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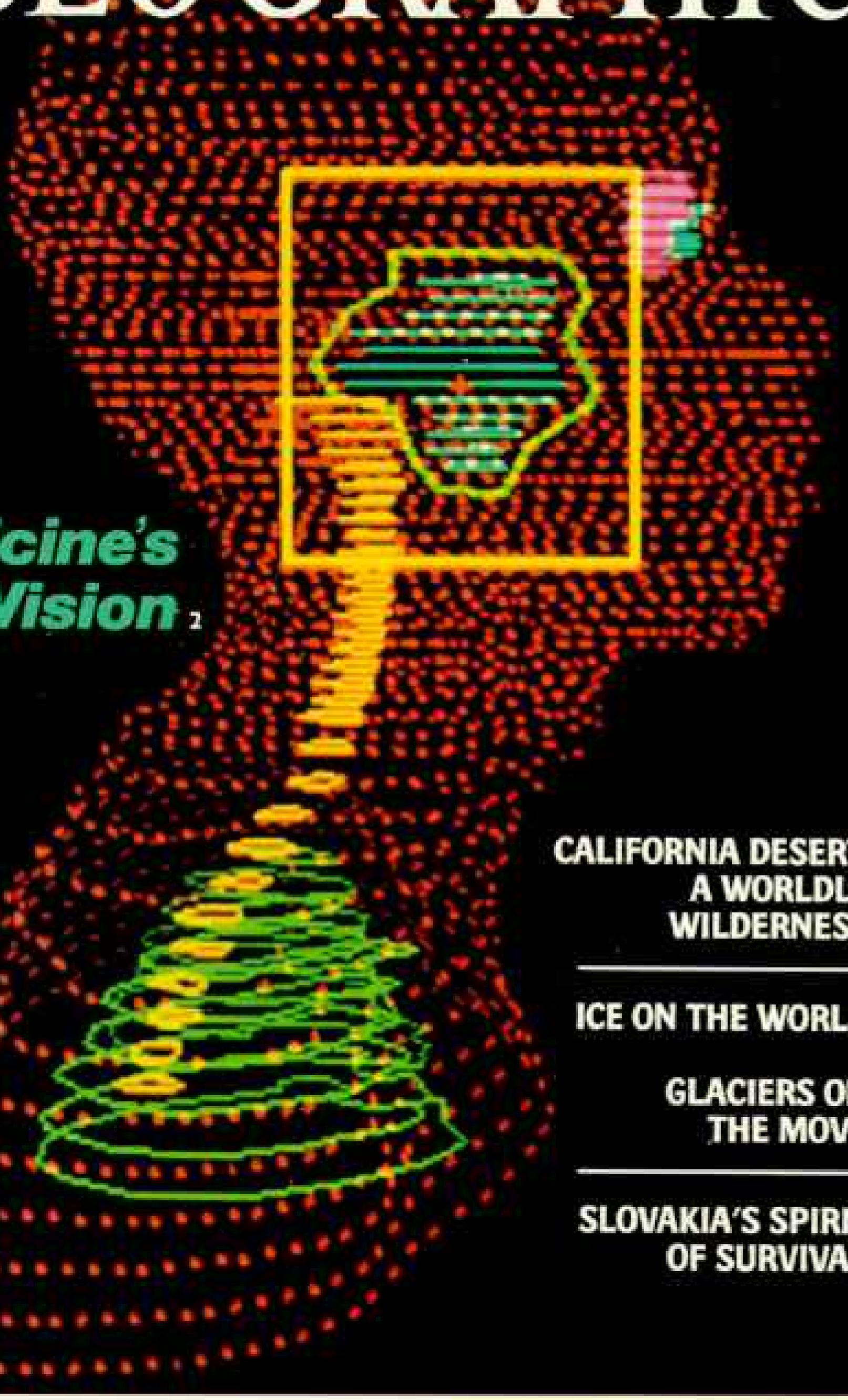
# NATIONAL GEOGRAPHIC



## Medicine's New Vision 2



SEE "LIONS OF THE AFRICAN NIGHT" WEDNESDAY, JANUARY 14, ON PBS TV

SPEEDING SOUTH from Paris to Brive, our train entered a tunnel dated 1887. After a bit of darkness, the bright light of day showed the other end was dated 1888.

Even as workers were boring through this mountain to improve communications in France, a small group of men in Washington, D. C., were planning a society to improve intellectual communications in the U. S. They wanted "to bring together (1) the scattered workers of our country; and (2) the persons who desire to promote their researches. . . . to diffuse the results of geographic research over a wider area than would otherwise be possible."

The next year the dream was realized. Our Society was born January 13, 1888. As we enter our hundredth year, I cannot resist looking back at our year of gestation to see the mood of the country that inspired these men.

The youthful United States was coming of age—going through a sort of national puberty and maturing as a world force. The railroads west had been connected and were providing daily service to the Pacific coast. In 1887 we acquired Pearl Harbor for a naval coaling base.

Missionaries and businessmen were scattering into Asia and Latin America. Our explorers were competing with Europeans to reach far recesses of the world. Stanley began his fourth expedition into Africa. Peary was in Greenland and already thinking North Pole.

With equal vigor inventors and entrepreneurs were grabbing for shares in the industrial revolution. In 1887 Edison patented a better light bulb. The flat phonograph record was invented by Berliner. And in 1888 Eastman introduced his "Kodak," a lightweight camera using dry roll film with commercial processing.

Hand in glove with this ferment was the growth of national research and exploration societies. The man handy with gun and ax had opened the country, but now the self-made Horatio Algers had to be armed with knowledge and handy with formulas. The timely inventions of the Linotype machine in 1883 and the modern halftone screen in 1885 were bringing a flood of books, journals, newspapers, and magazines, including the modest little journal of the National Geographic Society.

Both the French railroad tunnel and the Society are still doing their jobs 99 years later. The tunnel may pass its century mark quietly, but this year we'll be planning a memorable birthday bash for 1988.

Melbert B. Cabry

EDITOR

NATIONAL GEOGRAPHIC

JANUARY 1987



**COVER:** *A tumor of the nasopharynx, located by a CT scanner, appears blue in a three-dimensional computer image. The imaging system is being tested at New York City's Memorial Sloan-Kettering Cancer Center as a way to aim radiation beams precisely. Photograph by Howard Sochurek.*

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FOUNDED 1888

# Medicine's New Vision

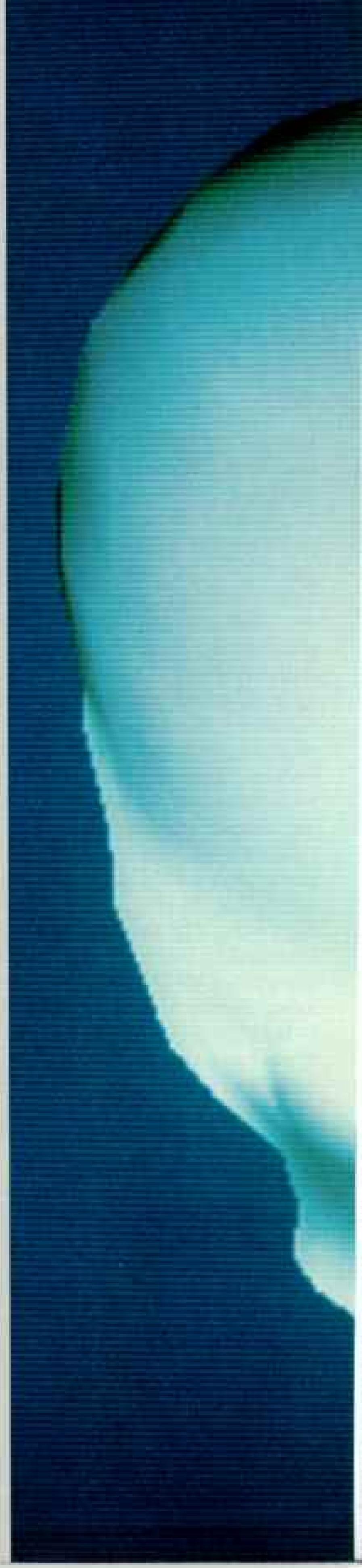
Lurking deep within the brain, a tumor glares red in a computer-generated picture of a man who collapsed at a Las Vegas gambling table. This three-dimensional view, looking through the forehead, shows the skull's surface as white and the brain's surface as yellow, based on data collected by a computed tomography scanner. Changing the face of medicine, a new breed of imaging devices enables doctors to watch vital organs at work, identify blockages and growths, and even detect warning signs of diseases not yet present—all without exploratory surgery. The tumor was removed, and the patient recovered.

UNIVERSITY OF KANSAS MEDICAL CENTER, KANSAS CITY, KANSAS

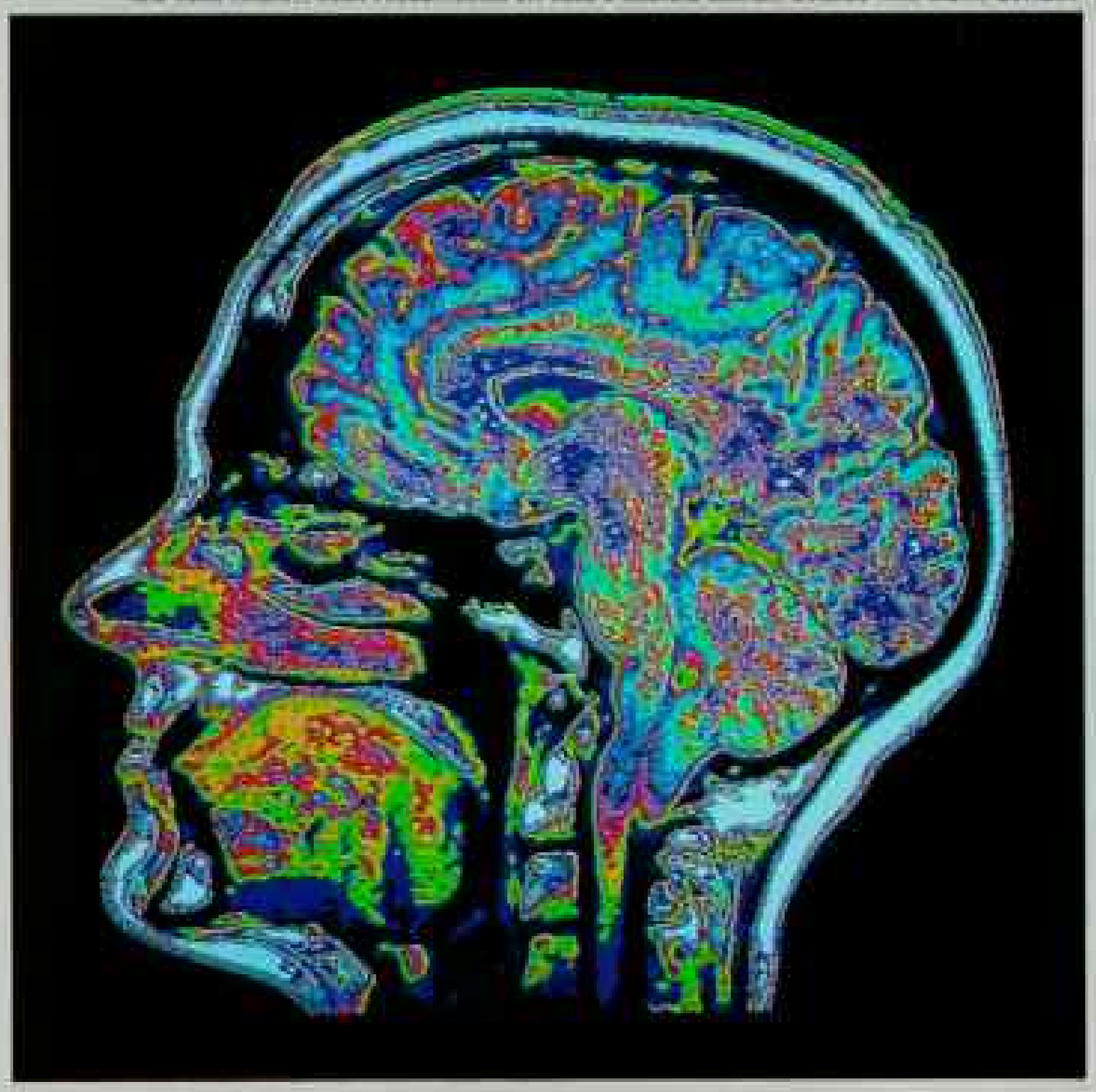
Article and photographs by
HOWARD SOCHUREK

Illustrations text by PETER MILLER
NATIONAL GEOGRAPHIC EDITORIAL STAFF

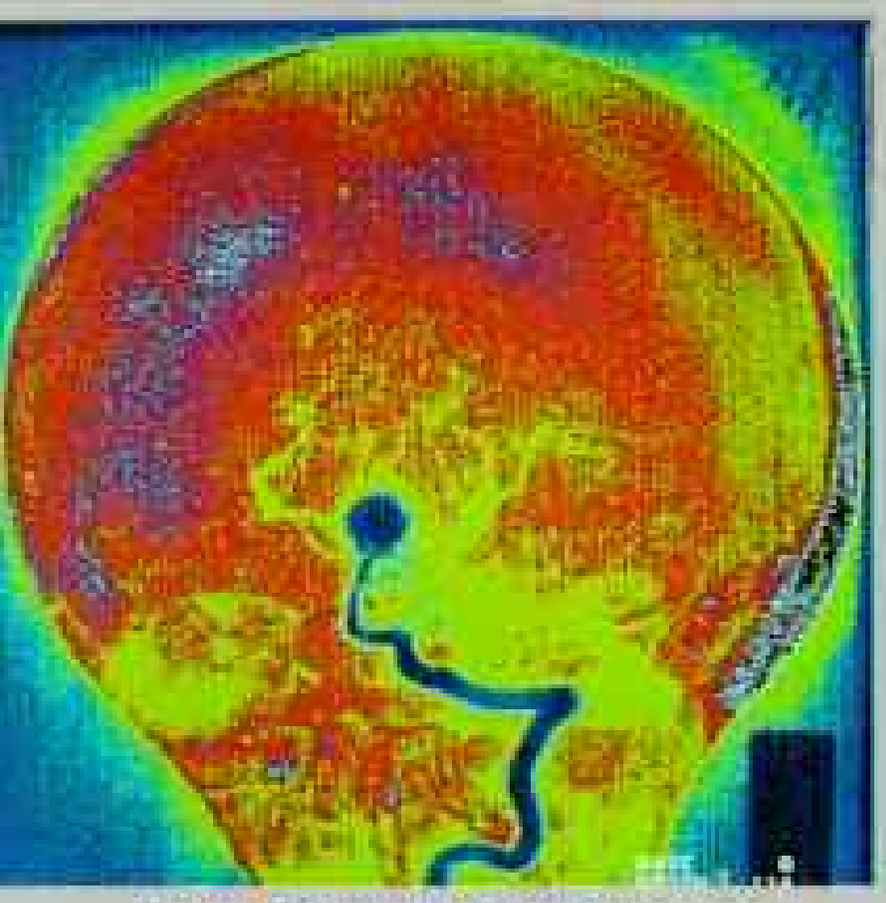




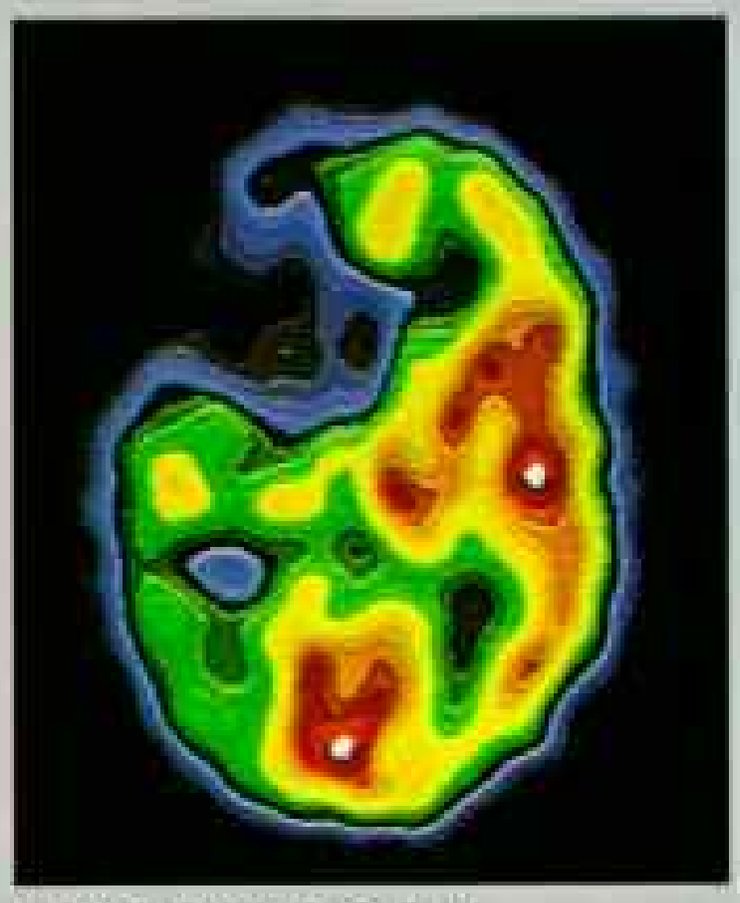
WALL (HORIZONTAL) INSTITUTE OF RADIOLOGY, ST. LOUIS (BELOW); UNIVERSITY OF KANSAS MEDICAL CENTER (BOTTOM LEFT); WALL (VERTICAL) INSTITUTE OF RADIOLOGY (BOTTOM RIGHT); MEMORIAL SLOAN-KETTERING CANCER CENTER, NEW YORK (ABOVE); RUSH PRESBYTERIAN ST. LUKE'S MEDICAL CENTER, CHICAGO (FAR RIGHT, BOTTOM)



*Magnetic Resonance Imaging*



*Digital Subtraction Angiography*



*Radioisotope Imaging*


*Computed Tomography*

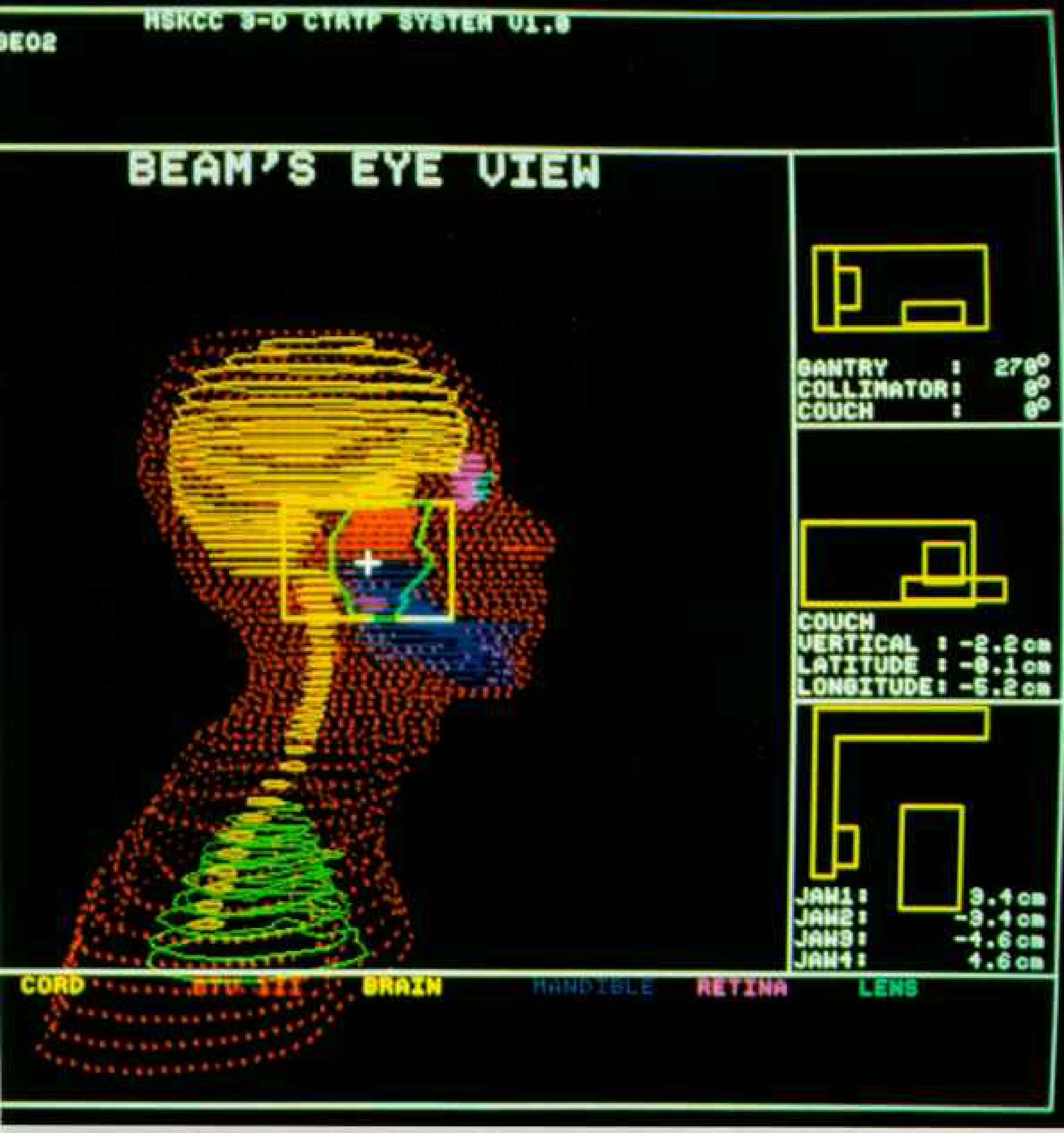
**Five views** *of the head show the magic of five computerized body-scanning systems.*

*A color-enhanced profile* (**top**) *made by magnetic resonance imaging (MRI) shows a herniating finger of tissue from a brain slumping into the base of the skull. Frequently used to view soft tissue such as the brain's, MRI machines do not use X rays to penetrate the body but instead employ a combination of radio waves and a strong magnetic field.*

*An artery at the base of the brain balloons with a dangerous aneurysm* (**above left**) *in an X-ray view enhanced by digital subtraction angiography (DSA). The keyhole shape of the picture was imposed by a shield on the X-ray machine.*

*A darkened area on the left side of a brain* (**above**) *depicted in cross section by positron emission tomography (PET), a form of radioisotope imaging, indicates damage from a stroke. Bright colors in the rest of the brain show normal blood flow.*

*Because computed tomography (CT) scanners can locate tumors with great precision, machines are being developed to use CT data in aiming beams of radiation during treatment. In a three-dimensional display* (**above**)




*created from dozens of CT scans, a cross marks a tumor. Pictures to the left show different angles from which to target the tumor, while diagrams at right depict the configuration of the radiation machine as seen from the front, side, and above. As the machine settings are adjusted, the diagrams change automatically. Organs sensitive to radiation, such as the lungs, spinal cord, and eyes, are color-coded to help avoid unnecessary exposure.*

*Considered safer than X rays for use on pregnant women, sonography works like sonar to create pictures such as this view of the head of a normal 18-week-old fetus (**right**). Usually viewed in black and white by a doctor, this image, like most in this article, has had color added.*

**Sonography**

"Howard, there may be something wrong with your heart."

I was laid out on a table, patient number 344 in what was to be only a test series. Addressing me was Dr. K. Lance Gould, a six-foot-six Texan who heads the Positron Diagnostic and Research Center at the University of Texas Medical School in Houston.

"I reviewed your medical records last night. Your EKG [electrocardiogram] shows a potential problem. We now have a doctor-patient relationship, meaning these results will be confidential. You may not be able to write this story."

This story was documenting amazing new technologies that provide detailed views of the body, fulfilling a dream as old as medicine. Recent rapid advances in imaging technology, or "machine vision," enable doctors to see inside a body without the trauma of exploratory surgery. As a result, more progress has been made in diagnostic medicine in the past 15 years than in the entire previous history of medicine.

To report on these uncanny new eyes, I had taken my cameras into innovative hospitals where I saw my blood pulsing through my arteries; I watched the muscled wall of my heart absorb a radioactive tracer; I saw the blocked arteries of another human heart starving for blood—a heart under attack; and I saw the huge yawn of a fetus snuggled in its mother's womb six weeks before it was born.

And now I was subjecting my beyond-middle-age body to the scrutiny of one of the marvelous machines—never dreaming my reporting would suddenly become deadly serious.

Dr. Gould was right, I admitted bleakly. He had agreed to give me a nuclear heart scan using his PET (positron emission tomography) scanner, one of the miraculous new seeing machines. The ground rules were that I would write about the test only if the results were normal. Otherwise my own health might be compromised by the rigors of pursuing the story. I had taken that gamble and, apparently, had lost.

Minutes earlier head research nurse Mary Haynie had used a fluoroscope to take a picture of my heart and made an outline of its position on my chest with a magic marker. I lay down on a table and was slowly moved into a huge two-ton metallic doughnut with a center hole just large enough for me to squeeze through—the 1.6-million-dollar PET scanner.

As a young cardiologist Dr. Gould had questioned the conventional medical practice of dealing with coronary disease only after complications had occurred. His early laboratory work had indicated that coronary disease could be detected much sooner. "If you could screen for coronary disease and find it five or ten years in advance of trouble—if that could be done—you could save countless lives."

Today, running a center with a staff of 75 and an annual budget of four million dollars, he uses nuclear medicine as a

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Veteran photojournalist **Howard Sochurek** lives in Bronxville, New York. This is his tenth article for NATIONAL GEOGRAPHIC.

## CT

## Computed Tomography

Fractured in a motorcycle accident, a young man's vertebrae seem to rise off the page in a three-dimensional image based on 63 CT scans. The force of the impact compressed and fragmented the vertebra at center, twisting the spine above and below it.

Developed in Great Britain in 1972, CT scanners convert X-ray pictures into digital computer code to make high-resolution video images. The computer graphics employed are similar to those used to reassemble pictures beamed back from distant space probes. Depicting bone structures in fine detail, CT scans can also show small differences between normal and abnormal tissues in the brain, lungs, and other organs. Still in the early stages of development, three-dimensional CT images are beginning to play an important role in reconstructive surgery.

3D/INTERNATIONAL MEDICINE, INC., MINNETONKA, MINNESOTA

screening technique to identify coronary disease even in patients without symptoms. And for this I was a prime candidate: tense, overweight, a hard-driven type-A personality pushing past 60.

From Mary Haynie's fluoroscopy it was clear that my heart, unlike most others, did not hang vertically in the chest cavity but was tipped sideways. Since the scanner covers only 11 centimeters (about four and a half inches), positioning of the body in the doughnut was critical. I remained still for 20 minutes while the scanner collected data.

Mary and a technician injected a low-level radioactive tracer (in this case N-13 ammonia) through the intravenous catheter in my right arm. Freshly brewed by Dr. Gould's cyclotron, the tracer had a ten-minute half-life, the time it takes to lose half its radioactivity. So it had to be administered quickly and with precision.

Fifteen minutes of scan time took place while the heart was beating normally. I heard cooling fans humming in the scanner and the *beep beep beep* of the EKG machine, which monitored me continuously. My head throbbed with anxiety, although Mary and Dr. Gould hovered around me.

Soon it was time to test my heart's response to stress. Dipyridamole, a drug that simulates stress to the heart, was injected through the intravenous catheter. Mary then gave me a hand grip to flex the finger, wrist, and forearm muscles; I clenched it tightly until the gauge recorded a pressure of 20 pounds. This, Mary explained, would increase blood flow to the heart more than in a conventional treadmill test.

A second injection of the nuclear tracer entered my arm, and the scanner hummed while it studied my heart for an additional 15 minutes.

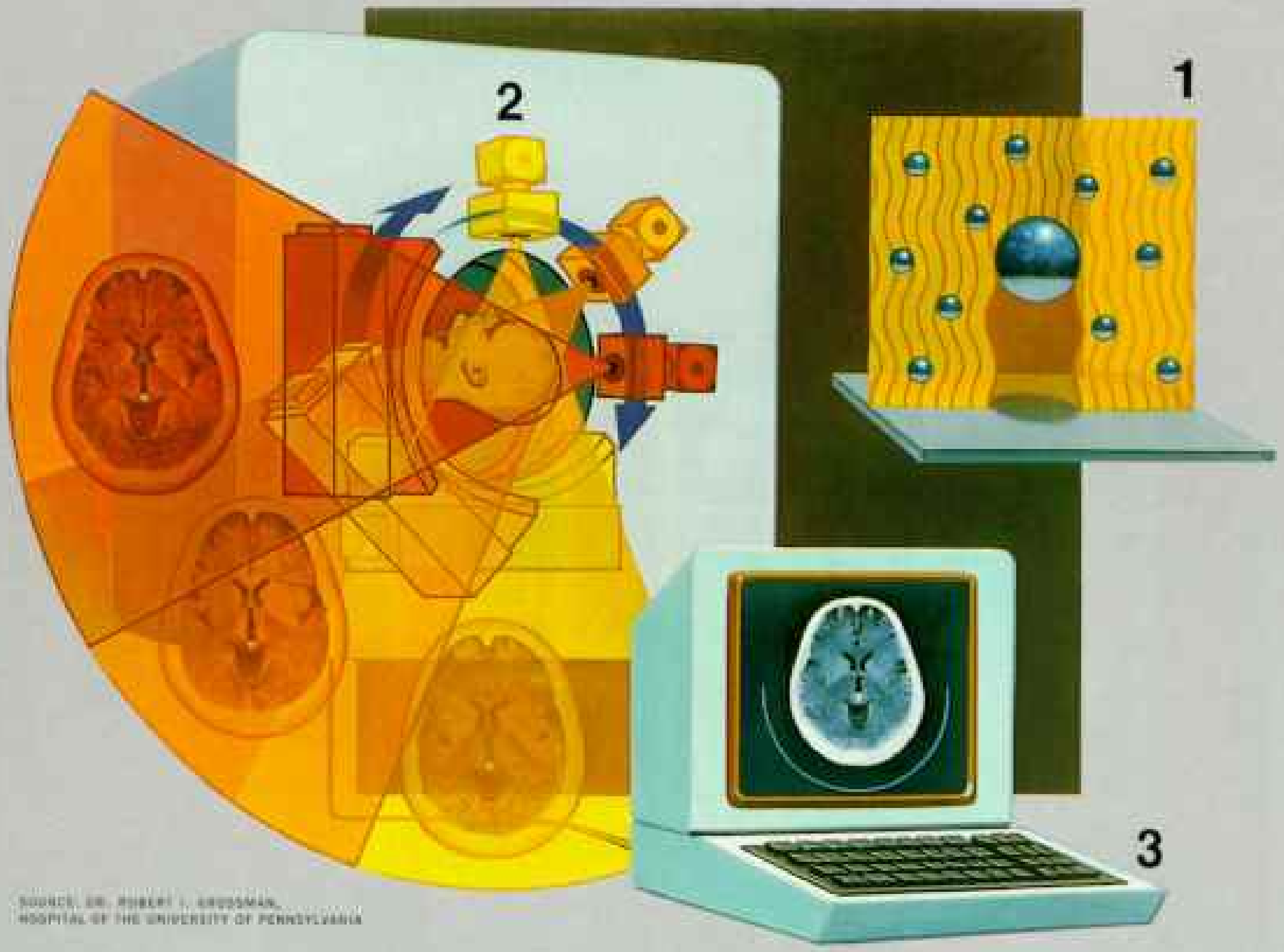
The "dipy," as the team called it, taxed my stamina, and my face took on a red flush. My left arm shivered as I maintained 20 pounds of pressure on the hand grip. The EKG sounded its *beep, beep, beep.*

## CT

***Magical but murky,*** *the first X-ray photograph, made by German physicist Wilhelm Konrad Röntgen in 1895, shows a ring on his wife's hand* ***(bottom left)****. Within months of his discovery, doctors began using X rays (so named by Röntgen because of their unknown nature) to diagnose fractures. They learned that the mysterious rays—now known to be an extremely shortwave form of electromagnetic radiation—are absorbed by the dense structure of bones, leaving shadows on the film. But softer tissues, which are more easily penetrated, do not appear distinctly in pictures.*

*Since then, many techniques have been developed to intensify the X ray's image and improve its clarity, resulting in detailed views such as this one of a hand* ***(bottom right)****. Some advanced X-ray machines digitize their data, allowing image contrasts to be mathematically enhanced to show subtle differences between tissues.*

DEUTSCHES MUSEUM, MUNICH, WEST GERMANY (LEFT); UNIVERSITY OF KANSAS MEDICAL CENTER, IMAGES BY HEDAVISION, SANTA BARBARA, CALIFORNIA




SOURCE: DR. ROBERT J. GRUSSMAN, HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA

To break the monotony, I talked to Mary about her family and mine. Her father had died of a heart attack at age 47, and her mother was left alone to raise her and seven brothers and sisters. Perhaps the test I was undergoing could have warned her father of his peril.

The exhausting 15 minutes finally passed, the humming of the scanner stopped, Mary removed the intravenous catheter from my right arm, and I released the grip in my left hand. After one hour and 30 minutes of lying still, it was over.

"Will I glow in the dark?" I asked Mary as I got up off the table.

In a back room a computer completed processing a staggering amount of digital data. It had digested more than five million bits a second during the entire time of the test.

Now came the moment of truth. Slowly the data assumed picture form in color on a cathode-ray tube (CRT). First the screen showed us the heart beating normally, with the blood supply circulating through the heart muscle. The screen flashed again, and alongside appeared a picture of the heart under stress. We studied the two images transfixed: If they should differ, it would indicate a blood-supply problem to the heart—and confirm the death of my story.

The images matched perfectly. Dr. Gould smiled, Mary smiled, I smiled.

What had caused Dr. Gould's original concern? "Because your heart lies on its side instead of hanging normally," he explained, "the EKGs in your medical records were misleading. Not until we obtained the PET picture to confirm the heart's

**Penetrating the body** *with a thin, fan-shaped X-ray beam, a CT scanner produces a cross-sectional view of tissues within. Conventional X-ray radiographs, which view the body from only one angle, can be difficult to interpret when the shadows of bones, muscles, and organs are superimposed on one another. Large molecules such as calcium absorb X rays as they pass through the body* **1**, *partially masking whatever lies behind them. But CT machines view a "slice" of the body from many angles by revolving an X-ray tube around the patient* **2**. *Sensitive detectors on the opposite side record what the scanner sees, and a computer* **3** *compares the many views to make a single video image.*

**Guided by pictures** *of the brain unimaginable 20 years ago, Dr. Paul O'Boynick (second from right) at the University of Kansas Medical Center delicately implants a tube in a patient's skull to drain excess fluid. Dr. Dwane Beckenhauer (left) prepares an incision where the tube, after being threaded beneath the skin,*

*will be inserted into the abdominal cavity for the fluid to be continuously absorbed. Behind them are images of another patient, made by CT, MRI, and conventional angiography, illustrating the variety of information available to neurosurgeons in modern operating rooms.*

position and flow capacity did I find all was OK. You have a healthy heart. You can write your story. Come back again in two years."

I had no aftereffects from my PET scan but developed a nasty headache after leaving the center. It may have been because, as directed, I had missed my usual hearty breakfast.

CEMAX, INC., SANTA CLARA, CALIFORNIA

## CT

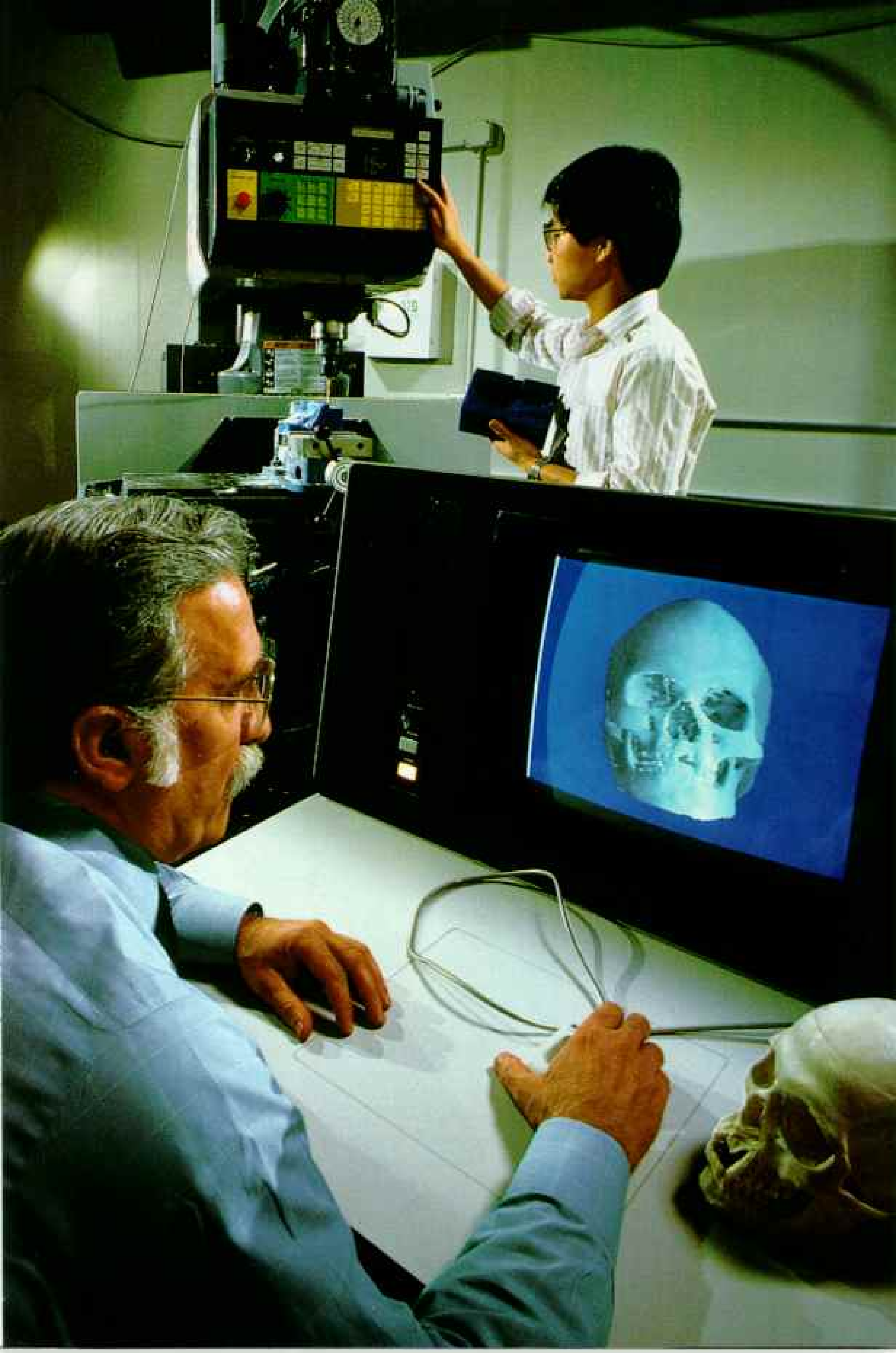
***All smiles,*** *My Tien Tran of Sunnyvale, California, stands with Dr. Steven Woolson* ***(top)*** *before an X ray showing her new right hip. A 3-D image of her pelvis before surgery* ***(above)*** *depicts the dislocated hip with which My Tien was born. Based on CT scans, the image was created by CEMAX, Inc., of Santa Clara, which fashioned from it a plastic model of My Tien's hip used by Dr. Woolson to plan the surgery. "I wanted to be certain that the implant would fit precisely," Dr. Woolson said.*

*Seated at a computer console in the CEMAX laboratory, Dr. Art Vassiliadis* ***(right)*** *calls up an image from another case. The plastic skull beside him, like the model of My Tien's hip, was cast from a mold made on the milling machine in the background. Holding a block of machinable wax, engineer Charles Lau helps set up the machine, whose every move is controlled by the computer.*

Another revolutionary technique is MRI—magnetic resonance imaging. It is an area of excitement and explosive growth. This seeing machine may prove to be as great a tool to modern medicine as the X ray, discovered by Wilhelm Konrad Röntgen in 1895.

Magnetic resonance imaging relies on the principle that hydrogen atoms, when subjected to a magnetic field, line up like so many soldiers. If a radio frequency is aimed at these atoms, it changes the alignment of their nuclei. When the radio waves are turned off, the nuclei realign themselves, transmitting a small electric signal. And since the body is primarily composed of hydrogen atoms, an image can be generated from the returning pulses, showing tissue and bone marrow as never seen before.

MRI is expensive. The equipment, which consists of a huge electromagnet, a radio-frequency generator, and a computer for



evaluation, costs about two million dollars. It must be in a room completely insulated from external radio frequencies, adding another three-quarters of a million dollars to the cost. To illustrate the importance of shielding, Dr. Pat Cahill of New York Hospital told me that for a time their new MRI machine received shortwave Vatican Radio.

A few patients cannot be placed in the magnet. Anyone wearing a pacemaker, for example. Or veterans with embedded shrapnel. The metal could actually be pulled from their bodies. And there was the case I heard about on Long Island, where a Mafia capo refused to be scanned when he learned he had to part with his gun. It too would have been sucked into the magnet.

**MRI**

## Magnetic Resonance Imaging

Ghostly in the dark, a normal face seems otherworldly when viewed by an MRI scanner. The eerie forehead, eyebrows, cheeks, nose, and lips appear brightest because water density is higher than in other tissues. MRI reflects water because it focuses on the behavior of hydrogen atoms in water molecules. This allows MRI to do certain things better than CT scanners, such as distinguishing between the brain's white matter and water-rich gray matter. Teeth and bones, which contain little water, do not appear at all in MRI, enabling doctors to see tissue surrounded by bone, such as the spinal cord. MRI has also been used to spot the tiny lesions of multiple sclerosis on brain and spinal tissue.

UNIVERSITY OF KANSAS MEDICAL CENTER

Some of the pioneer work in magnetic resonance imaging was done at University Hospital in Nottingham, England. Professor Brian S. Worthington told me about the first images made there, in 1974.

"We had a tiny magnet. The first thing we looked at was an onion, and we saw its inner rings. We had great concerns about what the magnet might do to human beings. I remember questioning whether too strong a field might even have an effect on the human memory."

In 1977 they tried one of the first MRI scans of living human tissue—a wrist. Two years later a bold scientist volunteer thrust his head into the magnetic field for a brain scan.

It is only since 1980 that the potential of magnetic resonance imaging has become generally recognized, and today some 400 machines are installed and operating in the United States—more than in any other country in the world. This explosive growth reflects MRI's wonderful diagnostic results.

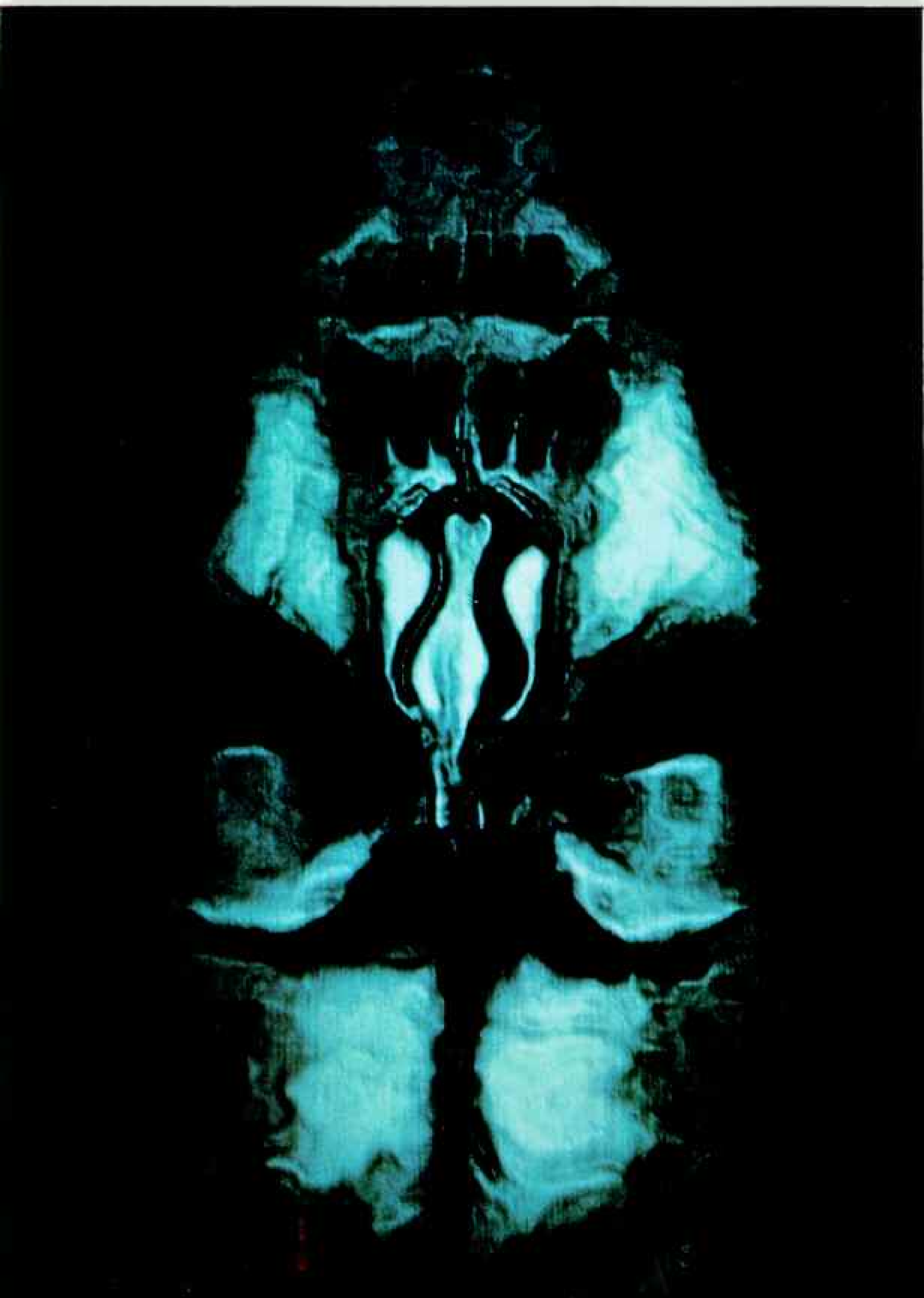
I heard about one such result in Phoenix, Arizona.

Nathan Tower is a bright, handsome boy who was born in the small town of Langley in British Columbia, 25 miles east of Vancouver. Unlike his older sister, now 12 and always healthy, Nathan at age two developed severe aches in his left ear and often vomited. Near his fifth birthday, in June 1985, the earaches were joined by terrible headaches. On bad nights Nathan was in constant pain; aspirin brought no relief. Trying to trace the cause, his frantic mother eventually consulted 11 different doctors. Some of them viewed her as psychotic.

Nathan's health deteriorated quickly. He lost the use of his left hand and arm and began losing the use of his left leg. In July his distraught parents took him to Reno, Nevada, for tests. Doctors saw evidence of a tumor on the brain stem and called it inoperable.

In desperation Mrs. Tower called her husband's sister, Barbara Barnhart, in Phoenix. Mrs. Barnhart called a neighbor, Dr. Donald A. Davis, who strongly suggested that the Towers bring Nathan to Phoenix's Barrow Neurological Institute at St. Joseph's Hospital and Medical Center.

The day after his arrival in *(Continued on page 19)*



All paintings by
DAVIS MELTZER

# MRI

***Like the director*** *of a chorus, an MRI scanner conducts the "singing" of hydrogen atoms within the human body.*

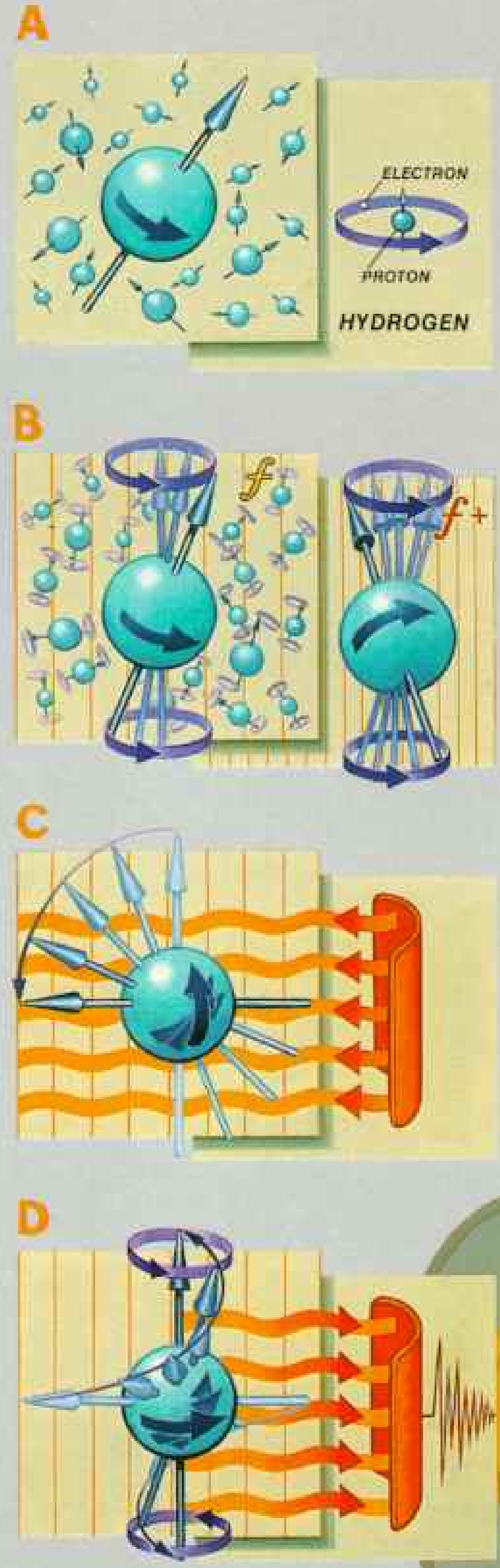
*The scanner surrounds the body with powerful electromagnets. Supercooled by liquid helium, they create a magnetic field as much as 60,000 times as strong as that of the earth.*

*This field has a profound effect on protons, the nuclei of hydrogen atoms. Spinning like tops, the protons normally point in random directions* **A**. *But inside the scanner's magnetic field* **B** *they align themselves in the direction of the field's poles. Even in alignment, however, they wobble, or precess, at a specific rate, or frequency. The stronger the magnetic field, the greater the frequency (f+).*

*When the scanner excites these protons with a radio pulse timed to the same frequency as their wobbling, it knocks them out of alignment* **C**. *Within milliseconds they spiral back into place* **D**, *singing out with a faint radio signal of their own.*

*A computer translates these faint signals into an image of the area scanned (diagrams on facing page). The image reveals varying densities of hydrogen atoms and their interaction with surrounding tissues in a cross section of the body. Since hydrogen reflects water content, doctors can use the image to make distinctions between tissues.*

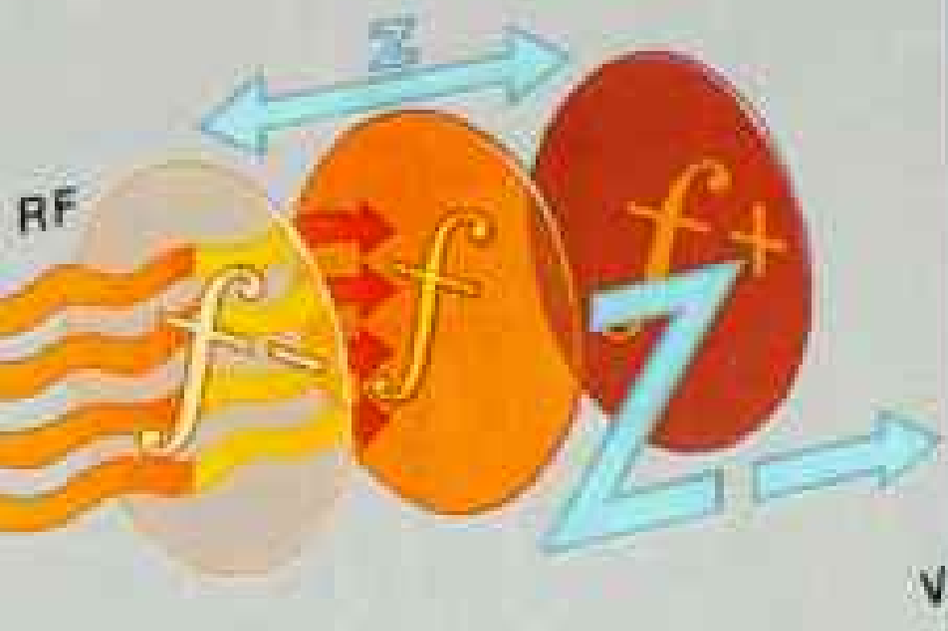
*Scientists picked hydrogen as the basis for MRI scanning because of its abundance in the body and its prominent magnetic qualities. Research is also under way on employing other elements, such as sodium or phosphorus, whose altered properties could provide early warning signs of strokes or heart attacks. It may even become routine to tag cloned antibodies with a detectable element, giving scientists a powerful tool to study such disorders as diabetes, allergies, infertility, and cancer.*

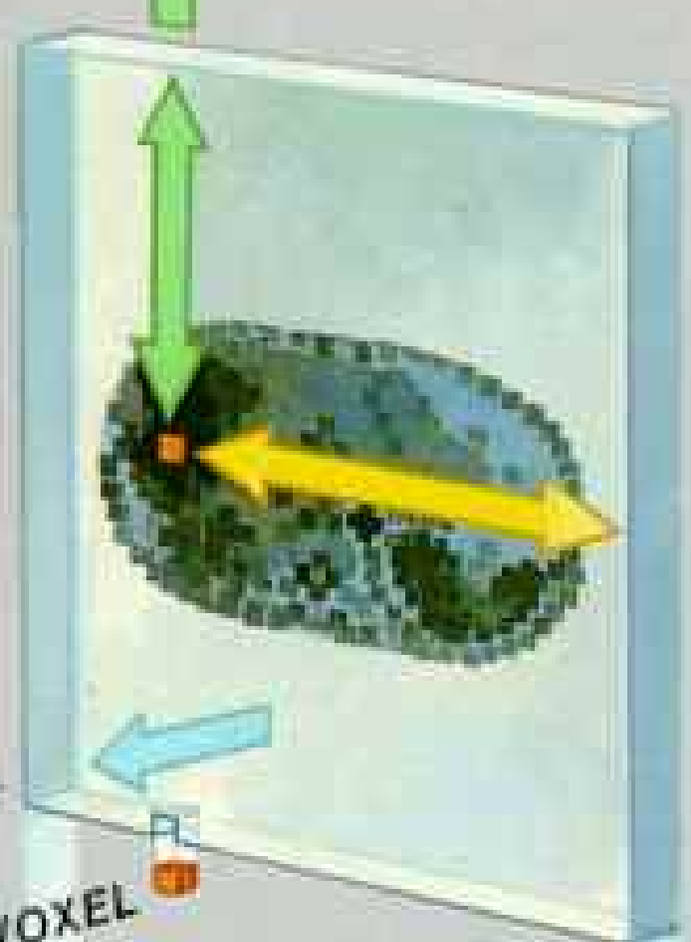



1 *To make an image (oval at center of page), the computer establishes a grid of tiny boxes, or voxels, in three dimensions, X, Y, and Z. First the magnetic field is varied in the Z direction, from head to toe, to define a plane of interest (orange disk) where the body will be scanned. Within this plane protons wobble at a given frequency, f. Radio frequency (RF) coils then emit a pulse at precisely the same frequency to topple these protons.*

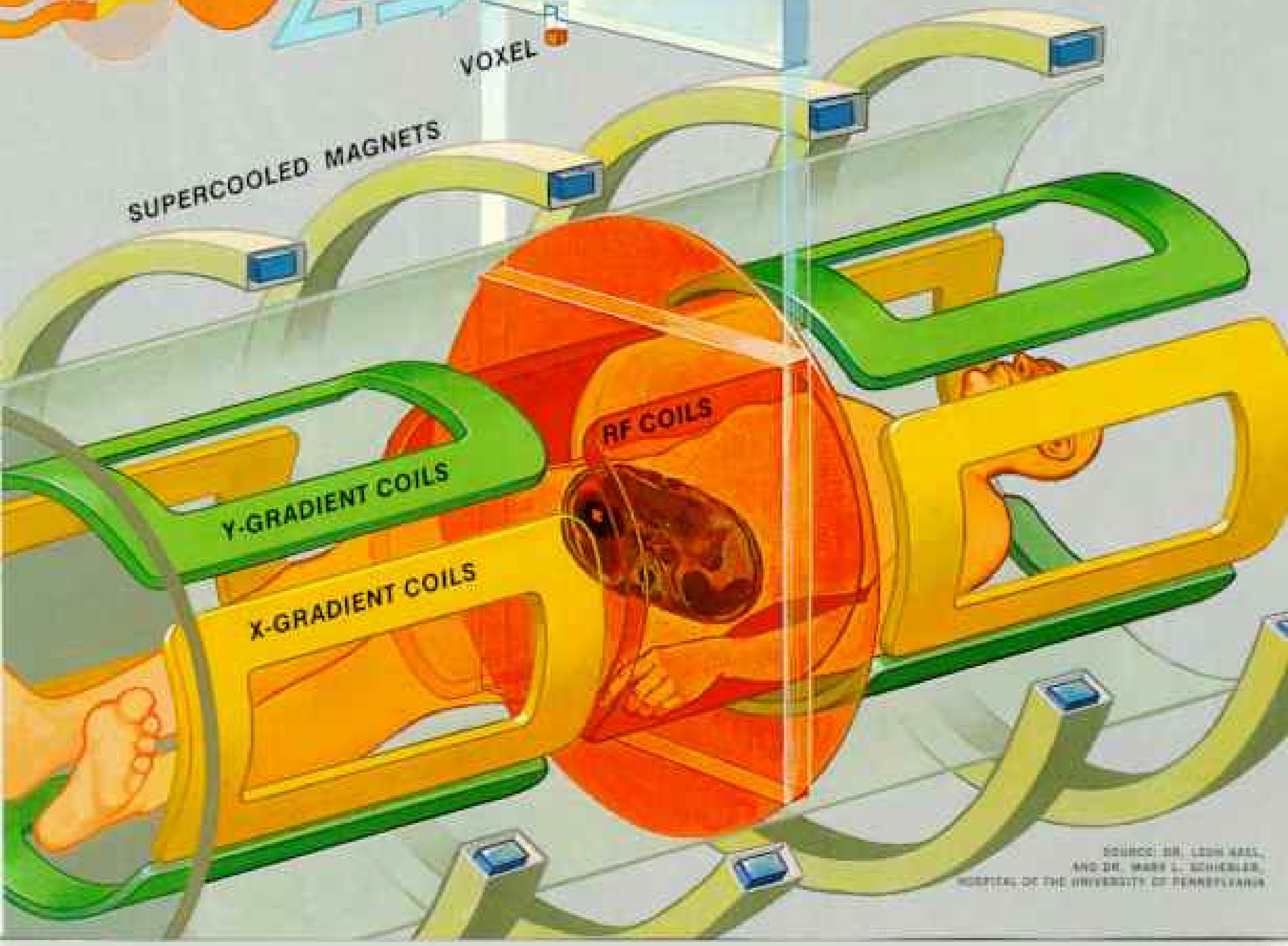
2 *Before the protons can realign themselves, other coils briefly vary the magnetic strength of the plane in the Y direction. This causes protons to wobble at different rates (clock faces) from the top of the plane to the bottom. Detecting these differences over hundreds of pulse-and-response cycles, the computer locates voxels in the Y direction.*


3 *Coils then vary the magnetic field from left to right in the X direction, causing protons to sing at different frequencies as they realign themselves. Having located each voxel in the X, Y, and Z directions, the computer assigns each voxel a spot on the video screen. The spot's brightness is determined by the number of protons within the voxel and the magnetic properties of the tissue. Together the dots form a readable image.*








SOURCE: DR. LEON AXEL,
AND DR. MARK L. SCHIEBLER,
HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA

UCLA SCHOOL OF MEDICINE (ABOVE AND RIGHT)

July 1985, Nathan was scheduled for an MRI scan (page 22). The machine had been installed only in May. "Mommy, is this a spaceship?" Nathan asked as he was eased into the magnet's six-foot-long tunnel.

The powerful magnetic field aligned the hydrogen nuclei in Nathan's brain, and a picture was transmitted to the CRT. There emerged a remarkably clear image of the tumor, lying at the base of the brain. The next day Dr. Harold L. Rekate, chief of pediatric neurosurgery, removed a tumor of the medulla in a delicate operation lasting more than eight hours. The tumor was one and a half inches long and half an inch in diameter.

I spoke with Dr. Rekate about the procedure. "With MRI," he said, "we are able to see brain structures we could never see before. Ten years ago this kid would have died."

When I talked to Nathan and his mother on the sunny porch of the Barnharts' home, he was wearing a "halo cast," or head brace, from subsequent surgery to fuse the vertebrae of his neck. But neurologically he was normal; no longer did he have a weak arm and leg. His overjoyed father, grateful for the key role of MRI in saving his son's life, plans to raise money to set up an MRI center in British Columbia.

## MRI

**Caught in time** *by doctors, a malignant tumor bulges between the kidney and spinal column of seven-month-old Ashleigh Slaughter* **(left)**. *Appearing dark blue and green, at left, in this enhanced MRI scan, the tumor is entering the spinal canal, compressing the cord. "She was in constant pain," said her mother, Connie. "She was unable to sit and slept with her back arched."*

*Fearing the trauma of spinal surgery on a patient so young, doctors at UCLA used chemotherapy to shrink the tumor before trying to remove it. Ashleigh responded so well to the medicine, however, that no surgery was necessary. The tumor vanished from her body* **(above left)**, *leaving her a healthy two-year-old, free to pursue yard work* **(above right)** *at her home in Bakersfield, California.*

## MRI

***Within a week*** *of the time this side-view MRI scan was made (**facing page**), the patient, a four-year-old Hmong girl, lost the use of her legs. The scan showed a tumor, shaded red in this enhanced version, growing in her spinal cord. Acting quickly, the girl's surgeon removed the tumor, and now, in a remarkable recovery, she can walk again without braces.*

*Because of MRI's ability to depict soft tissues in high contrast, it has proved to be an effective means of examining the spinal cord. Before MRI, doctors who wanted to look at the spinal cord had to inject it with an X-ray contrast agent during a procedure that could be risky and painful for the patient.*

ABBOTT NORTHWESTERN HOSPITAL, MINNEAPOLIS

Many of man's greatest inventions have expanded the capabilities of the human body. The computer has enhanced man's ability to see by making the invisible visible. This new vision lies at the heart of digital subtraction angiography (DSA), an imaging technique that produces clean, clear views of flowing blood or its blockage by narrowed vessels.

DSA depends on the injection into the vessels of a contrast agent containing iodine that is opaque to X rays. The shadow this opacity creates allows doctors to see the flow of blood. Frequently DSA is used to look at blood supply to the heart. Before injection of the contrast substance, an X-ray image is made and stored in a computer. After injection a second image is made highlighting the flowing blood as revealed by the substance. The computer then subtracts image one from image two, leaving a sharp picture of blood vessels such as the coronary arteries, the main suppliers of blood to the heart.

A common surgical procedure in the United States today is heart-bypass surgery. In this procedure blood vessels that are clogged with fatty or calcified material are bypassed using other vessels surgically removed from another part of the body, usually the leg. In recent years more than 200,000 operations of this kind have been performed annually at an average cost of about $25,000, for a staggering national price tag totaling some five billion dollars.

With the help of DSA and a procedure called angioplasty, many of these operations now can be avoided.

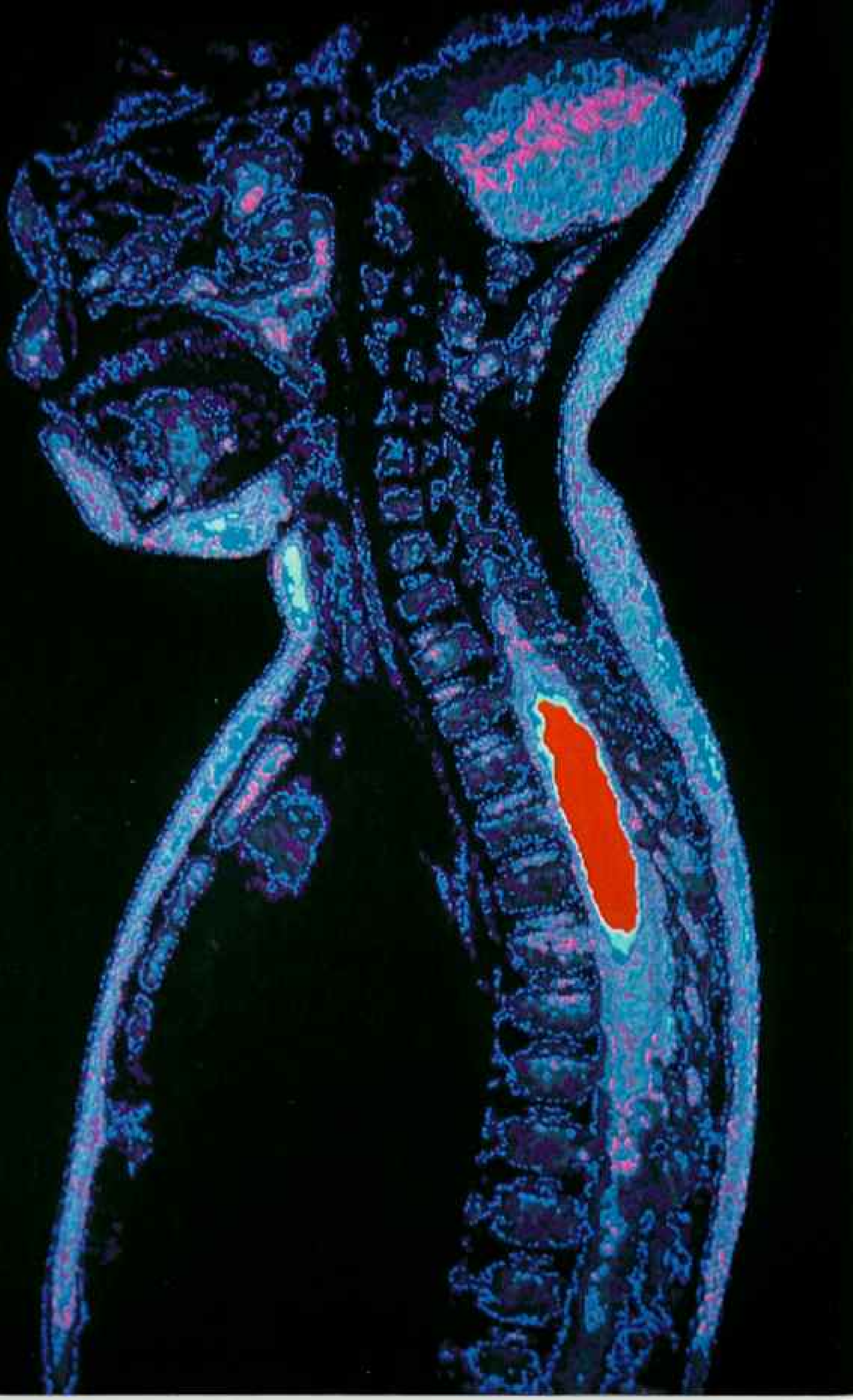
In coronary-artery angioplasty a doctor threads a catheter smaller than the graphite in a lead pencil through a blood vessel in the arm or groin. Seeing through the eyes of the DSA camera as images flicker on a screen, he guides the catheter into a coronary artery. At this time the contrast agent is injected, providing a clear image of the arterial blockage. A second, even smaller catheter inserted through the first carries a tiny balloon to the spot. The balloon is inflated until it compresses the materials clogging the artery and allows the blood again to supply the heart muscle.

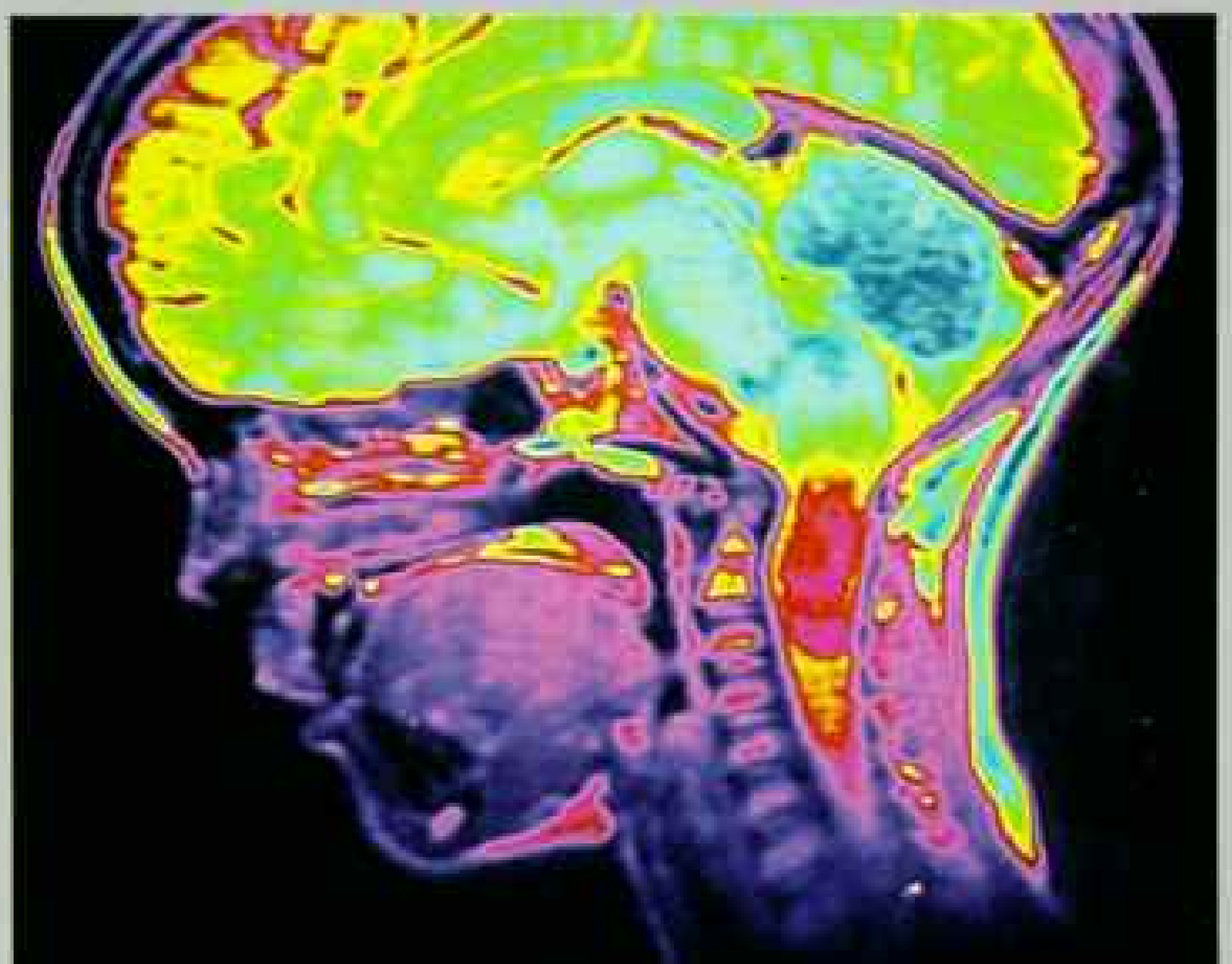
A leader in DSA and coronary angioplasty is Dr. P. Jeffrey Bower, who directs the Gulf South Heart Center in New Orleans, Louisiana. An energetic 51, he sometimes does as many as three 90-minute balloon angioplasties in a single day. We met at 7:30 a.m. in his second-floor hospital office.

"The perception by the public is that these procedures are life-threatening, and they are not. They are quick, painless, and there is no prolonged convalescence. With new catheters, new nontoxic agents, and entry through the arm instead of the leg, we will be able to do DSA on an outpatient basis."

Dr. Bower has a 92 percent success rate with angioplasty. About 5 percent of his patients still go on to have bypass surgery, often because the plaque buildup is of hardened, calcified material that cannot be pushed aside without applying so much pressure that it could rupture the vessel.

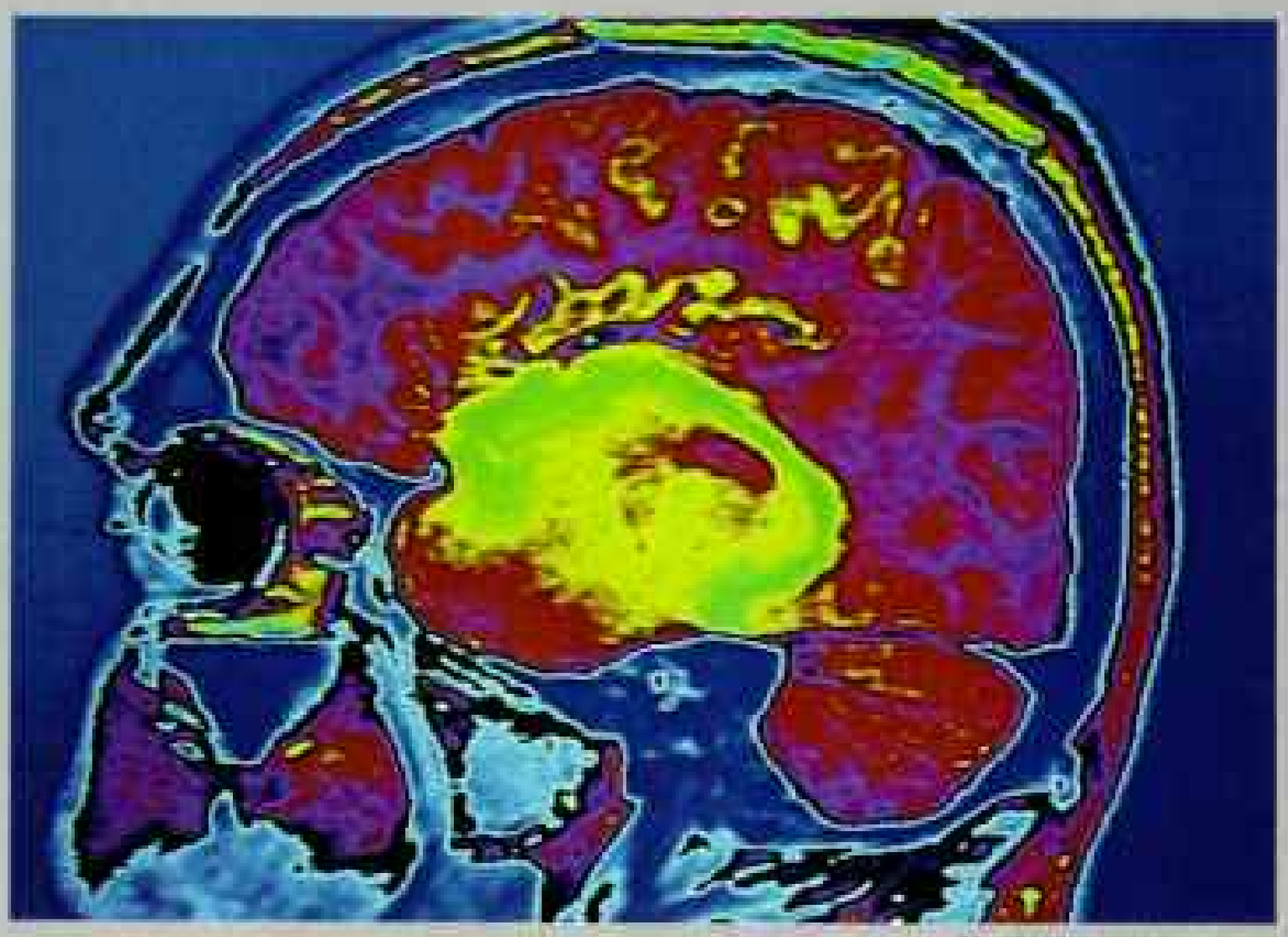
A staff of five cardiologists at the center performs more than





ST. JOSEPH'S HOSPITAL AND MEDICAL CENTER, PHOENIX

# MRI



ST. FRANCIS HOSPITAL, TULSA

***Without warning*** *one Sunday afternoon, Joe Silvers of Tulsa, Oklahoma, fell into a convulsion at his parents' home. "I don't even remember it happening," said Joe* (**bottom right**)*, who works in the garage of the Tulsa police department. A CT scan of Joe's brain showed what looked like a stroke. "But that didn't make sense at all," said Dr. David Fell, "especially in a healthy young man like Joe with no other neurological problems." The answer came in an MRI scan* (**top right**) *that showed a tumor (tinted yellow) surrounded by fluid-filled ventricles (green). Dr. Fell removed the tumor, and Joe has had no further trouble.*

*Six-year-old Nathan Tower, wearing a supportive halo cast* (**above left**)*, is alive today because of MRI scanning. When doctors in Reno, Nevada, diagnosed a brain-stem tumor, "they told us there was little hope," said his mother, Margaret Anne. But an MRI scan* (**left**) *convinced Dr. Harold L. Rekate of Phoenix, Arizona, that the tumor (shaded red) could be removed. "The MRI erased the bones around the spinal cord and showed the tumor clearly," said Dr. Rekate, who performed the operation. "Before MRI almost no one would have attempted it."*

300 angioplasties a year. In the 100,000 performed nationwide in 1985, there was only one percent mortality. This year the number of people helped could surpass 150,000, in some cases their very lives saved by DSA and balloon angioplasty.

Dr. Bower, who has a missionary enthusiasm for the procedures, urged me to talk to his patients.

I contacted James Quinn, age 63, a professor at Louisiana State University School of Dentistry (page 33). Dr. Quinn had seemed to do everything right: ran three miles a day, watched his cholesterol, was a nonsmoker and nondrinker of normal weight. His last treadmill stress test, in 1983, was normal, as was a nuclear heart scan the same year.

At 2 a.m. on January 9, 1986, he awoke to deep chest pains and arm numbness. At 2:30 a.m. his wife Judy called an ambulance that rushed him to the center. Dr. Bower saw him at 7 a.m., and by 9:30 the balloon catheter was inserted and dilated. Immediately it relieved a 100 percent blockage of the blood supply to a branch of the left coronary artery.

A week later Dr. Quinn repeated a treadmill test without chest pain. He has suffered no further heart damage. He has gone skiing, plays tennis regularly, and runs three miles a day again. The quality of his life has been restored.

Just as DSA helps in procedures to open up arteries, there are times when it is used in techniques for closing off blood supply to abnormal tissues or organs.

A leading practitioner of this application is Dr. Alex Berenstein, at New York University Medical Center in New York City. While serving his surgical internship in Israel in 1970, he became fascinated with the practice of drip irrigation used by Israeli farmers to conserve water in the desert. "Why can't this drop-by-drop method be applied in surgery?" he thought.

One day he applied a small amount of Gelfoam—a sealing gelatin sponge—to stop the bleeding in a patient's stomach. Guided by DSA equipment, he now uses catheters, some of his own design, to inject tiny drops of isobutyl-2-cyanoacrylate (a strong adhesive) and seal off the blood supply to growing tumors and to ruptured vessels. He has also used the technique in very delicate cases of brain hemorrhage.

## SONO

## Sonography

First snapshot for the family album, a picture made with ultrasound in the sixth month of pregnancy shows the face of a healthy fetus with mouth open in a yawn. "By this point the fetus does just about everything it will do after birth," said Dr. Christopher Merritt of New Orleans, who made the image. "It yawns, blinks, even sucks its thumb." Sonography lets us share these sneak previews by beaming high-frequency sound waves into the womb in short pulses. A computer translates the echoes that bounce back into an image of the fetus. The only body-scanning technique recommended for pregnant women, sonography is also well suited for examination of the breasts, heart, liver, and gall bladder.

SCHERER CLINIC, NEW ORLEANS

Of the five imaging techniques described in this story, none requires surgery. One of the simplest and cheapest uses ultrasound, an outgrowth of sonar development during World War II. The first good medical pictures were produced in the United States in the early 1950s. Today computerized display techniques team up with ultrasound to fill a vital niche in the doctor's black bag of imaging devices.

In this magical technique, known as sonography, a small transducer, or transmitter-receiver, is placed in contact with the area of the body being investigated. High-frequency sound waves penetrate the body, strike the organs within, and reflect back to the surface, where the transducer now functions as a receiver. The time delays of these returning signals sketch the

## SONO

**In trouble** *before birth, Joseph Ward was found to have a tumor growing in his throat that forced him to keep his mouth open inside the womb* **(right)**. *Another sonogram* **(above)** *displays a cross section of cheeks and rounded tongue, as seen from above, with the tumor, at right, pushing the tongue forward. Alarmed by the obstruction, Dr. Jason Birnholz of Rush Presbyterian St. Luke's Medical Center in Chicago asked a surgical team to stand by at Joseph's birth. When the baby failed to breathe, the team opened his breathing passage and saved his life. After diagnosis of the tumor was confirmed, the obstruction was removed, and Joseph, now almost three years old* **(right)**, *has gone on to bigger things.*

RUSH PRESBYTERIAN ST. LUKE'S MEDICAL CENTER (LEFT AND ABOVE)

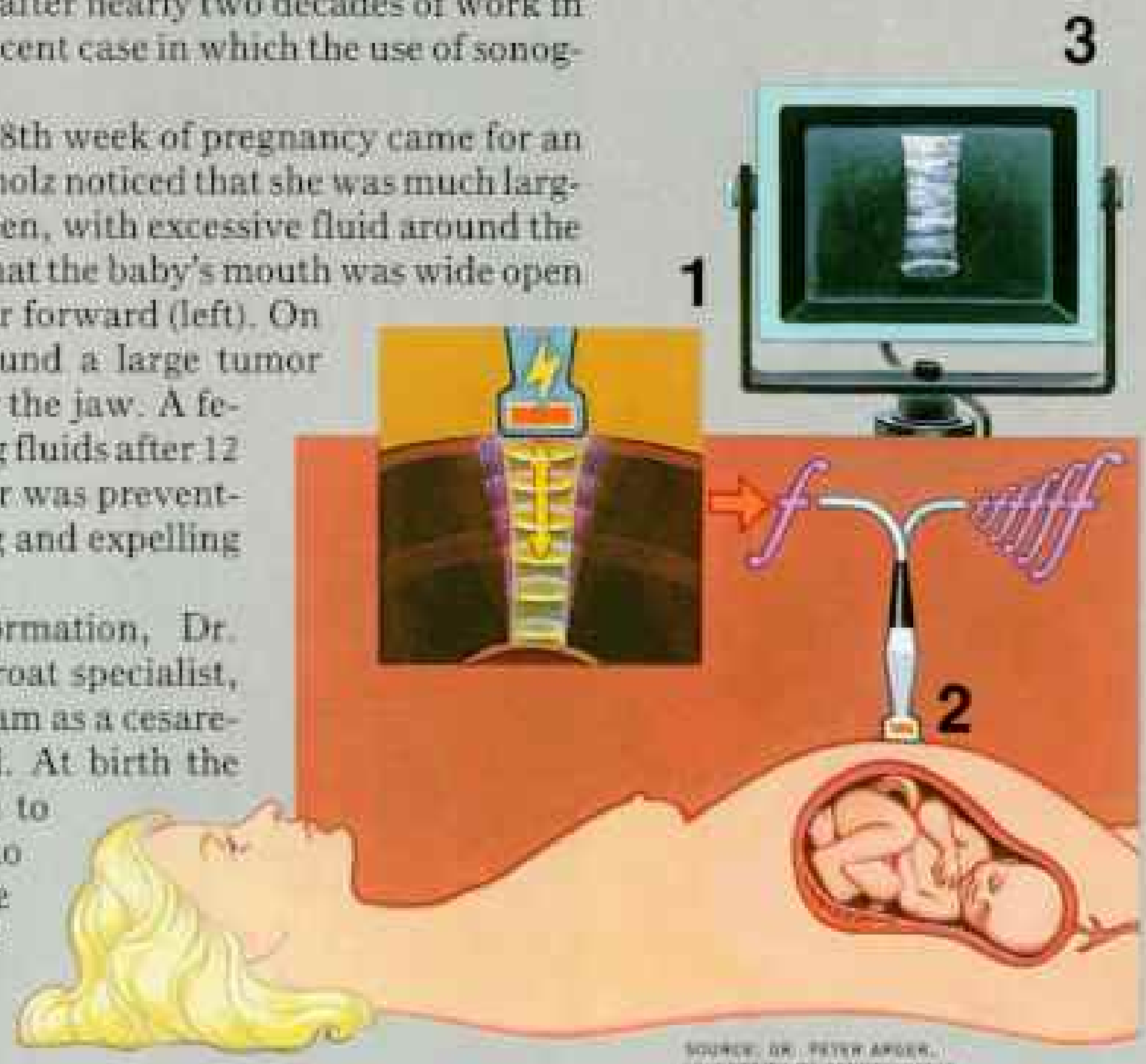
target's location, size, shape, even its texture, for display line by line on a screen.

One of the pioneers in sonography, first at Massachusetts General Hospital in Boston and now at Rush Presbyterian St. Luke's Medical Center in Chicago, is Dr. Jason Birnholz. Still bubbling with excitement after nearly two decades of work in the field, he told me of a recent case in which the use of sonography saved a life.

A schoolteacher in her 28th week of pregnancy came for an ultrasound scan. Dr. Birnholz noticed that she was much larger than she should have been, with excessive fluid around the baby. The scan revealed that the baby's mouth was wide open and its tongue stretched far forward (left). On closer investigation he found a large tumor growing in the neck under the jaw. A fetus commences swallowing fluids after 12 to 14 weeks, and the tumor was preventing the normal swallowing and expelling functions.

Armed with this information, Dr. Lauren D. Holinger, a throat specialist, stood by with a surgical team as a cesarean section was performed. At birth the child turned blue, unable to breathe. The team went into action to open up the breathing passage blocked by the tumor. Several days later Dr. Holinger removed the tumor.

Today Joseph Ward is a happy child who lives in Hazel Crest, Illinois. His life was saved by ultrasound.




SOURCE: DR. PETER ARGER, UNIVERSITY OF PENNSYLVANIA

***Probing painlessly,*** *sonography uses sound waves to look within. The heart of the system is a piezoelectric crystal* **1** *that converts electric pulses into vibrations that penetrate the body. These sound waves are reflected back to the crystal, which reconverts them into electric signals.*

*A doctor places a transducer containing a crystal* **2** *on the area to be scanned, such as the abdomen of a pregnant woman. Echoes from the fetus are translated into faint signals, which are processed by a computer into a video image* **3**.

The latest acquisition of the sonographer is digital color Doppler. With computer assistance it dramatically shows in picture form the flow and eddying of human blood as it courses through the heart, veins, and arteries. For this it harnesses the Doppler effect—the shift in the frequency of sound waves (or light waves or radio waves) produced by a moving object as it moves toward or away from a given point.

High-frequency sound waves penetrate the target area, a blood vessel, for instance. If the blood is flowing normally, the echoing sound resembles that of a gentle brook, and the image shows smooth flow. But if the blood flows through a narrow, irregular area, it produces a harsh sound, and the image shows uneven flow. This is how Doppler diagnosis detects a faulty valve or artery blockage that could cause a stroke.

After experiencing a nuclear heart scan in Houston, I was anxious for some comparative shopping—a look at my heart in color ultrasound. I visited Dr. Anthony DeMaria, chief of cardiology at the University of Kentucky Hospital in Lexington and a specialist in cardiac ultrasound.

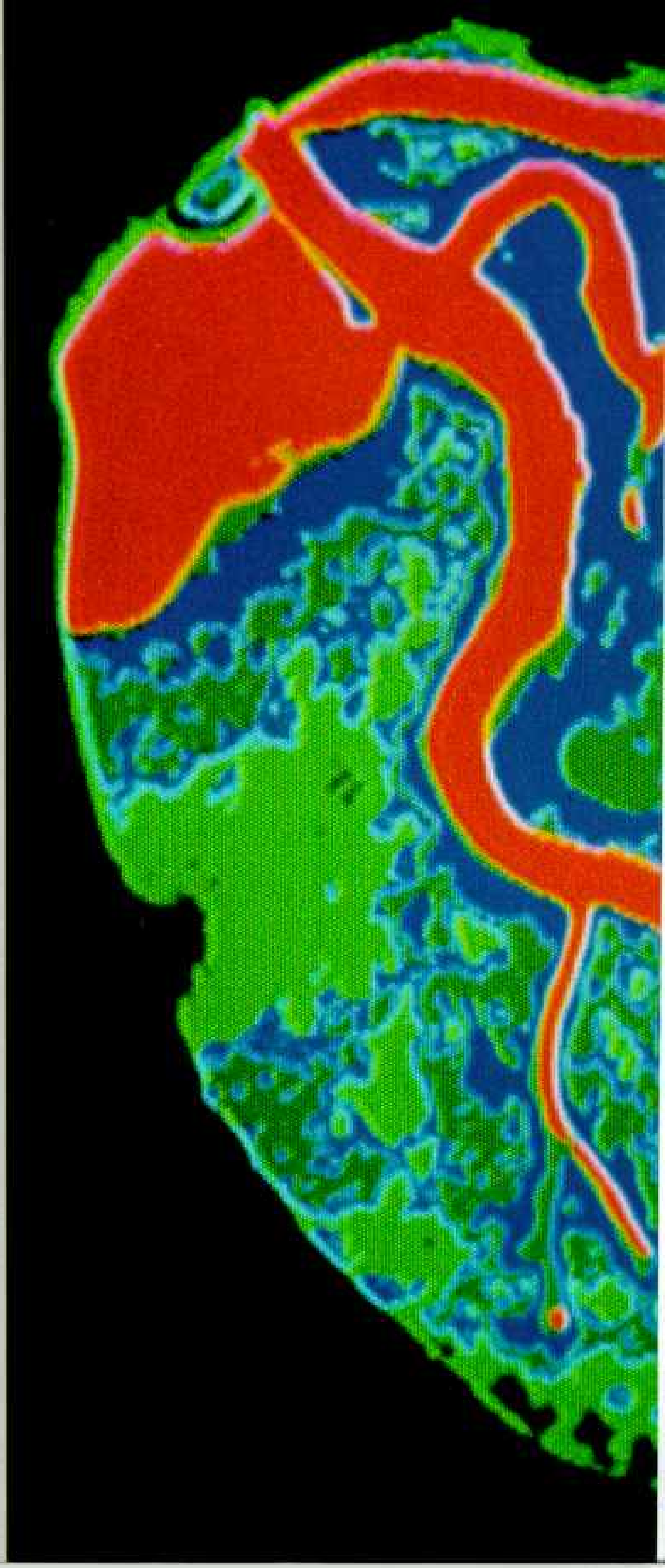
## DSA

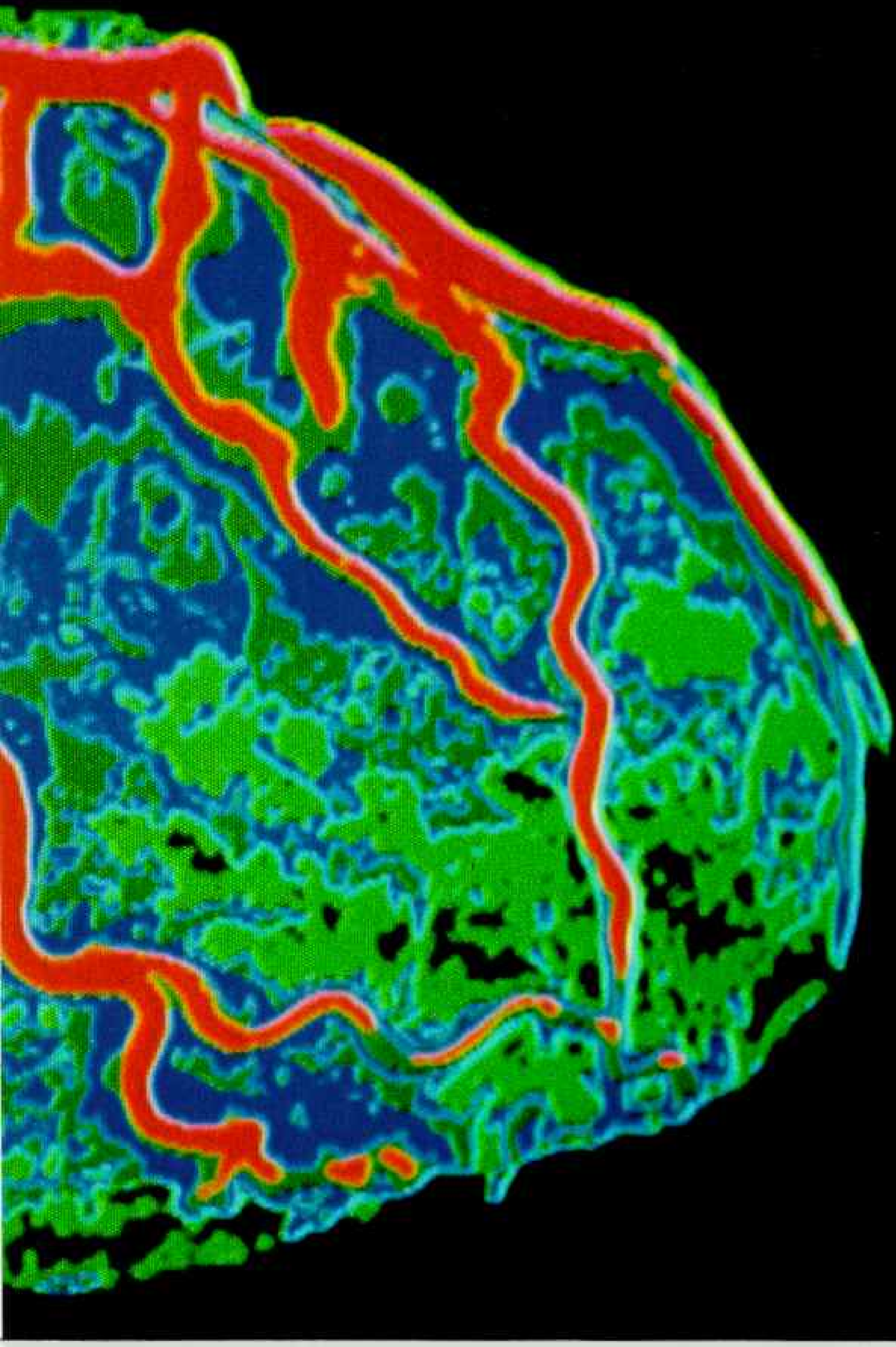
# Digital Subtraction Angiography

Life-giving blood vessels embrace the heart of a middle-aged man in this picture made by digital subtraction angiography (DSA). Filled with a substance opaque to X rays, the left coronary artery—bright red in this color-enhanced view—feeds a network of smaller vessels deep in the walls of the heart muscle. The red pool at left is the aorta root. A constriction in the coronary artery at top, appearing as a break, has choked off 60 percent of the blood supply to the lower part of the heart.

A computer measures the degree of constriction by converting the image into digital code and comparing it to others made from different angles. It also measures the rate at which blood diffuses into the heart muscle, giving doctors a good indication of whether or not a heart attack is likely to occur.

FISCHER IMAGING CORPORATION, DENVER





In a small cell-like room I removed my T-shirt and lay back on a semi-reclining bed. First Dr. DeMaria applied a jellylike balm on the skin above my heart. Then, placing the transducer in firm contact with my chest, he moved it in short, circular arcs. My throbbing, pulsing heart appeared in color on a monitor above me. Sound accompanied the sight. Enthralled, I heard and saw the butterfly action of the heart valves, the eddying of oxygen-rich blood upward through the aorta, the paler oxygen-poor blood flowing toward the lungs.

"My eyes are at my fingertips," Dr. DeMaria remarked as he pressed the transducer against my breast.

Sonography also assists in brain surgery. After the skull is opened (ultrasound cannot see through bone), the transducer is placed against the brain to locate soft-tissue tumors. Sometimes hard to see using other means, their distinctive tissue cannot hide from the sound waves, which portray the tumor's exact position and size.

## DSA

At Mallinckrodt Institute of Radiology in St. Louis, Dr. Klaus Sartor explained the problems of convincing neurosurgeons of the effectiveness of the new technology. Using an MRI scan, Dr. Sartor had detected a brain tumor in a male patient. A famous surgeon, armed with the film, opened the brain of the patient. During the operation, he paused to call Dr. Sartor.

"There is no evidence of a tumor in the area indicated on the scan," he insisted. Usually tumors have a different color or

***Two-for-one scanner,*** *the digital biplane angioscope at East Jefferson General Hospital in New Orleans provides views of the heart from two different angles. Laboratory supervisor Rich Becerra takes the role of patient by lying between the two X-ray tubes, while Dr. P. Jeffrey Bower, nurse Londa Hathaway, and technician Eve Rehkopf stand at the console. A screen can present four images, two live views of the heart, one digital recorded picture, and a display—here dark—of physiological data.*

texture from healthy surrounding tissue and are easily distinguished by the brain surgeon. In this case the experienced eye could detect nothing.

Dr. Sartor insisted on the accuracy of his MRI scan and suggested a biopsy, or evaluation, of the area indicated.

The report came back from the lab confirming the presence of a tumor in the exact area the MRI had indicated, and the surgeon immediately excised it. Machine vision had given information that the eye of a highly skilled brain surgeon could not provide.

The time had come to subject myself to an MRI scan. It was late in the evening after the last patient had left the Long Island Diagnostic Imaging Center. Nancy Ryan, the receptionist, gave me a patient-history form and a list of items forbidden in the test room, including surgical clips as well as dentures and metallic implants.

The center's magnetic machine, a General Electric Signa unit, weighs 15 tons and is supercooled with liquid helium to minus 452 degrees F. It cost 1.8 million dollars plus installation and incurs an $18,000 monthly bill for electricity and other costs. An average of ten patients a day undergo scanning, which takes about 45 minutes and costs $800.

I left my shirt, tie, and trousers on but removed my watch, belt, and ring. "Why be scanned if there is nothing wrong with you?" asked Bill Seuffert, the technician. "I wouldn't. They might find something."

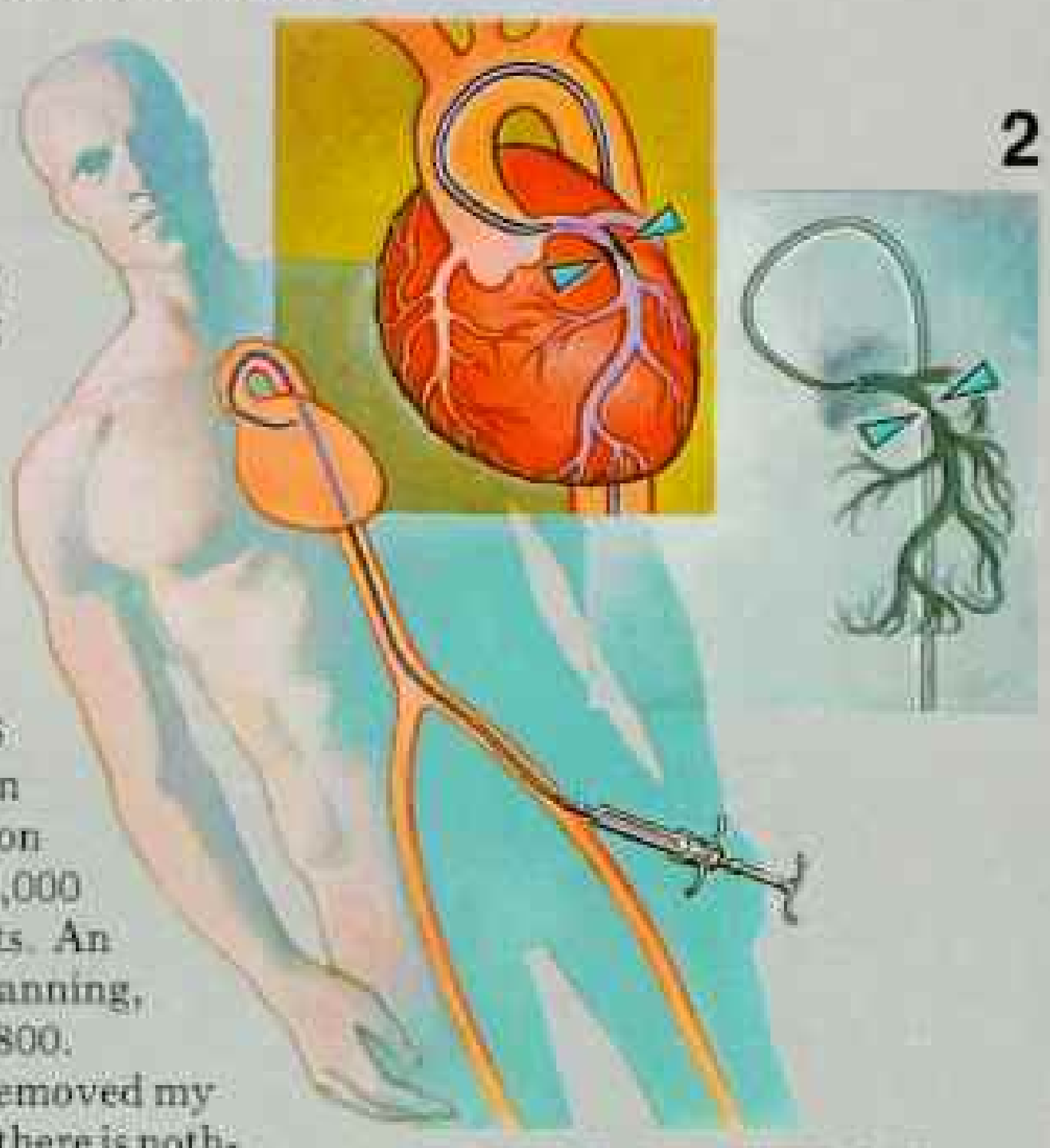
He had a point, of sorts. At the General Electric manufacturing and training center in Waukesha, Wisconsin, a young trainee who volunteered to be scanned was amazed to find he had a huge brain tumor. His only symptom had been occasional headaches. He is now debating what should be done. On checking, I found that it is not uncommon for people to live with brain tumors that have little, if any, effect.

I lay down on a table, head slightly raised, and was rolled into the tunnel-like magnet, about 36 inches in diameter. A laser beam located the midline of my brain. Bill Seuffert, in the control center, said over the intercom that he would do a cross-sectional scan of my midbrain.

For a minute I heard what seemed to be the tapping of a hundred hammers—the clatter of magnetic coils as Bill set up the correct frequencies for the highest image definition.

A brief lull, and then the tapping of hammers began again—this time in earnest. As time passed within the magnetic field, my skin tightened, and I felt the older fillings in my teeth tingle and grow warm.

In two and a half minutes the scan was done. Had this been a full-scale search instead of a demonstration, there would have




SOURCE: DR. JOHN W. HUSHFIELD, JR. AND DR. GORDON K. MILLAR, UNIVERSITY OF PENNSYLVANIA

***Less is more*** *with the wizardry of DSA, which removes everything from an image except what a doctor wants to examine. First a picture of the heart is made by a digital X-ray scanner. Next, as a contrast agent is injected through a catheter into the coronary arteries* **1**, *a second X-ray image is made showing the agent flowing through the heart's vessels. A computer subtracts the first image from the second, leaving only what has changed—blood vessels containing the agent* **2**—*and highlighting a blockage (arrows). DSA is only one application of the expanding field of computed angiography.*

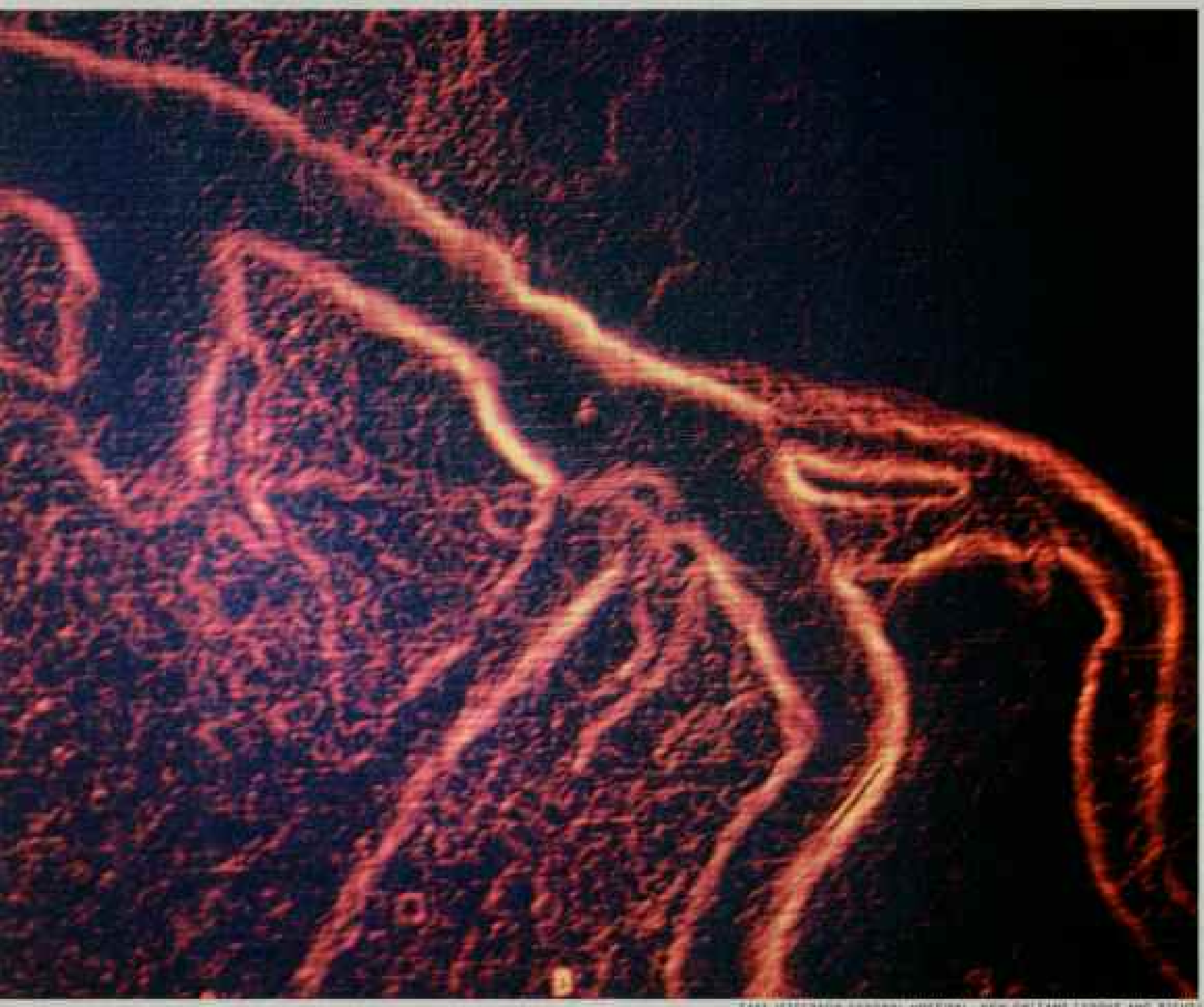
been ten or eleven additional scans, spaced to cover the entire depth of my head.

After the scan I got up from the table and walked to the control room, feeling fine. Already displayed on a monitor was the cross-sectional view of my brain. It showed no tumor or other abnormalities.

The diagnostic success of this tool is revealed by the explosive growth in the number of installations. General Electric, with about 40 percent of the market, shipped 15 MRI units in 1984. By the end of 1986 it had sold 230 worldwide.

The importance of the computer in medical diagnosis becomes evident in the new life it gives to the art of computed tomography, known as CT. Developed about 15 years ago, the technique employs a spinning X-ray tube on a yoke that allows 360-degree rotation. Today's computers, using CT images, produce detailed views of soft tissue—the brain or heart—in three dimensions.

In a typical CT scan, hundreds of crystal-chip detectors coated with cesium iodide move in an arc with the X-ray tube to examine salami-thin slices of body width. The detectors



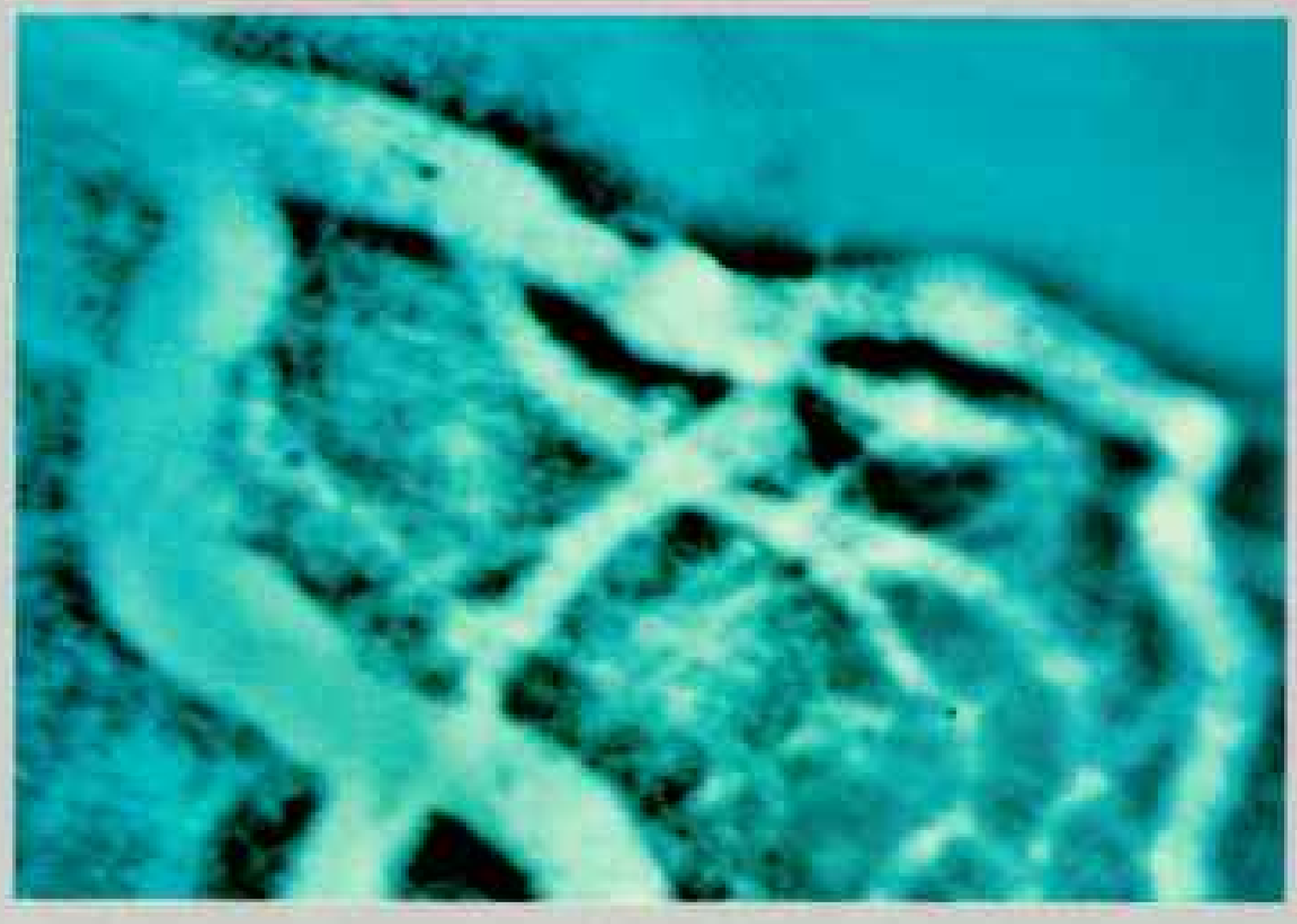
EAST JEFFERSON GENERAL HOSPITAL, NEW ORLEANS (ABOVE AND RIGHT)

deliver their information to a digital computer for display on a screen. With the computer's capacity to manage information, CT can zoom into and scan the anatomy, yielding vivid and precise 3-D views.

A single scan takes less than two seconds, and radiation dosages for a standard series of 12 images are less than that of some X rays. CT is cheaper than MRI, the average procedure costing about $500.

One of the most exciting applications of three-dimensional CT imaging is in the field of reconstructive surgery. In Palo Alto, California, I talked to Dr. Steven Woolson, who does orthopedic surgery. He introduced me to his patient, My Tien Tran, a young Vietnamese woman who was evacuated from Saigon the day before it fell to the Communists. For years My Tien had suffered severe pain from a congenital dislocation of her right hip (page 12). She had walked on crutches most of her life, and her right leg was three inches shorter than the left.

A series of CT scans of the hip and pelvis persuaded Dr. Woolson to do a total hip replacement. Aided by a milling machine and using CT data, CEMAX, Inc., in Santa Clara, California, made plastic *(Continued on page 39)*



## DSA

*"Exercise saved my life," says Dr. James Quinn (**above right**) of New Orleans, who for several days in 1986 felt a tightness in his chest during his daily three-mile run. "Then zap, one night I had this pain," he says. It was a major heart attack.*

*Made by digital subtraction angiography, a color-enhanced close-up picture of his left coronary artery (**left**) shows one branch, at far left, to be totally blocked. A blood clot stopped the flow of blood when it lodged against a deposit of plaque. Enlarged by exercise, his other arteries enabled him to survive the heart attack.*

*To remove the clot, Dr. Jeffrey Bower threaded a catheter into the heart through a blood vessel in the groin—watching its progress on a digital angiography unit—and injected a dissolving agent at the point of blockage. To open the artery further, he inserted a second catheter, fitted with a small balloon, through the first. Gently inflating the balloon, he compressed the plaque against the wall of the artery, slightly stretching its lining. A follow-up image (**above left**) shows the branch completely open again.*

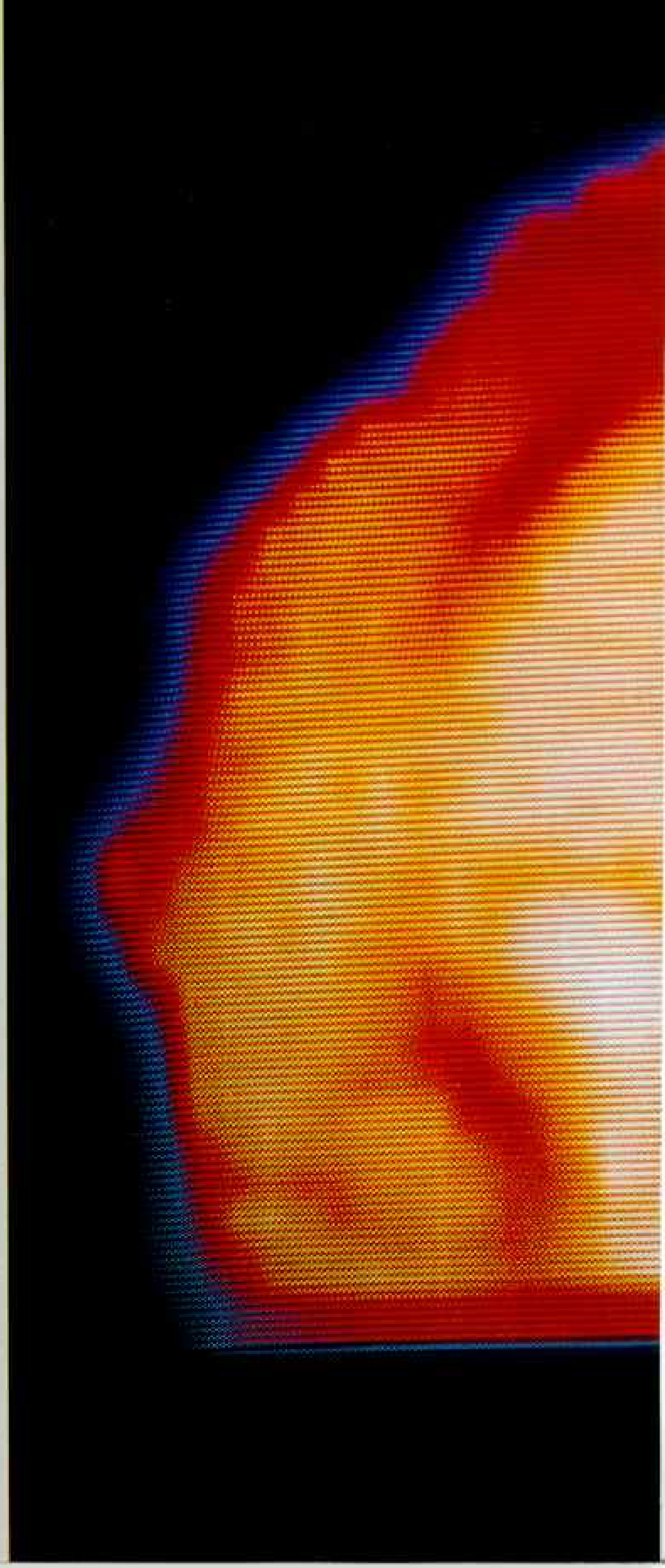
## PET/SPECT

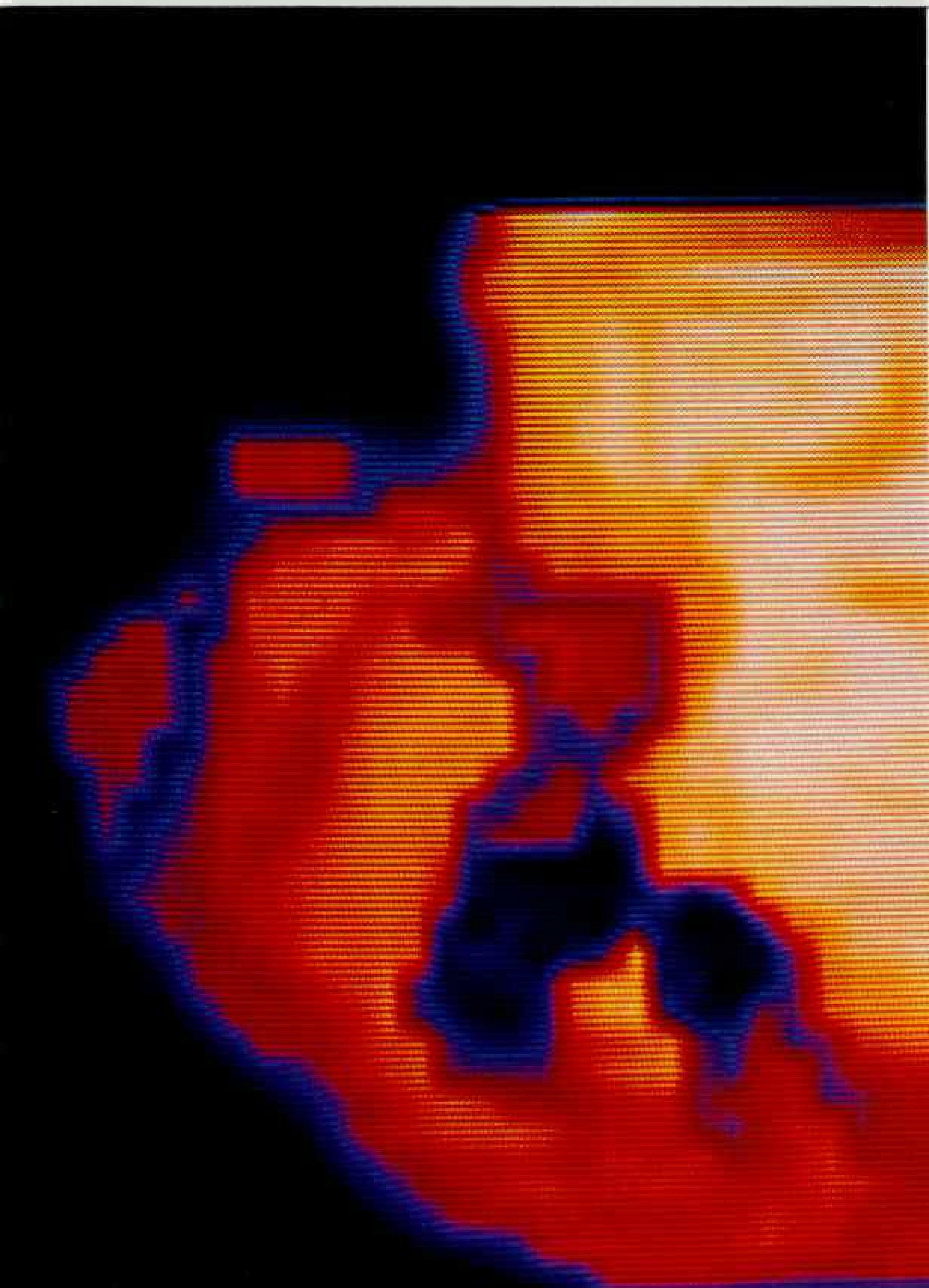
# Radioisotope Imaging

Picture of confusion, an image made by single photon emission computed tomography (SPECT) shows a patch of darkness in the brain of a 57-year-old man. Reflecting a decrease in blood flow to the parietal lobes — where sensations from the eyes and ears are associated with memory — the darkness symbolizes the agony of Alzheimer's disease.

SPECT shows blood flow by imaging trace amounts of radioisotopes. A more versatile technique, positron emission tomography (PET), can also measure metabolism, revealing how well the body is working. The use of radioactive tracers is well suited to studies of epilepsy, schizophrenia, Parkinson's disease, and stroke.

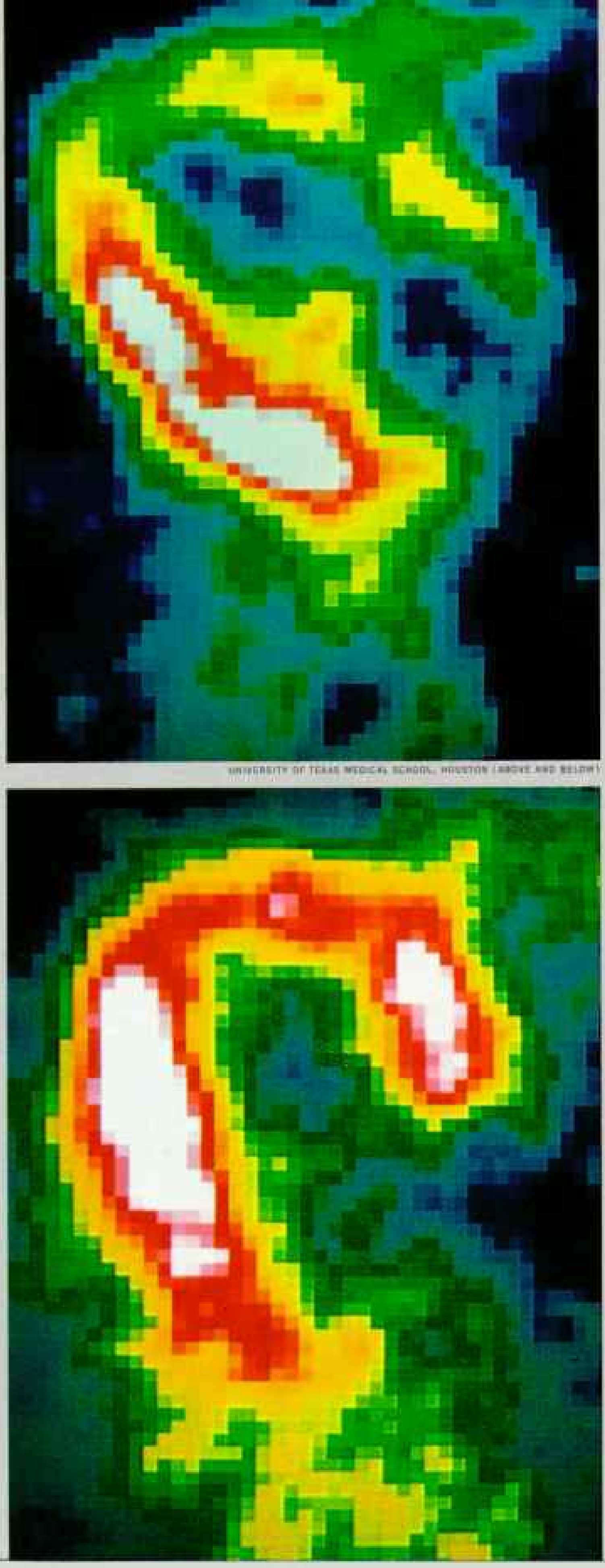
BRIGHAM AND WOMEN'S HOSPITAL, BOSTON





# PET/SPECT

***In the doughnut hole*** *of a PET scanner, a patient* ***(below)*** *squeezes a hand grip that helps stimulate the heart during a stress test. The PET scanner, at the University of Texas in Houston, images trace amounts of radioisotopes in the heart to determine whether or not muscle tissues are receiving a normal supply of blood. Electrodes on the*



UNIVERSITY OF TEXAS MEDICAL SCHOOL, HOUSTON (ABOVE AND BELOW)

*chest record an electrocardiogram monitored by research nurse Mary Haynie.*

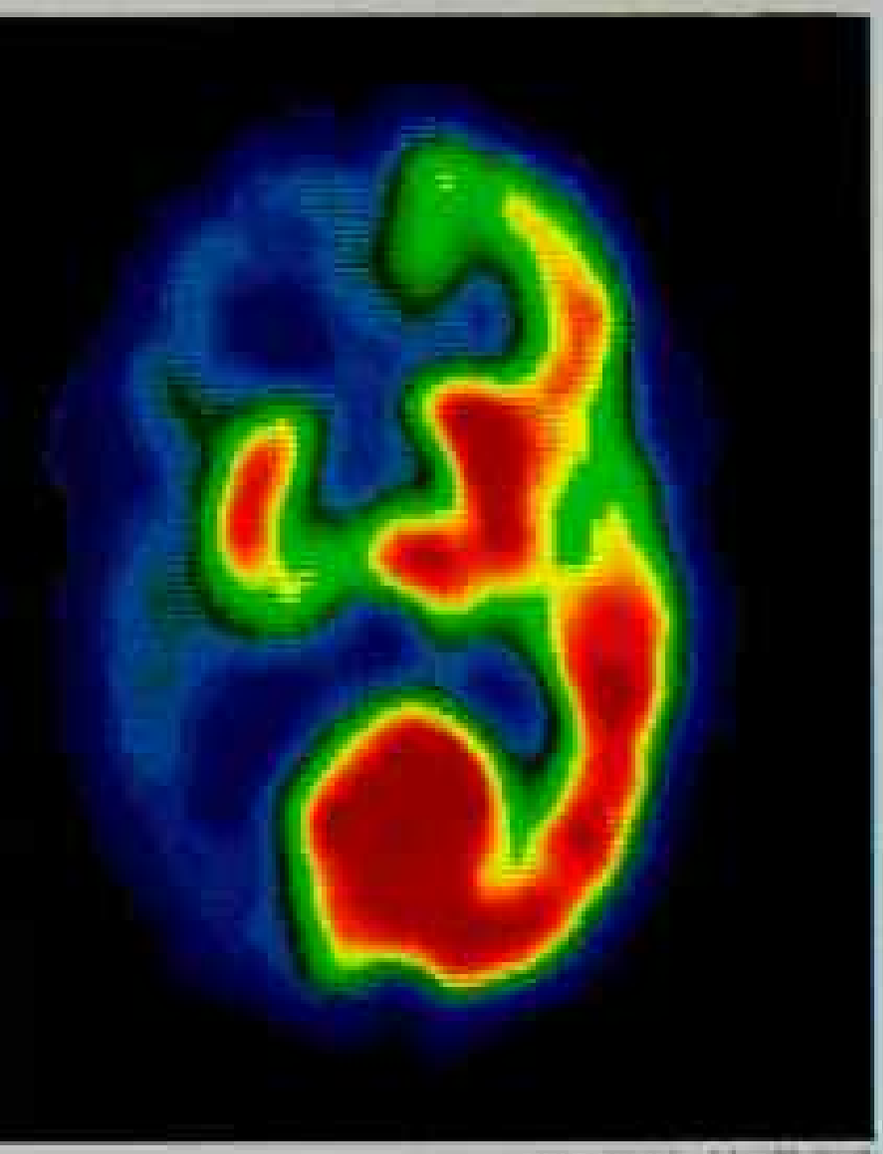
*Glowing brightly on a video screen, a PET image from another person shows a normal blood supply in a heart without stress (**facing page, bottom**). White, orange, and yellow areas show the walls of the left ventricle—as seen from above—absorbing a radioisotope, N-13 ammonia, from the blood. Both PET and SPECT depict the distribution of blood into tissue, but PET does so with greater accuracy.*

*A second PET image, showing the same heart under stress (**facing page, top**) reveals a problem in the blood supply to the ventricle's wall in the upper half of the picture. Stress was induced by an injection of dipyridamole, which simulates exercise by boosting blood flow to healthy muscle tissues. The increased flow, however, is blocked by an artery with a constriction.*

*In the unstressed heart the scanner shows white and orange where absorption of the radioisotope is greatest. But in the heart under stress there is only yellow in its upper half, indicating a partial blockage in the coronary artery feeding that part of the heart. Left untreated, this defect may eventually cause a heart attack. Detected by the PET scanner, it could be prevented.*

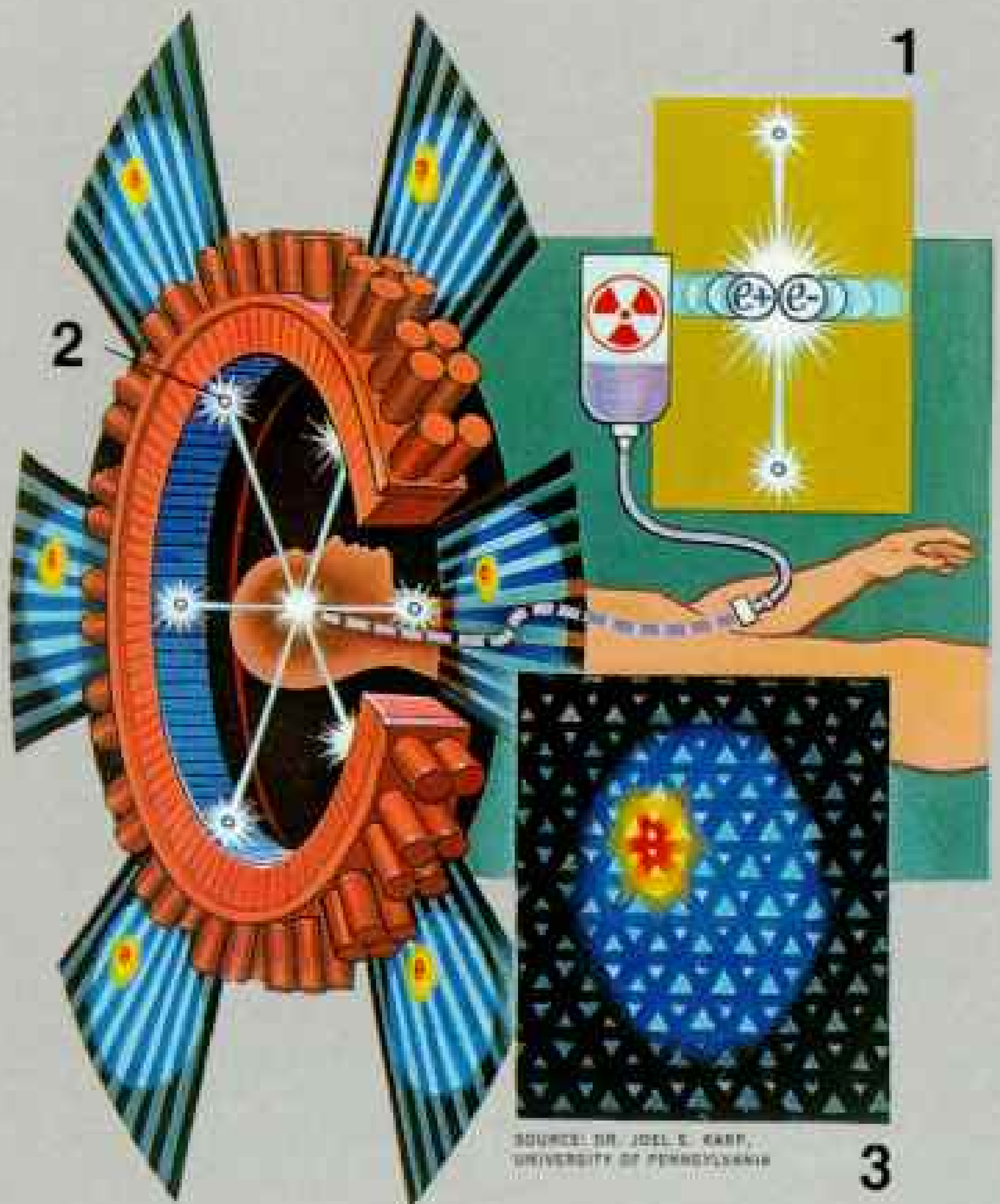


## PET/SPECT



UCLA SCHOOL OF MEDICINE

**Gaining strength** *every day, two-year-old Ryan Petersen of Great Falls, Virginia, was given little chance of surviving childhood. Unable to find a cause for the seizures he had suffered since birth, his doctors had given Ryan's parents little hope. Then while Ryan was visiting his grandparents in southern California, his seizures worsened. His parents took him to the UCLA Medical Center, where a PET scan* (**above**) *showed normal activity in the right hemisphere of his brain (red, yellow, green) but only minimal activity in his left (purple). After surgery that removed most of the left hemisphere, Ryan works with physical therapist Francie Mitchell* (**right**) *to improve control of his muscles.*




***To spy on the brain** in action, PET scanners watch the way brain cells consume substances such as sugar. The substance is tagged with a radioisotope brewed in a small, low-energy cyclotron. The isotope has a short half-life, meaning that it loses half of its radioactivity within only minutes or hours of being created. Injected into the body, the radioactive solution emits positrons wherever it flows.*

*The positrons collide with electrons, and the two annihilate one another, releasing a burst of energy in the form of two gamma rays. These rays shoot in opposite directions* **1** *and strike crystals in a ring of detectors* **2** *around the patient's head, causing the crystals to light up. A computer records the location of each flash and plots the source of radiation, translating that data into an image* **3**.

*By tracing the radioactive substance, a doctor can pinpoint areas of abnormal brain activity or determine the health of cells.*

*Unlike PET, which generally requires a cyclotron on site, SPECT uses commercially available radioisotopes, greatly reducing the cost of operation.*

*(Continued from page 33)* models of the hip-joint bones. With these models Dr. Woolson performed a rehearsal surgery to determine the precise size of the replacement parts and necessary bone grafts. Then came the surgery itself, with the use of the model bones as templates. Today My Tien's legs are of nearly equal length; she walks normally and has no hip pain.

A major center for research in three-dimensional CT imaging is at the University of Kansas Medical Center in Kansas City. There Dr. Larry T. Cook along with Dr. Sol Batnitzky and Dr. Kyo Rak Lee have developed computer software and color images that are unique in the field of medicine.

A recent challenge involved Dr. Cook and a most delicate eye operation. Another colleague at the university, Dr. Shankar Giri, had a patient with a tumor that had wrapped itself around the optic nerve of the right eye. Double vision resulted. In the extremely difficult area of the optic nerve, a small tremor of the surgeon's knife could cause irrevocable blindness. Surgery was ruled out. Only radiation therapy could help, but that too was risky.

Dr. Giri, working from 20 CT scans, prepared the delicate treatment plan: cobalt in two carefully controlled beams of two minutes' duration, given for five weeks.

The treatment diminished the tumor, and normal vision was restored. The patient moved to California's Sierra Nevada and has not been heard from since.

The marriage of the computer and medical imaging devices is already bearing fruit. It holds tremendous promise for the future. "In medicine, as in our society, we have embarked on a scientific revolution unlike any other in man's history," said Dr. Steven Nissen, a cardiologist at the University of Kentucky Medical School.

A growing number of young, dynamic doctors hold Ph.D.'s in physics or computer science along with their M.D.'s. And the burgeoning technology of computer graphics is being harnessed to transform the torrents of machine-vision data into meaningful diagnostic displays.

What directions will discoveries in diagnostic imaging take? During the nine months of my investigation, I asked this question of scores of physicists, physicians, and surgeons. Their answers confirmed that in the past they often had to wait for a disease to manifest itself, as a tumor, say, or a heart defect.

But diseases usually manifest themselves chemically before there is an anatomical change. In the future, MRI may be able to reveal such chemical changes by making images with elements such as phosphorus or sodium, as well as with hydrogen. By analyzing the amount of phosphorus in the heart, for example, physicians could determine at an early stage whether or not the muscle tissue was being starved of nourishment by a clogged artery. Future research may perfect methods of tagging cloned antibodies with a magnetically traceable element and using them as scouts in the body to search out cancerous tumors. Getting an MRI scan may someday become as common as getting an X ray.

How often while preparing this story did I hear: "I couldn't have saved this patient ten years ago." Because of the computer and the new tools of machine vision, many more lives will be saved in the years to come, and the quality of all our lives will be improved. □

HARVARD MEDICAL SCHOOL (RIGHT)

***The whole body*** *is captured in a bone scan made with radioisotope tracers (**facing page**). Created by a gamma camera, the image depicts emissions of gamma rays from a phosphate tagged with technetium-99m, a low-level radioactive material. Injected into the blood stream, the phosphate comes to rest mainly in bones, producing a comprehensive view of the skeletal system. Doctors made the picture to determine whether or not cancer had spread into the bones of a 56-year-old woman from a tumor in her breast. It had not.*

*Bringing together many views of a single patient, Dr. H. K. Huang of UCLA (**right**) shows Dr. Hooshang Kangarloo six images made by various scanning devices, each retrieved from a central computer bank. Among the first of its kind, the system demonstrates the type of ongoing innovation giving new eyes to medicine.*

# A Worldly Wilderness CALIFORNIA

By BARRY LOPEZ

AFTERNOON STORM CLOUDS SHADOW DEATH VALLEY IN A LANDSCAPE THAT HUMBLES HUMAN SCALE.

# DESERT

*This gaunt land celebrates the splendor of isolation. But human presence can compromise its integrity.*

Photographs by CRAIG AURNESS WEST LIGHT

*Incandescent graffiti of vehicle lights obscure the Imperial Sand Dunes near Glamis, where a holiday-weekend crowd numbers 40,000.*

*Other dunes are off-limits. Desert soils scar easily; damage caused by a few passes of an off-highway vehicle may last a century or more.*

*Conjured by temperate, well-spaced winter rains, coreopsis and poppies provide an ephemeral show in Antelope Valley. Unlike*

*cactus and ocotillo, which can survive drought, these species simply avoid it, germinating only under favorable conditions.*

*Hunting the wind, board sailors prepare for a competition on a pond used to replenish groundwater for the Coachella Valley.*

*Wind turbines—some of the more than 4,000 in this area—generate electricity for Southern California Edison.*

IT IS AN HOUR now since the sun has risen. I've been sitting here, 700 feet up on the crest of a sand dune, watching a soft, vaporous light fill Eureka Valley. The Eureka dunes rise at the southern end of this huge, quiet basin, beneath a jagged line of gray-blue and magenta mountains called the Last Chance Range. The cloudless dawn sky towers, intensifying a feeling of unbounded space.

The mountains that rim this valley, streaked with ocherous beiges and paprika reds, appear barren, but they are full of plants and animals that merely elude the eye. A pocket mouse the size of a walnut. A desert tortoise asleep in its burrow. Evening-snow, a wispy-stemmed plant that remains invisible against the ground until its white flowers open suddenly at nightfall.

A morning fog that earlier clung to the dunes has dissipated. The twittering of sage sparrows on the desert floor below, no longer muffled by the thick air, now drifts up. The air on this fall morning is not moist enough to also bring with it the odor of creosote bush and bur sage from below, but I can trace an unbroken line down the perfect French curve of the dune, out across the broad pastel strokes of the basin and into the mountains. I can get the feel of this land *that* way. The Saline Range, five miles to the west, is as crisp to my eye as the feather-stitching of beetle tracks in the sand by my hip. This near and far clarity of the valley tightens up the vastness—the land seems simultaneously remote and immediate.

It is as restful as a calm ocean, seen from the shore dunes.

Eureka Valley sits at the northern edge of the California Desert—technically speaking, those sections of the Mojave and Sonoran Deserts within the state's boundaries. The Mojave is a relatively cool, high desert, where snow falls in winter; the Sonoran, lying at a lower elevation to the south, is drier, hotter, and more extensive than the Mojave. (The Sonoran Desert includes the Colorado Desert, comprising the Imperial and Coachella Valleys, and the much smaller Yuha Desert southwest of the Imperial Valley.) Rainfall in both the high and the low desert is usually short and violent, and so undependable both as to time and place as to seem to have no pattern. Its lack, along with the sun's heat and light and erratic and fitful desert winds, sets a general limit on life here.

The California Desert is less arid, however, than Old World deserts like the Gobi and the Sahara. Also by comparison, the range of its plants and animals, many with a seeming genius for locating or retaining water, is stunning. As is its variety of habitats—hot springs, saline sinks, cool, foliated canyons, sun-blasted bajadas, sand-dune systems, perennial streams, and Joshua tree "forests." After a winter of moderate but well-spaced rains, wildflowers may rise like fragrant breath from the earth—carpets of blue lupines, white primroses, yellow marigolds, and purple sand verbena. In Lanfair Valley in the eastern Mojave blue grama grass, Indian ricegrass, and big galleta grass roll under the press of the wind like Kansas wheat.

GEOFF MANASSE

***Desert diary:*** *A salt pan records the footprints (**facing page**) of wildlife that passed this way—probably a jackrabbit, at right, and a coyote. The desert is also host to more than 265 species of birds, including the burrowing owl (**above**). This land rewards stillness. "The faster the eye is moving," says the author, "the fewer things it will see."*

The beauty of the California Desert lies more with its exotic character than with its landforms. The very subtle shading of its soils, pale greens fading into lavenders. The thick, velvet darkness of its midnight canyons. The tremulous voice of an elf owl at a fan palm oasis in the stone fastness of the Chuckwalla Mountains. The way saffron


# CALIFORNIA DESERT

## Population pressures on a fragile world

***Backdoor** to Los Angeles and San Diego, metropolises with a combined population of 15 million, the California Desert attracts weekenders who barrel down interstates, riding or towing off-highway vehicles.*

*To ensure that use does not jeopardize conservation, Congress, in 1976, directed the Bureau of Land*

*National Geographic, January 1987*


*Management (BLM) to formulate a program—the California Desert Conservation Area Plan—to guide recreational use while accommodating, to an extent, ranchers, miners, and the military.*

*The desert encompasses parts of the relatively cool, high Mojave and the lower, hotter Sonoran Desert.*

light vibrates over the white surface of a playa at sunset.

It is a land as open to the eye as the surface of the moon.

IT WOULD BE STRANGE, of course, if others didn't see the desert differently. For many it is not a place of hushed and intricate beauty, but a dreary stretch of wasteland between Las Vegas and Los Angeles. A vacant lot awaiting development. "There's nothing important out there," a driver told me at the start of the Barstow to Vegas motorcycle race, yelling over the racket of his engine. "We're the ones making something useful out of it, putting this race on."

The desert's usefulness is thought to lie, variously, with its considerable mineral wealth—borates, gypsum, gold—and its strategic reserves of molybdenum, tungsten, and lanthanides. Or with its dependably clear, sunny weather, eminently suited to the testing of missiles and aircraft. Or with its reservoirs of alternative energy—sunlight, wind, and hot groundwater. Or with its capacity to serve as an unfenced recreation area for a burgeoning population eager to escape the congestion and foul air of large cities.

These differing views of how best to use the desert were first brought into sharp focus early in the 1970s—with an explosion in the sale of off-highway vehicles. Interstates 8, 10, and 15 and California 14, the major routes into the desert from the populated coast, were now jammed on Friday nights with motor homes and recreation vehicles. Some pulled trailers full of equipment: gyrocopters, land yachts, ultralights, motocross bikes, and dune buggies. Once lonely places like Jawbone Canyon and Johnson Valley in the western Mojave were suddenly full of noise, dust, and people.

Ostensibly much of the initial disagreement over desert use was between vehicle operators and wilderness advocates, or between desert cattle ranchers and environmentalists. But real differences of opinion were more broad based. People living

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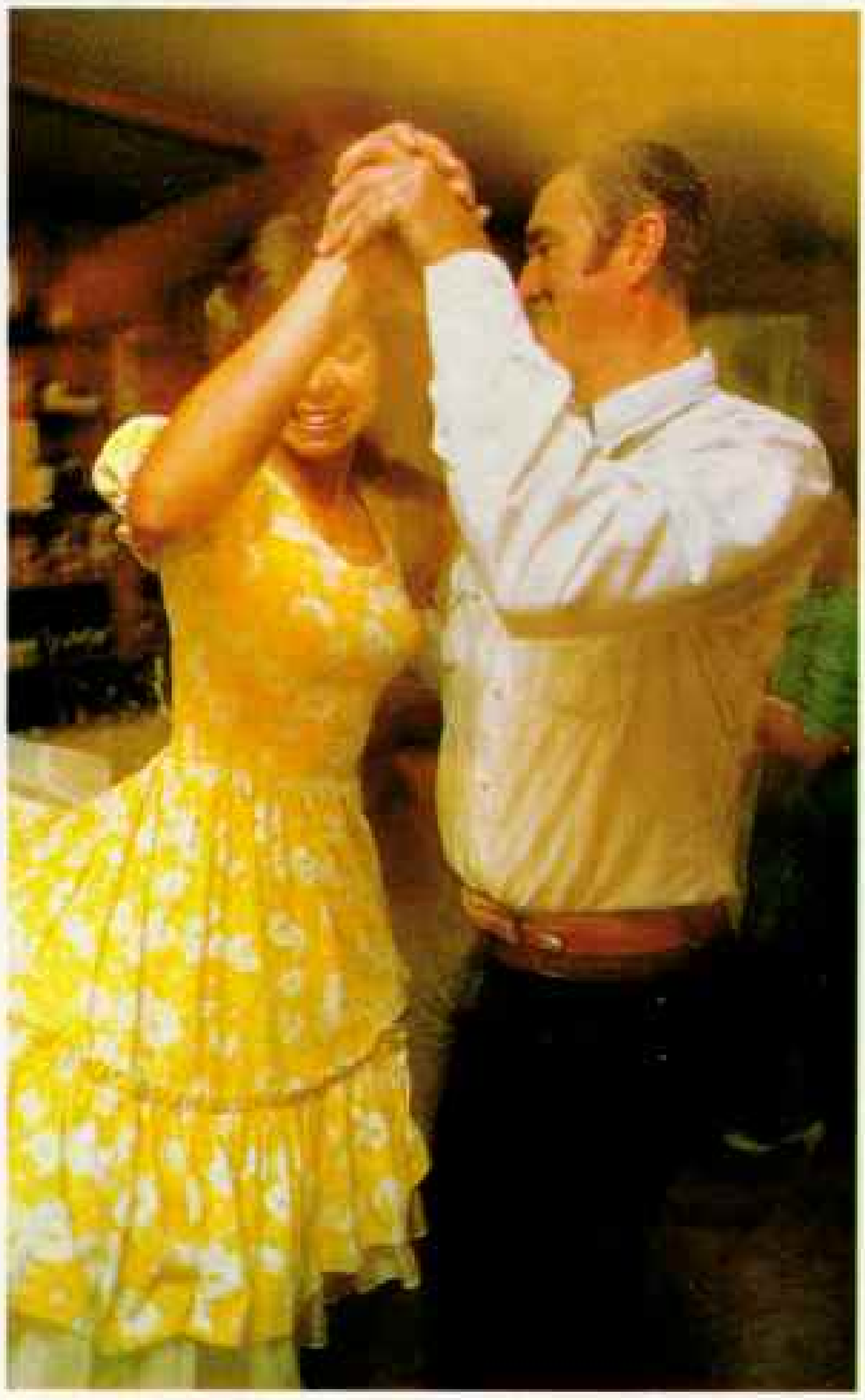
**Barry Lopez** is the author of *Arctic Dreams* and *Desert Notes*. **Craig Aurness**'s photographs have illustrated GEOGRAPHIC articles ranging from the Pony Express to troubled Mono Lake.



***Night out on the town*** *of Goffs (population 19) comes Thursdays, when the general store throws a square dance attended by ranchers from as far as Newberry Springs, a 100-mile drive away. Here Rob and Kate Blair step out* ***(above right)****. Square-dance dress preferred, please. "I once forgot my petticoats and was fined two dollars," says store co-owner Connie Swain.*

*"I go to Goffs, too, but I'm the barroom dancing type," says Tim Overson* ***(above left)****, who works on the 345,000-acre Valley View Ranch in the eastern Mojave. He takes a breather from a day that begins at 4 a.m. and may run till six that night.*

*Cap, gown, and sneakers is dress for at least one kindergarten graduate of Essex's one-room elementary school* ***(left)****. Teacher Mary Howard's daughter, Kathryn, at far left, played piano for commencement; she's a fourth grader. Mrs. Howard, who teaches all grades, attended Essex too. Her mother was the teacher then. Essex graduates attend high school in Needles, 40 miles distant.*


permanently in small, scattered communities in the desert didn't care for visitors running roughshod over the land on weekends, target shooting at isolated stock tanks and leaving piles of litter behind. Other visitors, those who had long regarded the desert as a sort of shopping mall for ironwood, pet tortoises and tarantulas, arrowheads, and barrel cactus, found themselves at odds with people who felt that public land should now be protected from such illegal poaching. Archaeologists were distraught over an increase in vandalism and theft at historic and prehistoric sites in the desert.

Clearly, an overall plan for managing recreation and other desert activities was needed. In 1976 Congress ordered the Bureau of Land Management (BLM) to come up with one. (Roughly 72 percent of the California Desert's 25 million acres is federally owned.) Four years and more than a hundred public meetings later, a final version of the California Desert Conservation Area Plan was drawn up, and its provisions now constitute a guide for desert managers' decisions. The meaning and intent of the plan in specific instances is still being interpreted, so special interest groups—power companies, ranchers, miners, cross-country motorcycle racers, scientists, educators,

***A wink of neon in the night,*** *Brady's Cafe on Highway 395 near Inyokern has sold food and gas to travelers pushing out into the desert since 1938. "We're even on the maps the service stations give out," says owner Harvey Welft. The Mobil flying-horse sign, a collector's item, is one of a few still in use.*

and the military—continue to press for interpretations and amendments that will favor their ends.

By all accounts the BLM has done a commendable, even heroic job of ameliorating conflict in putting the plan to work. Gerry Hillier, the articulate and energetic manager of the BLM's desert district, has not only gotten opposing interests to work out their differences, but has also gotten this least known of the federal land-management agencies more involved with the general public using the desert. Previously, the BLM dealt almost exclusively with mining, grazing, and logging interests in the West.

Few, however, see a bright future ahead. The population of the Los Angeles-San Diego area continues to grow and to make increasing demands on the desert. Vandalism and theft persist. According to the BLM, roughly one-third of the desert's prehistoric sites have been damaged, and about one percent of its prehistoric artifacts disappear each year. With its small staff—only 21 BLM rangers patrol the agency's 12 million acres—the BLM says it can't keep up with these and other problems—overgrazing, mining violations, illegal dumping, and the spread of introduced species like the burro and tamarisk, both of which drive out local animals and plants. Finally, in 1985 Congress gave the BLM only 26.2 percent of the operating funds it requested to administer the plan.

"It doesn't take a smart man to see what's wrong," cattleman and longtime resident Gary Overson told me one afternoon at his Kessler Springs Ranch in the eastern Mojave. "But it'll take a smart man to fix it."

In several months of travel and interviews in the desert I met no such Solomon. But the threads of wisdom—what to do to ensure the longevity of this unique part of North America—did become clear. The gist of nearly every thoughtful conversation I had was the same: a need for public education, developing an abiding regard for the land itself, and finding some way—public or private—to come to the aid of the BLM.

EDUCATION takes many forms. Mine was seen to in part by a young man named Bruce Bannerman, a biologist at the University of California's study center in the Granite Mountains. The lanky and blond Bannerman and I were walking down a dirt road one brilliantly clear morning, and he made a sweeping gesture to the south and east. "Where else," he beamed, "can you count 26

separate mountain ranges from your front door?" The evidence before us was vivid. Mountain ranges in this part of the Mojave surface whole from the earth, like stone porpoises. The sheer compass of it all makes you exuberant.

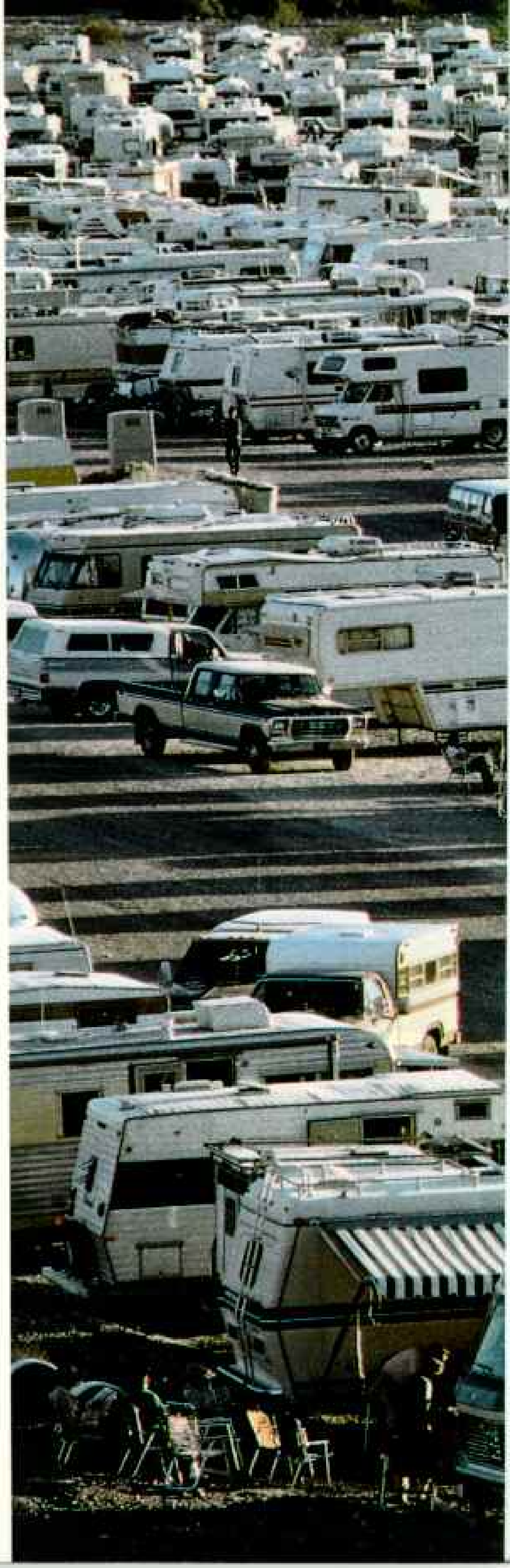
"I've smelled the Pacific this far inland once or twice," said Bannerman later, as if to further impress on me the unorthodox scale of the place. I had, in fact, begun to think of the desert itself as an ocean. The glint of sunlight on vast and uniform shields of gray-green vegetation is very like its metallic glare from a rolling sea. The mountain ranges stand on the land like archipelagoes. Cloud shadows drift slowly across the empty basins or across the flanks of salmon-tinted mountains like huge fish. Occasionally the land becomes so extensive the horizon itself becomes nautical—the edge of the earth seems to curve over into space.

Bannerman's destination was Snake Spring, a damp oasis tucked in a crevice of the Granite Mountains. We climbed up to it easily, and sat there in silence amid the trees. Water is so dear over so much of the desert that wherever it flows freely, as here, an atmosphere of serene calm prevails. The cool air fell over my shoulders like a mantle, and I surveyed the hundred square miles of desert basin below me, looking for coyotes and the lineaments of its geology.

"What was that?" I asked, breaking our long silence.

"Red-spotted toad," said Bannerman. "You rarely hear them during the day. It's a night sound."

Before we left the cove—I could not resist shuffling loudly through a thick layer of cottonwood and willow leaves on an incongruous swatch of green desert grasses as we departed—Bannerman showed me a shelter. It was a kind of natural breezeway in the granite where one could sit out of the sun and still watch the desert. I adjusted my sitting



**The not-so-deserted desert** *is site of an annual gathering of the Death Valley 49ers at Furnace Creek. The group promotes preservation of Death Valley. But crowds of up to 14,000—attracted by festivities that include a fiddler's contest, mineral displays, and a desert art show—strain park resources.*

position as I was directed and soon found what Bannerman intended I should—my hands came to rest on slick depressions in the rock alongside my hips. Knowing what to look for, I now saw four such pairs of depressions. They were bedrock metates. Centuries ago, perhaps, Indian women had sat here grinding seeds.

MONTHS LATER, on an August afternoon, I visited an older Indian site. Four of us clambered down a slope of basalt boulders and out onto a dry wash at the bottom of upper Renegade Canyon. My companions, civilians working for the Navy's environmental branch at the China Lake Naval Weapons Center, had brought me to a remarkable location in an area where more prehistoric rock art may be concentrated than in any other place in North America.

I stood transfixed before a wall of dark gray basalt. Pecked into its uneven surface was a bewildering array of images: large deer and mountain sheep, geometric designs in the shapes of shields and atlatls, or spear-throwing sticks, and human figures of different sorts. They were made by hunter-gatherers who apparently specialized in hunting mountain sheep.

What held my gaze was complicated—the sheer number of drawings, the seeming freshness of some of them, etched as they were by the late afternoon light, and how undisturbed the area appeared to be. (The Navy restricts public entry to the site.) I don't think I ever felt the presence of history so acutely—a conservative estimate puts a date of about 1000 B.C. on the oldest of these drawings.

At the southwestern end of the upper canyon, one of the archaeologists showed me an open-air site where these people had once camped. Here was evidence of their cooking fires, a waste midden, and the debitage of their stonework—myriad flakes of obsidian glass gleaming brilliantly in the setting sun. Here, too, were grinding slicks, bedrock metates like the one I had seen near Snake Spring. And odd petroglyphs called cupules—shallow holes the size of Concord grapes, pounded into the rock.

The falling light made it necessary to turn back, but I was most reluctant to leave. I


***Signs of indifference:*** *Trash piled near a request that visitors take it with them* ***(left)*** *was left by campers seemingly thumbing noses at authority. Vandalism includes shot-up road signs* ***(below)*** *and stolen cactus, ironwood, and potsherds. In fact, an estimated one percent of the archaeological artifacts disappear yearly. "People do things out here they'd never think of doing at home," a ranger told the author. BLM rangers are federal officers who can ticket offenders. But the 12 million acres under their control overstretches the 21 rangers, who often work extra hours voluntarily.*


*The BLM also mediates land-use questions. Desert district manager Gerry Hillier (***right,** *in white shirt) meets with University of California representatives, ranchers, and conservationists to discuss balancing different interests on a nature reserve used by the university.*

trailed behind the others, walking backward, so that I would not lose eye contact with the scene. It seemed imbued with the power of human history, like the stone walls of Jerusalem.

AT WHAT POINT, exactly, people first moved into the California Desert is a topic of considerable debate among archaeologists. Researchers at the Calico Early Man Site in the central Mojave claim stone tools found there establish man's presence about 200,000 years ago. Dates of 30,000 to 40,000 years before the present have been suggested for cultural materials found at China Lake. But a widely agreed upon date for man's presence in the desert doesn't come until the end of the Pleistocene, some 12,000 years ago.

The desert was a wetter, cooler place then. Paleo-Indians living on the shores of rain-fed lakes subsisted on waterfowl, shellfish, plant foods, and large and small game. Some 5,000 to 7,000 years ago, as the lakes slowly dried up, these cultures gave way to smaller, more nomadic groups that, increasingly, found their food in the drier uplands of the desert. These so-called Archaic traditions endured for several thousand more years, until the ancestors of the tribes known to modern history emerged.

During this same period the modern assemblages of plants and animals scientists today call "Mohave Desertscrub" (creosote bush, Joshua tree, Mojave yucca) and "Sonoran Desertscrub" (creosote bush, burrobrush, saguaro, indigobush) also came into being. At the close of the Wisconsin Ice Age, the only "dry desert" in the area existed around the mouth of the Colorado River. Over millennia, however, many of those plants and animals took advantage of the changing climate to extend their ranges farther north, while the northern plants and animals moved into higher elevations in the desert mountain ranges. Some of the original colonizers of one of the plants that came up from the south—the creosote bush—may, incredibly, still be alive. An individual creosote bush clone growing in Johnson Valley in the central Mojave, for example, has been traced back to an ancestor an estimated 11,700 years old.

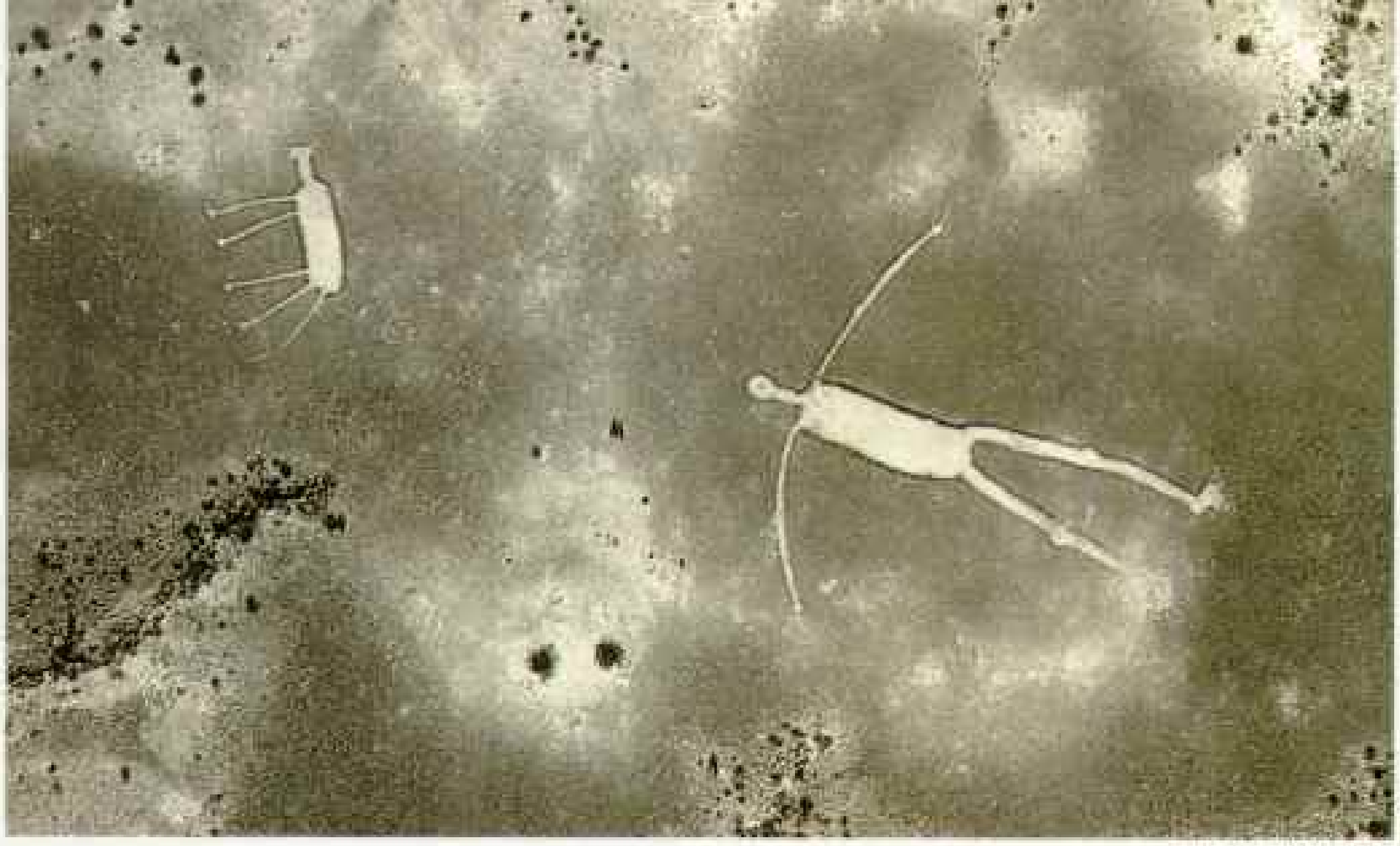
The Spanish, intent on establishing an

***Leaving tracks of their culture,*** *Indian peoples who lived along the lower Colorado River created intaglios near Blythe centuries ago. They are believed to represent creation myths. A photograph taken in the 1930s by the U. S. Army Air Corps shows the intaglios in pristine condition* ***(right)****. But as the public invaded the desert, the figures became scoured by vehicular tracks* ***(below right)****. In the mid-1970s the Bureau of Land Management erected fences; sections have been flattened and rebuilt several times. Recent legislation makes the defacing of archaeological resources a federal crime. A first-offense conviction may bring a year in jail and a $10,000 fine.*

*Tracks of wartime vintage were left at a training camp for Gen. George S. Patton's tank corps in the 1940s* ***(below left)****, located in the Mojave. Because of its clear skies and open spaces, the desert is prime training ground for the military. The California Desert incorporates nine military bases and testing grounds.*

*Aridity makes the desert a great preserver, conserving traces of someone who may have passed ten minutes or a thousand years before. Paths cut by pioneer wagons more than a hundred years ago can still be seen in the northern Mojave.*





U. S. AIR FORCE (ABOVE)

overland route between Mexico and the California coast in the 1700s, were the first Europeans to cross the desert. Mountain men like Jedediah Smith entered the Mojave early in the 19th century and by the 1860s a number of trails and wagon roads had been opened through the territory.

In the 1870s and '80s railroads brought an influx of miners to the region and the first cattle operations started up in the eastern Mojave. The first desert resort hotel at Palm Springs opened in 1886. By 1910, the Imperial, Coachella, and Palo Verde Valleys had been irrigated for farming. In the 1930s agriculture spread northward out of the Los Angeles basin into Antelope and Apple Valleys in the western Mojave, and people began to purchase five-acre "jackrabbit homesteads" there. The aircraft industry followed, attracted by the Mojave's year-round good flying weather. The military then discovered in the desert a perfectly lonely and dry place to train personnel, test weapons, and store matériel. (Military installations now occupy about 3.2 million acres in the desert.)

The Imperial Valley has grown to 470,000 acres and become the nation's winter vegetable garden. Nearly 80,000 people live in the Palm Springs area today, at the foot of the San Jacinto Mountains. And the single-blanket jackass prospector and 20-mule-team borax wagons have become part of the nation's folklore.

In many ways, the record of this history is one of the desert's most engaging dimensions—old mines with names like Queen of the Night, Chief of Sinners, and Pride of the Union. The Army's World War II desert training camps. And remnants of the Plank Road built across the Imperial Sand Dunes in 1915, to shorten the automobile route between El Centro and Yuma. In an effort to preserve this heritage, the BLM has listed such sites among 77 protected areas of critical environmental concern in the desert.

As I followed my companions out of upper Renegade Canyon and away from the petroglyphs that afternoon, I fretted over the vulnerability of the evidence of human history in this region. Although it is not specifically addressed in the desert plan, preserving a sense of the depth and breadth of human history in the desert, both aboriginal and modern, lies at its very foundation. It is this

***The careless side of carefree*** *shows up on weekends when off-highway vehicles crowd dunes. Watched by his mother, a toddler motors off at Dumont Dunes* ***(above)****. But some children are*

*unsupervised and get hurt. At Imperial Dunes a woman was injured when her vehicle overturned (**below left**). Some are permanently maimed, or worse. Nearly 70 have been killed at Imperial Dunes alone in the past 13 years. A conservation measure bans vehicles from dunes on Highway 78's north side. BLM ranger Bill Vernon tickets two trespassers (**below**).*

that makes acts of vandalism, such as the flagrant disregard of motorcyclists for intaglios (large, prehistoric ground drawings) in the Yuha Desert so depressing. That and the poor prospects for being able to protect what is left of this heritage in the desert.

IT WAS in the company of BLM rangers that I saw that side of the desert perhaps least familiar to most of us—the intense and sometimes strange use to which it is put. Many people regard the desert as worthless land and expect no interference in their activities out there. Some are completely unaware that they are violating state and federal laws, or that all the desert has been zoned according to the desert plan to control its use. You can no longer trail blaze with a four-wheel drive, build a squatter's vacation cabin, or harvest a truckload of ironwood to sell to Mexican carvers. Miners can no longer bulldoze roads wherever they wish. And someone who has just emptied his sewage tank in the blackbrush may be stunned to learn that a BLM ranger is a federal law-enforcement officer, handing him a federal ticket.

The primary job of BLM rangers is to protect the natural and cultural resources of the desert. An equal part of their work, however, judging from the time I spent with them, is education and public relations—explaining to varmint hunters, rockhounds, exotic-vehicle owners, amateur archaeologists, survivalists, and a million casual tourists that there is a new pattern of public use here.

The day I spent with Jerry Needy, a tall, circumspect ranger working out of Needles, was informative. Needy was familiar with a desert I did not know. As we pulled off U. S. 95 to begin a backroads tour of the Turtle and Old Woman Mountains, he said, matter-of-factly, "I pretty much operate on the theory that everyone out here is armed, or they've got a weapon in the vehicle." Needy once stumbled into a Colorado Desert training camp for Latin American revolutionaries stocked with, among other things, stolen military weapons. On another occasion he ran into a mobile drug-lab operation and two heavily armed men.

As Needy described the number and range of guns he'd seen in use in the desert, I realized how uneasy I had become about

***Thrilled to death:*** *Strictly for kicks, a weekender in a four-wheel-drive truck spins his wheels* ***(above)*** *in a heavily rained-on dry lake bed in the Mojave. When the gouged-out depressions dry, they form trenches—a dangerous surprise to off-highway vehicle drivers crossing the lake bed. Several months after this picture was taken, one person died and another was seriously injured when their speeding dune buggy hit a trench—here being inspected by BLM personnel* ***(right)****—and flipped.*

*Because of the BLM's limited resources and manpower, such damage may remain undetected until too late.*

them. Virtually every road sign I had seen in the desert was bullet riddled. Some had been hit by so many shotgun blasts they were mangled beyond recognition. It is the intensity rather than the mere fact of this kind of destruction that is finally so unnerving. Over a period of several months, as I stared at the remnants of mining operations and ghost towns like Picacho and Hart, destroyed by explosives, gunfire, and arson, and pulled apart by vehicular winches—people looking for the gold caches of dead prospectors, I was once told—I found myself fighting for perspective. It is a very small part of society that behaves like this, but all of us must confront the dismal evidence of their scorn for the value of human history. To see so much of it is unsettling.

Finding a "release from city tensions" took on new meaning the day I spent with ranger Bill Vernon at Imperial Dunes, a strip of sand hills 45 miles long and five miles wide at the eastern edge of the Imperial Valley. Over the past 13 years nearly 70 people have been killed here, most in recreation-vehicle-related accidents. The number of injuries suffered and the incidents of drinking under age, fistfights, and public nudity are uncounted. Over long holiday weekends, especially on Thanksgiving and Presidents' Day, 40,000 people may visit the area. (The BLM's figure is 792,000 visitor days per year.) In the hard-nosed view of Bill Vernon, a physically imposing, 42-year-old Vietnam veteran, ill-behaved adults who injure themselves out here deserve little sympathy. He feels anger and grief, however, when such people turn their children loose on vehicles they can barely control and the children are hurt. "Out here," said Vernon derisively, "the three-wheeler takes the place of the television as a baby-sitter."

There is a dizzying madness to the wild spectacle at Imperial Dunes, the aimless hurtling of vehicles through clouds of dust, noise, and darkness; but Vernon defends this antic racing, helter-skelter over the sand, night and day, as "legitimate sport." "Seventy-five percent of these folks are hardworking, good people; 10 percent are lowlifes, just incorrigible; 15 percent are running the ragged edge, usually with a few beers," he told me. "But they have as much right to the public lands as anyone else."

Some 200 miles to the north, a much more subdued and better behaved crowd gathers at Dumont Dunes on long weekends. The purpose of coming out to such a place to drive around in the sand is essentially social, one man told me. He and his family spend a total of 30 days a year in the desert. They drive out from Yorba Linda in their motor home, pulling a dune buggy and other recreation vehicles in a huge trailer. He brings his children, and his daughters bring their boyfriends. "The desert," he said, "is the greatest thing that ever happened to my family."

RECKLESS off-highway vehicle use and incidents of vandalism, because they leave such visible scars, draw an inordinate amount of attention, in the view of some. One four-wheel-drive operator, leading a group across the desert with scrupulous care, shrugged off my discomfort at bullet-riddled signs and vehicle-damaged hillsides. "What about the proliferation of power lines out here? That's *public* vandalism."

He spoke for many an irate citizen. The desert's unbroken expanse, so soothing to the eye, is now truncated in many places, not only by roads, fence lines, and railroad right-of-ways, but also by a network of high-tension power lines, natural-gas and petroleum pipelines, telephone wires, and water canals. Some of this development is confined to utility corridors, but the call for more gas and electricity in urban areas is creating a demand for additional corridor space. Especially perplexing, and something the desert plan did not anticipate, is a proliferation of microwave relay stations along the otherwise clean ridge lines of desert mountain ranges. With the divestiture of AT&T, each new telecommunications company must, by law, now build its own facilities.

In addition, because air-quality laws militate against the siting of new oil refineries and power plants in the Los Angeles basin, companies like Southern California Edison are looking to the desert itself for new sources of energy. Wind-farm complexes have been erected in the San Gorgonio Pass area, like orchards of propeller trees. Solar One, a complex of highly reflective

heliostats (mirrors) arrayed around a central receiving tower, has been built near Daggett. And plants to utilize geothermal sources now stand in the Imperial Valley.

Many off-highway vehicle enthusiasts, weary of having to shoulder most of the blame for the visual deterioration of the desert, say it is power development and large-scale mining, as well as ranching operations, military exercises, and agricultural expansion, that are the real culprits. They point a finger at abandoned munitions dumps, overgrazed hillsides, open-pit mines, and noxious fumes at chemical plants.

Their charges are undeniable. In Trona, California, where Kerr-McGee produces chemicals from a brine solution beneath the salt crust of adjacent Searles Lake, the air was so thick with sulfurous fumes one day that I became nauseated. An area I viewed from a helicopter on another day, in the vicinity of the Cady Mountains, was cross-hatched with cattle trails. From the Amboy Road, east of Twentynine Palms Marine Corps Base, one can clearly see heaps of overburden produced by the National Chloride Company and Leslie Salt in their surface operations on Bristol Lake. Outside of compliance with the law, however, there is little more that can be demanded of such operators by a society that insists on their products.

One day, weary of the sight of too many chemical plants, too much cow-burnt land, and, as one executive put it, too much "chloride farming," I made a detour to Big Morongo Canyon. There, at the 3,900-acre Big Morongo Canyon Preserve, I stepped out of the glazing heat into the shade of Fremont cottonwoods and red willows. More than 265 species of birds have been seen at Big Morongo Canyon. Their notes, along with the *kreck-ek* of the Pacific tree frog, fill the air. Along Big Morongo Creek one might see a docile red diamond rattlesnake sunning on flattened bulrushes. I walked the preserve's shaded trails and tried to collect my thoughts about the desert's future.

A weakness in the desert plan, in the view of many, is that while it apportions the desert equitably to different interest groups, and while it strives for a form of management that will ensure the desert's integrity for years to come, its basic operating premise—it directs the BLM to "manage, use, develop, and protect"—is an internal contradiction. Pressured by special interest groups, given a mandate like this, and hampered by a lack of funds and personnel, the BLM must compromise.

In view of its responsibility to manage a public trust, and the importance of what happens here—this is probably the largest regional planning effort ever attempted in the United States—the future of the California Desert is a subject of national interest. What the BLM accomplishes will say much about the fate of other lands now held in the public trust.

Dennis Casebier, a desert historian and longtime observer of conflicts over the desert's use, told me one day that conflict was no longer the central issue. "What's wrong," said Casebier, "is that we have no vision. How do all these different things—four-wheel-drive tours and cattle ranching and geothermal development—relate to each other? BLM can't just make everyone happy. They've got to sit down and decide what they want the desert to look like in 20 years." Which is to say the country itself, the people acting through Congress, must decide what they want the nation's public lands to look like in the future.

I LEFT Morongo Canyon that day, oddly, with a sense of hope about the desert's future. The Bureau of Land Management is staffed with dedicated and thoughtful people. Bill Vernon puts in 18-hour days at Imperial Dunes. Jerry Needy remembers to bring five gallons of water to an elderly miner isolated at his waterless claim without a vehicle. Ev Hayes, the BLM area manager at Needles, gets out of his truck during a torrential thunderstorm to carry several wandering desert tortoises safely across the road in Ivanpah Valley. In the face of a continuing pattern of budget and personnel cuts they remain hopeful.

A second cheering element is the extent to which private individuals and groups have come to the aid of the desert. Just east of Palm Springs a consortium including the Nature Conservancy, state and federal wildlife agencies, and the BLM has established the 13,000-acre Coachella Valley Preserve, principally to protect the threatened

***Prospecting for energy,*** *the experimental Solar One project near Daggett uses 1,818 heliostats to focus sunlight on a tower-mounted boiler that converts water to steam* ***(above right)****. It would take approximately 20 square miles of desert to provide energy for a million homes.*

*Mineral wealth is tapped by the Kerr-McGee Chemical Corporation in Trona* ***(above)****, which produces soda ash and boron from brine beneath a dry lake bed. Some 30,000 acres of the desert conservation area are under lease for minerals.*

Coachella Valley fringe-toed lizard, an animal highly adapted to life in and on sand dunes, and several palm oases from development. The California Off-Road Vehicle Association has worked with the U. S. Air Force to restore a section of the Plank Road in Imperial Dunes. Business organizations, private and public museums, and hundreds of volunteers have joined to build watering holes for desert bighorn sheep, maintain protected areas for the desert tortoise, and restore vandalized intaglios.

The final source of hope is much harder to define but unmistakable when you encounter it. It is the enthusiasm and thoughtfulness with which many of the desert's year-round residents conduct their lives. These ranchers, yucca harvesters, miners,

and even a landscape painter I spoke to all seemed to have one thing in common. They spend a great deal of time out on the land, and they feel it is a privilege to live in this country. Lean and reserved, it has a ring of integrity they admire and seek to imitate.

I also left with some misgivings. The sound of military jets is ubiquitous in the desert. Early one morning in Death Valley National Monument I was buzzed—twice—by an A-7 Corsair Navy jet. I had parked my car on the edge of a playa known as the Racetrack and walked out toward its center. It was immensely still. Then the jet came, screaming southward down the playa, 100 feet off the ground and 500 feet away. Five or six minutes later it returned, flying just as close, exploding overhead again like a freight train. An Air Force liaison officer with the Federal Aviation Administration in Los Angeles, in a breezy attempt to downplay the incident, told me later that I had only been disturbed by "the sound of freedom." But the jet was operating improperly in the park. The military has a number of high-speed, low-level training corridors for aircraft in the desert—two run right through Joshua Tree National Monument—but to judge from my interviews military pilots frequently operate outside them and the military has not always taken these violations seriously.

The military does not have a reputation for good manners in the desert. Numerous people I spoke with had been buzzed—I was buzzed on another occasion in the Saline

NATIONAL GEOGRAPHIC PHOTOGRAPHER JODI COBB (ABOVE)

***Conspicuous consumption*** *of water and wealth hallmarks Palm Springs, where outdoor air-conditioning cools off guests at the home of inventor John Kennedy* ***(above)****. His system uses 60 gallons of water an hour to create an air-chilling mist. Air-conditioning spurred growth of Palm Springs and nearby Rancho Mirage* ***(right)****. The Palm Springs region, population 80,000, boasts 42 golf courses and some 15,000 swimming pools. A local columnist says of the city, "Socializing is the number one industry."*



Valley—but the problem is not solely one of low-flying aircraft. In the Imperial Dunes one afternoon with Bill Vernon, I watched a Marine private drain aviation fuel onto the desert floor during an unauthorized helicopter refueling operation. The leader of an archaeological survey team from New Mexico State University told me his group was momentarily startled by the sudden approach of a light armored vehicle being driven down a sand wash in the Cadiz Valley—a violation of the agreement the military had with the BLM to test these vehicles on public land. Dick Rayner, a former chief ranger at Death Valley National Monument, told me about a set of practice bombs that were dropped within a few feet of an occupied civilian vehicle near Emigrant Spring in 1979. No one was injured.

DEATH VALLEY is the scene of yet another, more complex issue—the removal of the wild burro population. Few dispute the fact that a concentration of burros makes it hard for desert bighorn sheep to make a living alongside them. The burros foul water sources and denude the land, exposing it to

erosion. The thinking behind their removal, however, is somewhat fuzzy. There are many exotic species in the California Desert —English house sparrows, tumbleweeds, mosquitofish, wild horses—but the boom has been lowered only on the burro.

Gene Nunn, a BLM cowboy in his late 40s with sparkling blue eyes, has been in charge of the burro roundup in Death Valley for several years. "If the moon fell out of the sky," he told me, "and burros were around, they'd be blamed." The burro, reason Nunn and others, is probably not responsible for every one of the adverse environmental

***An accidental sea,*** *the Salton (**above left**) began forming in 1905 when the Colorado River spilled over its banks and flooded a low-lying area. Agricultural runoff has extended the original shoreline, inundating seaside structures. Introduction of various fish species spawned an active sportfishing industry, but their edibility remains questionable because of pollution from pesticides and sewage.*

*Completed in 1940, the All American Canal slips under Interstate 8 (**above**) on its 80-mile journey from the Colorado to the Imperial Valley.*

impacts he's blamed for in the desert. What's more, the burro never asked to be put there. He was brought in and then abandoned by prospectors to fend for himself—which he's done. There should be a place out there for him, thought Nunn.

I wasn't sympathetic to this argument at first, but after traveling with the cowboys for several days while they worked I felt admiration and sympathy for these small-footed, tough, sleepy-eyed animals. They have neither the allure nor the romance of the wild horse in their favor but they have a kind of dignity, by virtue of their survival in this arid and ungenerous land. It is we, really, who have changed the desert; the burro is just doing what he has always done.

In this context I recalled a bleak stretch of the Mojave east of Lancaster. The native species of grass there have nearly all been driven out, replaced by red bromegrass, cheatgrass, Russian thistle, and several other exotics. The dilapidated For Sale signs of land speculators wobbling in heat waves along the highway make the landscape here seem even drearier. How *will* we manage the desert in the years ahead? Will our wisdom in caring for it show to the same extent as this power we have to rearrange nature? And will there be a culprit as convenient as the burro to blame if it doesn't go right?

One winter evening, on my last trip to the desert, I drove down to Badwater in Death Valley from Furnace Creek and walked out on the playa. This is the lowest spot in the Western Hemisphere, 282 feet below sea level. I walked far out on the salt flat and stood there until the last bit of daylight faded from the western sky and the stars came out. The faint starlight was enough to see by. I could not see my car, but I was not worried. I could see the spine of the Amargosa Range against the indigo sky, and I knew the notch in that ridge below which memory had fixed an image of the car as I walked away.

Far out on the playa I realized these walks had become a habit. I went off arbitrarily, up dry washes and out across the most ordinary-looking bajadas. I let myself be tutored by the land, with the help of a few animal and plant guides and a handful of notes. Without fail I would come on something remarkable—a cactus, for example, called dead cactus, because it always looked that way. I would walk into the sudden red brilliance of a vermilion flycatcher put to flight. Or hear the low-throated booms of moving sand dunes. One day near Iron Mountain I went out across the desert just to stare into the Colorado River Aqueduct. The contrast between the cool, dark water and the sere desert plain all around, nearly white with the savage sunlight of an August afternoon, was extreme. The cavitating sounds of running water, headed for Los Angeles, seemed utterly magical.

I remembered, standing there at Badwater, the words of people who lived and worked in the desert. "You're on the edge of a drought all the time," cattle rancher Gary Overson had told me. I thought of what Ken Norris, a legendary professor of biology from the University of California at Santa Cruz, had said to students at the Granite Mountains study center: "The most powerful thing you can do out here is face reality." And I recalled the words of John Van Dyke, a turn-of-the-century desert traveler. What one seeks out here, he wrote, what finally holds you enthralled, is "the weird solitude, the great silence, the grim desolation."

A light wind came across the surface of the playa from the northeast. I squatted down and laid my hands flat on the ground. The surface was cool and gritty. A commons, I was thinking. This fierce land, with its wild flash floods, its resourceful plants and animals, its titanic reserves of quietude, its many shades of purple, its cholla cactus that snare afternoon sunlight and wear it like a cloak, all this is public land. A commons.

I fixed in my mind that point in the pitch darkness where I thought the car might be, and started walking. □

***The lilac-blue air** of the desert lingers like a barely remembered dream over Death Valley. Here heat like the breath of a furnace burns the air to record temperatures. Illusions linger as well. The air warps light. Improbable images appear: a phantom sea, rain. But reality prevails. This thorny land, so tough to the eye and foot, has a tender side. Abraded by man, its future is not assured.*

# ICE ON THE WORLD

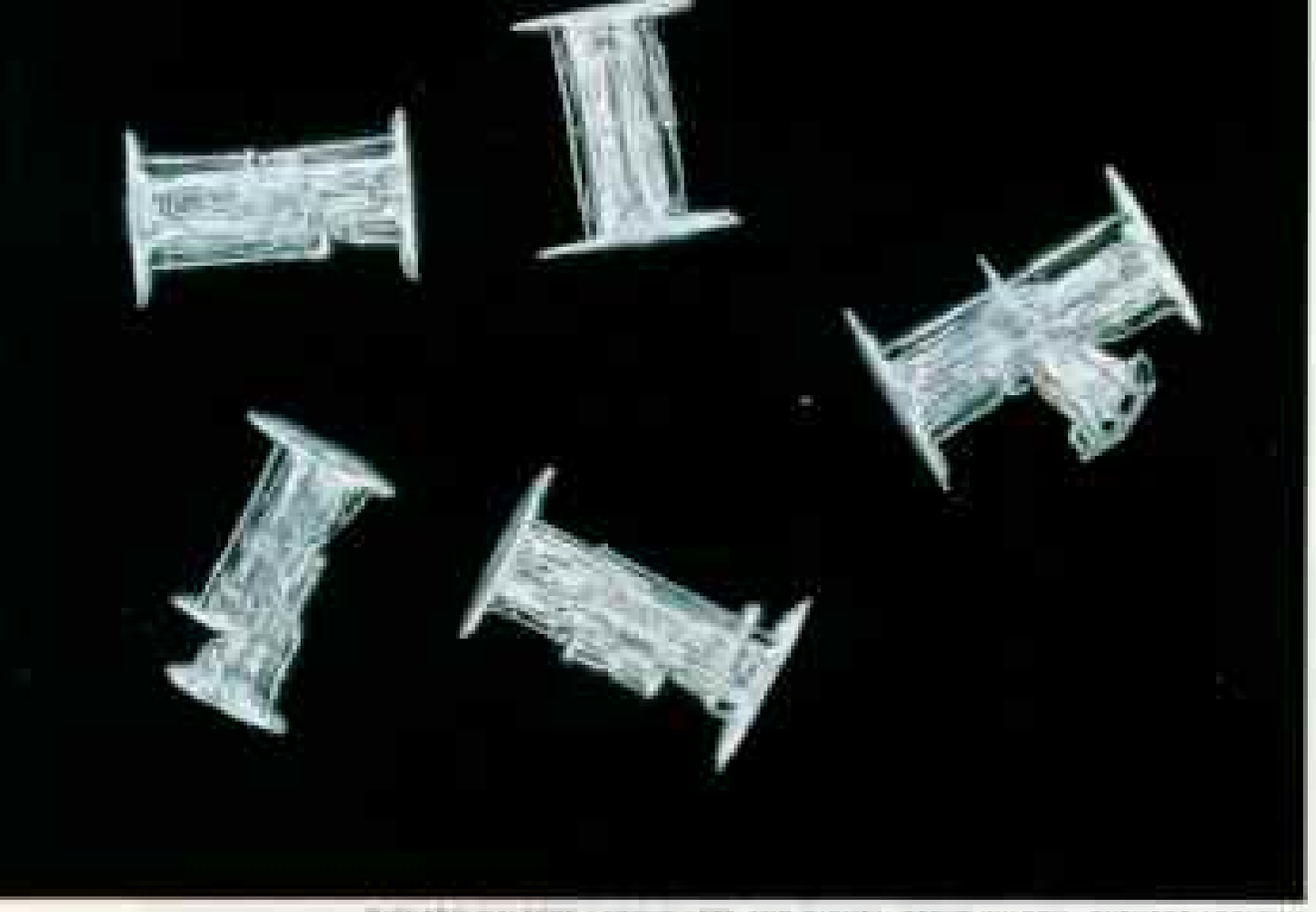
By SAMUEL W. MATTHEWS
SENIOR ASSISTANT EDITOR

Fleeting phenomenon of an ice cave lures an explorer into a remnant of the Muir Glacier in southeast Alaska. Creator and destroyer, ice relentlessly molds landforms and climate, yet can fall with a snowflake's lightness.

TOM BEAN

Ice as artist endlessly improvises: Rapidly frozen by plummeting temperatures, a beaver pond, below, traps gas bubbles rising from decaying vegetation. A fallen grass sprig locked in clear ice blossoms with a feathery crystal, below right, created by escaping water vapor.

Seeping through cracks in a dying plant stem, watery sap spreads an icy tutu, far right. Capped columns, right, are among the rare shapes snow crystals assume as they interlock and fall to earth, their form influenced by temperature, humidity, and speed of descent.



RICHARD WALTERS (ABOVE LEFT AND RIGHT); STEVE WILSON, ENTHEOS (BELOW)

Warmed by a coat of ice, strawberry plants in central Florida were sprayed with water when below-freezing temperatures were forecast. Thus encased at 32°F, they can survive while

JOHN KARR, ETSNA

air temperature falls lower. Arctic animals live by ice's insulating power when they burrow into snow on winter nights, as did the Inuit in their traditional igloos.

# ICE ON THE WORLD

IT BEGINS, if it can be said to have any one beginning, in the great storm of early December. The jet stream dips sharply south, and a huge tongue of polar air slides under warm and humid low-pressure air all across the North American heartland. Dense, blowing snow all but obliterates pro football games that Sunday in Minneapolis, Green Bay, Buffalo, and Boston. The snow falls, and blows into great drifts, for five days.

That winter brings a series of such storms, more than anyone in the North can remember. In January the snowpack on fields outside Buffalo lies 17 feet deep. The white blanket extends south to Mississippi. Orange groves in Florida die as far south as Okeechobee. There is ice on the Tenn-Tom Waterway and the aqueducts of the Central Arizona Project.

By July it should have been only a memory—but it is not. Snow still lies in sheltered, shadowy places outside Butte and Duluth and Bangor. It is colder across the northern tier than at any time in weather records.

And when the first snow comes again, in late August in the high country, it falls on snow from the winter before that has not melted. It piles up faster even than in that bad December. More of it comes, and keeps coming, again for months.

The TV weathermen talk about it constantly, but it is the glaciologists who recognize the signal. The Ice Age, which has really not left the planet for two million years, is reasserting itself. The warm time, which has lasted less than 12,000 years, is over. The next great return of ice has begun.

WAS THERE EVER REALLY an age of ice, long ago and far away?

Yes and no. Yes, an Ice Age (the most recent, that is) did exist in the time of man on earth—Cro-Magnon man and his ilk. Some 18,000 years ago it buried more than three-tenths of the world's land surface under thick ice and mantling snow. And no, the Ice Age, geologists say firmly, is still with us. We are living in only a slightly warmer spell of it.

Ice scoured and heaped the hills around New York City, fed the river courses that meet at St. Louis, shaped the lochs and golf links of Scotland, gouged the Great Lake basins and Norwegian fjords, and even now, by continued melting, is slowly raising the level of all the oceans. Someday—soon, say some climatologists, who think in millennia—ice could creep south again over North America to bulldoze away Chicago and shove its wreckage to St. Louis.

Ice still covers one-tenth of all earth's land. An entire ocean, the Arctic, is covered with it, like a solid scum on a bowl of cold pea soup. Huge domes of ice lie atop Antarctica and Greenland. Glacial rivers of ice in Canada and Alaska and on mountains even on the Equator help regulate earth's weather.

The Alaskan glaciers have recently been puzzling and bemusing scientists with unexpected, even startling, activity. While some are retreating, others are surging forward. Last spring the giant Hubbard Glacier blocked the mouth of a long tidal fjord and turned it into a fast-rising freshwater lake (pages 107-119).

Ice not only crowns polar reaches and towering mountains with white glory, it also gleams as diadems from roof edges and

***An oasis of fresh water*** *on sea ice quenches a Greenlander's thirst. Salt water freezes at 28.7°F. As sea floes thicken, gravity pulls brine from the surface. The relatively fresher layer on top can be sipped in summer or chipped and melted in winter.*

BRIAN AND CHERRY ALEXANDER

***Freshwater islands,*** *icebergs fall from oceanfront glaciers and sail on keels that form the bulk of their mass (**below**). North Atlantic icebergs, such as the one that sank* Titanic, *break away from Greenland and Canada.*

*Dye sprayed on the face of Antarctica's Ross Ice Shelf (**facing page**) locates a current meter emplaced for a study of ice and sea interaction. The shelf may have calved the largest berg ever recorded—some 200 by 60 miles.*

MITSUAKI IWAGO (ABOVE); STAN JACOBS, LAMONT-DOHERTY GEOLOGICAL OBSERVATORY (RIGHT)

sheathes forests and gardens in shimmering crystal, brings streams and waterfalls to frozen stillness.

It menaces your daily life. It can kill you on a street or highway, ground your plane or sink the ship you take to Europe, cause a tree or hailstones the size of baseballs to fall on your head. It can break your water pipes or car's engine block, flood your farm, freeze your crops, cut off your electricity.

As seen from the moon or space, the earth is blue, brown, and white. Much of the white is ice, whether solid, rime, snow, or frozen cloud.

A REMARKABLE STUFF indeed. Not only does ice produce heat while freezing and absorb it in melting; it floats, because (unlike almost every other substance) it is lighter as a solid than as a liquid.

If it were not for this phenomenon, ice cubes dropped in a glass of water would go straight to the bottom. Icebergs would not float. Lakes, rivers, and seas would freeze from the bottom up. The world would be in deep, cold trouble.

Ice is one of nature's most beautiful and elegant substances. It can form in the atmosphere as snow—lacy, delicate crystals, like fairy place mats, each flake unlike any other.

Thoreau called snowflakes chariot wheels fallen from a battle in the sky. To Job, Elihu said, "By the breath of God ice is given, and the broad waters are frozen fast."

On quiet ponds and lakes, as winter air drops water temperature to zero degrees C (32°F), a thin skim of ice glazes the surface. The heat given up by crystallization is lost to the air; the water beneath is both slightly warmer and denser. If the lake is absolutely still, the skim will rapidly thicken, forming a transparent pane on the surface. The pond creaks, even sometimes groans soulfully, as it freezes. In daylight it appears as black as the water beneath.

This black ice, skaters know, is the best of all—strong, absolutely smooth, lightning fast. If not yet too thick, it will undulate beneath you, yet safely hold your weight as you glide across it. If wind or current ripples the ice, or if snow falls upon it while freezing, a white, softer ice forms, full of air, rougher to the skates, opaque to the eye. It cannot be shaved down to black ice; unless it melts completely before the next freeze, that year's skating will be second-rate.

Sea ice is unlike freshwater ice. Because of its dissolved minerals (3.5 percent on average), salt water does not begin freezing until its temperature drops to minus 2°C (28.7°F). Then a thin slurry or scum of freshwater ice crystals appears. Between the crystals, as they grow and interconnect, tiny pockets of brine are trapped and enclosed.

Sea ice thus separates fresh and salt water to some extent. Newly frozen, it may be only

**Fighting ice with ice,** *an Exxon oil rig in Alaska's Beaufort Sea pumps out water that freezes into bulwarks against crushing ice floes. Standing on a steel mat anchored 60 feet down, the movable station reduces the cost of Arctic oil exploration.*

one-tenth as salty as the water beneath. As the ice grows older and thicker, it becomes fresher; the heavier brine migrates downward, pulled by gravity.

Eskimos know and make use of this phenomenon; they melt the surface ice and its covering snow for drinking and cooking. The Inuit, or Eskimos, have dozens of words for different kinds of ice.

SNOW THAT FALLS on land either melts away entirely the next summer or becomes thicker year by year, compresses by sheer weight, and gradually turns to ice.

"Whenever and wherever one year's snowfall doesn't melt before the next year's snow, a glacier is born," University of Wisconsin climatologist Reid Bryson reminds his students. "If it goes on long enough and widely enough, you have an ice sheet."

Such an ice sheet covered much of North America's northern half in the time geologists call the Pleistocene (map, facing page). The glacial age began more than 2.5 million years ago, when man's early forebears, the australopithecines, prowled Africa's plains. It was at its most recent peak only 18,000 years ago, when Cro-Magnon artists were painting cave walls in southern France.

In that human span of time the ice sheets and glaciers came and went, waxed and waned; the oceans rose and fell; extensive areas of the globe were alternately dry land and below sea level. The forcing mechanisms for these vast changes are now believed to be slow variations in earth's orbit around the sun, its tilt in space, and stately back-and-forth nodding of its spin axis.

These so-called Milankovitch cycles, named for the Yugoslav astronomer who calculated them in the 1920s, control the amount of sunlight received by the two hemispheres in winter and summer.

Much of this theory is supported by deep-sea sediments. Shells of long-dead sea creatures can reveal the temperature of the waters, both surface and deep, in which they grew and died. Core samples brought up by oceanographic research ships can reveal as well just how much ice existed on the earth in different geologic ages.

"Seabed cores are our library of the far past," marine geologist William Ruddiman of Columbia University's Lamont-Doherty Geological Observatory said to me recently. "They tell us the earth's past climate, the movements of its crustal plates, where the ice sheets lay, and why—in large part—life today is as it is."

At different times in the past one million years, there must have been about three times as much ice on the earth as now exists in Antarctica and Greenland. The greatest amount, the geologic record shows, lay on North America, in the Laurentide and

EXXON CORPORATION

***At its peak*** *about 18,000 years ago, the most recent advance of Pleistocene ice retreated to present locations by about 6000 B.C. Meltwater raised sea levels about 360 feet. Changes in the earth's orbit and spin axis may trigger the ice's ebb and flow. Experts differ on when the next major ice era might begin.*


GLACIATION TODAY

PRESENT LIMIT OF MULTI-YEAR SEA ICE

LAST GREAT PLEISTOCENE ICE SHEET 18,000 YEARS AGO


NGS CARTOGRAPHIC DIVISION
DESIGN: JOHN W. LOTHERS
RESEARCH: ROSS N. EMERSON
PRODUCTION: MARYANNE BREITHAUPT
MAP EDITOR: JOHN F. BOZEIS

PAINTING BY LLOYD K. TOWNSEND

PLEISTOCENE DATA FROM "THE LAST GREAT ICE SHEETS," BY GEORGE H. DENTON AND TERRENCE J. HUGHES

GENE MOORE (ABOVE); GERD PFEIFER

***Smashing property and prices,*** *a July 1984 hailstorm reduced the value of a used Porsche 944 on a Munich, West Germany, car lot from $15,000 to $4,000 (**below**). In Texas a baseball-size hailstone put a major-league dent in a car hood (**above**), striking at perhaps 90 miles an hour. Fallout from violent weather systems, hailstones grow onionlike layers as they pass through clouds of supercooled water droplets. (Frozen single raindrops are called sleet, a close cousin.) Economic damage from hail in the U. S., primarily through destruction of crops, exceeds that caused by tornadoes.*

Cordilleran ice sheets. Ice stretched from the high Arctic islands south across what is now Hudson Bay and the Great Lakes, down the midwestern plains as far as today's Ohio and Missouri River Valleys, and in the west across the Yukon and western British Columbia to Puget Sound.

In Europe an ice sheet covered the entire Scandinavian Peninsula, the North and Baltic Seas, much of the British Isles, and extended from the Low Countries across northern Germany and Poland into Russia. There was ice in Siberia and, beyond the dry Bering Strait, glaciers spilled out from the mountains of southern Alaska (although other parts of that far northern peninsula remained strangely ice free).

The Pleistocene ice advanced and withdrew, again and again. In the past million years there have been nine full glacial periods, separated by much shorter interglacials, or warm spells. Each glacial period has lasted about 100,000 years; each interglacial, as little as 10,000.

The most recent advance of the ice is called the Wisconsin glaciation in North America, the Würm in the Alps. At its height 18,000 years ago, it withdrew unevenly, probably in two distinct stages of melting, about 13,000 and 10,000 years ago, glaciologists now think.

That marks the start of the Holocene, or wholly modern, era. The world was warmer at 6000 B.C., in the so-called Climatic Optimum or Thermal Maximum, than at any time since the previous interglacial some 125,000 years ago.

There have been bitter returns to cold, wet times for mankind since then—from the second to the first millennium B.C., and again beginning after A.D. 1200 in high latitudes of the Northern Hemisphere, continuing until the mid-1800s. In the latter Little Ice Age, glaciers grew again in the Alps and southeastern Alaska. Viking colonies were frozen out in Greenland.

Then the world's climate turned warm again—warmer than in any period since the Climatic Optimum. From about 1880 until present, temperatures have ranged well above the average for the entire Holocene interglacial period. Yet, in our self-centered view, we regard our own time in history as "normal." It is anything but that.

HOW THICK were the northern ice sheets at the height of the Wisconsin? In New England the ice had to be at least 4,000 feet deep to have covered the White and Green Mountains. Over Hudson Bay and the ancient Canadian Shield it must have been more than two miles thick to have bent down and depressed bedrock as much as 1,000 feet. The land surface from the Great Lakes north is still rebounding from release of that great weight, as is all Scandinavia.

When the meltback began and the release came, it took relatively little time—a few thousand years. The land was unlocked, changed dramatically by both the coming and the going of the ice.

The ice sheet left ground-up debris, called till or drift, smeared wherever it had been. It left ridges, or moraines, of heaped-up debris along the farthest lines of advance; Long Island and Cape Cod are two such moraines. It left myriad lake basins, as in Wisconsin and Minnesota; ice-block potholes, called kettles; long sinuous ridges of stream-deposited gravel, called eskers; and curious ice-molded hills, called drumlins.

And it left water—sheets of water running from atop and below the ice, rivers gushing from tunnels in the ice front, huge glacial lakes such as Agassiz in Minnesota, Manitoba, and the Dakotas, and Bonneville in Utah and Nevada.

These lakes occasionally broke out from behind ice dams in monstrous floods. One swept across northern Idaho and southeastern Washington and created the channeled, tortuous scablands. Another came sweeping down the Mississippi Valley to decimate life in the Gulf of Mexico about 11,600 years ago. Year after year, century after century, the flow of meltwater must have been prodigious.

As the ice melted from North America, from northern Europe, from the icebergs that spilled from Antarctica and Greenland, the seas steadily rose. Measurements on the continental shelves, on drowned seamounts, on coral islands, all put the rise at close to 110 meters—360 feet. Intruding seas dramatically reshaped coastlines, broke up floating ice shelves, flooded into Hudson Bay and the Baltic Sea, and left the face of the globe much as we see it today.

**Winter was harvesttime,** *when neighbors came together to reap a summer's supply of ice, before the era of widespread artificial refrigeration. The old tools still work for members of the New Bremen, New York, Volunteer Fire Department* ***(top)****, who store ice to sell to campers. After scraping snow off Crystal Pond, they use a power saw to score the surface—horses pulled ice plows until early in this century—then saw the blocks by hand. Layers of sawdust insulate the crop in an icehouse.*

*The Chinese stockpiled ice as early as 1000 B.C. Ancient Greeks and Romans chilled their wine with snow kept in straw-lined pits, though Hippocrates thought "drinking out of ice" was a health hazard. Summer ice was a novelty for wealthy 18th-century Europeans, but storage techniques in Persia were so advanced that one traveler wrote, "the poorest are enabled to have it."*

*As long-term storage improved, ice became increasingly available to preserve food. The first "refrigerator" was patented in 1793 by Thomas Moore, a Maryland farmer famed for delivering hard butter in summer months. His invention was a cedar tub fitted at the top with a tin ice tray and wrapped in rabbit pelts for extra insulation. Moore's widely read essay describing how cold air sinks and circulates led others to design kitchen iceboxes. The tong-wielding icemen who stocked them* ***(right)*** *melted away in the 1930s with the advent of electric refrigerators.*

*Ice-harvesting companies, which once shipped their wares as far as Calcutta, also folded. The natural-ice industry had already been crippled by competitors who artificially froze ice through vapor compression.*

*In 1912, when fire destroyed a Mountain Ice Company warehouse in New Jersey* ***(far right)****, the surviving ice was simply allowed to melt "as it would not pay to prepare it for shipment under the prevailing low prices." The melting took weeks.*

*Now catering to a leisure society, the U. S. packaged-ice industry registers a billion dollars in annual sales.*

SETH RESNICK (ABOVE); BROWN BROTHERS (BELOW LEFT); WILLIAM DEVONVILLE (BELOW RIGHT)

TO GO BACK, to actually see what the ice atop North America must have been like, one can fly across Greenland en route to Iceland or Europe. Better yet, one can go to Antarctica.

Almost 90 percent of all the ice on earth lies atop the Antarctic Continent: seven million cubic miles of it (30 million cubic kilometers). It rises more than two miles; at the South Pole it is 9,200 feet thick; at the Soviet Union's Vostok Station, more than 12,000.

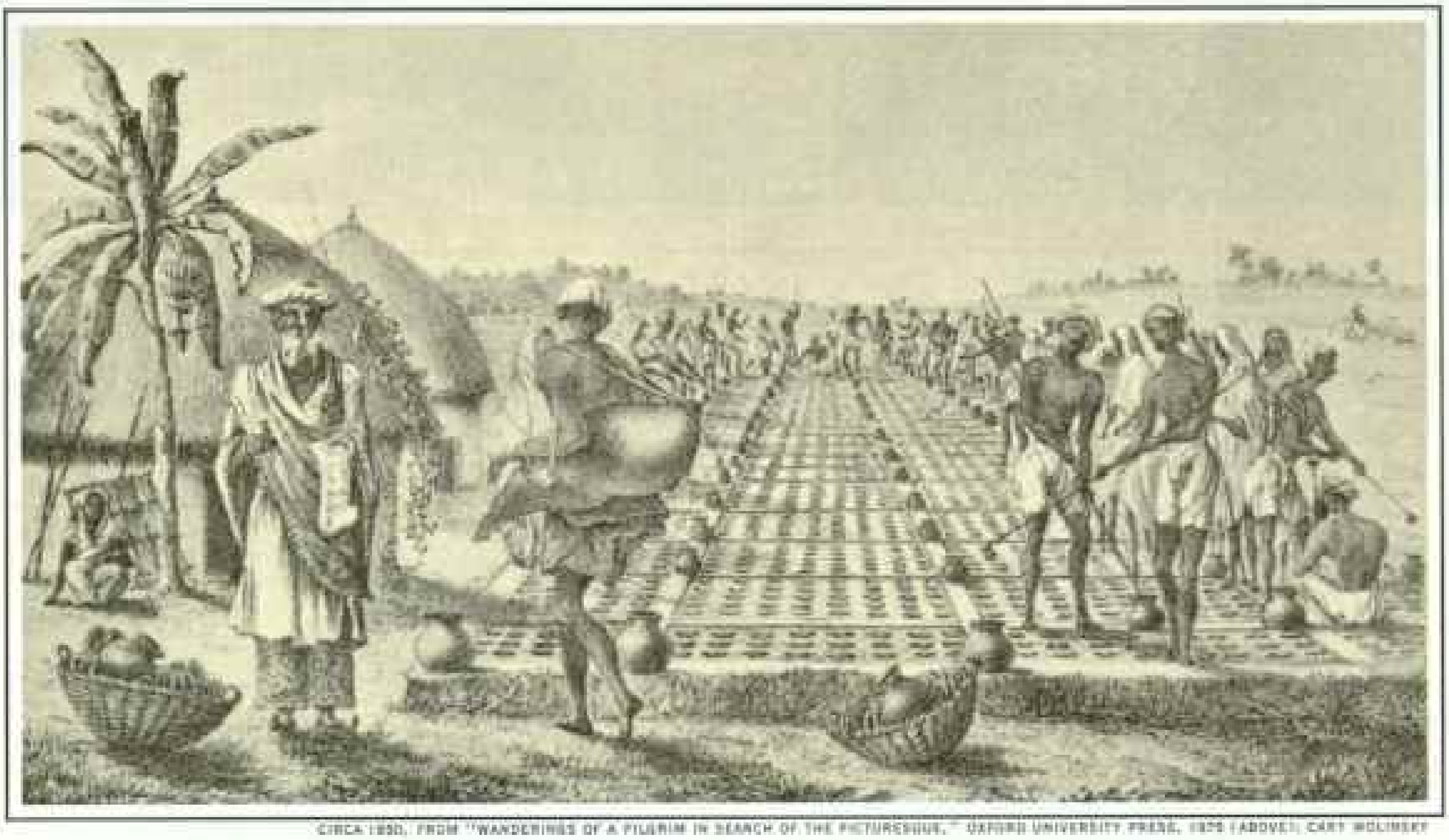
Antarctica is literally a desert; most of it gets less than two inches of snow a year. But that snow scarcely ever melts—it just blows from place to place and grows deeper.

From the lofty dome of ice deep in the interior, behind a wall of mountains that divides the white continent diagonally, ice slowly flows outward and down to the sea on all sides. It escapes through passages in the mountains to the ice-submerged archipelago called West Antarctica, and to the great ice shelves of the Ross and Weddell Seas.

To reach the South Pole, on the high inland plateau of ice, one flies from the main U. S. Antarctic base at McMurdo Sound, at the edge of the Ross Ice Shelf, up the massive, fractured Beardmore Glacier. On the dark, gaunt mountainsides, striations and narrow bands of glacial debris, called lateral moraines, show where ice higher than today's has scoured and scraped across in the dim past. More dramatically still, here and there run bands of lighter sandstones, and amid them jet black streaks of coal.

Antarctica was not always shrouded in ice. Long before the Pleistocene, the continent was warm and held lush vegetation, even forests. Only such organic matter, later covered by warm seas and thick marine sediment, could have produced the coal seams that run through the Transantarctic Mountains, some of the most extensive on earth.

Other startling evidence of ancient landscapes and seaways near the South Pole has recently been found high on these peaks. Tree stems, roots, pollen, and tiny fossils of open-water marine life have been identified



CIRCA 1850, FROM "WANDERINGS OF A PILGRIM IN SEARCH OF THE PICTURESQUE." OXFORD UNIVERSITY PRESS, 1978 (ABOVE); CARY WOLINSKY

"**We are making ice by evaporation** *almost every night.*" *In the winter of 1828 in Allahabad, "the oven of India," Englishwoman Fanny Parks described how water ladled into bowls set into the ground froze as a result of cooling evaporation even when air temperatures hovered above freezing. Preserved in pits covered by thatched-roofed huts, the 120 tons produced that year lasted into August. Today pond ice hauled from storage caves comes to market in Kashi, China* (**right**).

by Ohio State geologists Peter-Noel Webb, David M. Harwood, and John H. Mercer as being two to four million years old, from the Pliocene epoch. Yet up to now it has been thought that ice lay deep on Antarctica as long as 15, even 30, million years ago.

The shrub wood (following page) grew on the banks and shores of alpine streams and lakes during several interglacial periods, the researchers suggest. In those relatively warm times, great open seaways may have reached deep into the Antarctic interior, and the great central ice mass may have retreated to much smaller ice caps and high alpine glaciers (diagrams, page 97).

When, as in the Northern Hemisphere, the central ice sheet began growing again, it must have scraped up the tiny fossils from the floor of an inland sea and carried them high into the Transantarctic Mountains.

Or did the mountain range, the mightiest in Antarctica, also lurch and rise upward thousands of feet? If it once was lower, less ice would have been needed to override it.

The polar vegetation found on the flanks of the Beardmore Glacier late in 1985, say Webb and his colleagues, must have grown along the edges of the ice as it advanced and retreated, melted and returned, in a time much warmer than today.

Thus the microfossils from the sea and the ancient wood fragments require a major and radical rethinking of Antarctica's long glacial history. Its ice cover must have been unstable, subject to massive advances and retreats much like those of the northern half of the globe.

IS THE ICE on Antarctica today shrinking, growing, or in balance? On this subject scientists are deeply divided. Most admit they simply do not know, and say it will take years, if not decades, of further research to find out.

The outpouring of ice from the high interior down to the coast, feeding the great floating ice shelves, seemingly keeps Antarctica's ice cover in balance. "But that balance may

be illusory," says glaciologist George H. Denton of the University of Maine.

Denton and his colleague Terence J. Hughes are authors of a monumental study, *The Last Great Ice Sheets*. In it they discuss what might happen if the West Antarctic ice sheet, resting largely below sea level, were to "collapse," or melt away entirely.

"The edges of that ice sheet have clearly retreated," Denton says. "We see it in the Ross and Weddell Sea embayments and on coastal mountains poking up through the ice, like so many dipsticks in reverse."

Ian Whillans of Ohio State, studying great ice streams that drain the broad West Antarctic ice sheet, agrees: He sees thinning of ice on both sides of the Transantarctic Mountains. Denton, conversely, thinks the main East Antarctic ice cap is growing thicker. He cites increased snowfall brought on by a still warming climate. The paradox: warmer times, more snow and ice.

Oddly enough, in that much warmer time before the truly polar Pleistocene Ice Age began, the East Antarctic ice sheet must have been far thicker than today's, Denton says. As it grew, pushing perhaps through Peter Webb's inland seas, the ice left marks on the very tops of the Transantarctic Mountains, above 14,000 feet today.

If indeed the central ice sheet is again thickening, that growth may be matched by outflow of glaciers, by calving of icebergs from the ice shelves (recent Norwegian studies show more bergs being produced than previously assumed), and perhaps by melting underneath the ice shelves.

Hughes and others have calculated that a total collapse of West Antarctic ice, with the ice shelves gone, would cause a rise in sea level worldwide of four to six meters—14 to 20 feet—in as little as two to five centuries. But if the ice shelves hold, says Denton, the specter of collapse of Antarctic ice and a catastrophic rise of sea level seems unlikely.

Though worried by continuing increase of carbon dioxide in the atmosphere, leading to even warmer climate ahead, most scientists put the possible rise in sea level, largely from expansion of warm seawater and the melting of Northern Hemisphere glaciers, at only one to two feet by the year 2100.

After that, as polar ice grows thicker from more snowfall, sea level may fall again.

DRILLING DEEP into Antarctica's ice is a way for climatologists to read the far past. Such work in Antarctica was undertaken by the United States in 1967-68 at Byrd Station, where a core drill went down 2,164 meters (7,101 feet) before it hit liquid water near bedrock, then froze fast.

In 1970 Soviet scientists began drilling at Vostok Station, high on the inland ice cap in East Antarctica. In 1981-82 French scientists reached more than 900 meters beneath a point named Dome C, near the center of the huge ice cap. And since 1980 the Vostok ice drillers have bored through more than

JAMES A. SUGAR, BLACK STAR

2,080 meters of the 3,700 meters (12,140 feet) of the ice under the station.

"The Vostok core is the first to cover, completely and unambiguously, the entire last 150,000 years of earth's ice-age cycle," French glaciologist Claude Lorius reported in 1985, after working with Soviet scientists on the ice core. "It clearly goes back through earth's previous interglacial warm period, called the Eem or Sangamon, and well into the ice age before that.

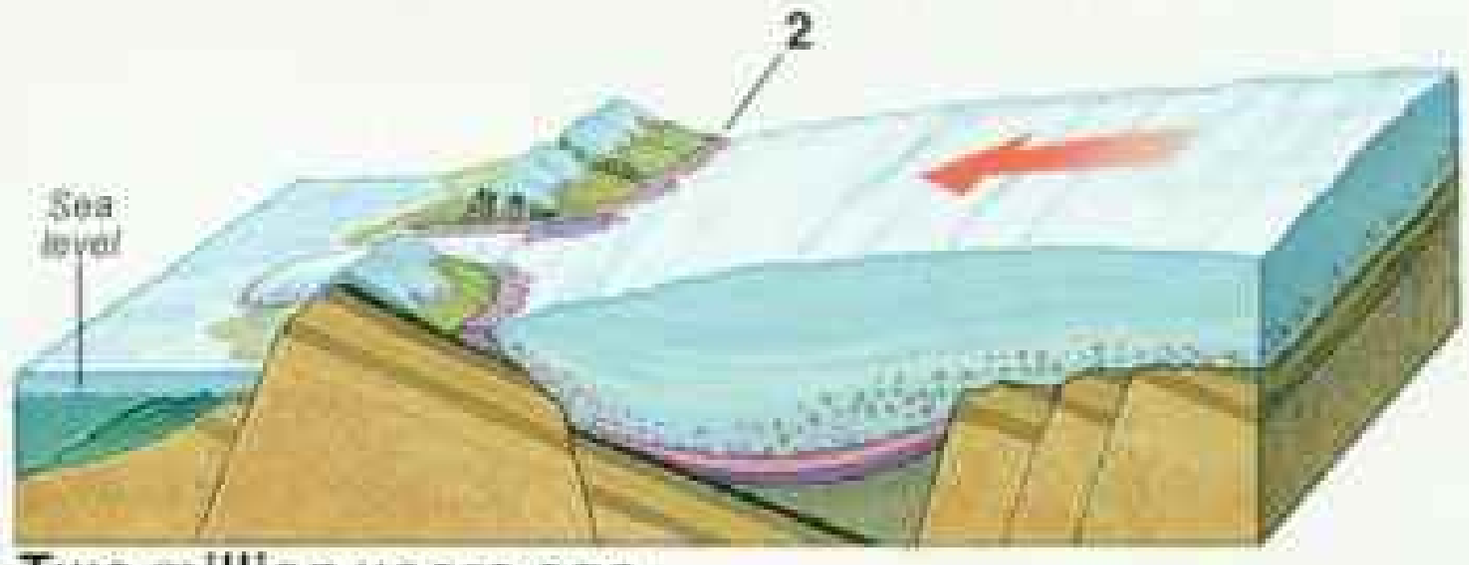
"That previous interglacial was similar but markedly warmer than our present warm spell, the Holocene," he told me in Washington, D. C., a few months after returning from Antarctica in 1985. "The beginning of the previous warming was as sharp and extensive as was the opening of the Holocene, between about 10,000 and 8,000 years ago."

The Vostok core, somewhat surprisingly

# Clues to an ice cap's history

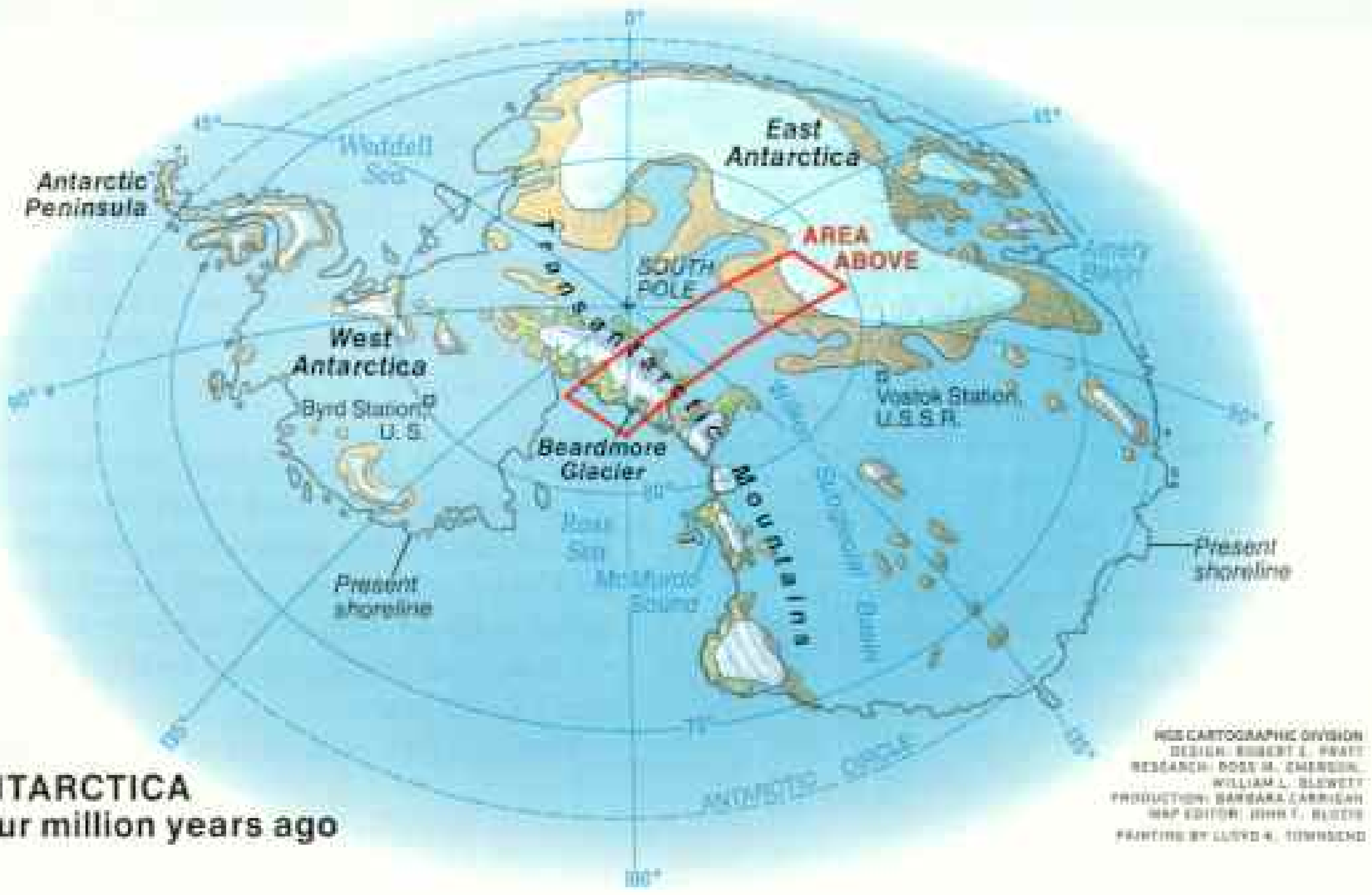
PREMIER LABORATORY *for deep-freeze science, Antarctica holds nearly 90 percent of the world's ice. Seven million cubic miles of ice as much as two miles deep mantle East Antarctica and the West Antarctic archipelago* (**below**). *In the Beardmore Glacier region recent discoveries of nonfossilized wood* (**left**) *and marine fossils perhaps four million years old challenge a theory that a thick ice cap has existed there for at least 15 million years. The finds suggest that the sea flowed through the continent's interior and vegetation grew on the flanks of the Transantarctic Mountains* **1** *during a more recent warm interglacial period. As temperatures cooled and ice advanced, fossil remains may have been thrust up the face of the range* **2**. *The mountains may also have risen thousands of feet, carrying the artifacts to their current location* **3**.


**Present**



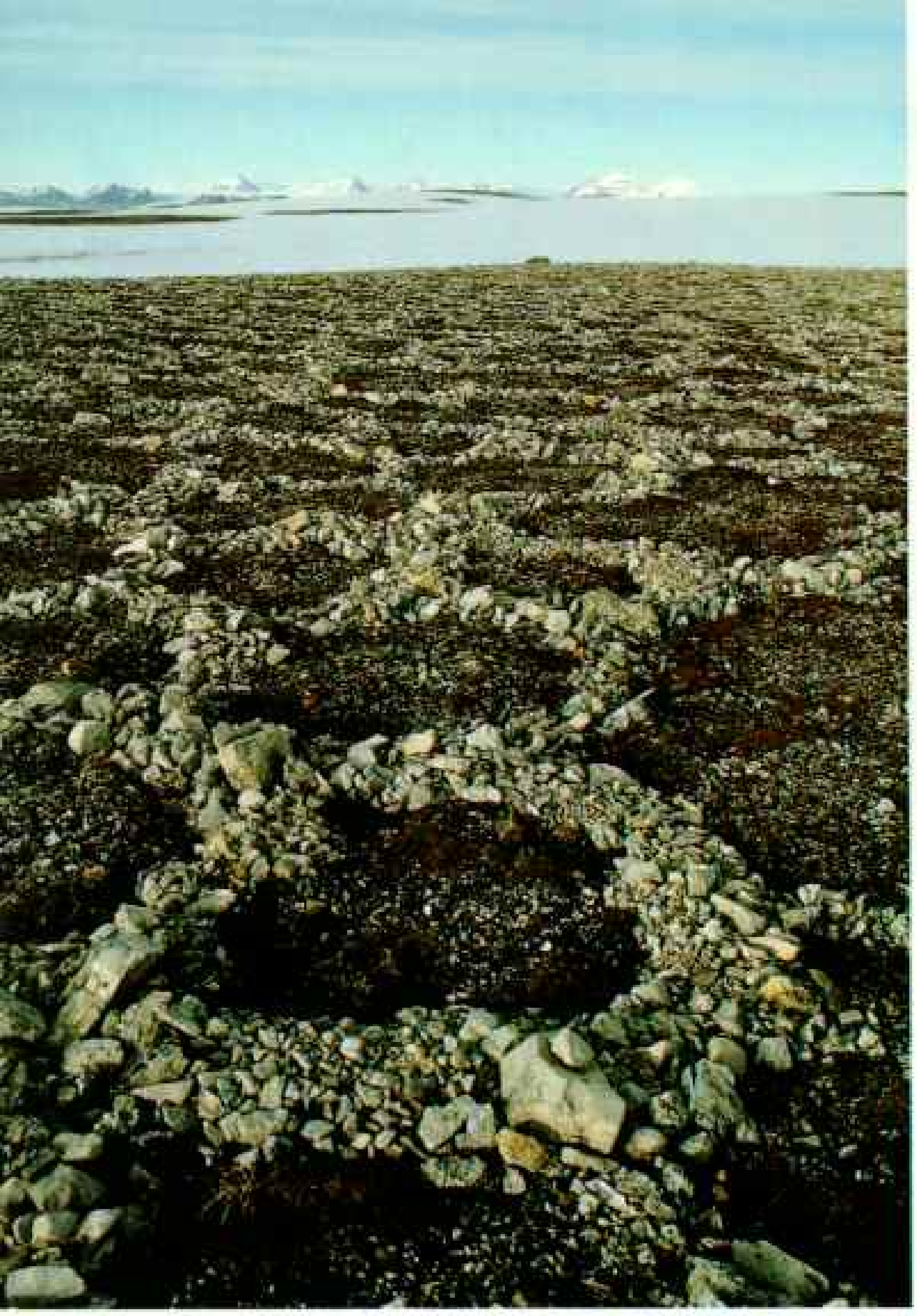

**Two million years ago**


**Four million years ago**




**ANTARCTICA**
**Four million years ago**

NGS CARTOGRAPHIC DIVISION
DESIGN: ROBERT E. PRATT
RESEARCH: ROSS M. EMERSON, WILLIAM L. SLOWEY
PRODUCTION: BARBARA CARRIGAN
MAP EDITOR: JOHN T. BLOCK
PAINTING BY LLOYD K. TOWNSEND



***Ice's handiwork*** *can be as annoying as a pothole or as magical as circles of stones found in Spitsbergen* ***(above)*** *and periglacial regions worldwide. As wet silty ground freezes and thaws, the soil slowly circulates by convection. Rocks lifted to the surface by repeated freezing drift to the border of the soil current. Eastern Pennsylvania resembled present-day Greenland when these red sandstone boulders* ***(center)*** *were fractured by frost and rounded by meltwater 10,000 years ago. In Alaska's Wrangell Mountains frost-shattered rock interlaced with ice creeps downhill one to two inches a year as a rock glacier* ***(far right)****.*

to Professor Lorius, does not hold evidence of more volcanic activity on earth during the past glacial age and previous interglacial than in modern times. But the volcanic dust seen there, as in cores taken from the Greenland ice cap, has given a precise and dramatic record of many great volcanic events of the distant past.

IN 1980-81 Danish, Swiss, and American scientists penetrated more than a mile deep at a point named Dye 3 in southern Greenland. From winter-summer variations in the preserved frozen core, the drillers can read year-by-year weather for the past 11,000 years.

The massive eruptions of the volcanoes



BERNARD HALLET (LEFT); CARY WOLINSKY (CENTER); GEORGE HERBEN (RIGHT)

Laki in Iceland in 1783 and Tambora in the East Indies in 1815 are clearly identifiable near the top of the Dye 3 core. The latter produced the notorious "Year Without a Summer" in New England in 1816, when crops froze and snow fell in July and August.

Sequences of heavy summer melting from A.D. 950 to roughly 1200 confirm the world's warmth during the time that Vikings settled and thrived in Greenland, before the cold of the Little Ice Age froze them out. (From about 1200 until the mid-1800s, world climate was colder than at any time since the last deglaciation.)

Even deeper in the core, volcanic acids show that an eruption must have darkened skies over Rome the year Julius Caesar was killed in 44 B.C. A blast in 1390 B.C. may have been one of several that spelled the end of the volcanic isle of Thera in the Aegean.

On back through time, the Dye 3 core gives absolute dates to unwritten events:

- 4401 B.C. Explosion of Mount Mazama in Oregon created Crater Lake.
- 7911 to 7090 B.C. Seven different great eruptions occurred somewhere on earth.
- From 25,000 down to 10,000 years ago, high amounts of wind-blown continental dust marked the last glacial maximum in the Northern Hemisphere, before the start of global warming in the Holocene.

Analyses of a previous deep ice core taken at Camp Century in Greenland provide ominous evidence that the last interglacial may

have ended suddenly and dramatically. A brief, sharp cooling was followed by temperatures only slightly lower than today's. But both ice and seabed cores show it took only 5,000 to 10,000 years for ice sheets to build up on the earth—some 25 million cubic kilometers of ice, with a corresponding 60-meter (200-foot) drop in world sea level.

Could it happen again? And that fast, in the stately turning of the geologic calendar?

EAST OF GREENLAND, which is no longer green, lies Iceland, an island of volcanic fire and ash more than of ice. But it does hold one of the largest ice caps outside Antarctica and

TOM BEAN

**Wiggling** *through tiny air pockets in an Alaska glacier, an inch-long ice worm—Mesenchytraeus solofiugus, once thought to be mythical—feeds on algae and pollen.*

Greenland, named Vatnajökull. Lying underneath Vatnajökull is an active volcano, Grímsvötn. And beneath the smaller Mýrdalsjökull, not far to the southwest, is another, Katla.

I have twice been to Iceland to see these glaciers, and to drive across vast outwash plains of black sand and ground-up lava between the ice-locked mountains and the cold sea. With an Icelandic glacier expert, Helgi Björnsson, I talked of what happens when a volcano exists under a huge sheet of ice.

"There is what we call a *jökulhlaup*—a glacier burst—and it is nothing to be in the way of," he said. "At least 13 have occurred from the Grímsvötn region of Vatna since 1955. Katla produced a catastrophic one in 1918; more water than the Amazon carries burst forth and flowed to the sea for only a few days.

"These floods shape much of Iceland's south coast. They keep stretches of it all but cut off from the rest of the country because of the washout of roads on the coastal plain.

"Vatna bursts about every two years, with a bad one every five years. In between, geothermal heat beneath the ice builds up a big pool or reservoir of meltwater, as much as a thousand feet deep. A ridge of rock holds it in, until suddenly it breaks open a channel under the ice, sometimes 30 miles long."

Helgi told me of an ambitious plan to end the Grímsvötn floods. After a future burst, when the glacier pool has drained to its lowest, a tunnel "the size of my office" might be drilled through the mountain ridge, he said, to carry off gathering meltwater and prevent another outburst.

FROM TALK of a volcano meltwater tunnel in Iceland, I traveled to a highway tunnel being bored through a mountain beneath the largest glacier left in Norway, Jostedalsbreen.

Much of west-central Norway is cut off from the populated south by deep fjords and the glacier-capped mountains above. Boats and roundabout roads provide the only way to reach towns and farms isolated by ice. But a dream of decades was nearing reality at the head of a lovely fjord and farm community named Fjærland.

"We'll be driving our cars 4,000 feet beneath the surface of Jostedalsbreen when the

tunnel is completed," said an old friend, glaciologist Olav Orheim of the Norsk Polarinstitutt. A veteran of research journeys to both the Arctic and Antarctic, Olav for years has helped his family operate a summer hotel at Fjærland. Its name, the Mundal, is not only that of the oldest farm in the valley, but also—as anglicized—that of former Vice President of the United States Walter Mondale, whose family came from there.

Olav and I and GEOGRAPHIC photographer Otis Imboden flew by floatplane over the heights of Jostedalsbreen, under clouds only a few hundred feet above the glacier surface. Down the tumbled, crevassed spillways of ice we twisted and turned, following ancient scour marks and moraine lines on the mountainsides. Finally we landed on the ink-dark water at Fjærland.

"This fjord drops to more than 3,000 feet deep at its mouth," Olav said, "and once it held solid ice up to 3,000 feet above us."

A LIVING DIORAMA of the Ice Age in the United States lies in the glaciers of Alaska's southeastern Panhandle and the Chugach, Wrangell, and St. Elias ranges between Anchorage on the west and Yakutat to the east.

Amid mountain scenery as spectacular as any on earth, the glaciers spill down from gaunt peaks, flow together, and fan out in

DOUG ALLEN, OXFORD SCIENTIFIC FILMS, LTD.

**A crimson tide** *of summer-blooming algae tints a glacier in the South Orkney Islands. Common throughout the world, these one-celled plants form a vital first link in polar food chains. Discovery of brown algae on the underside of Arctic ice floes renews concern about the effects of oil spills on the environment.*

LONNIE G. THOMPSON

***Frozen archive*** *of weather reports, the 50-meter face of the Quelccaya Ice Cap in Peru's Andes displays annual layers of snow separated by dry-season dust. A 165-meter-long ice core, taken at the ice cap's summit, holds 1,500 years of climatic data. Ice cores from Greenland and Antarctica trace conditions as far back as 150,000 years. But Quelccaya offers a rare record of equatorial weather patterns, such as El Niño, which can wreak global havoc.*

multistriped ice fields along the Gulf of Alaska. Each black stripe of glacial debris is a side moraine from a different ice river. Count the stripes, and you know the number of glaciers feeding the final broad ice stream.

Occasionally a glacier will "surge"—a technical term to glaciologists, translated in popular jargon to "galloping." The ice suddenly begins flowing far faster than normal, grinding and pushing downhill at speeds of tens, even hundreds of feet a day.

I went to Alaska in 1982 because a well-known glacier immediately adjacent to the Hubbard, the Variegated, was in early stages of a surge. Glaciologists from the Universities of Washington and Alaska, Caltech, and the Swiss Federal Institute of Technology were camped on the glacier with ice drills, theodolites, and other gear to record the ice river's gallop forward. It had begun only a few weeks before.

"Our thinking is that a glacier that surges has changed its internal plumbing system," explained Barclay Kamb of Caltech, a friendly, articulate ice scientist. "Meltwater at the base, blocked in its normal escape passages, builds up pressure until the friction between ice and rock is nearly overcome, allowing the ice to slide downhill much faster [diagrams, pages 114-15]."

Day by day I could sense it moving—hear it and all but see it. Along the edges of the Variegated, creaking and groaning and booming of tortured ice gave loud proof that the frozen river on which the scientists were camped was indeed lurching downhill.

"We can measure not only the surface motion—between three and twenty feet a day right now—but also what is more interesting to us: pulses of water pressure traveling underneath. In a series of drill holes through the glacier, we are recording pressure waves moving as fast as 1,000 feet an hour."

The surface of the ice was also rising and falling slowly, like the back of a massive caterpillar, measured by precise instruments mounted on high promontories and cliff ledges above the glacier. Water flowed through deep crevasses in the glacier and gushed in a milky freshet from its snout.

When British explorer George Vancouver sailed this coast in 1794, ice entirely blocked the mouths of several of today's deep,

winding fjords—among them, Glacier Bay southeast of Yakutat. He saw that an inlet existed there, but he could not sail in to prove it. Today ships as large as ocean liners call regularly in Glacier Bay—call with their great horns to try to bring down ice cliffs in thunderous collapse.

Muir Glacier, from the point where famed naturalist John Muir saw it in 1879, has retreated an additional 30 miles, nearly doubling the extent of the ice-freed bay.

ANOTHER ICE RIVER in Alaska is in the process of doing the same thing: Columbia Glacier, just west of the oil-pipeline port of Valdez. Its towering ice cliffs front on deep water in Prince William Sound. There it has stood, calving icebergs and smaller chunks called growlers and bergy bits and brash ice, for hundreds of years.

It has, that is, until a few years ago. Then, for reasons best known to the gods of ice and sea change, the cliffs began spawning more icebergs and inching back off the glacier's doorsill, its terminal moraine.

NATIONAL GEOGRAPHIC photographer Joe Scherschel and I visited Valdez in 1982 to see the Columbia as its retreat was accelerating. With a grizzled, friendly glaciologist named Austin Post, we flew over the Columbia and down along its face in an old Cessna. From the plane's open door we peered straight down and full face at a great embayment in the ice front. It towered 200 to 300 feet above the water. Loose brash ice and bergy bits clustered at its face, but remarkably few large icebergs.

Four years later the scene at the Columbia was far different (following pages). The glacier's face had moved back more than a mile and a half. In front of it, trapped between the glacier and its former submarine sill, lay a jam-packed apron of icebergs, floes, and bits—loose ice that kept any ship, no matter how large, from approaching.

"The Columbia went back fast the first couple of years," Austin told me. "Now it's thinned down somewhat and may be pausing before it begins breaking back again. But since the terminus lies in deep water [measured in September at nearly 1,000 feet], we think it will continue to retreat rapidly.

"Exactly the opposite is happening to the Hubbard. While the Columbia draws back, the Hubbard may be undergoing a major advance, heading back down its bay toward where it stood hundreds of years ago.

"Why? Tidewater glaciers such as these seem to follow long-term cycles of advance and retreat. They do not behave alike or in phase. Their changes relate to dynamics of ice movement, different shapes of their valleys and snow-accumulation areas, and conditions at and under their faces."

Extraordinarily heavy snows of the past three winters in southeastern Alaska, from 1983 to 1986, may be forcing the Hubbard's advance, says Dr. Maynard M. Miller of the University of Idaho. For 40 years he has studied and recorded glacier activity centered in the Juneau Ice Field.

But other glaciologists disagree. Many of them see little connection between local weather or short-term climate changes and the behavior of these great ice streams that end in the sea.

THUS GLACIOLOGISTS watch and measure and ponder: Under the inexorable Milankovitch cycles of earth's solar orbit, will the great continental ice sheets again begin growing? A hundred, a thousand years hence, will the ice have returned?

Certainly the planet's climate will change in coming millennia, say the scientists of a study called CLIMAP—an acronym for Climate: Long-range Investigation, Mapping, and Prediction. The Northern Hemisphere, overall but particularly in high latitudes, appears already to be cooling, after a century and a half of abnormal warmth.

On the other side of the equation is man himself. Will we, by our profligate burning of hydrocarbon fuels, intensify the greenhouse effect of excessive carbon dioxide in the atmosphere and delay the natural planetary cycle? Will the present interglacial thus become even warmer, and the oceans continue to rise, as the ice sheets of Antarctica and Greenland pull back and turn to water? Or will the ice caps grow and spread under increasing snowfall, and the seas begin to fall again?

Stay tuned for the weather broadcasts of the next millennium. □

The geologic tide has finally turned for the Columbia Glacier, a 425-square-mile ice fortress that has long awed cruise-ship visitors on Alaska's Prince William Sound. Stable since it was first studied in 1899, the Columbia is now in rapid retreat. In 1982 a large embayment (below, at right) indicated a weak spot. Since then the glacier has pulled back nearly two miles (left), with a broad fan of loose ice floating before its three-mile-wide face. In a few decades the Columbia may recede 20 miles or more and expose a new fjord, much as Glacier Bay was created 400 miles to the southeast.

NATIONAL GEOGRAPHIC PHOTOGRAPHER JOSEPH J. SCHERSCHEL (BELOW); CHRIS JOHNS

Alaska's two mightiest glaciers that meet tidewater, the Columbia (overleaf) and the Hubbard (following pages), are racing in opposite directions. The advancing Hubbard created a lake that swelled for five months, then emptied in a torrent as the glacial dam burst.

# GLACIERS ON THE MOVE

By JOHN L. ELIOT SENIOR EDITORIAL STAFF

Photographs by CHRIS JOHNS

AMID THUNDEROUS booms and cracks, a wall of ice confronted naturalist Karen Jettmar (***next pages,*** in red) and editor Sam Matthews last August. Karen knows Hubbard Glacier well. For five years she has often sat among wildflowers on this knob of bedrock called Osier Island, watching ice cascade from the glacier's face hundreds of yards distant.

Last spring, bearing down like a huge, noisy amoeba, the Hubbard all but swallowed the islet while turning a saltwater fjord behind it into a freshwater lake. "We were all incredulous at the changes," Karen says, as ice, earth, and sea clashed in high drama around the shores of Yakutat Bay on the Gulf of Alaska.

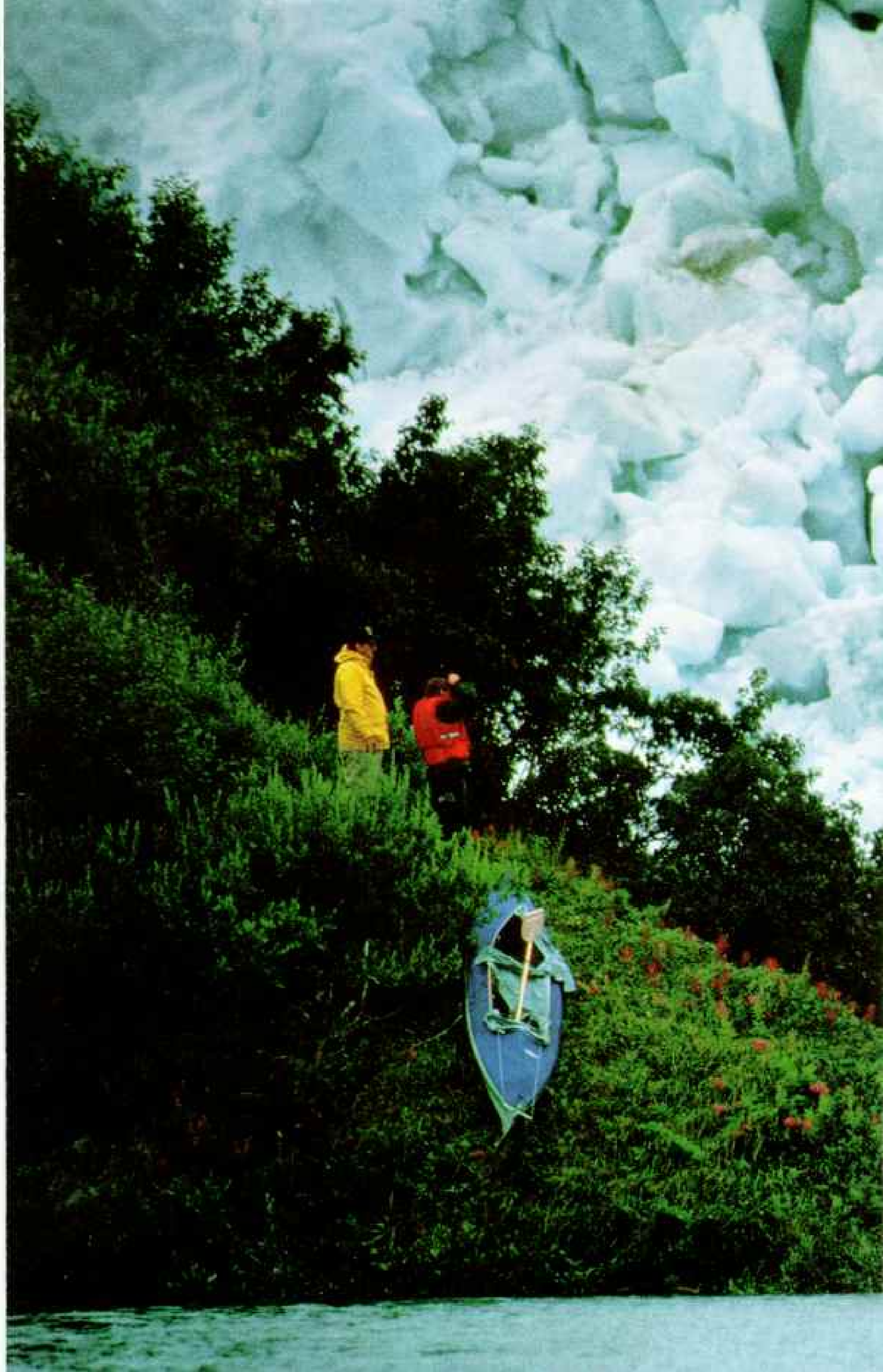
Glaciers are both the planet's premier sculptors and its humble hod carriers, carving the stone of uplifted mountains and hauling the grindings to enrich future farmland. Although the great ice sheets of the Pleistocene began retreating 14,000 years ago, countless thousands of glaciers still lie upon earth's face. Alaska, covered by about 30,000 square miles of ice, is a fountain of glaciers. While the Columbia is in the midst of a major disintegration, more than 20 other glaciers show signs of rapid advance. The vast Hubbard in Wrangell-St. Elias National Park, extending more than 90 miles from its Canadian ice-field source, has been moving forward for more than a century.

By Memorial Day the glacier had crossed a strait and pushed a thick plug of mud, gravel, and boulders to the far shore. Russell Fiord was cut off from salt water, and it began to rise fast from rain and glacial melt. A hunting guide, Mike Branham, first noticed the situation and spread the word in Yakutat, a town about 35 miles south. He reported water in the trees along the shore rising nearly a foot a day—and he knew that some force other than the tide was at work.

The water was increasingly fresh, flowing in as a layer atop the salt water in which fish, seals, and porpoises thrived. And the ice dam that held it was rising even faster. By early October Russell Lake—as it was by then known—stood more than 80 feet above sea level. But glaciologists monitoring the dam detected signs of weakness. The dramatic outcome is revealed on pages 112-13.

◀ THIS PAGE FOLDS OUT



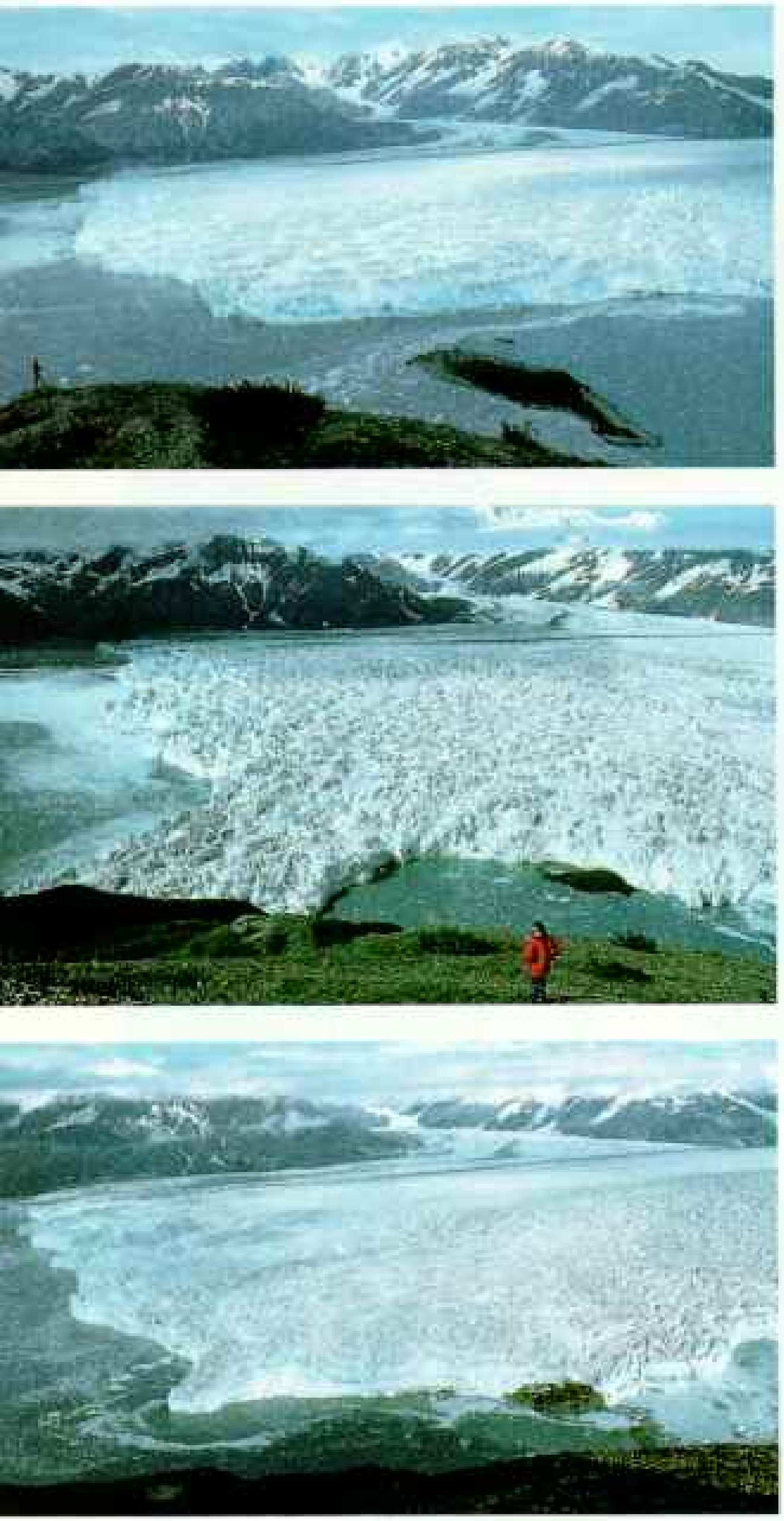


**The Hubbard's might explodes** *last July as a pillar of ice calves into Disenchantment Bay* (**above**), *the head of Yakutat Bay. Behind the glacial dam, as Russell Lake rose to drown shoreline trees, a volunteer* (**below**) *paddles in search of about 100 harbor seals and a score of harbor porpoises thought to be trapped there. Environmentalists feared that the animals' prey would not live in fresh water, nor would oxygen in the deeper salt water last indefinitely. A few volunteers tried to save the marine mammals. Other groups such as the Cousteau Society called the efforts futile. Though the porpoises eluded the*

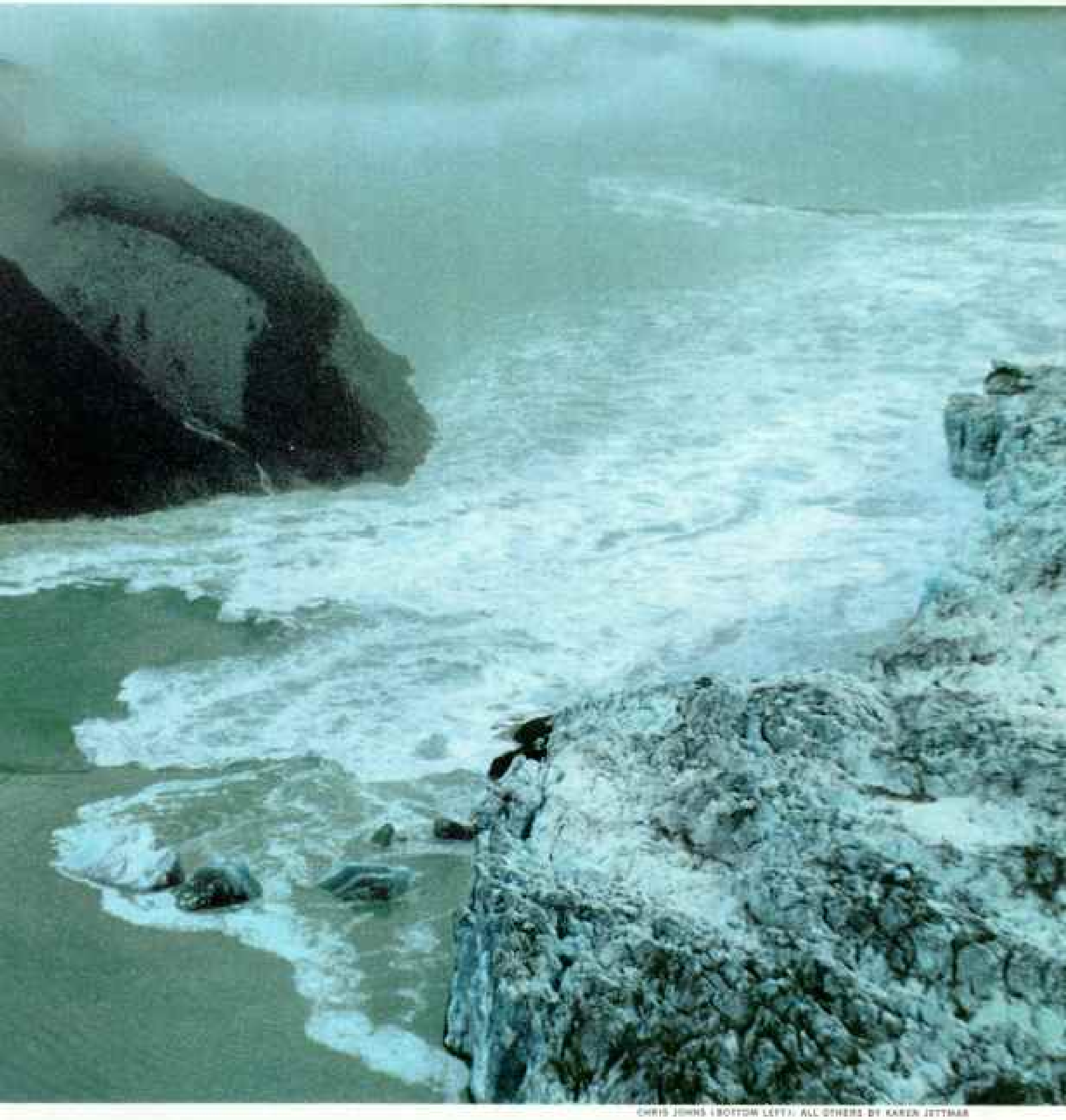
KAREN JETTMAR, BELOW


*rescuers, a few seals were aided. One that had crawled partway across the glacial moraine is carried the remaining distance (**right**) to Disenchantment Bay. Other seals traversed the dam—some 90 feet high and about a quarter of a mile wide—and rescued themselves, before the rock and ice gave way to free all the trapped sea life.*

*Residents of nearby Yakutat, where Tlingit Indians still hunt seals, were far more concerned that the lake might spill over into the Situk River and destroy spawning grounds on that world-famous fishing stream. Geologic evidence indicates such a past occurrence, along with the Hubbard's long cycle of advance and retreat (**map, above right**). Dotted lines show the glacier once filled not only Russell Fiord but all of Yakutat Bay.*



***Russell Lake breaks out,*** *racing into Disenchantment Bay on October 8* **(above right)** *after the glacial dam collapsed in a roaring torrent of massive icebergs, water, and debris that lasted for hours. A chronological sequence shows a landscape changing before our eyes. By 1982* **(top)** *Hubbard Glacier had nearly closed the bay. To the right of Osier Island lies Russell Fiord. In early 1986 a tributary glacier, the Valerie, in the background, began surging as fast as 130 feet a day, prodding the Hubbard into a rapid advance last spring* **(middle)**. *Here a spur of ice and debris has wedged against Gilbert Point, foreground, walling off the fjord and half-burying Osier Island. The spur gave way on October 8* **(bottom)**. *The dramatic midnight breakout kept four automatic cameras, placed jointly by* NATIONAL GEOGRAPHIC, *the National Park Service, and the University of Alaska, from recording the event's peak. One camera*

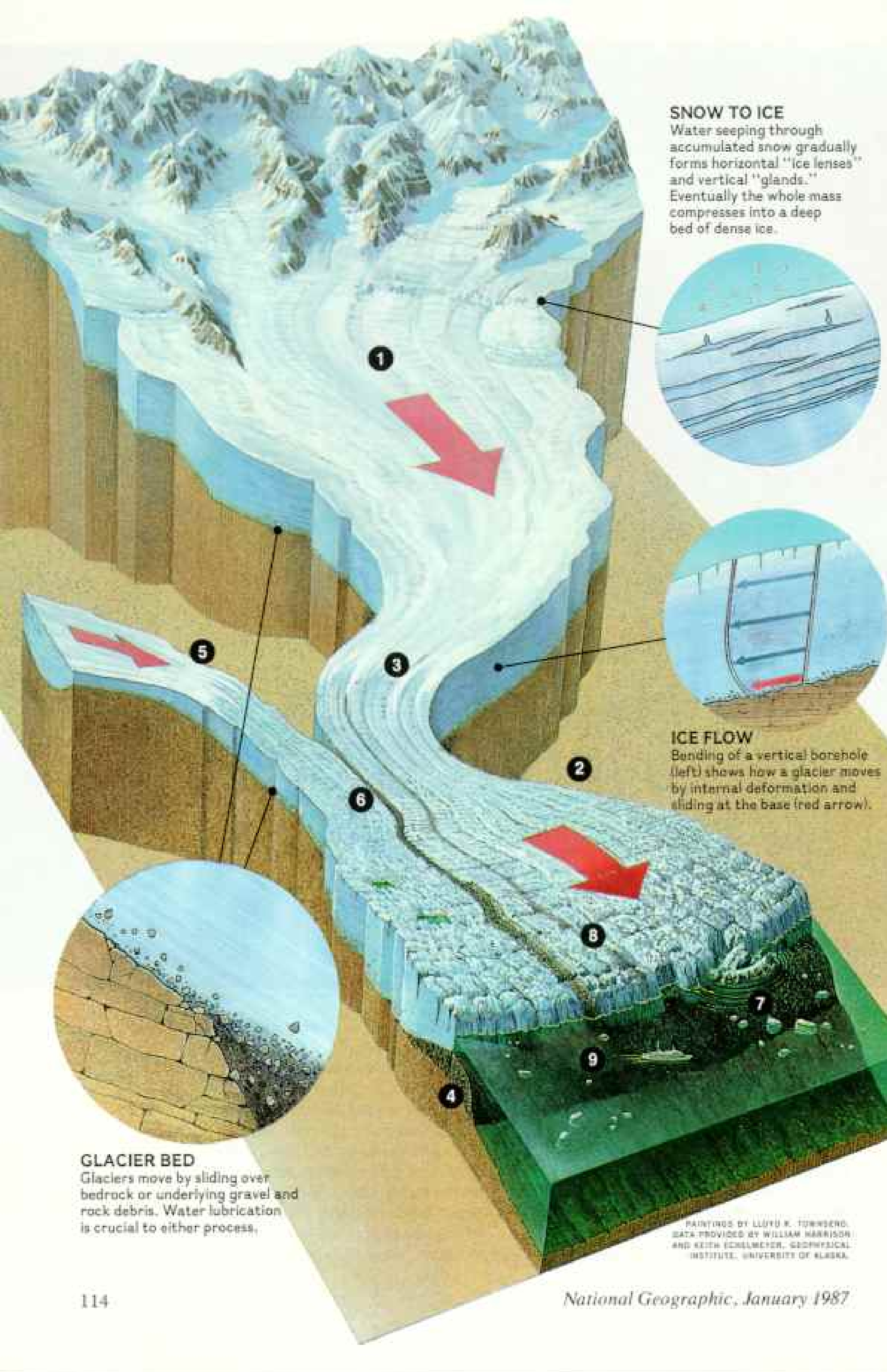


CHRIS JOHNS (BOTTOM LEFT); ALL OTHERS BY KAREN JETTMAR

*nearly was lost on a bluff sharply undercut by the flood.*

*Larry Mayo, glaciologist for the U. S. Geological Survey, earlier had predicted the dam's failure. The night it gave way he was camped high on Gilbert Point in a suitably supernatural atmosphere—blowing rain, snow, and fog that created a static discharge of "a blue flame, St. Elmo's fire, off my fingers, radio antennas, and cameras." He had been awakened by "a roaring and booming, punctuated by the explosive sound that large icebergs make."*

*Mayo later calculated the peak outflow at more than 3.5 million cubic feet a second, 35 times the flow of Niagara Falls, gushing out at 35 miles an hour. Standing waves towered 10 to 30 feet. The volume of ice released equaled 15 times the size of the Great Pyramid of Cheops. "I don't know if I'll ever again see anything like that much energy released at one time," says Mayo.*




**SNOW TO ICE**
Water seeping through accumulated snow gradually forms horizontal "ice lenses" and vertical "glands." Eventually the whole mass compresses into a deep bed of dense ice.

**ICE FLOW**
Bending of a vertical borehole (left) shows how a glacier moves by internal deformation and sliding at the base (red arrow).

**GLACIER BED**
Glaciers move by sliding over bedrock or underlying gravel and rock debris. Water lubrication is crucial to either process.

PAINTINGS BY LLOYD K. TOWNSEND. DATA PROVIDED BY WILLIAM HARRISON AND KEITH ECHELMEYER, GEOPHYSICAL INSTITUTE, UNIVERSITY OF ALASKA.

# Anatomy of a tidewater glacier

A GLACIER, simply put, is a slow-motion river of ice. It flows from high mountain peaks through rocky valleys, carrying off unmelted snow that has compacted over many years into a solid, creeping ice stream.

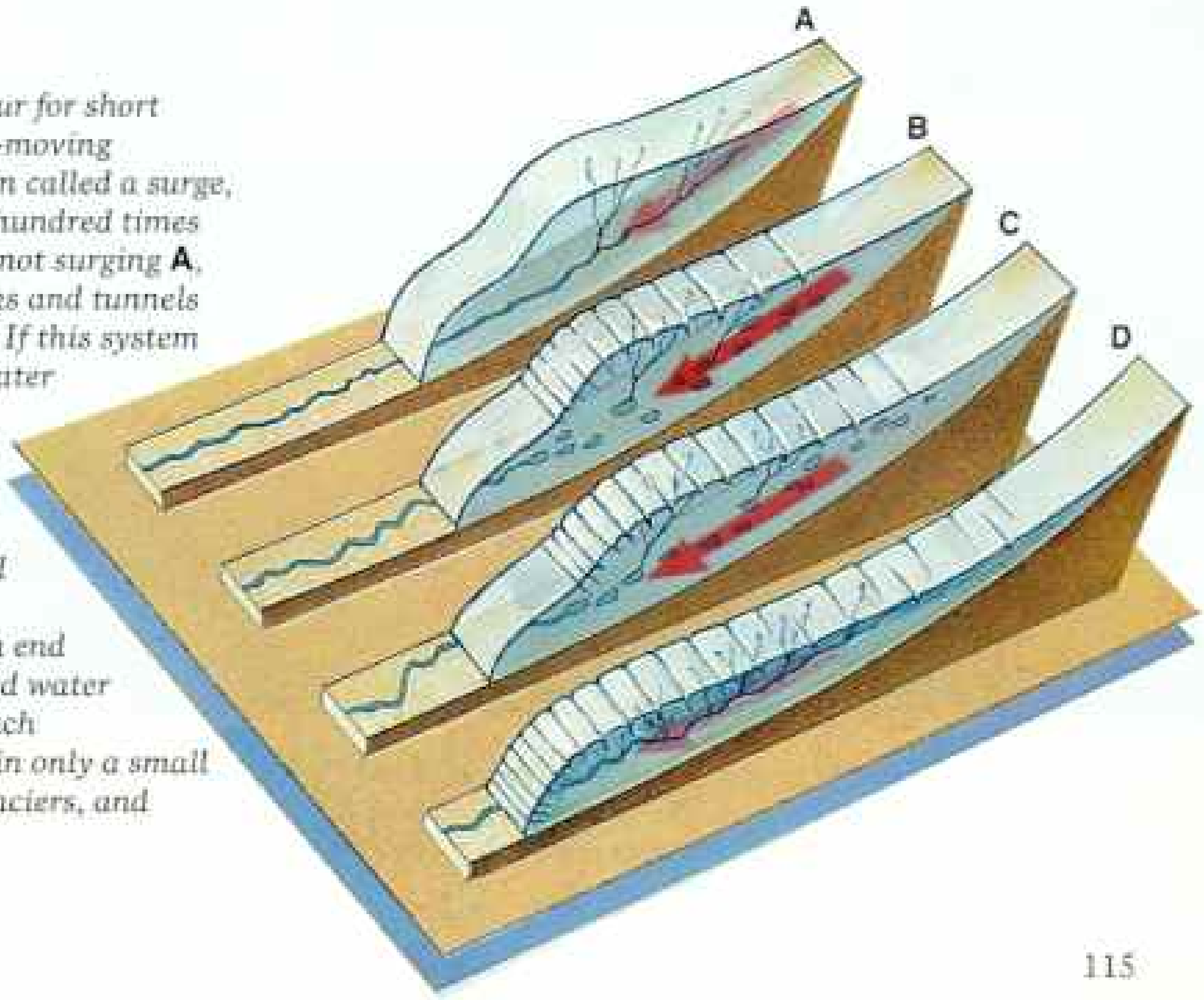
The ice flows like a conveyor belt, driven by gravity and the ever mounting snows behind it in an area called the accumulation zone **1**. In the lower region, or ablation zone **2**, the glacier loses ice through melting and evaporation. An equilibrium line **3** divides the two areas. If their budget is balanced, with enough new ice added to replace the loss, the glacier is stable, with little advance or retreat. If the balance is tipped, it shifts accordingly.

In Alaska only a few glaciers reach the sea, pushing out across the floor of a bay, fjord, or seacoast. The advancing ice scrapes and grinds the bedrock, boulders, and gravel beneath it and pushes ahead of itself a ridge or terminal moraine **4** of rock and earth. A tributary glacier **5** sometimes joins the main flow, adding a stripe of moraine debris **6**. The terminal, or toehold, moraine helps to anchor the glacier's face. There the ice, melting, fractured, and battered by the sea, breaks off as icebergs—a process called calving **7**—balancing the flow of ice from behind.

Below the equilibrium line, as the glacier nears its end, its surface thins and stretches and breaks into a mosaic of crevasses **8**. Meltwater flows through hidden channels and tunnels, reaching the base of the ice to lubricate its flow and pouring from under its face in a silt-laden cloud **9**.

As long as a glacier accumulates more snow and ice than melts or calves, it will advance. But should the ice back off its anchoring shoal into deeper water—as has the Columbia Glacier—the calving rate will increase dramatically. The glacier may break up rapidly, all the way back to shallow water. Then a new moraine may form and the glacier renew its advance.

The fronts of massive tidewater glaciers such as the Hubbard and the Columbia are thus always undergoing change. They wax and wane in cycles, driven by their internal dynamics, the valleys through which they flow, and the conditions at their terminal shoals. Long-term atmospheric warming or sustained changes in precipitation patterns will also affect the actions of these great cascades of mountain-born ice.




***Dramatic speed*** *can occur for short periods in normally slow-moving glaciers. In a phenomenon called a surge, they can race at ten to a hundred times their normal rate. When not surging* **A**, *the glacier contains cracks and tunnels that drain off meltwater. If this system is somehow blocked* **B**, *water pressure can lift and lubricate a part of the ice stream, letting it slide rapidly downhill* **C**. *The glacier heaves and undulates like a moving caterpillar. The surge can end suddenly* **D**, *as the blocked water gushes out at the face. Such downward gallops occur in only a small percentage of Alaska's glaciers, and often unpredictably.*

***Lovely face of the Hubbard,*** *surveyed aerially by a ranger, gleams intensely blue from recent calving. The glacier was named for Gardiner Greene Hubbard, first President of the National Geographic Society, by Israel C. Russell, whose name is borne by Russell*

*Fiord. In 1890 he explored the Mount St. Elias region on the Society's first expedition and called the Hubbard "most magnificent of the tide-water glaciers of Alaska yet discovered," reporting "pinnacles and towers of the grandest description."*

***Glacial calling card*** *makes a big impression on Karen Jettmar, dwarfed by an iceberg stranded on Gilbert Point after the flood receded. Such spectacles are by no means the end of the show. Glaciologists say that the Hubbard will be heard from again, and soon, because its advance will almost surely continue. The damming*

*and breakout of Russell Fiord may become cyclic. Tlingit stories tell how the Indians made glaciers retreat by throwing a sacrificed dog into a glacial crevasse. With no such powers, scientists can only sit back and marvel at a frozen colossus with a mind of its own—a mind to move.* □

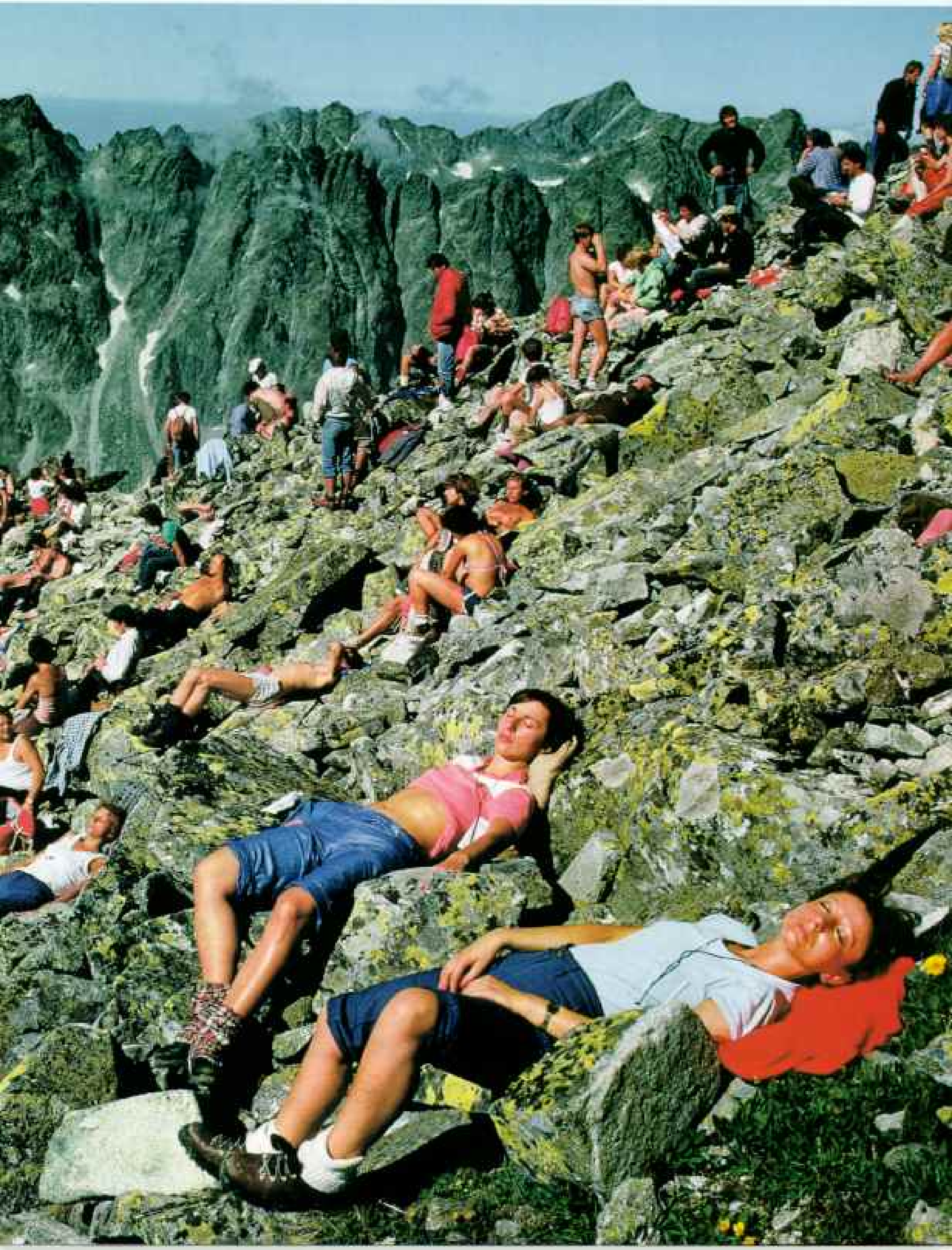
# Slovakia's Spirit

*Following in Lenin's footsteps, thousands of young Communists climb Rysy peak in the High Tatras of Slovakia, an annual pilgrimage commemorating his ascent in 1913. When the throngs depart and peace returns to the mountains, the music of past ages still echoes through the valleys.*

*Surviving centuries of foreign rule, Slovakia has never surrendered its cultural heritage. Since 1968, when Soviet tanks arrived in Czechoslovakia to quell "socialism with a human face," the Slovaks have practiced compliance in pursuit of increased prosperity, while preserving the language and spirit of their ancestors.*

# of Survival

Article and photographs
by YVA MOMATIUK
and JOHN EASTCOTT



*No one goes hungry in rural Slovakia. Villagers like Katarína Mišurová of Párnica raise livestock and vegetables to augment erratically*

*available store foods. Home produce, preserved for winter, supplements abundant potatoes and dairy products.*

"JURAJ JÁNOŠÍK was one hell of a man." The tired voice trailed off.

Then Vincent Patrnčiak, an old fiddle player from Terchová, a mountain village in Slovakia, one of Czechoslovakia's two republics, told me about Terchová's legendary hero, whose short and stormy life inspired the saddest mountain tunes. The story unfolded slowly, tattered memories that have survived more than 200 years.

"Jánošík was born here. Handsome and clever he was. He studied to be a priest. One day Jánošík's mother died. Her husband, Jánošík's father, buried her. But the *gróf*—people worked for big landlords in Slovakia—the gróf demanded to know why he wasn't at work. Burying his wife? That wasn't an excuse. And the gróf ordered the old man beaten. Four hundred lashes. . . ."

I listened intently. To my Polish ear the melodious Slovak language was familiar yet oddly archaic, springing from the ancient font of all Slavic tongues. Vincent went on:

"Jánošík saw his father's lifeless body. He told the gróf: 'I swear I will burn your castle down,' and he did. After that nothing could stop him. He plundered the rich and gave to the poor. People loved Jánošík. They prayed to him.

"One day a traitor gave him out. The captors put an iron hook between his ribs, hung him over a fire. Jánošík dangled there, smoking his pipe, swearing. At last he yelled, 'Now that you've cooked me, eat me!' and died. Even the mountains cried."

Vincent added sarcastically, "And now they say Jánošík fought for Communism."

During our months in Slovakia we found such pointed remarks rare. Fearful of the consequences, people seldom criticize Czechoslovakia's Communist system. While there are dissident groups in the large cities of Prague, Brno, and Bratislava, in the hills and mountains of rural Slovakia the lack of anonymity makes such groups virtually nonexistent. Most Slovaks resign themselves to the pursuit of safe, personal goals. Others cherish the material improvements of the past 40 years and accept the regime that, although oppressively rigid by Western democratic standards, they believe has brought prosperity to once impoverished Slovakia.

Leaving the old musician, I followed a path made by generations of feet between Terchová's blossoming orchards, looking for my husband, John, and Tara, our five-year-old daughter. They were watching Gypsies erect a shooting arcade and a merry-go-round.

Along Terchová's main street, banners heralded Jánošík Days. Loudspeakers, omnipresent in Czechoslovakia's towns and villages, blared folk music. A festive crowd marched toward Vrátna Valley's amphitheater, several miles away. John ran ahead. I followed with Tara in tow.

Suddenly a dusty bus puffed up behind me. "Get in!" said the driver. Helping hands grabbed my aluminum case and tapped it curiously. "Electronic equipment?"

"*Nie*," I said. "*Aparaty fotograficzne*."

"Ah, a Polish journalist! You must be spying for Jaruzelski." Loud laughter greeted this reference to Poland's leader.

"I live in the United States," I explained.

"Aha! Then you must be spying for Reagan." Even Tara joined in the laughter. Flushed and happy, she was already sitting in somebody's lap, her hands sticky with chocolate.

The Slovaks apologized for their jokes. How did I like their country? Wasn't Vrátna the most beautiful valley I had ever seen? Where was my man? A pretty woman should not run around alone.

"There he is, I see him!" our driver yelled. High on the slope was John, his cameras

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This is the sixth NATIONAL GEOGRAPHIC assignment for author-photographer team **Yva Momatiuk** and **John Eastcott**, also wife and husband. Their subjects have included Canada's Inuit, New Zealand's Maoris, and Poland's mountain people. They live in the Catskill Mountains of New York.

**Once upon a time** *the fairy-tale towers of Bojnice Castle, dating from the 1100s, housed Hungarian nobility. Now a museum to Slovakia's past, the castle forms a spectacular backdrop to bathers enjoying the mineral waters at Bojnice Spa. Other popular outdoor activities include hiking, skiing, climbing, and tennis.*

***Workers unite*** *to celebrate harvest's end on Cooperative Day in Liptovská Osada, where lengthy speeches finally give way to music, food, and dancing. Acceptance of the socialist land reforms of 1948 has grown with the improved standard of living. All houses now have electricity, and most have a TV and refrigerator.*

shining. "That's strange. He isn't fat. He isn't even old," the driver mused.

"What does he mean?" I asked my neighbor. She giggled. "When a Slovak girl marries an American, we suspect he must not only be rich but also old and fat. Is he an American?"

"No," I answered, "he's from New Zealand," and we both laughed.

At the Vrátna amphitheater we watched folk dancers from throughout Slovakia thundering on stage. Tense, light-footed steps followed masterful jumps. Native wind instruments joined violins, cymbals, and high-pitched voices. Yet amid rainbows of costumes the songs lamented.

I THOUGHT of the history of the Slovak people, as woeful as these songs. Their ancestors had migrated to this mountainous, landlocked heart of Europe more than 1,500 years ago. Invaded in turn by Avars, Magyars, Tatars, and Turks, they paid in blood to hold on to their lands. In the ninth century they were briefly part of the Great Moravian Empire, but the Magyar invasion resulted in a thousand years of Hungarian rule.

Incredibly, the Slovaks kept their identity. Schools taught them in Hungarian; churches saved their souls in Latin, Czech, and German. Their own language, not recorded in writing until the late 1700s, survived in the hills and mourned in songs:

*Feed us, God, feed us,*
*In these hard, hard times,*
*Or we will perish. . . .*

And many did perish.

After the First World War, independence returned. The new democratic Czechoslovak Republic united the agricultural, often impoverished Slovaks and the industrial, prosperous Czechs.

Soon came the tragic Hitler years, the partition of Czechoslovakia, and liberation by the Soviet Army. By 1948 the postwar coalition government succumbed to the country's militant Communist Party, which was aided by the Soviet Union; the U.S.S.R. thus gained one of its staunchest allies. Czechoslovakia's industry was completely nationalized, cooperative farms established, a new constitution adopted, and opposition silenced.

Today Czechs and Slovaks elect an equal number of deputies to the House of Nations in the Federal Assembly of Czechoslovakia. The Communist Party stresses harmony and brotherhood between both peoples. Yet Czechs often dismiss Slovaks as hillbillies, lacking culture, while many Slovaks perceive Czechs as cold and conceited.

Cradled inside the great arch of the Carpathians, Slovakia unfolds gracefully, rolling from wild peaks in the north to the


***Seeking the heart*** *of the Slovak Socialist Republic, the authors threaded the mountain valleys that rib eastern Czechoslovakia. Celtic tribes, then Slavs settled the fertile plain fed by the Danube. Slovakia was invaded by Avars, Tatars, and Turks and ruled by Hungary for a thousand years. Briefly a democratic republic, then controlled by Hitler, it fell to Communists in 1948.*

NGS CARTOGRAPHIC DIVISION DESIGN: NANCY SCHWEICKART; RESEARCH: DAVID B. WILLIS, MARGUERITE B. HUDDLE; PRODUCTION: MARYANNE BREITHAUPT

fertile plains of the Danube basin in the southwest. Medieval castles cast elegant shadows on wheat fields. Names of rivers—Váh, Hron, Cirocha, Hornád—tickle the throat with their harsh *r*'s and *h*'s.

New industrial plants dot the valleys, producing machines, engineering and transportation equipment, robots, pharmaceuticals, textiles, shoes, and beer. Domestic coal, nuclear and hydroelectric power, and Soviet oil and gas provide energy.

Not until the 1960s did the number of Slovaks working in industry approach the total of those in agriculture. Today only 15 percent till the land. With its five million citizens the Slovak Socialist Republic earns about 30 percent of the national income in a country of 15 million. Nearly every family owns a refrigerator, washing machine, and television; every third family, a car.

SLOVAKS COMPLAIN that the changing life-style has made people hurried, aloof; among the young, the divorce rate has soared.

A geologist said: "When I was young, the teacher spanked me, the priest spanked me, my father spanked me. Three big men tried to make a good citizen out of one little boy. Today they don't spank in school, the priest is less visible, and parents are busy working. Whom do we breed? Hooligans?"

Among family and friends, Slovaks are warm, generous, upholding old-fashioned courtesies of the rural communities from which many have stemmed.

Yet in casual encounters the very same people can be abrupt and rude. Store clerks, officials, repairmen, and waiters often treat customers with impatient indifference. A teacher told us: "We don't like this behavior

*Dwarfed by towering mountains, high rises mushroom in the old town of Poprad, part of an effort to meet housing needs of nearby*

*factories. Garden plots with storage sheds, foreground, allow apartment dwellers to grow their own produce and enjoy fresh air.*

any more than you do. But since almost everybody works for the state, people aren't worried about being fired, even for incompetence or rudeness."

People *can* be fired, however, for not adhering to the ruling Communist Party line, or—if they are teachers, police, or party members—for attending church services. For others, churchgoing can be detrimental to career advancement. On Sundays many people drive to distant village churches, hoping to worship in anonymity. Slovaks joke that if gasoline becomes rationed, party members will get double coupons. Why? Because they have farther to go to church.

One day we met a funeral procession. An old woman dressed in black took my hand. "Your legs are younger, dear," she said, leaning on me. In the cemetery she introduced me serenely to sunken tombstones. Here lay her parents, her sister, a baby daughter. "God gives, God takes away," she said simply.

The minister intoned over an open grave: "Through me the deceased says to his widow: 'Forgive me, darling, for not being able to cherish you one more day.'" Women wept. A soft breeze stirred white lilies.

***Political survivor*** *once imprisoned by his own party, Czechoslovakia's President Gustáv Husák* ***(above)*** *was selected in 1969 to restore law and order, Soviet style, after Alexander Dubček's attempt at liberalization. Husák has since made an unspoken bargain with his people—docility in return for increased material comforts. Party member Veronika Golidnova watches her friend Marta Rybárová* ***(left)*** *embroider a tablecloth for the local priest. Husák received a similar present from both women on his 70th birthday in 1983.*

"Now you can see that the church is alive here," the minister told us later. "Remember, Slovakia is a mosaic of nationalities: Czechs, Hungarians, Russians, Germans, Poles, Gypsies, and others. We have Catholics, Lutherans, and members of the Reformed and Orthodox Churches."

In Czechoslovakia, clergymen are civil servants, receiving salaries and funds to maintain their churches. They may not participate in political life or seek to motivate their followers politically.

"I am told that teachers cannot attend services," I said to him. He was suddenly ill at ease. "I understand that if you are a Communist, you can't teach in West Germany," he retorted.

COOPERATIVES, called *družstvá*, have changed the Slovak landscape even more than new industrial plants. The hills, once a bright patchwork of private plots, are now cultivated in multiacre sections. Quaint wooden farm buildings have been replaced with large družstvo compounds, their offices, barns, combines, and tractors protected by fences and armed guards.

The farms produce basic crops—grain, potatoes, fodder. Some add sugar beets, hops, fruits, and vegetables, or breed livestock. Thanks to machinery and fertilizers, one Slovak farm worker now feeds 15 people; his father might have fed three.

At the village of Liptovská Osada in central Slovakia, the director of the local cooperative told us that the farm's steep land supports 300,000 chickens, 50,000 geese, 12,000 sheep, 2,500 cattle, 2,000 pigs, and 45 horses. The cooperative also operates a vegetable store and a cheese factory, distills fiery plum brandy, sells carnations, and owns a tourist hotel.

"We employ 1,000 workers and earn about 180 million Czechoslovak crowns, or 30 million dollars annually," said Dr. Milan Paučula. Urbane and gentle, with degrees in law and agriculture, he oversees the farm.

"Wouldn't people prefer to own the land, the way their fathers did?" asked John.

Dr. Paučula laughed heartily at this. "Their fathers tell them how they had to get up at 3 a.m., work on a plot too small to feed them, rush to their factory job, then return to their field, often after dark."

IF YOU ASK about the Communist land reform of 1948, you will be told that farmers then considered it robbery. Today many have accepted it.

"When the official ordered me to sign our fields over to the družstvo," Mária Bartková-Mandačka told us in the village of Východná, "I grabbed a pot of boiling water to scald him, as if he were the devil. They ordered my husband home from work: 'You sit there till she signs.' After three weeks I gave up. We didn't get a penny! The other day the same man asked me: 'Mária, are you hurting?' And I said, 'Not at all!'"

Mária found her niche in the system. She proudly showed me medals awarded for her achievements. She hopes to have 36 grandchildren: "Multiply my six children by six. What do you get?"

But, I protested, most women today work outside their homes.

"At home they used to toil all day and nobody was even grateful," she replied. "Now women have their own money, friends, and children too." The government grants a working mother maternity leave for six months, including benefits amounting to 90 percent of her salary. Day-care centers charge five crowns, or 85 cents, a day.

But often in the morning I saw weary women on their way to the day-care center, carrying babies, urging on sleepy toddlers.

"I hate these superwomen who tell the government how they love to work full-time, rear children, and take care of the house," complained a mother of three. "Even our husbands expect us to work an 80-hour week and smile too."

The lure of industrial employment includes a salary averaging 3,000 crowns

***Slovak cowboy** Ján Záhorec **(above)** serves as caretaker of brood mares at the internationally renowned stud farm in Topoľčianky. Exported for breeding, Thoroughbreds, Arabians, and Lipizzaners boost the economy with much needed hard currency.*

*Taking a break from a hot anvil, the ranch's blacksmith **(facing page)** offers typical Slovak hospitality, sharing his lunch with the authors.*

($500) a month, as much as four weeks of paid vacation a year, and retirement between 53 and 60, with pension benefits up to 75 percent of pay. Workers have their own sports and recreation facilities.

We were told, however, that a quiet revolution is sweeping the factories, that hand-operated machines are being replaced by robots and computerized assembly lines.

Engineer Anton Kolenička, a balding veteran of 45 years in the steel industry, directs Slovakia's oldest ironworks, located in Podbrezová in central Slovakia. He considers himself lucky. "Automation! My successors will take it for granted. They won't see, as I did, the change it created in work psychology. People took it hard at first. About 15 years ago, nearly all they knew had become obsolete. They had to adapt, and I was privileged to witness this change."

Hard hats firmly on, we walked under red smoke from open-hearth furnaces, which are now being replaced by electric arc furnaces. Heaped beside the Hron River, rusty pyramids of scrap metal waited to be melted, pulled, and rounded into pipes of all sizes and many destinations: the Middle East, Germany, the Netherlands, Canada, the U.S.S.R.

Engineer Milan Pivovarči, a fourth-generation man of iron, took us through the works. They were no longer a man's world. Women were operating cranes and pipe-sorting machines. My ears tingled; the noise reached a deafening 90 decibels.

Outside, Milan told us: "The old workers marvel at our progress. Work is still hard, but the salaries we get are second only to what miners are paid, and average 3,550 crowns a month. We retire at 55." He laughed. "But these old crows just want to keep on working."

Such zest for the job is rare in Slovakia. Even during regular work hours shops are full of customers. People play hooky to visit a hairdresser, repair a car, or speed off to their summer cottage. Many feather their nests with illegally obtained building materials or quietly subcontract a state-owned bulldozer to do a bit of excavating for their new house. The government seems to be saying: "Keep your political profile low, and we won't interfere."

Restaurants employ a maximum number of workers and frequently offer minimum service. One person brings a menu, another takes your order, another delivers drinks, another serves the food. Money is handled by an elusive "cashier" waiter.

Rather than waiting for the missing links in this human chain, we learned to send Tara to fetch menus and summon waiters. Slovaks love children and indulge them shamelessly. Tara was often invited to the kitchen to watch the chef prepare monumental desserts of fruit, nuts, and *smrzlina*—ice cream.

On the road, away from petty annoyances, we traveled freely. Women in smocks and gum boots wielded scythes with fluid grace, trimming roadside ditches. Vacationing Slovaks searched for mushrooms and berries. Children splashed in warm streams, naked, light-headed from laughter.

IN SLOVAKIA the upbeat image of a happy society is cultivated by the government-controlled media. Posters advertise sunny holidays and bright prospects. Red banners praise the leadership of the proletariat. Slogans read: Long Live the Soviet Union! Communism Means Peace! Down With Imperialism!

The system guarantees jobs, housing, education, health services, and pensions, but the aspirations of the individual are mired by a political doctrine that relies on bureaucratic regulations to ensure loyalty.

Since the rise and fall of Poland's Solidarity trade union, neither Slovaks nor Poles can easily cross their joint border.

Slovaks show little interest in the political upheaval in Poland. "Frankly, we don't know what's happening in Poland," a forester explained to us. "People have learned not to touch matters they can't influence. They keep their heads down. They had their lesson in 1968."

That year a Slovak, Alexander Dubček, Czechoslovakia's Communist Party general secretary, aided by party members and ordinary citizens, sanctioned an unprecedented drive toward liberalization. His attempt to create "socialism with a human face" shook the country, ending abruptly with the Soviet-led invasion of Warsaw Pact troops. The "Prague Spring" of 1968 was discredited as an attempt to disrupt the very foundation of socialist order. Disgraced, Dubček was forced to resign.

One day we found Dubček's signature in a hotel scrapbook. "Did Dubček come here often?" I asked the receptionist. No, she said, only once, with friends.

I looked at her. Was there nothing to say about that springtime of hope? Her eyes flashed a message: "This topic is off-limits."

Yet Slovaks remember only too well. They are careful in their personal contacts.

***Raising a child*** *need not conflict with a job for Slovakia's mothers. The Tesla-Orava TV factory in Nižná runs a day-care center (**facing page**) staffed by professionals and catering to several hundred children. In spite of excellent standards in widespread state nurseries, some parents prefer the family touch. Retired grandparents provide willing help: Mária Námesná (**above**), from Žiar nad Hronom, mirrors her five-month-old granddaughter's winning smile. Working mothers may retire early based on how many children they have.*

***Prayers but not politics*** *are permitted in Slovak churches, where state-licensed priests receive government paychecks. Morning mass at the baroque church in Spišská Stará Ves (**right**) draws a large congregation. Policemen, teachers, and party members tend to worship far from home, to avoid recognition and potential harassment. At Levoča's School for the Blind, a kindergarten pupil (**left**) will be guaranteed a full education and, later, specialized vocational training.*

"It saddens me that most of us who used to press for political reforms no longer see one another," a retired schoolteacher told us in Levoča, a small history-rich town in the central part of Slovakia. "We withdrew into our shells, as if fearful of guilt by association. We pursue only tangible goals: a new car, a new house."

Indeed, boxlike houses were going up everywhere. "How many families live in each one of these?" wondered John, pointing to huge concrete villas. We asked around.

"Just one," a woman, busily washing her windows, informed us. "Families build for themselves. Grown children stay with them for a while, till they can afford their own."

"But can they?"

"Sure they can. They work for it too. They want that third bathroom, a large TV set. I ask my daughter: 'Do you have to get everything in such a hurry?' and she says, '*Maminka*, everybody does.' "

Factory work often ends at 2 p.m., leaving plenty of time for moonlighting. Enterprising Slovaks make souvenirs, rent rooms to holidaymakers, and cultivate *záhrady*, small plots allocated outside villages and towns. The lush gardens produce more than half the fruit and vegetables in the republic.

The average new house rises three stories above a full basement. Often the pastel stucco walls are adorned with small mirror chips. Such houses contain some 3,000 square feet and cost about 350,000 crowns, or $60,000. Proud owners frequently reside in the basement, venturing upstairs only for ceremonial occasions. Do-it-yourself building abounds, and since mortgage rates are 1.5 to 2.7 percent, a house is an excellent tangible investment.

These giant saltboxes are alien to the traditional Slovak design that once graced everything from decorated beehives to some of the world's finest Gothic wooden altars.

"After the war cultural values changed," declared Pavol Repka, an architect from Tatranská Lomnica. "Cosmopolitan styles, such as Tirolean villas and Italian neoclassic facades, were discredited as bourgeois. Our indigenous wooden architecture was denounced as primitive. Villages were to catch up with towns. We tore down what we could and moved into stone and brick boxes. Contractors encourage uniformity. It costs less. So we drown in mediocrity."

Pavol looked toward cloudy peaks: "Once I spent five days alone, snowed in on Mont Blanc in the French Alps. I decided that if I survived I'd search our past for what makes us tick, and build an honest Slovak house." His new house, an honest Slovak one, was rising just beside us.

ON WEEKENDS Slovaks flock to the country to swim, shoot rapids, fish, ski, windsurf, hike, even fly. We rode with a hang-gliding club into the hills above Banská Bystrica, capital of the Central Slovak Region. The

valley below us simmered in dusty heat; up on the ridge strong updrafts cooled the skin.

Out came picnic baskets. Men unfolded homemade gliders. Mike Harger, an American who is now a legend, brought one to Slovakia nine years ago, and they copied it.

Carefully checking the wind, the glider pilots joked with a 55-year-old grandfather and helped fasten his harness. Then they were off with a rustle of wings, soaring suspended under fragile canopies of Dacron.

"After my first flight I couldn't sleep," Jozef Čiliak, a truck driver, told us later over mugs of beer. "But up in the air it's all beauty and peace. Birds follow you, you join them. Man has wings at last."

FOUNDED IN 1255, Banská Bystrica, "pearl on the Hron River," was renowned in medieval Europe for copper and silver mines. Wealth created exquisite Gothic and Renaissance houses; power built the massive castle; faith erected lofty church spires.

Today in Red Army Square private gardeners dispense free medical advice to fruit buyers: "Black currants, good for your kidneys. . . ." Other entrepreneurs sell embroidered Slovak blouses, woodcrafts, and Western imports: T-shirts, jeans.

Banská Bystrica spills upward from its crowded historical center into hilly satellite suburbs. Rows of high-rise buildings or *paneláky*, as Slovaks call this prefabricated sameness, absorb a population that since 1945 has increased sixfold, to 76,000 people.

Banská Bystrica is a political town. Throughout the year busloads of delegations and tourists come to pay homage to SNP, the Slovak National Uprising. In the monument-museum, trained guides relate how in the bleak days of August 1944 the people, led by Slovak Communists, fought the Nazis to defeat; how the partisans joined the victorious Red Army and helped to establish a Communist regime after the war.

***Wedding guests dance the night away*** *in the village of Lendak* ***(below)****, where the revelry will last several days. The bride and groom* ***(facing page)****, in traditional embroidered costumes, take turns bidding their parents a moving farewell before going to church. Old-time customs and crafts, now encouraged by the state, still survive in pockets of Slovakia, which sponsors many folklore festivals.*

In August, preparations for the 40th anniversary of SNP swept the country. All shopkeepers were ordered to display SNP emblems. In Banská Bystrica houses were painted, flowers planted, new monuments erected, pineapples and bananas from Cuba delivered to grocery stores.

The big day came. Streets blossomed with summer dresses. Old peasant women cried out "Sweetheart! Beloved!" as they waved to small, white-haired Gustáv Husák. The president of the Czechoslovak Socialist Republic (C.S.S.R.) and general secretary of the Communist Party, himself a Slovak, waved back with a grandfatherly smile. He walked arm in arm with a Soviet marshal.

Under huge portraits of Marx, Engels, and Lenin, 100,000 Slovaks gathered. Speakers recalled the martyrdom of fallen partisans, praised the country's socialist order, and called for peaceful coexistence.

Yet the applause was lukewarm, the

*March of the matriarchs: Shouldering the bride's belongings, married women of Lendak proceed to the groom's house. Village*

*matchmakers keep energetic vigil, believing no young woman should remain single lest she "turn to vinegar."*

***Architects of the future,*** *on loan from a university in Bratislava, travel 200 miles to join the September potato campaign* ***(right)*** *on a cooperative farm near the Dunajec River. For two weeks a year the state recruits high-school and college students as well as factory and office workers to help harvest this important crop, providing board, lodging, and minimal wages in return. Some students*

*enjoy the break; others attempt to opt out with a doctor's note. Co-op members* ***(above)*** *distribute hefty 220-pound sacks to fellow workers, pausing at every house for a shot or two of vodka and a chat. Each Slovak family consumes some 700 pounds of potatoes annually, carefully storing supplies in cool cellars or in grass-covered shelters in the hills.*

boredom evident: People had heard all this before. For the majority, attendance was compulsory. "Unless I present a doctor's statement that my boys are sick, I have to be here," a mother of two small children explained. She waited until the ceremonies ended and quickly walked away.

EAGER TO ESCAPE the heat and the bustle of Banská Bystrica, we headed north to Tatra National Park. Wild mountain peaks soared suddenly above the surrounding flatness, peaks now brilliant in the sun, now sooty in a storm.

Gold-seekers, hunters, naturalists discovered the beauty of the Tatras in the 16th century. Today six million visitors a year come to hike, climb, and ski in the most spectacular alpine range in the 900-mile bow of the Carpathians.

Juraj Turošík has been director of Tatra National Park since 1961. "In the past 20 years," he told us, "the number of visitors has increased six times, an incredible strain. People dig out our alpine flowers and chase our marmots and chamois. The forests wilt,

poisoned by exhaust fumes. We limit access to certain areas and by 1990 hope to introduce electric trolleys, banning all cars."

Around the park, hotels, campgrounds, and private rooms are filled. In the once isolated village of Ždiar, now called the "largest hotel in C.S.S.R.," villagers offer up to 4,000 beds, mainly to East Germans. Having lost direct access to the Alps, they visit the Tatras in astonishing numbers.

The visitors also come to shop. In addition to the East Germans, Russians and Hungarians throng the local stores, buying everything from peaches to children's toys.

Among Eastern European countries, Czechoslovakia boasts one of the highest standards of living. Availability of goods, however, does not guarantee quality. Years ago Škoda cars sold well in international markets; today even the government Prago-car rental agency considers Škodas unreliable. Western imports are few and usually can be purchased only for hard currency—dollars, marks, francs—through special government-owned stores. Here a bottle of good Scotch costs only $3.50. And Ford

**Clearly an optimist,** *Mdria Chlebovcová* ***(right)*** *weaves a runner for her 18-year-old son's dowry, undeterred by his lack of a girlfriend. Her sister-in-law, at left, lends a hand; in mourning for her father, she will wear black for at least a year. In sickness and in health, family and neighbors look after each other, with state nursing homes used as a last resort. Everyone pitches in* ***(left)*** *at a christening party. Frequent family celebrations ritually call for vast quantities of food, free-flowing wine, and spirited singing.*

Escort cars from West Germany, priced at $6,000, sell readily.

The hard currency comes from relatives abroad, but demand exceeds supply. Few foreign tourists escape whispered inquiries: "*A dolâry mâte?*—Do you have dollars?"

In spite of the crush of tourists in Tatra National Park, folk traditions have survived the longest in the villages surrounding it. In the old, wooden village of Lendak we saw rituals preserved and folk costumes worn daily. Artificial flowers and holy pictures decorated TV sets, making them look like miniature altars.

To help assure the marital bliss of their children, Lendak families may spend as much as 100,000 crowns. A dowry may include a car, furniture, rugs, money.

One morning our phone rang. "Get up! We're going to a wedding," ordered Dr. Ján Olejník, the park's ethnographer.

To the bride's house came married women resplendent in voluminous costumes. Two of them got stuck in the door. Too many skirts or dumplings, who could tell?

They dressed the girl in silence. In her hand-pleated skirt, richly embroidered corset, and pearl-studded maiden crown she seemed a painted doll. Women slipped hundred-crown notes into her shoes as tokens of prosperity, a sprig of myrtle inside her blouse as a charm against sinister forces.

After the wedding, at the feast, the sight of sausage sent the maids of honor into giggles. Men ladled beer from tin buckets hour after hour. Matrons carried the bride's bedding to the groom's house (pages 140-41). They tossed a child onto the marriage bed as a symbol of procreation.

Night came. Surrounded by her maiden friends, the bride danced slowly, embracing them for the last time. In a dim corner a fiddle, clarinet, bass, and accordion played on.

SLOVAKS BELIEVE that music and mountains restore their spirit. To cure their ailing bodies, they visit the province's famous spas. We traveled from Lendak to the modern health complex of Piešťany, an ancient spa still using nature's gifts to heal the sick.

This grandest of Slovakia's spas once tended the rheumatic pains of European monarchs. Now it treats nearly 40,000 patients a year, including Americans, Arabs, and West Europeans.

I love mud, its sticky, oozing texture, and in Piešťany I got my wish: a pack of thermal, sulfurous goo filtered from the bottom of the Váh River. The heat slowly penetrated my body. Repeated applications promote gradual absorption of the sulfur into cartilage

***Crowned heads** of state, maharajas, and sheikhs have all basked in the sulfurous waters of Slovakia's famed Piešťany Spa. Workers can receive free treatment for ailments such as rheumatism or nervous disorders. This patient combines spinal traction with a thermal bath.*

and heal troubled joints, explained Dr. Oldřich Bláha, the spa's chief physician.

Foreigners pay about $50 a day; this includes necessary medical care and even tickets to cultural events. For C.S.S.R. patients spas, hospitals, and prescription drugs are free.

But some drugs are hard to find. When John became ill, we spent a day trying to fill his prescription, to no avail.

A Slovak friend ridiculed our naïveté. "What do you expect, miracles? This is an imported drug. If a pharmacy has it, it is most likely put aside for friends and relatives. Let me try." He procured it from the same pharmacy we had tried earlier. In Slovakia it helps to know the right people.

NO CONNECTIONS are needed to find Veronika Goliánova, a grand old woman who for 30 years ran the village of Detva's famous singing-and-dancing folk ensemble. Villagers readily point out her whitewashed house, with its traditional flower designs.

Inside, Veronika served *halušky s bryndzou*, tiny dumplings sprinkled with sheep cheese. By the window her granddaughter nursed a newborn son.

As a barefoot child Veronika, youngest of six, had to shine the shoes of the landlady. After the war, impressed by socialist ideals of equality, she embraced the new order. Convinced that Detva's heritage must be preserved from the onslaught of modernization, she organized cultural events and an artisans cooperative. Her embroidery decorated a lavish velvet tablecloth, given to President Husák for his 70th birthday.

Later she opened chests full of embroidered costumes she had rescued when people threw them out in favor of factory-made fashions. She carefully unfolded a blouse that was a hundred years old.

"We have a saying: 'From anything old a new sapling must grow.' That's what happened after the war. Fascism rotted away, and on its ruins we built socialism, such as it is. It could be better if people were better. Bad often tries to destroy the good."

"Are you a Communist?" I asked.

"Yes. But I go to church too. I argue with the priest. I also tell party officials what I think is wrong. I have hope. Because of the mistakes we've made, something new and better must be born one day."

Veronika gently stroked the upturned face of her great-grandson. "Who knows? Don't ask me what. I'm just an old woman with eight grades of village school."

We drove away slowly. Autumn was advancing steadily, wrapping river valleys in fog and turning beech trees copper. We reflected on the future of the Slovaks, who are historically so well versed in the art of survival. They seem to believe that change for the better must come slowly, from within the system. The times of Juraj Jánošík, the times of lonely battles, are over for now. □

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**Horned Guan** **Genus:** Oreophasis **Species:** derbianus **Adult size:** Length, 81-91cm **Adult weight:** 2.5-3kg **Habitat:** Cloud forests at altitudes of 1,600-3,350m in southern Mexico and Guatemala **Surviving number:** Unknown
Photographed by Fulvio Eccardi and Fernando Gonzalez

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# Joint ventures for joint adventures

SOLID PARTNERS are welcome in many enterprises. In the electronic expression of communications and education, they are a necessity.

The Society's longest running such partnership is with WQED/Pittsburgh. Again in 1987, the 13th year of our association, we will jointly with the Chevron Corporation bring four new National Geographic Television Specials to PBS. The first, "Lions of the African Night," airs January 14. The others: "In the Shadow of Vesuvius," February 11; "The Grizzlies," March 11; and "Treasures from the Past," April 15.

For the second year the Society will permit off-air taping of these programs by nonprofit educational institutions for use in classrooms. Also, with Chevron's generous support, we will provide to educators at no charge a *Resource Guide* to the Specials, a booklet that gives more information about the subject matter and suggests ways to incorporate program content into school courses.

We are about to start our second year of partnership with Turner Broadcasting in bringing two hours of EXPLORER over SuperStation WTBS to a cable television audience of some two million homes each week. To celebrate, EXPLORER on March 22 will broadcast "Secrets of the *Titanic*," a stunning hour-long documentary on finding and surveying the remains of the "unsinkable" luxury liner. "Secrets of the *Titanic*" is now also included in our home video series, in which Vestron Video is our partner in making many of the Society's classic programs available for viewing on personal videocassette players.

The Society has other new partners in Apple Computer, Inc., and Lucasfilm Ltd. Together we are researching optical technologies such as videodiscs and compact discs to explore how they might be effectively used in education.

PHOTOGRAPH BY CAROL HUGHES

DAVID HUGHES AT WORK FILMING IN AFRICA.

Both of these technologies permit storage on a single disc of vast amounts of information—the equivalent of a small library of still or moving images. There is further potential to integrate audio, text, and software, and—perhaps most important—to put students and teachers in control as they select and use information from all these media.

It is the joint plan of the Society, Apple, and Lucasfilm not merely to study these optical technologies and make recommendations in a report. We also intend to bring them to the point where they can be evaluated—and used—in the very real and sticky-fingered world of curious children.

Perhaps wildlife footage such as that by Carol and David Hughes (**above**), which we now marvel at in Geographic Specials, will someday be edited into "school papers"—electronic versions of today's cutting and pasting of photographs from NATIONAL GEOGRAPHIC.

We are on the way to that future with our solid partners and traveling companions.

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# Members Forum

## Sense of Smell

Asked for an article suggestion, I probably would have put the "Sense of Smell" pretty far down on my list. After reading it (September 1986) and completing the survey, I would rate it one of the most interesting, enlightening articles ever. Thanks for the insight to try the unusual.

John A. Alden
Remsen, New York

Forest fires that can't be seen can be smelled. As one of hundreds of firefighters who mopped up the 12,000-acre Houghton Creek [Montana] fire of 1984, I can attest to being able to locate "smokes," or hot spots, by smell—even when standing in the midst of blackened acres. The smell of active, even smoldering, combustion is distinct and identifiable.

David A. Forestieri
Kalispell, Montana

Can you imagine how it feels to have to take someone with you to buy a new perfume? To have someone next to you say, "Doesn't that smell great?" and you don't smell anything? To not be able to tell if milk is sour or meat gone bad without tasting it?

That's my world every day. It is so reassuring to know I am not the only one. Perhaps articles such as yours will bring more research to help anosmics "stop and smell the roses."

Denise Pipala
Philadelphia, Pennsylvania

My National Guard unit was deployed to Panama last year to construct a road. At 2 a.m. our first night there, I was awakened by guys telling war stories about Vietnam. Asked what was keeping them awake, one man responded, "The smell of green paint, the green canvas in this tent, the uniforms, the dirty bodies—this place smells like Nam. Over there, 2 a.m. was Charlie time. I can't sleep. I feel like I ought to be in my foxhole on alert." The odors even brought on a few nightmares among our veterans.

Gary W. Walker
Pineville, Louisiana

I have severe chemical hypersensitivities and environmental allergies, and my keen sense of smell alerts me to chemicals that trigger allergic reactions. The advertising industry has brainwashed us into believing that natural body odors must be camouflaged, that for something to be clean it must have a scent. The number of scented products has mushroomed over the past decade.

It is time for people to recognize that their headache, forgetfulness, and lack of concentration could be caused by chemical exposures.

Marcia S. Fisher
Berkeley, California

Unless there has been a fairly large earthquake that I haven't heard about, Gilroy [home of the Garlic Festival] is in the Santa Clara Valley, not the San Joaquin Valley, which is on the other side of the Diablo Range.

Marionette Tack
Los Gatos, California

My enjoyment of Boyd Gibbons's article came to a jarring halt on page 355. I never expected to find distorted, demeaning, and homophobic material in NATIONAL GEOGRAPHIC. Young people will see a human being set up for ridicule, accept as true the stereotype used to describe a homosexual, and think there is nothing wrong in making fun of him.

Maurice Lebianc
Ottawa, Ontario

*We apologize for the insensitivity.—The Editor*

I feel for those who smoke—they miss so much that life has to offer. I'm looking forward to the results of your survey.

J. Larry Grant
Klamath Falls, Oregon

*More than 1.4 million readers had returned our survey by November 1, 1986. Now being analyzed, the data will be published later this year and should tell us, among other fascinating insights, if smokers are missing much.*

## Meteorites

History ignores small tragedies—consider the assertion in "Invaders From Space" (September 1986) that an Alabama woman is the "only known victim of a meteorite." A 17th-century Franciscan friar was mortally wounded when struck by a chondrite on the streets of Milan, Italy. A medical description of the incident by a Milanese physician and a drawing of the fatal "lightning stone" still exist in the Ambrosian Library of Milan.

John J. Noble
Louisville, Kentucky

It is apparent to me as a professor of geology that plate-tectonic-induced changes in the distribution of continents, coupled with changes in ocean currents and climate, are the most plausible reasons for dinosaur extinction. Similar significant changes occurred prior to the dinosaur extinction, when the former supercontinent Pangaea broke up. A steady decline of the dinosaurs coincided with this breakup. A meteoritic impact could have been just one more factor for the last dinosaurs to contend with.

Richard L. Squires
Northridge, California

## North Pole Expedition

Congratulations to the expedition members (September 1986) for their success. Their accomplishment should, however, be measured against Peary's in 1909: As a man of 52, without modern materials, without a radio with which to call for help, without airplanes, without the mass of scientific information available today, and without anybody having been to the Pole, Peary was the first man to reach it and also had to fight his way back to civilization. The Society can be proud of having supported this dedicated man.

Peter Hietsch
Vienna, Austria

Re page 290: Dogs don't sweat.

Charles W. Kay
San Francisco, California

*Dogs sweat through the tips of their noses and the pads of their paws; granted, such moisture would add negligibly to the vapor trail from their breath.*

How could you feature the Pole and fail to mention Matthew Henson along with the others? He was the first man to set foot on that special spot, the North Pole, a black American. Without the great black explorer, the Robert Peary expedition would not have been successful.

Will Long
Costa Mesa, California

I was disappointed to see that the Arctic explorers left behind 300 pounds of non-biodegradable litter. "Pack it in, pack it out" should be everyone's motto in the wilderness.

Maret Webb
Phoenix, Arizona

*To reduce weight, the explorers burned some supplies but left nonflammable equipment, expecting to pick it up by aircraft. Delays prevented this, and the gear is likely two miles under the sea.*

## Polish Jews

Congratulations to Małgorzata Niezabitowska and Tomasz Tomaszewski for their masterful story (September 1986). Outside the Holocaust Memorial in Jerusalem are signs naming Christians and other non-Jews, in Poland and elsewhere, who helped Jewish friends escape, often paying for their efforts with their own lives.

Raymond H. Walker
Jacksonville, Florida

The author's statement that the Poles "did not always sympathize" during the Holocaust sounds almost absurd. Many Poles were actually hunting for concealed Jews and turning them over to the Nazis. After the war, when the tiny surviving groups from extermination camps trickled back, many Poles resented their survival and chased them out. I marched through Nazi Germany as an American Army sergeant, but our Polish allies would not let me take a trip into Poland to find survivors; I was not just an American, but a Jew.

George I. Polakov
New York, New York

Most readers have no familiarity with the unbelievable conditions of terror in Poland during the Nazi occupation. As a former inmate of Buchenwald, I wish to illuminate one point—a Pole who gave shelter to a Jew could be apprehended by the Gestapo and his family shot on the spot. Yet many Jews were saved by Poles.

Miroslaw C. Wierzbicki
Burlington, Massachusetts

I recently ventured to Poland to touch the remnants of my not too distant past. Unlike the author, I saw some beauty in the Jewish Cemetery of Warsaw. Some areas remain very well kept. The stones were for artists, actors, engineers, rabbis, scholars, doctors, broommakers, and, yes, ghetto fighters. What a wonderful Jewish society and culture it must have been.

Sari Anne Rapkin
Needham Heights, Massachusetts

From where did it come, this hatred of the Jews? Some Christian scholars trace it to passages in the New Testament that are interpreted to blame Jesus' death on the entire Jewish people. Yet Pope John and the Vatican II Council strongly rejected such an interpretation, and modern historians have presented evidence based on Roman histories that the relationship between the Jews and Jesus was primarily one of mutual respect, but for a small group led by the high priest.

Russ Weinstein
Melbourne, Florida

Is it correct to talk about the last Jews and assess their number at five thousand? Many more still in Poland are Jews and don't know it. A circumcised boy had no chance, but baby girls were picked up from hiding places or beside railroad tracks and passed to courageous, loving people not ashamed to have "the illegitimate child of a cousin from a ruined town." Others promised grief-stricken mothers to protect the children, swearing never to tell them who they are. Some died, never telling them of their real parents.

E. Kristine Belfoure
Baltimore, Maryland

*Letters should be addressed to* ***Members Forum****, National Geographic Magazine, Box 37448, Washington, D. C. 20013, and should include sender's address and telephone number. Not all letters can be used. Those that are will often be edited and excerpted.*

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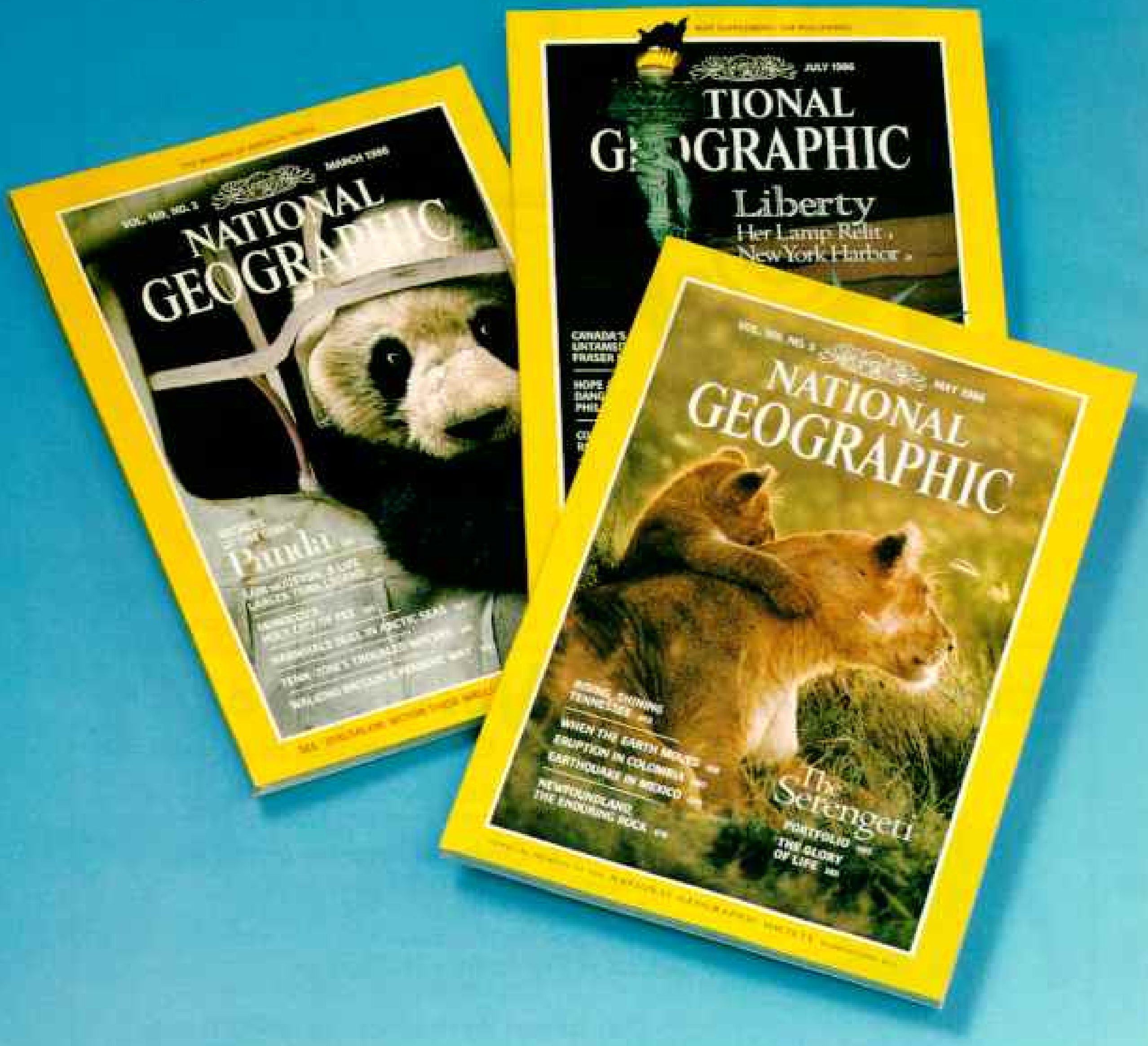


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# On Assignment

ICE BECAME a slippery subject last year for Senior Assistant Editor ***Samuel W. Matthews*** when Alaska's Hubbard Glacier advanced to turn Russell Fiord into a freshwater Russell Lake. At work on an article about how ice affects the earth, Sam (***above***, in bow) paddled the lake last August with Alaska naturalist Karen Jettmar. Meanwhile, glaciologists were keeping a close eye on the huge dam of ice, rock, and mud. Would it hold, and for how long? In a thunderous outburst that lasted for hours, it gave way early on October 8 (pages 112-13).

Earth, air, fire, and water—especially water—are all vital elements for Sam, examining a model of an ice crystal's molecular structure (***right***). After serving in the Pacific with the U. S. Navy and reporting science news in Washington, D. C., he joined the GEOGRAPHIC in 1951. His 16 magazine articles include a volcanic eruption, ocean research, plate tectonics, earth's climate, and his abiding love, Antarctica. "It's absolutely spectacular, both in the sun and in blizzards," he says—"assuming you've got a place to crawl into."

CHRIS JOHNS (TOP); NATIONAL GEOGRAPHIC PHOTOGRAPHER JOSEPH H. BAILEY