Then he mused: "We should get into the *Guinness Book of World Records* as the worst businessmen on earth. We had a hundred-year grip on the world's richest trade and ended up poorer. We let the wealth of the East slip through our fingers into the coffers of Antwerp merchant syndicates. Proceeds were lavished on Moroccan wars, dynastic marriages, ostentatious display." Portugal achieved a geographic revolution, not a financial one.

Back in Washington, at a special showing of the 1492 exhibition at the National Gallery of Art, I asked Mário Soares, President of the Republic of Portugal, how he'd sum up Portugal's global encounter.

"Portugal's navigators," he said to me, "showing Europe the way across the oceans, brought back more than spices, gold, precious stones, and silk. They interacted with ancient cultures and gave us the vision of the one world we have today.

"At the close of the cycle of empire, as we enter universal civilization, Portugal will remain, as our poet Fernando Pessoa saw, 'the face of Europe that looks out to the rest of the world.' " □

Silent requiem for a remarkable age, assembled reliquaries in the shape of hands honor a host of saints in Goa's Basilica of Bom Jesus—shrine of St. Francis Xavier, Apostle of the Indies. Xavier died in 1552 on an island off the coast of China. He and thousands of other Portuguese missionaries followed in the worldly wake of great adventurers like Vasco da Gama, whose remains lie under marble at the Jerónimos Monastery in Lisbon (right).



Maya Heartland

BY GEORGE E. STUART SENIOR ASSISTANT EDITOR

Under Siege

PHOTOGRAPHS BY MIGUEL LUIS FAIRBANKS

"Who cuts the trees as he pleases cuts short his own life." The Maya adage, born of common sense and a close bond with the land, is spoken in a language that uses the same word for both "blood" and "tree sap." The analogy could not be more apt today. Guatemala's Petén region—heartland of the ancient Maya—is wounded daily by chain saw and ax (left) as forest is felled to make way for corn.

The Petén—"island" in Maya—is a 14,000-square-mile sweep of uneven tropical forest and savanna covering the northern third of Guatemala; it is part of the largest expanse of forest left in Central America. And it is getting a reprieve. In landmark legislation in 1990 Guatemala set aside 40 percent of the Petén as the Maya Biosphere Reserve.

For me and other archaeologists the Petén still evokes the romantic images that drew us there in the first place—trackless jungle, exotic plants and animals, and the crumbling ruins of one of the great civilizations of antiquity.

We have learned that the place is far more complex. Every new discovery we make raises more mysteries about the ancient Maya, especially about their relationship to the land. Maya civilization flickered into being in the first millennium B.C., shone brilliantly between 300 B.C. and A.D. 900 with a population of several million, and then disappeared in what is called the Classic Maya collapse. We know that behind the soaring pyramid temples with their ruling elite lay the extraordinary skill of the Maya farmer. But we don't agree on why large cities like El Mirador and Tikal grew up in a region of thin soil and scant surface water. Or on how a huge population could be sustained by rainy-season farming alone. Or on why the population crested like a roller coaster, then plummeted off the chart.

Such questions led a team of five specialists in forestry, environmental management, and archaeology to apply the tools of remote sensing to the Petén. With NASA funding they have looked at the region from space and from the ground for five years. Their goals: to establish patterns of ancient settlement, to gather clues on the impact of humans on this landscape, and to monitor ongoing changes.

The frontier farmer in the Petén clears a forest plot, crops the field, or *milpa*, and then abandons it. First, trees are cut and torched, turning them into ghostly nutrient-rich ash (right) that fertilizes the thin soil. Corn, beans, and squash (facing page) thrive, but only for a few years.

For Paco Burgos and his family (below), their milpa is the key to life. They continue to work their land even though it is now in the reserve, off-limits to new farming and cattle ranching. They have nowhere else to go. The population of the Petén has skyrocketed from 15,000 in 1950 to more than 300,000, mostly south of the reserve. As more settlers arrive from southern Guatemala, the temptation to farm in the reserve is great.

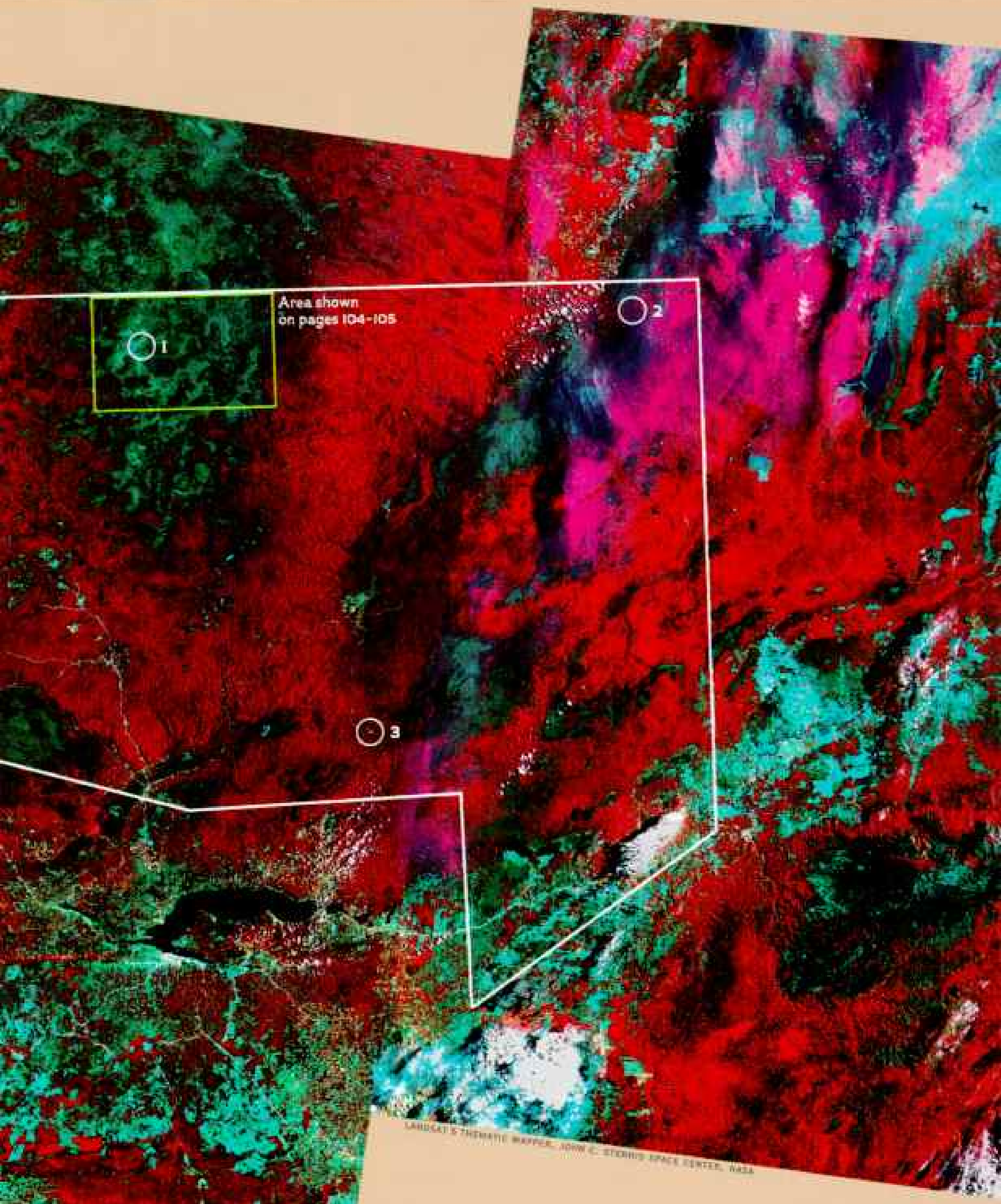
KENNETH GARRETT

Milpas also served the early Maya, but with a difference. The ancients planted dozens of food and fiber crops among trees, valued for erosion control. They kept turkeys and small mammals, cultivated breadnut trees, and hunted and gathered the wealth of the forest. For centuries the combination worked well, I believe, until the population finally overcame the capacity of the land. A simplified and shortsighted milpa system has survived.

Area shown on page 100

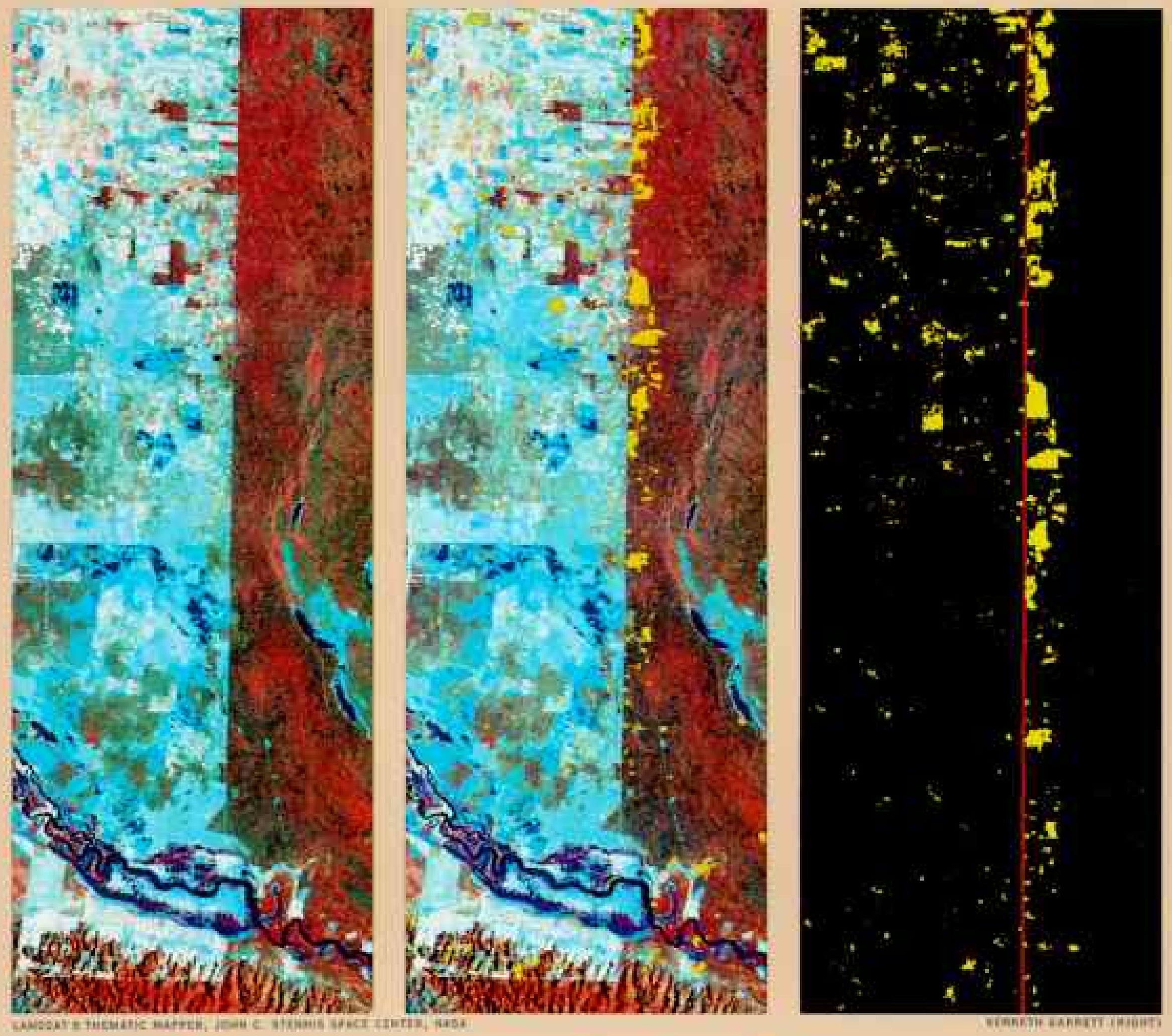
A mosaic of three false-color satellite images taken from 440 miles up reveals the receding forest cover (red) in the Maya Biosphere Reserve. Farmland and pastures (blue), and towns, roads, and bare fields (white) steadily encroach. Many wetlands (green) but few lakes and rivers (black) mark the reserve. Natural tilting and folding of the limestone bedrock produced ridges, at lower left.

Special places are granted



extra protection. National parks surround ruins at El Mirador (1), Río Azul (2), Tikal (3), and within the Sierra del Lacandón (4). In three biotopes Guatemalan conservationists and students monitor pristine areas.

Sustainable forestry, such as chicle tapping and allspice harvesting, is allowed in most of the reserve to provide income for the local people. All logging permits were revoked last March because settlers used roads built for logging and oil exploration to reach protected forest, and cattle ranchers came right behind. In the past two decades the Petén has lost more than a third of its forest to such activities.



LANDSAT'S THEMATIC MAPPER, JOHN C. STENNIS SPACE CENTER, NASA

KENNETH GARRETT (RIGHT)

Breaching an international boundary

Two nations and two policies face off across the Mexico-Guatemala border (facing page). In the 1970s the Mexican government sponsored a homestead program here, giving forestland to settlers to clear for corn. As the soil gave out, they turned to cattle—and to the forests of Guatemala. Crossing the unpatrolled border, Mexicans harvested trees, grazed their herds, and burned milpas.

The Landsat sequence of the border, arrowing north from the San Pedro River, reveals little intrusion into the Guatemalan forest, shown in red, in 1986 (above, at left). Lakes and rivers are dark blue; fields are white and light blue. In the 1990 image, at center, yellow indicates changes detected—cleared forest.

NASA archaeologist Tom Sever, the team leader, isolated the yellow areas of the 1990 image for emphasis, at right. Measuring the change by computer, he estimates that 10 percent of this strip along the border has changed in four years; 1,130 acres of forest have been felled.

As the forest goes, so go its treasures. Wildlife vanishes, and archaeological sites lie exposed to looters. Thus whole chapters of natural and human history are erased. Standing against the tide of destruction is the Guatemalan government's National Council of Protected Areas. So far, this youthful corps of dedicated environmentalists has persevered in the face of death threats and the burning of their guard posts by loggers and those who would profit from the depredation.

"With the satellite images we can monitor the region as never before," says James Nations of Conservation International. "Knowing the extent of the problem is the first step."

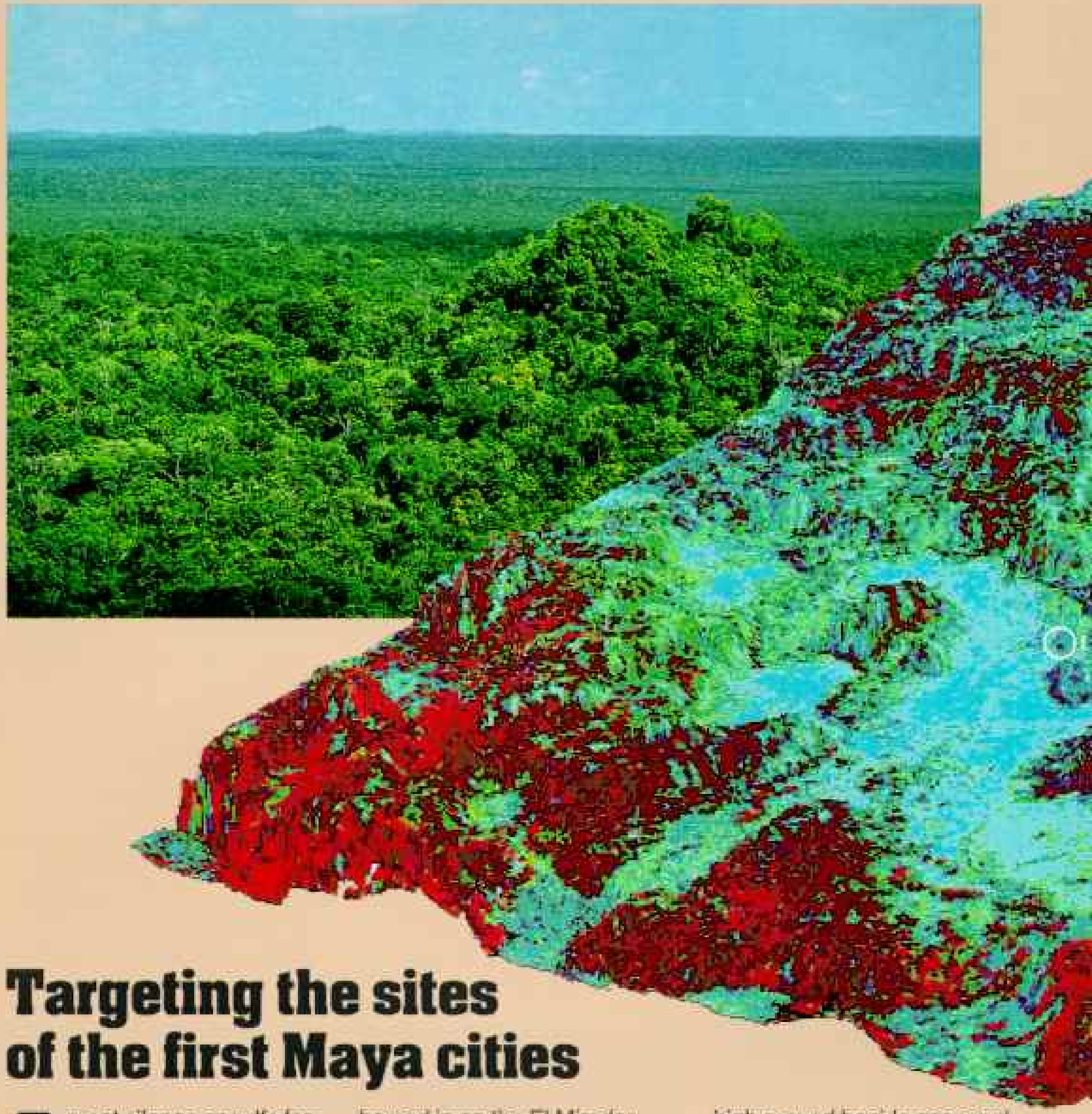
For cooking fires and for building material, hardwood in the Petén is consumed faster than it can grow. Within the biosphere reserve, horses laden with firewood are coaxed along a forest trail (left).

Today each family in the Petén consumes 10 to 20 cords of wood a year, requiring hundreds of trees. The ancient Maya needed even more, to burn limestone for stucco and mortar.

Framed by palm fronds, clandestine loggers (above) chain-saw mahogany trees into planks for construction. Catering to this lucrative logging, stores in Guatemala City sell hundreds of chain saws each year, and the number is rising.

For an impromptu game of checkers, a board is chalked on mahogany; corn and beans serve as pieces (below).

Cottage industries using faster growing species of trees could benefit both people and forests. Carvings, children's toys, and game boards would supply the tourist trade, which already brings 25 million dollars to the Petén each year.



Targeting the sites of the first Maya cities

A great silence engulfs forest that once resounded with the voices of thousands who lived, worked, and worshiped here 2,000 years ago. Mounds rising above the forest canopy hint at the magnitude of some of the largest temple pyramids in Mesoamerica. Ruins at Nakbe (above, foreground) lie seven and a half miles southeast of another Maya metropolis, El Mirador, on the horizon.

Processing satellite data, computer specialist Daniel Lee homed in on the El Mirador region (page 99 and above), rendering the information in perspective and exaggerating heights by 20 percent for emphasis. Various types of vegetation account for different tones of red and green.

Digital data can also be manipulated to reconstruct probable ancient routes between sites of the same age. This helps pinpoint early trade and intercity relationships.

The ancient Maya positioned El Mirador (1) and Nakbe (2) on high ground beside seasonal swamps called *bajos* (blue). These natural depressions dotting the limestone floor of the forest collect water in the rainy season. The Maya sometimes reinforced the bajo edges with plaster to conserve the precious water and prevent it from draining rapidly away.

As the rainy season begins, bajos turn to mud. Guatemalan conservation official Santiago Billy (right) leads other team members on a trek from the village of Carmelita to El Mirador.

LANDSAT 5 THEMATIC MAPPER,
JOHN C. STENNIS SPACE CENTER, NASA

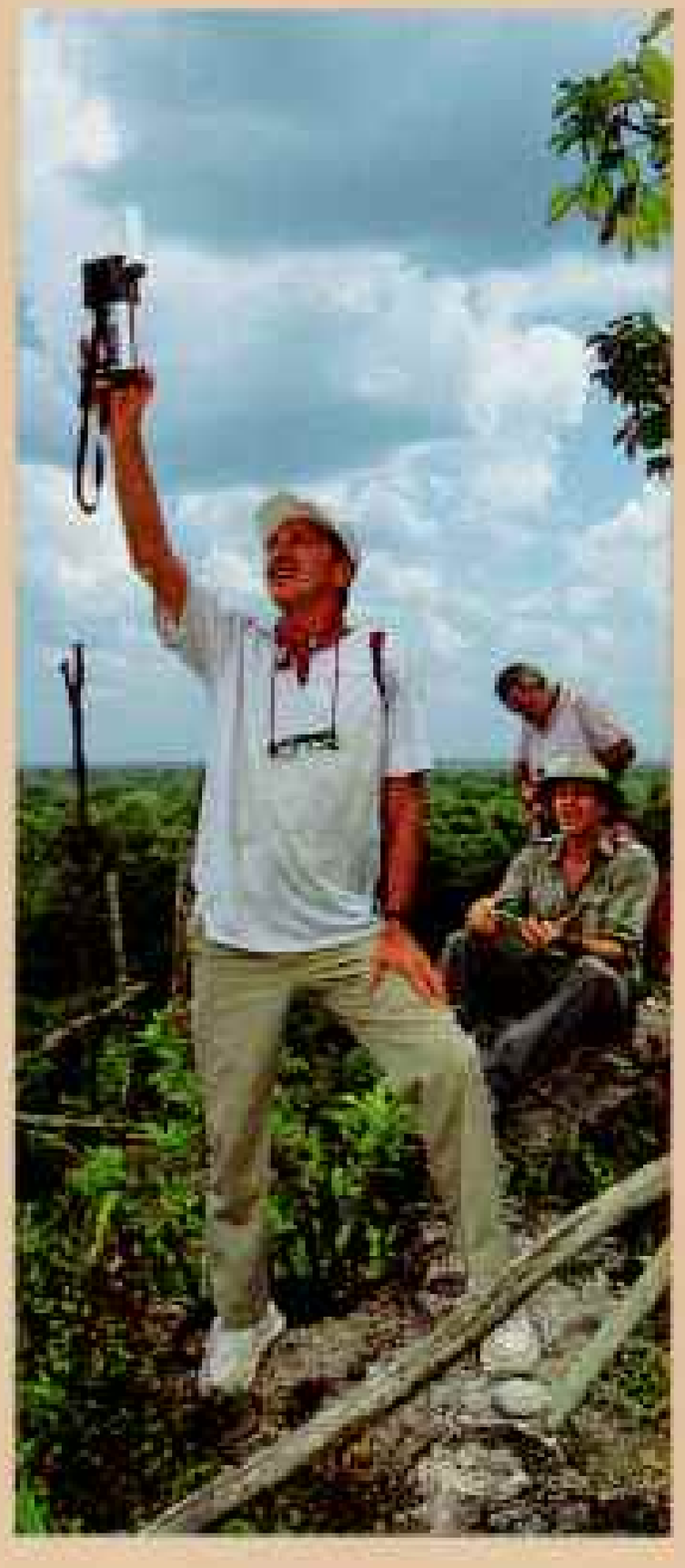
BOTH BY KENNETH GARRETT

Getting a fix on exactly where he is, forester Frank Miller of Mississippi State University aims a global positioning system (GPS) receiver to the sky from the Maya city of Nakum. Bouncing signals off passing satellites, he obtains coordinates of the temple on which he stands.

With Santiago Billy (below, at left) James Nations points out particular vegetation for comparison with satellite readings. Tom Sever, at right, will use the GPS coordinates to adjust satellite images distorted by lenses and the earth's curvature. The team will then extrapolate information about soils, vegetation, and bajos on Landsat images of unexplored areas in the reserve.

The infrared photograph (right) of El Mirador, taken by a NASA aircraft a mile up, adds another dimension to the study. A guard station clearing (largest white area) shows up left of Tigre Temple, which rises 18 stories and overlooks a large bajo (gray). There low causeways, or *sacbes*, can be detected in the infrared photograph because of differences in the vegetation growing along the roadways. Three sacbes join in an area called the Crossroads, at upper left. Another, at upper right, leads northwest. The roads underscore the importance of El Mirador as a great trade center.

"By understanding the Maya past," Sever says, "we can apply its lessons to today's environmental problems." □



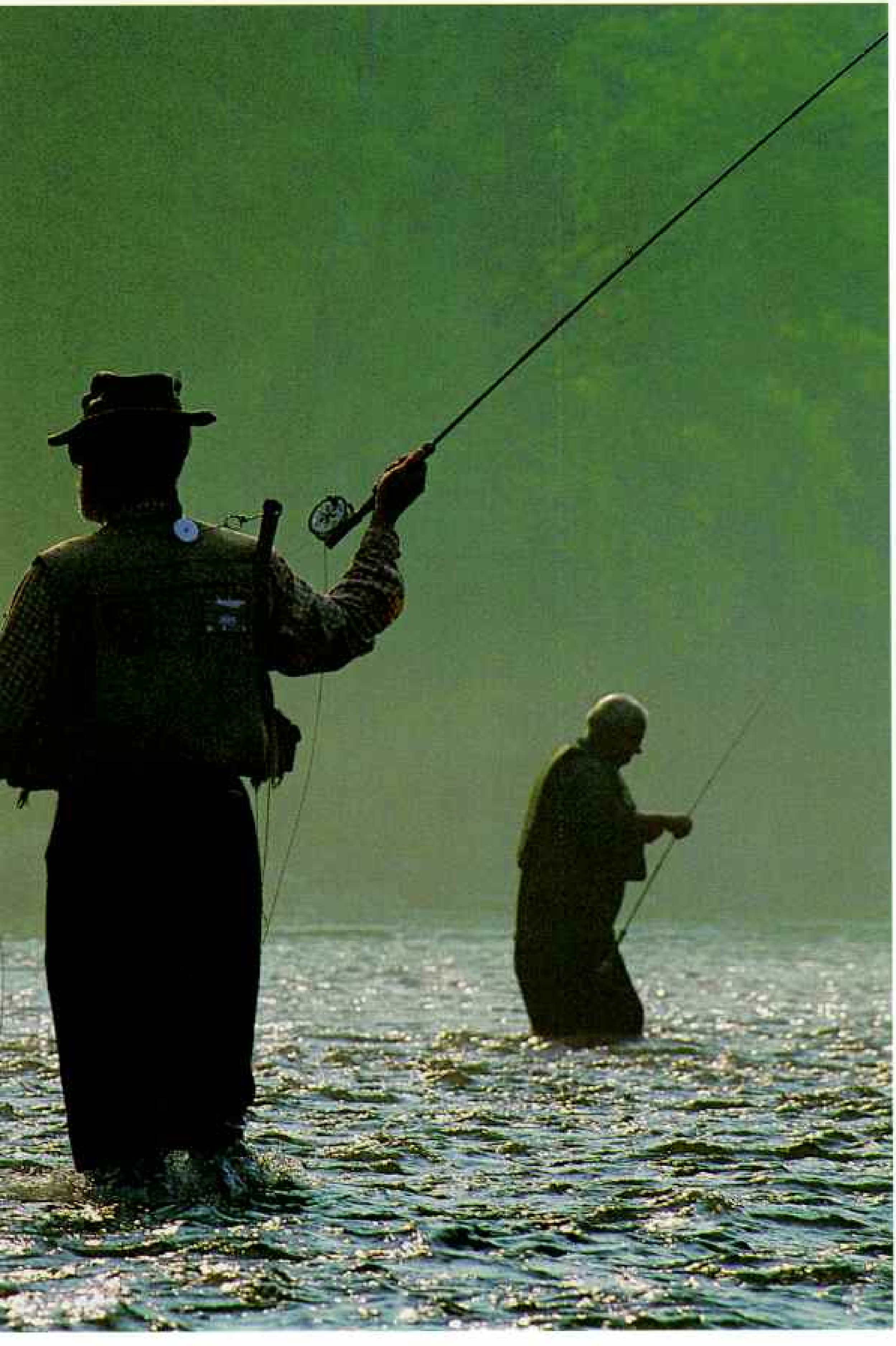
JOHN C. STENNIS SPACE CENTER, NASA (RIGHT)

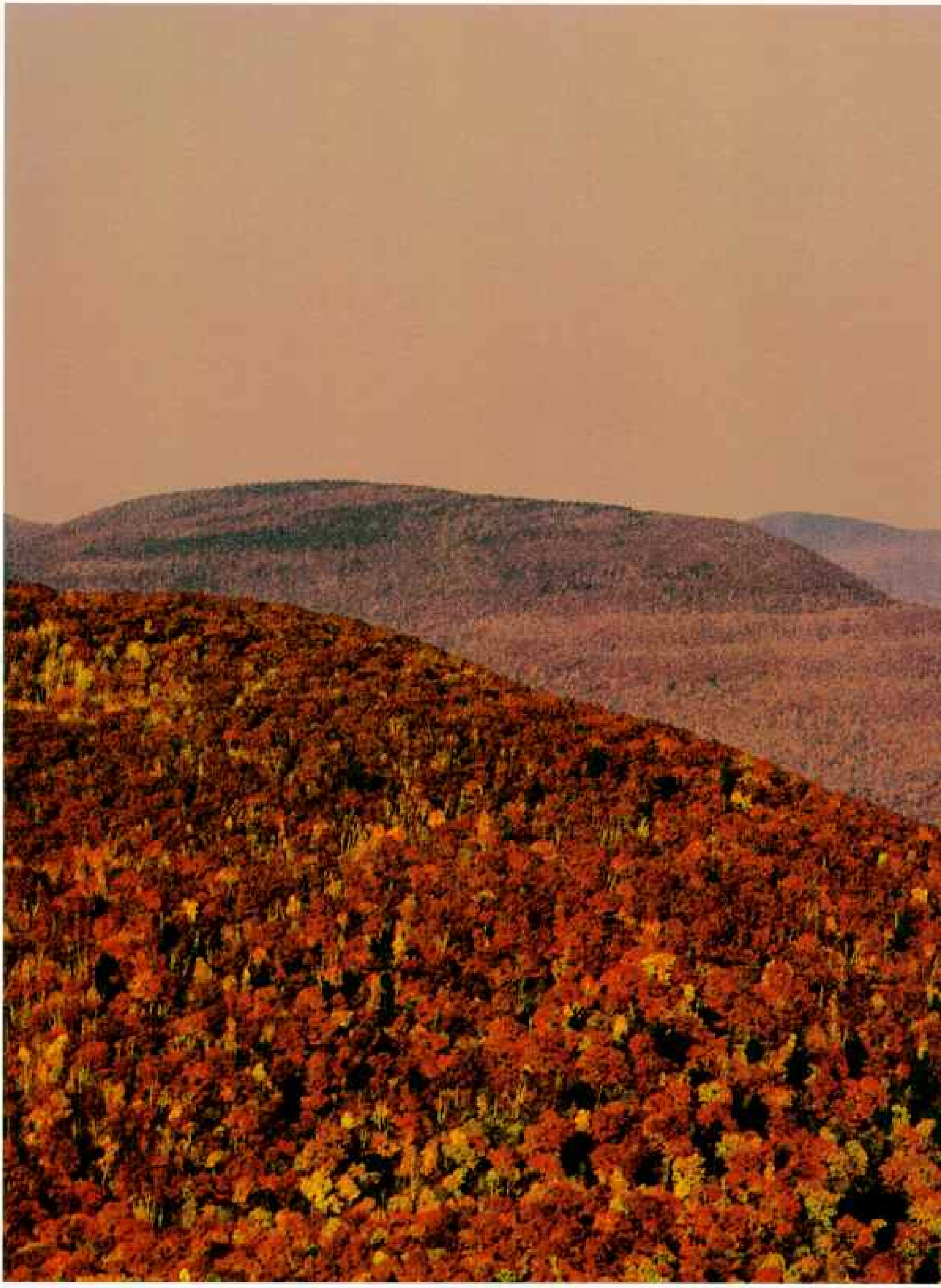
The Lure of the Catskills

Just a few hours north of New York City, guide Jerry Bartlett, center, teaches tourists how to fly-fish for trout on Esopus Creek. In the meantime, residents cope with crowds hooked by the gentle charms of Catskill mountain country.

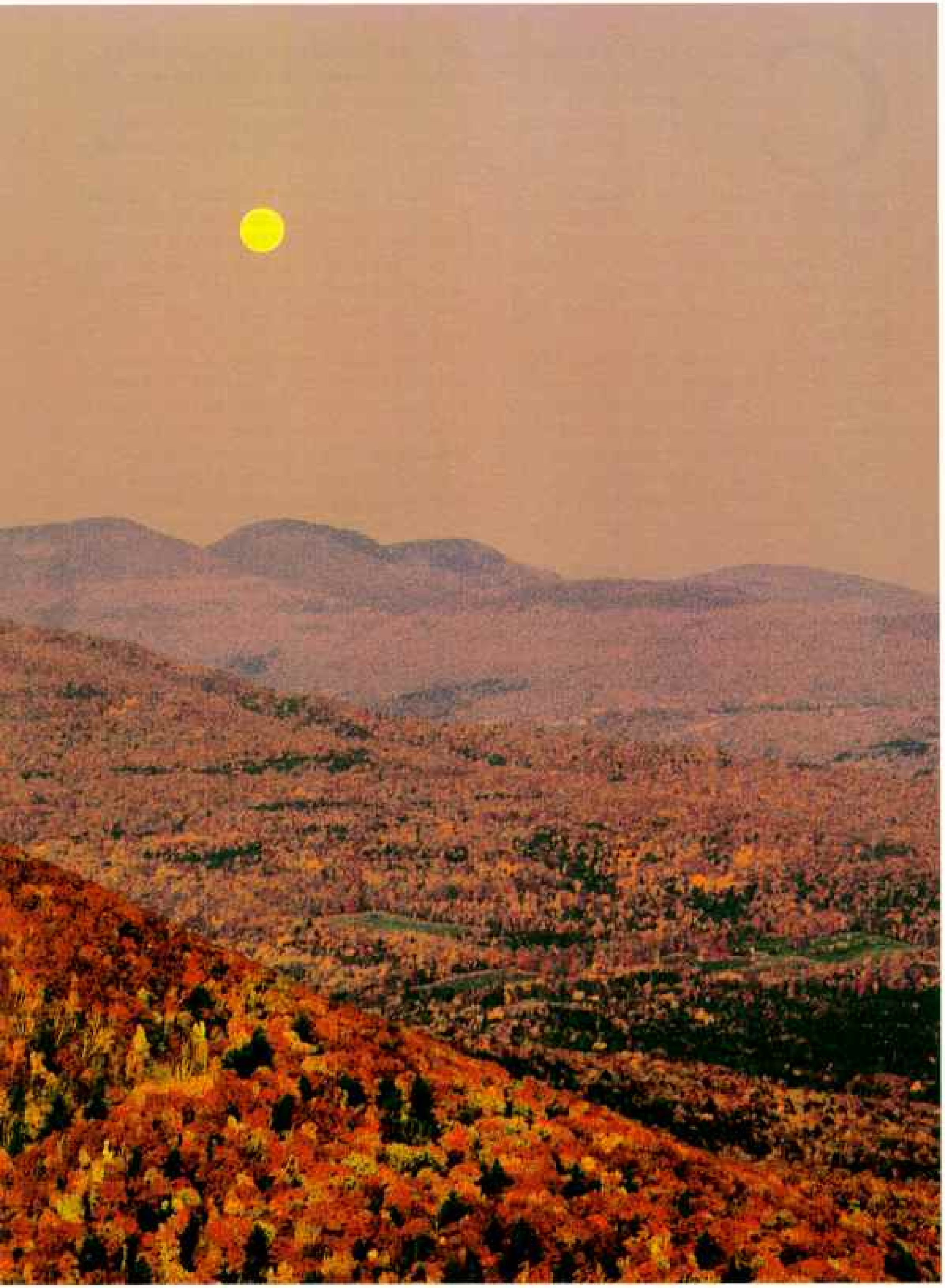
By CATHY NEWMAN
NATIONAL GEOGRAPHIC SENIOR STAFF

Photographs by MARIA STENZEL





Stripped by lumbermen and tanners in the mid-1800s, the heart of the Catskills was resuscitated in 1885 when the New York State Legislature established the Catskill Forest Preserve, which became part of Catskill Park.



Later the state constitution was amended to further protect the land—especially from corrupt politicians. "That's the beauty of the preserve," says forest ranger Patricia Rudge. "It can never be taken from us. It can only grow."

COMEDIAN Mal Z. Lawrence is on a roll. He's hot as horseradish, and the crowd at the ten o'clock show at Kutsher's Country Club hotel loves it. He's skittering across the floor like dice on a gaming table, radiant in white suit with pink handkerchief and matching tie, his graying hair tied into a tiny ponytail.

"The big activity here is food, food, food. People check in as guests. They check out as cargo. They don't need bellhops, they need forklifts."

Bellies coping with the aftershocks of dinner shake with laughter. Mal Z. has been working resorts in the Catskill Mountains for nearly 40 years; he knows how to read an audience. Tonight the Geritol set predominates.

"Can you imagine what casinos here would be like? What symbols on the slot machines! No cherries, no oranges—prunes!"

The crowd eats it up.

The next morning at breakfast it's clear that Mal's impersonation of Kutsher's brash, wisecracking waiters is pitch perfect. Do I want pickled herring, herring in sour cream, herring in wine sauce, herring baked, herring fried, herring in tomato sauce? Salmon pickled or smoked? Nova, perhaps?

"Dear," counsels a woman from Long Island, leaning across the table. "Try them all. That's what you're here for."

Take my order—please.

Think Catskills, think gefilte fish with humor on the side. For most folk, at least, the Catskills stand for the traditionally Jewish resort area known as the borscht belt. A generation of American comics cut their teeth here: Danny Kaye, Milton Berle, Buddy Hackett, Sid Caesar, Alan King. The wit was self-mocking, sarcastic. Jewish food, Jewish angst, Jewish mothers. But you didn't have to be Jewish to laugh.

Yet the borscht belt represents only one corner of these low, rolling New York mountains—4,000 square miles of Americana. The Catskills are also dairy farms, trout streams, small towns with steepled churches and white-as-milk clapboard homes. Mix in a legacy of bohemian art colonies and the lingering vibes of the 1969 Woodstock festival. All this only two hours north of Times Square. And that's just the problem—so many people want a piece of it.

Mention New York City—indeed, any city—to a Catskiller, and the eyes squint in suspicion. Nearly everywhere you look, fields once flecked with Holsteins now sprout houses, most built in the 1980s as second homes for the people native Catskillers call flatlanders.

Among Catskillers struggling to keep their farms, or working two or three jobs to make ends meet, there is understandable resentment. "It's hard for us to watch cityfolk buy 20 packs of lamb chops, so a lot of us don't set foot in a grocery store on weekends," said a local waitress.

"The Catskills are changing, and no one can get a handle on it," said Whitty Sanford, a regional planner. "People feel less connected to the land. Development swept through, and now they have the city on their back."

This identity crisis is compounded by the fact that the four-county region, home to 326,500 people, already has multiple personalities. Greene County, which considers itself the "true Catskills," has ski resorts and condos. Sullivan and Ulster are the most suburban, catching the overflow from the fast-growing Hudson River Valley. Delaware County is the most rural.

The natives never cast themselves as being "from the Catskills." Hometowns come first. People are from Roxbury, West Kill, Grahamsville, Oliverea, or the aptly named Bovina Center.

Mountains are dividers, not unifiers, Catskill historian Alf Evers reminded me. He once asked a man in Roxbury what he thought of Woodstock, 30 miles away. "Never been there," the man replied. "Everything I value in life can be found here in Roxbury."

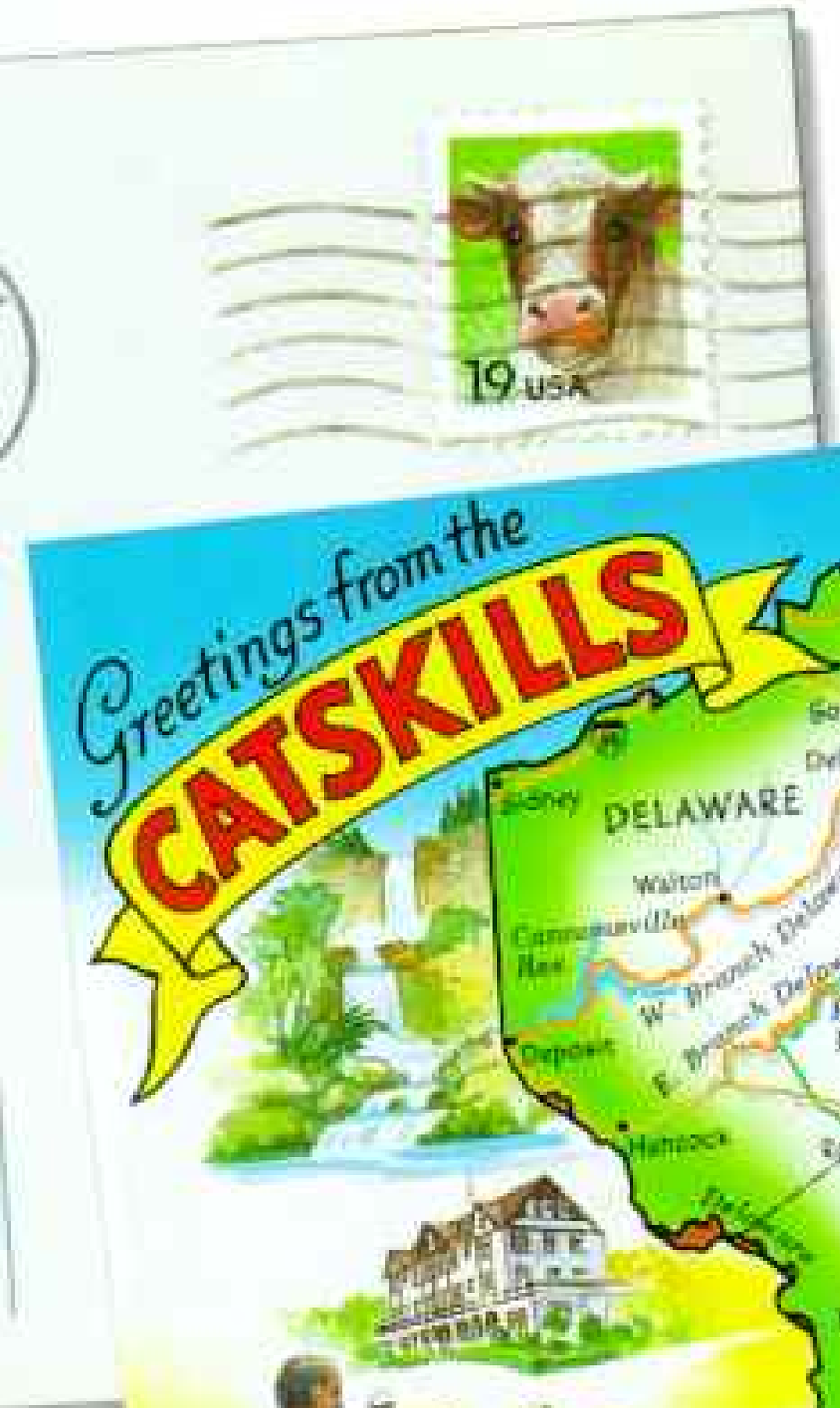
TECHNICALLY the Catskills aren't mountains at all but a dissected plateau—an uplifted landmass scoured by glaciers into a hundred or so gentle peaks, now carpeted in spruce, hemlock, birch, maple, and oak and veined by more than 1,500 miles of trout streams. They are a geologic hiccup. The tallest peak, Ulster County's Slide Mountain, rises a modest 4,180 feet.

"They are as comfortable as home," said writer T. Morris Longstreth at the turn of this century. "They were created, not for observation-cars, but for bungalow porches."

And that's where people lingered as the Catskills began attracting tourists by stagecoach and steamboat in the early 1800s. For people from the eastern seaboard, this was the wilderness. James Fenimore Cooper's Natty Bumppo told them that from here one could see "creation . . . all creation."

Another literary character from the 1820s, Washington Irving's Rip Van Winkle, so personifies the Catskills that tourists drop by the Haines Falls Library in Greene County to ask where Rip took his 20-year nap. Surely it is the Mountain Top, a section of the northern Catskills cleft by dark, spooky ravines called cloves for their old Dutch name, *kloven*.

Place-names here hiss the threat of the diabolical: Devil's Kitchen, Devil's Lake, Hell Hole. Hiking up Kaaterskill Clove, "a solitary bye-path to the nether world," in the notes of one late 19th-century traveler, it seemed that a whiff of brimstone would not be amiss. At the top, Kaaterskill Falls—one



She still mambos, but Jackie Horner—who inspired the 1987 movie Dirty Dancing *—now teaches an older crowd at hotels where line dancing keeps folks in step, and bingo can leave them out of luck.*

of the highest in New York—spills its thin ribbon of water 110 feet down a ledge, takes a breath, then leaps 85 feet before stepping over boulders and off into dark shade.

"Niagara it's not," I said to Greene County historian Justine Hommel, who accompanied me. She seemed slightly hurt. "Well I was disappointed in Niagara," Justine said. "Volume. Not much else."

IN THE CATSKILLS I found something I'd missed after four decades of living in cities: simple courtesy. Like a friendly wave, for example. It is unthinkable not to return one.

"Tell you a story about that," said Walt Meade, a naturalist who lives in Roxbury, on the Catskills' northern slope. He cocked his head like a songbird about to launch forth.

"I was going to Grand Gorge when Jane Hubbell drove by and waved. But I didn't see her till it was too late. The next time I saw her, she berated me. 'I wasted a perfectly good wave on you, Walt Meade. And I don't know as I'm going to wave at you again.' "

There is a deeper courtesy, and that is compassion. Catskillers know about that too.

"My father died when I was 15," Matt Budine told me as he judged cattle at the Delaware County Fair. "Mom was 33 and had five kids. The farmers got together to bring in our hay. Their wives put on food. The Holstein Club collected money so we could hire a man to help until we could get on our feet."

I heard his story repeated time after time.

"When my dad's barn burned down, the neighbors put a new one up in three days."

"When our daughter was killed, the neighbors just came in and took over."

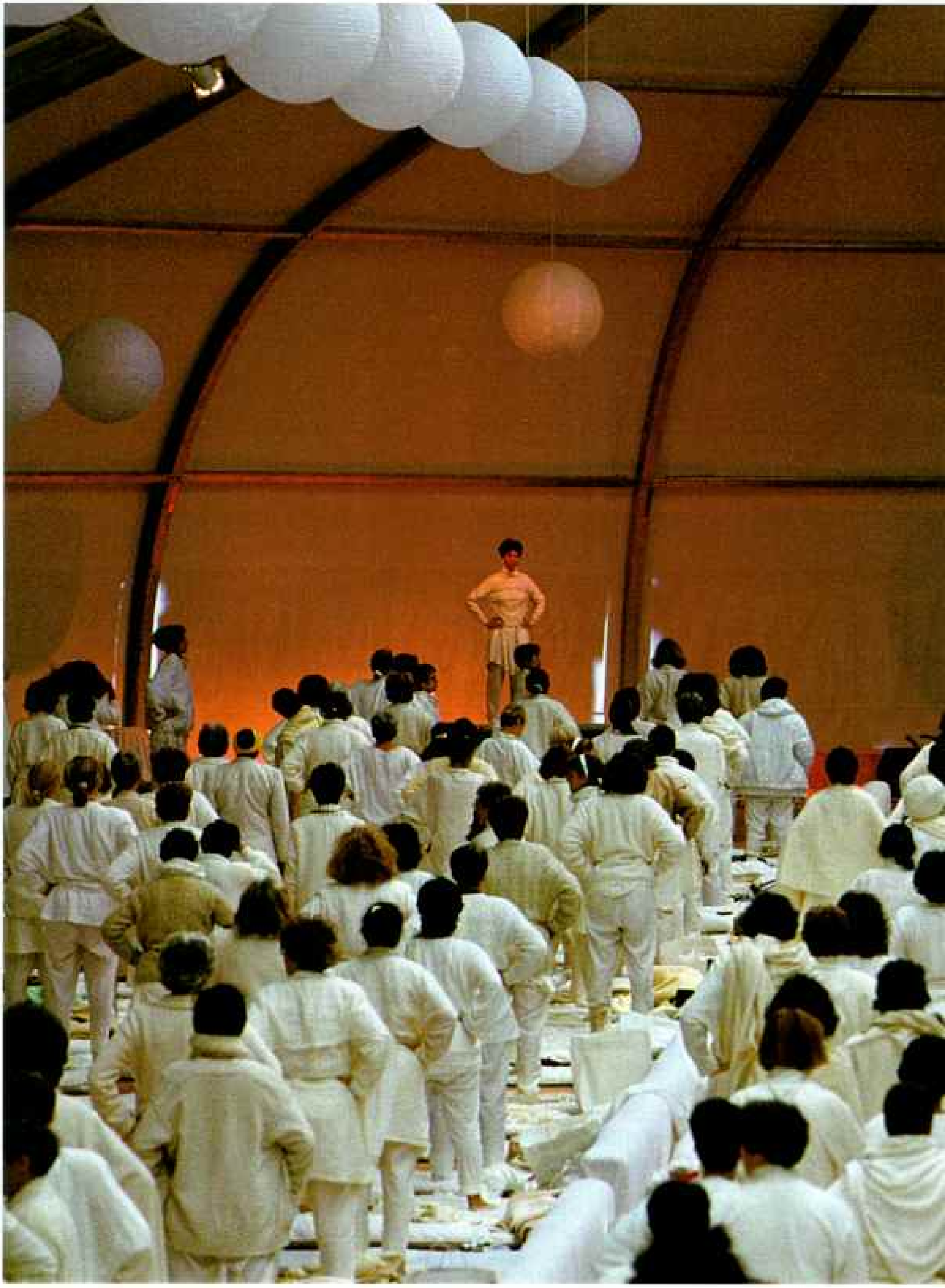
Sit in Bud's general store in Roxbury and watch the overalled-and-flannel-shirted regulars drift in for breakfast. One by one they claim their counter stools and trade gossip in flat cadences. It's as easy and comfortable as a pair of old work boots.

A glass of orange juice at Bud's costs 85 cents. Several mountains over at Misty's in Woodstock—just down the street from a business called Surreal Estate—the orange juice is $2.75, though the menu also lists "affordable orange juice" at $1.50. The conversation is different as well. At Misty's I overheard a woman in cobalt blue boots confide to her companion: "Teresa is big fun. She doesn't go in for predesigned thinking."

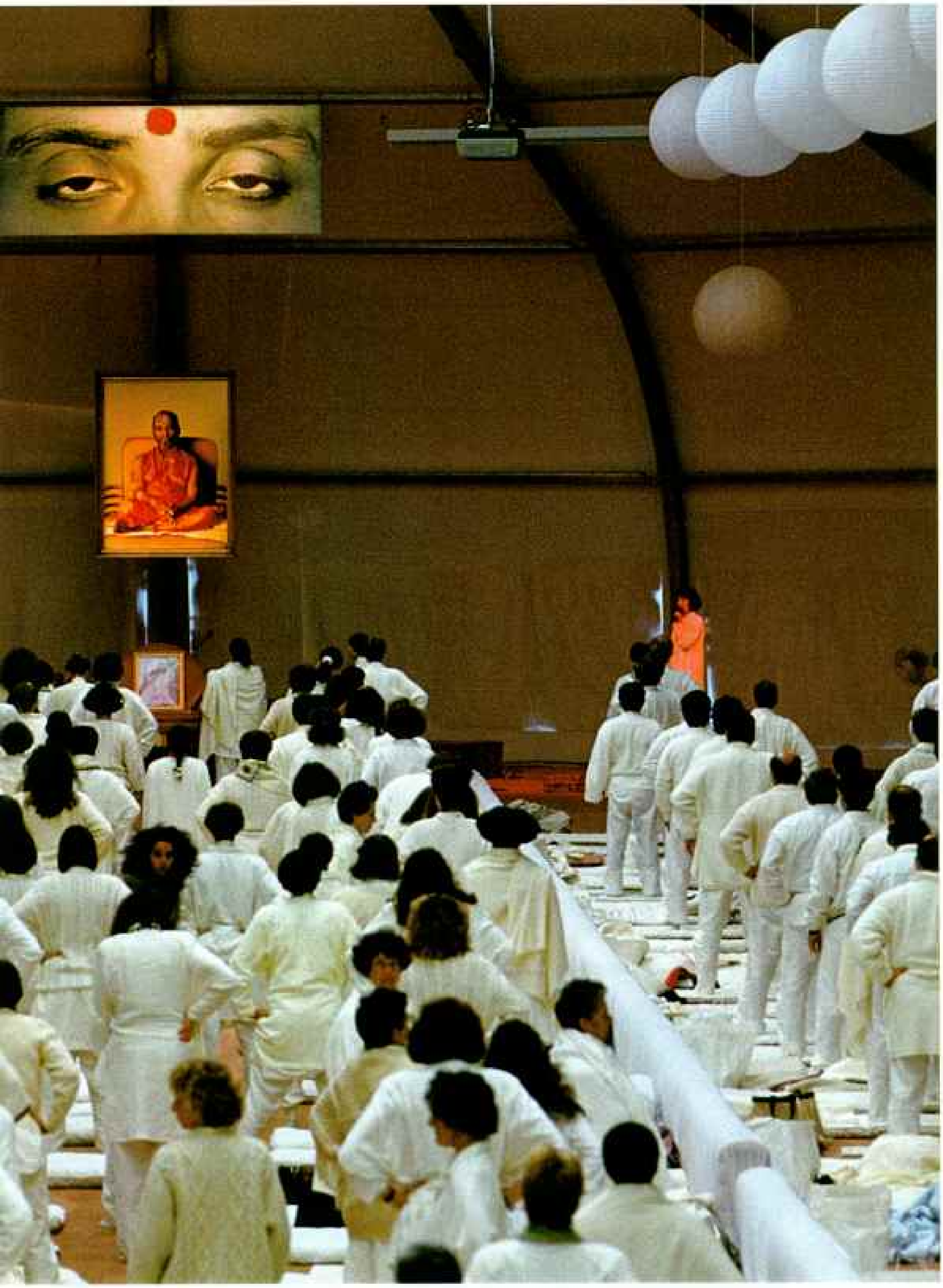
For all its affectations, Woodstock is big fun too. It lies somewhere between bizarre and bazaar, its stores hawking Zen books, fringed leather coats, crystals, meditation gear, and health food.

"Being a sixties reliquary is not what makes Woodstock," insists the publisher of the *Woodstock Times*, Geddy Sveikauskas. He is dressed in a T-shirt, torn jeans, and leather sandals. "We're a mix: about a third natives, a third hippies and artists, and a third IBMers."

Despite the disclaimer, it's hard *not* to see Woodstock as a time warp. Walk into Yusko's Cut & Dry, and step back 25 years. "Hey, man, need a do?" asked Dennis



The eyes have it—the power, knowledge, and authority of the Siddha Meditation Masters. Swami Chidvilasananda, guru-in-residence at an ashram in Fallsburg, says her eyes-only photograph facilitates deep



meditation and "a state of oneness with the Great Light." Local critics, though, focus on finance: They claim the ashram is not a religious organization and therefore should not be exempt from paying state property tax.

Albert Yusko, who goes by his acronym, Day. It is the aging of Aquarius. The bearded, beaded, balding Day is an elder of the Woodstock Clan of the Rainbow Family of Living Light, founded at the legendary music festival.

"We are organizing the Woodstock Nation," Day told me. "Peace, love, music, and service will unite the world."

Woodstock's festival roots go back to 1915, when an art colony called the Maverick put on a feast at which an audience costumed as Gypsies, pirates, and sailors applauded Russian singers and 14 members of the Metropolitan Opera Orchestra. Another big hit, writes Alf Evers, was "the white goat with her

Cutting corn to feed the cows and "picking rock" to clear the soil persuades many young dairymen to find sweat-free jobs. Not Tom Clark, who doesn't envy his officebound friends: "They join health clubs just to stay in shape."

horns painted blue who assumed striking poses on the tops of rocks."

The most famous festival actually took place 50 miles away, at Max Yasgur's dairy farm outside Bethel. Several towns gave the cold shoulder to promoters before they found safe haven in Yasgur's fields.

The festival posters with their logo of a dove perched on a guitar neck promised three days of peace and music, and, despite incessant rain, it was. It was also a happening that lumped all the icons of the sixties in one mixed bag: peace signs, long hair, pot, acid, Jimi Hendrix, Janis Joplin, Joan Baez. Estimates put the crowd at half a million.

On a day of light drizzle I drove over to see the site for myself. The field, marked by a plaque, has gone to wild grasses. Plows, I am told, still turn over an occasional sandal.

After Woodstock many of my generation cut their hair and switched from tofu to Brie. Jogging replaced pot as the feel-good high.

I suddenly felt old.

CHANGING TASTES AND TIMES have forced the borscht belt to tighten several notches. When Mal Z. Lawrence got his first laughs in the mid-1950s, there were 500 hotels in Sullivan County. Many had grown up from Jewish farms that at the turn of the century took in Jewish tourists, barred from other resorts.

Today there are only five major resorts and 51 smaller resorts and motels. Guests, who once stayed for weeks or months—indulging in tennis lessons by day, mambo lessons by night—are gone after an average of 2.5 days.

"We passed the peak without even knowing it," Ken Dinnerstein told me as we walked through the Stevensville Hotel in Swan Lake. The 350-room hotel was owned by Ken's family from 1922 to 1989, when it was sold to a Korean businessman, who promptly ran it into bankruptcy. Weeds blanketed the grounds. Graffiti marked the walls.

Money doesn't motivate Michael Esposito, who gave away his inheritance when he moved to Woodstock in 1968. Although he played guitar for the Blues Magoos, Michael didn't perform at the legendary music

festival; he made peanut-butter-and-jelly sandwiches for hordes of hungry hippies. Nowadays he fixes bikes and hangs out with his fiancée, Linda. "Most of the time I don't have much to do," he says, "and I like it."

What do the Catskill Mountains provide besides a view of the Hudson River and points east? They encompass a watershed that supplies New York City with 90 percent of its drinking water, delivered via aqueducts and tunnels.

"The golden days were in the 1950s," Ken said. "People had money and spent it. Hotels added rooms, whole wings, indoor swimming pools, ice-skating rinks."

Then several things happened. "First, the move to suburbia and air-conditioning reduced the need to get away in summer. And there was a lessening of anti-Semitism. After World War II more places opened up to Jews." The final blow: jet planes and cheap airfares. "You didn't need the Catskills. You had the Caribbean."

We stopped at the indoor pool. Deck chairs were overturned; paint had peeled off in blotches. Ken's face darkened. "Thank God my father's not here to see this."

Today a quarter of Sullivan County's tourists are 65 or older. "We want to attract a younger clientele, but we're not sure how," said Jerome Ehrlich, owner of the Pines.

They're trying. The Pines has bluegrass festivals. The Concord trumpets a new fitness center and singles weekends. There's summer camp for the kids at Kutsher's. Another new wrinkle: Conventions represent 60 percent of the business. Also the clientele has changed. If you leave out Jewish holidays and the summer, 75 percent of the business is non-Jewish.

In response, the Concord serves nonkosher food in the clubhouse. A bacon cheeseburger? Coming right up. Some places have gone nonkosher altogether. Even the sobriquet "borscht belt" is held at arm's length by hoteliers. Says Milton Kutsher: "Who wants to be named for a soup?"

EVEN AS THE OLD RESORTS CLOSE, other religious groups are finding sanctuary in the Catskills. Most ambitious is the SYDA Foundation Ashram, a retreat for devotees of Siddha yoga, a Hindu belief that aspires to an awareness of God in each person. In three former hotels in Fallsburg the ashram houses several hundred residents and can accommodate 3,000 more who attend workshops such as "Refreshing the Spirit" and "Ganeshpuri Temple Chants."

Because New York law exempts religious institutions from property taxes, Fallsburg's tax revenue has been affected. Claiming the ashram is as much a business as a religion, the town put SYDA on its tax rolls. The ashram countered with a lawsuit. The case is still pending in the state supreme court, and the ashram awaits the ruling—as it does all things—with tranquillity.

"I hope you feel what I feel," says David Wishingrad, a former businessman in the garment industry, who shows me around. "The peace, the love. . . ." He gazes reverently at a picture in the reception center of Swami Chidvilasananda, known by her devotees as Gurumayi. She is the spiritual leader of

Siddha yoga. Her image is everywhere: on walls, on dashboards, on the computer at the registration desk.

"But you must experience Gurumayi for yourself," he urges. One summer evening in the glass-walled, marble-floored Mandap Pavilion, I do.

After three hours of chanting, hundreds of shining faces line up for an audience with Gurumayi. The wait is hours long. Luckily I am propelled to the front. Gurumayi sits cross-legged on a silk pillow on a Lucite throne. She is dressed in scarlet robes. Devotees prostrate themselves on the ground before her; I am reassured that in my case a nod will suffice.

A slight, handsome woman with gentle brown eyes behind tinted glasses, she greets me by name and touches me with her peacock feathers before I am swept out.

Later I walk through the ashram's garden. Interspersed with the glorious blooms of summer are large painted plaster statues of Siva, Moses, Jesus, Martin Luther King, Jr. The effect is at first incongruous, then poignant. We are all searching, I am reminded, hoping to find some sort of light to illumine the soul.

KATHY SHERWOOD'S EYES brim with tears as she shows me a photograph of a well-worn green house. "This is our new home," she says.

It's in Oneida County, a two-and-a-half-hour drive upstate from the Sherwoods' family farm in Delaware County. The farm they are leaving has been in her husband's family for five generations.

"We started moving in April. Now it's August, and we're about to move the cows. It's like dying a slow death."

In 1955 there were 2,306 dairy farms in Delaware County. By 1985 the number had dropped to 503. In 1991, only 321 remained. Soon there would be one less.

Dairy farming, Delaware County's most important industry, generates 40 million dollars a year. But the Sherwoods and others are finding it hard to survive, as inflation outpaces the cost of working this difficult land.

In the Catskills, it is said, there are "two stones for every dirt." With each frost and thaw the earth heaves up a new crop of stones that must be cleared before spring plowing can begin. Picking rock, it's called.

The rocks and the steep slopes chew up machinery, and much farmland is relegated to timber. The Sherwoods have 289 acres. Only 50 are tillable. Also the growing season is brief. Two hay crops compared with three or four in other parts of the state. "So I have to buy feed," says Gary. In 1991 it cost him $14.25 to produce a hundredweight of milk that sold for $11.

"Of course, we could sell out and leave farming altogether," says Kathy. But farming is as much a calling as a job, a way of life that binds a family with common values.

Each season unfolds with its own rhythm, explains 21-year-old Chris, the Sherwoods' oldest son. Planting in spring, haying in summer, harvesting corn in fall. Winter is the time for fixing machinery. On cold, dark winter mornings in the barn, the flank of the cow warms your cheek as you hook up the milking machine. It is a time to gather thoughts.

"Our farm is the last one living," Chris confided to his diary. "Hiding in the hollow away from the approaching city. Hoping that it will not find it and destroy its beauty as it has all the others. Once there were 50 in the valley, now we stand alone up in the hollow."

The Sherwoods hope a farmer buys their place. It is a faint hope. Their best bet is to sell to a family looking for a vacation home. Failing that, it could go to a developer who will chop it into five-acre lots.

Developer Eric Wedemeyer got his start in 1969 when he bought a farm, divided it, bought another, divided it, and realized he was in the real estate business. He quit his high school teaching job on Long Island and moved to Delaware County.

"Ninety percent of our sales are to people from New York City and its suburbs, usually professionals with above-average incomes," he says. "Many see a place here as a year-round second home."

We drive out to look at one of his developments: two-story wood-and-glass houses tucked neatly into wooded slopes.

"There will be development, the question is what kind," Eric says. "These farms would go under anyway."

Still, he'll always remember the native who said: "Eric, I want to congratulate you. Your subdivisions are lovely. Can you take me to a parcel I can afford?"

"He was right," Eric concedes. "These

people see $300,000 homes going up, and they can't even afford a first home. It's sad, but what do you do?"

THE PAIN OF TRANSITION has afflicted Catskillers before. "We live in an age of iron and have all we can do to keep the iron from entering our souls," naturalist John Burroughs, a true son of the Catskills, wrote in 1918. Burroughs, whose essays celebrate the thrill of stars at night and the first violets of spring, roamed the Catskills as a boy, happy in the company of foxes and owls.

"I early learned that from almost any stream in a trout country the true angler could take trout, and that the great secret was this . . . there was one thing you must always put upon your hook, namely, your heart."

His spiritual heirs are to be found today on any Catskill stream.

The air temperature was 25 degrees, the water a chilling 36 on the opening of trout season (April Fool's Day, appropriately) in Roscoe—self-proclaimed Trout Town, U.S.A.

Roscoe sits at the western end of the Catskills, within casting distance of two fabled trout streams, the Beaver Kill and the Willowemoc. You know it's spring when fishermen practice their casts on the lawns of local inns.

To fish opening day on the Beaver Kill, the great sportswriter Red Smith once said, is like celebrating Christmas in Bethlehem.

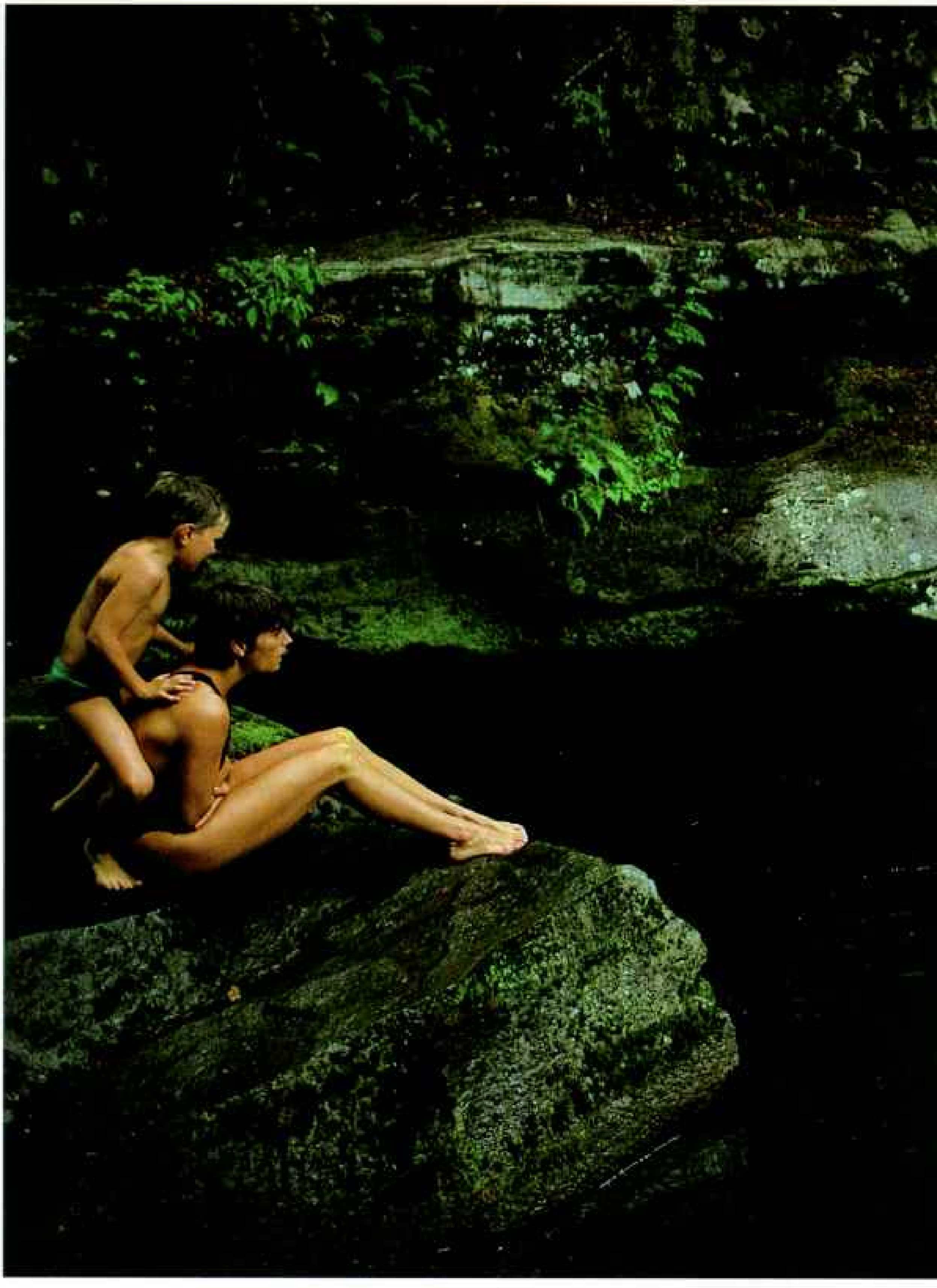
By 8 a.m. there were 35 fishermen in the water, wearing waders and fishing vests cluttered with more gadgets than there are ribbons on an admiral's chest.

"Big fish fry tonight," said Ray Bivaletz of New Jersey, who showed off the first fish of the day: a 15-inch brown trout.

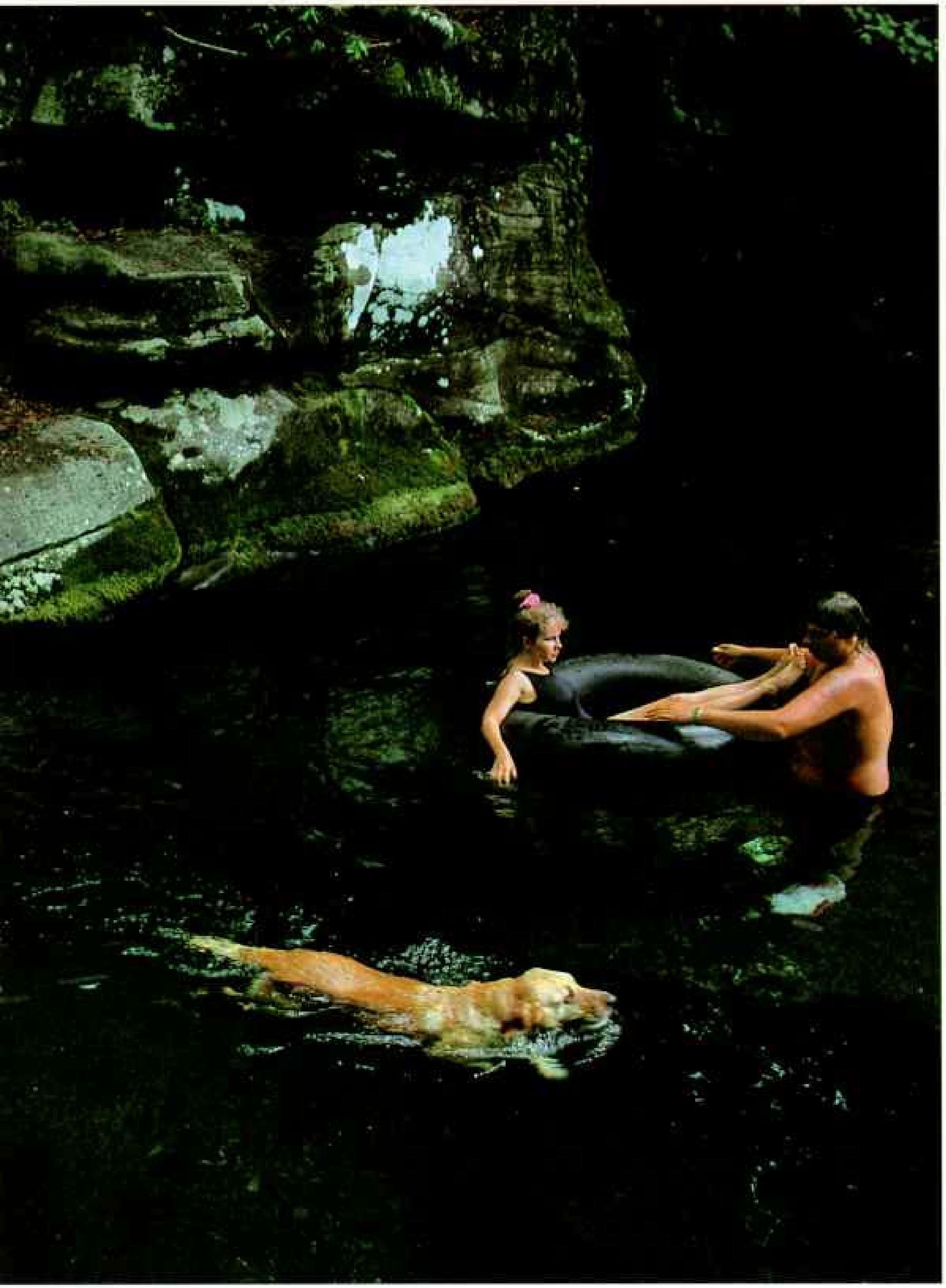
By 10 a.m. it was snowing. The fishermen count had risen to 41, but odds still favored the trout. Only two more had been caught.

"What are you catching?" I asked Charlie Rall. Rall didn't miss a cast. "A cold."

From South Kortright it's 15 miles to the nearest supermarket and 30 miles to a movie theater. But it's just a short stroll down the town's main street to the Presbyterian church's annual rummage sale.



Taking a dip in the clean, cold Neversink River, swimmers savor the Catskills' waters—"the best in the world," according to 19th-century naturalist John Burroughs. In essays that celebrated his lifetime love affair



with this wilderness, Burroughs often seemed enraptured, intoxicated. "For the first few days," he wrote about his bikes in the mountains, "one feels as if he could almost live on the water alone; he cannot drink enough of it."

THE BEAVER KILL and the Willowemoc are the only Catskill waters allowed to flow unhampered. The Delaware, Esopus, Rondout, Schoharie, and Neversink wind up in reservoirs that supply 90 percent of New York City's drinking water.

From 1907 to 1964 the city bought 57,619 acres of Catskill land, razed towns and farms, and moved 4,964 people in order to scoop out six reservoirs. The water is excellent, requiring little more than a splash of chlorine. But in 1989 the Environmental Protection Agency ordered communities to filter drinking water, not just chlorinate it, unless they had adequate watershed protection.

A filtration plant for New York City could cost five billion dollars to build, 300 million dollars a year to operate. To avoid that burden, in 1991 the city sought to protect the watershed by requiring that septic tanks and fertilizer and manure storage be prohibited within 500 feet of any watercourse. New construction would be limited to 10 percent of the area within 500 feet of a stream.

Because the region is a cobweb of streams, the proposed regulations threatened to put a third of the watershed off-limits to development and hundreds of farms out of business.

"These decisions are made," scoffed one farmer, "by people who sit with their feet on their desks and haven't ever milked a cow."

Catskill towns, never noted for cohesiveness, suddenly found common ground and formed the Coalition of Watershed Towns to go nose to nose with the city.

"The big issue is compensation," said Perry Shelton, chairman of the coalition. "Why should we have to pay for their water?"

Al Appleton, New York City's Commissioner of the Department of Environmental Protection, was unapologetic. "Water is the state's leading economic asset. We're not doing this just to meet today's crisis. We have to frame this for the long haul."

The city later eased off its proposed restrictions on farmers and agreed to a voluntary program. But the rancor will be slow to fade.

"For all my life all I can remember is New York City taking, taking, taking," said former dairyman Leonard Utter. "City people coming and buying farms because they had more money than my children. They put in reservoirs and power lines, and now they're telling me again what to do with my land."

The town he grew up in, Arena, was one of four "taken out" by the Pepacton Reservoir on the east branch of the Delaware River. For the past 33 years, those who lived in towns flooded by the reservoir have met during Labor Day weekend on a hill overlooking the Pepacton. The gathering is part high school reunion, part veterans convention. The nostalgia is bitter.

"The older I get, the madder I get," said Dot Andrews of Shavertown.

"They took the best farmland in Delaware County. People practically had their houses knocked down around their ears," said Gerald Norris of Union Grove.

Yet, there is a nod of resignation.

Another dairy farm disappears at auction, where a wagon wheel fetches more money without the wagon. While arrivistes buy such artifacts as decorations for their new country homes, fourth-generation native Randy Ostrander, a logger, worries about where to sell his timber.

"It had to be done," said Ivan Miller, a retired high school teacher born in Shaver Hollow. He is soft-spoken, deliberate. "A few hundred of us couldn't sit on this good water supply and deprive millions."

Work on the Pepacton started in 1947; the water was impounded in September 1954. Ivan Miller was one of the last to leave.

"Before the water came clear up top the next spring, I went down to look where our house used to be," he said. "In the driveway a little portulaca had blossomed, as if there were still a family there to take care of it."

To Miller, the bright flower growing gallantly among the ruins bore a message of no surrender. "Life doesn't give up," he said.

WITH A LITTLE LUCK, neither will the Catskills. But how much gentrification can they absorb? As wilderness and farms turn to country suburb, distinctions blur, local color fades.

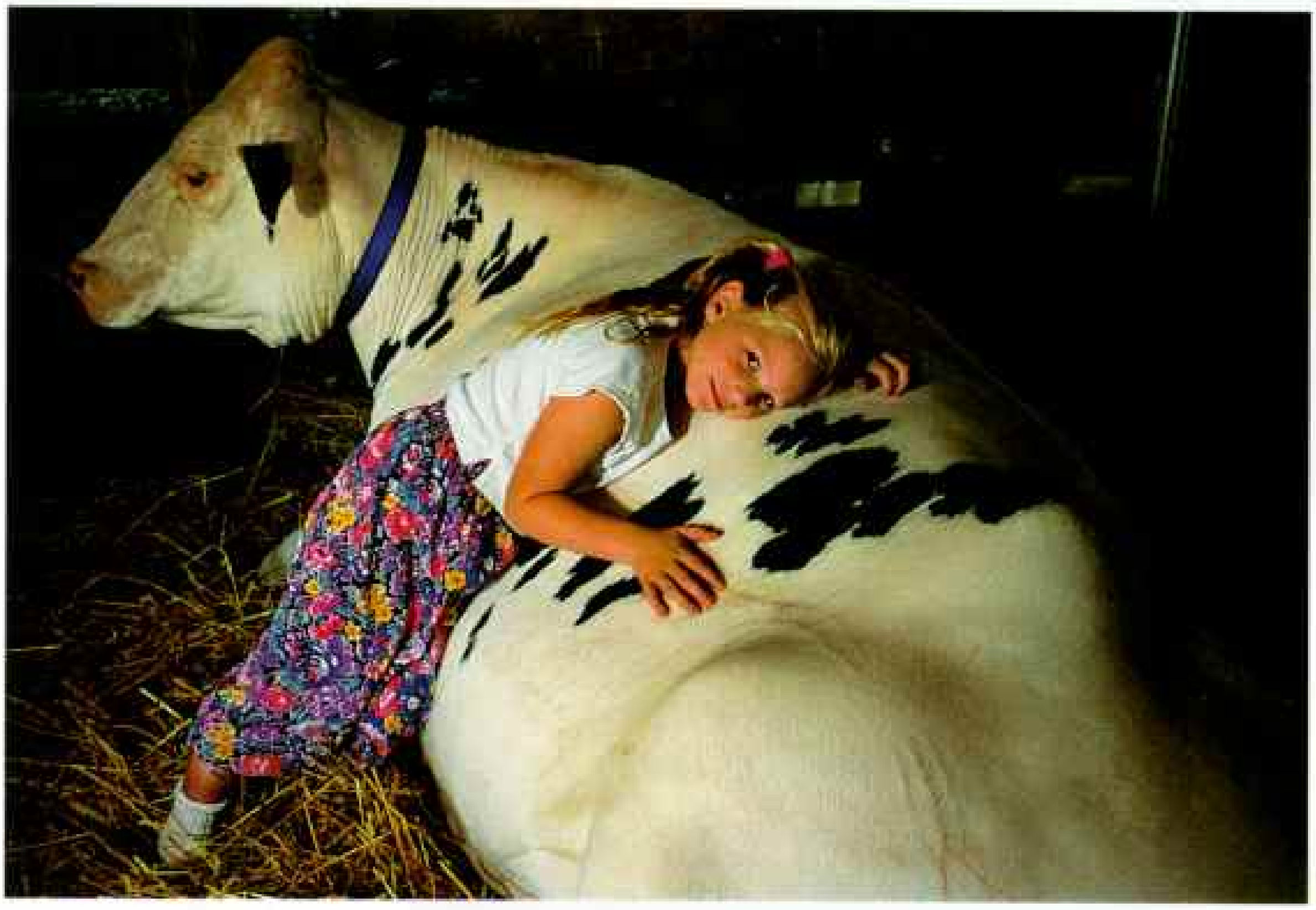
In the Margaretville A & P, where romaine lettuce was once considered hoity-toity, bins bulge with arugula and radicchio. The Agway, where farmers bought their feed and fertilizer, has been replaced by a store that sells birdbaths and lawn ornaments.

But not every nouvelle notion takes root. A year or so ago Patty's Pantry, a local eatery in Andes (population 1,291), decided to go trendy, moved a few miles down the road to Arkville (population 509), and emerged as Patricia's.

Patty's Pantry had been a down-home place where a bottle of catsup passed as a centerpiece. Patricia's featured jacketed waiters who served between-course sorbets with tiny chilled spoons.

"No one knew what to do with those chilled spoons," said the woman who told me this. "I mean, this was Arkville."

The out-of-town crowd was amused. The locals were, well, puzzled. Eight months later Patricia's closed for the night—for good. □



Best buddies Karen Inman, seven, and Alene, an eight-year-old Holstein, relax at the Delaware County Fair, where kids often sleep in the hay at night so they can be close to their cows.

Introducing Mercury Villager.

A minivan is a minivan is a minivan. Unless it's a Mercury. Which means when you get behind the wheel of this front-wheel-drive, V-6 powered minivan, you'll experience the smooth, quiet ride and easy handling you've come to expect from a Mercury.

But for all its car-like amenities, Villager hasn't forgotten that it's a minivan first and foremost. With plenty of room for seven passengers, and an innovative sliding rear seat that requires no tools to adjust. Just a flick of a switch and you can easily slide it forward to make extra room for additional cargo.

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If It Were Just It Wouldn't

federal passenger car safety standards* and comes with standard four-wheel anti-lock brakes.

There are other Mercury qualities that separate this minivan from the pack. Like available power moonroof, CD/cassette player and keyless entry system. For quick access to the Villager cargo area, the rear window opens independent of the liftgate door.

So if you're in the market for a minivan, why settle for just another minivan? Drive the Villager. And experience a minivan that comes with a very special quality.

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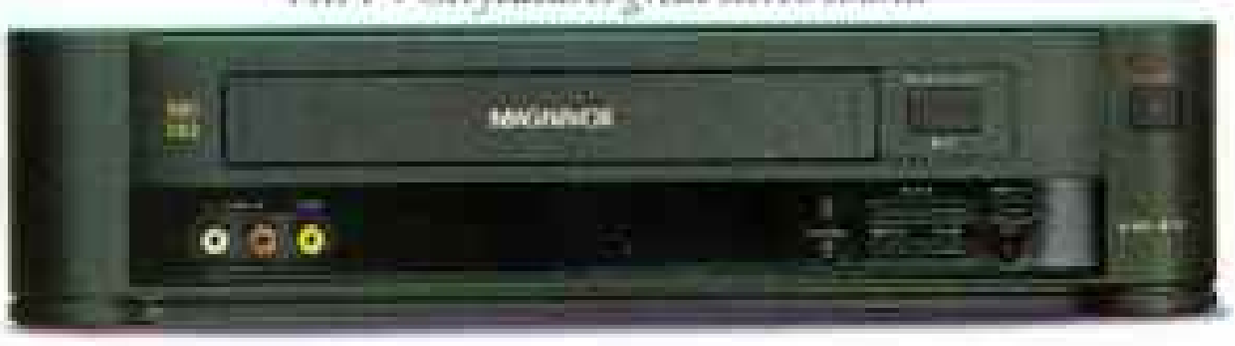

informed by the photographer to move back, because they can still see me."

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Geographica

World Changes Spell Change in NGS Atlas

What a difference two years make! In 1990 the National Geographic Society published the sixth edition of its *Atlas of the World*, expecting it to last years. But events—notably the breakup of the Soviet Union and of Yugoslavia—forced a change of plans. Beginning this month, new atlas purchasers will receive a far different "revised sixth edition."

"We couldn't just go back and print more of the original," says John F. Shupe, the Society's Chief Cartographer. "We want to offer the most current atlas possible."

The revision covers 20 new nations: 15 former Soviet republics, whose flags appear below, as well as the reborn Yugoslavia and the nations that split from it—Slovenia, Bosnia and Herzegovina, Croatia, and Macedonia. "In terms of impact, we've never seen anything like this in our lifetime," says Peter Miller, atlas text editor.

That's not all. Every map naming any part of either Yugoslavia or the U.S.S.R.—even a map of Alaska, which shares the Bering Strait with Russia—changed. So too did many of the 150,000 place-names in the index. More than 95 percent of Ukraine's place-names reverted to what they were before it fell under Soviet rule.

MICHAEL NICHOLS, MAGNUM

A Shooting in the Forest: Mountain Gorilla Is Slain

The autopsy reveals the stark facts: four holes where bullets entered; a large hole, "probably an exit hole"; two 7.62-caliber bullets, fired by light automatic assault weapons.

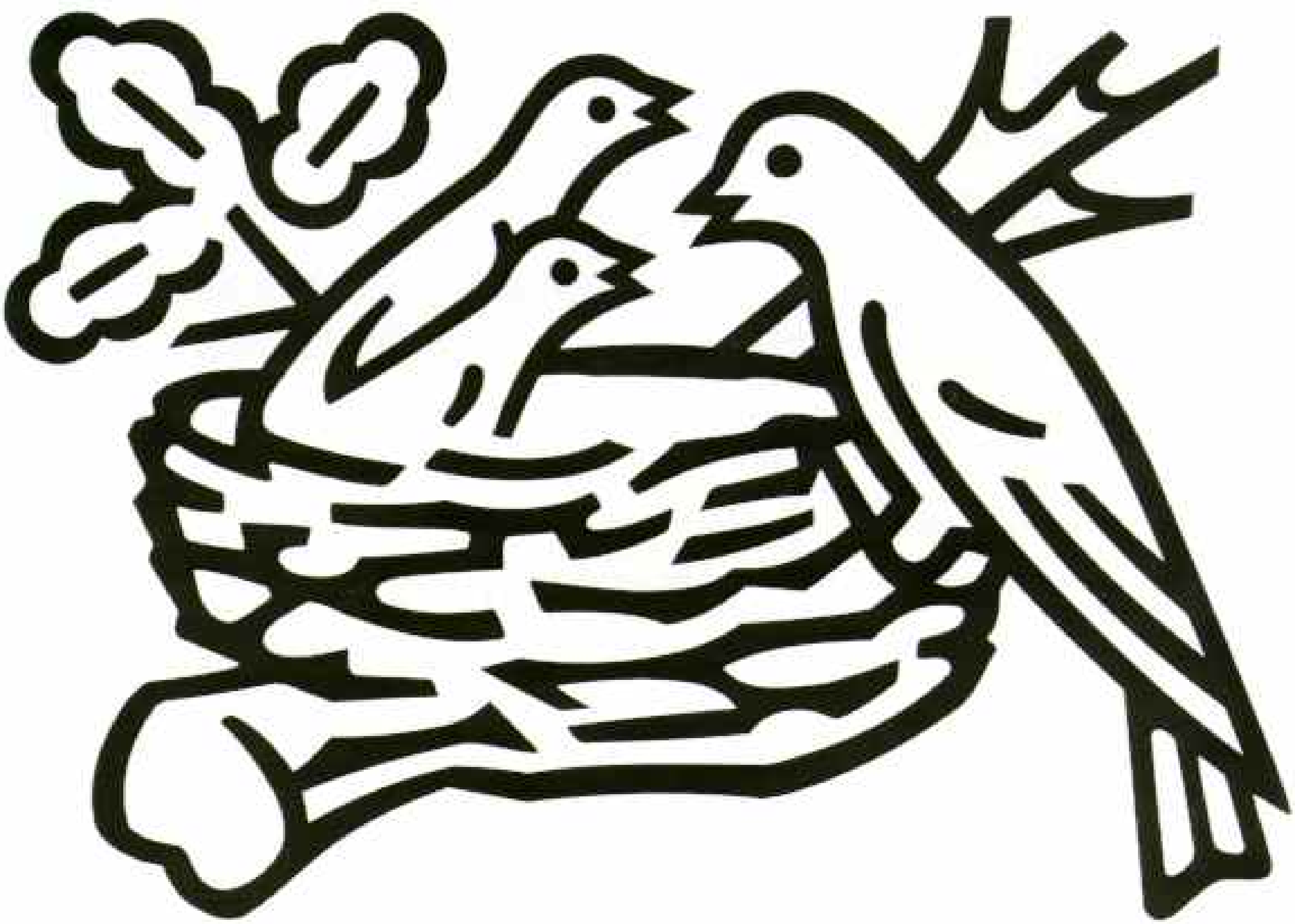
The victim? Mrithi (above), a majestic, 24-year-old mountain gorilla in Rwanda's Parc National des Volcans, featured in the film of Dian Fossey's life, *Gorillas in the Mist*. His loss shocked observers, who fear civil war will bring more gorilla deaths and loss of habitat. Only 600 or so mountain gorillas remain in the wild.

Dr. Elizabeth Macfie, director of the park's Volcano Veterinary Center, says it's unclear whether government soldiers or Rwandan Patriotic Front rebels shot Mrithi, leader of a 12-member family: "We're sure it was an accident, and it could happen again tomorrow."

Antipoaching patrols have decreased since fighting began in 1990, as has tourism, a key factor in Rwanda's economy (GEOGRAPHIC, March 1992). Gorillas too have been caught in snares set for game.

Mrithi's survivors clung together in the weeks after his death, led by Ukwacumi, a 12-year-old male. But he may be too young for leadership, and the group may yet dissolve.

National Geographic, November 1992



All Over The World This Is A Symbol For Warmth, Family And Shelter.

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Nestlé

Makes the very best.

Geographica

The Amazing Survival of All-female Salamanders

Incredible as it may seem—and perhaps contrary to what you learned in high school—single-sex, all-female lineages exist within the animal kingdom. Among them are female salamanders that mate with males of closely related species only to stimulate egg development. The males contribute no genes, and all the offspring are female.

Without the addition of male genes, most single-sex lineages—of fish, lizards, and snakes as well as salamanders—vanish in an evolutionary wink, a mere 10,000 years; a few last 100,000 years. Yet a team of biologists has learned that North America's all-female salamanders have hung on for a record four million years. The team, seeking to identify the common ancestor of the salamanders by sequencing their mitochondrial DNA, was astonished by the longevity of the lineages.

"Sexual reproduction is supposed to be good in nature because it encourages genetic variation, and that helps a species adapt to a changing environment," says S. Blair Hedges of Pennsylvania State University, who led the team. Hedges and his colleagues speculate that male genes in rare instances "leak" into the egg during mating, a genetic change that helps these unisexual salamanders adapt and persist.

Diving Into History in King Herod's Harbor

Get ready for the next wave of tourist attractions: underwater archaeological parks.

Officials in Jamaica and Bulgaria, hoping to lure tourists and intrigued by the world's first such park at Caesarea Maritima in Israel, have enlisted the aid of marine archaeologist Avner Raban of the University of Haifa. Raban helped design the park at Caesarea, the massive city and harbor that Herod the Great, King of Judaea from 37 to 4 B.C., built on the Mediterranean coast to honor Caesar Augustus (GEOGRAPHIC, February 1987).

More than two thousand divers have swum one of the four courses through Caesarea's port facilities since June 1991, following guidelines of plastic-covered steel cable. Rigid plastic maps identify, in English and Hebrew, the anchors, chunks of marble, amphora sherds, ballast blocks, building stones (below), and rubble that litter the seafloor.

MARK A. LITTLE

TOM MORGAN, PHOTO RESEARCHERS (LEFT); COURTESY DANIEL WOLF

At Last! A Daguerreotype View of New York City

After years of searching, Joseph Buberger has found what one dealer calls "the holy grail of daguerreotypes"—a New York City streetscape.

Following 1839, when Louis-Jacques-Mandé Daguerre fixed an image from life onto a silver-coated copper plate (GEOGRAPHIC, October 1989), daguerreotype shops sprang up across the U. S. Images of other cities survived, but none of New York were known until Buberger, a North Haven, Connecticut, "dag" expert, tracked one down through an antique dealer and alerted Daniel Wolf, a photograph dealer, who was able to buy it.

The 4¼-by-5½-inch image—of an area in lower Manhattan near what is now the foot of the Brooklyn Bridge (above)—was taken around 1850, probably from the second-floor window of a daguerreotypist's shop on Chatham Street.

"It's inconceivable that no daguerreotype view of Manhattan had come to light before," says Dale Neighbors of the New-York Historical Society.

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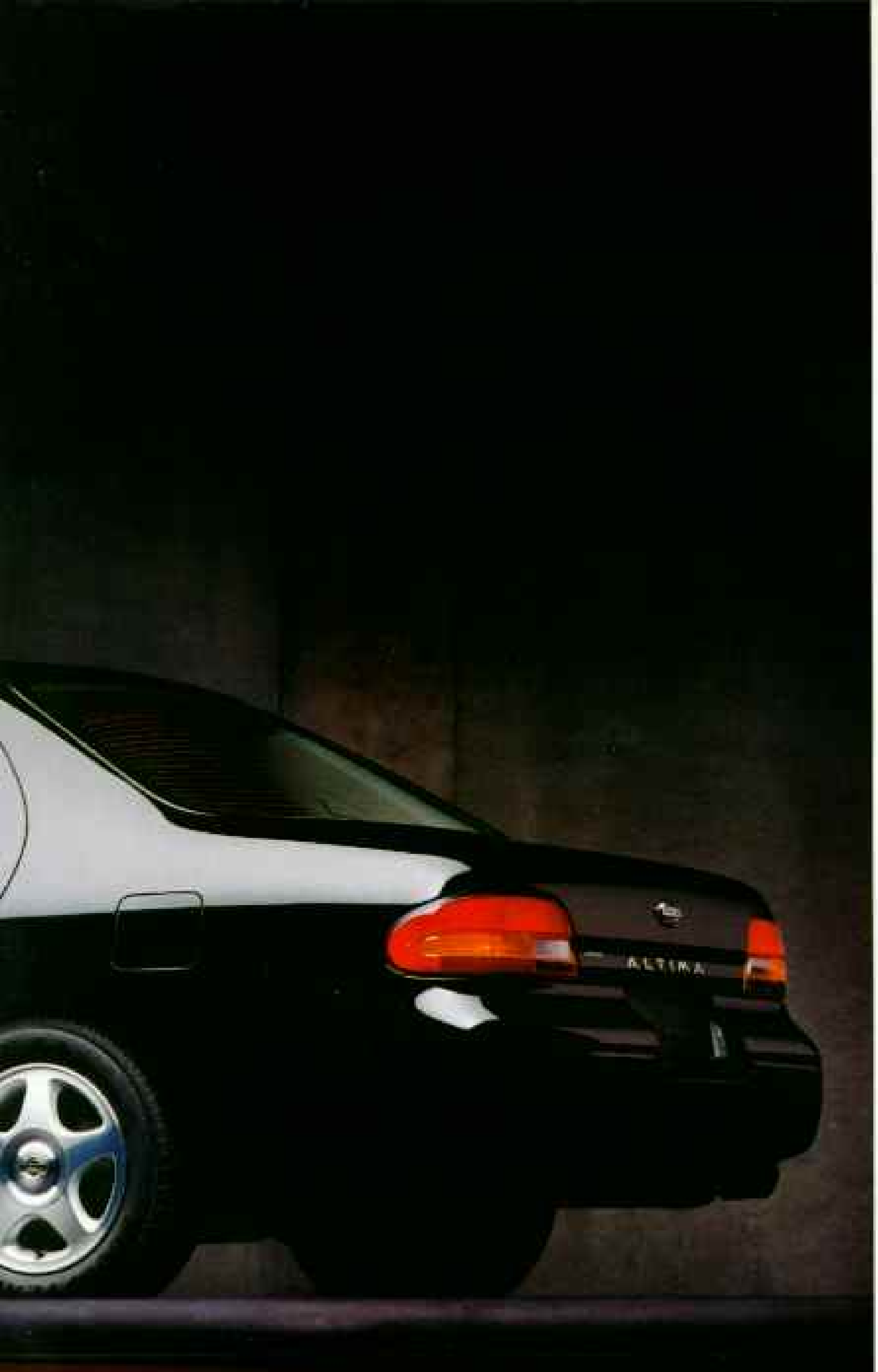

The first response we typically get is its smooth flowing lines look European. Some even say it seems almost Jaguar-like. But our engineers will tell you that under its solid steel body is where the real beauty resides. The *Nissan Altima*® has more freeway merging power than a Mercedes 190E 2.3, it can out-slalom a Lexus ES 300, and with optional ABS, it can out-brake a BMW 325i.* In other words, now you can own the road and you don't have to sell the farm, either.

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As you can see, the *Nissan Altima* isn't merely a car cloaked in a luxury sedan's clothing. The inside delivers all the comfort, sophistication and attention to detail that the outside suggests. Every button is perfectly in place. The gauges are large and easy to read. Everything is meticulously tailored around the driver.

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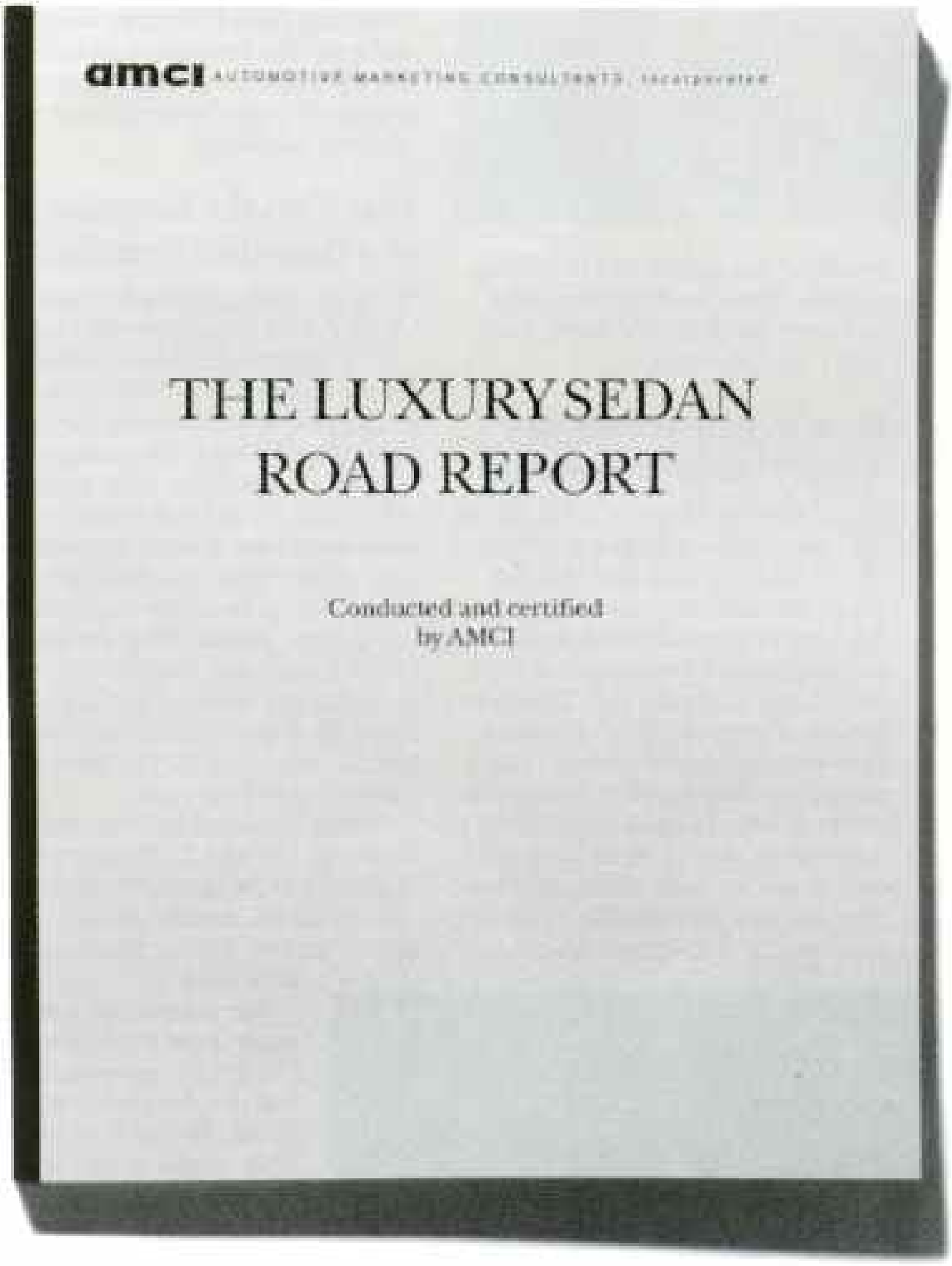
Finally, proof in advertising.



Car companies make lots of claims about their cars. "It's faster." "It's bigger." "It's sexier." At Nissan,® we don't just make claims about the *Nissan Altima*™ – we offer proof. The proof is free. Call 1-800-NISSAN-3, to receive The Luxury Sedan Road Report. It contains the surprising results of an independent study which shows the *Altima* going head-to-head in emergency and performance road tests against cars like the BMW 325i, the Acura Legend L Sedan, and the Mercedes-Benz 190E 2.3. Think of it as the study that demonstrates that luxury and affordability are not mutually exclusive.

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Geographica

ROBERT CAPUTO

Got a Plant Problem? Call a Master Gardener

Alice Nicolson approaches the shade garden she calls "my baby" and frowns. She falls to her knees, plunges her practiced hand beneath a plant, and rips out a guilty weed.

Nicolson knows a weed when she sees one: She's a certified master gardener in Arlington, Virginia.

A boon to gardeners (GEOGRAPHIC, May 1992) who have petunia problems or compost concerns, the master gardener concept originated in 1972 in the Seattle area. Master gardeners now volunteer in 46 states, the District of Columbia, and four Canadian provinces.

Organized by county Cooperative Extension Service agents and linked to state land-grant universities, master gardeners take heavyweight horticulture classes. In Nicolson's area students must attend 50 hours of classes that run the gamut from pruning to pesticide management. Graduates must perform at least 50 hours of volunteer work, from answering phone queries and appearing at plant clinics to mulching "beautification islands," local miniparks.

To Nicolson, who trained in 1980 and "got hooked," the appeal lies in helping people. "You can hold their hand and reassure them that their plant won't die," she says.

How to Fool a Piranha: Two "Heads" Are Better

In a fish-eat-fish world, two heads are definitely better than one.

Young piranhas within the genus *Serrasalmus* cruise the lowland river basins of South America, cadging meals by nipping at the tail fins of other unlucky fish. But three genera of large cichlids—relatively slow-moving, perchlike fish—often escape fin damage. Kirk Winemiller of Texas A&M University thinks it's no accident that all three have tails with dense, opaque scales, overlapping fins that give the fish a virtually symmetrical shape from the side,

D. W. GREENWOOD, ARDEA PHOTOGRAPHICS

and a bright colored spot that resembles an eye (below).

While other fish have eyespots, none has evolved such a distinctive, "headlike" tail, according to Winemiller, whose study in Venezuela is supported by the National Geographic Society.

To help verify his field observations, Winemiller put some young piranhas and several 12-inch cichlids called oscars into a tank with North American fish of the same shape and size. The piranhas attacked the fins of the northern fish; the South American varieties swam around virtually unscathed.

Was This the Beginning of a Beautiful Friendship?

Were dogs already "man's best friend" by 6500 B.C.? Did their human masters mourn the loss of useful helpers?

The people who lived in the Illinois River Valley 8,500 years ago certainly cared about their domesticated dogs. A team of scientists has uncovered almost complete skeletons of four dogs, carefully laid on their sides, in specially dug, individual shallow graves. They are the oldest known dog burials in North America and among the oldest domestic dog remains found anywhere, says Darcy F. Morey of the University of Tennessee.

"What was notable," says team co-leader Michael D. Wiant of the Illinois State Museum, "was that we also found the remains of humans, also in shallow graves, also lying on their sides."

The excavators don't know if the burial position had a ritual purpose or was just the easiest way of burial. Nor do they know if the dogs—about the size of a Brittany spaniel—were pets or if they helped hunt or transport gear and food. But, Wiant says, "there was some appreciation of these animals. Care was taken for how they were treated when they died."

—BORIS WEINTRAUB

National Geographic, November 1992

WILDLIFE AS CANON SEES IT

Radiated Tortoise
Genus: *Geochelone*
Species: *radiata*
Adult size: Shell length, 30–40 cm
Adult weight: 8–14 kg
Habitat: Spiny desert in southern Madagascar
Surviving number: Unknown
Photographed by John L. Behler

A radiated tortoise pauses in the early morning sun on a sand dune overlooking the Indian Ocean. After basking, it will forage on various plants before retiring into the shade of a low thornbush. Up to 95% of the plants in the tortoise's habitat are found nowhere else on earth. With its ecology remaining largely unknown, the future of this distinctive tortoise is closely tied to the preservation of its habitat. To save endangered species, it is essential to protect their habitats and understand the vital role of each species within the earth's ecosystems. Color images, with their unique ability to reach people, can help promote a greater awareness and understanding of the radiated tortoise and our entire wildlife heritage.

Forum

Albania

All dictators eventually fall, but often the repercussions of their excesses take years to heal. Such will be the case with Albania (July 1992), which I visited in May. Despite the hardships of daily life, I, a stranger with no Albanian roots, was treated as an honored guest—often the first Westerner with whom people had direct contact.

LEN MILICH
Tucson, Arizona

You state that Albania is the only nation located entirely in Europe where a majority of the people are Muslims. Most mapmakers, however, list the Caucasian republics in Europe. Azerbaijan is also predominantly Muslim, mainly Shiite, whereas the majority in Albania are Sunni Muslims.

KEN MITCHELL
Newburgh, New York

Geographers have long used the ridgeline of the Caucasus Mountains as the physical boundary between Europe and Asia. In light of recent political changes, there may be a rethinking about whether a country belongs in Europe or in Asia.

On your maps (page 75) the region between Greece and Yugoslavia is named Macedonia. However, that is the name of the northern province of Greece, birthplace of Alexander the Great. In 1945 Marshall Tito borrowed, or stole, a page of Greek history and named the southern part of Yugoslavia Macedonia. In 1946 with Stalin's backing he supported efforts by a faction in Greece to communize that country. Tito called this a war to unite Yugoslav and Greek provinces into a Macedonian nation. The attempt was stopped by the Greek people, aided by the Truman Doctrine.

Today the southern province of former Yugoslavia has formed a state with Skopje as its capital; it seeks recognition as the Republic of Macedonia, a name Greece opposes. The European Community refuses to recognize the state until it changes its name, and the U. S. accepts this position.

DIMITRIS P. KOUTSOUKOS
Austin, Texas

After the bloody Balkan Wars of 1912-13, the large geographic region of Macedonia was partitioned among Greece, Serbia (later part of Yugoslavia), and Bulgaria. Slavic Macedonians are the majority in the country whose name is in dispute. If the name is changed, our maps will change too.

Mountain Lions

The "ghost cat" may not be a specter in the eastern United States after all. There is a documented case of mountain lions in Pennsylvania in this century. My uncle, John Gallant, shot and killed a young female lion in Crawford County on October 28, 1967. The following day I shot at another cougar in the back of my garden, but it escaped. As the years have passed, I have learned to respect these great beasts. We need them back. We are being overrun by deer and rabbits. A reintroduction program would be interesting.

ROY JOSEPH GALLANT
State College, Pennsylvania

Here in Ontario there have been a number of cougar sightings, many recorded by the Ministry of Natural Resources, which seeks to determine if a remnant eastern population still exists. *Canadian Geographic* of August/September 1989 referred to 318 sightings in Ontario between 1935 and 1983. One specimen was killed in Manitoba in 1973.

CLIFFORD G. NIETVELT
Mississauga, Ontario

In the 1980s both the U. S. Fish and Wildlife Service and the World Wildlife Fund in Canada conducted systematic searches for eastern cougars without success. Sightings are on the rise—as our mail indicates—but are attributed to misidentification or to escaped or released pet cougars. The few specimens recorded in Manitoba may be western cougars.

Dr. Hornocker and company deserve much support for the fine research on mountain lions. But I believe an ethical boundary is violated in suggesting that extreme aggression can be bred out of populations in captivity and the less aggressive progeny returned to the wild. What right does science have to tame the wild? Isn't this genetic lobotomizing of wild animals?

LONNER F. HOLDEN
San Francisco, California

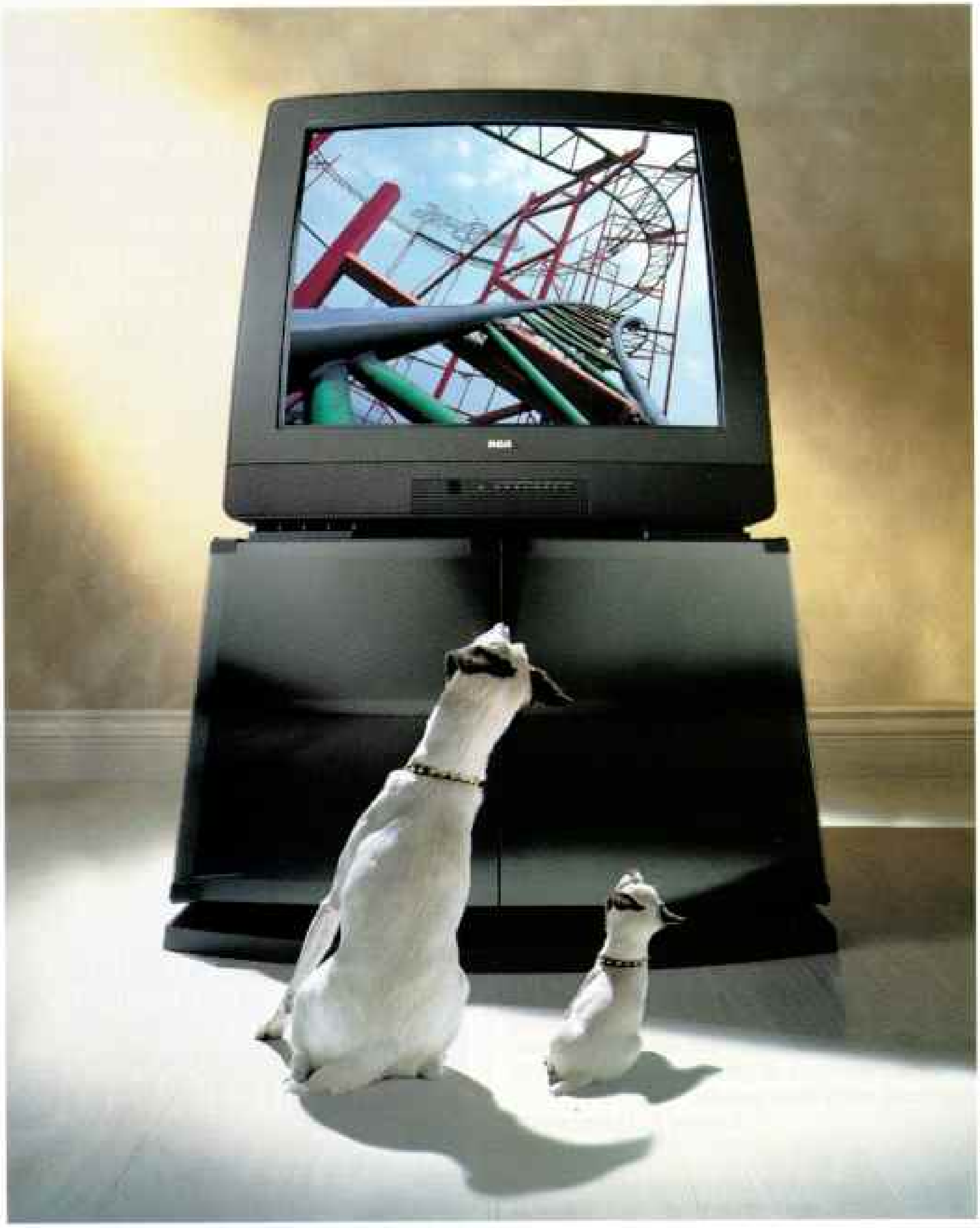
Recently a rancher near Corona, New Mexico, lost 28 sheep to one mountain lion. An officer from the animal damage control department trapped the offending lion and found a tattoo in one ear, a tag in the other, and a number on the lion's collar identifying it as part of Dr. Hornocker's experiment. If the lion had been left undisturbed in the San Andres Mountains, its taste for domestic sheep would have had little chance to develop.

ALMA HOBBS
Tatum, New Mexico

The lion was not part of the relocation experiment but wandered about a hundred miles from the San Andres Mountains research area. Of 150 lions studied there, only this one has preyed on livestock.

The "extraordinary predatory skills" of a mountain lion do not always result in fine dining. At Rocky Mountain National Park a few years ago, a

The RCA 35" Home Theatre. So real, it's scary.



Looking at a roller coaster on the RCA Home Theatre is like riding it without getting strained vocal cords, your hair messed up, or a strange feeling in the pit of your stomach. The picture's so lifelike (up to 55 watts of picture power) and the sound's so intense you'll feel like part of the show. Experience the Home Theatre™ at an RCA dealer. We promise, there's nothing to be afraid of. **Changing Entertainment. Again.™** RCA

ranger found a dead elk in a closed campground, and beneath it a female cougar. The scene told the story. The cougar attacked the elk, breaking its neck. But the pair tumbled down a slope, and the body of the elk crashed down on the predator, pinning her to the ground, where she eventually died. The cat, stuffed and mounted, is now displayed in the park museum.

GLEN KAYE
Santa Fe, New Mexico

The statement that the Proposition 117 ban on hunting California lions was a victory for the lions might prove wrong. This is, perhaps, a terrible precedent. Think about it: the science of wildlife management determined by the voting box.

KENT ARNAUD
Monett, Missouri

Life on a Wharf Piling

The Chesapeake Bay is Maryland's greatest natural resource; 95 percent of the land in the state drains into the bay, and every Maryland citizen affects the bay. George Grall's article and beautiful photographs bring bay wildlife closer to the people who can save it.

WILLIAM DONALD SCHAEFER, GOVERNOR
Annapolis, Maryland

As a student of marine biology, I found it interesting to compare marine wildlife on the East Coast with the West Coast fauna that are familiar to me. Although the same kinds of animals exist on both coasts, there are many subtle differences arising from the distinct environments. I invite George Grall to repeat his bay work in a West Coast tide pool.

ALANA V. MURRAY
Victoria, British Columbia

See Robert F. Sisson's article on California's tide pools in the February 1986 issue.

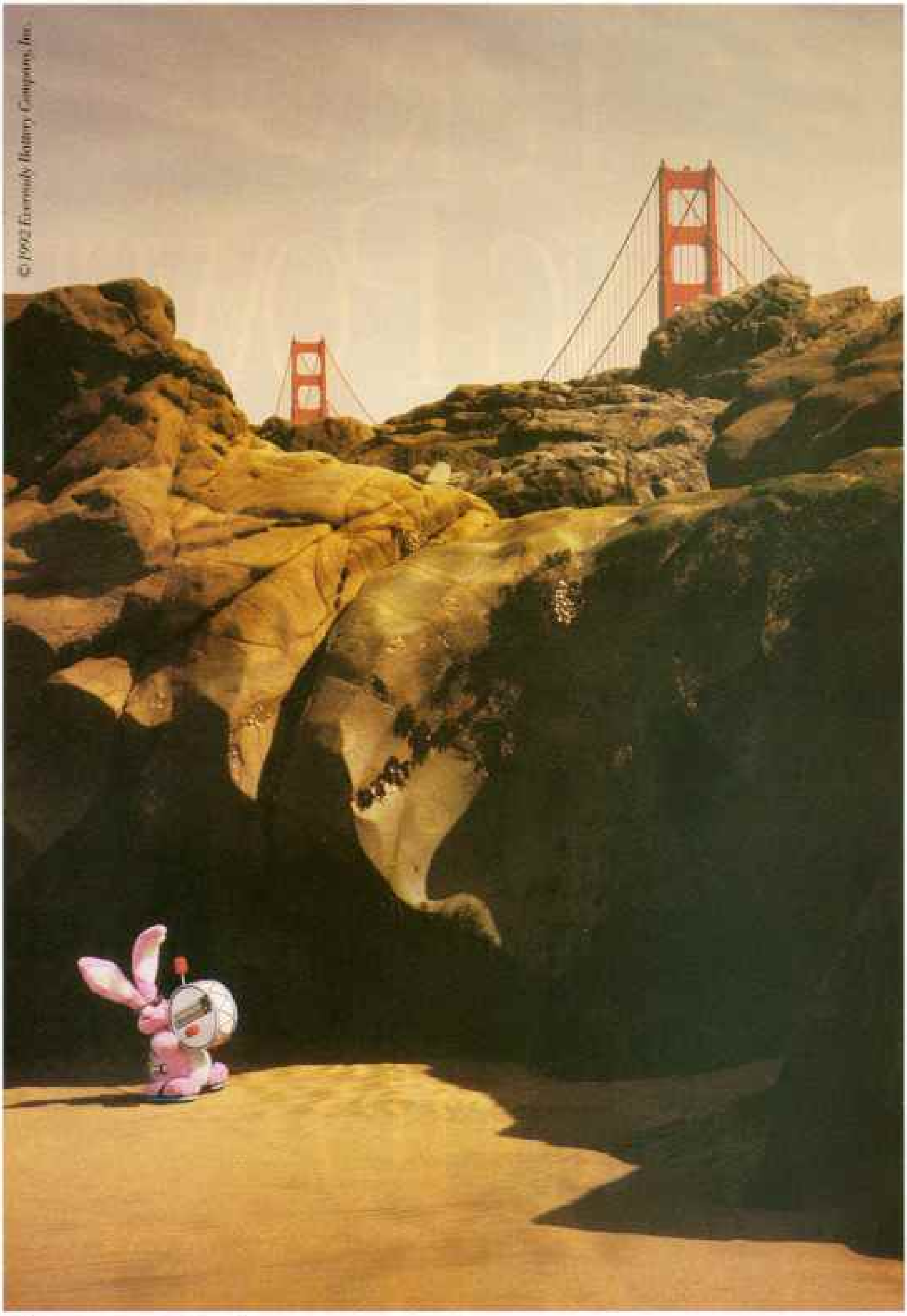
America's Gulf Coast

Douglas Lee's "Third Coast" reminded me of just how much has changed since I grew up in Venice, Florida, in the 1950s. Venice was a sleepy fishing town of 2,000 or so locals when my family arrived. Now the population of Sarasota County grows by that much every three months.

PATRICK R. HOUSEWORTH
Celina, Ohio

The statement by G. P. Cokinos on page 21 about the Texas oil boom—"This is where it began"—reminded me of how I tried to counter a misconception held by many Texans when I was working in a refinery at Baytown in the 1970s. The oil age began when the nation's first well was drilled on August 27, 1859, in Titusville, Pennsylvania. The oil rush in Texas was of tremendous historical significance, but it did not start until the industry was more than 40 years old in Pennsylvania. In fact,

TURN BUYING POWER INTO HORSEPOWER.℠



SAN FRANCISCO, CALIFORNIA. 11:28 A.M. STILL GOING.
NOTHING OUTLASTS THE ENERGIZER BATTERY.

many early Texas oilmen invested their exploration grubstakes in Pennsylvania oil fields before heading south to make their fortunes.

JERRY LYNCH
Oil City, Pennsylvania

In a recent national survey conducted by a University of Maryland geographer, three of the United States' 20 best beaches were between Perdido Key and Seagrove Beach. Grayton Beach, Florida, ranked second, after Hawaii's Kapalua.

C. KEITH COMER, JR.
Santa Rosa Beach, Florida

The map ignores Cape Coral, which has nearly 80,000 people, more than either Fort Myers or North Fort Myers, which you show. Among cities in the state, we rival Tampa in land area; only Jacksonville is larger.

M. RASICOT
Cape Coral, Florida

Trobriand Islands

In 1943 I spent several days in the Trobriand Islands and wish to convey my appreciation for your authentic account of a paradise in the South Pacific. In my free time I visited with the chief, who was very polite and informative about the Trobrianders' customs and their sharing of goods. It was refreshing to read that very little has changed.

DARRELL G. GEROT
Dover, Arizona

The islanders are described as having an idyllic lifestyle with references to laughing children, male teenagers enjoying privacy with girlfriends, and adult male fishermen who think their life cannot be improved upon. I am left wondering about the women. No mention was made about what they think of life in the Trobriand Islands.

KATHLEEN CANNON
Dayton, Ohio

Paul Theroux states that "For a reason that no one can explain, the birthrate is lower than might be expected." Then he writes about the yam, one of the staple foods. The yam, or *Dioscorea*, was long known by certain Mexican Indians to have a contraceptive effect. In 1939 Dr. Russell Marker, an American chemist, determined the molecular structure of diosgenin, a steroid substance with progesteronic effect derived from the yam root. Based on this information, Organon, a leading producer of contraceptive pills, uses the diosgenin from Mexican yam roots as the raw material for some of its products.

MELY LECHTICH DE RÉVAI, M.D.
Caracas, Venezuela

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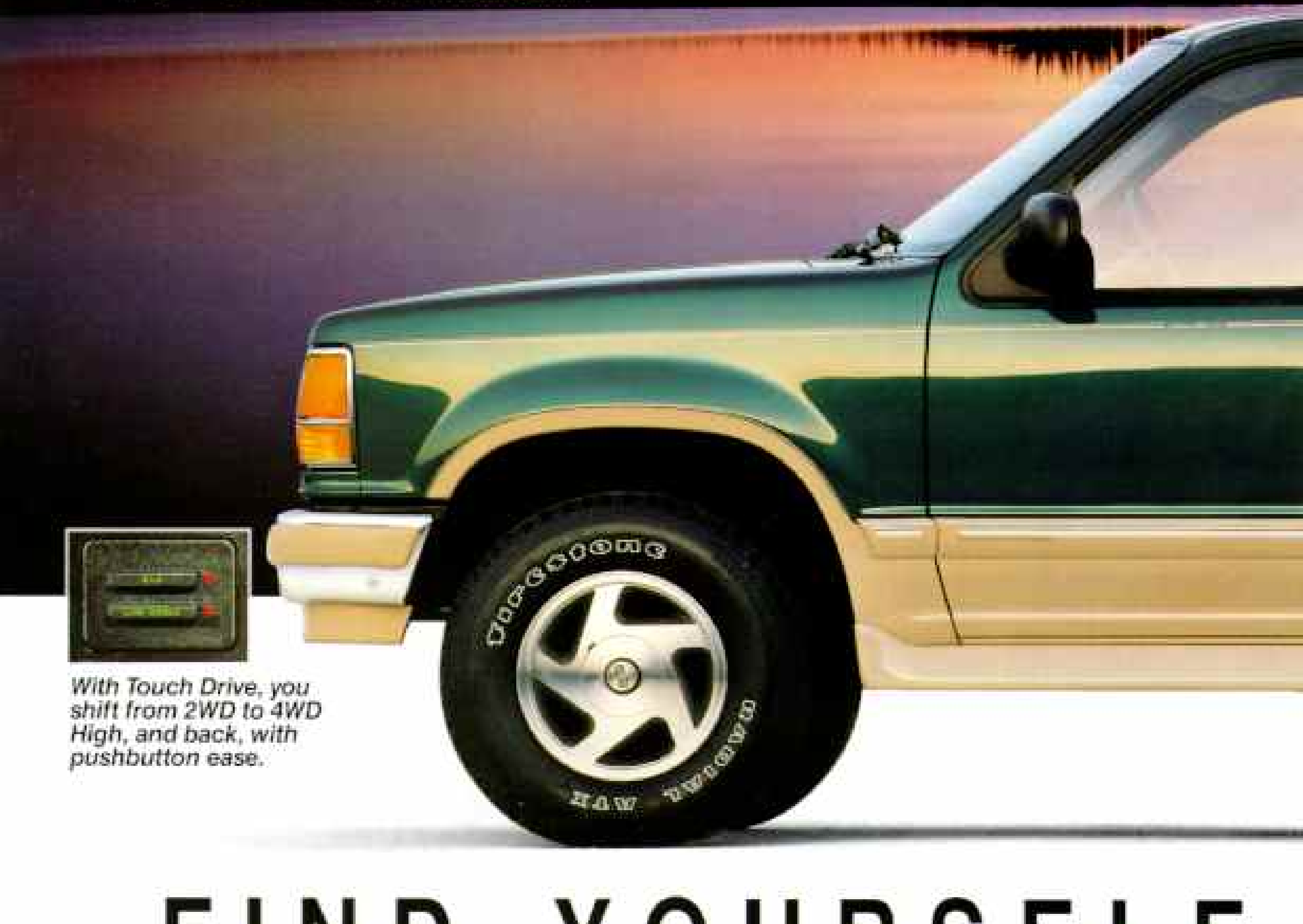

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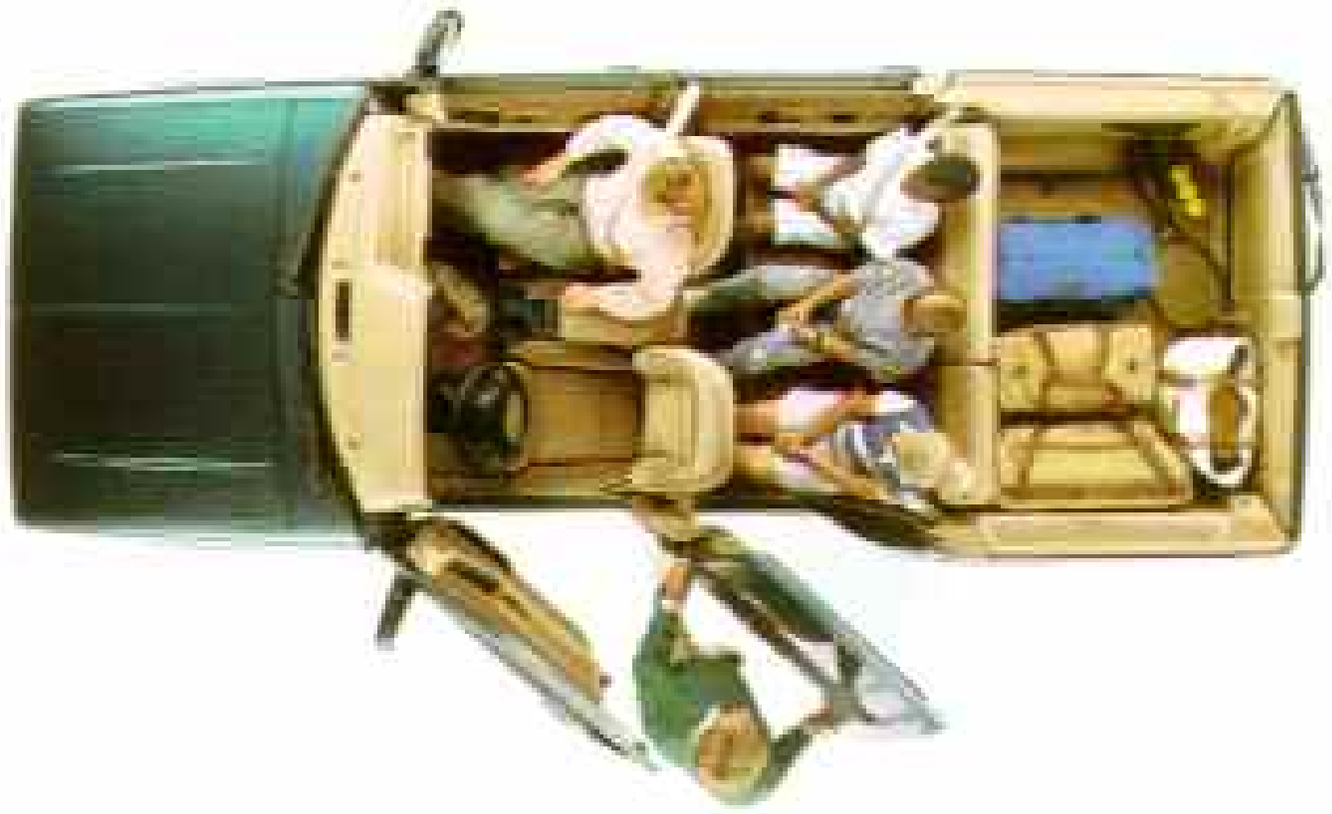

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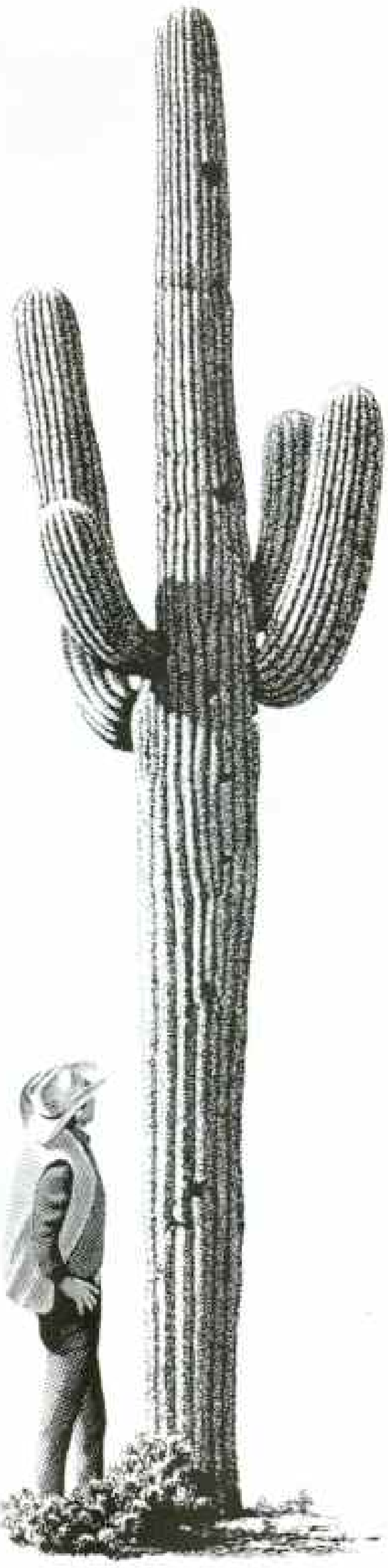

The Slow-growing Saguaro

King of Cactuses

A full-grown saguaro can reach 50 feet in height, weigh nine tons, and live 200 years. The sturdy cactus thrives only in parts of Arizona, California, and northern Mexico. Birds excavating nest holes convert saguaros into high-rise housing.

From the single stem of *Carnegiea gigantea* shallow roots may radiate 50 feet or more in all directions, collecting every drop of scarce moisture. The saguaro's tough, waxy skin guards against evaporation, helping it survive months-long dry spells. When the rains come, the furrows between the accordion ribs of the water-starved cactus fill out.

Saguaros grow slowly: a ten-year-old may be just one inch tall; a 30-year-old may measure four feet. White, waxy blossoms appear once a year after the half-century mark, and the distinctive "stick 'em up" arms develop only after the plant turns 75.

Such old-timers are rare. As the Sunbelt's human population expands, all cactuses feel the pressure. Vandals with guns and pocketknives cause damage that can kill. Some cactuses have fallen to developers' bulldozers; others have been stolen for sale to collectors and landscapers. Miles of desert around Arizona cities have been denuded by diggers. The rare crested saguaro, a mutation valued by collectors (below), is believed to number fewer than 200.

Cactus poachers work quickly, under the cover of darkness. An 80-year-old specimen nearly 20 feet tall can be uprooted, winched onto a specially equipped truck, and hauled away in just 15 minutes. It's worth more than a thousand dollars on the black market. Cactus poaching in and around Saguaro National Monument became so pervasive that in 1981 Arizona appealed to the U. S. government for assistance in enforcing the state's protected species law.

Intense undercover work paid off in January 1990, when the U. S. Fish and Wildlife Service's Branch of Special Operations rounded up 21 cactus poachers. A record 19 were convicted of theft, conspiracy, and trafficking in protected plants; most received heavy fines and jail sentences—almost unheard of for plant theft. Federal protection and local conservation continue the fight to keep the saguaro in the wild. □

WILLIAM H. BOND, NGS

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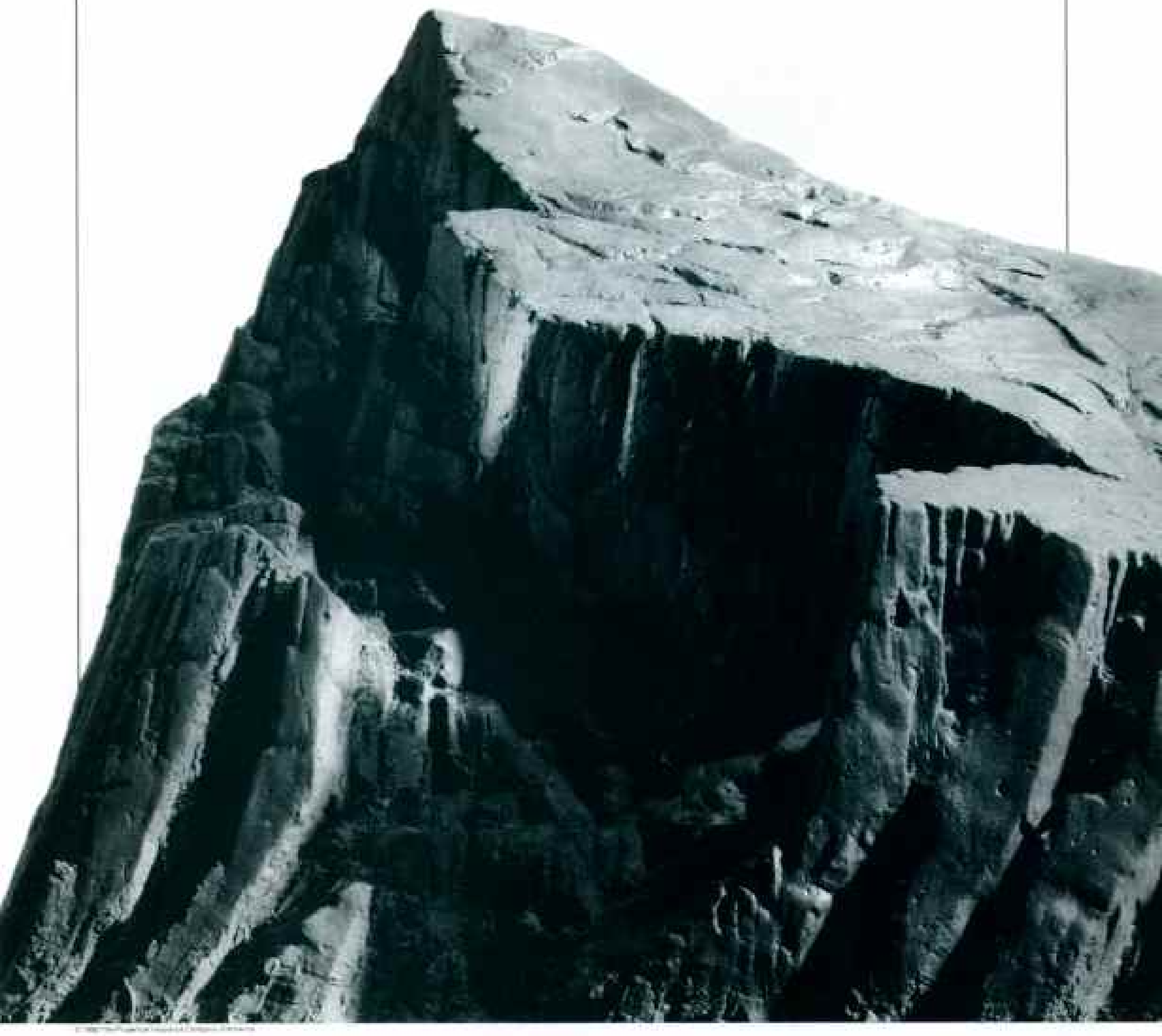

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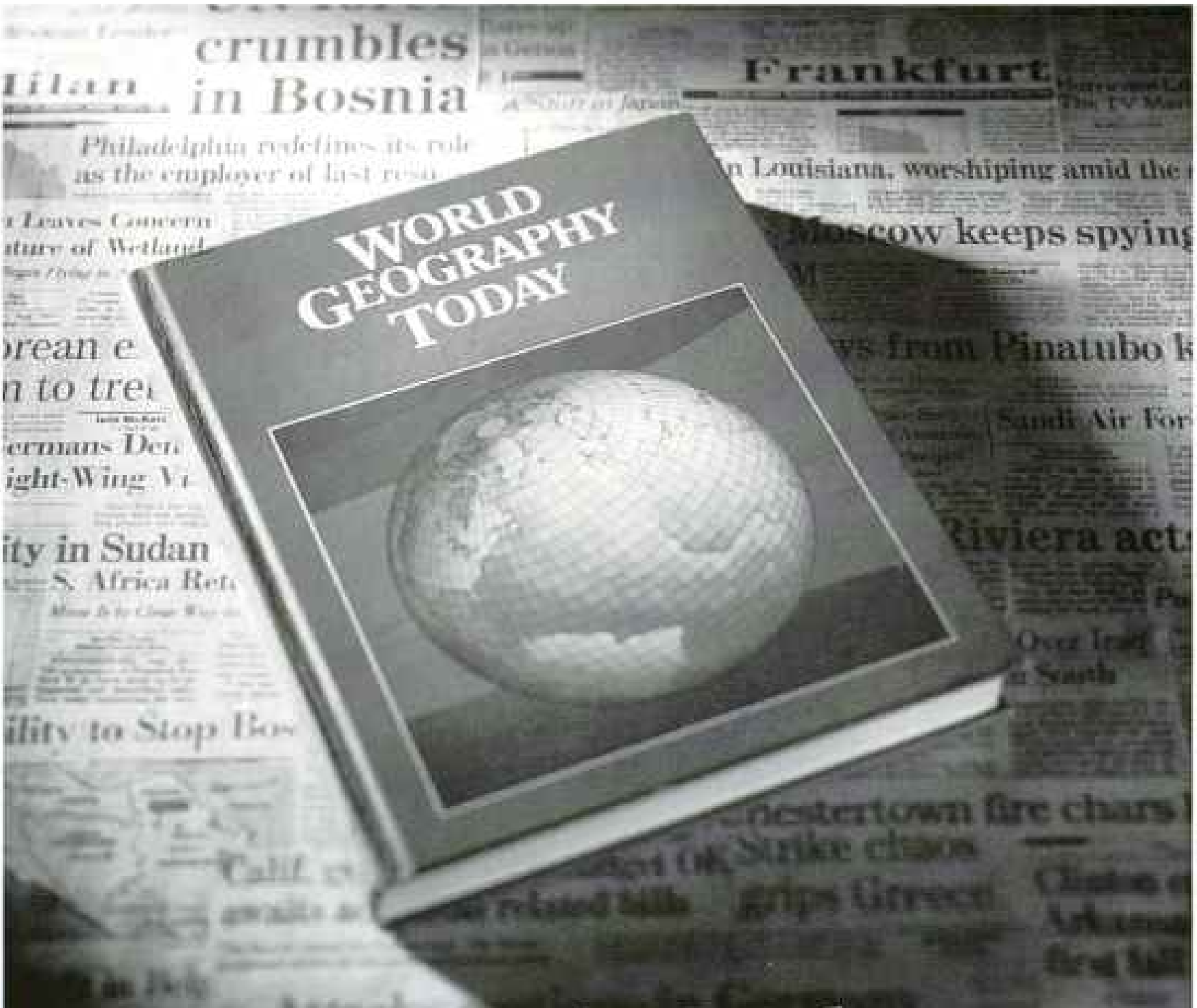
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Fergie on a rock

by

Ann Crump, painter

The Nikon N6006 is a serious SLR that almost anyone, anywhere can pick up anytime and have fun with.

Case in point, one Ann Crump, watercolorist and oil painter from Belvedere, California.

In other words, she's not a professional photographer.

Yet, using the N6006 and a 28mm Autofocus Nikkor lens, she and her three-year-old pug Fergie have created nothing short of a masterpiece.

Or at least one killer dog picture.

The N6006 is why. It focuses automatically in light as dim as a single candle, or you can focus manually.

It selects the proper exposure automatically, or lets you do it.

You can select from a Spot Meter, a Center-Weighted Meter, or the Nikon Matrix Meter, which reacts instantly when the action is moving fast or the light changes unexpectedly.

Here, the built-in flash automatically brightened the foreground while letting the sun shine through in the background.

Maybe you thought a picture like that was too difficult.

Well, Ann Crump did it with just one hand, while holding a dog biscuit over her head.

Quite a picture in itself.

The Nikon N6006 is controlled by a convenient dial and a simple multi-button keypad. An LCD readout clearly shows you what you're doing. Press any two buttons on the keypad and the camera reverts to totally automatic.

It forgives you, instantly.

With Focus Tracking, the N6006 can even keep moving subjects, such as cars or bikes, in focus.

Its motor advances the film fast and rewinds automatically.

You can choose from twenty interchangeable autofocus Nikkor lenses. Nearly seven out of ten pros who use 35mm use Nikkor lenses.

In other words, the N6006 is not a toy.

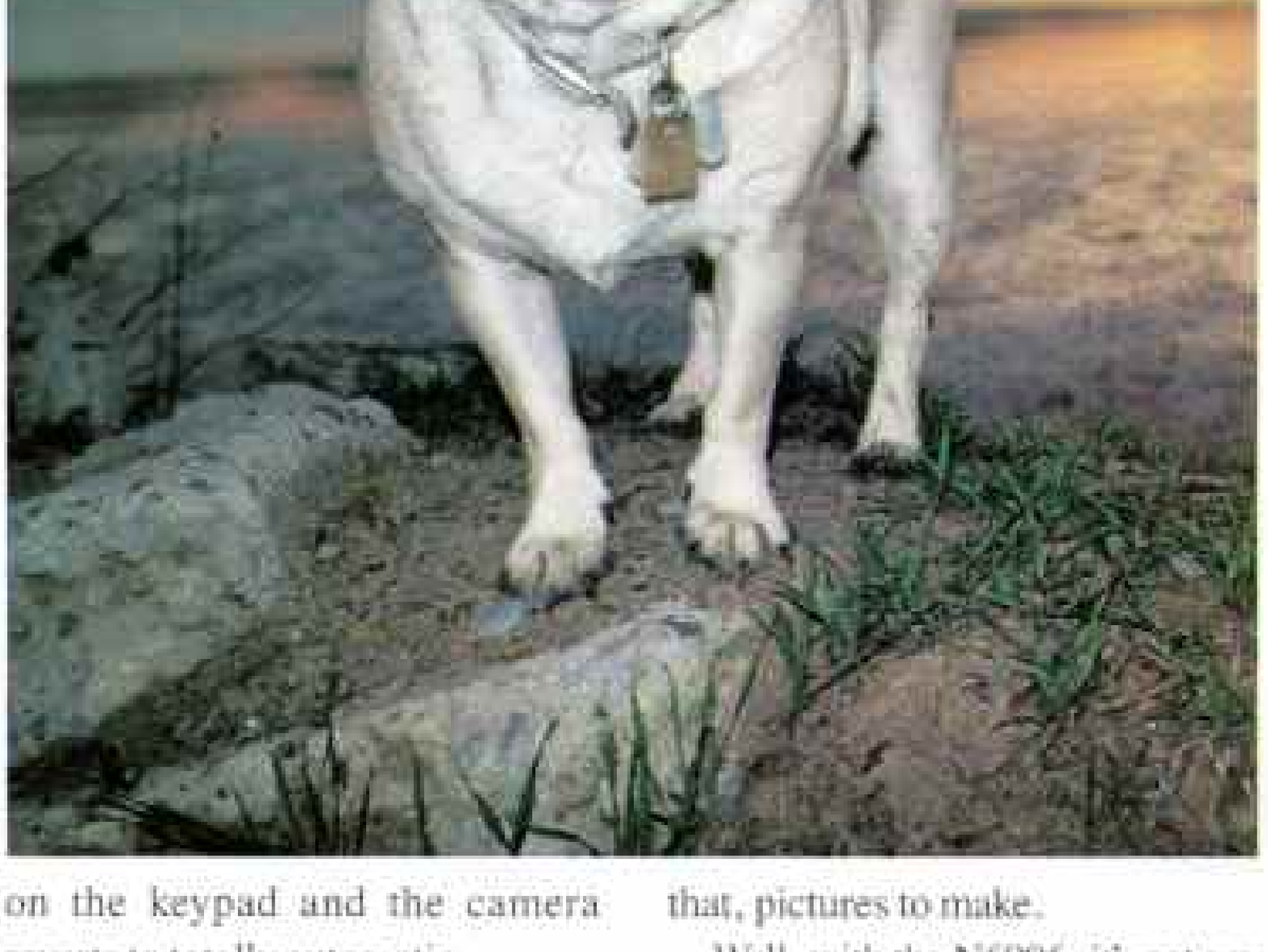
It's the camera designed for people with dogs to walk, kids to chase and a job to go to.

And somewhere in between all that, pictures to make.

Well, with the N6006, it's not any harder to use a Nikon. It's not any harder to take the kind of pictures you've always dreamed of instead of just plain old pictures.

After all, the shot above was made by an ordinary person using an extraordinary camera.

Could it *possibly* be more beautiful?



See the N6006 at authorized Nikon Dealers. Just look for this symbol. For more about the N6006 and the benefits of the exclusive Nikon MasterCard, call 1-800-NIKON-35.

Fergie, ordinary dog. Ann Crump, regular person. They took a walk with the N6006 and some leaf chasers. Art happened.

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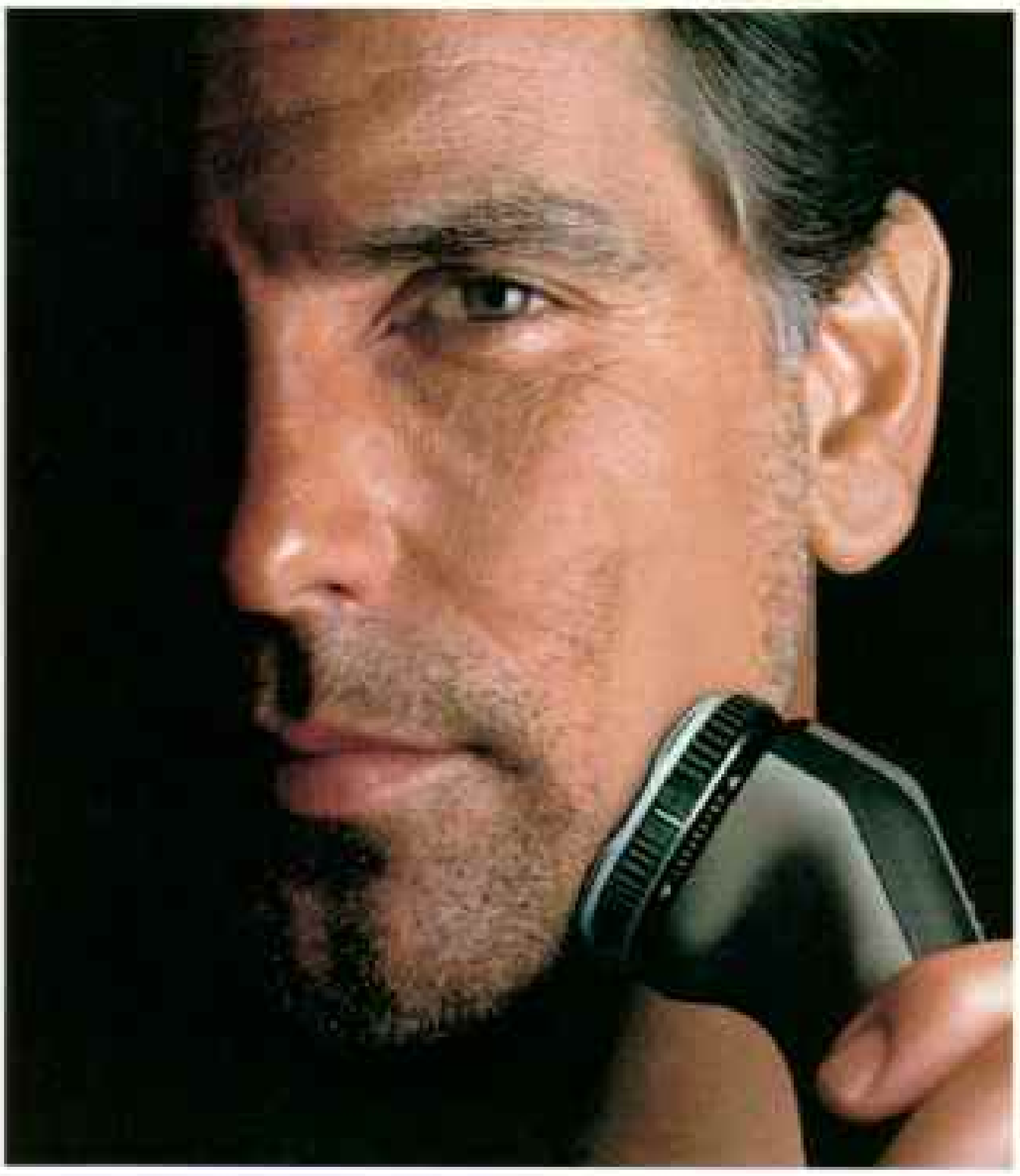

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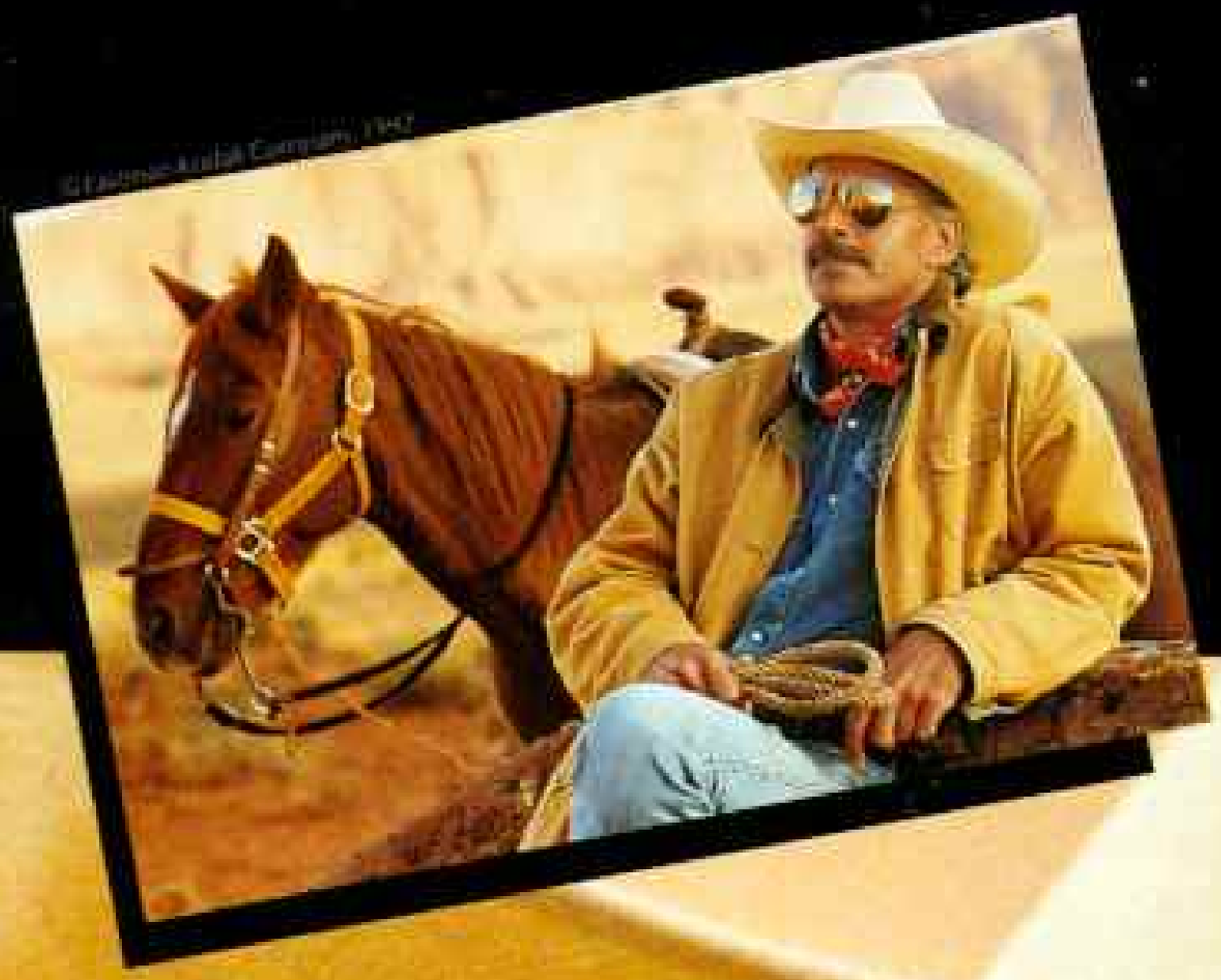

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Well, at Nissan, we believe that parents have enough sacrifices to make. The pleasure of driving shouldn't be one of them. Which is why we designed the new *Nissan Quest*® to be as much fun to drive as the sedan you now own.

Slip behind the wheel and you immediately notice an absence of the swaying motion minivans are known for. A front stabilizer bar keeps it level during cornering or lane changes. And an independent front suspension allows each front wheel to react independently to the road surface for exceptional traction control.

If you think the *Nissan Quest* has an appetite for curves, however, you'll find it's positively famished when it comes to hills. A 3.0 liter V6 van has more standard horsepower.* Period. And it's the only import brand minivan to combine both V6 power and front-wheel drive.*

But perhaps the most important area where the *Nissan Quest* performs like a sedan is in safety. This uncanny feeling that you're driving a sedan is further enhanced by a sophisticated front-wheel drive that is able to deliver a tighter and quicker overhead cam engine delivers an impressive 151 hp.

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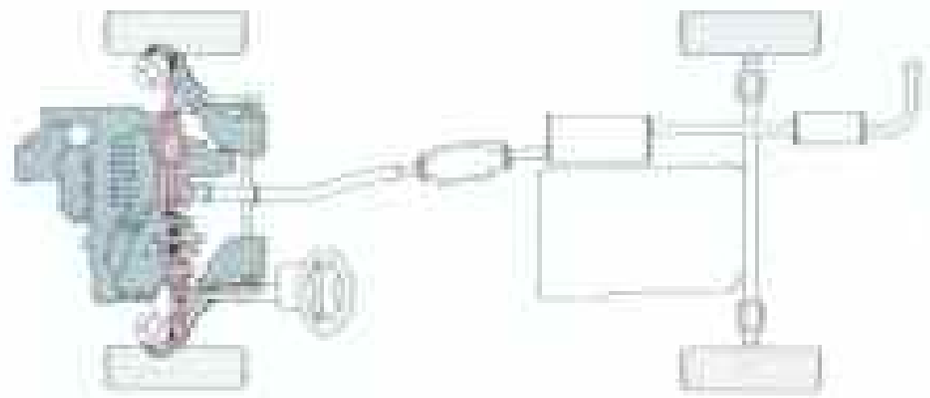

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Cruise control†

and an optional sunroof*** have been made available so you can concentrate on the scenery instead of the speedometer.

Attention to ergonomics is so complete that the controls to the power windows, door locks and mirrors have been thoughtfully nestled close at hand in the driver's-side door.†

Of course, we intend to spoil your children as well.

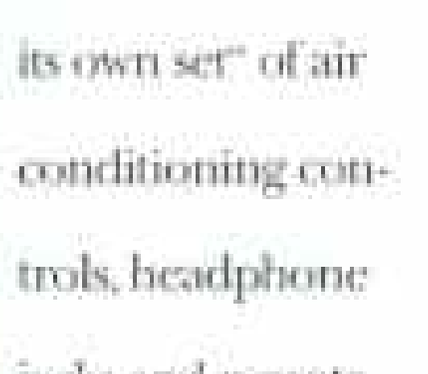
A second row of luxurious captain's chairs†† has been provided to keep your children from squirming about.

To keep them entertained, the second row even has its own set† of air conditioning controls, headphone jacks and remote audio controls.

And since we know how much kids enjoy playing musical chairs, you should know that our QUEST TRAC† Flexible Seating System can be reconfigured up to as many as twenty-four different ways.†††

The new *Nissan Quest* offers better handling and more luxurious comfort than you'd ever expect from a minivan. In fact, it'll make you feel like you're driving a car.

That is, of course, until one of the kids in the back seat throws another temper tantrum.



The New Nissan Quest.

It's time to expect more from a minivan.

*Info. *1992 model comparison. **Except models with privacy glass. ***GXE model. †Optional on XE model, standard on GXE. ††Optional on GXE model. †††GXE with optional 2nd row captains chairs.*

On Television

Going Underground: The Lure of Caving

"Someday I hope to discover a huge cave no one else has been in before," says Leah Brown (below) of Huntsville, Alabama—at nine years old a caver and champion rope climber. With broad areas of the United States underlain by "cave rocks"—limestone, dolomite, marble, and gypsum—but only a fraction of existing caves explored, she stands a good chance of realizing her dream. Hers and other dreams take form in "Mysteries

ADAM STEPAN

Underground," the first film of the 1992-93 season of National Geographic Television Specials, funded by Chevron.

Even in *their* wildest dreams Dave Allured, Rick Bridges, and Neil Backstrom could not have imagined the magnitude of their discovery on May 25, 1986, in Carlsbad Caverns National Park, New Mexico. Digging in a 90-foot-deep pit, they uncovered an extraordinary cave system. More than 1,600 feet down, Lechuguilla is the deepest cave in the U. S. and, with 60 miles mapped so far, the fourth longest (NATIONAL GEOGRAPHIC, March 1991).

Now for the first time and, to protect the cave's fragile environment, maybe the last, the National Park Service has allowed a film crew to document the find.

"Mysteries Underground" gives its audience an unparalleled view of this splendid cavern—immense rooms lavishly decorated with glittering white gypsum chandeliers 20 feet long; delicately carved calcite columns that rise more than 50 feet from floor to ceiling (above); halls festooned with "bushes" of aragonite; shimmering sapphire pools.

From ice caves to underwater caves, from frantic rescues of human visitors to glimpses of the behavior of full-time inhabitants, "Mysteries Underground" is illuminated, says producer Lionel Friedberg, "by the spirit of the caving community and the infinite variety of what's down below."

"Mysteries Underground" Special on PBS, November 18, 8 p.m. ET.

MICHAEL NICHOLS, MAGNUM

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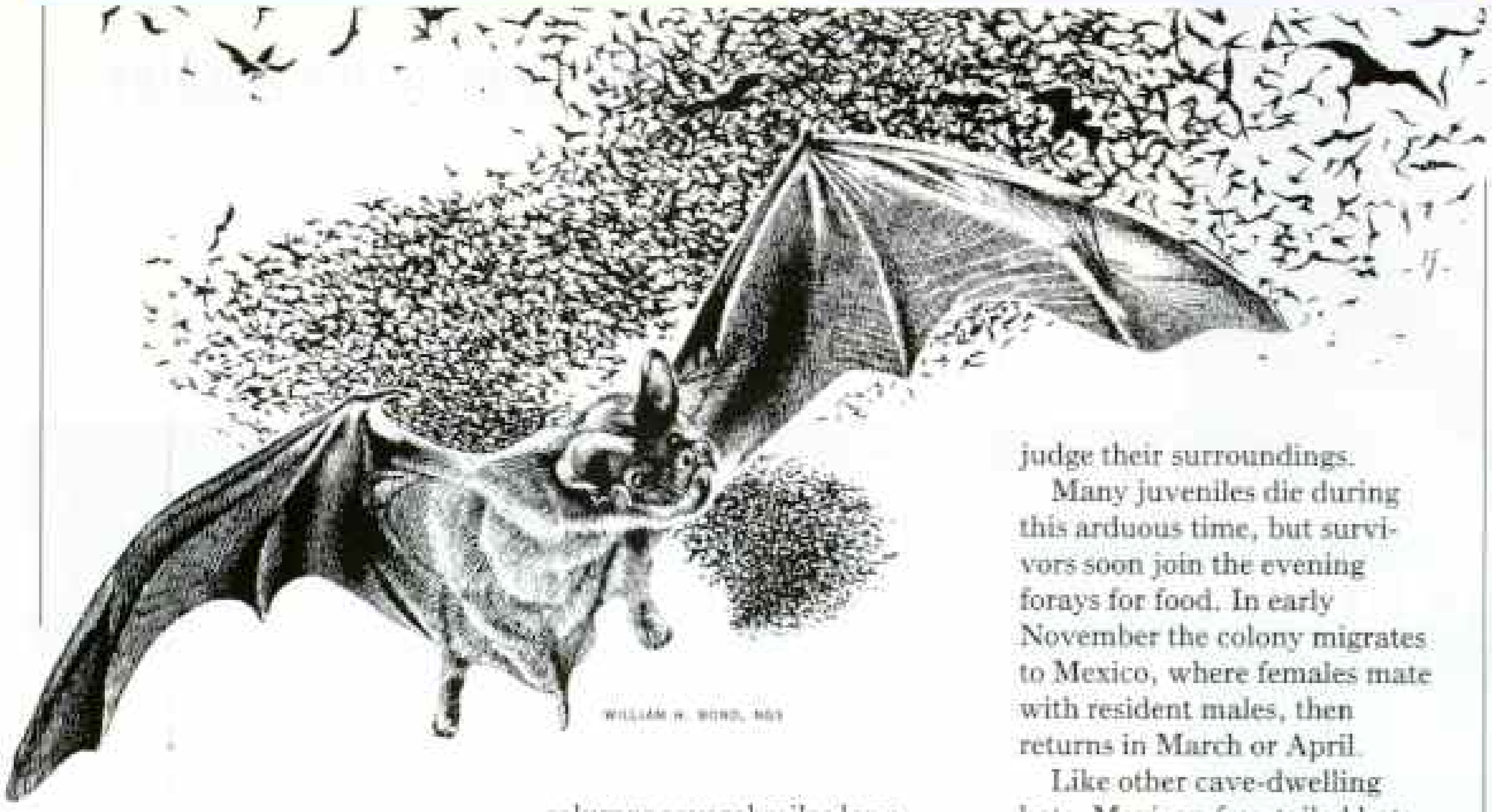

WILLIAM H. BOND, NGS

The Incredible Mexican Free-tailed Bat

Something besides jumbo jets and Piper Cubs shows up on airport radar in San Antonio, Texas, each summer: Mexican free-tailed bats. Just one of the half-ounce creatures with its wingspan of 12 inches would not be detected. But when 20 million depart nearby Bracken Cave at dusk, they appear on radar and in the sky as living columns several miles long.

Bracken Cave hosts the largest known colony of *Tadarida brasiliensis*. Most are female. While the range of the Mexican free-tailed bat extends from the United States to South America and the Caribbean, mothers and young are mostly found in a dozen huge nursery colonies in the southwestern United States.

The night-feeding bats fly to heights of 10,000 feet or more and cover thousands of square miles. In just one night the Bracken Cave colony consumes up to 250 tons of insects, including crop pests and mosquitoes. Back in the cave they roost, 200 adults to each square foot of space, creating the ideal temperature for rearing young. The female has an amazing ability to identify her offspring's cry and scent amid thousands, according to Gary McCracken of the University of Tennessee.

At five weeks the pups begin practice flights in the dark cave, a precarious training base. Vision is no help here; the bats use echolocation—a sort of sonar system—to judge their surroundings.

Many juveniles die during this arduous time, but survivors soon join the evening forays for food. In early November the colony migrates to Mexico, where females mate with resident males, then returns in March or April.

Like other cave-dwelling bats, Mexican free-tailed bats are extremely vulnerable to human destruction. Entire colonies have been wiped out in moments by people dynamiting or setting fire to the caves. In 1963 an estimated 30 million bats lived in Arizona's Eagle Creek Cave. By 1970 some 30,000 remained; gunshell casings were found outside. DDT and other pesticides also take a toll.

Many bat caves, including Eagle Creek, desperately need help to ensure a comeback for the animals. To this end in 1982 Merlin Tuttle of Austin, Texas, who wrote about bats in the June 1991 GEOGRAPHIC, founded Bat Conservation International to promote conservation of Chiroptera, the largest order of mammals after Rodentia. The group has gained protection for a number of important bat sites, including Bracken Cave. Protected bat colonies are reestablishing themselves and populations are rising. But for the Mexican free-tailed bat, says Dr. Tuttle, human fear and misunderstanding remain the number one threat to survival. □

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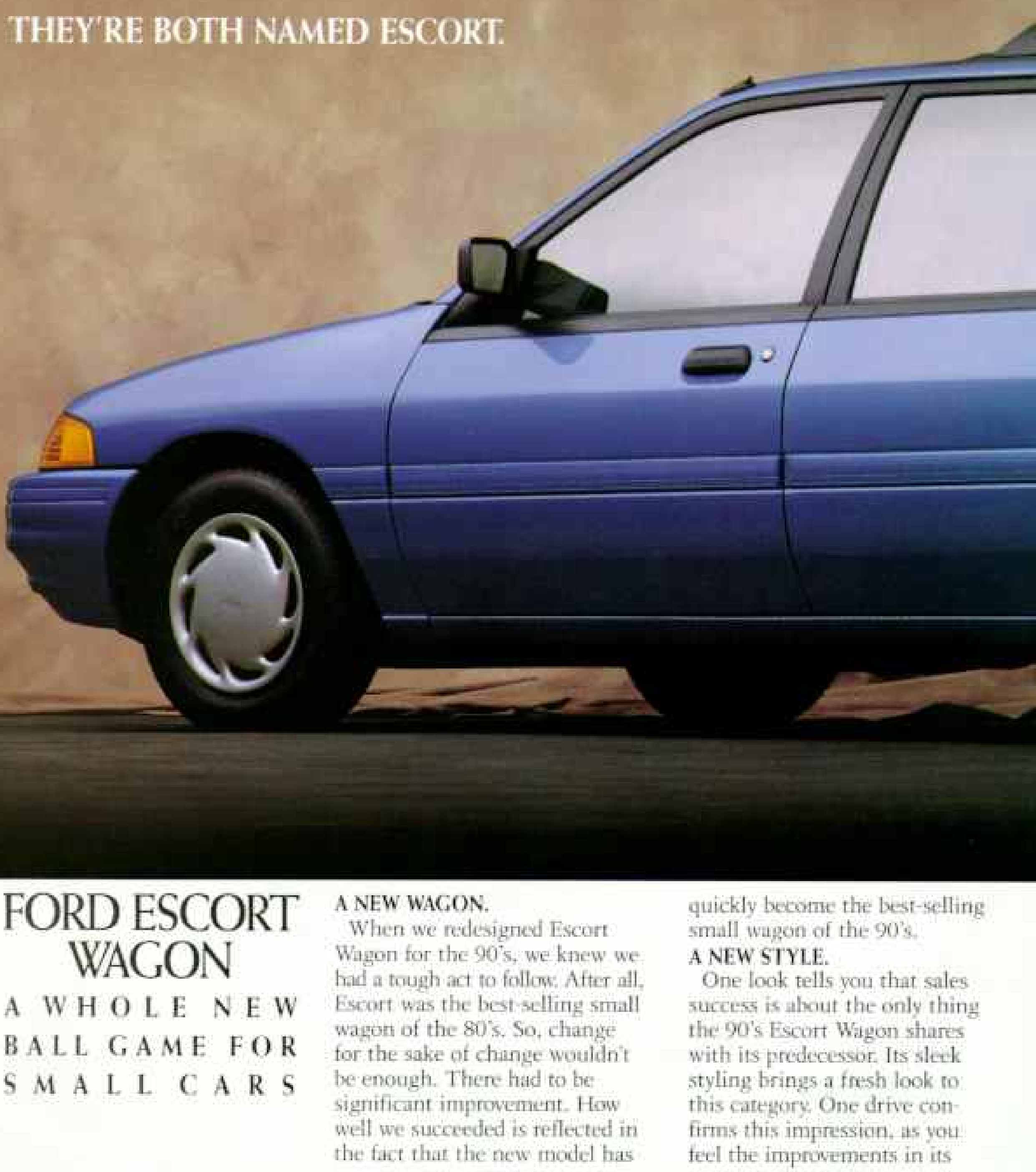

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[illegible]

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GARY MEDVEDOW

Saving Peat Bogs—and Their Strange Denizens

With a face that nature forgot to finish, a star-nosed mole pokes its snout out of a peat bog in northeastern Ohio. Although the mole's sense of smell is poor, 22 sensitive pink tentacles surrounding its nose detect meals of insects and worms by touch.

These hardy moles are among the few animals that have adapted to acidic peat bogs—quaking wetlands of waterlogged, oxygen-poor soil. There plants decay into peat, long burned for energy in Europe (NATIONAL GEOGRAPHIC, March 1987). Studies of these important ecosystems are increasing, along with sentiment to preserve them.

Harvesting peat and draining bogs for agriculture have carved up the world's two million square miles of peat bogs, including some 90 million acres left in the U. S. In 1975 a Minnesota utility's failed attempt to dig peat and synthesize natural gas from it spurred interest in bog protection. Last year Minnesota added 146,000 acres to the state's system of scientific and natural areas, safeguarding the bogs from loggers, road builders, and miners, who search for copper and nickel as well as peat.

"In most of the areas, access will be strictly limited to the scientific community," says Paul Glaser, a University of Minnesota botanist. "Wheeled vehicles compact the peat, change the hydrology, and cause subsidence."

Putting Back the Kinks to Restore the Kissimmee

The moribund Kissimmee River in Florida may soon be granted a new lease on life. This fall Congress is weighing approval of a 280-million-dollar project that would restore much of the river to its old self. On one section south of Orlando, the state of Florida already has re-created a bit of the stream's original ways (below). But the rest of the Kissimmee remains shackled by U. S. Army Corps of Engineers dams and dredging that turned 103 miles of lively river into a 56-mile canal for flood control (GEOGRAPHIC, July 1990).

ROBIN FLEMING

The river's flanking wetlands were drained, and oxygen levels in the old channel plummeted, decimating fish, wading birds, and waterfowl. Critics demanded that the damage be undone. The current plan—the largest such effort attempted in the U. S.—could take 15 years. Twenty-two miles of the canal would be filled with dirt to let the plain re-flood and the river re-form its curves and oxbows. The effort, which reflects the corps's new environmental awareness, is supported by one of its old antagonists, the Sierra Club.

National Geographic, November 1992

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REINARD THOMPSON

California Smog: Removing a Certain Air

Perfume pollutes, says the state of California. So do hundreds of other common household products that will soon be governed by new state anti-pollution standards.

Perfumes, colognes, and hair sprays are among 27 categories of items to be regulated. They contain volatile organic compounds such as alcohols and hydrocarbon propellants that react in air to form smog. The new standards call for reducing or eliminating those ingredients in an effort to reduce air pollution by 60 tons a day. While some manufacturers will switch from aerosol cans to pump containers, others are in a mad scramble to completely reformulate their products. Perfumes and colognes marketed in California before 1994 will be exempt, however.

"We're starting to see similar laws in other states," says S. William Becker of the Association of Local Air Pollution Control Officials. "Nationwide the largest smog-producing industries have been regulated, but there are still other sources—like oil-based paints—that contribute significantly to the problem."

Bird-size Grasshopper Invades South Florida

Floridians are used to being overrun by bizarre aliens—walking catfish, Colombian iguanas, toxic toads. Now another potential environmental nightmare has arrived—one of the world's largest grasshoppers, five inches long with an eight-and-a-half-inch wingspan. And it has a sweet tooth.

"We've only found five so far, in Broward and Dade Counties," says state entomologist Harold Denmark. "They're not established yet. All five were females, but none had eggs. We don't know how they arrived. They're native to Costa Rica, Venezuela, and Brazil. They have a ravenous appetite for sugarcane, and that worries us because sugarcane is important here."

Denmark says the first invader turned up last February "when a lady called in saying she'd found a huge grasshopper. We asked her to try capturing it, so she herded it into her carport, bashed it with a broom, and sent it in." He had expected a common three-inch-long Florida grasshopper called an eastern lubber, but was amazed to find the genus *Eutropidacris*.

"Stay Clear!" Alarm Warns Whales

Newfoundland watermen, fishing inshore for cod, often wind up with humpback whales in their nets. That can be fatal to the whales and a disaster to the fishermen. Last year the nets took about 1,300 hits, causing nearly a million dollars in damage. A record 137 humpbacks were trapped, and 15 died. But the rest lived, thanks largely to Jon Lien of Newfoundland's Memorial University. He has freed more than 650 humpbacks since 1978.

Now Lien is refining alarms that he attaches to a cod net to frighten the cetaceans away. An aluminum fishing float houses a battery-powered noisemaker that sounds like a distant hammer pounding an anvil. Using several of the devices on their nets, one group of fishermen reported fewer collisions. But the alarms cost about $150 each, too expensive for widespread use. Lien hopes mass production can reduce that to $25.

STEPHEN DALTON, PHOTO RESEARCHERS (LEFT); BRYAN AND CHERRY ALEXANDER

—John L. Eliot

National Geographic, November 1992

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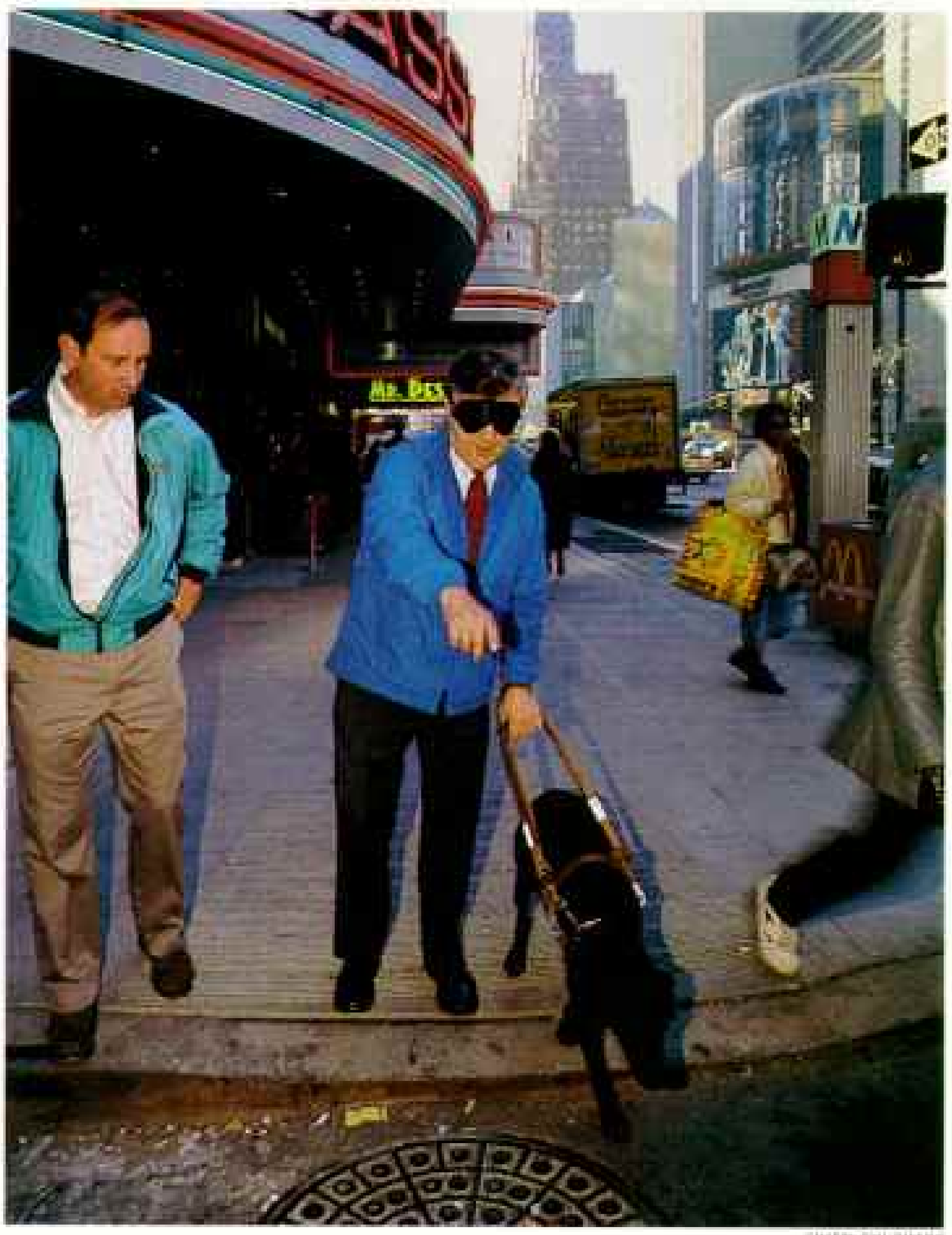
On Assignment

"I wanted to experience blindness," says staff writer MICHAEL E. LONG about this month's cover story. So he donned a blindfold and entrusted a Seeing Eye dog named Jade to lead him through Times Square (right). Doug Roberts of Seeing Eye, Inc., coached the 25-minute walk through the heart of Manhattan.

"It was just an approximation, of course, but I wanted to pass that feeling on to the reader, and this was as close as I could come."

During 26 years at the magazine, Mike has always thrown himself into his stories. In Baja California (October 1972) he drove most of a thousand-mile off-road race before breaking an axle. Investigating aircraft safety (August 1977), the ex-Marine Corps pilot landed a Boeing 747. In fact, Mike has taken the controls of 38 different kinds of airplanes while on assignment.

But that was not as great a challenge as being piloted by a 60-pound Labrador retriever. "You have to make a conscious decision to trust the dog," he says. "It's like stepping off a bridge."



CHIEN-CHI CHANG

Staff member PETER L. PORTEOUS also likes to immerse himself in a story: He played mother hen while feeding a chick (below) for his eagle article. "It was harder than it looks," reports Peter. "The chick's head bobbed around like a dashboard mascot." Peter helped scientists haul equipment through the wilderness and keep a 24-hour vigil over the eggs and hatchlings. The constant demands "made me feel like a new parent again," says Peter, father of two boys, 7 and 11.

Back in the office Indiana-born Peter resumed his duties as an issue editor, coordinating the work of writers and researchers during an article's final production stages.

Soon after his return Peter, responding to a cry from his seven-year-old, leaped out of bed, tripped, and broke his foot. He adds, "Maybe it's safer out in the field."

RICHARD DAY, G. M. SUTTON AVIAN RESEARCH CENTER

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