SPECIAL SUPPLEMENT: MAP OF THE HEAVENS

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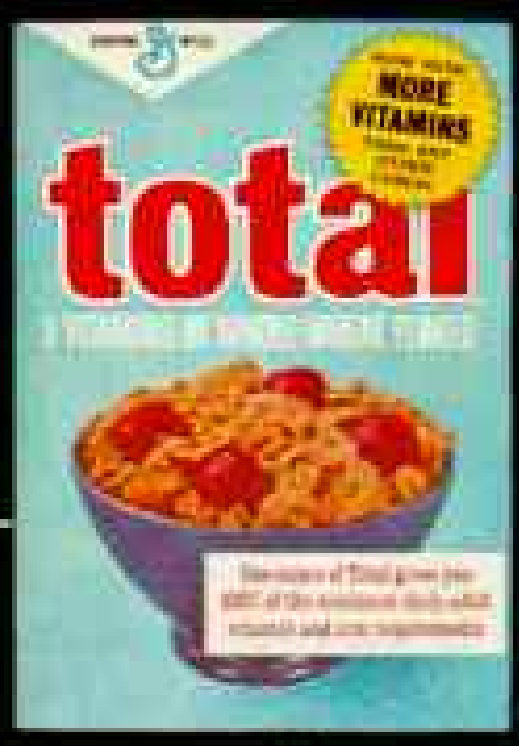

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Probing our universe, from planets to plankton

THE INFINITELY VAST AND DISTANT and the infinitely small and near: NATIONAL GEOGRAPHIC this month focuses on these extremes. With telescope, microscope, and artist's brush, the magazine explores our solar system and the galaxies of creatures that inhabit an ordinary pond.

Assistant Editor Kenneth F. Weaver takes you on an epic journey for a close-up look at the planets. Czech artist Ludek Pesek (upper left) dramatically portrays them from a viewpoint man has yet to experience: crescent Mars (above) looms over its cratered satellite Phobos.

Biologist William H. Amos introduces us to the marvels of a rural pond. He lectures (left) on the tactics of a diving beetle. Stars of an unseen world, *Asterionella* diatoms—60 times life-size—drift in liquid limbo (right).

Invite your friends to share in wonders large and small by nominating them on the form below.

DATACHROME BY JAMES R. HOLLAND

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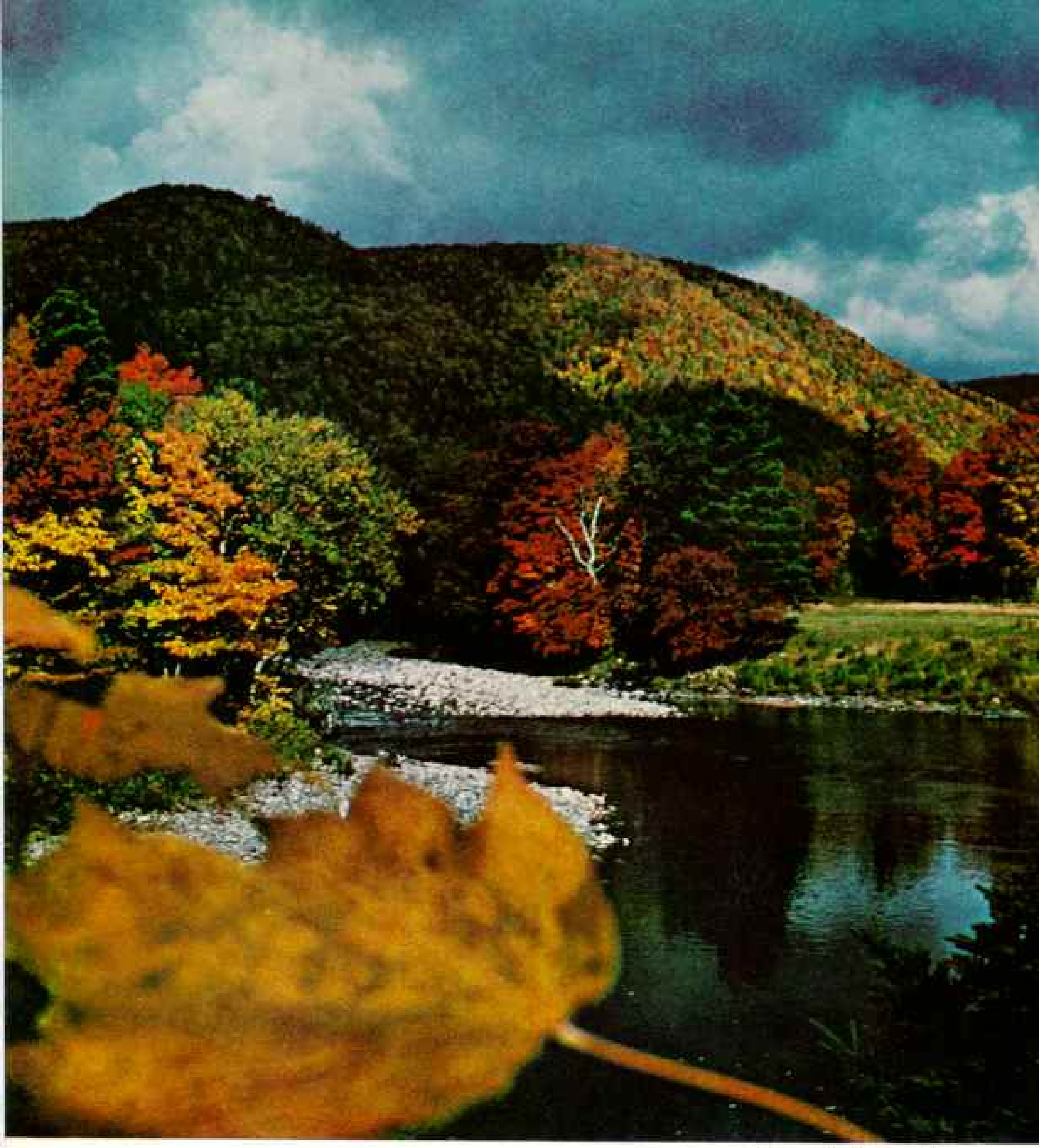

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SHELL

August 1970

NATIONAL GEOGRAPHIC

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Voyage to the Planets

By KENNETH F. WEAVER
Assistant Editor

Paintings by LUDEK PESEK

To take us in imagination to the farthest reaches of our solar system, the NATIONAL GEOGRAPHIC has teamed its award-winning science writer Kenneth F. Weaver with the noted Czech painter of astronomical subjects, Ludek Pesek. Their work reflects the knowledge gained from American and Soviet deep-space probes. It incorporates the latest thinking of leading U. S. authorities on each of the planets, and for their many contributions to the interest and accuracy of this presentation we are deeply grateful.—THE EDITOR

I have reached these lands but newly
From an ultimate dim Thule—
From a wild weird clime that lieth, sublime,
Out of Space—out of Time.

—EDGAR ALLAN POE, "DREAMLAND"

AS SHEPHERDS OF OLD watched the starry arch of night wheel majestically overhead, they took comfort in the apparent constancy of the heavens. Save for an occasional meteor whose brilliant trail flashed across the vault, each heavenly lamp stayed firmly fixed in its niche.

Well, not quite all. Amid the thousands of naked-eye stars, several of the brightest disobeyed the usual pattern. Unaccountably and mysteriously, they drifted from night to night across the winking field of lights in their own fashion, coming and going. Sometimes they disappeared for weeks at a time.

To some ancient shepherds, who in imagination saw a herdsman in the constellation Boötes, these five mavericks were stray animals. The Greeks called them *planetes*, or wanderers. The Romans gave them names of their gods: Mercury, Venus, Mars, Jupiter, and Saturn. And from earliest recorded times, astrologers ascribed mystical qualities to these celestial bodies, as well as to the sun and the moon, teaching that they affected the destinies of nations and of kings.

The Babylonians, who embraced the notions of astrology, associated the planet Jupiter with the god Marduk, a benign power. Saturn they linked to Ninurta, the god of war. Mars, whose ruddy color suggested blood, was a sign of Nergal, god of the underworld.

A Babylonian clay tablet of about 700 B.C. warns: "When Ishtar [Venus] grows dim and disappears . . . there will be a slaughter. . . . When Ishtar appears . . . the crops of the land will be prosperous."

Fancies such as these persisted through the centuries—in Greece, in Rome, in the Moslem East, in medieval Europe, and in

the Orient. Astrologers advised princes and kings, casting their horoscopes to determine the positions of sun, moon, and planets in relation to the zodiac at some crucial moment and studying the charts for omens of good and ill.

With the intellectual ferment of the Renaissance, men began again to study the nature of the universe, and astrology became discredited in the Western World. (It is, perhaps, a sign of our unsettled times that the occult practices of astrology are currently enjoying a new vogue.)

When Galileo, in 1609, first trained the newly invented telescope on the heavens, scientific investigation of the planets became more exact and much more exciting.

What a world of marvels could be glimpsed through the new instrument! No longer were the planets simple points of light; they were small disks. Venus, brightest of all, showed phases like those of the moon. And Earth was not the only planet to have a satellite: Jupiter had its own family of moons. As for Saturn, it was in time revealed as the most beautiful object in the sky, with a gleaming girdle of rings about its equator (cover and page 184).

IMPORTANT DISCOVERIES soon changed man's most fundamental concepts of the universe. Already Copernicus had pronounced (in a book published the year of his death, 1543) that the sun, not Earth, was the center of things. Now Kepler showed that the orbits of planets about the sun are elliptical, not circular; Newton, with his law of gravitational force, enabled men who followed him to work out those complicated orbits. By the 1840's, two additional planets, Uranus and Neptune, had been spotted.

But even through the telescope, the planets yielded their secrets grudgingly. Astronomers still had to peer through Earth's shimmering atmospheric veil, which made details come and go in the most tantalizing way. Much depended on the observer's imagination.

By World War I these dark bodies, which shine only by reflected sunlight, seemed to lose their appeal. In the '20's and '30's most professional astronomers turned their attention to the distant stars, whose abundant outpourings of light and other radiant energy soon told us more about stellar interiors many trillions of miles away than we knew about even the surfaces of our closest neighbors.

All that has been changing in the past dozen years. Solar-system astronomy is again in ferment, and the '70's promise to be the decade of planetary investigation. Powerful new tools, such as radar and radio telescopes, sensitive detectors of infrared and other invisible radiations, sounding rockets and spacecraft that climb beyond Earth's clouded atmosphere, are beginning to produce an avalanche of information and a number of surprises. They have challenged many of our most cherished notions about the planets, and have proved how little we really knew about our neighbors.

Venus, for example, once supposed to be a well-watered twin of Earth, is really an inferno. Ridiculously, it rotates backward!

Mercury, which was long thought to keep the same face steadfastly toward the sun, so that its front side was a furnace and its eternally dark back side the coldest place in the solar system, embarrassingly does indeed turn its face from the fire.

And Mars, the abode of a race of intelligent canal builders in the eyes of Percival Lowell and his followers at the turn of the century, has proved to have no canals and offers no evidence of water in liquid form, or of anything else that would encourage life as we know it on Earth.

One of today's specialists on planets, Dr. Bruce C. Murray, Professor of Planetary Science at the California Institute of Technology, sums it up this way: "We find that most of the ideas we had about Mars were wrong; in fact, most of the ideas we have about any celestial body prove wrong when we get real knowledge about it."

During the past decade, besides landing men on the moon, the National Aeronautics and Space Administration has completed

	MERCURY	VENUS	EARTH	MARS	JUPITER
EQUATORIAL DIAMETER (EARTH=1 or 7,926.4 miles)	0.38	0.95	1	0.53	11.19
MASS (EARTH=1)	0.06	0.82	1	0.11	317.9
VOLUME (EARTH=1)	0.06	0.88	1	0.15	1318
DENSITY (WATER=1)	5.50	5.27	5.52	3.95	1.33
EQUATORIAL SURFACE GRAVITY (EARTH=1)	0.39	0.91	1	0.38	2.31
NUMBER OF SATELLITES	0	0	1	2	12
ROTATION ON AXIS (EARTH TIME)	59.65 days	243 days	1 day	1.03 days	9.93 hours
REVOLUTION AROUND SUN (EARTH TIME)	88 days	224.7 days	1 year	1.88 years	11.86 years
MEAN DISTANCE FROM SUN (EARTH=1 or 92,956,524.4 miles)	0.39	0.72	1	1.52	5.20

PLANETARY DATA FROM JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY

ORBITS OF THE PLANETS

Like ripples on a pond, paths of the planets range outward from the sun in this view of their positions on August 1, 1970. Most of the orbits lie approximately on the ecliptic, the plane of Earth's movements about the sun. But Pluto revolves at an angle of 17° from the ecliptic, and the orbital plane of Mercury tilts 7°. Between Mars and Jupiter, a wide belt swirls with perhaps 100,000 asteroids that can be detected through Earth's largest telescope.

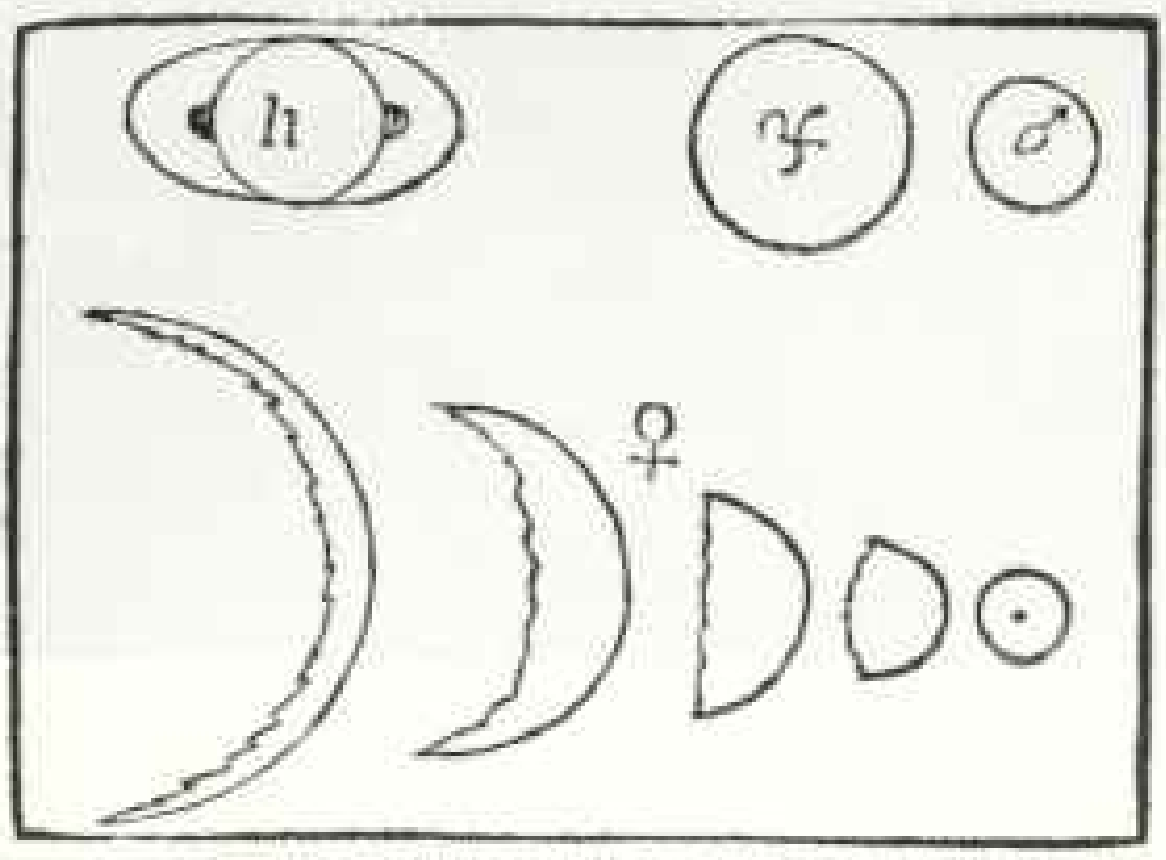
Colossus in the pageant of planets, banded Jupiter stares down with baleful red eye on its giant satellite Ganymede, foreground. Big enough to swallow 1,300 Earths, Jupiter with its powerful gravity controls a dozen moons and tugs at every other body in the solar system. Another moon, Europa, floats at far right. PAINTING BY LUDEK PESEK © N.G.S.

THIS PAGE FOLDS OUT

RELATIVE SIZES OF SUN AND PLANETS

SATURN	URANUS	NEPTUNE	PLUTO
9.5	3.7	3.9	0.5?
95.1	14.5	17.3	0.18?
769	50	59	?
0.69	1.7	1.6	?
0.88	1	1.1	?
10	5	2	0
10.23 hours	10.8 hours?	15.8 hours?	6.39 days
29.46 years	84.01 years	164.1 years	247 years
9.52	19.18	29.99	39.37

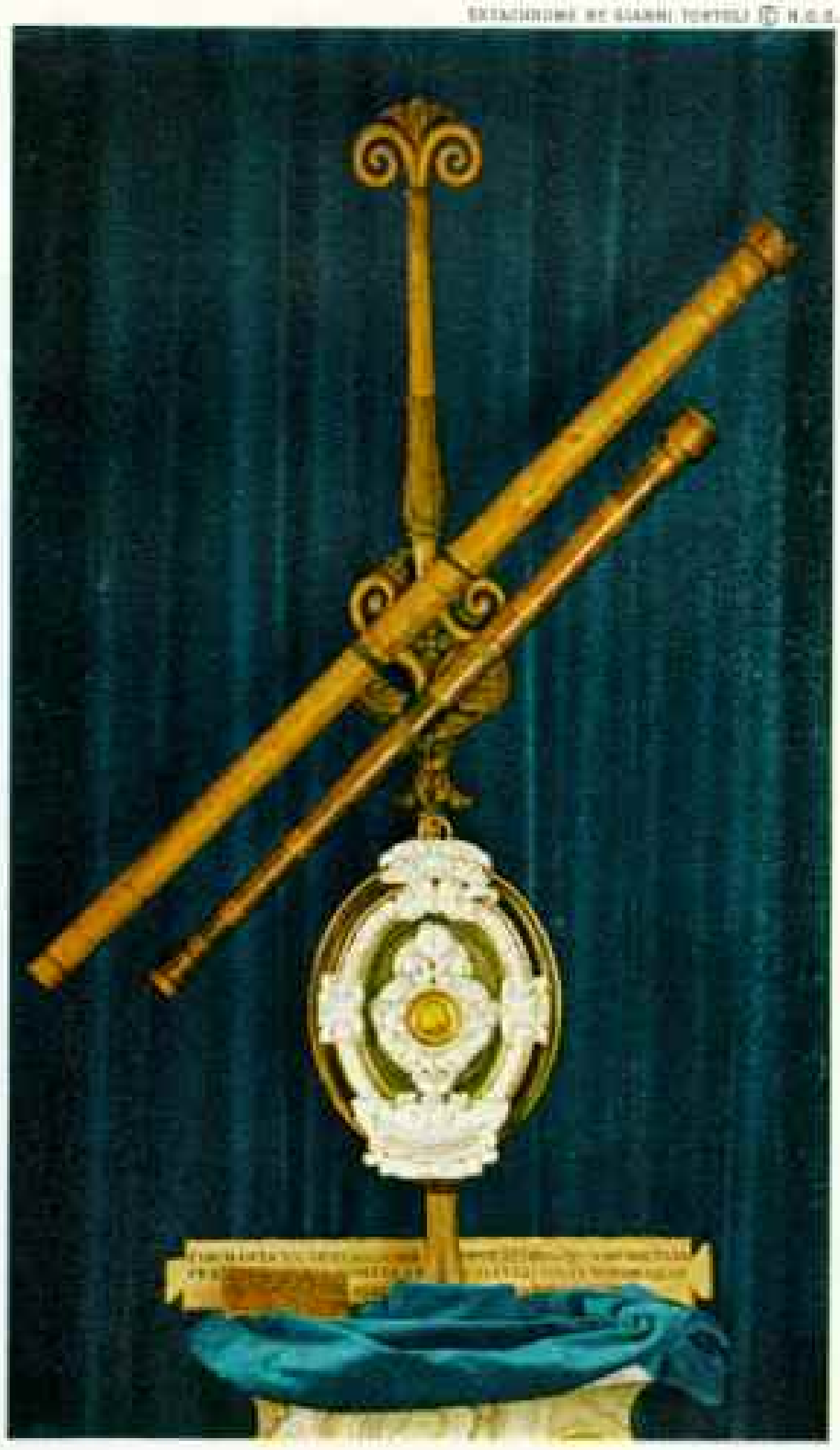
PAINTING ABOVE BY DAVID MILTON AND DIAGRAM BY LEO ZEBARTH, GEOGRAPHIC ART DIVISION © N.G.S.



DRAWINGS BY GALILEO GALILEI FROM GALILEO'S "IL SAGGIATORE," 1656

Galileo's own sketches, bearing the planetary signs (page 158), illustrate his epochal discoveries: the phases of Venus (next to a sun symbol at lower right), the rings of Saturn, and the blank disks of Jupiter and Mars, which man had seen earlier only as points of light.

EXCAVATIONS BY GIANNI TORTOLI © N.G.S.



First to explore the planets by telescope, Galileo Galilei (below) beheld awesome vistas. He launched the era of modern astronomy 360 years ago.

Gazing at Venus, the Italian mathematician detected its moonlike phases. This told him it revolves around the sun instead of Earth, supporting the then-heretical theory of the Polish astronomer Copernicus of a sun-centered solar system.

He delightedly observed four "little stars" attending Jupiter—the Galilean satellites—and puzzled over the strange configuration of Saturn. Training on the fiery solar disk itself, he saw sunspots—and discovered that they moved about.

PAINTING BY SUSTO SUSTERMAN, UFFIZI GALLERY, FLORENCE; PHOTOGRAPH FROM SCALA

Crude challengers of the infinite, two of Galileo's telescopes, each about 30 power, still point skyward. Ivory mount below them holds one of his cracked lenses. Although a Dutch lens maker had invented the telescope a year earlier, in 1608, Galileo was the first to train it on the heavens, using instruments he himself made.

Treasures of the Institute and Museum of the History of Science in Florence, Italy, Galileo's telescopes escaped the 1966 Florence flood only when the director risked her life to snatch them from the torrent (GEOGRAPHIC, July 1967).

five successful flybys of the planets—two to Venus and three to Mars. The Soviet Union has plunged three transmitting space probes into the dense atmosphere of Venus.

"This decade," says NASA Administrator Thomas O. Paine, "the entire solar system is the goal. No one knows how ambitious the Russian plans are, but before the end of the 1970's the United States hopes to send unmanned spacecraft racing toward every single one of the planets."

These robots from Earth will take pictures, sniff the atmospheres, gauge temperatures and pressures, measure radiations and magnetic fields, and—in the case of Mars—look for evidences of life.

Major scientific questions underlie this program of exploration—questions of consummate interest to all mankind:

1. How did the solar system begin, and how did it evolve?

2. How did life begin—and is there life elsewhere?

3. What can we learn about the missing chapters in the history of our own planet that will help us to understand better the workings of Earth and to solve the problems of our environment?

Dr. Von R. Eshleman, of Stanford University, echoes the feelings of many scientists when he says, "We need examples from other planets to guide our thinking and to throw new light on our attempts to understand puzzling terrestrial phenomena."

Let us take a look at this family of the sun, with its 9 planets and 32 satellites and thousands of asteroids and comets, stretching over a domain at least 8 billion miles across—so far that light, traveling at 186,282 miles a second, requires *half a day* to cross it.

If you think of the sun as a grapefruit, then a grain of sand 40 feet away would represent Earth, a cranberry 200 feet away would be Jupiter, and another grain of sand nearly a third of a mile away would be Pluto, the outermost planet. The nearest star would be another grapefruit, 2,000 miles distant.

Earth

Suppose we visit each planet, seeing it as if we were aboard an unmanned NASA spacecraft that will approach it sometime within the next few years. As a base for comparison, let us start with Earth. How would our planet look to men and instruments in spacecraft from another planet, orbiting above and then landing on the surface to make observations?

EARTH

The good planet Earth, sun-blessed sanctuary of life, travels in tandem with its sterile moon. Artist Pesek imaginatively portrays them from the vantage point of the asteroid Hermes, as it swept to within a mere 500,000 miles of Earth in 1937. So large is the moon—a fourth Earth's diameter—that many astronomers regard the pair as almost a double planet. Here the moon, closer to the asteroid, appears abnormally large.

PAINTING BY LUDEK PESEK © N.G.S.

I can imagine that these extraterrestrial astronauts might make brief entries in their log something like this:

Blue-and-white planet—only one in this system. Water covers 71 percent.

Low cloud masses, in swirling patterns, block much of view. Atmosphere: 78 percent nitrogen, 21 percent oxygen, and 1 percent argon, carbon dioxide, and other gases; water vapor variable; no appreciable hydrogen or helium. Atmospheric pressure, 14.7 pounds per square inch. Atmosphere and water vapor block part of radiation from the sun, 93,000,000 miles away. Planet acts like a magnet. Many meteoroids reach atmosphere; most burn up before striking surface.*

Land surface chiefly silicates; heavily modified by water and wind. Smooth in places; elsewhere rough and marked by steep uplifts. Crust shudders and spews molten material. Must be very hot underneath.

Temperature variations moderate. Coldest near poles (frozen water); minimum −127° F. Hottest near equator; maximum 136° F.

Life abundant; many forms; heavily dependent on liquid water and—in most cases—oxygen. Vegetation shows seasonal changes because planet is tilted, with first one hemisphere, then the other, toward sun during a 365-day orbit. Rotation on axis, 24 hours.

One large moon; with Earth, essentially a double planet.

*See in the GEOGRAPHIC: "The Earth From Orbit," by Paul D. Lowman, Jr., November 1966; and "Historic Color Portrait of Earth From Space," November 1967, and "The Flight of Apollo 11: 'One Giant Leap for Mankind,'" December 1969, both by Kenneth F. Weaver.

Venus

In the autumn of 1973, if NASA's plans hold, an Atlas-Centaur rocket will launch a Mariner spacecraft on a voyage to Venus and Mercury, the two planets lying between Earth and the sun. It will be the first United States attempt to fly past Mercury and the first gravity-assisted mission to a planet: That is, the spacecraft will be aimed so that as it passes Venus the gravitational field of that planet will help swing it,

VENUS

Hades of the heavens, Venus seethes with fumaroles and glowing lava in this vivid conception of Earth's cloud-veiled neighbor. In reality, even an observer on the surface of Venus could see no such panorama, for the planet's atmosphere—about a hundred times denser than Earth's—would blind like a thick fog.

Brutally hostile, the planet broils at nearly 1,000° F. beneath a smothering carbon-dioxide atmosphere that traps solar heat by the "greenhouse effect." Yet Venus works her charms. For us she glows faithfully as the morning and evening "star." Light from Venus, the brightest heavenly body except for the sun and the moon, can cause earthbound objects to cast a faint shadow on moonless nights.

somewhat like a ball on a string, and send it with the proper speed and direction toward Mercury.

This mission, like all those planned for the planets in the '70's, will be unmanned. But imagine that you are aboard as the spaceship approaches its first goal, Venus. The date is between February 3 and 6, 1974, and your spacecraft has been on the way for more than three months.*

Time: One hour before closest approach. We are coming in on Venus's dark side. Only a sliver of the lighted side of the planet is clearly visible.

Behind us, 28 million miles distant, our home planet has shrunk to a brilliant "star"—

*All flight information in this article is based on tentative plans now being refined by Caltech's Jet Propulsion Laboratory and (for the Pioneer missions to Jupiter) NASA's Ames Research Center. Figures may vary on the actual missions.

PAINTING BY LUCAS PESEX © NATIONAL GEOGRAPHIC SOCIETY

the brightest in the heavens except for the sun. Our messages, traveling at the speed of light, take two and a half minutes to reach the 210-foot radio dish at Goldstone, California.

The sun, only 67 million miles away, has grown a third larger than it appears from Earth. Now twice as much solar heat and light beat down upon our spacecraft.

As we curve around the planet, the glowing crescent rapidly enlarges. At closest approach —about 3,100 miles away—a half Venus nearly fills our field of vision, shining brilliantly with a slightly yellowish color. Then the entire dazzling spectacle sweeps into view as we swing on around and head for Mercury; Venus is more than three times as bright as Earth if seen from the same distance.

During the flyby, our cameras are taking pictures of the scene and our instruments are recording temperatures and other information about the planet's environment.

All we can see, however, is an expanse of dense clouds. That is all any man has ever seen of Venus. And it may be all any man will ever see, for what lurks below that veil is an awesome world of unbearable heat and pressures and of terrifying distortions.

Back on Earth, scientists have just begun to crack the many mysteries of Venus. By piecing together evidence from earth-based radar, from the Soviet probes (Venera 4 in October 1967 and Venera 5 and 6 in May 1969), and from our own Mariner 2 in December 1962 and Mariner 5 in October 1967, they are beginning to find out what makes Venus such a grim place.*

Key to the matter is a remarkable atmosphere, now thought to be about 95 percent carbon dioxide, that exerts a pressure of a hundred atmospheres (that is, a hundred times the pressure of Earth's atmosphere). Equivalent to the weight of water more than half a mile under the sea, this enormously dense atmosphere is believed to have crushed the three parachuting Soviet probes like so many eggshells when they were still 15 miles or more above the surface of Venus.

LAYERS OF THICK CLOUDS above Venus reach the astonishing altitude of 35 miles. (On Earth, even the highest clouds seldom go above ten miles.) They may block much of the sun's light. In addition, molecules in the extremely dense atmosphere scatter light as does a fog. The result, according to some scientists, may be a murky twilight; others see it as an eerie whiteout, or like living at the bottom of a dust storm or a dense smog.

The thick atmosphere that weighs so oppressively on the surface tortures it in another way: It traps the sun's energy and helps build up the most furnacelike heat yet found on any planet.

At least, this is the theory held by many scientists, based on the well-known "greenhouse effect." Solar energy filtering down through the clouds is absorbed by the surface, then re-radiated as longer-wavelength infrared, or heat. Much of this heat would escape to space and thus cool the planet but for the fact that the atmosphere (like the glass in a greenhouse) effectively blocks infrared.

Some specialists feel that the greenhouse effect is not sufficient to explain the riddle of Venus's ultrahigh temperatures. At the equator they are observed to reach as high as 1,000° F., and, because heat is transferred so efficiently by a dense atmosphere, even the poles probably are not much cooler. At such temperatures lead, tin, and zinc will melt, and any number of compounds vaporize.

If you could stand on the surface of Venus, few obstacles would block the view. Recent observations with the 120-foot Haystack radar telescope (opposite), operated by the Massachusetts Institute of Technology's

*See "Mariner Scans a Lifeless Venus," by Frank Sartwell, NATIONAL GEOGRAPHIC, May 1963.

The planetary symbols

MERCURY: stylized caduceus, staff of the messenger of Roman gods

JUPITER: modified *Z* for Zeus, Greek counterpart of Rome's chief deity

VENUS: mirror, emblem of the Roman goddess of beauty

SATURN: scythe of the Roman god of harvest

EARTH: Equator and meridian on a globe

URANUS: symbol of the heavens, representing the sky god

MARS: shield and spear of the Roman god of war

NEPTUNE: trident of the Roman god of the seas

THE ASTEROIDS: National Geographic-devised symbol representing the many minor planets

PLUTO: monogram formed from the planet's first two letters

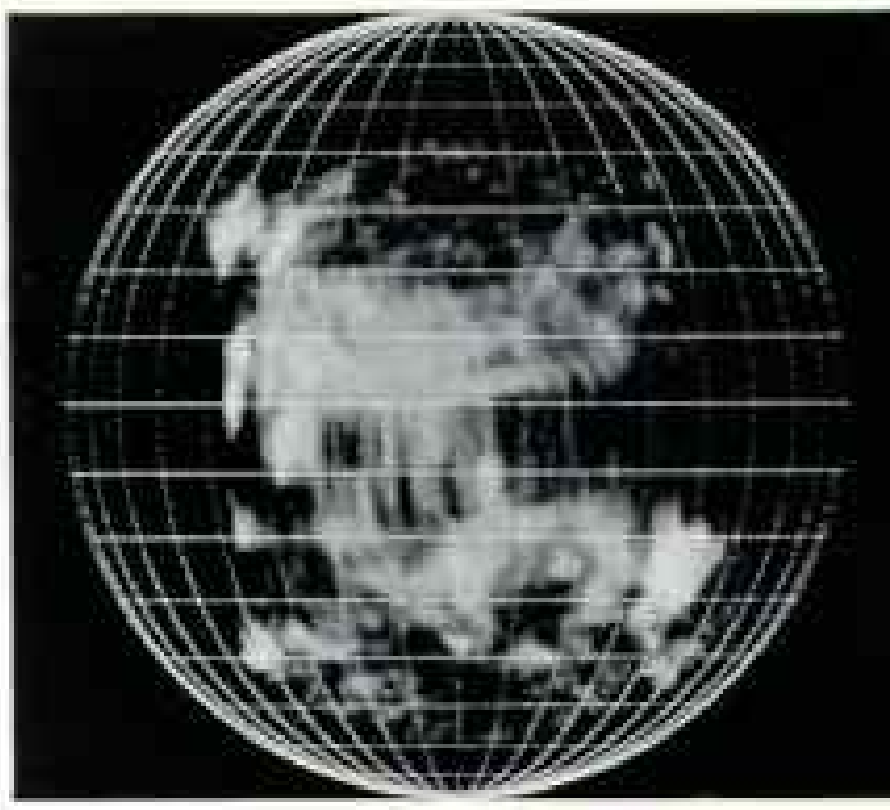
NEW MEXICO STATE UNIVERSITY OBSERVATORY

High Venus clouds, smudges as seen three hours apart in the two ultraviolet images at left, appear to circle the planet 60 times as fast as Venus itself rotates. No features mark a green-filtered image, right.

To part the shroud that wraps Venus, astronomers on Earth feel her torrid face with radar waves, broadcast by such mammoth facilities as MIT's Haystack antenna (below). Located in Tyngsboro, Massachusetts, the 120-foot dish transmits through a radome that shields it from the weather.

Haystack's invisible waves fill in blurred but meaningful Venus features. In a 1969 image (right), bright regions of high reflectivity betray rough terrain, possibly mountains. Fainter echoes tell of smooth areas. The waves also see a surface apparently very solid, though perhaps dust-covered.

Radar astonished astronomers with its 1962 revelation of Venus's unorthodox rotation. Instead of spinning counterclockwise like its neighbors, the planet rotates the other way—one leisurely clockwise turn every 243 earth days.



RADARSCOPE (RIGHT) BY ERNEST KOLMAN © R.A.L., MASSACHUSETTS INSTITUTE OF TECHNOLOGY, LINCOLN LABORATORY (ABOVE)

Lincoln Laboratory near Boston, have detected a low mountain range, but in general the surface of Venus is thought to be quite gentle in slope. Bright areas showing up on radar pictures at Haystack, and at the Jet Propulsion Laboratory's Goldstone installation, are generally interpreted as local rough spots, not necessarily elevations.

But of far greater effect on visibility would be the thick atmosphere of Venus and its capacity to bend light rays sharply, just as a prism does. This refraction would make it seem that you were standing in a bowl, with the horizon turning up in every direction.

In fact, the light bending is so extreme that, were it not for the low visibility, if you shone an enormously powerful light ahead of you, the light would go completely around the planet, hitting you in the back of the head. That is the whimsical suggestion of Dr. Von R. Eshleman, who has studied the way light and radio waves act in the atmosphere of Venus. Put another way, if such an atmosphere were totally transparent, you could theoretically see all the way around the planet.

IN THE LATE 18TH CENTURY, Sir William Herschel, Britain's Court Astronomer, believed that life existed on all the planets, as well as the sun. What a shock Venus would be for him today! Although some terrestrial organisms can withstand unbelievably hostile conditions, such as salt lakes and boiling hot springs, no organisms that we know could live on the hot surface of Venus. Nor is water in liquid form thought to be there, and some liquid water seems to be an essential for earthly life, at least.

Dr. Carl Sagan, of Cornell University, points out, however, that life on another planet would not in any case require terrestrial conditions—that it would be adapted to its own special environment. He suggests that microscopic forms of life may exist at some level in the clouds, like plankton in Earth's seas. At the top layer of the Venus clouds, temperatures have been measured at about −35° F., and somewhere between the frigid cloud tops and the searing surface must be a "comfortable" temperature.

One of the many mysteries about Venus is where its water has gone—if, indeed, it ever had any. Was Venus made from materials that lacked water? Or did it outgas or exhale water in large amounts over the ages, just as has Earth, through volcanoes and fumaroles, and then somehow lose it?

All we know for sure is that recent observations of the planet's infrared absorption indicate that the amount of water vapor in the upper atmosphere is extremely low—no more than 1/1,000 the amount in Earth's atmosphere. Controversy surrounds the question of whether water droplets or ice crystals could exist in the Venus cloud layers.

It is an astonishing fact that Earth has nearly as much carbon dioxide as does Venus, even though only a small fraction of a percent is found in our atmosphere. Most of our carbon dioxide has dissolved in the oceans, where it has become locked up in calcium carbonate, such as in sea shells and limestone. If that lock were picked, Earth would have a dense carbon-dioxide atmosphere, very much like that of Venus.

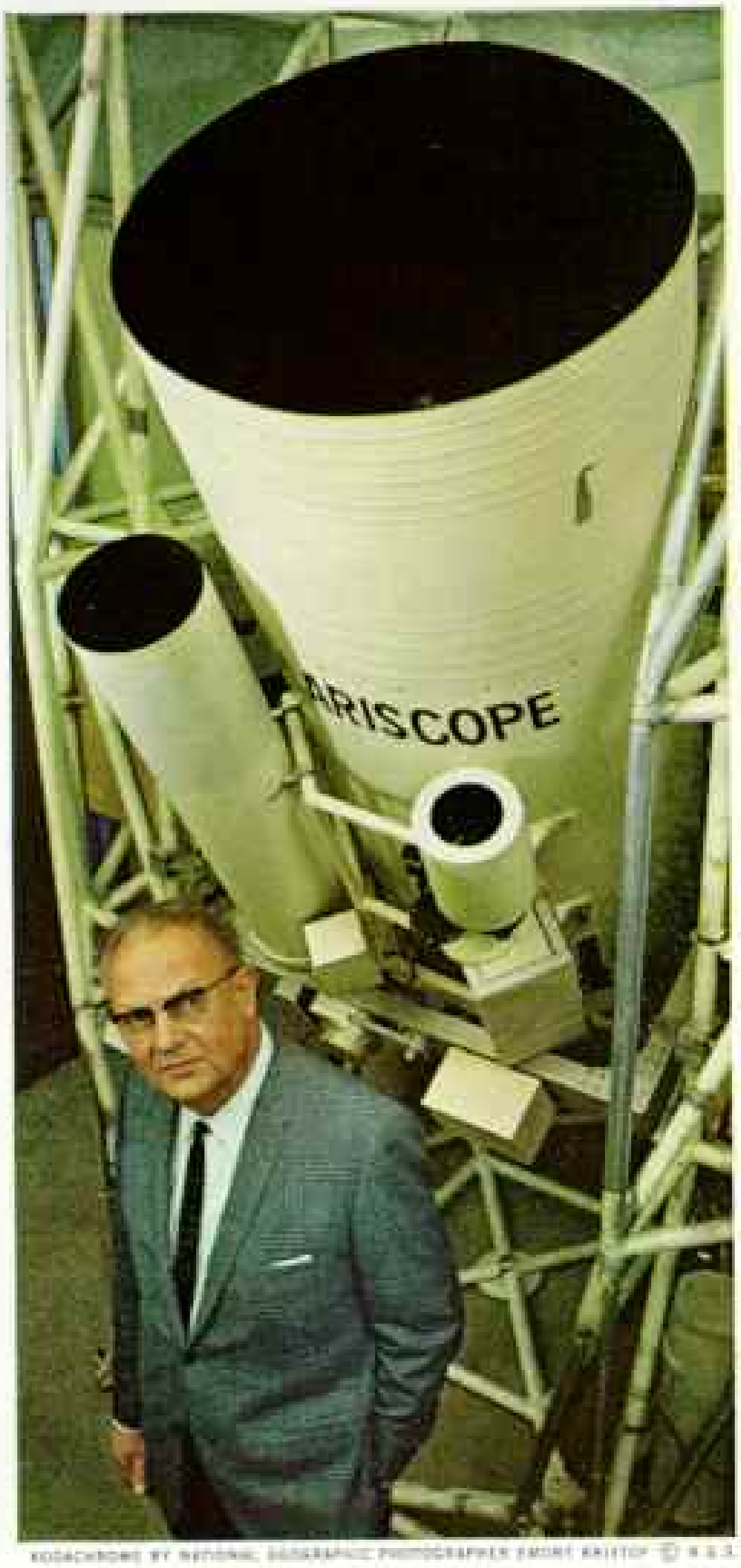
THE ROTATION PERIOD of Venus was for centuries a matter of dispute. Published guesses varied from 22 hours to 365 days. But nobody knew for sure, because they couldn't see the surface of the planet itself.

Increasingly sensitive radar observations, which pierce through the clouds, have settled the matter. Venus makes a complete rotation on its axis once every 243 days. To everyone's astonishment, it turns clockwise, backward to the typical motion of the planets.

Because of the combination of this slow backward rotation and the 225 days it takes the planet to make one orbit around the sun, Venus "sees" the sun come up *in the west* every 117 earth days.

One of the controversies raging most vigorously in planetary astronomy today centers on the question of what makes up the Venus clouds. When I posed the matter to Dr. Donald Hunten, of the Kitt Peak National Observatory, he commented wryly, "We get many answers to that question, which means we just don't know."

Some specialists insist that they find evidence of water droplets or ice crystals; others see dust. Among other substances that have been suggested are compounds of mercury and a form of iron chloride which might explain the yellowish color so characteristic of Venus. The truth, most likely, is that the Venus clouds will prove to contain a mixture of substances.



KODACHROME BY NATIONAL GEOGRAPHIC PHOTOGRAPHER FRONT KRITIAN © N.G.S.

Veteran viewer of the solar system, Dr. Gerard P. Kuiper has discovered two satellites of outer planets: Miranda, a moon of Uranus, in 1948, and Neptune's Nereid in 1949. Director of the Lunar and Planetary Laboratory of the University of Arizona in Tucson, he stands beside a balloon-riding telescope that records ultraviolet radiation.

Mercury

Catapulted by Venus's gravitational field, our spacecraft bends its flight path by some 40 degrees and races on toward Mercury, the solar system's innermost and smallest planet.

On March 30, 1974, we reach this second goal. Mercury has only about a third the diameter of Earth. We approach it so fast and it looms so swiftly that we almost feel vertigo. Now our cameras and instruments race to record information. After years of preparation and 5½ months in flight, we have only two hours to gather all the close-up information on Mercury we will get in this decade.

Earth lies 93 million miles behind, still a very bright point of light. The scientists there, at the Jet Propulsion Laboratory in Pasadena, California, wait tensely for the information from our instruments and tape recorders; the signals take more than eight minutes to reach Earth.

The sun, now only 43 million miles away, appears more than twice as large as when seen from Earth; the solar radiation bombarding us is five times as intense as that striking Earth's atmosphere. If our spacecraft were truly designed for manned flight, it would require much more radiation shielding and temperature control.

The surface of Mercury filling our view is a rare sight, never clearly seen from Earth. Now we can see it with perfect clarity; no atmospheric effects block the vista. We are only about 600 miles from the surface, and our eyes can distinguish objects as small as 1,700 feet across. Everywhere we see evidence that this rocky cinder has been cratered by comets and asteroids, and it is not hard to imagine that it was once scorched by tremendous heat.

Dr. Gerard Kuiper (left), Director of the Lunar and Planetary Laboratory of the University of Arizona, explains Mercury's heated past this way: "Early in solar-system history, I believe, the sun blazed for a short time, maybe ten thousand years, with a luminosity as much as thirty times greater than that of today. Mercury was probably twice as massive then as it is now, but the sun evaporated away half its substance. The lighter, more volatile elements escaped, leaving a heavy planet that is probably about 30 percent silicates, or rock, and 70 percent metals. It is 5½ times as dense as water."

Even today Mercury bathes constantly in ferocious heat. When the planet is at aphelion, the farthermost point from the sun in its eccentric orbit, the flow of solar energy is five times as great as that reaching the vicinity of Earth. When Mercury comes into perihelion, its closest approach, the searing radiation is ten times as great. Temperatures reach 650° F. on the equator, though they probably drop during the long night to −300° F.

MERCURY

Desolate cinder scorched by the sun's fiery breath, Mercury unfolds a moonscape of meteorite pits and ridgelike crater rims. Apparently devoid of protective atmosphere, the copper-hued orb cooks at 650° F. on the daylight side, while nights plunge to a brittle −300° F.

Orbiting close to the blinding sun, Mercury confounds earthbound observers. But radar, uncannily reading echoes as weak as if bounced from a dime 10,000 miles away, detects huge areas of rough terrain.

NEW MEXICO STATE UNIVERSITY OBSERVATORY

Best likeness of Mercury, taken through a 24-inch telescope, captures only faint, undecipherable shadings.

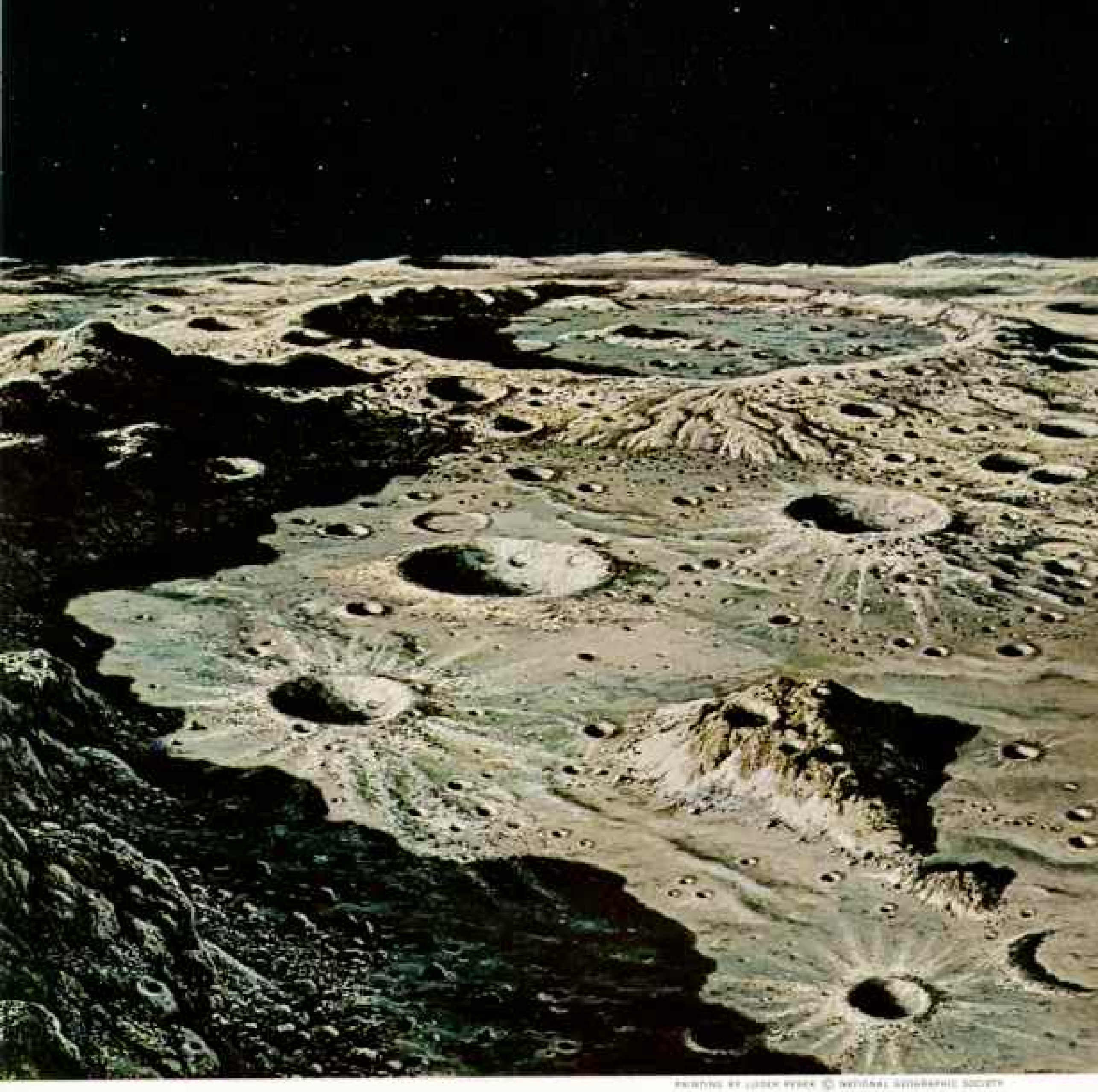
GEOGRAPHIC ART DIVISION © N.G.S.

Mercury's new twist: Radar proved in 1965 that the planet rotates on its axis every 59 earth days, as indicated here by an imaginary spot on the surface. Earlier dogma held the rotation to be synchronous with the orbit—once every 88 earth days.

Actually, in those 88 days the spot would move precisely from noon to midnight. Thus a Mercury year lasts only half a Mercury day.

And there is apparently no atmosphere such as our own planet enjoys for a shield. At any rate, the way Mercury reflects and polarizes light is similar to that of the airless moon. With low gravity (only a third that of Earth) and high temperatures, atoms and molecules of most gases would move so rapidly that, over the eons, they would escape to interplanetary space.

The pictures telemetered back to Earth in the Mercury mission will arouse unprecedented interest among scientist and layman alike. Astronomers have never seen Mercury really well, even though it is reasonably close to Earth as distances go in the solar system. The planet stays so close to the sun in its relatively tiny orbit that, to the naked eye, it is



PAINTING BY LUDEK PESEK © NATIONAL GEOGRAPHIC SOCIETY

almost always swallowed up in the glare. On Earth it can sometimes be seen briefly as an evening star just after sunset, or as a morning star (the ancients called it Apollo) just before dawn. But Earth's thick, haze-and-dust-filled atmosphere on the horizon often blots it out.

For the same reasons that Mercury is difficult to see, it is a problem to photograph. In fact, only about 100 photographic plates have ever been made showing markings on the surface (opposite). Virtually all these were taken at the observatory of New Mexico State University, at Las Cruces. When I visited the observatory, I learned that in an intensive program spanning more than ten years it has taken some 800,000 pictures of the planets, more than any other observatory.

OVER THE DECADES, astronomers who patiently waited for glimpses of Mercury, and laboriously sketched the few bright and dark markings they thought they saw, were convinced that Mercury always kept the same face toward the sun. The widely held theory was that Mercury's rotation, like the moon's, was synchronous—that is, the body turned on its axis in just the same time as it took to orbit the sun. That period was 88 earth days.

But, in 1965, Dr. Gordon H. Pettengill, working at Cornell's huge 1,000-foot radio reflector set in the ground at Arecibo, Puerto Rico, monitored the planet's rotation at only about 59 days. Now there was a puzzle indeed! Astronomers almost to a man were astonished by the discovery.

Then it was noticed that 59 was almost exactly two-thirds of 88. Could that have meaning? It not only could but does. It means that Mercury spins three times for every two revolutions about the sun, showing astronomers nearly the same face with the same markings each successive time the planet is in the most favorable viewing position.

So Mercury's year is 88 earth days long, and its sidereal day (as seen from the stars) is 58.65 earth days. But its solar day—that is, the period from one midnight or noon to the next—is exactly twice as long as its year, 176 earth days (diagram, page 162).

All this strange combination of rotation and orbiting rates, with an eccentric orbit, brings about a most peculiar effect in the apparent motion of the sun over Mercury. If you were on Mercury at dawn just at perihelion passage, you would see the sun come up, hang for a brief time in the sky, drop back below the horizon, then rise again.

Because of this strange phenomenon, Professor Bruce W. Hapke, of the University of Pittsburgh, calls Mercury "the Joshua planet." He refers, of course, to the Old Testament prophet who commanded the sun to stand still over Gibeon during the battle between the Israelites and the Amorites.

Could there be life on Mercury? Conditions do not seem at all favorable, and no one seriously suggests it.

Mars

Years ago I learned a simple mnemonic device for keeping the order of the planets straight: "Matilda Visits Every Monday, Just Stays Until Noon, Period." Take the first letters of these nine words, and you have the initials of the nine planets.

And following that order brings us to the first of the planets outside Earth's orbit—Mars, the red planet, whose color suggested blood and once chilled the hearts of men. Mars, the planet of war, whose symbol represents a shield and spear, and whose two tiny

Raw flank of the red planet Mars looms less than 4,000 miles away, as depicted from the satellite Phobos. Dust storms swirl in the thin atmosphere, upper left, while the terminator, the line dividing day and night, recedes at right. Mars's dark regions, some scientists believe, may represent jumbled or cratered terrain of poor reflectivity.

Phobos is the darkest body yet observed in the solar system, possibly because meteorites have scoured it clean of reflecting dust.

PAINTING BY LUIS FUEN © N.G.S.

♂
MARS

DRAWN BY HUYGENS
1672

DRAWN BY SCHIAPARELLI
1886

MARS AS SEEN THROUGH THE CENTURIES

Revealing shadowy features through even early telescopes, Mars has long challenged astronomers to map its face. Christiaan Huygens of Holland identified the vast dark region of Syrtis Major and sketched in the south polar cap, which he located at the top because telescopes invert the image.

The Italian astronomer Giovanni Schiaparelli saw Mars as streaked with a web of *canali*—Italian for "channels" or "canals." Many took this to mean there was intelligent life on Mars. U. S. Mariner spacecraft 6 and 7 in mid-1969 revealed some to be alignments of craters or patches of dark terrain.

Polar areas gleam in the third view. Craters ringed probably by dry ice pit the south polar cap (below), as seen by Mariner 7 from 3,100 miles away.

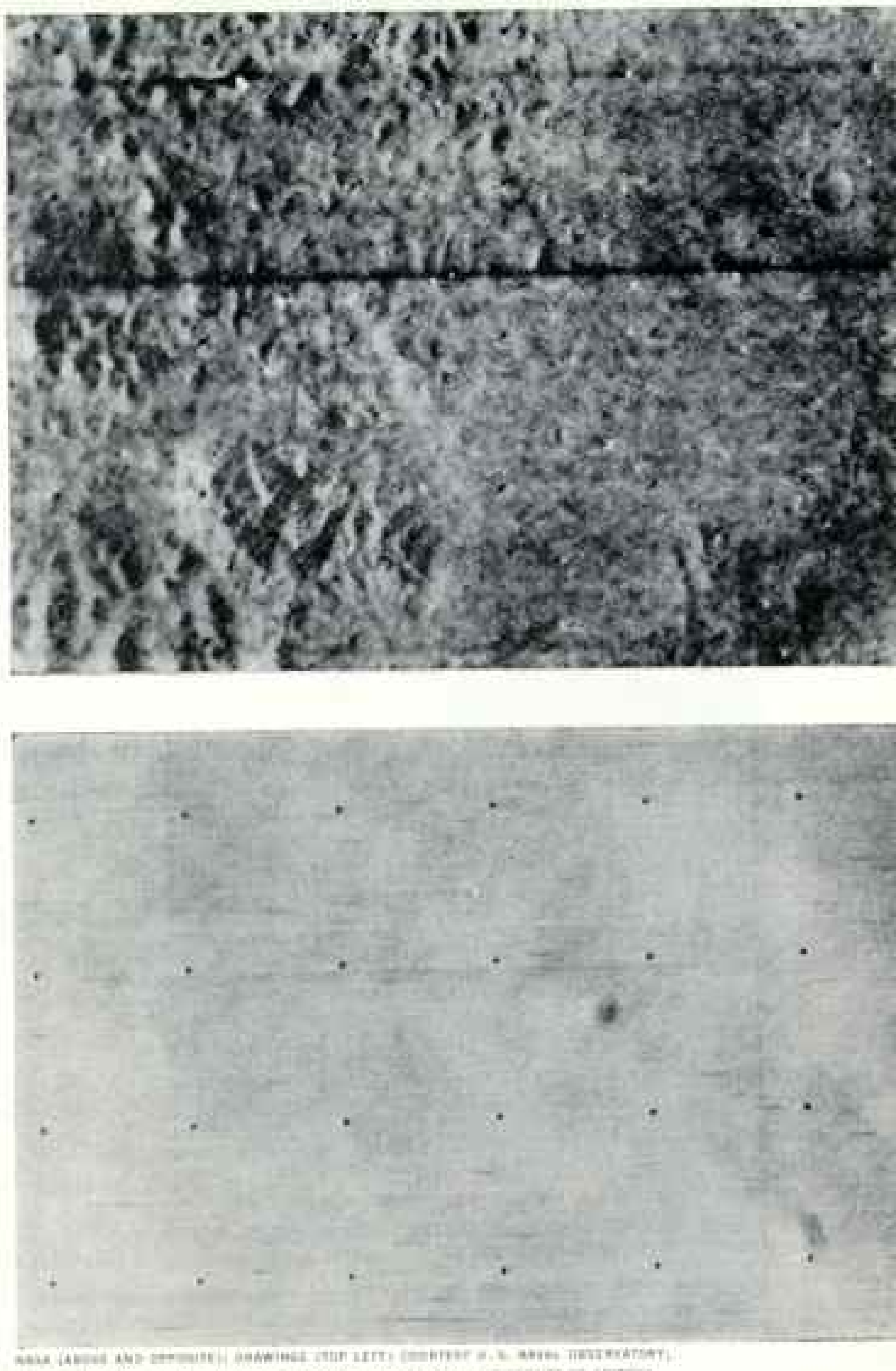
PHOTOGRAPHED BY 60-INCH TELESCOPE AT
CERRO TOLOLO INTER-AMERICAN
OBSERVATORY, CHILE. 1969

satellites, Phobos (Fear) and Deimos (Terror), were named for the war god's attendants. Mars, the home planet of Dejah Thoris, Princess of Helium, if my boyhood memory of reading Edgar Rice Burroughs serves me right.

Time: November 14, 1971. Just 193 days ago our one-ton Mariner spacecraft left Cape Kennedy, propelled by an Atlas-Centaur rocket. It is unmanned, but let us imagine we are aboard. Now we are at our closest approach to Mars, only 1,000 miles above the ruddy surface. The colors are burnt ocher in the bright areas and a grayer red in the dark, with none of the greens and blues observers "see" in their telescopes. The bright greens and blues are very largely an optical illusion.

Our cameras are greedily recording the scene below. This time will be no simple flyby, such as the previous three Mariner Mars missions. Our spacecraft has gone into an orbit that will swing out to a distance of 10,500 miles and bring us back to a 1,000-mile altitude just 12 hours from now. For the next 90 days we will orbit in this fashion, photographing strip after strip, mapping 70 percent of the entire planet.

We scan the dark and light areas, searching for familiar outlines. Nix Olympica (Snow of Olympus), a bright-ringed crater 300 miles across, lies far to the northwest. Below us and to the west is Solis Lacus (Lake of the Sun),



From monotony to chaos: Mars shows varying terrain. Sweeping within 2,200 miles of the red planet in 1969, two unmanned United States spacecraft, Mariners 6 and 7, flashed back streams of television pictures. Poring over them on Earth, thrilled Mars-watchers beheld three distinctive landscapes: a vast featureless plain, cratered regions, and terrain rightly labeled chaotic.

Craters abound in the south polar area (left), one of the planet's more pitted regions. Two craters dubbed the "Giant's Footprint" lie near the dark line of the terminator. Mars has one huge crater 300 miles across—Nix Olympica (Snow of Olympus).

Finely crumpled ridges, each a mile or so wide and several miles long, wrinkle a chaotic region (right, upper), photographed by Mariner 6 from 3,300 miles. The rugged but almost craterless maze covers hundreds of thousands of square miles. Pondering the expanse, some scientists suggest it formed when a subterranean substance such as permafrost withdrew, causing surface areas to collapse.

A quarter-million square miles of featureless terrain fill a Mariner 7 picture of the Hellas "desert," made from 2,250 miles away (lower). The two dark smudges stem from TV defects. Mars specialists believe that a powerful erasing process—such as blanketing by wind-borne material—accounts for plains like Hellas.

NASA (ABOVE AND OPPOSITE); DRAWINGS (TOP LEFT) COURTESY U. S. NAVAL OBSERVATORY; TELESCOPIC PHOTOGRAPH, LUNAR AND PLANETARY LABORATORY, UNIVERSITY OF ARIZONA

and just ahead are the dark region Aurorae Sinus (Bay of the Dawn) and the bright regions Candor and Xanthe. What romantic names these are, given at a time when every educated man was steeped in mythology.

Craters dominate the landscape. We can see no mountain chains, no bodies of water, no canals. The atmosphere seems clear almost to the horizon, where a narrow rim of bluish haze, with an occasional bright patch, gives way quickly to the blackness of space.

And out in that blackness, 130,000,000 miles away, shines a diminished sun, two-thirds its remembered size. Only half as much solar energy is falling on Mars as on Earth.

Back on Earth, 400 seconds away as our telemetry signals travel, scientists at the Jet Propulsion Laboratory are processing Mariner's TV pictures and information from our instruments about temperatures, atmospheric constituents, and possibly some of the materials of the surface.

Re-creating a Mars on Earth, Bradford A. Smith plots features reported by Mariners 6 and 7 onto a globe for comparison with observations from Earth. Professor Smith directs planetary programs at New Mexico State University.

Ten days from now another Mariner exactly like ours will arrive, go into a somewhat different orbit, and for 90 days flash back to Earth findings about seasonal changes. Between these two Mariner 1971 missions, we hope to clear up some of the enigmas of Mars.

BEFORE the Mariner 4 mission in 1964-65, when all we knew of Mars had been painfully gleaned through telescopes, many people believed that Mars was much like Earth. It was the only planet, of course, whose surface we could clearly see. Its solar day lasted only about 40 minutes longer than ours. The tilt of its axis with respect to the orbit was only about two degrees greater than Earth's, which gave the two planets much the same seasonal variations.

Observations showed that Mars had a thin atmosphere. Surface temperatures, at least at midday on the equator, were comparable to air temperatures on Earth on a spring day.

We could clearly see polar caps like Earth's, presumably made of water ice, that waxed and waned with the seasons. The spring "wave of darkening," which some observers discerned, suggested vegetation responding to the advance of a wave of moisture from the polar regions.

And of course there were the "canals." Ever since the Italian astronomer Giovanni Schiaparelli in 1877 described seeing many straight lines on Mars, people had persisted in construing his word *canali* (channels or canals) as suggesting that intelligent beings had dug them. Percival Lowell, founder of the Lowell Observatory in Arizona, pyramided Schiaparelli's canali into a full-blown fantasy of intelligent beings on Mars.

But the three Mariners (one in 1964–65 and two in 1969) have demolished most of these notions. From close-up pictures sent back to Earth, showing some 20 percent of the Martian surface, and from infrared and ultraviolet studies, we now see a Mars that is quite different from Earth and, indeed, from anything else now known in the solar system.

The Martian atmosphere, chiefly carbon dioxide, measures less than 1 percent the density and pressure of Earth's. You would have to climb more than 20 miles above the surface of Earth to find air so thin. The planet enjoys little protection against the sun's radiations, especially ultraviolet, that would quickly

kill any unprotected Earth organisms. If there is any life on Mars, it clearly must have some kind of shield or filter.*

It will also have to be able to endure abrupt and extreme changes in temperature. At midday on the equator, a thermometer might measure as high as 80° F., but that night it could drop to 150° below zero.

Finally, Martian life would very likely have to get along without water; no liquid water has ever been detected on the surface. Mars appears to be much drier than Earth's most arid deserts.

Some scientists believe that Mars retains water in the form of permafrost, perhaps many feet under the surface. In addition, there is a very small amount of water vapor in the atmosphere. Although the thin haze that seems to hang high in the atmosphere probably consists of fine particles of frozen carbon dioxide, brightenings on the disk, chiefly in the equatorial regions, may be water-ice fog or clouds, or even surface frost.

The polar caps in all probability are dry ice—frozen carbon dioxide—with a small amount of water ice. As they warm up in spring, they do not melt but sublime, or evaporate. It's unlikely there is enough water in any form to support vegetation that might produce the "wave of darkening."

IN VIEW of these hostile conditions, I asked Dr. Norman H. Horowitz, Professor of Biology at Caltech, about prospects of finding life on Mars.

"Mariner's observations have certainly not improved the chances, although at the same time nothing in the Mariner findings disproves the possibility of life," he says. "If life does exist on Mars, it must be something very primitive, like bacteria; the idea of substantial plants or animals is out."

A few scientists are less pessimistic. In any case, no orbiter or flyby can answer the question, only a landing vehicle. That's why NASA hopes to send a spacecraft called Viking to Mars in 1976, landing instruments to scoop up soil and test for life (pages 172-3). Either way the answer goes, biologists regard it as of the utmost importance in helping to understand life on Earth.

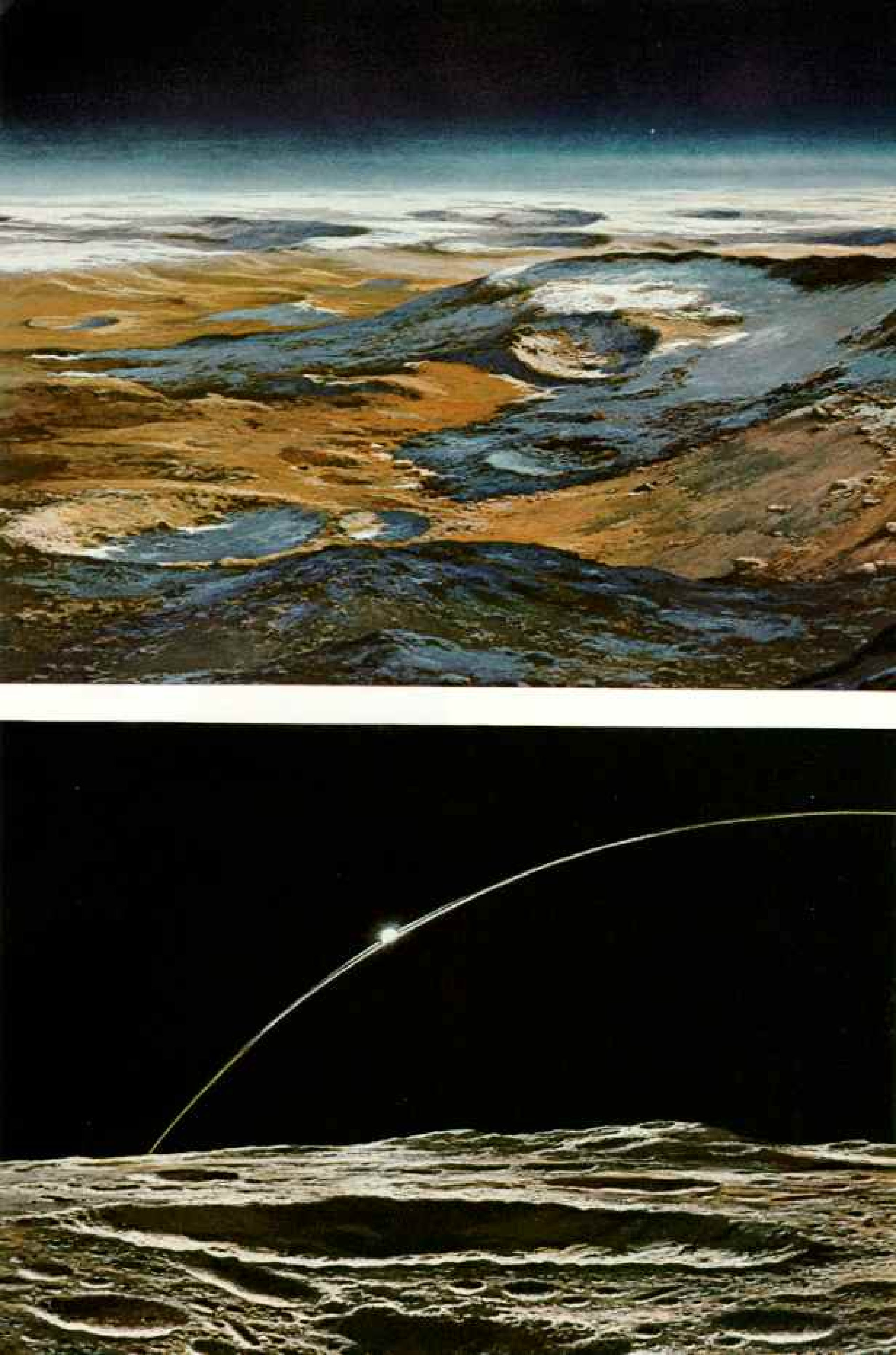
"When men first land on Mars—as they may actually do before the end of this century—they will find rather uninteresting terrain for the most part," suggests Professor Robert Leighton (below), of the California Institute of Technology, who was in charge of the Mariner Mars television experiments.

"Everything in the Mariner pictures indicates very gentle slopes on Mars. There are no mountain ranges, no great faults, no extensive volcanic fields, in fact no evidence of volcanic activity. You could stand in a crater on Mars and never know it—even one that appears sharp and clear in the pictures."

Mars does indeed have highlands and lowlands. Using Lincoln Lab's Haystack radar, Dr. Gordon Pettengill, now Director of the Arecibo Ionospheric Observatory, has found a difference of about eight miles in elevation between the highest and lowest point on the planet. But the changes in elevation are gradual and the slopes are gentle as one climbs from the lowland basins to the highest plateaus.

*See "Mars: A New World to Explore," by Carl Sagan, NATIONAL GEOGRAPHIC, December 1967.

Man behind the Mars pictures, Dr. Robert Leighton, Professor of Physics at the California Institute of Technology in Pasadena, had charge of the successful TV studies of Mars by Mariners 6 and 7, as well as by Mariner 4 in 1964-5.



PAINTINGS BY LUDEK PESEK © NATIONAL GEOGRAPHIC SOCIETY

PHOTOGRAPH BY EMORY KRISTOF © N.G.S.

Portraitist for the family of planets, artist Ludek Pesek touches up his paintings at National Geographic headquarters in Washington, D. C. He worked more than a year preparing the illustrations for this article.

A native Czech who now lives in Switzerland, the versatile Mr. Pesek not only has illustrated two widely published books on the planets, but also has written five novels.

Summer nibbles at the south polar cap of Mars (upper painting), evaporating dry ice from sunlit slopes. Drifted fields of carbon-dioxide snow spread beneath a CO_2 haze.

View from Phobos, one of two Martian moons, shows a jewel-like sunrise glinting above the inky planet. The haze layer close by the sun, just above the rim, was first observed by Mariners 6 and 7. The latter, photographing Phobos from only 82,000 miles, revealed that this moon is shaped like a baking potato, 11 by 14 miles in size.

PAINTING BY LOUIS PEREZ, ROADSHOWS (BELOW) BY EMORY KRISTOF © N.G.S.

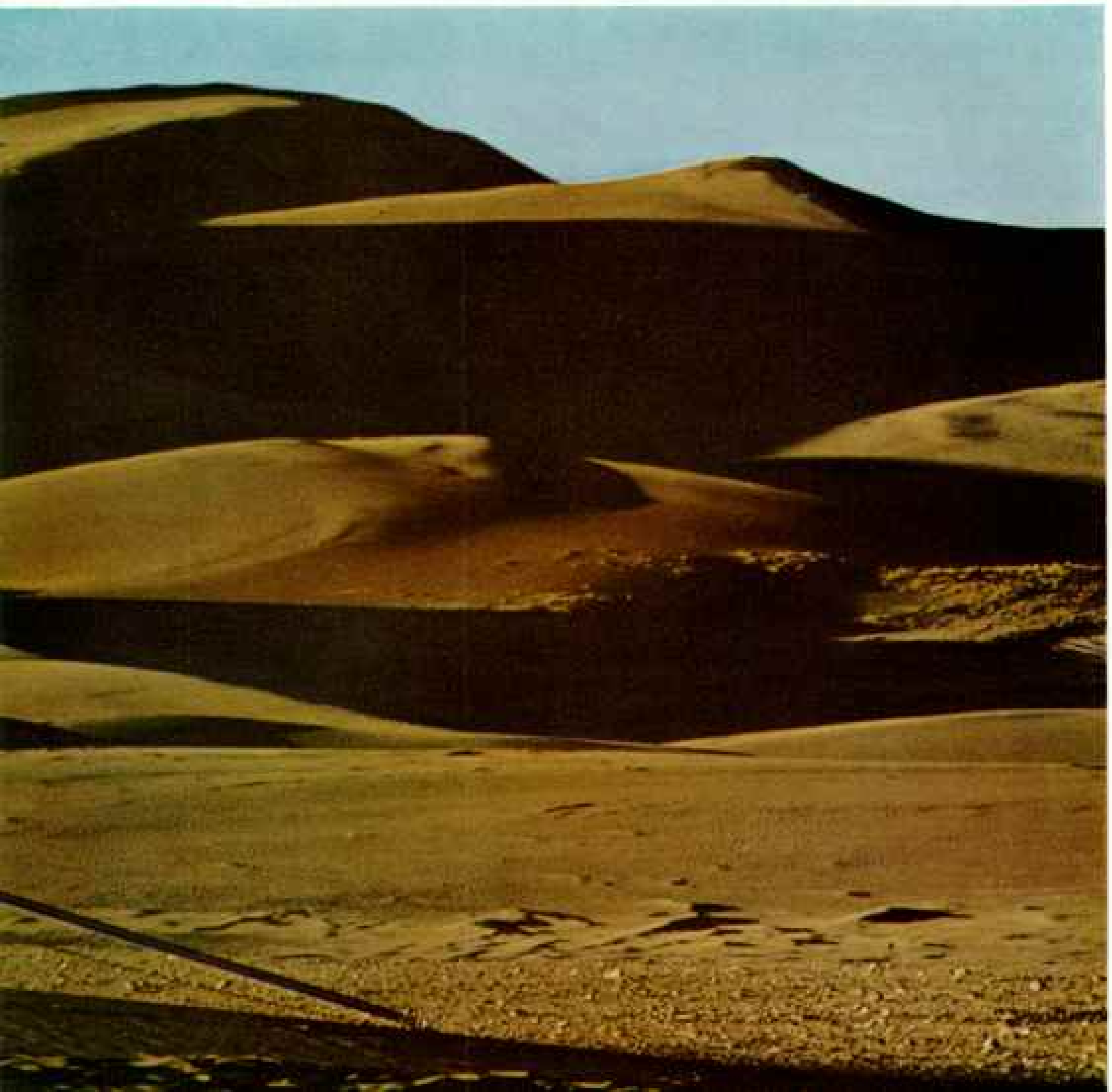
"A dull uninteresting landscape," says Dr. Leighton of russet Mars. Here it stretches away in a dreary sameness of shallow craters. Despite Mariner pictures that captured features as small as 1,000 feet across, Mars has yet to reveal evidence of water in liquid form or of tectonic activity—the folding, faulting, and volcanic upheavals that still shape Earth.

Mission: to explore Mars. A test model of NASA's Viking probe squats at Great Sand Dunes National Monument in Colorado. Built by Martin Marietta Corporation of Denver for launch in 1975, the Viking lander is designed to ride to Mars on an orbital spacecraft, then descend by parachute and braking rockets to the surface. There it will send back photographs; assay the thin atmosphere, and stretch out a long arm, right, to snatch up soil samples. These it will analyze for possible life forms.

THREE radically different kinds of terrain show up in the Mariner pictures: cratered, "chaotic," and featureless (pages 166-7). As on the moon, craters appear prominently, even in the thin south polar cap. But in depth and slope, they vary distinctly from those of the lunar surface, suggesting differences in the geological processes that modify them. Many of the Martian craters appear as though their rims had been sandpapered off, and they show very flat bottoms.

A second kind of terrain, essentially free of craters, appears in the region between Aurorae Sinus and Margaritifer Sinus. Its irregular, jumbled topography of short ridges and furrows, covering in one area as much as half a million square miles—the size of Alaska—has been given the name "chaotic terrain." It somewhat resembles the debris of a terrestrial landslide, but nowhere on Earth do formations like this extend over such large regions.

The bright circular "desert" of Hellas (really



a misnomer, since all Mars is a desert) represents the third kind of topography of Mars. It is called featureless because in a large smooth basin, some 1,200 miles across, hardly any craters can be seen. Nothing on the moon looks like this, but it does somewhat resemble the great plains of Earth.

By contrast, the dark highland region to the west, Hellespontus, is heavily cratered. Geologists scratch their heads when you ask them to explain why. What could allow meteoroids to fall on Hellespontus but protect Hellas? Or what could erase the craters in one region and not in the other?

Professor Robert Sharp, of the Department of Geology at the California Institute of Technology, proposes the most interesting theory. He suggests that possibly Hellas is floored with some unusually light, porous material (which he dubs "micro-popcorn"). The Martian winds, perhaps occasionally reaching 100-mile-an-hour velocities, could easily move this material, and craters would quickly be filled in and lost.

PROFESSOR Bradford A. Smith, Director of the planet-photographing observatory at New Mexico State University (page 168), offers a plausible explanation for the evanescent lines called "canals."

"Now that we have seen the Mariner pictures, the idea of canals should cease to exist. Some of the classical lines are discovered to be chains of dark-floored craters, some are irregular alignments of dark patches. Most of the rest will be figments—illusory and misinterpreted."

Two scientists at the University of Massachusetts, Dr. William T. Plummer and Robert K. Carson, report that the reflection spectrum of Mars resembles that of an uncommon substance known as carbon suboxide, a foul-smelling compound with the formula C_3O_2. When ultraviolet radiation hits this substance, it forms polymers, or molecular chains, with an orange or reddish-brown color. Carbon suboxide, rather than iron minerals, could account for the color of Mars, the two scientists believe.

This report has aroused substantial controversy. However, a comment by Dr. Leighton becomes quite pertinent: "If you're planning to go to Mars, better take a clothespin for your nose. They tell me it smells like fermented sweat socks."

Asteroids

Time: Midsummer 1972. The Pioneer F spacecraft, which left Earth 140 days ago, has long since crossed the orbit of Mars. It is 125,000,000 miles from Earth, headed for Jupiter, largest of the planets. To us, as imaginary passengers, it appears as a mere point of light; its banded disk will not be clearly visible for many weeks.

Now we are running the gantlet of the asteroid belt. The moment of truth has arrived. Will we survive passage through the minor planets and millions of smaller objects that swirl in this celestial grinding machine between Mars and Jupiter? It will take us some 200 days to cross the 150,000,000-mile-wide belt.

A particle even the size of a pea moving at 12 miles a second could completely disable our spacecraft. What are the odds? Fortunately very low, according to the experts planning the Pioneer flights.

We scan the blackness, hoping to see one of the minor planets, but in vain. Calculations are that while traversing the belt we might be within viewing distance of no more than one object as large as 450 feet in diameter. Perhaps 20 bodies as large as 130 feet across will come close enough to be detected, but only if we are looking in the right direction at the right time.

On New Year's Day in 1801 an Italian, Giuseppe Piazzi, discovered a starlike body beyond the orbit of Mars, where a "missing planet" was supposed to be located. Named Ceres, it proved to be the first and largest of a group of objects called asteroids that circle the sun in a wide belt between the orbits of Mars and Jupiter.

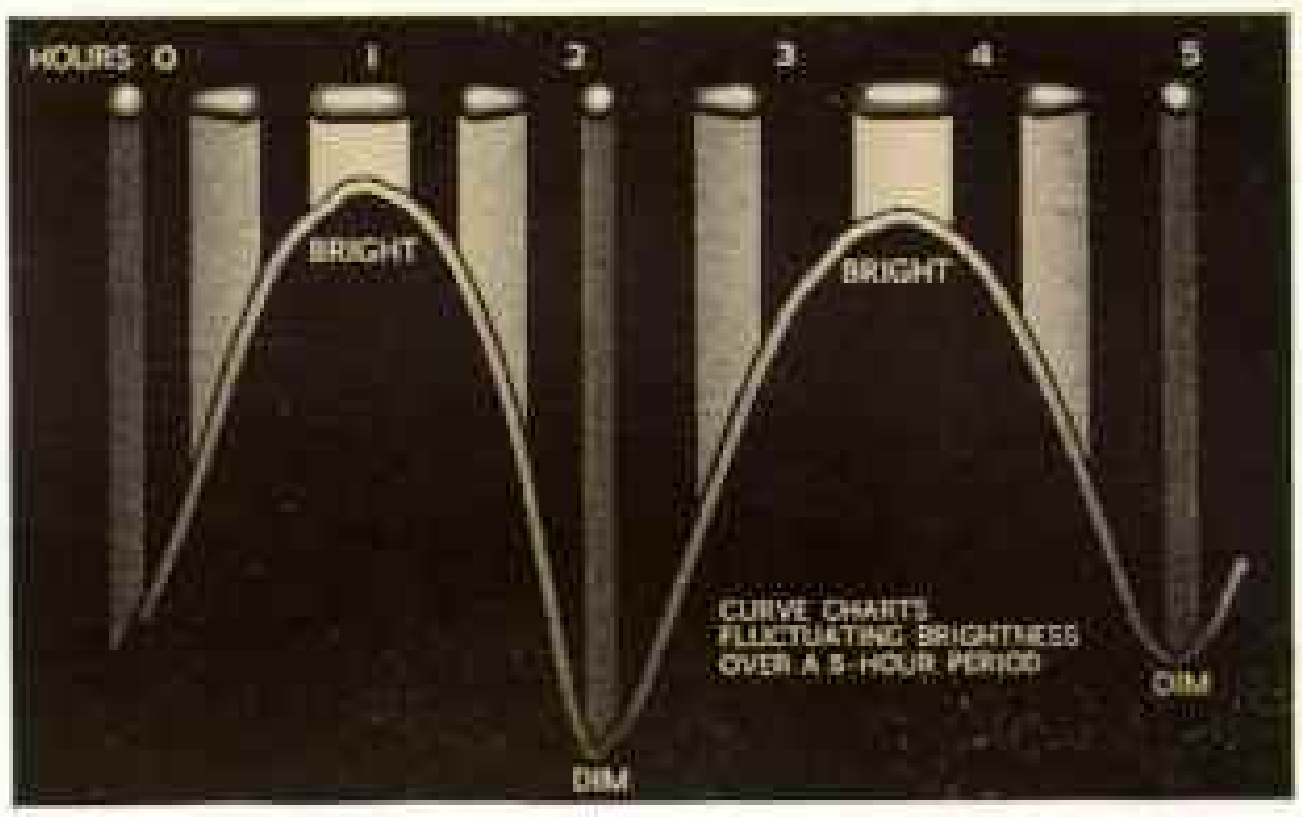
Ceres, an airless, lifeless ball 480 miles in diameter, is large enough to be termed a miniature planet, and so are a few others, such as Pallas, Juno, and Vesta. But the great majority are irregular chunks no more than a mile across, and countless numbers range down to the size of dust grains. Perhaps 100,000 could be detected with the 200-inch Hale telescope on Palomar Mountain, California. Only one, Vesta (page 195), is ever visible to the naked eye. If all were swept up together, they would be less than a thousandth the mass of Earth.

Nearly two thousand asteroids have been observed enough to be given numbers and names. Many bear mythological names. Others honor astronomers (Kepler and Hale), flowers

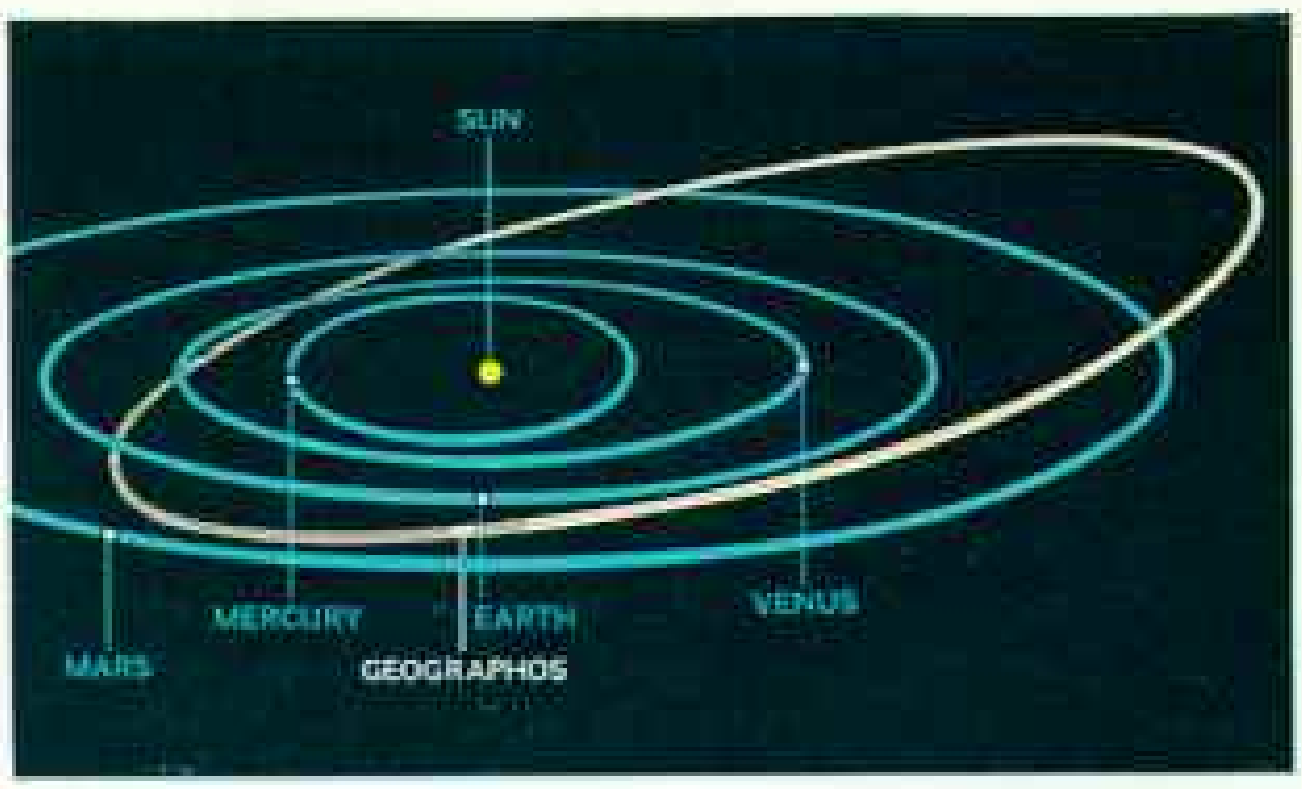
PAINTING BY DAVID MILTON (ABOVE); DIAGRAMS BY GEOGRAPHIC ART DIVISION © N.G.S.

Celestial cigar, the asteroid Geographos makes its 1969 sweep to within 5.6 million miles of a tiny blue Earth, background. Recent recalculation by asteroid expert Dr. Tom Gehrels measures Geographos as 2½ miles long by half a mile wide. Discovered in the National Geographic-sponsored Palomar Observatory Sky Survey of 1949-58, the asteroid was named for your Society.

ASTEROIDS



Cavorting in space, Geographos rhythmically brightens and dims, defining a predictable light curve (upper diagram). This leads astronomers to deduce that the asteroid is an oblong body that constantly tumbles, reflecting brightest when broadside to Earth. Diagram of the 1969 sweep past Earth (lower) shows how the asteroid's orbit, tilted 13°, slices the ecliptic.



EXTACHROME (ABOVE) BY LUNAR AND PLANETARY LABORATORY, UNIVERSITY OF ARIZONA; PAINTING BY LUDEK PESEK © N.G.S.

Tumultuous cloud currents sweep Jupiter and eddy around the Great Red Spot in a revealing 1966 photograph. Bulging equator reflects the planet's rapid rotation, once every 9 hours and 55 minutes.

Jupiter's turbulent atmospheric bands, composed largely of frozen and liquid ammonia compounds, kaleidoscopically change shapes and colors; they swirl above a stormy interior of mounting pressure, perhaps crackling with lightning. Deep inside, at a level no instrument can detect from Earth, the planet's substance is crushed into a solid core of hydrogen.

Baring its woundlike brand, a crescent Jupiter overwhelms its snowy satellite Amalthea, foreground, only 70,000 miles away. The Great Red Spot, weirdly vivid in this portrayal, puzzlingly waxes and wanes, all the while drifting across the southern hemisphere.

Monstrous Jupiter, a quarter-million miles around, has one and a half times the volume of all the other planets combined. Its satellite Ganymede equals Mercury in size.

Jupiter seems in some ways to be less a planet than a star, or rather, a potential star whose nuclear furnace never lighted. Like the sun and other stars, it gives off more energy than it receives, while around it swirl a dozen satellites—its own planetary system.

Jupiter's atmosphere contains ammonia and methane, gases that wrapped the primordial Earth billions of years ago, when life began. Thus Jupiter could offer a natural laboratory for viewing chemical reactions that might launch life.

(Crocus and Begonia), cities (Yalta and Chicago), and women (Sheba, Dulcinea, and Marlene—yes, Marlene Dietrich).

An easy assumption would be that the asteroids are the debris of a planet that exploded. But the reverse may well be true.

Dr. Tom Gehrels, a long-time student of these objects at the Lunar and Planetary Laboratory of the University of Arizona, regards them as building stones of the solar system. "The asteroids are probably part of the original record of the nebula, or dust cloud, from which we believe the sun and planets condensed some five billion years ago," he says. "Asteroids are dust that has been compacted—accretion products—or fragments from collisions of such bodies."

While most of these small bodies stay close to the asteroid belt, a few have eccentric orbits that invade the inner solar system, and some fly so close to our own planet that they might be called "Earth-grazers."

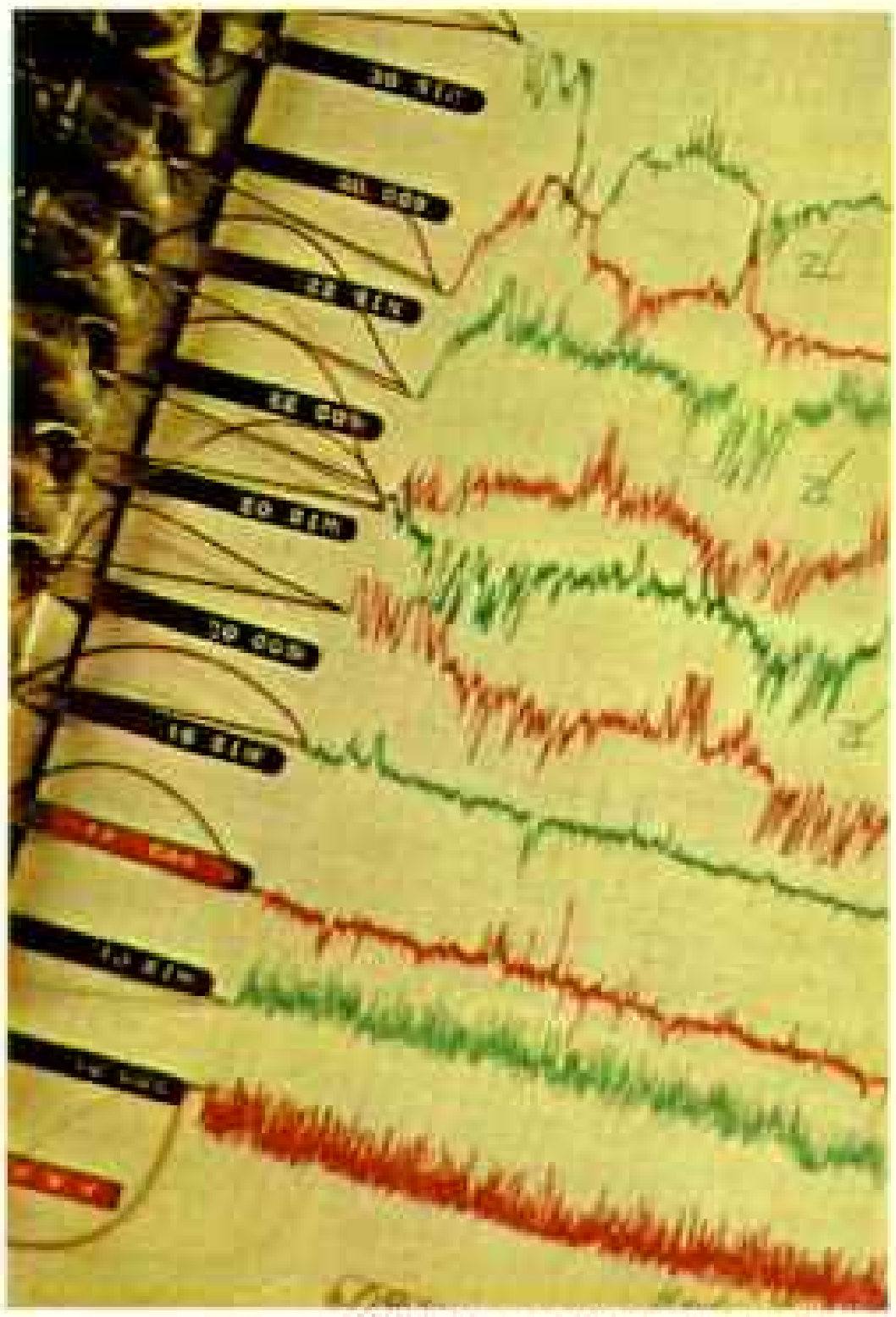
Icarus, for example, swings out 183 million miles from the sun, but every 409 days, at perihelion, it comes within 17 million miles of the sun's raging heat. At such close encounter its half-mile-thick bulk may become red hot. Appropriately, it bears the name of the lad in Greek mythology who came to grief when he tried to fly with wax-bound wings and approached too close to the sun.

In June 1968, Icarus missed Earth by only 4,000,000 miles. Another space rock, Hermes, only 1,000 feet across, came within half a million miles of us in 1937, barely twice the distance to the moon (painting, page 155).

And just a year ago this month, astronomers took aim at a most unusual Earth-grazer, Geographos, which came within 5.6 million miles of their telescopes. Discovered in 1951 during the National Geographic Society-Palomar Observatory Sky Survey, this planetoid was named in honor of the Society. Its catalog number is 1620, which leads one astronomer to refer to it as "Plymouth Rock."

When Geographos's light was measured with a photometer, it showed a peculiar rhythmic fluctuation in brightness. At periodic intervals, it seemed to be six times as bright as at other times. No other asteroid shows such extreme variation.

From this and other light measurements, Dr. Gehrels has recently determined that Geographos is a cigar-shaped body about 2½ miles long and half a mile wide. It tumbles end over end, so that part of the time we see reflection from its long side and part of the time only from an end. This explains the wide fluctuation in brightness (page 175).



The voice of Jupiter: Spasmodically and cryptically, restless Jupiter bursts forth with powerful radio noises—emissions once thought peculiar to the stars and galaxies. Apparently associated with the planet's magnetic field, the radiation is affected by the position of the satellite Io.

Here at a University of Texas radio telescope near Marfa, Jupiter symbols mark a Jovian radio storm. Other squiggles are noise and interference.

HUGE CRATERS on the moon testify to what happens when the orbits of these flying mountains bring them into collision with other celestial bodies. Scientists generally accept the idea that some meteoroids are pieces from the asteroid belt, although others are the debris of comets.

Earth's atmosphere burns up the small meteoroids. And no one need worry about a large one striking Earth. Calculations suggest that it happens no more than once in 50,000 years in North America, even for a rock only 100 feet across, the size of the one that blasted out Arizona's Meteor Crater.

KODACHROME BY EMORY KRISTOF © N.G.S.

Spindly envoy to the king of planets, a Pioneer spacecraft model spreads wiry limbs before a photograph of its goal. Two unmanned Pioneers, built by TRW Inc., of Los Angeles, may embark in 1972 and 1973 on 600- to 900-day voyages to within 80,000 miles of Jupiter. Their instruments, powered by miniature radio-isotope generators on the outthrust struts, will study characteristics of the planet, and relay images back to Earth.

Jupiter

Time: Between December 7, 1973, and March 17, 1974.

Safely through the asteroid belt, our buglike Pioneer F spacecraft approaches Jupiter, giant of the solar system. Earth, now a bluish point, lies more than 500 million miles behind. The sun, almost as far, shows a disk about a fifth its normal size.

Solar cells for energy would be of marginal use to us now: We receive only one twenty-seventh the solar radiation Earth receives. So, on two long booms stretching beyond our big antenna dish, we have generators using radioactive materials to produce power to operate our electronic equipment (above). Messages to Earth, carrying pictures and information on magnetic fields, ionized particles, temperature, and planet chemistry, now take 47 minutes to travel that great distance one way.

There seems no end to the enormous bulk below us. Although we are 80,000 miles away, this gargantuan hydrogen ball is so huge—enough to swallow up 1,300 Earths—that we cannot see an entire hemisphere. Only when we were farther out could we view it as a sphere and see how it is flattened at the poles because of its high rotation rate.

Irregular bands of alternate yellow and bluish or brownish gray cover the surface—and yet perhaps one should not say surface, for all we see are clouds. No man knows at what depth, perhaps thousands of miles down, Jupiter's enormous pressures have turned its hydrogen to a metallic solid.

Two striking phenomena catch the eye:

The Great Red Spot, one of the most curious objects of the entire solar system, stands out like a blemish on the southern hemisphere. Its elliptical area, seeming to "float" among the clouds, is larger than Earth's surface (pages 148, 176, and 177). The most likely theory yet proposed suggests that it is a kind of eddy in the atmosphere caused by a depression or a high spot far below.

A crisp black circle marks the shadow of Io, one of Jupiter's 12 moons. Inexplicably, this shadow has been known to emit more radiant heat than the cloud layer around it.

Io itself has been easily visible to us as we approached, and so have the other three satellites Galileo first saw: Ganymede, larger than Mercury; Callisto, larger than Earth's one moon; and Europa, a fifth the size of Earth. Eight additional—and smaller—satellites give Jupiter a family larger than the sun's.

We know all too little about Jupiter; it is a series of perplexing questions and riddles. Yet what scientists do know and what they surmise make it in many ways the most exciting, the most provocative, body in the solar system.

"We regard this vast ball, so different from any of the rocky terrestrial planets, as a 'deep-freeze sample' of the original cloud of dust and gas from which the solar system condensed," says Dr. Tobias Owen, of the Illinois Institute of Technology Research Institute. Cold outer temperatures and high gravitational force (two and a third times that of Earth) have most likely prevented the primordial gases from escaping.

"Moreover," says Dr. Owen, "Jupiter may

be considered almost a star. If it were only a little more massive, gravitational contraction would release so much energy that it would turn into a nuclear furnace, like the sun or any other star, and become incandescent."

Though Jupiter is no more than a "near-star," something most unusual goes on within its deep, turbulent atmosphere: The giant planet gives off substantially more energy than it receives from the sun—two to three times as much. No one knows why, although gravitational contraction has been suggested as a cause. Scientists suspect that temperatures rise steadily from −200° F. at the cloud tops to as much as 20,000° at the core.

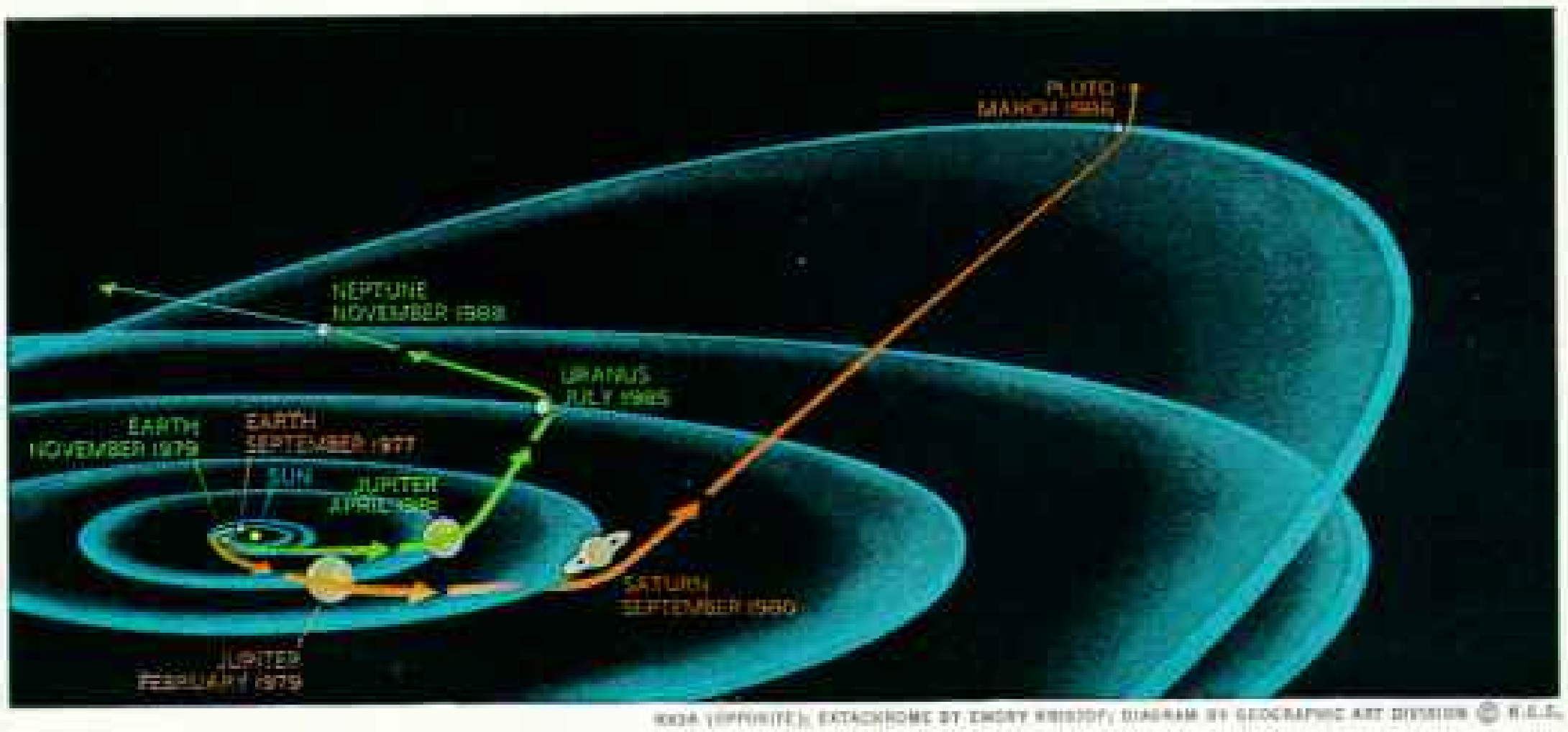
And through some mechanism not clearly understood, the Jovian planet emits random bursts of intense radio energy at long wavelengths (page 178). It is, as radio astronomers perceive it, the most powerful radio object in the sky except for the sun. Apparently these emissions are tied to the planet's powerful magnetic field and radiation belts (regions of charged particles above the atmosphere), something no other planet except Earth is known to have. To add to the puzzle, the radiocasts are affected by the position of Io, second closest of Jupiter's moons.

Astronomers analyzing Jupiter's upper atmosphere with spectrometers conclude that it consists largely of hydrogen and helium, a finding that explains why the planet's density is only a fourth that of Earth's.

Pioneer F—and Pioneer G, scheduled to go to Jupiter 13 months later—will seek to establish the all-important proportions of hydrogen and helium. These two gases, the lightest and simplest of all chemical elements, make up 99 percent of the universe, and their ratio will help indicate whether Jupiter truly is a living fossil of the solar system.

Methane and ammonia, simple compounds formed when hydrogen joins with carbon and nitrogen respectively, have also been detected. What lies deeper can only be conjectured; water has often been suggested.

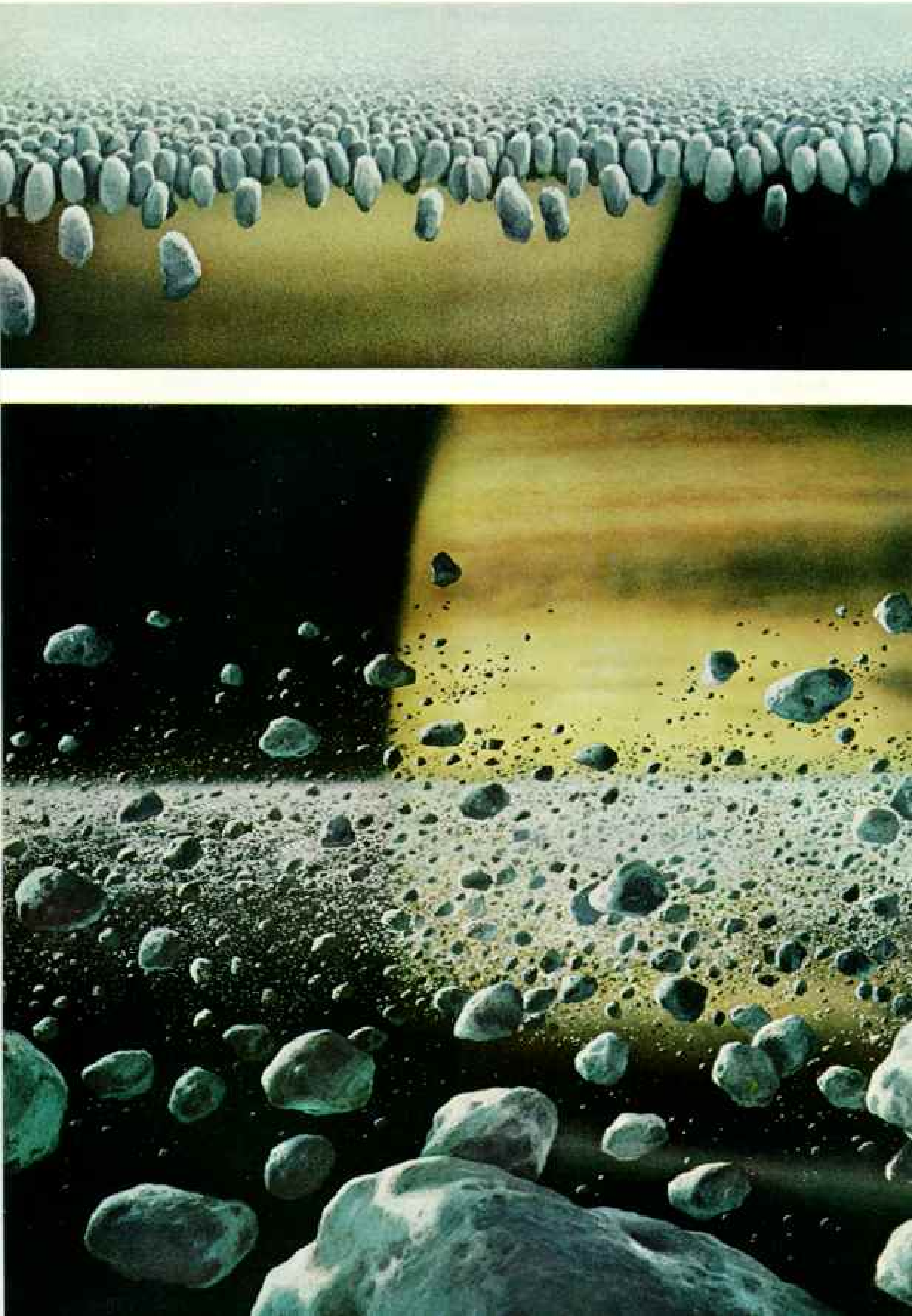
Floating high in the Jovian atmosphere are the enormous bands of pastel-colored clouds, thought to be composed of frozen and liquid ammonia compounds. They rotate at



NASA (UPPER); EXTACHROME BY EMORY KRISTOF; DIAGRAM BY GEOGRAPHIC ART DIVISION © N.G.S.

"Grand Tours": Two unmanned spacecraft may explore the remote outer planets in the late 1980's. Gravitational pulls will bend their courses and reduce flight times from decades to only 8½ years to Pluto, and 9 years to Neptune on a launch 26 months later.

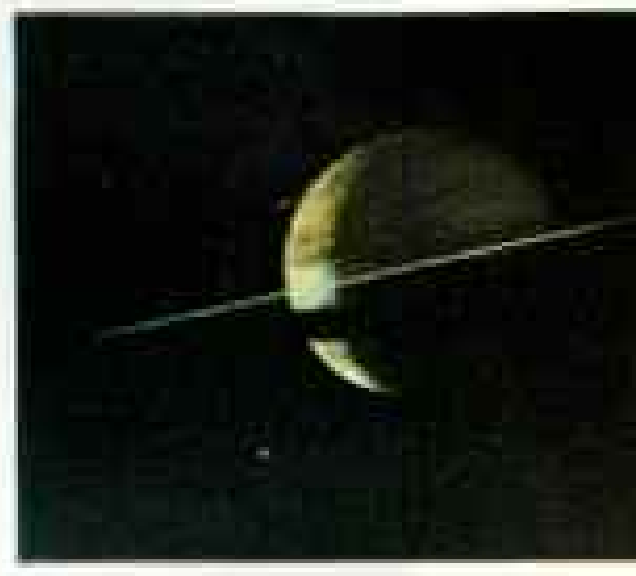
Might-be Martians, bacteria magnified 17,000 times, drift in a culture at NASA's Ames Research Center in Mountain View, California. A common soil microbe, rugged *Aerobacter aerogenes* thrives in a simulated Martian atmosphere of carbon dioxide and daily freezings and thawings, encouraging a belief that life could survive on other planets—provided they have water. Exploring the beginnings of life itself, Ames chemist Dr. Cyril Ponnamperuma (inset) bombards a flask of primordial planetary gases—ammonia, methane, and water vapor—with ultraviolet radiation. Result: He synthesizes complex organic compounds that form the basic building blocks of life.



PAINTINGS BY LOUIS PESEK © NATIONAL GEOGRAPHIC SOCIETY

Twirling like a top in space, Saturn intrigues astronomers with its delicate rings, here seen edge-on as they cast a shadow on the planet (right). Composed of countless minuscule moonlets and stretching outward some 50,000 miles, the rings have a thickness of at most a few thousand feet—and possibly only inches. So filmy are the rings that bright stars behind them sometimes shine through.

At left, Mr. Pesek illustrates two concepts of the rings' structure. Icy cylinders, worn by constantly rolling against each other, wheel around the planet in a thin-ring version (upper). Ice-coated rocks from pea- to piano-size hurtle around a thick-ringed Saturn (lower).



SATURN

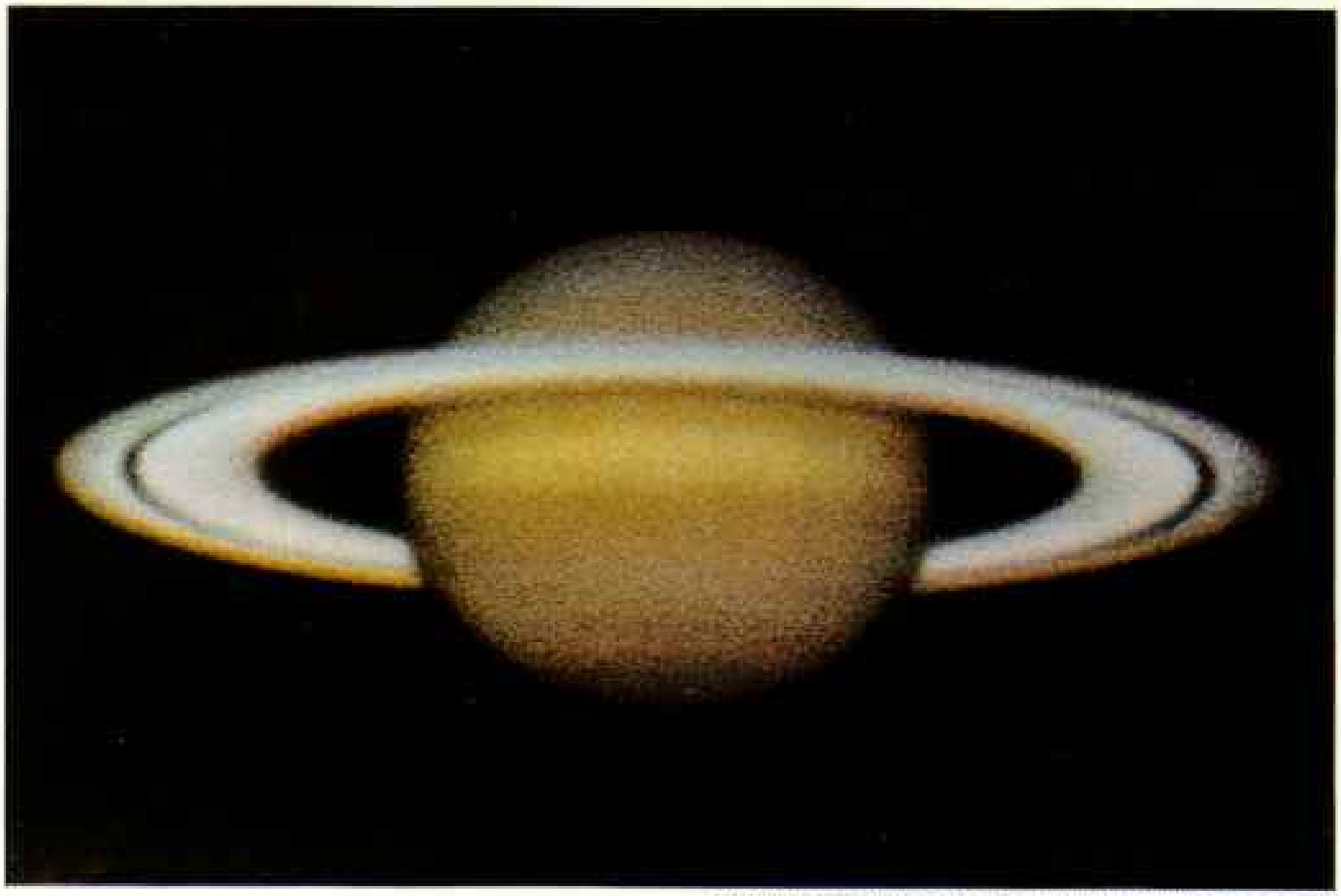
whirlwind speed; although Jupiter has eleven times the diameter of Earth, its rotation rate is more than twice as fast—one complete turn in less than ten hours! No wonder the planet bulges at the equator.

It may surprise those who are Earth-oriented to learn that Jupiter, rather than Earth, may now be the solar system's most hospitable environment for the beginning of life. Scientists concluded years ago that primitive life probably first appeared in an atmosphere of hydrogen, methane, ammonia, and water, such as Earth very likely had some 4½ billion years ago. And that is thought to be the kind of atmosphere Jupiter has today.

A number of intriguing experiments, begun in the laboratory of Dr. Stanley Miller at the University of Chicago as long ago as 1953, support this belief. When a simulated primitive Earth atmosphere of hydrogen, methane, ammonia, and water, similar to Jupiter's present atmosphere, is subjected to an electric discharge (comparable to a bolt of lightning) or ultraviolet radiation (such as that from the sun), something immensely important happens. Complex organic molecules appear, the building blocks of living cells (page 180). These include glycine, alanine, and other of the amino acids from which proteins are formed in living things.

LATE IN THE 1970's, if the present planning of NASA and the Jet Propulsion Laboratory is carried out, two unmanned missions called the "Grand Tours" will set forth on journeys to the outer reaches of the solar system. They will take advantage of an opportunity arising only once every 175 years, when the outer planets line up relatively close together along an arc, like pearls on a string.

The two 1,300-pound robot craft will aim first for Jupiter, whose enormous gravitational effect



DETACHMENT FROM LUNAR AND PLANETARY LABORATORY, UNIVERSITY OF ARIZONA

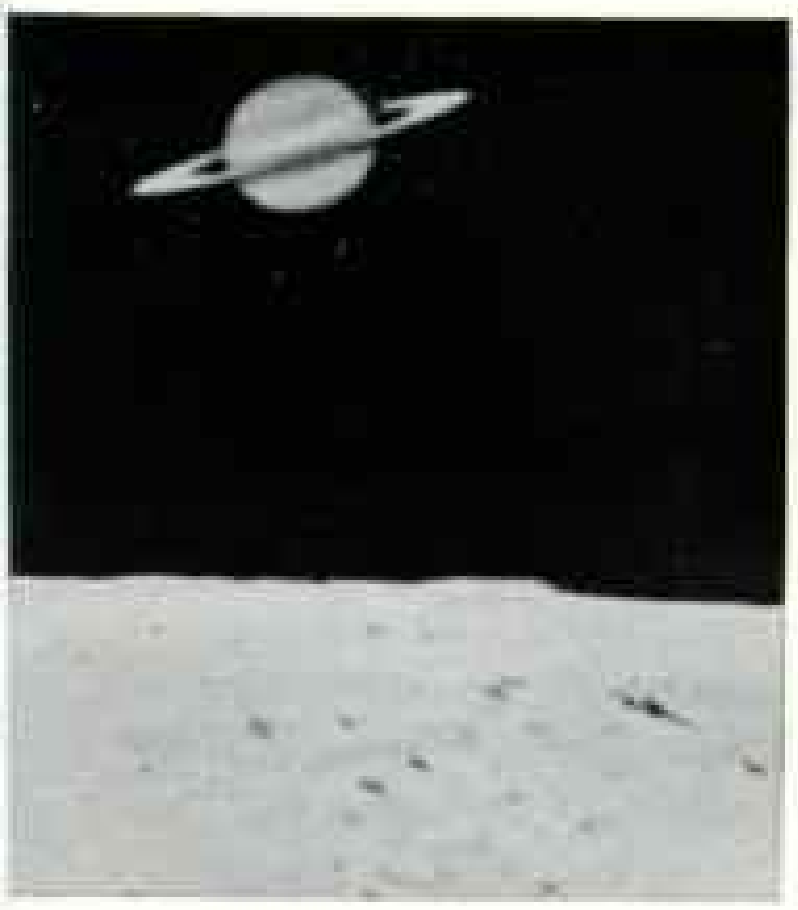
Resplendent with its halo, Saturn glows a characteristic yellow in the twilight nearly 900 million miles from the sun. In this exquisite 1968 photograph, two rings glimmer clearly, separated by a gap called the Cassini Division. Closer in, a filamentous third ring and a very faint fourth (observed in 1969 by the French astronomer Pierre Guérin) defy the camera's eye. Scientists believe the rings may be space matter that never condensed into a satellite.

Like Jupiter, Saturn churns with a violent atmosphere that swirls in bands around its girth. Slowly changing color, the surface on rare occasions erupts with mammoth white spots.

With far less mass, Saturn lacks the strong Jovian gravity needed to squeeze itself into a compact ball. Thus the bloated planet compares in density to an ordinary hardwood; it would float in water.

Swarming with ten satellites, Saturn claims one moon unlike all others known to the solar system: Titan, nearly 3,000 miles across, has an atmosphere.

Saturn rises beyond the rubble-strewn rim of Earth's moon (below, far right to left), in an unusual sequence filmed through a 24-inch telescope in New Mexico. As the moon moves, the planet seems to scoot like a flying saucer across the lunar surface.



will carom them off at greatly increased velocity to the next planet, where the process will be repeated. These might appropriately be called the "By Jove" missions.

One voyage, beginning in 1977, is planned to visit Jupiter, Saturn, and Pluto, making the trip in 8½ years instead of the 40 it would take to go to Pluto alone if this game of celestial billiards were not played. The other Grand Tour, starting in 1979, aims for Jupiter, Uranus, and Neptune (diagram, page 181).

Saturn

Time: September 12, 1980. Since leaving Earth it has taken three years, even with Jupiter's powerful kick, for us to reach Saturn—sixth planet of our system. The sun lies nearly 900 million miles behind us, twice as far as from Jupiter. Its warmth and light are only a hundredth of what we are accustomed to; Saturn travels in eternal twilight. A message to Earth—at the speed of light—now requires nearly an hour and a half.

We are diving under Saturn, staying well clear of its hazardous rings and its ten moons. Our path will then turn up to throw us out of the ecliptic (the plane in which Earth orbits the sun) and toward Pluto, whose orbit is tilted 17° to the ecliptic (pages 152-3, lower).

Some 281,000 miles away, Saturn—the most extravagant sight in the family of the sun—glows with a dull yellowish hue. But the brilliant white of the rings suggests the glitter of countless diamonds.

I know something of what the space traveler will see when he looks down on Saturn. In the company of Dr. Tom Gehrels, I watched this remarkable planet, fascinated, through one of the University of Arizona telescopes. The half tilt of the rings presented a favorable view, and the seeing that winter night was exceptional. Even the faint bands on the planet itself were clearly discernible.

If I felt any disappointment, it was only that this exquisite spectacle, almost a billion miles away, presented the static quality of a carving in ice. Somehow I expected the rings in my eyepiece to whirl like a spinning top.

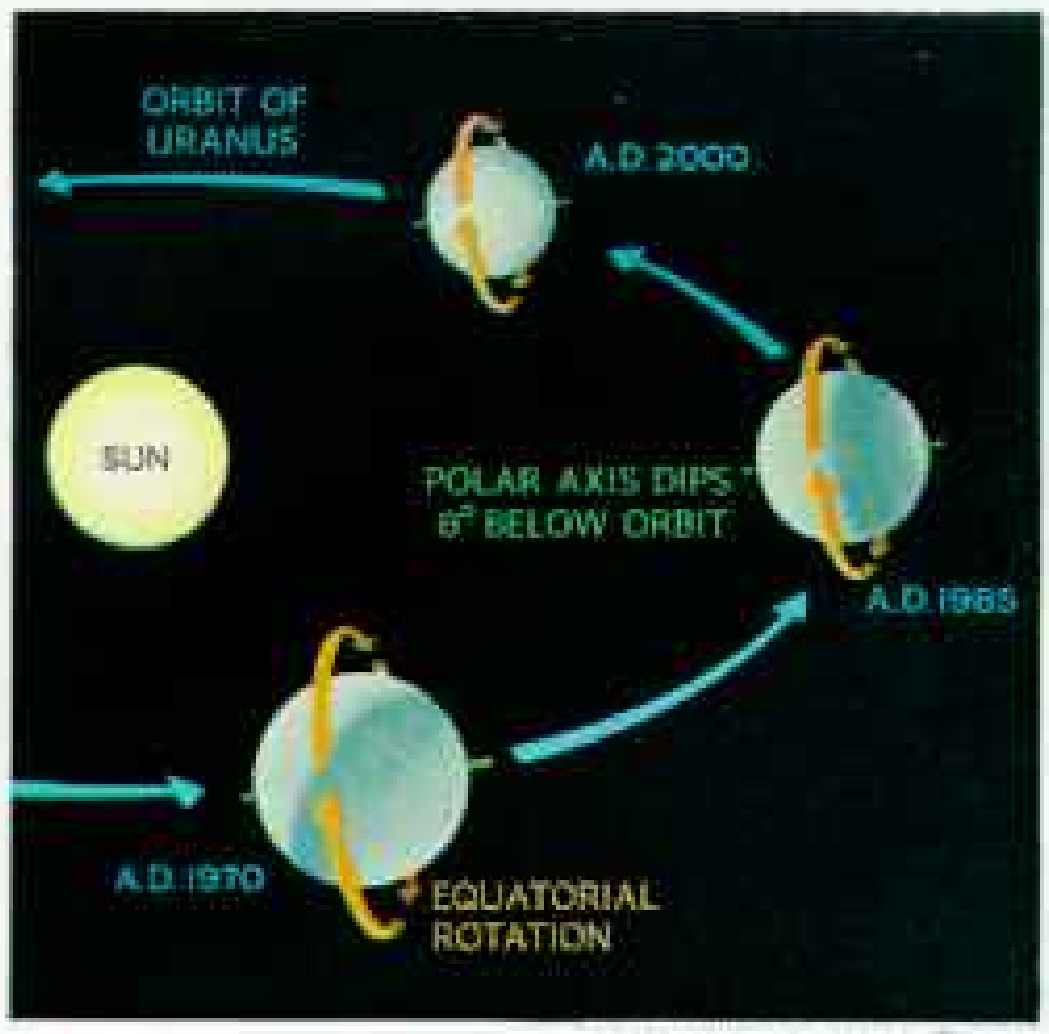
Controversy surrounds the rings. Most specialists, however, would agree that they represent particles that never did accrete into a satellite (or just possibly a satellite that swung too close to Saturn and broke up in its gravitational grip); and that they consist of chunks of water ice, or ice-coated bits of rock, each in its own orbit (paintings, pages 182-3).

Spectral traveler near the limit of man's normal vision, chill Uranus (following pages) roamed its enormous orbit undetected until betrayed by the prying telescope in 1781. Here the planet hulks like a great domed head behind the rock and snow of satellite Umbriel, 150,000 miles distant. Two closer moons, Ariel, center, and fleet Miranda, ply their lower orbits. Some observers have reported atmospheric bands vaguely striping the planet.

PAINTING (FOLLOWING PAGES) BY LUBOS KOZIK © N.G.S.

URANUS

BRADFORD A. SMITH, NEW MEXICO STATE UNIVERSITY OBSERVATORY



GEOGRAPHIC SET DIVISION © N.G.S.

As if it took a tumble, Uranus revolves around the sun with its axis lying only 8° from its orbital plane, instead of more nearly vertical like other planets. Thus, for half its 84-year orbit, one of its poles constantly sees the "midnight sun," while the opposite pole dwells in frigid darkness.

Dead-pan disk of Uranus peers from a high-resolution photograph taken last March at an altitude of 80,000 feet by Stratoscope II, a balloon-

PRINCETON UNIVERSITY

borne observatory launched at Palestine, Texas. Stratoscope scientists, astronomers at Princeton University, hope that computerized sharpening of such images will establish whether Uranus has faint surface markings.

Together with neighboring Jupiter, Saturn, and Neptune, Uranus belongs to a subfamily in the solar system called the Jovian planets. All rotate furiously, wear dense atmospheres, and consist of far lighter elements than the earthlike, or terrestrial, planets. Despite the bitter cold of its outer atmosphere, Jupiter at least may harbor life. Somewhere in its depths, where temperatures rise, life zones may support organisms.

Collisions among particles whose orbits crossed because they were elliptical or tilted have gradually forced all the particles into circular orbits in approximately the same flat plane, a plane thinner than a sheet of paper in proportion to its width.

Dr. Gerard Kuiper believes that the particles can be no more than about ten inches thick, and that the rings are probably not much thicker.

Bradford Smith and others contend that the rings are more likely half a mile thick, because they can still be photographed when they are edge-on to Earth, every 15 years. An analysis of light measurements made by Professor Smith may settle the matter by the end of this year. In any case, the rings are not completely opaque; stars have been seen through them.

Two bright rings are clearly visible, separated by the Cassini Division. A third, the Crape Ring, a dusky band, lies closer in. And inside these, reaching almost to Saturn, is a fourth ring, extremely faint, observed last year by Pierre Guérin of France.

Second planet in size, Saturn is another gas giant with a composition much like Jupiter's. If you could get it into a tub of water, it would float, for the density of Saturn is only 7/10 that of water.

Uranus

Time: July 28, 1985, six years since leaving Earth and four years from Jupiter. We are moving into the bitter cold and unrelieved darkness of the outer solar system, crossing the orbits of far-ranging comets. Uranus lies only 15,500 miles below, a pale greenish orb with faint markings. Five moons make up its retinue.

Earth glimmers nearly two billion miles away, a distance requiring 2 hours and 45 minutes for our radio signals to span.

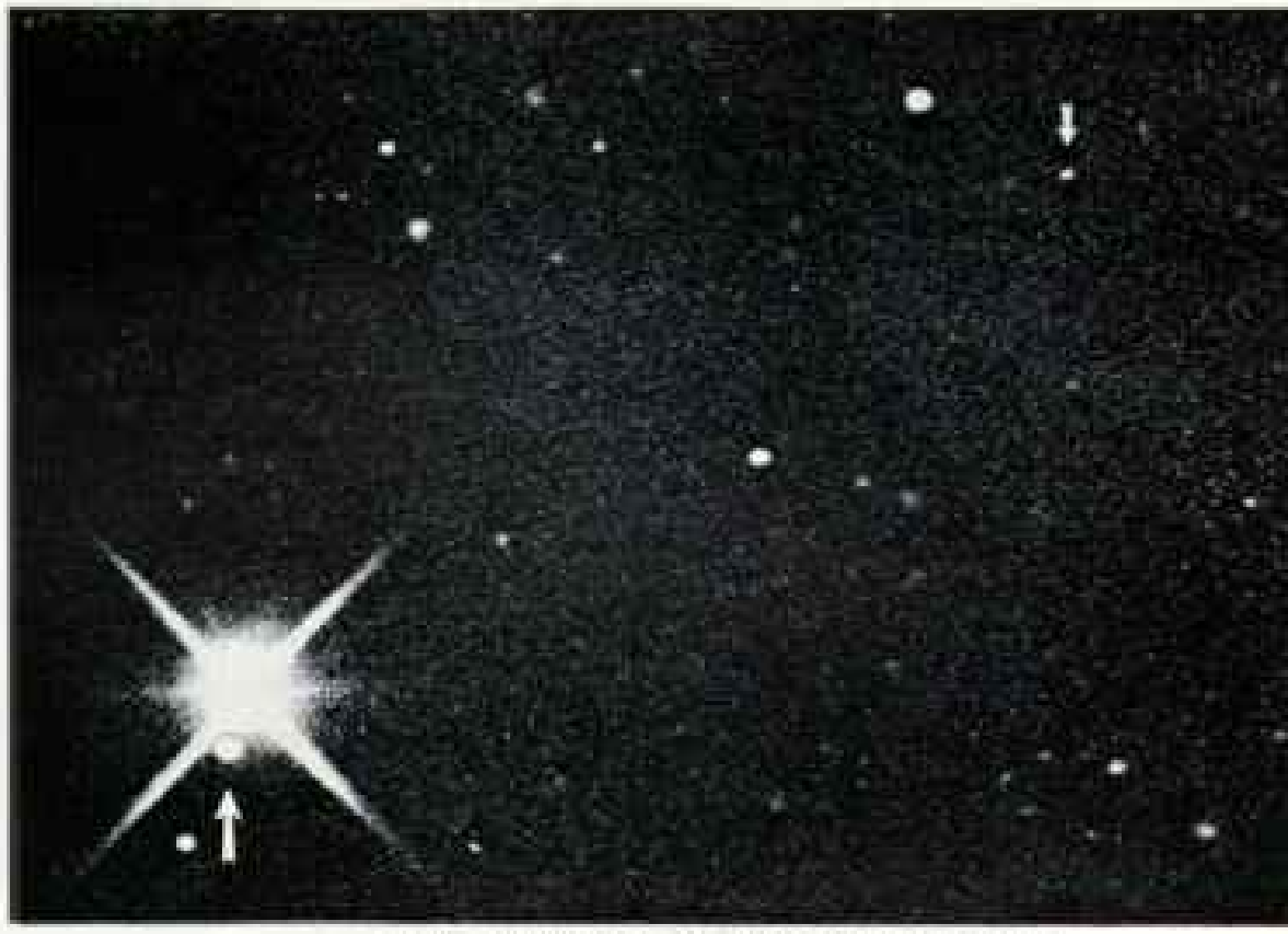
"From here on out," says Dr. Bruce Murray, "we know so little about the planets that we can hardly ask questions."

Even with the best telescopes, cameras rarely if ever record true surface features on Uranus. Its diameter and rotation period are imperfectly known, and its surface markings and atmosphere are still speculative.

Quite unlike its neighbors, Uranus lies on its side, so that at intervals in its orbit its poles point almost directly toward the sun (diagram, above). If you watched from one of the poles, you would see the sun for 42 years, and then live in darkness for another 42.

NEPTUNE

Neptune sparkles like a star in a 20-minute exposure, distorted by the telescope. Arrows mark the planet's moons: little Nereid, at upper right, and Triton, seemingly engulfed. Because of Triton's nearness to Neptune and its hugeness—larger than Earth's moon—Dr. Thomas McCord of MIT predicts that in 10 to 100 million years a decaying orbit will drop it into the planet's atmosphere.



YERKES OBSERVATORY, PHOTOGRAPHED BY DR. GERARD P. KUIPER

Like cotton candy, Neptune floats above the stark reaches of its satellite Triton, 200,000 miles away. As depicted by artist Pesek, the planet wears faint atmospheric bands—features suspected by observers but never actually photographed.

PAINTING BY LUDEK PESEK © N.G.S.

Neptune

Time: November 28, 1988. We see Neptune dead ahead, a bluish-green sphere whose features have never been photographed from Earth. Farthest out of the giant planets, this twin of Uranus now moves nearly three billion miles from the sun. So intense is the cold that our spacecraft would drop to 370° below zero F., except for the heat from our radio-isotope thermal generators.

Radio time to Earth: four hours, six minutes. The data our instruments are now recording, and the pictures being sent to Earth, will add immeasurably to our understanding of Neptune and its moons, for our knowledge is meager indeed.

Both Uranus and Neptune have densities greater than Jupiter and Saturn. This fact suggests that the two outer planets are not as rich in hydrogen and helium, but must contain a higher proportion of water and ammonia ices, as do comets.

Pluto

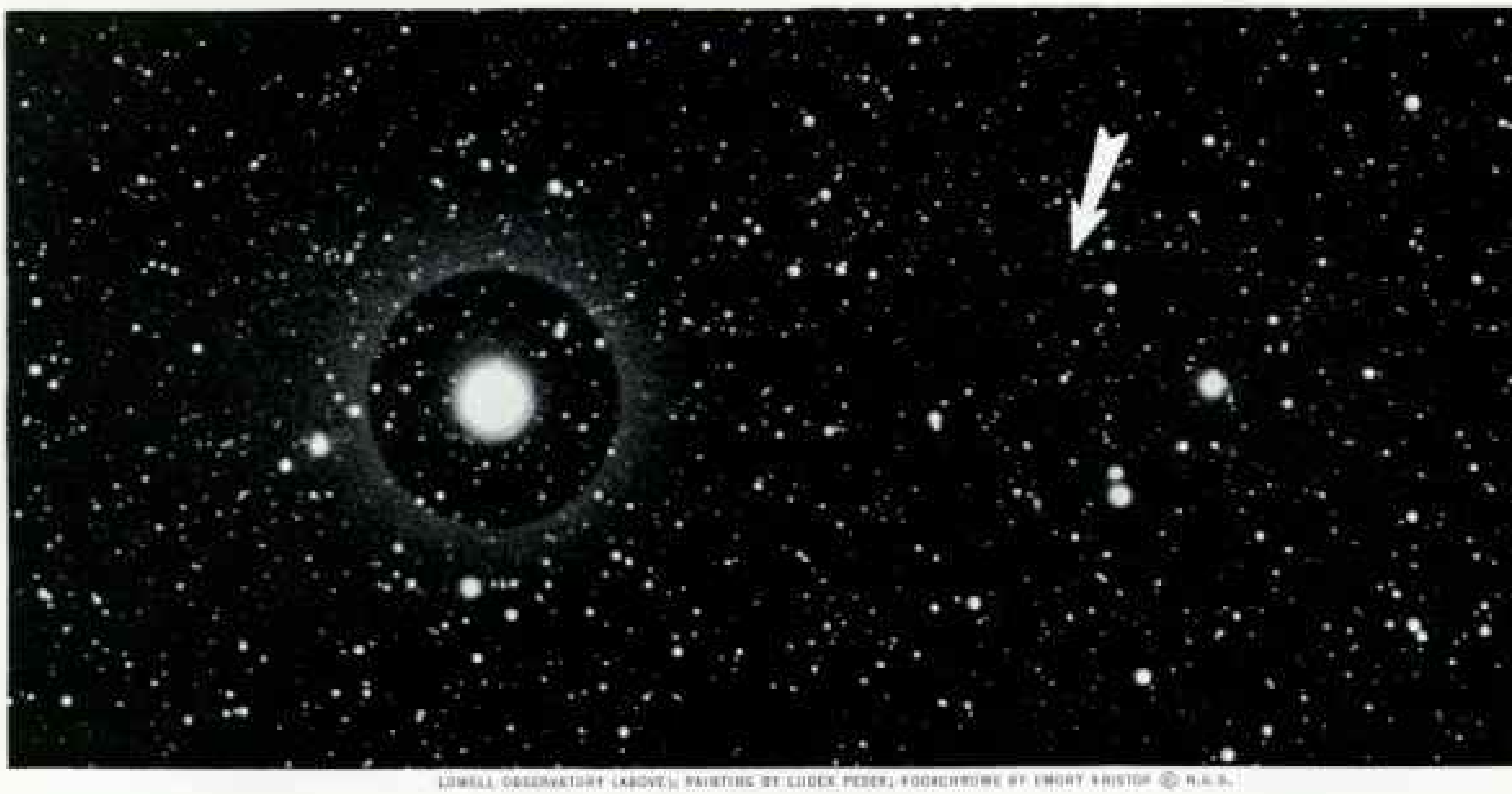
In the 1840's, a Frenchman and an Englishman, working separately, concluded that the gravitational tug of an unknown planet was forcing Uranus to wander from its predicted orbit. The location where the missing planet should be was calculated, and Neptune was found within an hour's search.

But Neptune's pull seemingly did not fully account for the observed wanderings of Uranus. Two Americans, Percival Lowell and W. H. Pickering, insisted that still another planet would be found, and predicted its path around the sun.

In 1929, Clyde W. Tombaugh, a young astronomer at the Lowell Observatory in Flagstaff, Arizona, undertook to look for "Planet X." I well remember the excitement stirred by his discovery of Pluto in 1930. So I felt more than ordinary pleasure a few months ago when I talked to Professor Tombaugh, now at New Mexico State University, and heard his own account of the search.

Tombaugh's technique was to make two photographs of a section of the sky a few nights apart, then compare the images. He showed me one of his glass-plate negatives that had recorded a million stars in an area of 14 by 17 inches. It looked as if it had been spattered with soot.

Under a viewing device known as a blink comparator, he examined first one plate, then the other, in rapid succession, studying



LOWELL OBSERVATORY (ABOVE); PAINTING BY LUDEK PESEK; FOREGROUND BY EMORY KRISTOF © N.G.S.

Elusively roaming the solar system's frozen frontiers, Pluto evaded discovery until 1930. Then, in one of astronomy's great triumphs, it fell captive to the patient eye of Clyde W. Tombaugh (left), here standing beside a 24-inch planetary telescope of New Mexico State University at Las Cruces.

Tombaugh's original photographic plate (above), exposed for an hour, preserves man's first glimpse of Pluto, arrow. Bright body is Delta Geminorum, the only star on the plate visible to the naked eye.

Arid, frigid, and dark, Pluto numbs the mind with its remoteness and hostility. Icy hummocks and a sprawling crater (below) glimmer in wan light of a tiny sun (bright star) nearly four billion miles away.

PLUTO

Steppingstone to the planets: A space station, left, orbits 280 miles above Earth, in a scene combining a number of actions that normally would occur over several days. Planned for the late 1970's, the station will provide a laboratory for studying Earth and the planets and help reveal the demands of sustained space travel on men and equipment.

Tall as a four-story house, the station houses a crew of 12 for shifts as long as six months. Men on the station's lower level control a mechanical arm that unloads a supply module from a streamlined 200-foot-long space shuttle parked alongside, right. The module will dock at a port beneath the winglike solar panel that supplies the station's power.

Other crew members exercise, dine in the wardroom, and perform chores in the weightlessness of zero gravity. Beneath an outthrust radio antenna, a technican replaces a data package in an astronomy module, attached to the station for servicing. Released with solar panels outstretched, the unmanned observatory will study the heavens free of the

PAINTING © NATIONAL GEOGRAPHIC SOCIETY

distortions of Earth's atmosphere.

After delivering its load, the space shuttle will descend to land on a conventional runway. Launched from Cape Kennedy, another shuttle separates from a re-usable booster that carried it into space. To include the maneuver in this panorama, artist Meltzer portrays it at nearly the altitude of the station. Actually the booster will separate at only 47 miles up.

one small area at a time. If any object had moved against the star background in that interval of several nights, it would seem to jump.

Asteroids and spurious images complicated this tedious work. But on February 18, 1930, after seven months' painstaking inspection of some six million star images, Professor Tombaugh found his quarry—a yellowish body with a magnitude of about 15, only 1/4000 as bright as the faintest star you can see with the naked eye. It was named Pluto, and the first two letters of the name, which also are Percival Lowell's initials, became its symbol.

The outermost planet is so small and so remote that it is exceedingly difficult to measure accurately. Thus we know almost nothing about it, except that it orbits the sun in 247 earth years, rotates in 6.4 days (known from fluctuation of its light), and appears to be no larger than Mars. It is thought to be solid and not made of gases. Its eccentric orbit brings it inside Neptune's orbit near perihelion; in fact, it comes closer to the sun than Neptune ever does. For this and other reasons, some astronomers think Pluto is actually an escaped satellite of Neptune.

Following his discovery, Tombaugh continued searching for other planets. Fourteen years of work on 338 pairs of plates with 90 million star images left him exhausted but convinced: "If anyone wants to go out and look for more planets, O.K., but he'd better look up what is involved," declares the man who found Pluto.

Ironically, the calculations of Uranus's deviations on which Lowell's prediction was based have since been shown to be in error. So the discovery of the ninth planet, although the result of the most tedious systematic searching, was in reality a happy accident.

ON MARCH 9, 1986, we encounter Pluto on our Grand Tour. At that time the little planet, probably a snow-covered rock, is thirty times as far from the sun as is Earth, and the solar energy falling on each square mile is a thousandth of that for Earth.

Our long voyage to the planets is ended. The Grand Tour spacecraft moves on to an endless wandering beyond the solar system and into the mazes of the Milky Way. We have traveled farther than any man before us, and have seen such wonders as no eye has ever beheld.

With Immanuel Kant, the 18th-century philosopher, we may say: "I have . . . ventured on a dangerous journey, and I already behold the foothills of new lands. Those who have the courage to continue the search will set foot upon them. . . ." THE END

Exploring the Heavens With the Society's New Map

ACROSS THE SPANGLED CHASM of space, from as far away as the most distant glimmer the eye can see, the National Geographic's map **The Heavens** brings the magnitude of the celestial canopy as close as the observer's backyard.

The Society's revised sky map, distributed with this issue of the magazine,* appears as the world's attention turns again to the timeless panorama of the heavens—drawn there by new adventures in space.

Your Society first published a sky chart 51 years ago, in the pages of the NATIONAL GEOGRAPHIC MAGAZINE, and distributed the first wall map of the heavens as a special supplement in 1957. To meet continuing demand, the map had to be reprinted twice.

Because of soaring interest in space, and because the Society's membership has grown greatly, the map has been revised for a second distribution with the magazine. The original version went to 2,200,000 member-families; the new one will reach 6,800,000.

Charts Depict the Changing Show

The two "hemispheres" of the map show the skies as they appear from the North and South Poles of Earth. Observers in lower latitudes do not see all the stars in one of these hemispheres at any one time, of course, or even identical celestial arrangements at the same hour week after week.

Around the hemispheres, the names of the months indicate when the stars in each segment of sky are brought into prominence by Earth's annual journey around the sun. Our planet's daily rotation on its axis also changes the heavenly picture, obscuring some stars in sunlight while others parade past by night. Earth's turning seems to spin the constellations near the poles of the celestial canopy in orbits of their own, while causing stars in lower latitudes to appear to rise and set.

The charts on the reverse side of the map, designed by Dr. Donald H. Menzel, former Director of the Harvard College Observatory (see "Solar Eclipse, Nature's Super Spectacular," page 222), show the positions of the major stars and constellations for viewing in every month, from various latitudes.

Of course no map could display more than a fraction of the hundred billion stars of our galaxy, the Milky Way—or the quadrillions of suns shining in the millions of galaxies visible in powerful telescopes. Of the 6,000 or so stars the unaided eye can see, the map shows 1,971 of the most apparent, especially those that form the 88 constellations.

A strip map depicts the constellations of the zodiac, that band of sky centered on the ecliptic, the plane of Earth's orbit around the sun. Above the zodiac, a panel tells where the planets visible to the eye may be seen during the next three years.

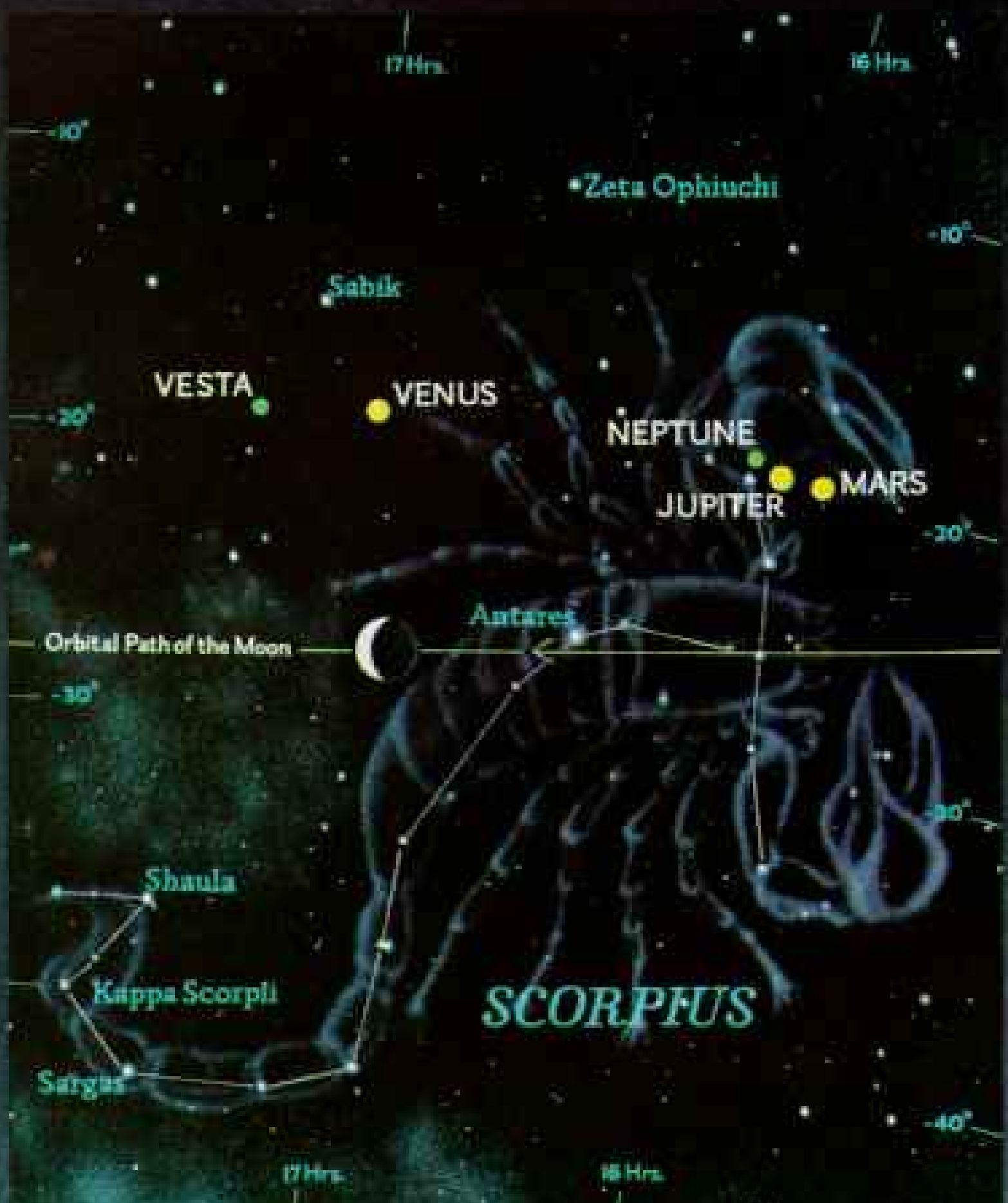
Artist Aided by Photographs From Space

Illustrator Jay Inge, a member of the Society's Cartographic Division, painted the pictures of Earth, Earth's moon, and the planets Mars, Jupiter, and Saturn. He used photographs transmitted from Mariner spacecraft 6 and 7 to show the craters of Mars as we now know them; photographs from the Apollo missions guided him in painting Earth as our planet appears from space.

The stargazer who takes out his map on a clear night to study the heavens joins a fraternity of the mind chartered at the dawn of history. The Chinese, Egyptians, and Babylonians had discerned method in the seeming celestial madness more than 2,000 years before Christ, establishing astronomy as one of man's oldest sciences. Now moon-voyaging astronauts and physicists plotting spacecraft flights to the planets turn again to astronomy to carry out man's boldest explorations.

Except for a select few, space travel remains—in our era—a vicarious adventure, lived through televised images and the crackle of voices across the ethereal chasm. Still, the heavens belong to everyone who gazes at their glittering display and seeks his own answers to the riddles there. The fraternity of stargazers, ancient and honorable order, remains, as ever, open to all.

*Additional copies of the map **The Heavens**, and other wall maps of the Society, may be ordered by mail from Dept. 61, National Geographic Society, Washington, D. C. 20036. Prices include postage and handling: $2.15 on paper, $3.30 on plastic (unfolded).



DRAWING BY JAY L. INGE, CARTOGRAPHIC DIVISION, EXTACHROME BY THOMAS ANTHONY DATED © N.G.S.

Celestial traffic jam: Venus, Mars, Jupiter, Neptune, the moon, and the asteroid Vesta will converge next year in the region of the zodiac called Scorpius (at left in the panel "The Zodiac" at the bottom of the new map **The Heavens**). This drawing shows the wanderers as they will pass in parade shortly before dawn next January 23. At the same time Mercury will glow in the neighboring constellation of Sagittarius. All except Neptune and Vesta will be visible without binoculars.

Sightseeing in space, sky-watchers on a hilltop use **The Heavens** map to identify stars, constellations, and planets. Its reverse side contains charts showing what is visible each month, with detailed instructions for use. While the boy shines a flashlight on the map, the man orients it with the northern horizon.

"**Sunrises and sunsets grow side by side** in these woods," wrote Herman Melville of the changeful maple, ash, and birch forests mantling the Berkshire Hills in western Massachusetts. From an observation tower on the Mohawk Trail, visitors enjoy an October vista that includes 3,491-foot Mount Greylock, highest of the peaks, in the distance. At Tannery Falls (right) picnickers frolic below a 30-foot cascade.

Home to the Enduring Berkshires

By CHARLES McCARRY

Photographs by JONATHAN S. BLAIR

NEAR MY HOUSE in the Berkshire Hills of Massachusetts is a lovely forest place where three brooks meet. Standing by one stream, you can hear the others ringing, as in a choir loft you can hear the separate voices of the singers. These cold waters, in their ancient courses, cut through gray ledges and white boulders, creating by an eddy here and there a stone animal face that wears a forelock of white froth. Finally the brooks come together at the top of a high cliff and fall in twin cascades, like the braids of an Indian enchantress, into a basin of stone—then spill downward in yet another waterfall.

In the spring of my son Caleb's eighth year, he and I stood by these brooks. The blood that flows in Caleb's veins has been Berkshire blood for six generations, and settlement of the hills goes back little further than that. Caleb asked about the rocks, about the glaciers that left them (and the volcanoes before the glaciers), about the Indians who may have worshiped them, about the pioneers who tried to farm among them.

"These rocks," Caleb observed, "are like the mind of the earth. They know everything that ever happened here."

The wild beauty of the Berkshire woods

was new to Caleb's eyes, for he had spent his entire life abroad. He and his three brothers—the first members of our family to be born outside the Berkshires since the 18th century—had just begun to explore the landscape and the history of these ancient hills which lie, blue as a Yankee eye, between the New York State border and the Connecticut River in western Massachusetts (map, page 200).

Poets and writers like William Cullen Bryant, Henry Wadsworth Longfellow, Nathaniel Hawthorne, Herman Melville, and Pulitzer Prize-winning poet Richard Wilbur, who lives on a hilltop above Cummington, have all celebrated the Berkshires' lyric quality.* But I confess that as a boy behind a plow, I would have loved the Berkshire soil better if there had been fewer rocks in it.

The woods were a place to cut the winter's fuel, rather than a place to muse over wild flowers. For many a Berkshire man—still adding to the stone walls around his fields with the rocks turned up by the spring plowing, still fighting the forests that would soon

*See "Literary Landmarks of Massachusetts," by William H. Nicholas, GEOGRAPHIC, March 1950.

KODACHROME BY JONATHAN S. BLAIR © N.G.S.

Through a foot of fresh snow rides Raphael Howes, making the rounds of his sugar maples with a five-barrel sap sled. He and his brother Stebbins set out 800 buckets; by mid-March, warm days and freezing nights have usually brought on the run. For generations the Howes family has managed a dairy farm on the steep slopes near Cummington.

take his mowings back if he neglected them—the hills are anything but lyrical.

"Things don't grow here," my father used to say. "They just manage to cling."

Stebbins Howes, who works his family's farm on the slopes above the village of Swift River, told me, "I guess it's about as pretty here as anywhere. But, by gosh, it keeps you busy to stay ahead of nature."

As he spoke, Stebbins stood knee-deep in the late snow. It was the first day of sugaring—that brief period in early spring when maple sap is collected from tapped trees—and the steam of the evaporator in which the sap is boiled down into syrup (30 to 40 gallons of sap will yield one gallon of syrup) belched from his sugarhouse (page 201).*

I asked Stebbins if sugaring, with all the work it involved, was still worth the effort.

"No more effort than it ever was," he replied. "And there's no sense letting the maple trees just stand there."

The Berkshires are the eroded remains of loftier mountains that may have been standing 460 million years ago. Even in the late 1600's their formidable eastern rampart, rising an average of 2,000 feet, halted settlers. By then, Mahican Indians had come in from the west and established a village in the region they knew as Housatonic, "the place beyond the mountain." (In *The Last of the Mohicans*, James Fenimore Cooper gave the name of this tribe a different spelling which is still preferred by many—but not in the Berkshires.)

Until the early 1700's, the range discouraged the westward expansion of those colonists long settled in the Connecticut River Valley. And another half century passed before they arrived in any sizable numbers.

Yankee Traders Drove a Hard Bargain

A delegation of Massachusetts men met the Mahican leader, Konkapot, at Westfield in 1724 and persuaded him to accept £460, three barrels of cider, and 30 quarts of rum for "all of Housatonic." This tract covered about a fourth of what is now Berkshire County. In similar fashion, these unwarlike and upright Indians lost the rest of their Berkshire land before the end of the century.

The dispossessed Indians are still very much alive for Mrs. Polly Pierce, curator of the Historical Room in the Stockbridge Library. James Fenimore Cooper, she told me, was premature about the disappearance of the Mahicans.

Two years ago, four descendants of the Stockbridge Mahicans visited their tribe's

(Continued on page 204)

*See "Sugar Weather in the Green Mountains," by Stephen Greene, NATIONAL GEOGRAPHIC, April 1954.

"THE LOVELY and the wild, Mingled in harmony on Nature's face." Thus poet William Cullen Bryant described his beloved Berkshires, which today encompass numerous state forests and reservations (shaded gray areas), hundreds of lakes and ponds, and scores of trout streams.

Williams College, chartered in 1793, takes pride in one of the Nation's most beautiful campuses. Outstanding alumni include President James A. Garfield and poet William Cullen Bryant.

VERMONT
MASSACHUSETTS
FRANKLIN COUNTY
Williamstown
Williams College
Summer Theatre
North Adams
Taconic Range
Hoosac Range
Whitcomb Hill
Florida
Adams Mt.
MOHAWK TRAIL STATE FOREST
GREYLOCK RESERVATION
Mt. Williams
Mt. Greylock
Adams
New Ashford
SAVOY MOUNTAIN STATE FOREST
Tannery Falls
Charlemont
Berkshire Mountain
Cheshire
Savoy
Hancock
Lanesboro
Bellamy Rock State Park
Weston Mt.
Windsor
WINDSOR STATE FOREST
Plainfield
Pontoosuc Lake
Onota Lake
Dalton
Crane & Co.
Wahconah Falls State Park
Bryant Homestead
Cummington
Swift River
New Lebanon
Pittsfield
Berkshire Museum
Hancock Shaker Village
Hinsdale
HAMPSHIRE COUNTY
BERKSHIRE COUNTY
Washington
Haskell Hill
Worthington
Lenox
Tanglewood
Lenox School
OCTOBER MOUNTAIN STATE FOREST
West Stockbridge
Becket
Stockbridge
Berkshire Playhouse
Chesterwood
Naumkeag
Lee
Chester
Jacob's Pillow
Housatonic
BEARTOWN STATE FOREST
CHESTER-BLANDFORD STATE FOREST
Huntington
Simon's Rock
Great Barrington
HOUSATONIC RIVER BASIN
Otis
OTIS STATE FOREST
Blandford
Russell
CATAMOUNT
EAST MOUNTAIN STATE FOREST
Otis Reservoir
Cobble Mt. Reservoir
Covered Bridge
MT. EVERETT RES.
Mt. Everett
New Marlboro
TOLLAND STATE FOREST
Sheffield
Covered Bridge
FLYING CLOUD
SANDISFIELD STATE FOREST
New Boston
BASH-BISH FALLS STATE FOREST
Mt. Frissell
Twin Lakes
Canaan
MASSACHUSETTS
CONNECTICUT
Skiing
Airport
Elevations in feet

KODACHROME © K.A.S.

Sweet smell of spring fills the sugarhouse of Stebbins and Raphael Howes as maple sap bubbles in an evaporator pan atop a roaring fire. Excess water passes off as steam and escapes through a vent in the roof. One gallon of syrup requires 30 to 40 gallons of sap—depending on the degree of sweetness, which can vary from year to year. Local stores buy most of the Howes's output.

Woodlands resplendent in the radiant robes of autumn ring a country church in the town of Florida.

KODACHROME BY JONATHAN S. BLAIR © N.G.S.

Perched above a cloud-canopied valley, the clapboard chapel gleams in the first light of day.

Precious moments of play—those last few before the bell rings—absorb youngsters outside their one-room schoolhouse in Savoy. Such small schools once sprinkled the pastoral Berkshires, and author McCarry well remembers his early years in one at Plainfield. "But mine was much larger," he recalls; "it had two rooms."

lost lands. It seems that some Indians of Mahican ancestry still live in Wisconsin.

"They've forgotten their language," Mrs. Pierce said sadly, "but they haven't forgotten the descriptions of Berkshire scenes handed down from elder to elder in their legends.

"One of them, a wonderful old man named Elmer Davids, whom younger members of the group called 'Pop,' told me there was a story in their lore about a place on the Housatonic River where it was faster to portage canoes than to paddle round a big bend," Mrs. Pierce continued. "Well, we took Pop to a spot that we call Horseshoe Bend, and he was seized with excitement. 'Yes,' he said, 'it is just as our legend tells us!' And he gave the young people a fatherly look, as if to say, 'Trust the legends!' "

Berkshire People Decry "Bahstin" Time

For most of Massachusetts, the Berkshire valleys remained for 150 years "the place beyond the mountain." The majority of the Berkshires' people came in from Connecticut or from eastern New York, and the produce they wrested from their stubborn, stony land went south to New York City, not east to Boston.

Boston attitudes and Boston politics have never figured much in Berkshire life. The region may have paid its taxes to Boston and obeyed Boston's laws, but its life was its own.

"I don't care what time it is in Bahstin," a farmer I know once told a commonwealth official, "and in Bahstin they don't *know* what time it is."

The sentiment is cordially mutual, as almost any Bostonian—who would rather broil on Cape Cod or shiver in New Hampshire than drive west two hours to paradise—will attest.

The largest exception to this good-natured rivalry between Boston and the Berkshires is, of course, the Berkshire Festival at Tanglewood, near Lenox. Practically every summer since 1937, the Boston Symphony Orchestra has played there, attracting thousands of music lovers from all over the world, including easternmost Massachusetts (pages 214-15).

The Berkshire ski resorts have also broken down Bostonian indifference. Bousquet's in Pittsfield, the oldest ski slope in Massachusetts, began drawing the cityfolk to the mountains in 1932. Having introduced the first ski train in the region in 1934, the first night skiing in 1935, and one of the first snowmaking machines in 1956, Bousquet's keeps its 16 slopes busy.

Other ski resorts make their own contribution to intrastate amity: Brodie Mountain in New Ashford, largest, newest, and highest ski area in Massachusetts (pages 212-13), and Jiminy Peak at Hancock, an important training ground for youngsters who aspire to the U. S. Olympic skiing team.

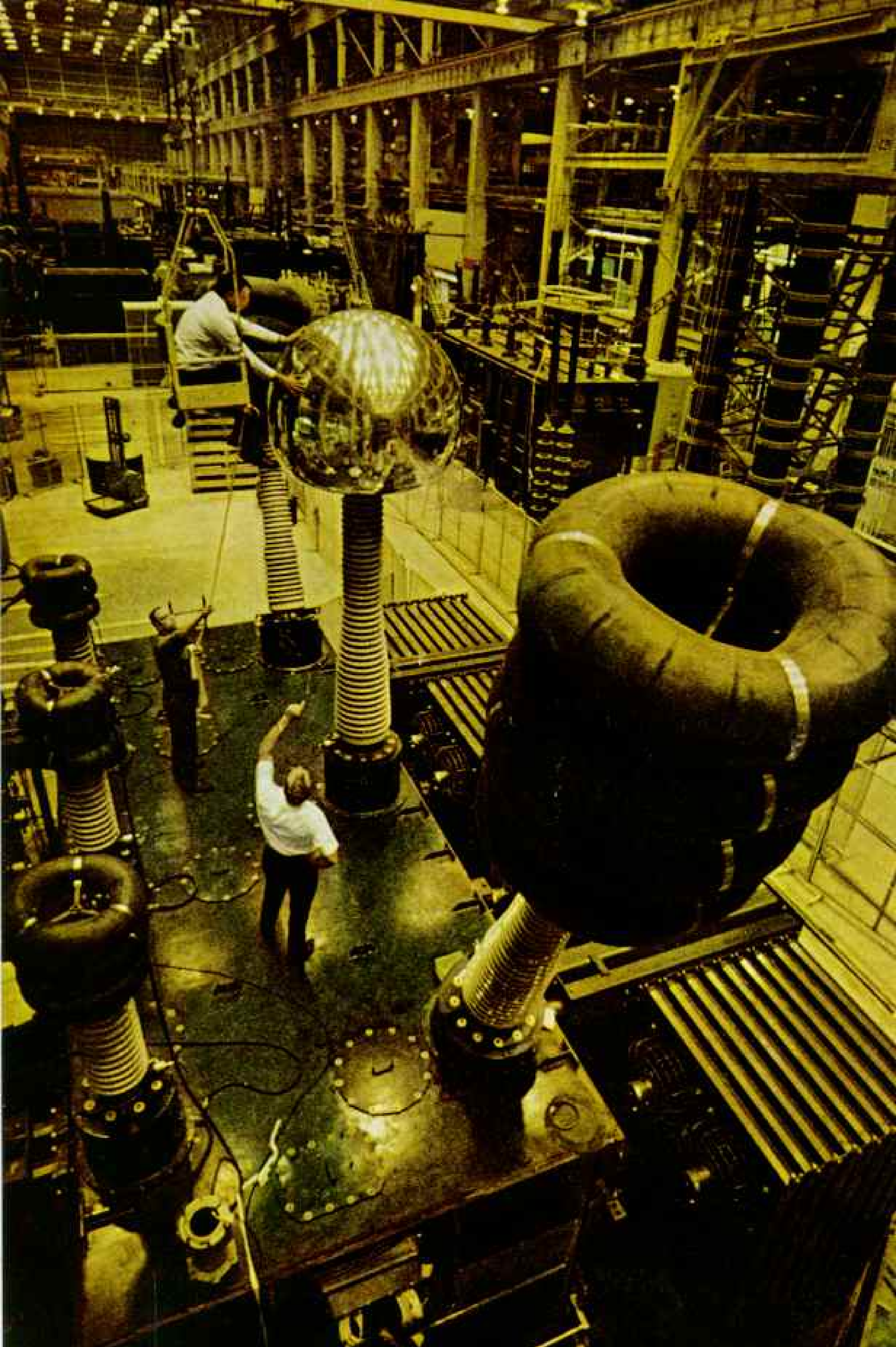
For those who, like my wife and me, prefer

a less pell-mell sport, the Berkshire woods, traversed by hundreds of miles of unplowed back roads, are a quiet paradise for the cross-country skier. Riding our narrow, limber boards, we ghost over drift and crust to places seldom seen. On a sun-bright December day, the track of our skis intersects the footprints of a black bear and her cub, who, confused by a recent warm spell, are still wandering when they should be in winter sleep. Jays bicker in birches jeweled by an ice storm that has coated each twig with crystal. A partridge explodes from the snow at the tip of a ski, and a white-tailed buck whistles and bounds away among the beeches with his does.

Harry Guyette, my old friend and neighbor, just shakes his head when he sees me skiing for the edge of the woods. "Life," Harry used to say, "is just getting through one winter and getting ready for the next."

Weather, in the Berkshires, is a fearsome companion, and I can understand why Harry does not love the snow. Even now, when a good wind is blowing, I can remember winter as it used to be on the hill farms. We rose at five to do the chores, and struggled to the barn in the dark through ten-foot drifts. The scuttles that covered the gutter drains behind the stanchioned cows froze and had to be chopped loose before the stalls could be cleaned. Milk sometimes froze in the pail if you left it by an open door, and once a basket containing two dozen new-gathered eggs was blown from my hand by a 60-mile-an-hour wind as I stepped out of the henhouse.

Water for the hens, the hogs, the young



stock had to be carried half a mile in a wagon. The water that sloshed on our clothes froze before we reached home, and my mother used to thaw our buttonholes with a hot flatiron while we stood, my brother and I, spread-eagled in our frozen jackets and trousers like crayoned figures in a child's drawing.

It is still as cold in the Berkshires, but that rustic life is almost gone. Harry Guyette and a few others live a version of it, but tractors, milking machines, and chain saws make it easier. The passing of the old ways is regretted, yet understood, by Thomas T. Packard, who lives with his brother Harold on land their great-great-grandfather cleared.

"When you talk about the past," Tom told me one February afternoon, "you're talking about folks that loved the future. They came here in the 1700's and 1800's when this was nothing but woods. They cleared the land, walled up, planted trees, built to last, and made a fine future for those who came after. The church, the school, the family, those three things had to be. Today, their skills are forgotten, their ideas don't count. All gone."

When I was a boy, Tom was a young man. His hair was dark as a Mahican's. Today, at 68, he is still as sinewy as his wit, but his hair is white and he is likely to mention that the life lived by six generations of Packards—filled with the color of crops and the scent of livestock—will end when he and Harold, both bachelors, are gone. Tom is chairman of the Board of Assessors in Plainfield, and, as president of the historical society, knows as much about our town's past as anyone.

I remember well when the Packard tradition of living on the farm began to fall apart. It was a winter night in 1946, sometime after milking. My brother and I saw a red glow in the sky about three miles away. It was the Packards' barn burning. By the time we and most of the rest of the townspeople got there, little could be done to help.

"I got the horses out," Tom recalls, "but we lost seven, eight head of cattle, maybe ten, and two fat hogs—and the barn and the hay and corn in it, of course."

Tom could never afford to get back into general farming. He went into potato raising, and expanded his maple-syrup business.

"Got up to 3,000 buckets at one time," Tom says, "but I can't do it any more because of my health. You can't hire help, because you put all your money into wages. You can't make syrup for less than $7 a gallon, and you can't make a profit unless you do it yourself."

Farmer Strives to Preserve Old Ways

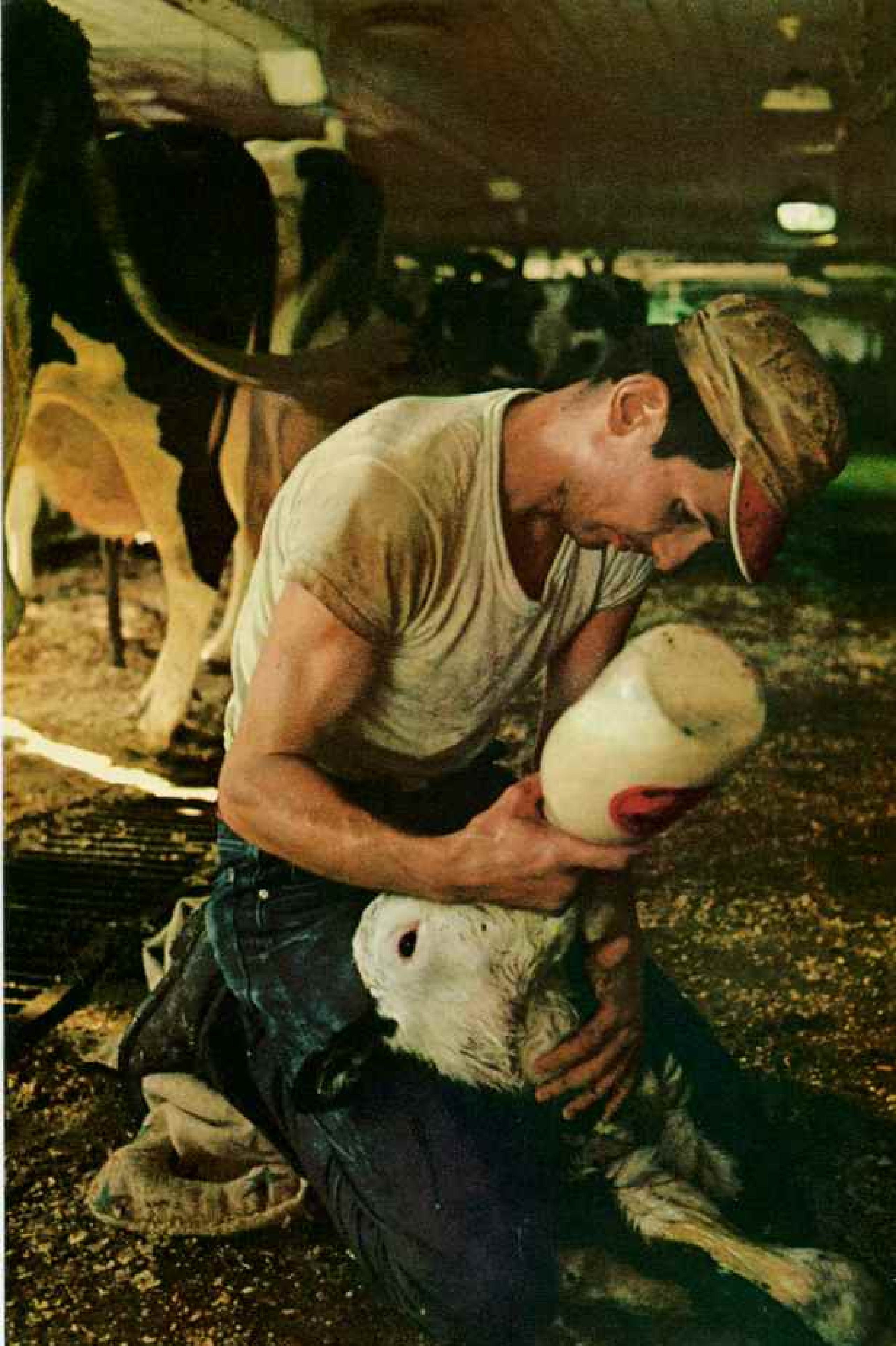
The Packards have the best natural stand of high-bush blueberries for miles around, and in season they sell picking privileges to all for "so much a quart." Tom bought the blueberry patch from a neighbor who was tempted to sell it to a large potato grower.

"I didn't want to see the blueberries ripped out," Tom says. "There's plenty of potato fields around."

Tom Packard's barn was once the scene of a yearly cornhusking bee where, in Tom's

Three stories high, a giant power transformer undergoes preparation for a final high-voltage test at the General Electric plant in Pittsfield. A G.E. invention, Lucalox lights bathe the vast building in a golden glow. The Berkshires' major industrial complex, G.E. employs 11,000.

Masked against lint, a worker spreads finely chopped cotton rags in a storage room at Crane & Company in Dalton. Founded in 1801, the firm specializes in high-quality stationery; it also produces paper used for United States currency.



words, "Neighbors got together to do a little work and have a good time. That was a bee."

We young people of the town sat in a circle on the barn floor between the full haymows, and shucked 300 bushels of flint corn by lantern light. Finding a red ear entitled you to kiss any girl (or boy) you liked. Cider and doughnuts, laid out in unlimited quantities on a rough lumber table by Tom's sister Olive, were a reward not much less sweet than the kissing. The husking bee is gone, too.

In winter Tom could be counted on for hayrides, when the moon was full and Plainfield Pond was ready for harvesting. Men of the town cleared away the snow, cut the ice into blocks, and skidded them ashore. Each family took a share and stored it in sawdust. It lasted all summer, and was used to cool the milk that most farms sold in bulk.

Before the ice was cut, there would be a moonlight skating party. We crowded together under horse blankets on a bed of fragrant timothy hay on Tom Packard's sledge. Tom put bells on his horses, and the steel runners of the sledge would squeal over the cold snow as Tom guided it beneath the arches of bare maples to every house in town where a child lived. Tom always built a big bonfire at the edge of the ice, starting it with just some twigs and one match.

Tom had told me how, in his boyhood, he had helped his father build a new barn on a foundation of stones they had collected from the fields. Mostly it was made of sawed lumber, but Mr. Packard and Tom hewed the beams by hand, scoring them with a hand ax and shaping them with a broadax. It's an ancient skill.

"It occurred to me years later," Tom said, "that he was getting my hand in, teaching me how to do it so the art wouldn't be lost."

It occurs to me now that Tom did something like that for a couple of generations of boys and girls when he let them husk his corn, or hauled them to Plainfield Pond to skate by the light of a bonfire on ice that was as clear as the conscience of a neighborly man.

Even in the 19th century, the focus of Berkshire life had begun to shift away from farmers like the Packards. A remarkable group of industrialists and inventors lived in the Berkshire valleys side by side with writers like Bryant and Hawthorne and Melville. Author and entrepreneur were drawn there for the same reasons: the hills with their thick woods, the streams in their downhill race. But where the writers saw God's glory in the great trees and in the flow of the Hoosic and Housatonic, the manufacturers saw timber and water power.

William Stanley perfected the electrical transformer that made Great Barrington the first town in the Nation to use alternating current commercially. Allen Wilson invented a sewing machine in Pittsfield. Fine papers were made in Dalton, Hinsdale, Lee, and Housatonic. Marble gouged from quarries, also located at Lee, was used in the United States Capitol and for headstones in national cemeteries. Textiles were woven in at least a dozen places.

Tunnel Proves an Engineering Triumph

The Berkshires and Boston finally agreed that some of these goods ought to flow eastward, but the Hoosac Range stood in the way. So it was decided to bore a railroad tunnel 4¾ miles long through the mountains.

Construction started in 1851. For 24 years the work was plagued with delay—drilling difficulties and mounting expenses. Finally, after the introduction of pneumatic drills and nitroglycerin, the Hoosac Tunnel (map, page 200) was completed in 1875. The project had cost 195 lives. Soon trains started rolling through, and the Boston & Maine Railroad still travels the dank darkness of what was, when it opened, the longest tunnel in the world, after the Fréjus that links France and Italy.

One of the products still flowing out of the Berkshires is literally a money crop, created by the Dalton papermaking firm of Crane & Company (page 207). Every day, most Americans touch something that comes from Crane. For their mills have been manufacturing, for almost a century, all but a minute portion of the paper from which United States currency is made.

Helping hand for a newcomer: On the dairy farm of Dean Morey in Cummington, Charles Dutelle feeds a calf too weak to stand and suckle. A Berkshire borner—as natives call themselves—Mr. Morey, with one hired hand, milks by machine more than 60 cows twice each day. Last December, after fire struck this barn and killed 38 animals, friends, working in sub-zero weather, joined him in re-roofing the structure.

"Meet me at the fair!"

LATE EACH AUGUST normally quiet Cummington pulses with excitement as it blossoms with tents and thrill rides (left): it's fair time!

Her pocket full of prize ribbons, a handler grooms a sheep (upper left).

Past awards adorn the living room of Mr. and Mrs. Franklin Streeter (above). On their 200-acre farm in Cummington they raise pure-bred Polled Herefords. "We used to go to 15 or more fairs a summer," says Mrs. Streeter, "but that was in our prime; we don't do it any more."

Winthrop M. Crane III, great-great-grandson of Zenas Crane, who founded the company in 1801, told me, "Our family has an old connection with papers for currency. The Cranes, who then had a mill near Boston, sold 'money paper' to Paul Revere for some of the early Massachusetts currency."

In 1879 the Cranes began making the distinctive security paper that has been the bane of counterfeiters ever since. Their papers are also used in stock certificates and bonds, in traveler's checks, in the currencies of several foreign governments, and for numerous stationery and industrial purposes.

Papermaking was long a mainstay of Berkshire economy, and the Cranes have had plenty of competition from the Westons, in Dalton, and the Eatons of Pittsfield. Early rivalries among them have given way to amicable relations, Mr. Crane told me with a twinkle. "I have an Eaton mother, a Crane father, and a Weston wife."

Three miles from the Crane mills, on the eastern edge of Pittsfield, the Berkshires' biggest city, stands a great industrial complex of the General Electric Company. "The shop," G.E. is called by its 11,000 employees, who make some of the most amazing products of modern technology. These include the "star scope" and the "people sniffer"—devices which gather starlight so that American fighting men in Viet Nam can see the enemy at night, or detect his presence through his human odor though he lurks in the thickest jungle growth.*

At the famed High Voltage Laboratory (page 206), a man sitting at a Space Age console twirled some dials. Through a large

*See "Remote Sensing: New Eyes to See the World," by Kenneth F. Weaver, GEOGRAPHIC, January 1969.

picture window we viewed the results. Outside, with a crash like artillery, five million volts flashed from one high tower to another across the gray winter sky.

"We're learning a great deal about how these very high voltages behave—something no one really understands completely," said George W. Alexander, head of the laboratory. "We're going to have to understand if we are to design transmission systems that will carry the voltages the Nation needs for the future."

A quieter but no less determined search for knowledge than General Electric's has been going on since 1793 at Williamstown, home of Williams College—after Harvard, the oldest institution of higher learning in Massachusetts.

Williams, in the tradition of its most renowned professor, the Reverend Mark Hopkins, who was college president from 1836 to 1872, still emphasizes small classes and close student-teacher relations. A celebrated alumnus epitomized his school and teacher: "The ideal college is Mark Hopkins on one end of a log and a student on the other," said James A. Garfield a few years before he became President of the United States.

Campus Welcomes Co-ed Invasion

I wondered what Calvinist Hopkins, who set stern standards for Williams men, would have thought of mini-skirts in the snow. On the campus I had noticed an unusual scene for a men's college. Slender young women, their winter-pinkened faces framed by long hair, were walking to classes with their books. They were some of the 60 girls studying at Williams under exchange programs with Vassar, Mount Holyoke, Smith, Wheaton, and Connecticut College for Women.

When I put the question to Dr. John E. Sawyer, Williams's twelfth president, he chuckled. "Mark Hopkins was interested in human growth, above all. I don't think the sight would have startled him. Nor would the scene in September of 1971, when we begin admitting our own freshmen girls."

Near the Williams campus, in a marble building, is a treasure house of art. It is the Sterling and Francine Clark Art Institute. Here, along beautifully lighted corridors, hang 30 Renoirs, together with some 200 works by Monet, Manet, Pissarro, Degas, Rembrandt, Rubens, Gainsborough, Turner, Goya, Toulouse-Lautrec, Inness, Remington, Piero della Francesca, and a score of others.

"**Largest night-skiing area** in the world," owner James W. Kelly boasts of his Brodie Mountain resort in New Ashford. Last season during 158 days of operation, 200,000 sportsmen streaked

down three lighted slopes named Shamrock, Paddy's Promenade, and Kelly's Leap. "We run out of people before we do snow," claims Kelly. "Back in the city, they see bare ground before we do and begin to think golf and boats." Here a contestant in the St. Patrick's Day race, a night-time event with $1,000 in prize money, zooms toward the finish line.

Bach to hard rock

MECCA FOR MUSIC LOVERS, the Berkshire Festival attracts throngs each summer to Tanglewood, a former estate near Lenox. Many come to listen; others come to learn. An appearance there of the Boston Pops Orchestra, conducted by Arthur Fiedler (above), means homecoming—40 members are alumni of the famous music center.

Last year, at a Contemporary Trends Concert, The Who (upper left) performed for 6,000 in the open-sided Music Shed against a huge screen flashing the Joshua Light Show. Thousands more sprawled on manicured lawns.

One of the country's foremost folk singers, Arlo Guthrie (below), and his wife Jackie live in the Berkshire town of Washington, Massachusetts.

ENTACHROMES (TOP) AND KODACHROMES BY JONATHAN S. BLAIR © N.G.S.

The donor of this magnificent collection, Robert Sterling Clark, was the grandson of Edward Clark, partner to the sewing-machine magnate Isaac Singer. He acquired many of his paintings while living in Paris. In death as in life, Mr. Clark arranged to be surrounded by a dignified privacy; very little is known about him. George Heard Hamilton, director of the institute, told me that from the time Mr. Clark began collecting, he wanted to create an art museum in a small community. He was attracted to Williamstown because of the educational and cultural advantages it offered and the great natural beauty of its setting.

Some 20 miles south of Williamstown and just west of Pittsfield a religious sect called the Shakers pursued a kind of privacy that makes Mr. Clark's look like extroversion. At Hancock Shaker Village, founded in 1790, Mrs. Lawrence K. Miller, president of Shaker Community, Inc., told me, "They withdrew from the world because of its overpowering temptations. In so doing, they hoped

to make themselves very nearly perfect."

Since the Shakers practiced celibacy, their disappearance, lacking conversions, was only a matter of time. By 1960, Hancock had only three aged survivors. To save Shaker Village, Mrs. Miller and a group of 33 other citizens raised $125,000 and bought it. With the help of foundations and private donors, the Shaker Community, Inc., has painstakingly restored many of the austere buildings, including the famed round masonry barn, and each year some 35,000 visitors come to explore and admire them (following pages).

The young curator of Hancock Shaker Village, Eugene M. Dodd, leads a bachelor's life in a remodeled room of the great communal house in which the Shaker "brothers and sisters" lived.

"We've tried to restore this house so it's almost as it was in the last century," Mr. Dodd said, as we inspected the vast kitchen, with its bricked bread ovens and enormous pots and pans in which the community's meals were cooked.

"The Shakers," said Mr. Dodd, "must have been among the most ingenious people who ever lived. They had running water in here more than a hundred years ago, and they invented a cast-iron stove about 1810 that still throws more heat than any modern heater I've ever seen."

Mankind Benefits From Shaker Skills

The Shakers are credited with many inventions and improvements, among them a washing machine, a circular saw, the common clothespin, and a metal-nibbed pen. Their dwelling place is still a cornucopia of efficient window fasteners, elegantly simple furniture, and various types of cleverly made tools.

Upstairs, Mr. Dodd showed me the austere rooms in which the sisters and the brothers slept, and the dining room in which they ate at separate tables.

I remarked on the absence of locks on inside doors. "The Shakers didn't believe in locks," Mr. Dodd explained, "but they made a very good lock for the front door when they found that the world had a way of walking right in."

Mr. Dodd, who is writing a book about Shaker design, filled me in on some history: "The founder of the sect was a forceful Englishwoman named Mother Ann Lee. She came with eight followers to America in 1774.

"Hancock Village was the country's third

EKTACHROME © N.G.S.

Master of the magazine cover, famed painter Norman Rockwell works at his home in Stockbridge. Here he adds finishing touches to an oil depicting a young art student nervously awaiting an interview with an editor. A carved wooden angel with brush in hand dangles above the easel. On the wall hang cherished paintings given to the artist, including canvases done by Mr. Rockwell's grandfather and son. The studio is a converted carriage house, once a part of the estate of Aaron Burr.

Shaker community; earlier ones had been founded in New York at Watervliet, outside Albany, and New Lebanon. At the height of the Shaker movement, just before the Civil War, there were about 6,000 members of the sect in 18 communities ranging as far west as Ohio and as far south as Kentucky."

Mr. Dodd produced an old engraving of one of the Shakers' strange sessions of worship. In the picture, the faithful were dancing themselves into the shaking frenzy from which they took their name (opposite).

"There's a prophecy of Mother Ann's that the sect will have a rebirth when its numbers are reduced to the number of her original mission," Mr. Dodd said. "Although I don't have a complete list of present-day members, I suspect they may now be close to that count on a nationwide basis."

My mother, who is 79, remembers visiting the Shakers with her father, a farmer who liked to buy their famous vegetable seeds. On their way home to West Stockbridge, grandfather would sometimes steer his buggy through Lenox.

"We've seen some plain and honest birds this morning," he'd say to his small daughter. "Let's look at the peacocks in the afternoon."

The "peacocks" were the New Yorkers who were spending millions around Lenox on mansions and grandiose hospitality in imitation of Edwardian English country life. Their edifices included 100-room "cottages," and even one reproduction of the Petit Trianon at Versailles.

Many Estates Now Serve Educational Purposes

The great houses of Lenox are now filled mostly with school children, for many have been taken over by the boarding schools for which the Berkshires are well known. Lenox School, begun in 1926 by the Episcopal Church, occupies the former Schermerhorn estate and adjacent properties in a setting of shady woods and splendid buildings.

The institution, "a place asking moderate tuition for boys of moderate means," has 180 students, taught by a faculty of 27.

"We try to instill the idea of service in our boys," David H. Wood, assistant headmaster, said, "and we're particularly proud of our summer projects. Our groups have spent summers really helping out the disadvantaged in Japan, Mexico, Canada, England, and an American Indian reservation."

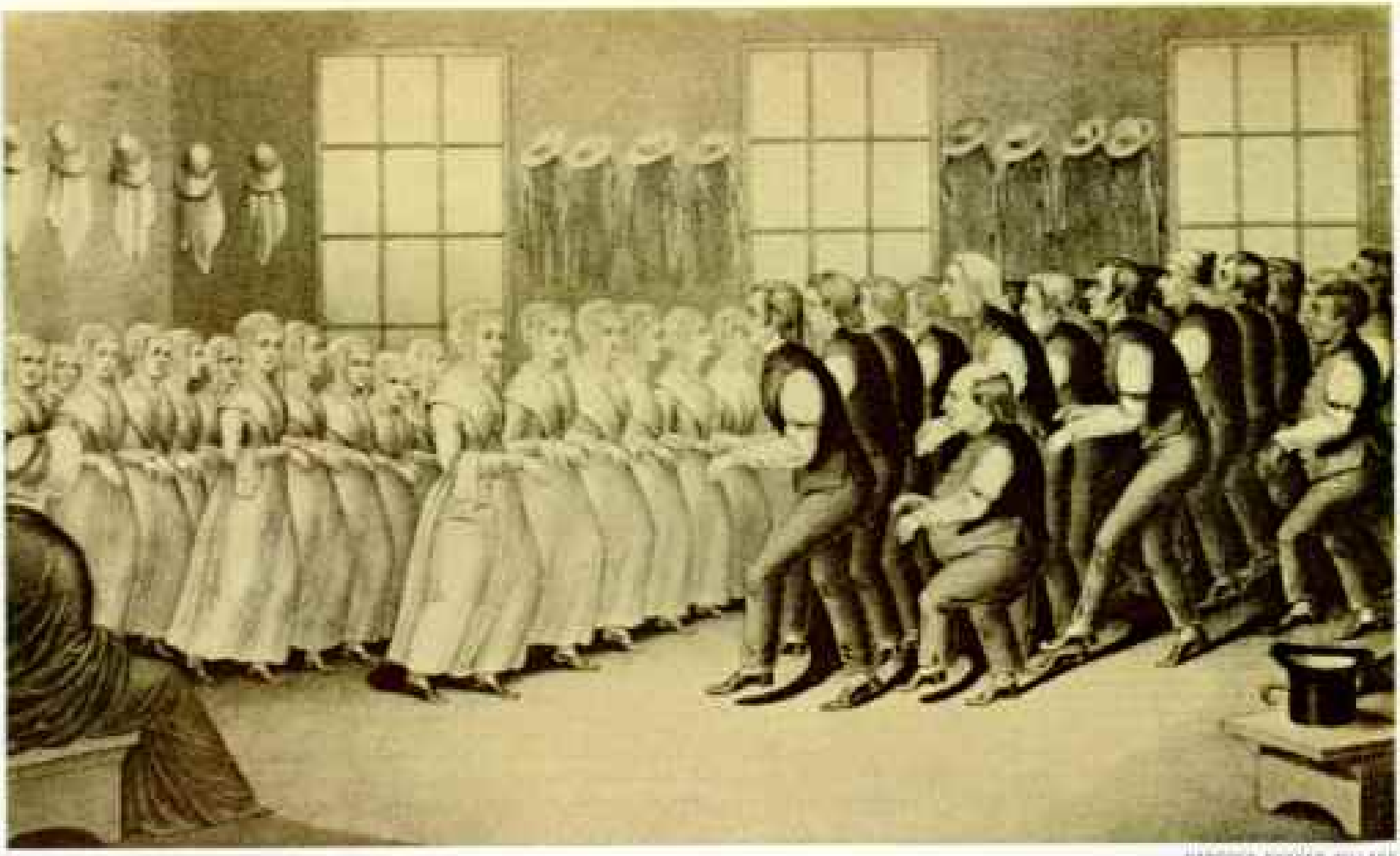
One of the newest of Berkshire's schools, Simon's Rock, lies 11 miles south of Lenox, in a fold of the hills in Great Barrington. The founder, Mrs. Elizabeth B. Hall, told me that the site was once the home of her parents. Here she is creating something new in American education—a four-year course in college-level liberal arts for students who have completed the tenth grade. About 130 now study at Simon's Rock, which graduated its first class this year.

Any area students whose talents run to the performing arts find themselves in a good geographical position for summertime extracurricular studies. The Berkshire Theater Festival is at Stockbridge at the end of that Main Street which resident Norman Rockwell (preceding pages) has celebrated in one of his paintings. Since its founding in 1966, the festival has provided a stage for new plays away from the financial and critical pressures of Broadway.

"**Shake, shake** along, shake along, Daniel; Shake out of me all things carnal." So chanted members of the Shaker sect during Sunday dances (right) at their communal farm near Pittsfield.

For more than a century, beginning in 1790, the colony thrived here, breeding cattle and developing an extensive garden-seed business. The society required converts to accept celibacy, and, despite taking in orphans, the Berkshire community dwindled to three by 1960.

Last year 35,000 visitors toured the settlement, now a museum that includes the circular barn, workshops, and five-story brick dwelling (below).



HANCOCK SHAKER VILLAGE

EKTACHROME © K.O.D.

Thirty miles north, the Williamstown Theatre presents a summer program of proven plays. And, near Lee, Ted Shawn and his associates have made some of the supple history of the modern dance at Shawn's famous school and festival site, Jacob's Pillow.

The summer event for which Lenox and all the Berkshires are most famous takes place at Tanglewood, a name first popularized in Nathaniel Hawthorne's *Tanglewood Tales*. A replica of the plain red cottage in which Hawthorne wrote *The House of the Seven Gables* stands on the extensive grounds, and visitors to Tanglewood may gaze, as did Hawthorne, on the placid waters of Stockbridge Bowl, washing the knees of the hills.

Summer home of the Boston Symphony Orchestra, Tanglewood is the setting, throughout July and August, for concerts by some of the country's leading contemporary and classical groups (pages 214-15). The Music Shed, where they play, has such remarkable acoustics that the music carries clearly to the lawns. Gathered here are young people and old, their faces filled with the light which shines from the human race when it meets its own beauty and goodness for a happy moment.

The establishment of Tanglewood in 1937

Wave upon wave of blue hills billow across a landscape that inspired William Cullen Bryant to write of "The hills Rock-ribbed and ancient as the sun,—the vales Stretching in pensive quietness between. . . ." This view, looking southeast from Whitcomb Hill, embraces a portion of 6,452-acre Mohawk Trail State Forest. In the Berkshires "the wild and the cultivated are close companions," a resident once wrote, "and we are happy in the companionship."

was the culmination of a dream of the late Serge Koussevitzky, long-time conductor of the Boston Symphony Orchestra. Part of his dream was to interweave music and landscape, to create a place where a great orchestra could play greatly outdoors. The other feature of Koussevitzky's dream was the Berkshire Music Center for accomplished young musicians about to embark on concert careers. This summer the most famous of the original Tanglewood fellows of 1940 returns to the Berkshire Festival as an adviser. His name is Leonard Bernstein.

The fellowship program brings carefully screened young musicians to Tanglewood each summer for intensive study with members of the orchestra. The success of its graduates is impressive: They comprise 10 percent of all musicians in major American orchestras, including 13 conductors.

The famous and the gifted are surely an adornment to the Berkshires, but the Berkshires they are not. These hills have produced an upright people, different from any other. They are my mother's great-grandfather, who with his 11 sons chopped a farm out of the wilderness. They are my father's grandfather, who came here from the British Isles and lived his life within earshot of the factory clamor of the industrial revolution.

They are the generations who sleep in ancient graveyards under names that the rains have washed away, behind stone walls tumbled by the frost of two centuries. They are the boys I went to school with, in a room where Bryant and John Brown studied; who went to wars, as their forebears had gone to the Revolution and the Civil War, in places that were too far away from the hills.

No tourists will stop by their houses, built on timbers hewn by the broadaxes of their great-grandfathers. No stranger, poet or not, will dance as they danced on summer evenings after the haying, fight as they fought over the girls who have mothered their children. No outsider, driving by a stone wall, will count in his mind the rocks turned up by the plow and carried in callused hands to the edge of the field.

And no poet that I have ever read will know the hills for what they are as an old man in Worthington knows them. He was in the woods last spring, as he had been since boyhood, gathering sap from his maples.

"I was just taking the last bucket off a tree," Rob Cudworth said, "and getting pretty tired of it, when I looked down by my boot in the snow—and there, by Heaven, was a Mayflower!"

THE END

Solar Eclipse

NATURE'S SUPER SPECTACULAR

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EKTACHROMES BY ALBERT MOLDVAY (C) N.G.S. AND (RIGHT) HARVARD COLLEGE OBSERVATORY-SMITHSONIAN ASTROPHYSICAL OBSERVATORY-NATIONAL GEOGRAPHIC SOCIETY EXPEDITION

ABOUT EVERY 18 months, some part of our world experiences an event that awes astronomer and layman alike. In a remarkable coincidence of size and distance, the 2,160-mile diameter of the moon—1/400 the size of the sun but also only 1/400 as far from the earth—blots out the face of the sun, that huge ball of glowing gas. The result: a rather eerie false night for anyone in the lunar shadow.

As a dedicated observer of total solar eclipses, I have been privileged to witness 13, perhaps as many as anyone in the

world. My first occurred over the Colorado Rockies in 1918. Jay, my colleague on the latest expedition, viewed his first of three total eclipses in 1959, when he joined other members of my freshman seminar at Harvard on an eclipse pursuit by airplane over Boston.

Corona Holds the Key

Like most eclipse chasers, we seize any opportunity to stand within the lunar shadow for a brief, invaluable glimpse into the secrets of the sun. Our key to those secrets is the incredibly hot corona, the halo of pearly light surrounding the eclipsed sun (above).

Most scientists believe the corona's ionized gases stretch all the way to the earth, enveloping our planet as well as the sun. Thus, understanding the corona is relevant to understanding our own environment.

Though eclipses occur reasonably often, opportunities to examine the corona arise rarely. The central dark shadow, or umbra, has a most perverse habit of crossing our globe in inaccessible regions. The umbra touched down on the broad Pacific Ocean, for example, in the

Celestial gem: Sunlight bursting through a lunar valley produces the "diamond-ring effect," signaling the end of the total eclipse of March 7, 1970.

With support from the National Geographic Society, the authors led a 17-man expedition to the village of Miahuatlán in southern Mexico to record the dramatic alignment. Near the end of totality (left), astronomers Menzel, right, and Pasachoff gaze at the phenomenon, visible in their coelostat—a motor-driven mirror that reflects the eclipse into a spectrograph (next page).

eclipse of May 30, 1965, hitting only remote islands. On July 10, 1972, the shadow will cut through inhospitable areas of Russia, Alaska, and Canada, before leaving land at Nova Scotia. The following major eclipse, on June 30, 1973, will occur over the Sahara.

Washington, Oregon, Idaho, and Montana will lie within the umbral shadow on February 26, 1979. The U. S. East Coast must wait until August 21, 2017, for its next total eclipse.

Fortunately for professional and amateur astronomers, the eclipse of March 7, 1970, represented a welcome exception to the rule of inaccessibility. The last total solar eclipse to occur over the eastern United States in this century cast its shadow across the homes of more than a million and a half people from Mexico to Newfoundland.

Shadow Grazes Edge of North America

Starting over the Pacific, the umbra first touched land in southern Mexico (diagram, page 232). The wave of midday darkness crossed the Isthmus of Tehuantepec and traversed the Gulf of Mexico before striking land again in northern Florida. The shadow streaked up the coast of Georgia, South and North Carolina, and Virginia, then quickly swept across Atlantic waters to blanket Nantucket Island and touch Nova Scotia. The three-hour journey ended at sea beyond Newfoundland, 8,500 miles from touchdown point.

Undoubtedly more people traveled to see this eclipse than any other in history. Some fifty million people lived within a day's drive of the umbra's path, from 80 to 100 miles wide. Countless thousands lined highways and beaches during the eclipse, awaiting the two to three minutes of totality to watch a vision of rare beauty, the sun's corona. Totally or partially, the eclipse could be seen over nearly every section of North America.

Many interested scientists, however, established observation posts not in the populated centers of the East but in the mountains and valleys of southern Mexico. There we were promised the clearest weather and longest duration of totality, about 3½ minutes.

Our 17-member expedition, sponsored by the Harvard College Observatory, the Smithsonian Astrophysical Observatory, and the National Geographic Society, chose as its base of operations the Indian community of Miahuatlán.* Some 300 miles southwest of Mexico City, the town lies in the midst of magnificent archeological remains from the Zapotec civilization. The state government at Oaxaca, 50 miles north of Miahuatlán, arranged for a suitable observation site and headquarters.

Our advance party arrived in Mexico on February 7, allowing only a month to set up our complex equipment. The temporary quarters delighted us. We had two rooms and the courtyard of an old music school, the Escuela Filarmonica Municipal, atop the tallest hill in town. The school's high adobe walls blocked the sweeping winds and dust, and offered protection from friendly but curious Miahuatlecans who might have unwittingly interfered with our work.

Electric lines, toilets, and running water—

*Additional support came from the Air Force Cambridge Research Laboratories; National Science Foundation; Austin Stanton Foundation; Duncan H. Read of Middleburg, Virginia; John J. Terlep of Pueblo, Colorado; and Videonics, Inc., of Cambridge, Massachusetts.

SUNSHOTS BY ALBERT MOLITAY (ABOVE) AND GUILLERMO ALIANA ESPINOSA © N.G.S.

Awesome rendezvous of sun and moon draws villagers to Miahuatlán's main square and cathedral roof. Some watch the progress of the eclipse through smoked glass or goggles of dense film. Eclipse day nearly doubled the population of this Indian town of 16,500; the area offered astronomers from more than a dozen nations clear skies and a long period of totality—3 minutes, 23 seconds.

Awaiting darkness at noon (left), Doctors Menzel, right, and Pasachoff check the solar image on the spectrograph that separates it into component colors for analysis. A ghost image of the partial eclipse, reflected in the camera lens, appears beside them.

even a hot shower—had been installed. We had our own telephone, a rarity thereabouts. Our number was easy to remember: Miahuatlán 7.

Bob Hamilton, our architect, directed local craftsmen who constructed a wood-and-aluminum structure for our delicate spectrograph. An adjoining patio provided an observation site for five Peruvian astronomers, who joined us later. They were led by Fernando de Romaña, an old friend who, during the eclipse of 1937, was the first person to photograph the corona with Polaroid filters.

One room within the school building served as our laboratory, darkroom, and storage space. The other, fitted with a stove and electric refrigerator, became our kitchen, dining room, and dormitory. We also moved cots and a bed into the nearby, as yet unoccupied, new store of the village mayor, Moisés López Ramírez.

Cooks in Nuns' Habits Help Astronomers

We ate most meals at an improvised restaurant established on our behalf by the sisters of the local parochial school. The nuns provided an indispensable—albeit somewhat confused—service. Unaccustomed to fussing over hungry guests, as many as five "chefs" in habit bent over the stove simultaneously, all carefully tending the same solitary omelet.

Observers from around the world converted the usually quiet region into an international community of several hundred scientists from more than a dozen countries. Compared with some others, our accommodations were plush.

The Russians, who had a large party of 32 astronomers, roughed it more than most on an open plain four miles away. Wind and dust swirled often around their tents, but did not inhibit their scientific or social activities (pages 228-9).

The three-week period of aligning and testing equipment to prepare for the big event passed quickly, but with occasional problems, which were not unexpected. An electric motor—which turned the guiding mirror to follow the sun—burned out. This caused some anxious moments. Fortunately, not an hour later a telephone call from Boston radio station WHDH asked how we were faring.

We explained about the motor and how to obtain a replacement in Cambridge. Within 24 hours we received assurance that a replacement was on its way, as indeed it was.

A week before the eclipse, all Miahuatlán assumed a carnival atmosphere. Perhaps the townspeople found the scientific value of the eclipse a bit vague, but they recognized a festive occasion. Nightly fiestas enlivened the *zócalo*, the village square, and everyone danced to music and Indian chants.

"**Most exciting thing we have seen** . . . streamers extending as far from the sun as have ever been photographed," said Dr. Menzel, veteran of 13 total eclipses. Films revealed the corona—the white-hot halo of luminous gas that is most visible when the moon blocks the sun's dazzling face—thrusting spikes more than five million miles into space. Tracing the energy from the pearly ring helps explain the makeup of the sun as well as the bombardments of radiation that may distort radio communications and endanger space travelers.

Church bells clanged frequently and interminably, and nerve-shattering fireworks displays added a new dimension to the clamor. The supply of fireworks seemed inexhaustible. Within five blocks of our quarters, no fewer than seven factories turned out elaborate displays.

Though we tried not to think about it, one recurring situation bothered us. Each morning the sun shone brilliantly, but high cirrus clouds often drifted over before noon. Sister Maria Gutiérez Muñoz told us not to worry; this was a crazy month. "*Febrero es loco,*" she said, assuring us that March—and the day of the eclipse—would be better. She was right. Of the nine days immediately preceding the eclipse, seven were excellent.

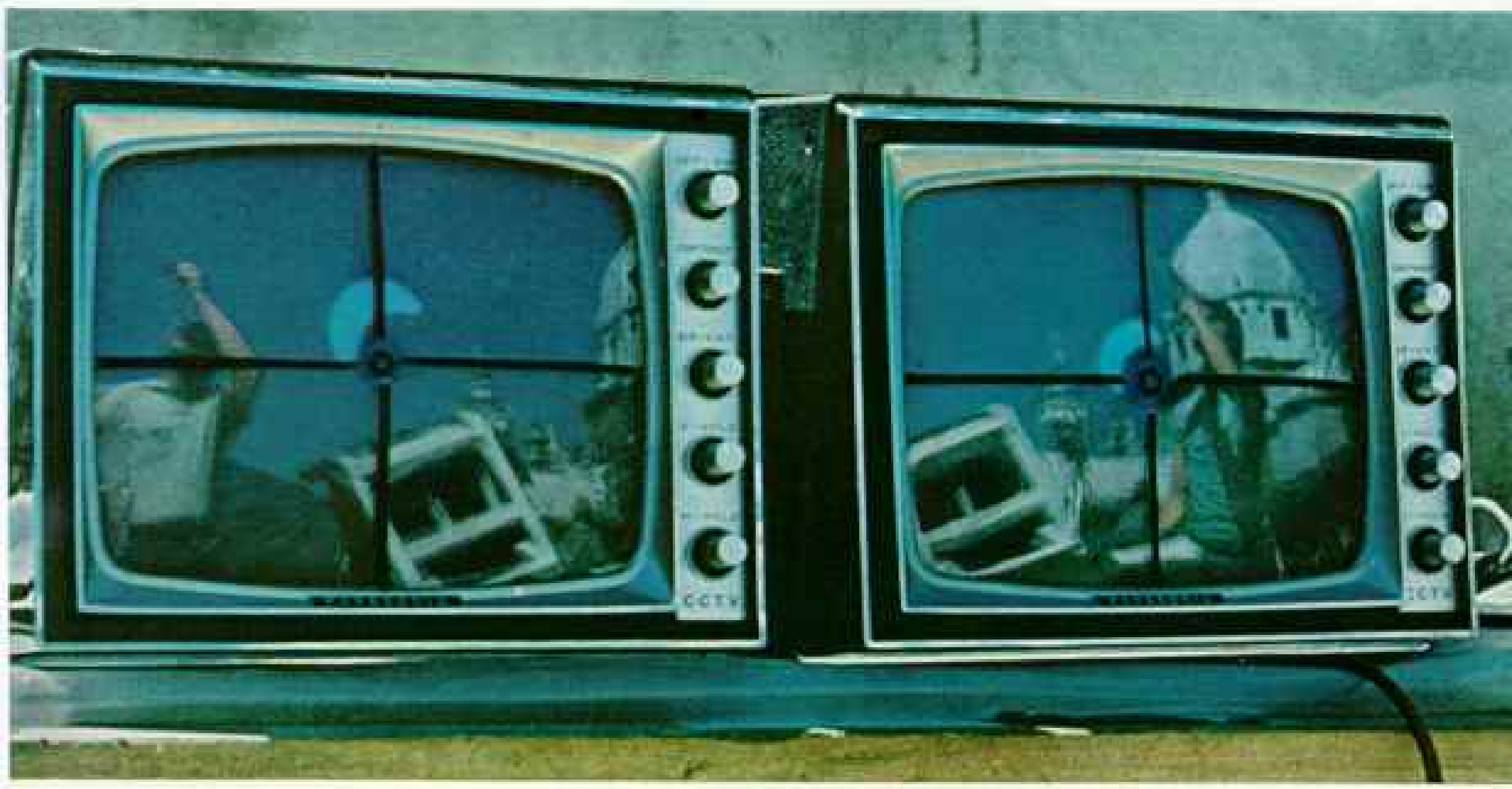
Sky Clears for Eclipse Day

Rising at dawn on March 7, we saw no clouds anywhere. I am a specialist in beautiful skies, and I've never seen one more magnificent. The color was a deep blue, seldom seen except at much higher altitudes than mile-high Miahuatlán. Not the slightest trace of dust, fog, or cloud marred the view. It was the most perfect sky I had ever seen.

As the first contact of moon and sun occurred on schedule at 10:07 a.m., the sky remained unbelievably blue. The moon bit into the sun's disk about an hour and a half before totality, and we completed our final tests. The sun became a narrow crescent and, just before totality, the shadow bands—ripples of light and dark caused by irregularities in the earth's upper atmosphere—rushed over the ground.

My voice, counting off the seconds to totality, boomed from a tape recorder. We had made the recording a few days earlier so that we could devote all our attention to the spectrograph.

Our largest single piece of equipment, the spectrograph was designed by Dr. James G. Baker of Harvard, a leading specialist in optical systems. The instrument, which analyzes light by breaking it down into its component colors, is so massive that

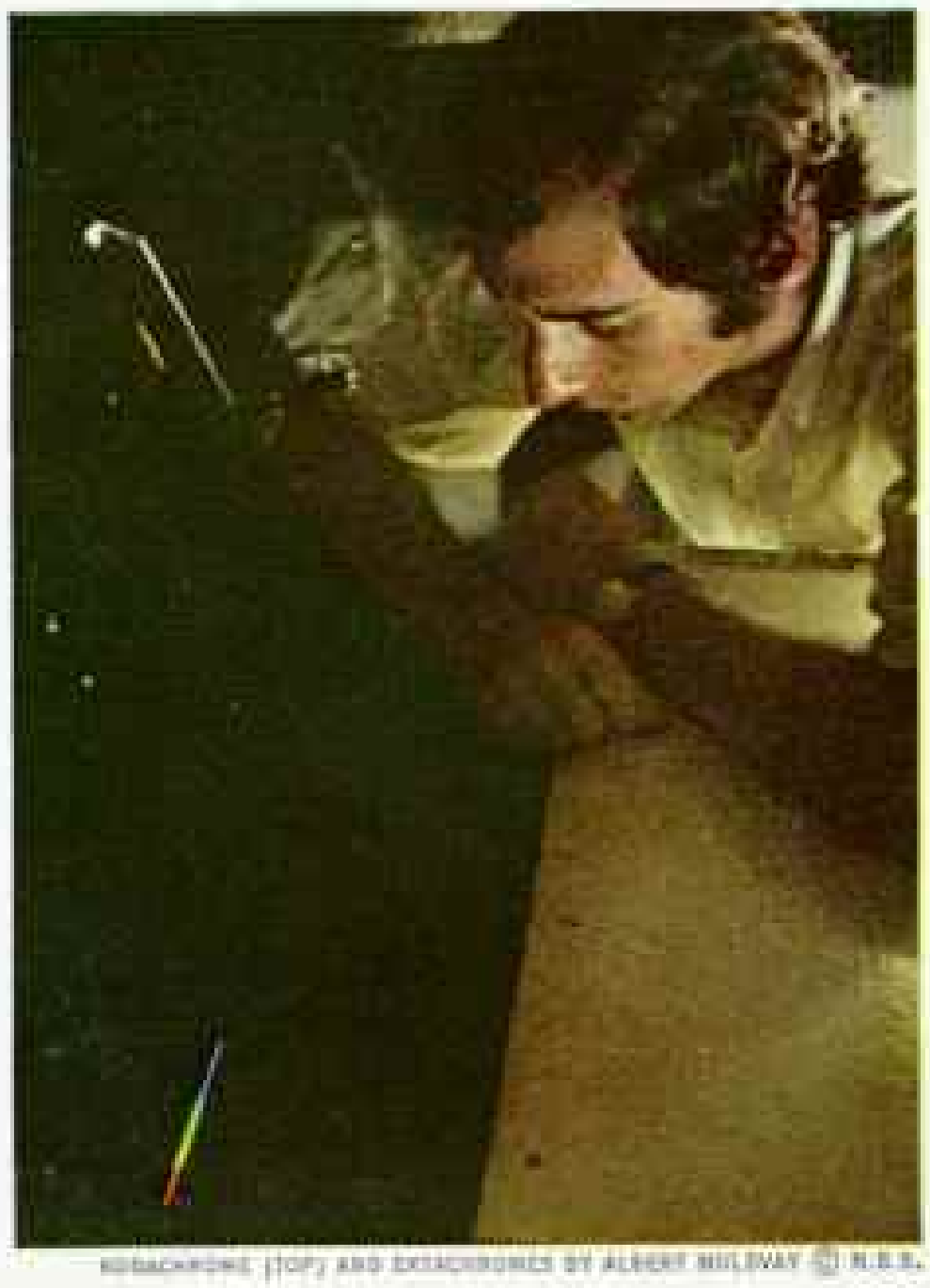


The universal urge to study the sun

SOVIET GROUP LEADER Dr. N. V. Steshenko, center, escorts the authors and Mexican student Caesar Sepulveda, rear, on a tour of the 32-man Russian camp, one of the largest of more than 40 teams at Miahuatlán. Mexican and Soviet flags fly at right. Plastic cover protects a battery of telescopes, left, from dust. Clouds over the mountains never advanced to the plain; thin clouds overhead threatened for two days, but did not appear on March 7.

In the Harvard camp before "E-Day," Dr. Pasachoff opens the spectrograph (right), revealing the band of solar color. A dust-free hut housed the 1,500-pound instrument; only its first lens protruded.

During the eclipse, solar crescents appear in monitors (left) for TV cameras, used for the first time to measure polarization of coronal light. Video tape records the images for later study. Screens reflect two of the expedition's 17 members, Darrell Fernald, left, and Jeffrey Pitts, manning cameras beside a church.



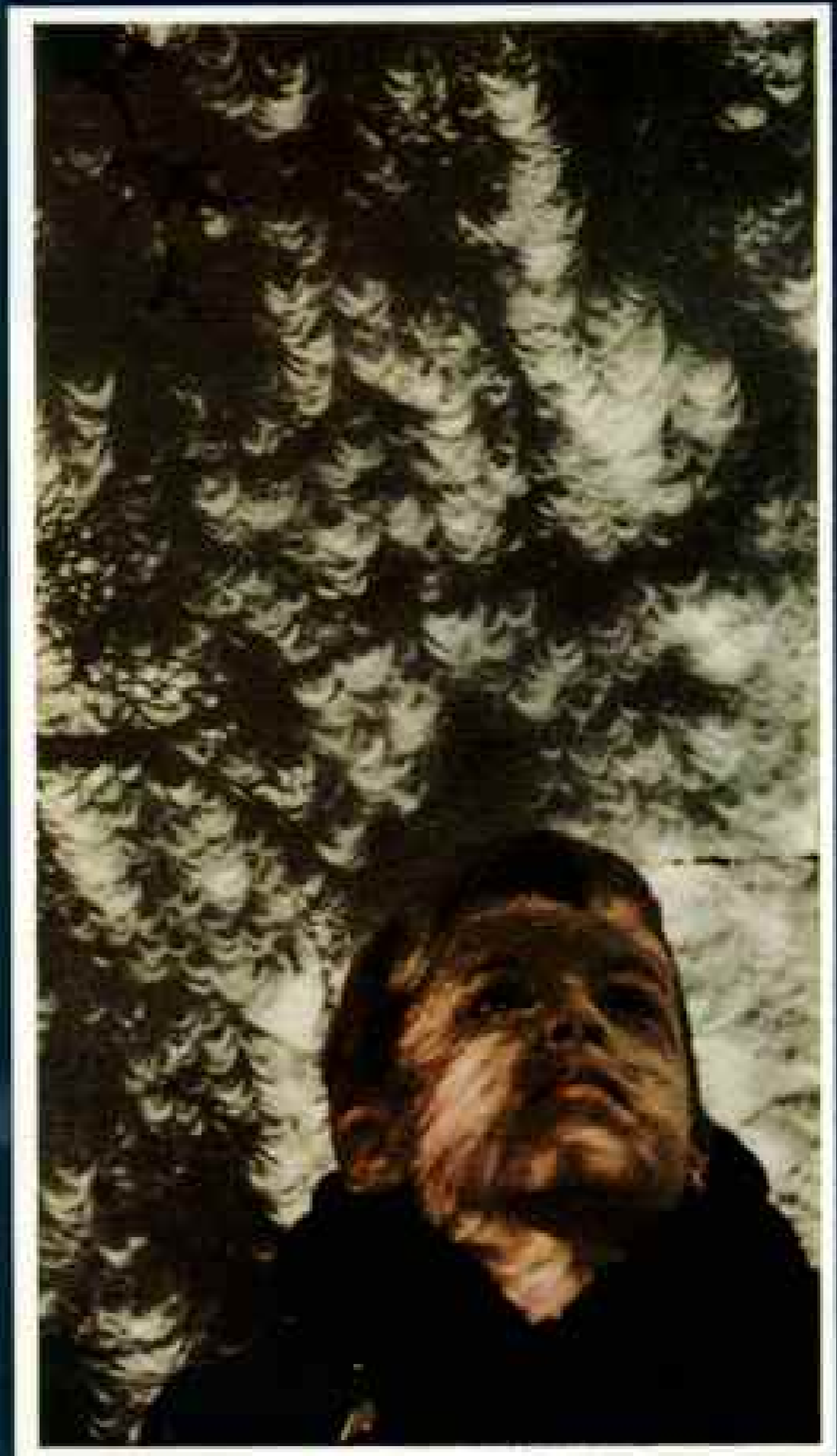
Tongues of luminous gas arch more than 25,000 miles above the sun's vanishing rim in the upper photograph, taken through a six-inch telescope in Kinston, North Carolina. Sunlight shines through the moon's irregular terrain in final gleams known as Baily's beads.

As the moon draws its slow curtain across the sun's face, the lower sequence—taken at Assateague Island, Virginia, with a 3½-inch telescope—reveals sunspots as dark specks, some larger than the earth.

Crescents quilt a wall in Annandale, Virginia (right), as light leaks through foliage and projects inverted images of the eclipse. Stephen Mazzatenta, four, watches near totality.

On a special Eastern Airlines flight (left), racing the moon's shadow over Nantucket Island, Massachusetts, Dr. Leonard Carmichael, Chairman of the Society's Committee for Research and Exploration, peers through dense film. Flares from the camera lens seem to float across the picture.

KODACHROME BY JAMES J. KREBS AND RICHARD K. JECK © N.G.S.



KODACHROME BY O. LOUIS MAZZATENTA © N.G.S.

it cannot readily be pointed at the sky and turned to follow the sun. Instead, we built brick piers to support it horizontally, and a rotating mirror, called a coelostat, reflected the sun's image into the lens (page 224).

Our two and a half tons of equipment also included four television cameras (page 228) for recording the corona on video tape at different wavelengths through turning Polaroid filters. Measuring the polarization tells us how much of the light we see as the corona comes from the sun's upper atmosphere, and how much is sunlight scattered by dust particles between the earth and the sun.

We also used a special eclipse camera-telescope to photograph the sun through a polarizing filter oriented at different angles, and we used seven additional still cameras and two movie cameras to record the corona with various lenses.

For a change, we had enough people to handle all this equipment. My wife Florence, who had often assisted me at eclipses in the past, could relax and enjoy this one.

Wave of Night Sweeps Over the Camp

As we tended to our different assignments, the camp grew darker. Birds flew aimlessly above us. A distant rooster crowed. Then silence. The sky, by now reflecting a pink tint from the horizon, dimmed as if a storm were approaching. It grew noticeably colder. The solar crescent vanished behind the dark moon, and slivers of light—Baily's beads—sparkled momentarily through the valleys and crags of the lunar edge. The beads slipped away, leaving a quick flash, the "diamond-ring effect" (page 223), as the corona burst into view.

"Totality!" I shouted. Our programs of picture-taking already were in motion.

Jay, using a sheet of black foam rubber, acted as a human shutter for the lens of the spectrograph, avoiding the possibility of mechanical failure. I checked the guiding of the solar image in the coelostat. Others managed the cameras and telescopic gear.

Time stood still, but eventually Baily's beads peeked from the other edge of the moon. With sighs of relief and joy, we threw our arms around one another.

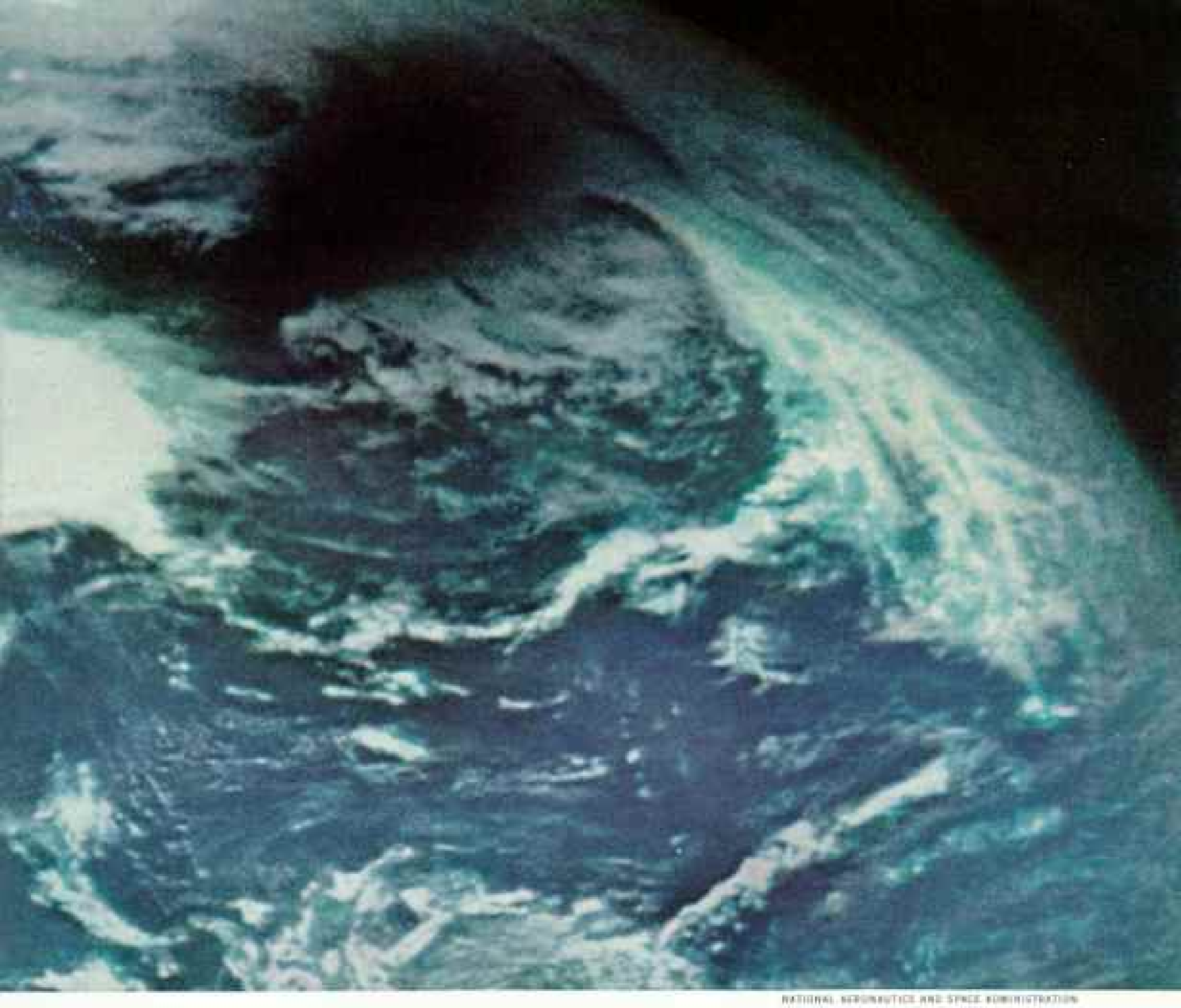
Some of our most intense work still lies ahead. Much of the data collected will be fed into machines and computers during the coming months. Even at this preliminary stage, however, we have reason to be excited. Amazingly, our auxiliary cameras gave us a thrilling prize: perhaps the longest solar

"I will darken the earth in the clear day" AMOS 8:9

VIEW FROM A NASA SATELLITE, poised in synchronous earth orbit 22,300 miles over Quito, Ecuador, offers the first look from space at an entire eclipse shadow, the dark umbra surrounded by the fuzzy, lighter penumbra. Like an ink stain on the earth's bright face, the moonshade shrouds Newfoundland just before slipping off into space. The United States and Mexico, with Baja California clearly visible at left center, lie partly covered by clouds.

Whimsical sketch (right) by Dr. Menzel, well-known among academic colleagues for his scientific doodles, depicts the path of totality. Drawn with a toothy grin, Comet Bennett, visible during March, watches the scene. Point of the conical umbra touches earth about every 18 months on the average and most often on oceans or inaccessible land. Streaking 8,500 miles in three hours, this shadow skimmed the populous Eastern Seaboard. It was the last total eclipse the eastern United States will see in this century.

SOLAR ECLIPSE OF MARCH 7, 1970
AS SKETCHED BY DR. MENZEL



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

streamers ever photographed (pages 226-7).

The sky's extreme clarity enabled us to see those spikes jutting out at least five diameters from the sun. Streamers I had seen in the past extended barely two diameters.

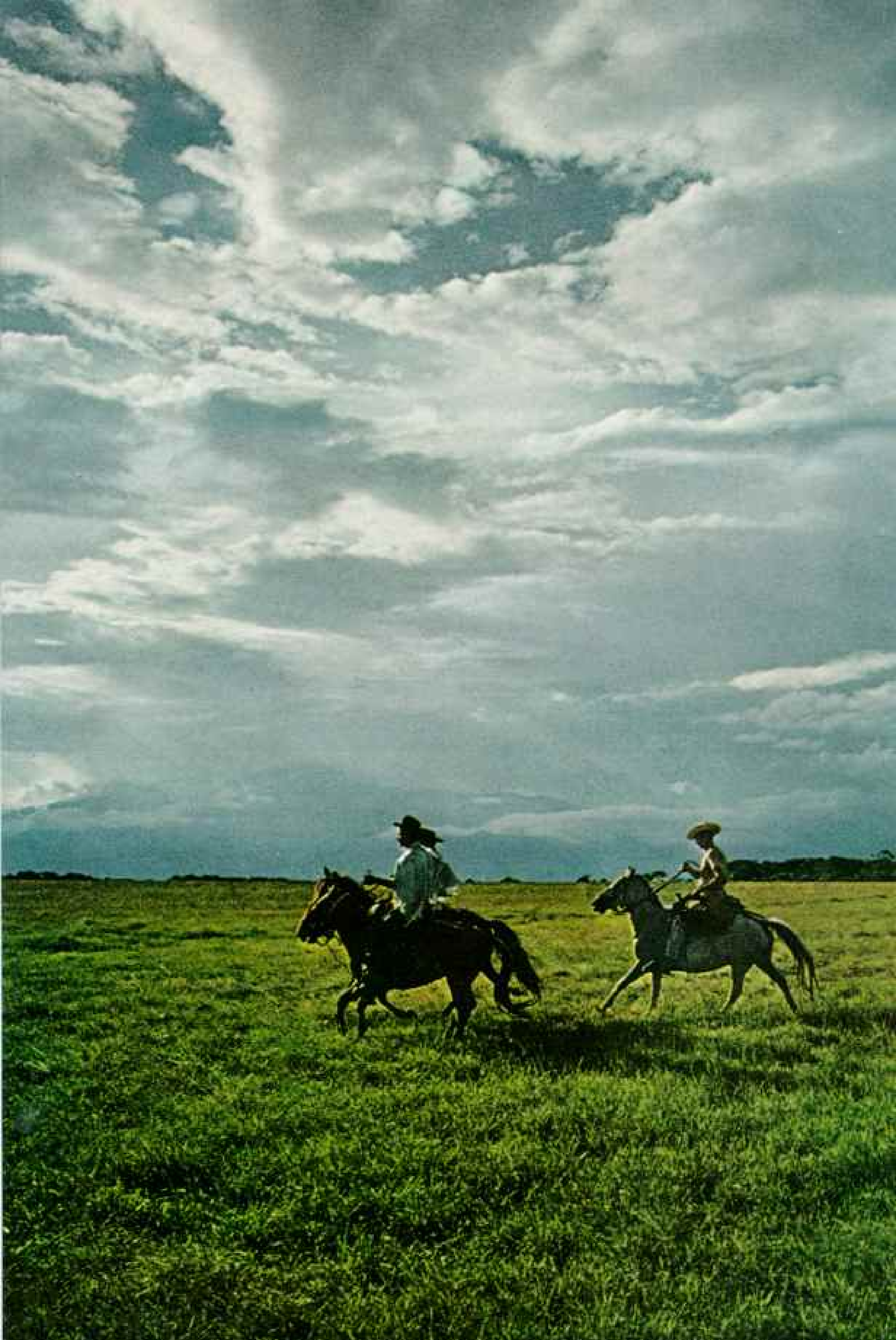
These rays tell us much about the nature of the corona. The streamers' great length convinces me that interplanetary dust contributes little to the brightness of the outer corona, and that the role of dust has been greatly overestimated. This evidence has enormous significance in our quest to learn how much of the light we see comes directly from the sun's outer atmosphere and how much results from reflection by particles in space.

The answer to this question, and others, would have immediate application. For example, we must learn what we can about the solar wind, the outer corona blowing by the earth. Further, if a major blast of protons from a solar flare were to strike an astronaut, the effect would be much the same as would be caused by radiation from an atomic blast. Most important, eclipse studies also help us to understand the sun itself.

The final fiesta at Miahuatlán, overflowing with joy and gratitude for completely successful expeditions, lingers in our thoughts as we ponder the test results at our observatory. Even the people of the village—some of whom had expressed misgivings about the entire affair—seemed reassured now that the crisis had passed. Though missionaries had tried for weeks to calm the Indians, many clung to the belief that the sun and moon would "bump" and be lost forever.

At least one senior citizen actually relished the experience, however. A Mexican colonel assigned to Miahuatlán explained later, "This wise old man of the village said that he enjoyed the festivities and excitement, and wondered if you couldn't make the eclipse an annual affair."

We wish we could.



"OVER MY HORSE, only I; and over me, only my sombrero," rings the creed of freedom-loving cowboys of Colombia's wild, wild east. Ancestors of these plainsmen fought beside Simón Bolívar in 1819 to free the country from Spanish rule. KODACHROME © N.G.S.

FROM AMAZON TO SPANISH MAIN

Colombia

Article and photographs by
LOREN McINTYRE

Colombia, from Amazon to Spanish Main

I HAD COUNTED more than 60 varieties of moth around a ceiling bulb when the bunkhouse began to resonate to a throb of helicopters. I ran to join the Trans-Andean Pipeline gang on the porch.

A hint of equatorial dawn sharpened the skyline of forest surrounding the jungle camp. Far off, red and green navigation lights bobbed through cloud tendrils that touched the forest crown. At hand, along the 2-by-4 porch railing, a few votive candles sustained the Immaculate Conception vigil observed throughout Colombia the night of December 7.

Pipeline Men Commute by Helicopter

The column of helicopters blustered into the compound, blowing the hard hat off a welder's head. The candles went out.

As aircraft skids touched ground, workmen scrambled on board with lunch boxes and water jugs to begin their daily trip into primeval wilderness to lay an oil pipeline from eastern jungle to western ocean.

"Ride shotgun with me," George Mann, an American construction superintendent, shouted in my ear.

We crowded into the chopper from which he supervised traffic from Amazon tributaries to Andean summits, a 35-mile stretch supplied entirely by air. A placard on the instrument panel claimed that the helicopter had a world record of 14,209 flying hours.

"You'll be spoiled for flatland flying," George predicted as we lifted toward cloud-mantled mountains. "And once you've flown with Sanchez, no other pilot will do."

Both predictions came true by sunup. Capt. Alvaro Sanchez, a Guajiro Indian born on the Spanish Main, handled the helicopter as if it were wired into his nervous system. He veered into a gorge, sinking almost into the spume of the rapids. He bored upstream just under low cloud, fanning foliage on both sides.

The pipeline snaked up the Andes. We followed it. We perched on cliffs to discharge workmen. At an ugly slide where five men had fallen 1,300 feet into the river (page 238), a clump of trees rumbled down toward us, riding upright on an avalanche of boulders. With Red Baron aplomb, Sanchez whisked us out of danger and cranked straight up to 9,000 feet, where hailstones bombarded our hull.

While other helicopters hauled cabins, bulldozers, and bridges into the rain forest, we picked pipe off a stockpile. We darted out of a cloudburst like a hummingbird in a waterfall, carrying in our bellyhook a one-ton tube 43 feet long to welders who were coupling sections of the $52,000,000 pipeline. It runs from the oil wells near Orito to the seaport of Tumaco, in Colombia's southwest corner (map, page 241).

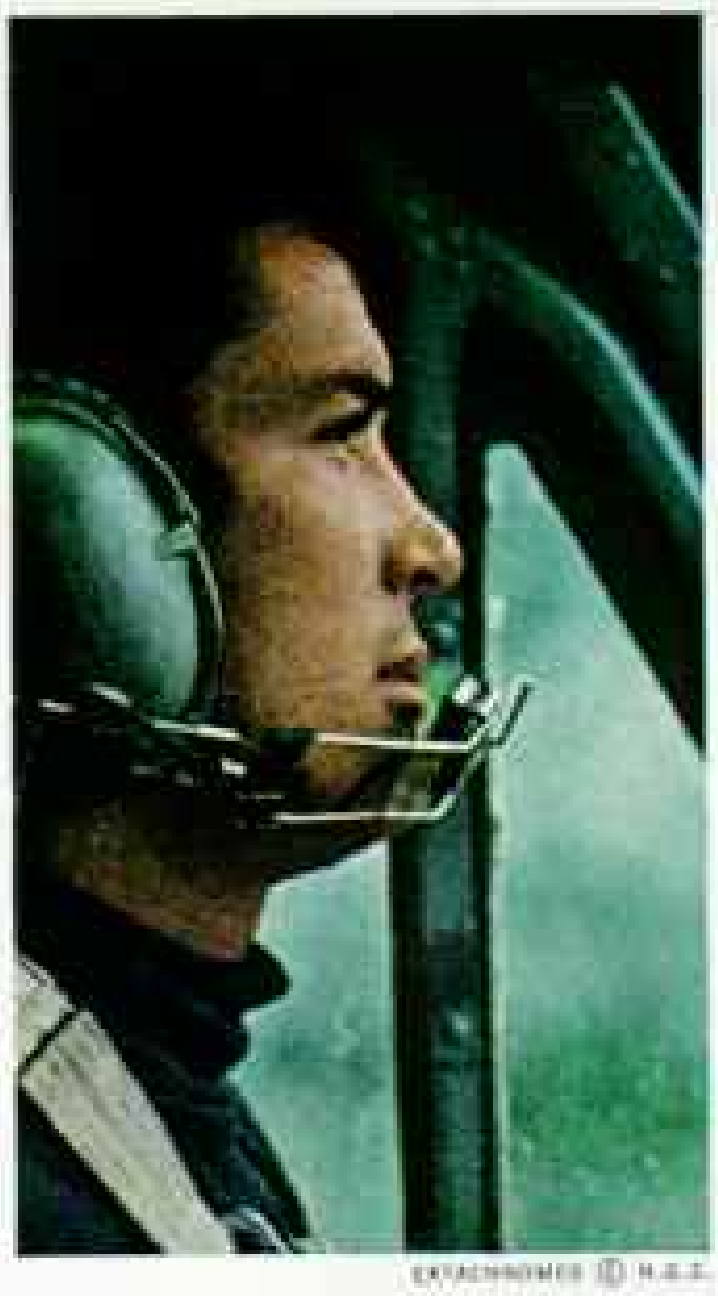
More than 300 miles northeast, in Bogotá, my wife Sue awaited my return from the oilfields—one of the few places too rugged for her to accompany me during our 18,000 miles of travel throughout Colombia. As I flew to the capital via Colombia's Avianca (founded in 1919 and the oldest civil airline in the Americas), I reflected on aviation's role in unifying this once-disjointed country. Bogotá, an admirable base for our forays by car and plane to all corners of Colombia, used to be as secluded as Samarkand.

The first European to reach that high Andean plateau had a terrible trip. Gonzalo Jiménez de Quesada arrived in 1537 from the Spanish Main with 166 survivors of an 800-man expedition up the Rio Magdalena, the country's main waterway. He was looking for El Dorado, but failed to track down "the Gilded One" (page 249). After conquering the settlements of the Chibcha Indians, Quesada staked out a town called Santa Fé de Bogotá. He later became marshal of the New Kingdom of Granada, a realm that ultimately approximated present-day Colombia, Venezuela, Ecuador, and Panama.

Lofty Capital Bristles With Skyscrapers

Beneath my plane the vast billows of the Andes flattened. Strewn at the foot of a final swell lay Quesada's town (pages 242-3), now numbering two and a half million people, loftiest of the world's great cities at 8,660 feet altitude. Really over 9,000 feet, I thought, trying in vain to count all the skyscrapers I could see as we banked to land. Then Eldorado welcomed me with a free cup of 100 percent Colombian coffee. "Eldorado" is the name given the jet airport.

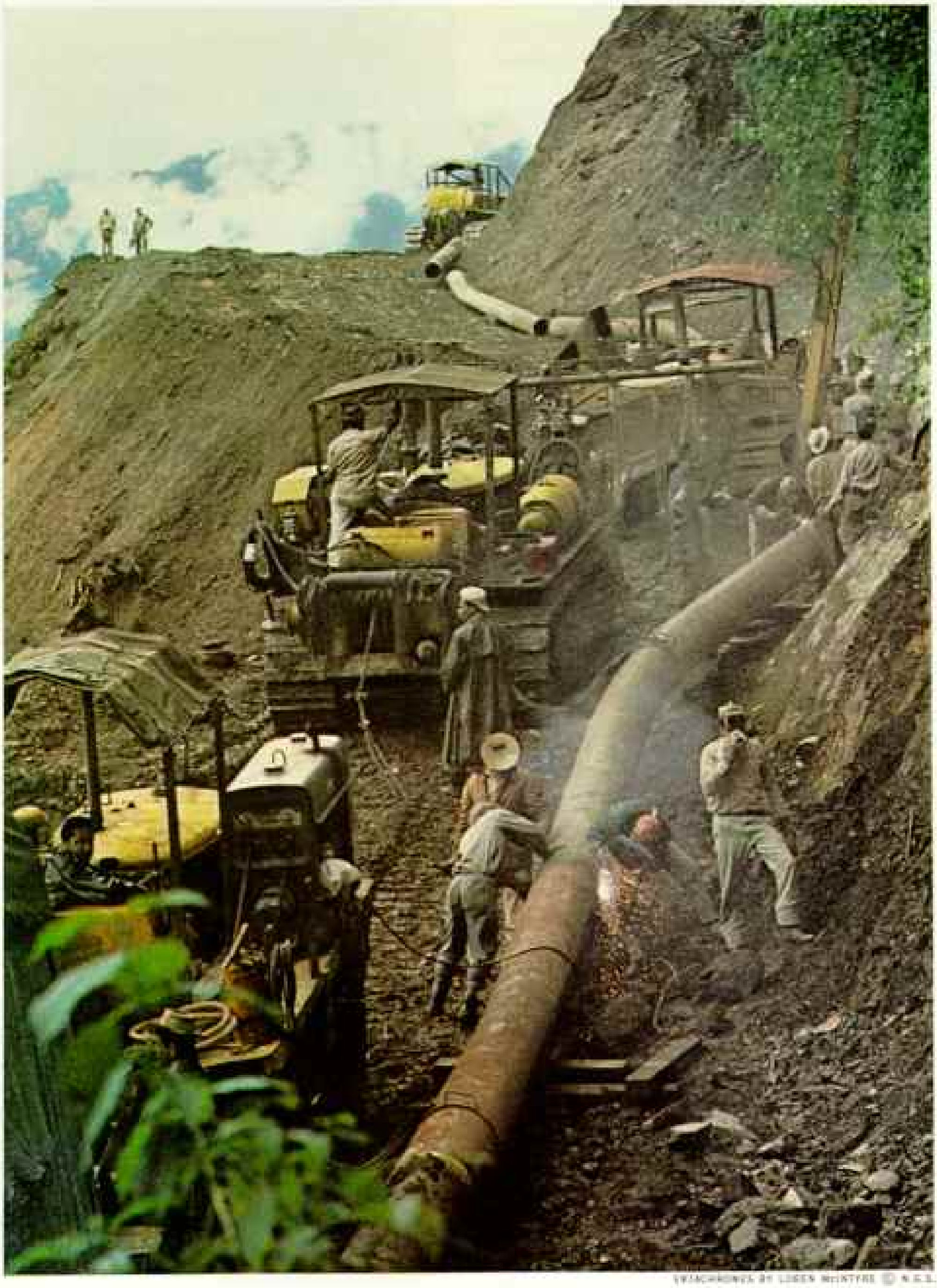
Whizzing along the freeway into town, I recalled how Bogotá used to depress visitors with bleak buildings, xenophobic stares, drab ponchos, abandoned children sleeping under newspapers in downtown doorways, and news stories of rural murder and urban



EXACTNOMICS © N.G.S.

Leapfrogging the Andes, a Colombian pilot jockeys his helicopter along razorback ridges and rapids-choked gorges during construction of an oil pipeline across some of the world's most awesome terrain. United States companies—Texaco and Gulf—completed the conduit last year to move 100,000 barrels of crude oil a day. The 194-mile line connects the Orito oil fields on the eastern slope of the Andes to the Pacific terminal of Tumaco (map, page 241).

Choppers flown by Colombians ferried workers and tons of tractors, cabins, and pipe to otherwise inaccessible sites. Flying commuters swing down the Guamués River (right) to a base camp after working 12 hours on the line. Forested 11,000-foot ridges, rainfall as high as 29 feet a year, landslides, and six rivers to cross created what professional pipeline builders called "our most difficult job—anywhere."



Crossing the "impossible" cliff

SPECKS on the shoulder of the 1,300-foot scar (opposite) resolve into men and machines laying an oil pipeline (above). When crews cut a slanting traverse on the far left of this precipice above Rio Sucio (Dirty River), earth slides tore it away, taking five lives. Finally, bulldozers dug across nearer the top.

Welders tie in 43-foot-long sections of pipe; X-rays check their work. Machine in the distance bends pipe to fit the curves. Cables linked tractors in pairs for safety.

Colombia's oil exports rank second only to coffee in value. Foreign-developed oil concessions revert to the government at the expiration of 40-year leases.

destruction. But smiles, mini-skirts, and the sheen of prosperity dispelled my outdated memories. Old buildings had been scrubbed for Pope Paul's visit in 1968, and new construction sparkled. Dusty provincial stores had yielded to smart shops.

I found Sue at her favorite haunt, the Gold Museum, looking at a magnificent exhibit of pre-Columbian art. She had talked curator Luis Barriga into letting her handle an emerald as big as her fist (page 249).

"This 1,796-carat gem used to be kept in a cigar box," said Dr. Barriga. The current receptacle is a luxurious bank vault that visitors enter in darkness. Softly a glow begins to illuminate displays of the best of some 13,000 gold artifacts that escaped being melted down by Spanish conquerors.

Bank Has Many Interests

The Gold Museum was built by the Banco de la República, surely the world's strangest bank. The bank not only is the repository for the nation's currency, but it also engages in cultural and philanthropic activities that amazed us.

"The bank buys period art, prints books as well as money, and has helped restore historic sites," explained Dr. Barriga. "Its Luis-Angel Arango Library houses an art gallery and concert hall. Until this year, it managed the nation's salt resources, and thus was custodian of the enormous Salt Cathedral, a temple established in an underground salt mine at Zipaquirá, near Bogotá. Its projects include six hundred water wells for nomads in the desert of the Guajira Peninsula" (map, opposite).

He showed us a cast gold figure of a ruler with his entourage on a ceremonial raft (page 248). "This treasure—we acquired it last year—suggests that the local Chibcha legend of El Dorado wasn't simply a tale concocted to delude the conquistadors. The Chibchas dusted their king with gold and rowed him out on Lake Guatavita, near Bogotá. Then he submerged himself and rinsed off the gold, while his subjects threw in offerings of gold objects and emeralds as sacrifices to the god of the lake."

The new Gold Museum, Banco de la República, and 38-story Avianca Building flank Parque Santander, a monument to Colombia's first republican statesman and jurist. Francisco de Paula Santander helped organize Simón Bolívar's successful 1819-1822 campaign to free Colombia, Venezuela, and Ecuador from

Pre-Columbian stone idol glowers in a park at San Agustín, southwestern Colombia.

Mighty mountain spine bisects a land of lofty plateaus, river-veined jungles, and warm shorelines. The Trans-Andean oil pipeline, a major engineering feat, crosses the mountains near the border with Ecuador.

Colombia

LAND OF COFFEE, oil, emeralds, and gold, South America's fourth largest country—after Brazil, Argentina, and Peru—touches the Pacific Ocean, the Caribbean Sea, and the Amazon Basin.

Wracked for a decade by banditry and undeclared civil war, the nation adopted a coalition government in 1958 and enjoyed a dozen years of freedom from political strife. Economic growth of 6 percent a year encouraged foreign investments. The coalition, however, narrowly escaped defeat in the elections last April 19.

AREA: 439,735 sq. mi. **POPULATION:** 21,100,000. **LANGUAGE:** Spanish. **RELIGION:** Roman Catholic. **ECONOMY:** Agricultural. Exports coffee, oil, cotton, sugar, bananas. **MAJOR CITIES:** Bogotá (pop. 2,500,000), capital; Medellín, manufacturing; Cali, trade center.


Caribbean Sea
Pacific Ocean
Bahía Honda
Punta Gallinas
Cabo de la Vela
Península de la Guajira
Manaure
Riohacha
Sierra Nevada de Sta. Marta
Puerto Estrella
Castilletes
Golfo de Venezuela
Punta Cardón
Aruba
Curaçao
Bonaire
Netherlands
GUAJIRA
Santa Marta
Ciénaga
Barranquilla
Ciénaga Grande de Magdalena
Cartagena
Arjona
Fundación
Valledupar
Atánquez
Maracaibo
Rosario
Lago de Maracaibo
Punta Barú
Ariguaní
Plato
San Onofre
Codazzi
CESAR
Golfo de Morrosquillo
Lorica
Coveñas
Sincelejo
Magangué
Mompós
El Banco
San Carlos del Zulia
Montería
Planeta Rica
CÓRDOBA
Acandí
Turbo
Caucasia
Ocaña
Cúcuta
San Antonio
San Cristóbal
PAN AMERICAN HWY
Riosucio
Mutatá
Puerto Wilches
Pamplona
Barrancabermeja
El Playón
Bucaramanga
Jurado
Dabeiba
Yarumal
ANTIOQUIA
El Amparo
Arauca
VENEZUELA
COLOMBIA
Cupica
Golfo de Cupica
San Gil
Tame
Puerto Rondón
Socorro
Soatá
Bello
Medellín
Puerto Mutis
CHOCÓ
Envigado
Hato Corozal
El Caimán
Puerto Páez
Puerto Carreño
Golfo de Tibugá
Bolombolo
Sonsón
Chiquinquirá
Paz de Río
Sogamoso
Puerto Nuevo
Puerto Ayacucho
Quibdó
Tunja
Yopal
Trinidad
BOYACÁ
Maipures
Bajo Baudó
Manizales
Zipaquirá
Sémondoco
Maní
Pereira
Orocué
El Porvenir
Agua Clara
Sucuaro
Armenia
BOGOTÁ
Ibagué
Girardot
Pta. Charambirá
Tuluá
Espinal
Villavicencio
La Esperanza
Buga
Buenaventura
San Martín
Chaparral
Cali
Palmira
Puerto Tejada
Uribe
Cerro Rabón
I. Gorgona
Santander
Neiva
Campoalegre
San José del Guaviare
Cejal
Victorino
Guapi
Mosquera
Popayán
La Plata
Mosquitos
Loro
El Tigre
Garzón
San Vicente del Caguán
San Felipe
Isla del Gallo
Pitalito
San Agustín
Puerto Rico
Florencia
VAUPÉS
Tumaco
Laguna Cuyarí
Palo Negro
Miraflores
Yavarate
Tuquerres
Pasto
Mocoa
Ipiales
Whiskey
Tío Barbas
Mitú
Tres Esquinas
Tulcán
Ibarra
Acaricuara
Iparana
ECUADOR
Mabujer
Taraquá
QUITO
La Tagua
EQUATOR
Puerto Leguízamo
El Refugio
COLOMBIA
Latacunga
Nuevo Rocafuerte
Pantoja
Ambato
PAN AMERICAN HWY
Chimborazo
Cononaco
Bellavista
Santa María
Abisinia
La Pedrera
Vila Bittencourt
Barras
Puerto Carlos
Arica
Macas
ECUADOR
PERU
CARTOGRAPHIC DIVISION
NATIONAL GEOGRAPHIC SOCIETY
Puca Urco
Santa Clara
BRAZIL
0 50 100 150 200
STATUTE MILES
Vidal
PERU
Puca Barranca
Puerto Copal
Santa Rosa
Puerto Socorro
Santo Antônio do Içá
Roads
Railroads
Airfields
Elevations in Feet
Oil Pipelines
Pebas
Mazán
Iquitos
Loreto
San Mateo
Caballococha
Leticia
Benjamin Constant
Ilha Aramaná
Nueva Esperanza
Borja
Concordia
Nauta
PERU
BRAZIL
Amazonas
Solimões (Amazon)
Providencia
San Andrés
CANAL ZONE
PANAMÁ
Caribbean Sea
Antilles
Caracas
VENEZUELA
Georgetown
Bogotá
COLOMBIA
Pacific Ocean
Quito
ECUADOR
PERU
BRAZIL
Manaus
ANDES
76°
72°
68°
12°
8°
4°
0°
4°

Reaching for the sun, skyscrapers sprout amid red-tile roofs in the mountain-ringed capital, Bogotá. In the 1960's the city mushroomed, spurred by industrialization. It underwent feverish renovation

and road improvement in 1968 in preparation for Paul VI, the first Pope to visit South America. One out of every two Colombians lives in an urban area; 20 cities have surpassed the 100,000 mark.

Spanish rule. The venerable Plaza de Bolivar is bigger, as befits the stature of the Liberator.

Bolivar tried to weld the former Spanish colonies into a union he christened Gran Colombia. Venezuela and Ecuador dropped out, leaving Colombia weakened. Resistance to attempts to centralize authority led to murderous political conflict and made a travesty of national life. This and geographical barriers abetted the rise of cities—today a score exceed 100,000 population—and denied Bogotá the monopoly of wealth and power possessed by most Latin American capitals.

Not until 1886, after six changes, did the nation finally settle on its current name—Republic of Colombia—and write the constitution that has survived to the present day.

Partisan animosity persisted, leading to insurrections and civil wars, including the War of a Thousand Days, from 1899 to 1902, which took 100,000 lives. A period of calm followed, but underlying political dissension erupted again in 1948, when the assassination of a political leader during a major inter-American conference in Bogotá incited the *bogotazo*, an event with cataclysmic significance in Colombia. Mobs destroyed the business district, provoking an epidemic of carnage. In the provinces partisan villages eliminated one another hideously. Whole families, including infants, were butchered. Rural war lords set up independent "governments." Terrorists like Tiro Fijo (Sure Shot) became local folk heroes to some, folk horrors to most.

Dispossessed peasants fled to cities, creating slums and swelling Colombia's urban population to more than 50 percent. Countless orphans, called "children of violence," scavenged town and countryside committing mindless vandalism. In less than a decade, "la violencia" brought death to more than 100,000 citizens.

Hatred Gives Way to Progress

For a dozen years, however, Colombia has had a stable government, and I traveled by day and by night without fear. From Bogotá Sue and I ranged north to the Spanish Main and west to the Pacific shores. We followed the Andean ranges northeast to Venezuela and south to Ecuador. We flew into the grasslands covering the eastern third of the country drained by the Orinoco River. We canoed into the jungle of the southern third drained by the Amazon.

"Energy once wasted on hate has been channeled into growth in recent years," remarked our old friend Marvin Weissman, who heads the Colombian program of the United States Agency for International Development. "Exports are catching up with imports. Gross national product is jumping 6 percent a year."

In 1958 an elected government replaced the dictatorship of Gen. Gustavo Rojas Pinilla, and Colombia moved rapidly from grisly chaos to laudable achievement. What enabled the republic to attain a dozen years of peace and progress? I asked Alberto Lleras Camargo, twice President of Colombia and for seven years Secretary-General of the Organization of American States, a writer-editor of immense prestige throughout the Americas.

Mark of a vote cast, an index finger dipped in indelible red ink prevents a citizen from voting more than once.

High tension of last April's presidential election shows in the faces of voters as a supporter of Gen. Gustavo Rojas Pinilla casts her ballot. Her *ruana*, or poncho, bears pictures of him and his daughter, who managed his campaign.

Dictator of Colombia from 1953 to 1957, the 70-year-old Rojas gained support by promising jobs, land, cars, lower taxes, and more services. Narrowly defeated by Misael Pastrana Borrero, Rojas claimed fraud and threatened violence. The government temporarily imposed martial law.

He answered with a line from Colombia's national anthem: "'*En surcos de dolores, El bién germina ya.* In furrows of pain, Good now germinates.' I offer four reasons for our progress." He ticked them off on his fingertips.

"A coalition government of Liberals and Conservatives that alternates presidents every four years; reassertion of government presence, in humane ways, throughout the republic; better education and communications; and the emergence of a top-notch young managerial class in government and industry."

Dr. Lleras didn't mention a critical fifth ingredient of national well-being—himself. As protagonist of the Liberal-Conservative alliance, he engineered the coalition which supplanted the Rojas dictatorship. As first president, from 1958 to 1962, he led his country out of anarchy.

But the coalition government, intent on long-range planning, neglected grass-roots politics, and its presidential candidate, Misael Pastrana Borrero, nearly lost the 1970 election. The ex-dictator Rojas, promising jobs, land, and lower taxes, almost regained the presidency via the ballot box. The government had to exert firm measures—martial law and a curfew—to prevent urban violence by the aging general's disappointed followers.

Nevertheless, the coalition's achievements have been considerable. One of its officials offered us a swift survey of his agency's

projects in the south. The offer was realized with astonishing efficiency, like every plan of 40-year-old Enrique Peñalosa, then director of INCORA, the *Instituto Colombiano de la Reforma Agraria*. Enrique and his deputy, Carlos Villamil, picked us up at daybreak.

We watched green mountainsides unroll beneath the plane. Enrique said, "That Kikuyu grass was imported from Kenya. It keeps our soil from sluicing down into the Amazon." He pointed out a town. "That's El Paujil. When INCORA went in there seven years ago, they threatened to lynch us. Now they fete us. The banquets are unbelievable."

We landed at Florencia on an Amazon tributary and jeeped 70 miles to visit new colonies. The highland population was flowing into lowlands cleared of jungle. INCORA was providing facilities and issuing titles. Though our stopovers were unannounced, brass bands came running like volunteer fire departments. White tablecloths appeared. Champagne corks popped. Everyone—even I—made spontaneous speeches lauding pioneer virtues and self-help.

Enrique carved a slice of meat from a corn-stuffed whole roast pig. "INCORA titles revert to the state if farmers quit their land," he told us. "That thwarts land seizure by terrorism, once a cause of rural violence in overpopulated regions."

On we flew to the muggy Pacific coast, where most of the people are black. Our pilot poked through overcast so sodden that sea and sky and the coastal rain forest seemed to merge. He ranged up and down a mangrove maze and finally found Guapi amid a network of rivers and salt estuaries.

Exploding Population Requires Land

We boated 20 miles upriver to visit INCORA-sponsored homesteader Victoriano Cuero and family, who dwelt in a makeshift tent in a tangle of mangrove roots. They had no house; Victoriano's first efforts had been to dig drainage ditches and plant coconuts and yucca to amortize his INCORA loan. At night the family slept in the rain under sheets of pastel plastic.

"Such hardships may seem absurd," said Enrique. "But we've got to salvage every acre to stave off mass starvation—at least until the birth rate levels off. Public health measures caused a giant population increase before agriculture was geared to nourish so many people."

Carlos added, "You may doubt it when you see so much empty land, but the population explosion is our number-one national problem. Today we have 21,100,000 people—about as many as Canada on 11 percent of its area. In 80 years we'll have as many as the United States has now. By 2070 there will be 300 million Colombians—if the current rate of increase isn't slowed down."

In Tumaco I broke away from our group to do a little exploring on my own. I'd long wanted to visit Isla del Gallo—Isle of the Rooster—scene of Pizarro's bold decision in 1527 to press on with the invasion of the Inca empire. The island hid in the mist offshore. Along the mangrove coast some said the island's sole inhabitant was a sorceress.

Jovita Deals Two Whacks to Remember

I navigated a dugout across 12 miles of riptides, beached it, and approached a solitary dwelling perched on stilts in a coconut grove. Suddenly a barefoot white-haired Negro woman jumped out of a thicket and whacked the seat of my pants with the flat of a machete.

I gasped, dumbfounded. The old lady drew back and laughed.

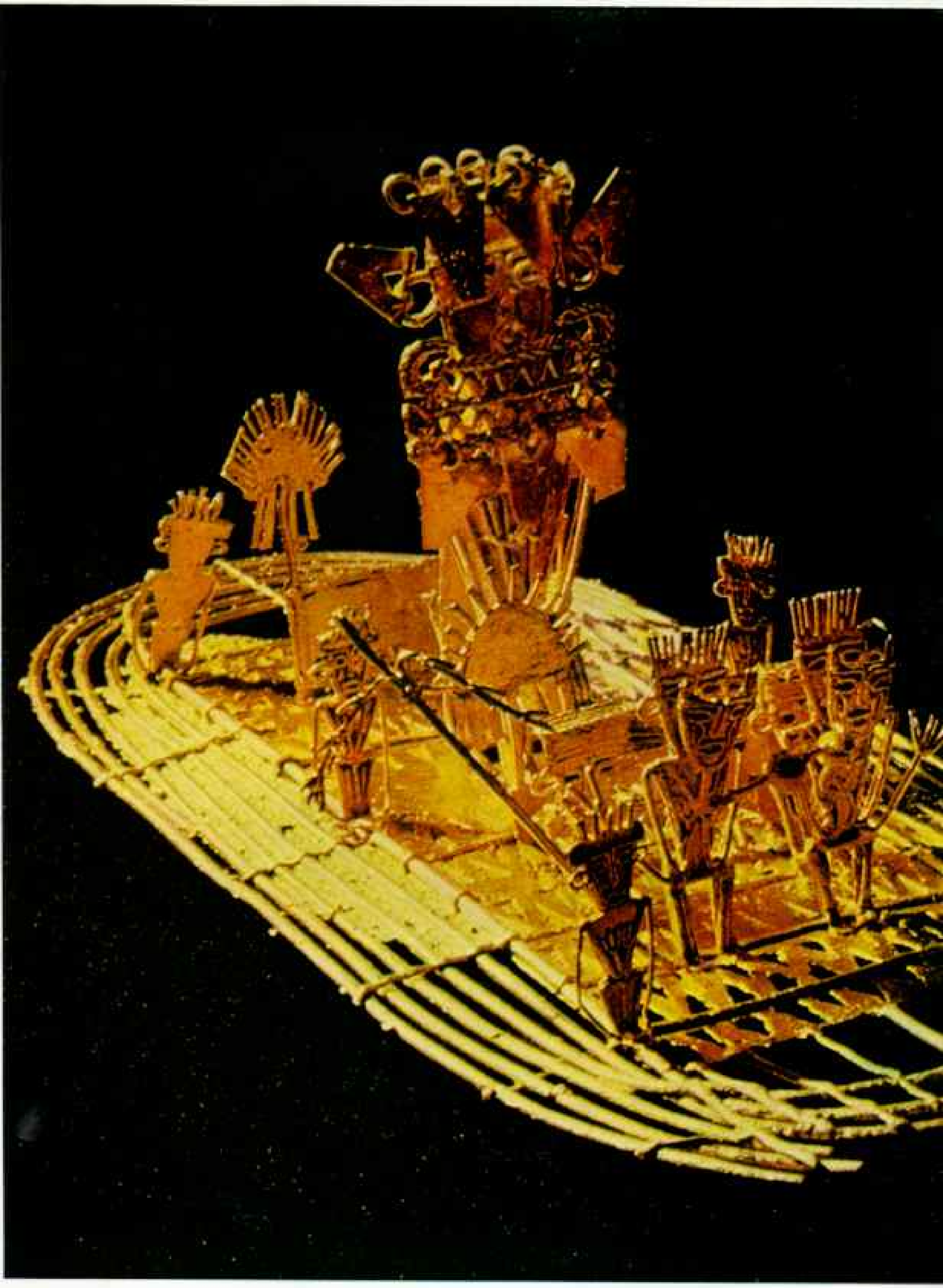
"Now you'll never forget Jovita." She squinted at my cameras. "So you've come to take pictures. Good. There's not much time left. I'm 84. I'm going to die next year."

I followed dutifully as Jovita led me along black beaches and white beaches, past patterned driftwood, through humid jungle, and into secret caves. I asked if she was really a sorceress. She admitted to a knack for cures.

Until 1906, she told me, there was a village on the island. Then a tidal wave swept it away. She was one of the few survivors.

Jovita ran into the surf until the Pacific Ocean lapped at her skirts. "Here Pizarro landed!" She strode ashore, brandishing her machete (opposite), re-enacting her own

"Here Pizarro landed," shouts Jovita de Mosquera, brandishing a machete like a Spaniard's sword. Sole inhabitant of the Isla del Gallo, she portrays the conquistador who here in 1527 determined to pursue his search for gold. Drawing a line on the sand, Francisco Pizarro challenged his men to cross it to the fabled riches of Peru. Within six years his band had crushed the mighty Inca empire, which reached north to southern Colombia.

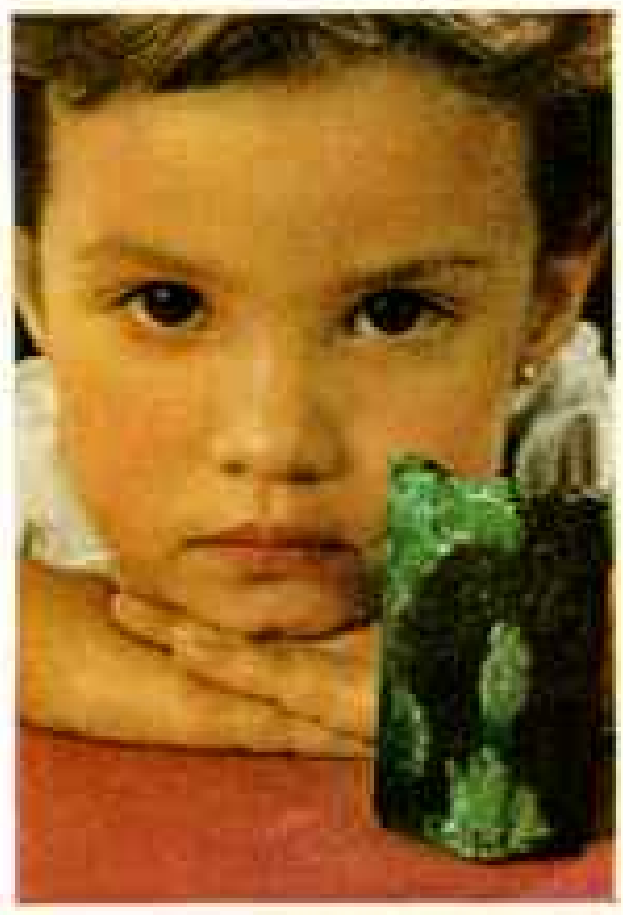


KODACHROMES BY LOREN McINTYRE © N.G.S.

El Dorado's glory

THE DREAM of a fantastic city of gold shimmering just over the horizon spurred the Spanish to conquer a continent. The fantasy grew out of a solemn ritual of Colombia's Chibcha Indians; an ancient artisan depicted part of the ceremony in this seven-inch-long gold raft (left).

The Chibchas dusted each new king with powdered gold and cloaked him with decorations. Attendants, facing away from the royal person, rowed him into Lake Guatavita, near Bogotá. There the sovereign submerged momentarily, washing away his bright covering as a sacrifice to the god of the lake. Subjects tossed in offerings—gold objects and emeralds from the mines of Muzo and Somondoco. As men retold the story, this El Dorado, or Gilded One, "resplendent as the beaming sun," came to symbolize a metropolis of infinite riches.



No such city appeared, but eager Spaniards found wealth in the plunder of Indian temples, homes, and tombs. They melted ornaments into ingots and sent them to the coffers of Spain—a bounty worth billions. Yet secret hoards escaped the ravage. Only last year hunters found the golden raft in a cave. The Banco de la República displays the work in its Gold Museum, a stunning collection of 13,000 objects. Among them: a chief's wafer-thin dangling gold earrings, shown by a museum guide (top), and one of the world's largest gem emeralds, weighing 1,796 carats (above).

Colombia has long led South America in gold production and the world in emeralds. Other minerals hold promise: iron, coal, and limestone deposits feed the Paz de Río steel mill; oil, silver, lead, and platinum contribute to the economy.

version of the historic moment, and announcing, "I take possession of this land in the name of the King of Spain!"

At her house a woodsman from the mainland lay in a hammock recovering from a snake bite. Jovita had been treating him.

She revealed two neatly folded flags that explained her awareness of island history. One Colombian, one Peruvian, the flags had been hoisted over a small monument erected to Pizarro during a bi-national visit of warships in 1965. Jovita, as the island's only resident, had been left in charge of the flags.

She hid the flags to prevent theft by beachcombers, but kept a seaward watch, ready to run out and hoist the colors when the vessels returned. I wondered who would guard the flags if Jovita died at age 85, according to plan.

The tide had gone out. When I bent to launch my canoe, Jovita belted me on the rear again with the flat of her machete.

"Remember me!" She waved.

President Logs Back-country Mileage

Soon after our return to Bogotá, I came to know President Carlos Lleras Restrepo, who told me his most profound wish was "that all Colombians—not just pressure groups—participate in decisions affecting their destiny."

He was bound for Monteria, near the Caribbean, to put his wish to work. I joined him aboard the presidential plane as he and several cabinet officers headed north to inaugurate a cattlemen's convention, then tour the countryside by helicopter. The president averaged 25 trips a year to outlying districts.

"Perhaps my visits help make people aware of their citizenship and ease the harshness of their lives," said President Lleras. He pointed out the window. "Those new roads will bring many into the mainstream. I hope they lead not only to prosperous markets but also to equality under a just government."

Back in Bogotá, Sue and I decided to make a month-long swing along the eastern highways to the mountains and seashore of the Caribbean coast, over the western Andes through Medellin to the coffee zone, then back to the capital (map, page 241).

We began by following a progression of market days deep into the Department of Boyacá. These social, commercial, drinking occasions fall on different days of the week in Tunja, Chiquinquirá, Paipa, and neighboring mountain towns. We bargained for toy tops of wood, for a guitar-like Colombian *tiple*, and for miniature chess sets carved of palm nuts. In Ráquira we bought ceramics portraying artisans making ceramics. Sue tried on a *ruana*, the Colombian poncho.

Boyacá's paved highways follow the campaign trail of Simón Bolívar, whose winning streak began in 1819 at the Bridge of Boyacá, near Tunja. Side roads lead to towns which are virtual museums of colonial Colombia. Major film producers use Leiva, for example, for colonial sets just as it is. Its hotel is a remodeled 400-year-old mill where breakfast begins with cream-of-herbs soup served by chapped-cheeked Indian maidens.

Zigzagging northward, Sue and I rolled into helplessly hot Valledupar, one of the fastest-growing cities in Colombia. There we joined my Ecuadorean mountain climbing companion, Rómulo Pazmiño,* who had arranged to accompany me in an attempt to set foot on the highest ground in Colombia.

Sue drove on alone 155 miles to see the annual Sea Festival at Santa Marta, Colombia's oldest city. Rómulo and I jeeped to a foothill village, Atanquez, and hired a pair of mules to lug our gear into the Sierra Nevada de Santa Marta. The range rises in isolation from the Andean chain, bounded by scorched plains and the Caribbean Sea. The only way to reach the lakes and snows of this largest of Colombia's national parks—half the size of Delaware—is on foot or on mule.

The valley sizzled under the sun. Thirst tormented us. Luckily, a few rivulets crossed the trail. Higher up, we showered under waterfalls. The screech of wooden gears from an unseen sugar-cane mill haunted our ascent from the Guatapuri River to the crest of a 6,700-foot ridge. Birdcalls beckoned us down the other side to the Donachui River Valley where the trail was littered with ripe mangoes and hundreds of big buttery avocados.

Tribute Demanded by Indians

At Donachui, a cluster of mud huts, Arhuaco Indian braves—dressed in robes and tall hempen caps—scowled as we pitched camp. Their red-dyed and curled hair fell below their shoulders (page 255), and they carried narcotics kits of coca leaves and lime.

In the morning, Arhuaco chief Apolinar Torres, machete in hand, demanded tribute before we could proceed to the "sacred" snows. Mindful that the summits, first climbed in 1939, had been scaled only half a dozen times

*See "Ecuador—Low and Lofty Land Astride the Equator," by Loren McIntyre, NATIONAL GEOGRAPHIC, February 1968.

since, Rómulo queried, "What do you do for money when no climbers pass by here?"

Apolinar pointed his machete at an ox being loaded with mangoes and avocados. "We sell those fruits in Valledupar."

A week's travel on oxback to and from market. "For how much?"

"Fifty pesos a thousand."

Three for a penny—for giant avocados worth a fat sum in U. S. markets! I paid tribute equal to 3,000 avocados.

Through dense forests and cold rain, we climbed to Meollaca, highest village of the pigmy-size Kogi Indians. The populace fled at our approach. Offers of medical aid lured some back. The tribal medicine man gave us shelter in return for our promise to stay away from the totem lodge.

Above the timber line, beyond spongy meadows bordered by talus, our trail ended at a necklace of glacial lakes higher than the Matterhorn. While we made base camp, altitude sickness—nausea and headaches—leveled both of us.

Snowstorm Catches Climbers at Summit

Next day Rómulo scaled a nameless pinnacle to map our route up Cristóbal Colón (Christopher Columbus), 18,947 feet high. Heartened by granite far safer than the ash of his native volcanoes, he declared we could reach the summit in one day without making a high camp—a risky tactic in the September rains and snows.

On September 10 we started up the talus at 2 a.m., reaching ice by daybreak. A condor spiraled up for a look at us. Hour after hour we roped up the southeast face of Colón. Twice we were blocked by neck-deep drifts that had to be cleared so we could chop footholds in underlying ice. We marked crevasses with flags and worried about avalanches.

A sudden snowstorm blotted the sky. A gale drove us to our knees as we clawed toward the highest point. At 4 p.m. we drove our ice axes into the summit of Cristóbal Colón, highest point in Colombia, just 22 miles from sunny Caribbean shores.

Wind erased our tracks. We followed our flags down in utter darkness and 10 inches of new snow. We stopped and huddled under a poncho to wait for the full moon to show us our way. Within two hours, violent shivering gave way to drowsiness. Rómulo and I quickened to the danger of freezing to death and roped on down with failing flashlights.

A midnight moon broke through, unveiling

In tune with a carefree day, Laura Obregón sunbathes on a schooner designed by her father, a Bogotá architect. The family sails off Cartagena, resort center of Colombia's 660-mile coastline on the Caribbean.

EKTACHROME (FOLLOWING PAGES) AND KODACHROME BY LOREN MCINTYRE © N.G.S.

Radiance of an ancient god, according to the Incas, a rainbow ends near the church of Cajicá (following pages). Most Colombians are Roman Catholics, but some Indians cling to aboriginal beliefs.

a totally white, unrecognizable world. We stumbled homeward, falling often but without injury, somehow avoiding dead ends. At 3 a.m. we flopped into our tent after 25 hours on the mountain.

We slept all day; then, deciding to try once more for better pictures, we picked the most photogenic peak, La Reina (page 257).

My log, September 12: "Assaulted La Reina (The Queen), 18,271 ft. high. Lovely but distant, 7 hrs. away. Long glacier seems easy ramp to summit. But Rómulo objects to crevasses, claims, 'I'm too young to die deep-frozen in foreign fissure.' Detours up right-hand ridge, guaranteed avalanche-free when on top. Razor edge, honed by wind. Loose snow, crampons clogged. Rómulo ecstatic, McIntyre qualmish. If we slip left, we plunge to glacier; if we slip right, we skydive 2,000 ft. w/o chute. Hope Sue's enjoying Santa Marta water-ski show.

"Summit comfortably flat, though 3 sides sheer. Snowstorm again! Nasty descent. Slipped once on knife ridge, sprawled, embracing Queen with vast longing. Unrequited. No moon. Down, down. Blundered into lake. Which lake? Argued 1 hr. over map, compass. Then tripped over tent, buried in snow, only 50 ft. away. Rómulo froze toe, probably 1st in history within sight of Caribbean."

His skill makes metal sing: Near Sogamoso, Feliz Montaño shapes clay molds for the casting of bronze church bells by a secret family formula. "Once when I cast a bell for a Venezuelan convent," he said, "nuns threw their rings into the molten metal and I did not object. How else

Over hot chocolate we decided to break camp; our mules were starving. Their fodder, sparse lakeshore grass, was sheathed with ice.

Because we were overdue, I ran ahead next morning in an all-out effort to contact Sue by nightfall. Stripped to shorts and running shoes, I rushed nearly 40 miles to Atanquez before dark, descending 12,000 feet and swimming the Guatapuri, swollen by rains. I drove to sultry Valledupar and phoned Sue

can one change a jewel into a beautiful sound that everyone can enjoy and no one can steal?"

Long and luxuriant, an Arhuaco Indian's hair is his pride. Men of the Sierra Nevada de Santa Marta make pottery and weave cotton and agave fibers for robes and hats, women and children harvest yucca, maize, avocados, and mangoes.

Another tribesman shows how he mixes mineral lime from the gourd held by the author (right) with dried coca leaves for chewing. Incas used the mild narcotic on special occasions. Spaniards gave coca to laborers so that they would not feel hunger and fatigue.

to announce that Rómulo and I had crowned Christopher Columbus and The Queen.

My next trip took me into the Guajira desert of northernmost Colombia, beyond the Sierra Nevada. My rented jeep bucked through sand and scrub. I was saddened by the remains of a harvest of great sea turtles at Riohacha. This coastal town, plundered by Drake and Hawkins, still seemed smitten. I heard Riohacha mothers discipline their children with a 400-year-old threat, "Be quiet or Drake will eat you!"

Forty-four thousand proud aborigines wander the peninsula with tents and livestock, the only desert nomads in South America. The few Guajiros I met turned away when they saw my camera.

Salt Harvesters Work by Moonlight

Caked with dust, I arrived after dark at Manaure, where the Banco de la República until this year managed a vast expanse of maritime salt pans. The night sparkled with campfires, as if an army had encamped in the surrounding sands.

"Thousands of families have come in from the desert with hammock and tent," explained manager Luis Correa, as he escorted me to the guesthouse. "They harvest salt twice a year."

At 4 a.m. Dr. Correa wakened me. Campfires had died, but the moon glistened on salt pans as far as I could see. Like fishermen on an ice floe, thousands of Guajiros were sprinkled upon two 100-acre cakes of salt where they had scratched out claims in the cool of the night. They harvested in ghostly silence (pages 270-71). Women in unbelted calico gowns broke the crust with iron-tipped shafts. Tall barelegged men with pompons bobbing about their hips shoveled the crystals into piles and sacks. Now and then two men hoisted a sack onto a woman's back. I hefted a sack: About 130 pounds, I reckoned.

The east glowed amber with the dawn. Guajiros began to shoulder their shovels and head for their hammocks. Dr. Correa spoke: "You are watching one of the final performances. Except for these two pans, our entire operation, from sea water to soda plant in Cartagena, is automated. Manual harvesting is six hundred times more costly. We must find better ways for Guajiros to earn money."

I thought of another Guajiro, Captain Sanchez of the Trans-Andean Pipeline. "Teach them to fly helicopters," I said.

Driving to the northwestern tip of the Guajira Peninsula, I sped over hard sand, picking whatever tracks suited my fancy, or making my own. Veering left to follow the Caribbean shore, I passed beached dugouts, a wizened hamlet, then nothing but occasional heaps of oystershell. Inland, a column of women on donkeyback trudged through veils of dust, bearing water jars, their voluminous robes flapping. They vanished like a vision of the *Flying Dutchman*.

At Cabo de la Vela, a promontory dominates the land's end. I climbed to the lighthouse. Trades ripped the green Caribbean, clutched at my clothes, and whined past my ears. A flagless schooner rounded the cape, yawing before a quartering sea. As I watched, it reversed course. A smuggler?

Tawny haze shrouded the shore. The sun burned down on an empty sea, bright with a sheen of unreality. Cabo de la Vela, like the summit of Cristóbal Colón, was an exposed and yet secret place.

Drake Pillaged Cartagena

After two weeks of extreme exertion on wilderness trails, I was famished. Visions of juicy steaks danced in my head. Santa Marta lay 175 lonely miles down the Spanish Main. I made it in a day.

With Sue as guide, I switched to a *bon vivant* role, sampling cuisines of 18 beach hotels and restaurants. When I had regained ten pounds, we headed southwest.

Our next stop along the Emerald Coast was Cartagena, Pearl of the Indies, one of the brightest gems in the Caribbean tourist crown (pages 262-3). Cartagena used to dread foreigners. French corsair Robert Baal sacked the town in 1543-44, just as the treasure fleet assembled to sail for Spain. Martin Cote was next, followed in 1586 by history's most audacious sea raider, Sir Francis Drake, who started to burn the port, block by block, until ransom was paid. French Baron de Pointis led 9,000 buccaneers to loot Cartagena in 1697.

Spain amassed ramparts of coral and 29

Winter reigns in the Sierra Nevada de Santa Marta, just 22 miles from the sunny Caribbean. Roaming the length and breadth of Colombia for this article, the author became one of the few men ever to climb 18,271-foot La Reina, the conspicuous peak on the skyline at center, and 18,947-foot Cristóbal Colón, the country's highest peak, to its right and nearer the camera.

KODACHROME © NATIONAL GEOGRAPHIC SOCIETY

Lovingly tended treasure of volcanic slopes, coffee ripens in the shade of banana trees near Armenia. Farmers hand-pick the coffee cherries, which reach maturity at different times on the same tree. Their plantations, averaging only eight acres,

stone forts to defend the city, at such astronomical cost that King Philip II—legend says—peered westward on clear days, sarcastically expressing the hope of seeing the loftiest battlements in the Americas.

In 1741 the defenders of the fortress and a pitiless ally, tropical fever, blocked a British attempt to wrest the Caribbean from Spanish control. They decimated the largest European force deployed in the Americas up to that time: some 190 ships and 27,000 men led by Sir Edward Vernon. One of Cartagena's thwarted attackers, Lawrence Washington, half brother of George, named his estate on the Potomac River Mount Vernon in honor of the defeated English admiral.

Colombia owns a pair of small Caribbean islands—San Andrés and Providencia—440 miles northwest of Cartagena. From an airliner, palm-covered San Andrés seems to swim lazily beside a coral reef, while to the north the volcanic peaks of Providencia

occupy nearly one-third of the country's cultivated land and produce its prime export. Cotton is the second major crop.

EKTACHROME (ABOVE) AND KODACHROME BY LUIS MARDINI © N.G.S.

New taste for coffee lovers, *café helado* delights Luz Stella Baena of Armenia. The recipe: Whip concentrated coffee, sugar syrup, vanilla, and crushed ice in a blender.

remind one of some of the Hawaiian Islands.

Both islands appear on a 1527 chart. English Puritans immigrated there about 1630 to raise cotton and tobacco. They soon found greater profit in plundering Spanish galleons. The freebooter Edward Mansveldt captured Providencia in 1666. Morgan based there for an assault on Panama and reputedly hid booty on the island.

On sea horse-shaped San Andrés (page 263), an airstrip cuts a swath from eye to ear in a seven-mile-long solid plantation of palms. The sea horse's face is red with tile roofs beneath which Colombian weekenders buy duty-free English porcelains, French perfumes, Italian bikinis, and American TV sets.

The Road—San Andrés' main thoroughfare—is bordered by islanders' homes, each with its cistern. It leads to The Hill, dominated by a Baptist church. On Sunday we saw 28 neophytes, with surnames like Archbold, Kelly, Newball, and Forbes, baptized by total

immersion. With outsiders the natives speak a courtly English; among themselves they use a patois all their own. They call their islands Saint Andrews and Old Providence.

A Baptist pastor, the Reverend Bonnell Williams, told us that emigration once held the population down, but now increasing jobs keep young people from leaving.

"Most older folks on Saint Andrews own a parcel of its coconut palms," he said. "We've never known poverty—or riches, either. And no illiteracy. Until recently we had no serious crime . . . not even a jail. But the aeroplane is changing island ways. We're vexed by rising costs, and becoming poorer."

An interisland schooner promised passage to Providencia "tomorrow," but never got underway. We searched for another vessel and chartered 24-foot homemade *Delfin*.

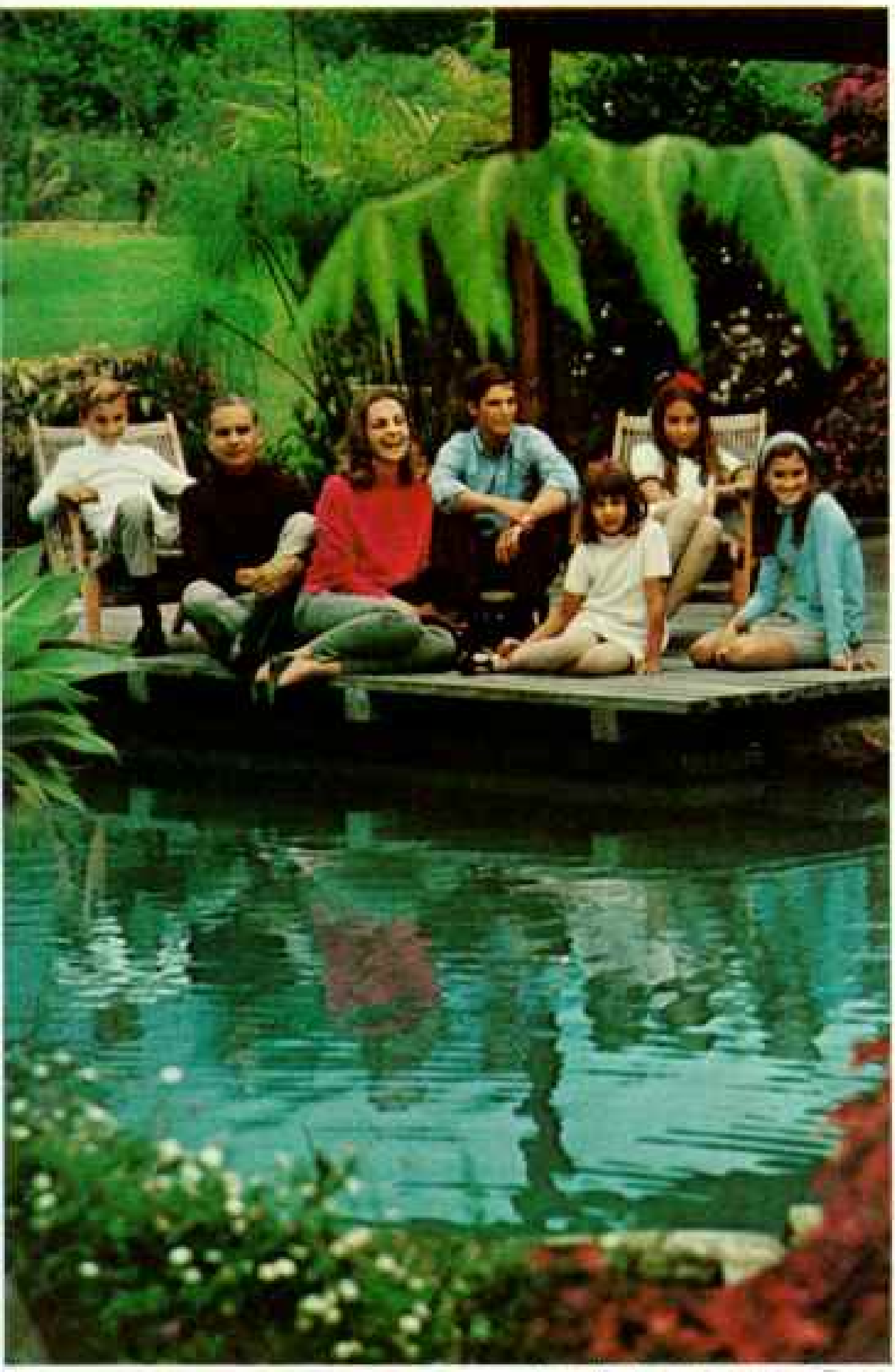
Daylight brought high winds. Capt. Restrepo Forbes Wilson tipped his cap to Sue. "'Tiz a bleak day, mistress, for a sail to Old Providence." Outside the reef, *Delfin* pounded sickeningly, occasionally taking green water. We didn't raise the 1,200-foot peaks of Providencia until nightfall. By midnight we gained the lee and steered for the lights of Santa Isabel. Restrepo put a conch shell to his lips and hooted at the town.

Morning traffic on the island road consisted of one circuit rider on horseback announcing a funeral. None of the three motor vehicles was functioning. Renting a sailing canoe, we went spearfishing at McBean's Lagoon and boated lobster, conch, and red snapper. We found no restaurant, but a resident, Daisy Bush, fried our fish. "Not much excitement hereabouts since Franklin D. Roosevelt stopped by in 1938," she said.

A following sea sped us back to San Andrés with a basket of sweetsops (custard apples) and a sack of chickens. Then we flew to Cartagena and picked up our car to follow the highway south toward Medellín.

Panama City lay only 250 miles to our west, on the other side of a region as impassable today as when Pizarro worked down the Pacific coast in 1526-27.* The tangle of mountains, jungles, rivers, and swamps remains the only gap in the Pan American Highway System between Circle, Alaska, and Puerto Montt, Chile.

*See "Panama, Link Between Oceans and Continents," by Jules B. Billard, NATIONAL GEOGRAPHIC, March 1970.



Energetic businessman Carlos Angel, here at his pool with his wife, family, and friends, typifies the men of Medellín who have made an industrial center of Colombia's second city. They developed food-processing and chemical plants, and South America's most modern textile mills.

National flower of Colombia, regal orchids are commoners in Medellín. Species such as this *Miltonia franz wickman* bloom on many porches.

Seashore to cloudscape: the patchwork of Colombia

ARROWING INTO THE CARIBBEAN, Cartagena once stock-piled wealth of the Spanish Main—emeralds, gold, pearls, and silver—for the annual voyage of the treasure fleet to Spain. When riches tempted pirates, engineers built the fortress of San Felipe (above, at lower right), and raised city walls 60 feet wide and 40 feet high.

Fertile slopes near Pasto (opposite, upper) attracted colonial farmers, whose heirs divided and redivided the land, creating Colombia's characteristic *minifundios*, or little estates, averaging ten acres.

Artery for traders, the Atrato River (lower right) snakes through swampy jungle so thick that even today the Pan American Highway System remains unfinished in northwestern Colombia.

In the Sierra Nevada, the Kogi Indians found refuge from the Spanish. Never assimilated, they still construct conical thatch houses (lower, center) and cultivate yucca, maize, and potatoes.

The little-known Caribbean island of San Andrés (right) was inherited from the splintered Spanish empire. This Catholic church claims only a few of the 15,000 residents, who are mainly English-speaking, African-descended Baptists.

We picked up the Pan American Highway again in the Andean Department of Antioquia. In western Colombia, town after ridge-top town twists along a single main street, with short cross streets delivering rain, wastes, and the unwary into an abyss on either side.

Nearing Medellín, we persuaded a campesino to let us list the contents of his *carriel*, badge of the Antioqueño—an accordion-pleated bag slung from left shoulder to right hip. The carriel contained cash, dice, playing cards, love letter, lock of hair, tobacco, flint-and-wick lighter, candle, handkerchief, straight razor, comb, string, patent medicine, jaguar-tooth amulet, lucky beans, St. Christopher medal, picture of Jesus, booklet of supplications, almanac, and a notebook of jottings about debts, addresses, jokes, proverbs, and good businesses to try.

Antioqueños Lead Nation's Progress

The Basques who came to mine gold in the north-central Andes of Antioquia encountered few aborigines. They made up for the lack of an indigenous labor force by producing enormous families and living to great age. Their regional culture was strong on enterprise, and Antioqueños have spearheaded Colombia's modernization.

A city of 170,000 only 30 years ago, Medellín now has a population of more than one million. Orchids bloom colorfully in many homes and gardens (page 261). Breezes freshen the mile-high valley. The climate control stays set on springtime.

From Medellín, Sue and I headed south toward hilltop Manizales, coffee capital of Colombia. With Dr. Hernán Uribe, director of the Development and Diversification Fund of the Coffee Zone, we toured carefully cultivated countryside and prosperous towns of the mountainous region west of Bogotá.

"Coffee supports a third of all Colombians, but none get rich," Dr. Uribe told us. "The 300,000 growers are smallholders [pages 258-9]. Farms average eight acres. There are no estates; the largest farm is 600 acres.

"Coffee earns more than half our foreign exchange. We must diversify to escape catastrophic price fluctuations. Thus we steer marginal growers into cotton, yucca, cacao, sugar cane, potatoes, bananas, or livestock. World quotas restrict our share of the coffee market, so we grow better coffee and get better prices."

"Why is Colombian coffee better?" I asked a campesino at an experimental farm. "We pick only the ripe cherry," he replied. "We never strip the bush." His fingers darted along the stems, pinching clumps of red coffee cherries into a basket at his waist, leaving green clusters for as many as 30 subsequent pickings. "Besides, we raise *legítimo café de montaña*—authentic mountain coffee."

Dr. Uribe explained. "Geography gives us a long lead over competitors. Our mountains provide a choice of climates, determined by altitude. Many places are favored by the required 59 inches of annual rainfall, while the slopes ensure proper runoff."

The mountains also obliged the paved highway to contort all the way back to Bogotá. We were glad to put the car away for a while and take out our map to study the eastern two-thirds of Colombia, where aircraft and canoes are more useful than autos.

People Flow Into Empty East

Eastern Colombia holds only 2 percent of the nation's people. Not surprisingly, migrants from overpopulated highlands are moving into the grasslands and jungle. Many descend the eastern slope of the Andes from Bogotá to Villavicencio, "gateway to the llanos (plains)." A seat in a bus costs 84 cents, in a taxi $1.70, in a plane $3.

- They can settle within sight of the Andes on farms, on ranches, or in new towns with names (in translation) like Peanuts and The Hope, Vortex and Whirlpool, The Tiger, The Crocodile, and The Future. Most towns have doubled in population in the past four years.
- If they want to go it alone, migrants may canoe southeastward down Amazon tributaries, portaging frequent rapids. They may tie up in Whiskey, El Refugio, or Abisinia or hack a clearing in the jungle 20 miles from their nearest neighbor. Few care to face the biological hazards—not beasts, but insects:

"It makes me feel like a man," said this young cowherd in northern Colombia, referring to his razor-sharp machete. Thus he exhibits the *machismo*, or aggressive manliness, encouraged by Latin American cultures. Such campesinos are handicapped by lack of land, by backward farming methods, and by distance from markets.

FROTHING CALDRON, *Yurupari*
—the Devil's Cataract—
hinders navigation on the
Vaupés River, a tributary of
the Amazon. Tucano Indians
wrestle their mahogany canoe
on a slippery portage. Heavy
rainfall, perilous rivers, trackless
jungle, and isolation deter
settlement along the Brazilian
border, now the domain of
a handful of Indians and
missionaries.

mosquitoes, ants, and *manta blanca*, the dreaded "white veil," minute sticky bugs in dense swarms that are awful when inadvertently inhaled.

• Migrants may join the homesteaders migrating to the northeastern grasslands of the upper Orinoco drainage basin. There, today as in colonial times, the chief pursuit is cattle raising. Toward Venezuela, herds thin out and humans are scarce. Just a few cowboys and Indians ride the plains (pages 234-5).

"Over my horse, only I; and over me, only my sombrero." This creed of the *llaneros*, horsemen of the llanos who formed Bolivar's indomitable cavalry, foretold the ruin of the Liberator's dream of a united South America. The plainsmen who helped vanquish the Spaniards tolerated no rule, nothing over them but their hats.

We based at Lomalinda, lakeside quarters of the Summer Institute of Linguistics—a U.S. missionary organization—a half-hour flight beyond Villavicencio. We teamed up with pilot-photographer George DeVoucalla and other old friends who had guided me to Amazon tribes in four Andean countries for two decades. Few of the linguist-missionaries stay at the base; most of them live among 32

On wings like fluttering flags of pink, roseate spoonbills rise from a mangrove swamp near Manaure. The paler juvenile gains color as it matures. Found from

of Colombia's 70 or more tribes, analyzing their languages and translating the Bible.

George piloted Sue and me to tribes near the Brazilian border. Two and a half hours southeast of Lomalinda we sighted the Vaupés River cutting a constant-width channel through virgin jungle, looping as if carved by a giant ditchdigger gone berserk.

Palm Fruit Flavors Drink

Banking over the Yurupari, most fearful of Vaupés cataracts (pages 266-7), we splash-landed on a muddy strip alongside the skeleton of a Catalina amphibian at a speck on the map named Tio Barbas, after its owner, Hernando Gomez, known as "Uncle Whiskers." Here Indians from 15 tribes were harvesting wild rubber for Hernando and gathering fruit from the Mauritia palm, to be used in flavoring their native tapiocalike drink.

I breakfasted on fish soup, yucca, fried bananas, and paca. Especially paca.

"What's paca?" asked Sue.

"A jungle rodent, like a rat, only bigger. Much tastier."

Sue pushed breakfast aside.

Our next stop, Acaricuará, lay many days distant by river or by forest trail, but only

Florida to Uruguay, *Ajaia ajaja* often winters on this wild Caribbean shore.

Pumas do change spots: Unlike the leopard, this young *Felis concolor* will lose his markings by adulthood.

Desert nomads harvest salt

IN STIFLING HEAT at Manaure, Guajiro Indians shovel sun-dried salt, the crystallized residue of sea water in two 100-acre pans—the last unmechanized flats of the national salt industry. Twice a year the Indians earn extra money at the harvest. A woman (right) empties a 130-pound load at a collection point for later shipment to a chemical plant at Cartagena.

Always independent, the Guajiros began to herd livestock after the conquest, roaming from water hole to water hole. Women wear voluminous gowns (far left) and cover their cheeks with vegetable dye to shield their skin from the sun. Men adorn their aprons with pompons (near left). In this society of 44,000, women hold the rights of inheritance.

minutes away by air. When we buzzed the Catholic mission school, Indian children streamed out like startled ants. We landed. The youngsters lined up at the airstrip and shook hands firmly instead of offering limp fingertips or turning away without touching as their jungle-dwelling fathers would have done. Most of the 160 children from seven tribes had even given up painting their faces to ward off evil, measles, hunger, fatigue, heat, and sunburn. Antioqueño priests and nuns provided other means of survival.

Chief's Son Speculates on Space

In Sunday uniforms, the youngsters staged a dugout regatta on the Paca River in our honor, girls racing boys down the rapids. All the canoes foundered; nobody won. Happiness was swimming in full uniform.

That night linguist missionaries Betty Welch and Birdie West served us banana pie with candles and sang, "Happy wedding anniversary to you," while Indians stood in a circle moving their lips. Betty and Birdie's informant, son of a Tucano Indian leader, emptied Sue's purse, studying each item, particularly the credit cards, then put everything back. Afterwards, we walked in the night with him.

The chief's son pointed to Venus, almost hung on the horns of the moon. "After the moon, do you think we will ever land on Venus?" he asked in Spanish.

Astonished at the "we" as much as the enlightened speculation, I replied, "No, but we may reach Mars."

"I hope so," said the chief's son. "The outer planets are too big and cold."

On a Rio Negro tributary near Brazil an Indian told George DeVoucalla and me that he was building a big dugout canoe. "A good picture," suggested George. "Let's shoot it and get out before rain grounds our plane. Francisco, where's your canoe?"

"Upriver." Francisco shoved off in a tiny dugout. George and I paddled hotly behind, enveloped in a cloud of butterflies. The brown river poured over sand bars like tea over sugar. After 20 minutes we yelled, "How much farther?"

"*Diez vueltas del rio*—ten bends of the river." Francisco spread the fingers of both hands. The clouds blackened. Ten curves later we paused.

"About here?" No. Only halfway. To Francisco, a "vuelta" was an S-curve. We could hear the rain approaching.

Finally Francisco beached his dugout and led us to a newly felled tree. "My canoe."

"This is a canoe? It still has branches! When did you start to build it?"

"Yesterday."

The rain roared down.

Sue and I wanted to go next to Leticia, Colombia's port on the Amazon River, only 325 miles due south. Direct flight was impossible for lack of gasoline. Overland travel was unthinkable. River travel would require almost 2,000 miles of boating down the Rio Negro to Manaus, Brazil, and back up the Amazon. So, like sensible Colombians, we doubled back to Bogotá and flew Avianca to Leticia—a mere 1,100 miles.

The settlement looked forlorn against the immensity of jungle and a river that is two miles wide even here, 1,700 miles from its mouth (map, page 241).

Zoo Harbors "Invisible" Wildlife

We were met by my old friend Mike Tsalickis, animal collector, zoo-keeper, safari guide, river-fleet operator, hotel manager, airline promoter, steamship agent, philanthropist, town mediator, social worker, and once U. S. consular agent. Mike installed us in a hotel room full of fresh fruit and cold drinks, then took us in tow as he doctored the festering leg of a Yagua Indian, gave her a bar of soap to wash her baby, bought a batch of blowguns from a Brazilian canoeist, and checked on patients at the hospital.

"My father used to dive for sponges, like most of the Florida Greeks," Mike told Sue as we walked through the wards. "I've collected animals ever since I was a kid in Tarpon Springs. I worked south from the Everglades, and 17 years ago I hit Leticia. But it was nowhere till I got air travel going."

I agreed. Leticia is ten times bigger and livelier than it was two decades ago when I first went there. It's still the best place to find wild animals in the entire Amazon Basin.

Compared to African wildlife, the Amazon's is relatively invisible. Early explorers perished for lack of game. But at Mike's home and zoo I saw more animals in five minutes than I've ever seen in the bush. Several hundred native trappers bring him anacondas, pumas, rare birds, porpoises, manatees, monkeys, marmosets, and other animals. Most of the primates are sold for medical research.

One night on Mike's island in mid-Amazon, which he stocks with monkeys and banana trees, a squirrel monkey rode out of the jungle

Orphan of the Amazon jungle, Chi Chi, a young female capuchin monkey, soon found a place in the author's heart and his Virginia home. Expressive *Cebus apella* possesses a lively intelligence, including the ability to make tools, such as rolling a newspaper to reach for objects.

on a pig's back. Then he rode various hounds around the house, sometimes Roman riding two, like a circus performer. Finally he switched to his favorite mount, a friendly giant tomcat, which strolled about with what struck us as exaggerated care. The monkey was too wild to let us touch him.

I asked Mike to get me a baby capuchin monkey to photograph. Capuchins express many human emotions and speak in a sort of birdcall that I understand because I had a capuchin in Bolivia years ago. Mike found an infant, orphaned and woefully dependent upon primate companionship. I put her on a Victoria Regia lily pad five feet in diameter and backed my canoe away to take a picture. She reached out her arms and trilled her loneliness call. When I pushed farther away, the 12-ounce monkey, whose natural abode is the treetops, resolutely jumped into the Amazon River and swam toward my canoe.

That hooked me. I've had a monkey on my back ever since. When we left for Bogotá and the long flight home, she went with us. At every stopover on our trip back to the States I got off and traded loneliness calls with her. Her trill floated from some unseen dark corner of the jet's baggage compartment.

We call this little native of the Colombian jungle Chi Chi. She cowers when a bird flies over, but wants to play with cats and dogs. She smiles at plump ladies and laughs at big feet. She peeks over my shoulder as I type. Her breath tickles my ear. Her face shows wonder, bewilderment, joy—all in miniature (above). Her tail locks around my neck as she reaches to tap the keys: g, x 4/k. Helping me not at all. THE END

Teeming Life of a Pond

SUMMER DAYS on Noxontown Pond begin quietly enough. A painted turtle clambers out on a log to catch the warming rays of the sun. A kingfisher scoops a minnow from the shallows. A red-winged blackbird calls. And sometimes a biologist, who enjoys the two exciting worlds of laboratories and ponds, appears at water's edge.

I am that biologist and my life with Noxontown Pond goes back more than two decades, to the year when I joined the faculty of St. Andrew's School near Middletown, Delaware (maps, pages 284-5). The school borders most of the pond, a two-mile-long stretch of water with many wooded coves and a remarkable concentration of living creatures.

On still summer mornings, I often walk

Article and photographs by
WILLIAM H. AMOS

Wonder of a water world: Stirring duckweed and watermeal at a pond's edge, the author's son Steve sees

little of the marvels of magnification (below). Beneath the surface lies a tangle of bizarre forms. Stinging tentacles of a hydra—its tubular body bulging with a developing egg, left—reach toward green, cup-shaped Stentor *at right. Strands of algae,* Spirogyra, *resemble glass rods.*

18 TIMES LIFE-SIZE. ROUGACHROMES BY WILLIAM H. AMOS © N.G.S.

TWICE LIFE-SIZE. BIOMORPHOTOS © N.G.S.

the 50 yards from our home through the woods to the cove below. As the rising sun casts light upon the pond, I sense the stirrings of life evident only to those who will watch closely and listen patiently. I think of others who have praised such small bodies of water —Henry David Thoreau, for instance, who captured the essence of a pond so well, describing it as "the landscape's most beautiful and expressive feature. It is earth's eye; looking into which the beholder measures the depth of his own nature."

Not infrequently my thoughts drift back to my first plunge into this cove. I had been studying and photographing ponds for many months, yet during that dive I became, for the first time, a part of one. Explorations in succeeding years have made this underwater world more familiar to me, but no less exciting.

I CALL TO MIND one typical, yet special, June morning not long ago when I ventured once again into this complex community of Noxontown Pond. Face mask, snorkel, swim fins, and underwater camera all in place, I slowly submerged beneath tall, graceful columns of pondweed and stems of water lilies.

Delicate strands of bladderwort, with bulbous deathtraps awaiting small organisms, rose from the pond's bottom (page 279). Minute planktonic animals, illuminated by sunlight from above, danced in the water like dust motes in the air.

Dense clouds of minnows emerged from behind a forest of aquatic plants to greet me, momentarily obscuring my vision. Hundreds swarmed within three feet of my mask, ready to dart off at my least movement.

A giant water bug, more than three inches long, rose among the minnows and sculled to the surface, where it exchanged stale air for fresh, trapping a new supply under its wing covers.

When the cool water became uncomfortable, I waded ashore. As I walked beside the pond, peeling wet leaves and weeds from my hair and shoulders, I was met by my son Steve, who had come to call me to breakfast. "The Creature from the Black Lagoon!" he laughed, as he helped untangle weeds from my hair.

Steve (page 274) and his older brother Bill discovered the excitement of pond-exploring on trips we have taken all through the East. As we discussed this at breakfast that morning, Bill commented, "I'll bet we have seen a couple of hundred ponds, and every one is different."

"That's possible," I said, "but what makes them different?" Bill thought for a moment before replying.

"A lot of things," he said finally, "like climate, the pond's age,

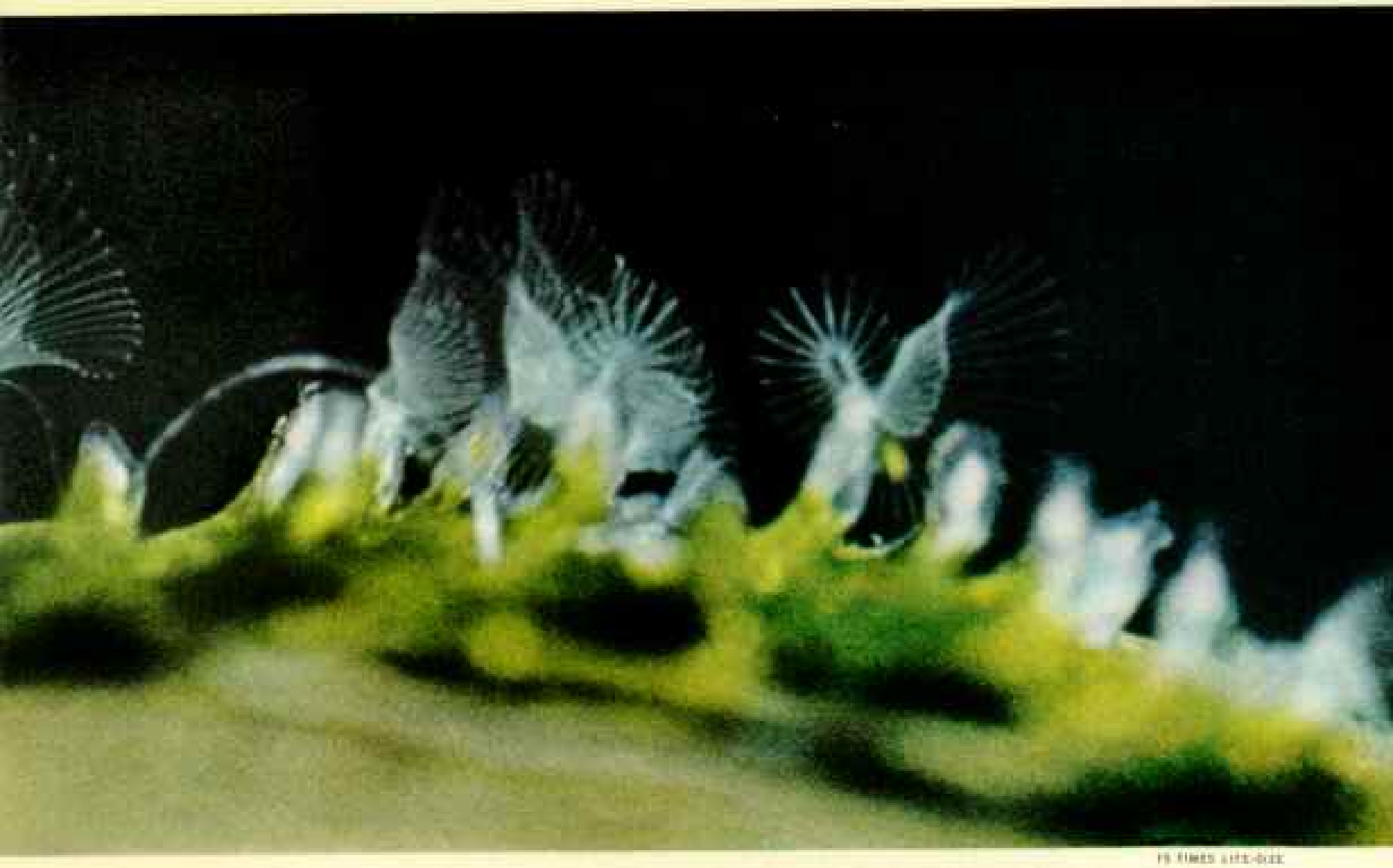
Water surface divides two realms

Man in water must either sink or swim, but the water's surface film provides a floor for some fragile creatures, a ceiling for others. Skating across the aquatic rink on six long legs, the water strider (left) makes a dent in the pond that mirrors its image. An underwater dweller, the damselfly nymph (below) presses against the surface tension, bending the water in its search for food.

Topside or in the depths, the pond offers hospitality to life in marvelous variety (pages 290-92). And each pond, among more than two million man-made and natural ones scattered across the Nation, boasts its own distinctive identity, whether just born, mature, or dying.

10 TIMES LIFE-SIZE

Endless quest: Underwater carnivores set fantastic traps for food



FIVE TIMES LIFE-SIZE

TWICE LIFE-SIZE

Silvery crowns bear tiny cilia that waft meals of algae and protozoans into the maws of a colony of moss animals, called bryozoans.

On the prowl, a dragonfly nymph (far left) devours an earthworm caught by an ingenious lower lip, here folded beneath the head. Hinged and tipped with two pincers, the lethal lower lip whips out, grasps the victim, and flips it back to the mouth.

Pretty as a garden shrub, the bladderwort (left) packs deathtraps along its branches. In repose, the bladders appear as flattened sacs, but they can expand instantly to suck up any small creature that ruffles hairs guarding their openings.

the kind of bottom it has, the streams that enter or leave it, the plants and animals that live in it."

The ponds that Bill and the rest of us know best range over a 600-mile stretch of the Northeast, from Maryland to northern Maine and Quebec. Yet we always return to our home pond in Delaware with anticipation of learning more of its secrets.

When we first came to St. Andrew's, my wife Catherine, observing the pond's size, asked me, "Why isn't Noxontown a lake? What is a pond anyway?"

There are no set rules. Most limnologists agree that a pond is a small, completely enclosed body of water, shallow enough to encourage aquatic vegetation. Lakes are usually larger, deeper, and older.

ONE OF THE NICE THINGS about a pond is its accessibility. Nearly everyone lives close to some kind of pond. Scattered across the United States are more than a million man-made ponds serving as watering holes, swimming pools, or sources of water for fire protection. They harbor aquatic plants and animals, and sometimes game fish, too. Together with countless natural ponds, they form an aquatic chain inhabited by thousands of species of living things. Many ponds also provide resting and feeding stops on a flyway system. Thousands of waterfowl, including the great Canada goose, visit Noxontown Pond each year.

Often the children and I walk to the pond and pause on its bank, where our gaze spans almost its entire length. Once Julie spotted a bent stick half in and half out of the water. Momentary excitement erupted when the stick turned into a banded water snake that swam gracefully out of reach into the lily pads.

As the chatter of the children recedes in my consciousness, the days I have spent here begin to blend in a kaleidoscopic fusion of passing seasons and years . . .

On a day in early fall, a handful of my students are following the intricate territorial flights of dragonflies.

Now, it is midwinter. The zoology class and I brave the bitter cold to cut holes in the ice through which we lower a generator-driven pump to obtain plankton.

With spring upon us, my family and I enter a lily-choked cove aboard our collecting barge. Son Bobby shouts excitedly, and somewhat inaccurately, "Look! A bald-headed eagle, a bald-headed eagle!" And there, sure enough, a bald eagle hovers directly above us, diving repeatedly only 50 yards away until it snatches a fish trapped in the shallows.

Toward the end of school, two students and I listen one night to a mixed chorus of frog voices: the guttering of the pickerel frog; banjo plunks from green frogs; the clicks of chorus frogs; the sonorous roar of a bullfrog. A sudden splash and a shrill scream, abruptly terminated, mark the end of a frog life and a meal for a snapping turtle or pickerel. . . .

Whenever our family travels about the country, the children watch for ponds in various stages of development. Each pond, they understand, is a living entity in itself. A pond has a birth, a slow period of growth, and a long maturity, before it declines into senescence and finally disappears.

Not long ago Howard Schmolze, a faculty colleague at St. Andrew's, invited me to look at a pond he had dug a few months earlier. He seemed puzzled that his pond could support so much activity so soon.

"How did these water plants get here?" he asked, "and where did all the diving bugs come from?"

His miniature shoreline already was crowded with spike rush, and the water teemed with back swimmers, water boatmen, diving beetles, water striders, and other insects.

A new pond, I explained, is invaded quickly by pioneer plants, such as the spike rush, which take root along the shore and grow outward into the water. Within hours after flooding, aquatic insects may arrive on the wing, drawn by light reflections. Bacteria, algae, and protozoans break out of resting spores and cysts to become active once more.

If the pond is stream-fed, fish soon take up quarters there. Ducks and other water birds transport on their feet additional cysts, spores, seeds, and eggs. Soon the pond, young as it is, supports a teeming population that grows richer with time (painting, pages 290-92). Only six months after the Schmolze pond was filled with water, it had become a thriving aquatic community.

Noxontown Pond is much older, of course. Originally a marsh, dammed in 1736 to serve the gristmill of Thomas Noxon, the pond still is watched over today by his descendant, Mrs. William Y. Ellison, who lives near the old mill. The pond is now at the height of its productivity, as measured by the plants and animals it supports. Someday, if nature has its way, sediment will accumulate, the shoreline will advance, and water will begin to

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For a deprived midge, blood runs red

In oxygen-poor waters close to a pond's bottom the colorless body fluid of the midge larva turns fire-bright with a pigment related to hemoglobin in human blood. It shares the common name "bloodworm" with an aquatic worm fishermen use for bait. Other midge larvae appear yellow, green, or brown.

Tale of a tadpole

The incredible frog metamorphoses from a fishlike aquatic creature into a land-oriented amphibian.

Newly hatched tadpoles (left) squirm in the gelatinous egg mass. A month-old tadpole (right), with tail partly shown, digests food in a watch-spring intestine, easily seen in the almost transparent body; early pigment cells show as small dots.

As the tadpole turns into a frog, gills give way to lungs, heart and eyes prepare for the change from water to air, and the tail is absorbed as legs grow strong (below).

8 TIMES LIFE-SIZE

8 TIMES LIFE-SIZE (LEFT)

TWICE LIFE-SIZE; PHOTOGRAPHED BY WILLIAM R. AMOS © N.G.S.

disappear. The underwater plant and animal population will dwindle, then vanish. And where Noxontown Pond now stands, a stream will cut through the center of a small, fertile valley fringed with invading trees.

A pond's history can be read in its bottom deposits. There the events that have gone before lie recorded in the sequence of organic contributions made during different seasons. When students look closely into the three-foot-long cores brought up from the bottom of Noxontown Pond, they find, only six inches down, evidence of Thomas Noxon's world. Lower layers tell of earlier centuries, for the sediments reveal what the passing years were like, even what vegetation grew on neighboring fields. The history is all there for an expert to read.

ONE DAY, standing high on a point above the water, the children and I paid heed not to the pond's past but to its present. We looked over a sun-swept cove and took note of the distinct zones of life along the shore.

We recognized our favorite frog-catching grounds among the shallow-water emergent plants, such as cattails and reed grass. Farther out, in the zone of floating-leaved plants, tiny animals, we knew, were clinging to the undersides and stalks of lily pads. The undersurfaces of watermeal—the world's smallest seed plant—and duckweed provide attachment points for a whole community of living things.

Whenever we come out here, our youngest children, Alison and Bobby, like to hang over the edge of a wharf that projects into the cove. They squint their eyes and study the softly rippling water. The molecules of water at the surface create an elastic film so tough that aquatic insects and spiders can skate across it. They may dimple it with their weight, but they seldom break through (page 276).

If the children reach out to touch a nearby whirligig beetle or a fishing spider, however, the creature may penetrate the surface film and dive to safety, carrying air with it (page 294).

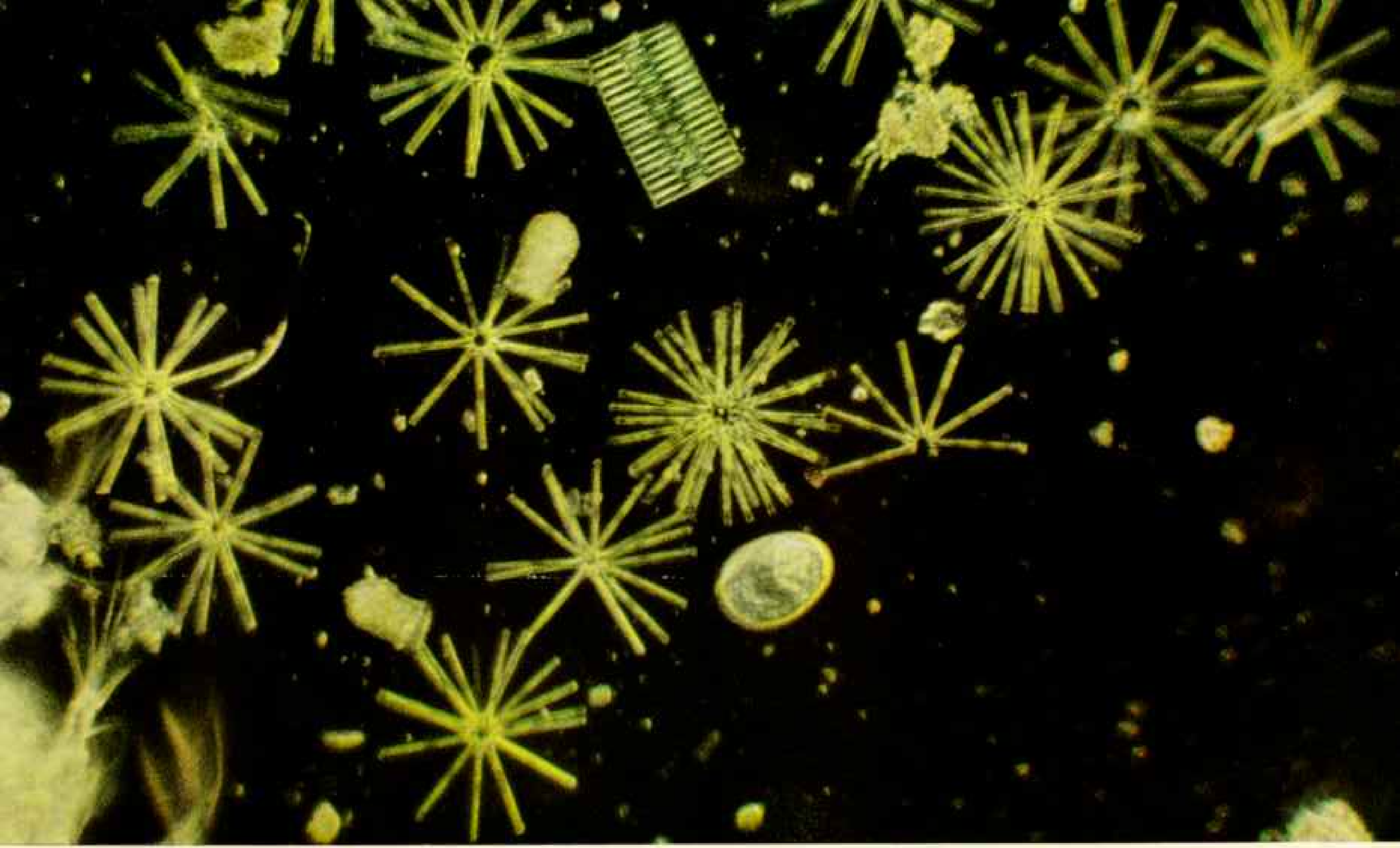
Even smaller animals live on the undersurface of the film, where they hang down or creep across it from beneath. Some are the familiar snails and hydras. A few of the smallest crustaceans, such as water fleas, may swim so close to the film that suddenly they find themselves caught in it. There on the quiet surface of the pond the upper parts of their curved, shelled bodies glisten in the sun.

The surface tension is so great that the little crustaceans can be caught there in a deathtrap. However, if they are in the process of molting,

Noxontown Pond

Living laboratory, Noxontown Pond lies near St. Andrew's School, background, where the author, right, heads the science department. Here he and two students gather specimens for class study.

A two-mile sheet of water scalloped with wooded coves, the pond was created in 1736 when Thomas Noxon dammed a marsh to provide power for his gristmill. This "earth's eye," as Henry David Thoreau described a pond, is now in the prime of its life.



Life explodes in a burst of beauty

Microscopic galaxy of starlike Asterionella *diatoms (left) spangles pond waters. These one-celled plants, linked in a radial pattern, lie dormant in winter and burgeon in the spring, sometimes turning ponds yellow. With them in the watery firmament float a rectangular stack of* Fragilaria *diatoms and a rotifer egg.*

With its trunklike extension, the water flea Bosmina *(above), a crustacean about a fiftieth of an inch long, resembles the head of an elephant.*

A female copepod (right) carries on the sides of her abdomen packets of eggs that may yield some 40 young.

Free-loading leeches

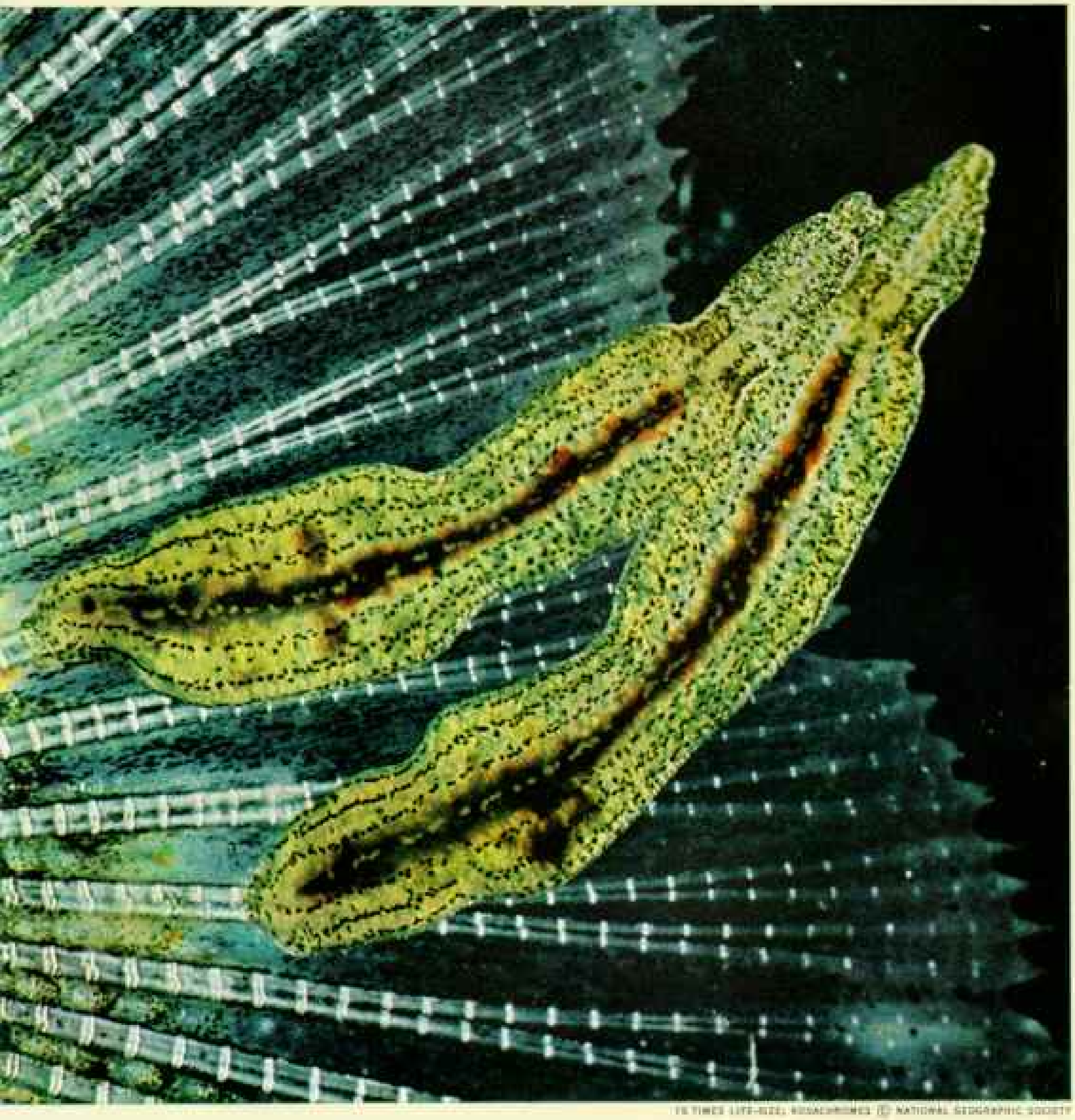
Predators and parasites, leeches feed on their own kind as well as others. As the parent (above) broods its yellow-colored young, three small gray leeches attack them.

Caudal fin of a pumpkinseed sunfish (right) carries a couple of leeches along for the ride. These bloodsuckers cling by suction cups (one shown at top of picture above).

Of some forty leech species in the United States, only about half a dozen attach themselves to humans. Many are parasitic on fish, frogs, and turtles, and some feast on snails.

they may escape by slipping out of their skeletal coverings, which adhere to the surface, and dropping back into the watery world below. Their new outer skeletons quickly harden.

Through the next lower zone of life —the mass of the pond's water—swim leeches, mites, fishes, turtles, frogs, newts, diving ducks, insects, muskrats, and, on rare occasions, an otter. In the most densely inhabited zone, hidden from our eyes as we stand on the shore, the fragmented organic matter and mud of the bottom provide a home for scavengers—crayfish, worms, insect larvae, and snails, and many



15 TIMES LIFE-SIZE; KODACHROMES © NATIONAL GEOGRAPHIC SOCIETY

creatures seen only through a microscope.

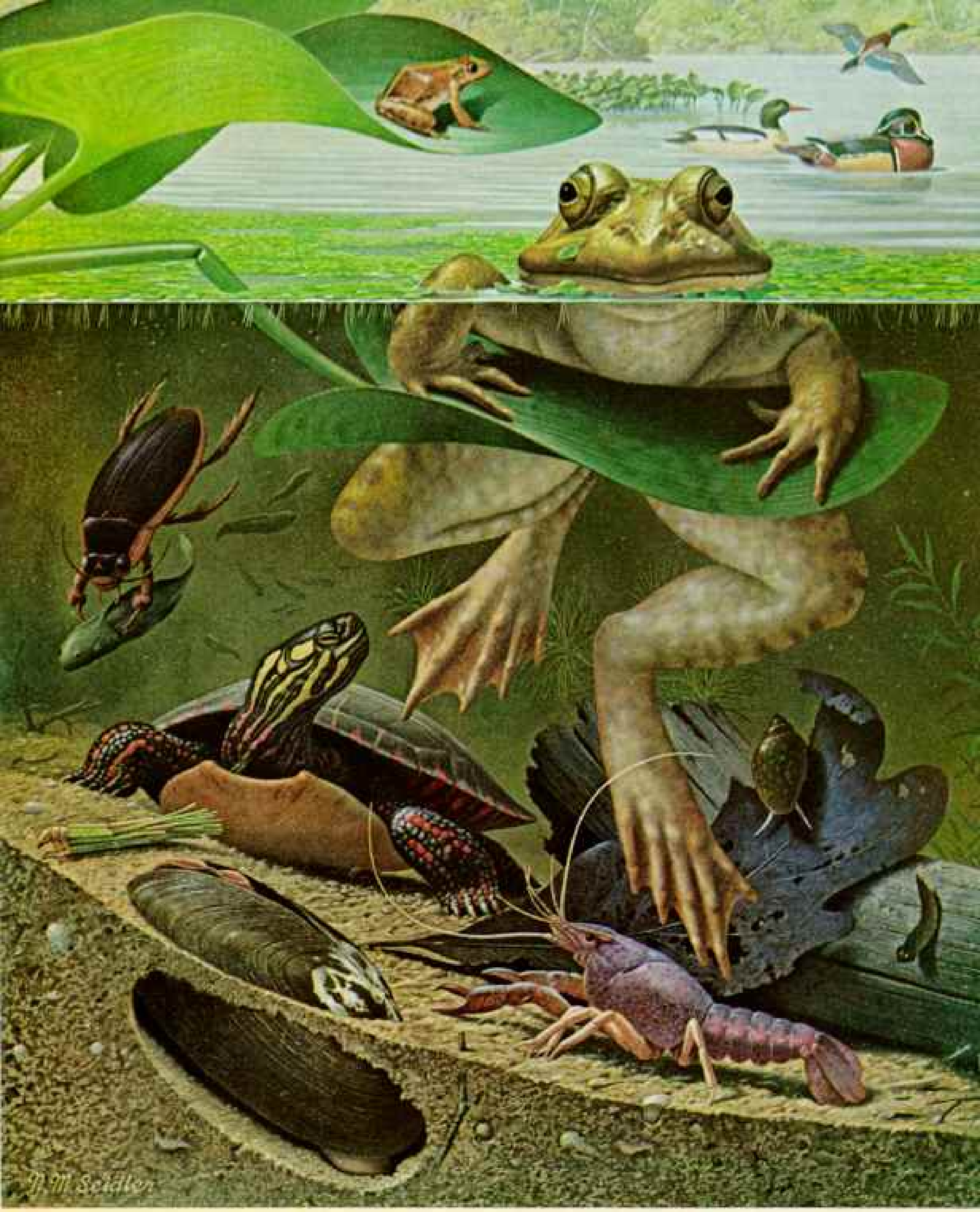
Earlier naturalists called ponds microcosms. In a general sense this is true, but we also know that no living community is completely isolated from the world around it. A pond is influenced by atmospheric changes, by contributions from streams, and by runoff from surrounding fields. A small pond, which is especially vulnerable, can be suddenly and often drastically polluted by many substances, from both domestic and agricultural sources.

Fortunately, only minor changes have taken place so far here at Noxontown Pond, and the water remains heavily populated. We spend countless and rewarding hours studying the habits and customs of its denizens. Take, for example, the ways in which they move about.

Many people think a fish swims simply by means of a tail fin; actually, most of its propulsive power comes from alternating waves of muscular contractions, down first one side, then the other. The fish bends in sinuous curves, creating pressure points that push against the water, much the way a skater thrusts out with blades to skim across ice.

Swimming leeches also move by making muscular ripples that pass down their bodies, but they undulate up and down, not from side

(Continued on page 295)



What is a pond? To a fisherman it may offer a bass, to a boy a jar of tadpoles, but to a biologist it serves as a lesson in the balance of nature. Oxygen-giving plants and plankton—the food of mollusks, insect larvae, and young

fish—thrive here. Predatory beetles dart amid fronds, and snails rasp at algae on stems. Insect-eating frogs may themselves provide a meal for turtles, fish, and snakes. Waterfowl dine on plants, fish, and insects, but seeds and eggs picked up at other pools drop from their feet to help replenish life. Bottom-feeding snails, crayfish, and catfish consume animal and vegetable debris. If undisturbed, these relationships may sustain a pond for centuries.

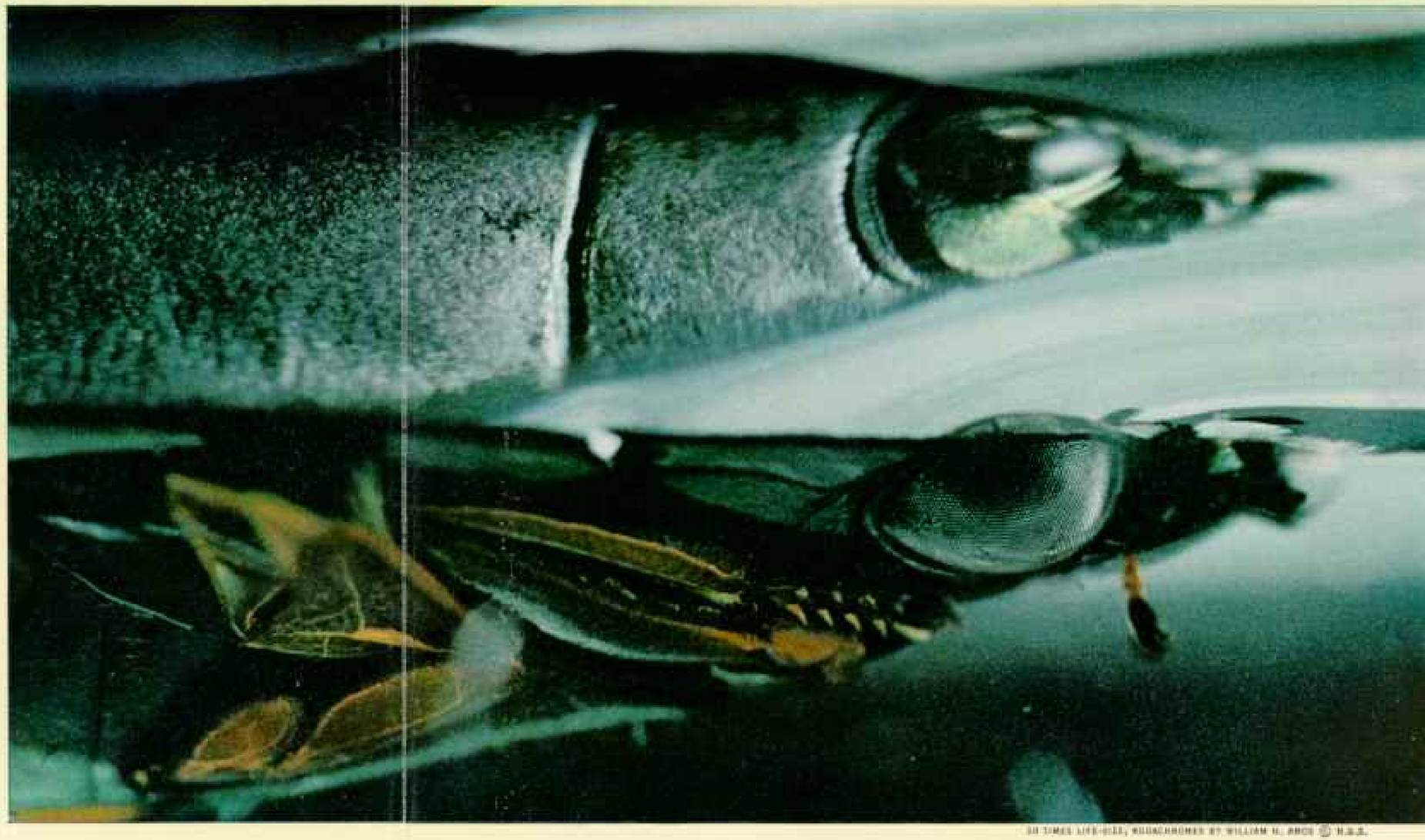
BLACK DUCK
BLUE-WINGED TEAL
GREEN DARNER DRAGONFLY
GREAT BLUE HERON
RED-WINGED BLACKBIRD
BELTED KINGFISHER
NORTHERN WATER SNAKE
RED-BELLIED TURTLE
WATER STRIDER
WATER SURFACE
WHIRLIGIG BEETLE
WATER SCORPION
SNAPPING TURTLE
BACK SWIMMER
LARGEMOUTH BASS
GOLDEN SHINER
HORNWORT
SATINFIN SHINER
DRAGONFLY NYMPH
BULLHEAD CATFISH
FRESH-WATER SPONGE
SCUD
FINGERNAIL CLAM
DAMSELFLY NYMPH ON WATERWEED
HORSE LEECH
MUSK TURTLE
TUBIFEX
PLANKTON
A COPEPOD (CYCLOPS)
B WATER FLEA (DAPHNIA)
C GREEN ALGAE
D DIATOMS
CHAIN PICKEREL
PICKEREL FROG
CRISP LEAF PONDWEED
ORB SNAIL
PUMPKINSEED SUNFISH
ASELLUS
LARVAL RED SALAMANDER

Snorkeling scorpion

Innocent looking as a dead twig, the patient water scorpion hangs beneath the pond's surface and breathes through a tail-like snorkel (below). Two grooved filaments bound together by interlocking bristles form the tube. Water-repellent hairs at the tip keep the opening in the surface film clear of liquid.

The water scorpion's powerful forelegs (bottom), similar to those of the praying mantis, capture passing insects and even small tadpoles. Parasitic larvae of the red water mite (page 297) find security on the scorpion's legs.

10 TIMES LIFE-SIZE



10 TIMES LIFE-SIZE; HIGHLIGHTED BY WILLIAM H. AMOS © N.G.S.

Beetle with built- in bifocals

7 TIMES LIFE-SIZE

Keeping watch on both domains, each of the whirligig beetle's eyes is divided into two half-circles—the upper adapts to air, the lower to subsurface conditions. The beetle's water-repellent upper body helps keep it afloat as it darts and circles after insects caught in the surface film.

Occasionally the whirligig dives for the bottom, carrying air beneath its wings and in a bubble at the tip of its abdomen (right). This bubble acts as a gill, absorbing oxygen from water for the submerged beetle.

8 TIMES LIFE-SIZE

to side. Turtles derive most of their swimming power from their webbed hind feet; their clawed front feet are used primarily for shredding food and walking on land.

A dragonfly nymph, on the other hand, can employ a totally different method of movement. It can take off from a standing start by ejecting spurts of water from an abdominal cavity—a form of true jet propulsion.

All the manufactured devices we use in our studies—masks, snorkels, and swim fins—have natural equivalents in the pond world. Humans need a faceplate to see well underwater, but whirligig beetles have eyes with two hemispheres—one focused for vision in water, the other for vision in air (page 294).

AS FOR SPEEDY SWIMMING, many water animals enjoy a natural form of flipper or paddle. Some crustaceans, such as water fleas, swim with elongated, branched antennae or by rapidly moving legs. Water boatmen and back swimmers, two insect species that spend much time underwater, row through the pond with oarlike legs.

The legs of diving beetles have either folding plates or hairs that increase the surface area on the power stroke, then fold and offer little water resistance when the leg is brought forward.

A snorkel, too, is a device common to many of the pond's air breathers. With elongated nostrils, for example, snapping turtles and musk turtles can reach through the surface without revealing the rest of their heads.

Many aquatic insects come armed with long breathing tubes tipped with water-repellent hairs. When these insects rise to the surface, the hairs quickly penetrate the film and anchor the animals in place. At the same time, the hairs prevent water from entering the insects' breathing tubes (page 293).

Similar hairs cover large fishing spiders, which also enjoy still another invaluable piece of equipment—an air tank. When one of these spiders submerges, air trapped in its dense hair forms a silvery bubble that contains enough oxygen for an hour underwater.

In some cases the bubble of air that accompanies a submerging animal—like the whirligig beetle (page 294)—provides more than a reservoir it can draw upon. The bubble's surface acts as a gill membrane that allows oxygen to pass from the water to the insect and carbon dioxide from the insect to the water. Thus, the insect can remain submerged for as long as several hours. Nitrogen, which makes up most of the bubble's size, slowly escapes into the water and the sac collapses. At this point, the insect must rise again to the surface to capture a new air supply.

When we take our family to the pond, Catherine brings plenty of food. Sometimes we suspect that our children get hungry simply watching the constant—and often bizarre—feeding activities of our pond's inhabitants. All of us have watched with fascination, for example, as a dragonfly nymph, with its long hinged underlip tipped with a pair of pincers, grabs its prey (page 278).

Fiercest and largest predator in the pond world remains the snapping turtle, which is capable of amputating a small child's finger with a single bite.* A few years ago two of my students brought back a 48-pound snapper they had found in a net. I had no place to keep such a formidable beast in the laboratory, so I gave it temporary quarters in our bathtub. That proved to be a mistake.

The snapper barely had time to settle down in its new home before it greeted an unexpected guest—a visiting Chinese bishop who did not know that the bathroom was occupied. After a shocked silence, the bishop emerged quickly, lapsing momentarily into his native tongue. Explanations were difficult.

The next morning, at Catherine's prompting, I went to get the turtle and transfer it to more suitable quarters. I walked in and found my two-year-old son leaning over the tub, tenderly stroking the reptile's armored back, and crooning, "Nice turtle, nice turtle."

Unlike snapping turtles, some large diving beetles make good pets. I recall when Steve ran into the house, crying, "I found a monster, Dad!" His cupped hands held a two-inch water beetle that had blundered against the lighted screen door during its migration from one pond to another. We kept the "monster" for a year, feeding it bits of meat and an occasional earthworm until it died from an undetermined cause.

Numerous large oval water beetles became special pets of our daughter Alison when she was younger. One day she and I chanced upon a big red-bellied turtle on the bank, preparing to lay eggs. The turtle's foot-long back still glistened with moisture. Seeing us, she quickly

*See "Nature's Tank, the Turtle," by Doris M. Cochran, NATIONAL GEOGRAPHIC, May 1952.

PAGE 292 FOLDS OUT

pulled in her head and legs so that only the convex shell was evident.

Alison shrilled, "Look, Daddy! Look at the big, big bug!" As we watched, her big bug gradually turned back into a turtle and, ignoring us, went about the important business of laying eggs.

On another day, as the sun began to warm us, our barge drifted far up the pond and into a small cove. I watched as Bill, deftly swinging a dip net, captured a young bluegill. The other children gathered around and admired his catch. Bobby studied the fish closely and curiously, then asked me, "What are all those little black dots on the fins?"

"Clams," I replied, to the children's complete disbelief.

Large fresh-water clams release many minute embryonic young. Each of them bears stout teeth along the edges of its shell and a long filament that floats upward in the water. Whenever something moves nearby, the disturbance sends these tiny clams swirling. Their toothed shells snap wildly and must fasten to a fish fin or gill if they are to complete their life cycle. The clams then become embedded in the fish's tissues and undergo gradual development, later emerging and dropping to the bottom to grow to full size, as much as six inches long.

The reproductive behavior of pond animals like the clam often is a fascinating example of adaptation. Some leeches, for example, brood their defenseless young beneath their bodies. This protects the progeny against would-be predators. At times, however, other leeches may maneuver themselves under the female's body and attack the young anyway (page 288).

We moored the barge to the trunk of an overhanging beech, and the children scattered in search of treasures. The first to return, Alison, offered a prize find—tadpoles she had discovered skittering in the shallows among arrowhead stalks (pages 282-3). I admired her new pets and told her that, as frogs, they would spend all their lives along the shoreline, especially in weedy coves. Each kind of frog has its own special place where it lays its eggs, and its own time of laying, from late winter into summer.

When the other children returned, we sat on the barge and quietly watched and listened. A great blue heron alighted on an overhanging branch only 30 feet away. A resplendent wood duck and its mate paddled out of the thickets of water willow, feeding among the mats of duckweed and watermeal covering the surface. Startled by our presence, a large pickerel made a sudden rush through the surrounding pond lilies, causing them to bend and sway.

We stretched out on the barge and leaned over the edge until our noses practically touched the water. Water striders, both predators and scavengers, skated across the surface in search of dying and dead animals caught in the tension of the water (page 276).

"Watch this," Bobby called. Aware that water striders are attracted to any light-colored debris on the water, he tossed out bits of bread. As quickly as a morsel touched the surface, a strider would dart over and grasp it with nimble front legs.

NIGHT TIME on Noxontown Pond offers a whole new set of experiences. It was evening when we next boarded the barge and put out from shore, soon to become enveloped in another frenzy of activity and new dimensions of beauty.

We moved only a short distance, then sat silently listening to the insistent hoots of a barred owl from a tree leaning over the pond. Soon it was fully dark, and I turned on my headlamp. Here and there the light was reflected in pinpoints of green brilliance, revealing the eight blazing eyes of a great fishing spider resting on a lily pad.

Scores of small pond dwellers, seldom noticed during the day, came to life under the bright beam of my light. We watched the

All body, no head

Clown of nature, the red water mite Hydrachna *comes with big eyes set in a melon-shaped body and four pairs of hair-fringed legs that propel it helter-skelter through the water. Here, a specimen rests on a sprig of stonewort. Related to the spider, mites dare year-round life in the pond, even in ice-covered winter.*

TO TIMES LIFE-SIZE; KODACHROME BY WILLIAM H. AMOS © NATIONAL GEOGRAPHIC SOCIETY

Ingenious home builder

A soft-bodied caddisfly larva, which fishermen call "stick bait," lives in a protective case constructed of plant fragments glued together with its own secretion. Other caddisfly species build with sand or selected debris; material used in the abodes helps identify the occupant.

emergence of midges from their motile pupae that had struggled to the surface. Schools of young fish darted in and out of the beam. Bullhead catfish groped about in now deliberate, now frenzied fashion, then dived for cover beneath clumps of algae as the light picked them out. Small leeches, busily waving about for a passing fish victim, waited among these same clusters.

We noticed that the algae and surrounding plants were covered with tiny oval crustaceans, ostracods, so abundant that they lent the green filaments an orange cast. Some swam about, but most fed quietly on small forms of plant life, diatoms, which coated the plant stalks and pebbles of the bottom. As I bent close to the water's surface, I saw minute specks twisting and swimming about—protozoans and rotifers, too small to classify with the naked eye.

I snapped off the light. The sounds of night, dominated by a chorus of countless frogs, echoed across the pond. Holding our breath, we listened to a contrasting rhythm: the soft splashes, gulps, and gurgles made by the myriad and ever-moving animals of the hidden pond world.

When I flicked the light back on, its beam filled with insects, pulled out of the dark by uncontrollable reactions. They alighted on my head, crawled across my face, and burrowed under my shirt.

I again turned off the light, and almost at once I felt a gentle fanning breeze that came and went with the merest suggestion of larger wings. On went the light—to reveal the rapid, skillful flight of bats as they rushed out of the blackness to capture moths only inches from my face.

As we strolled home through the darkness, other sounds told us of many more creatures the night concealed. A quotation by Thomas Huxley came to mind: "To a person uninstructed in natural history, his country or seaside stroll is a walk through a gallery filled with wonderful works of art, nine-tenths of which have their faces turned to the wall."

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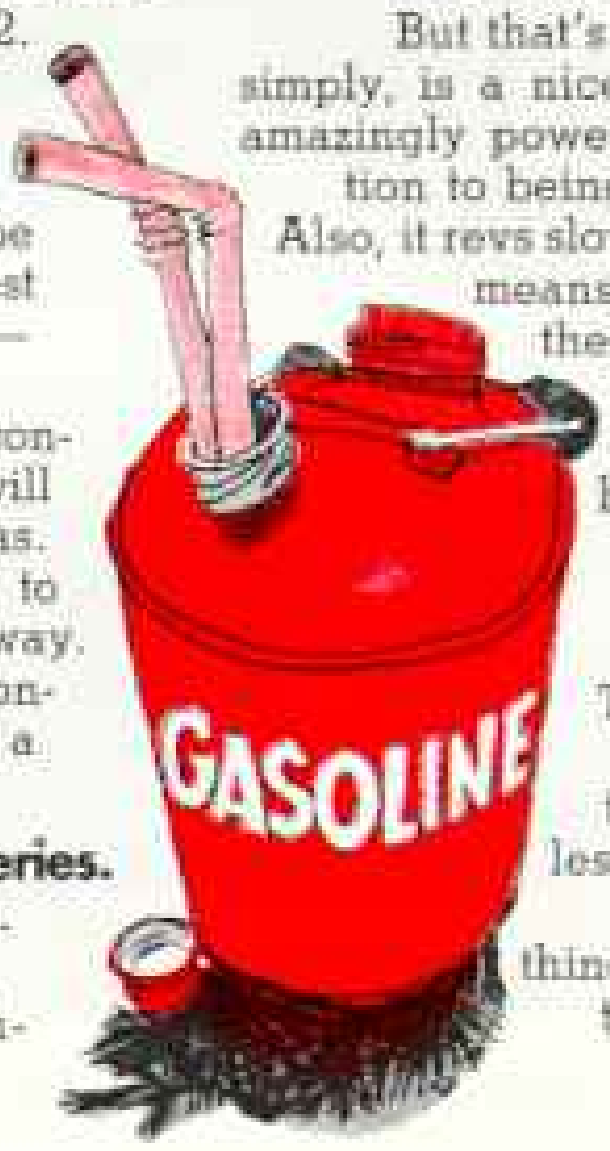

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