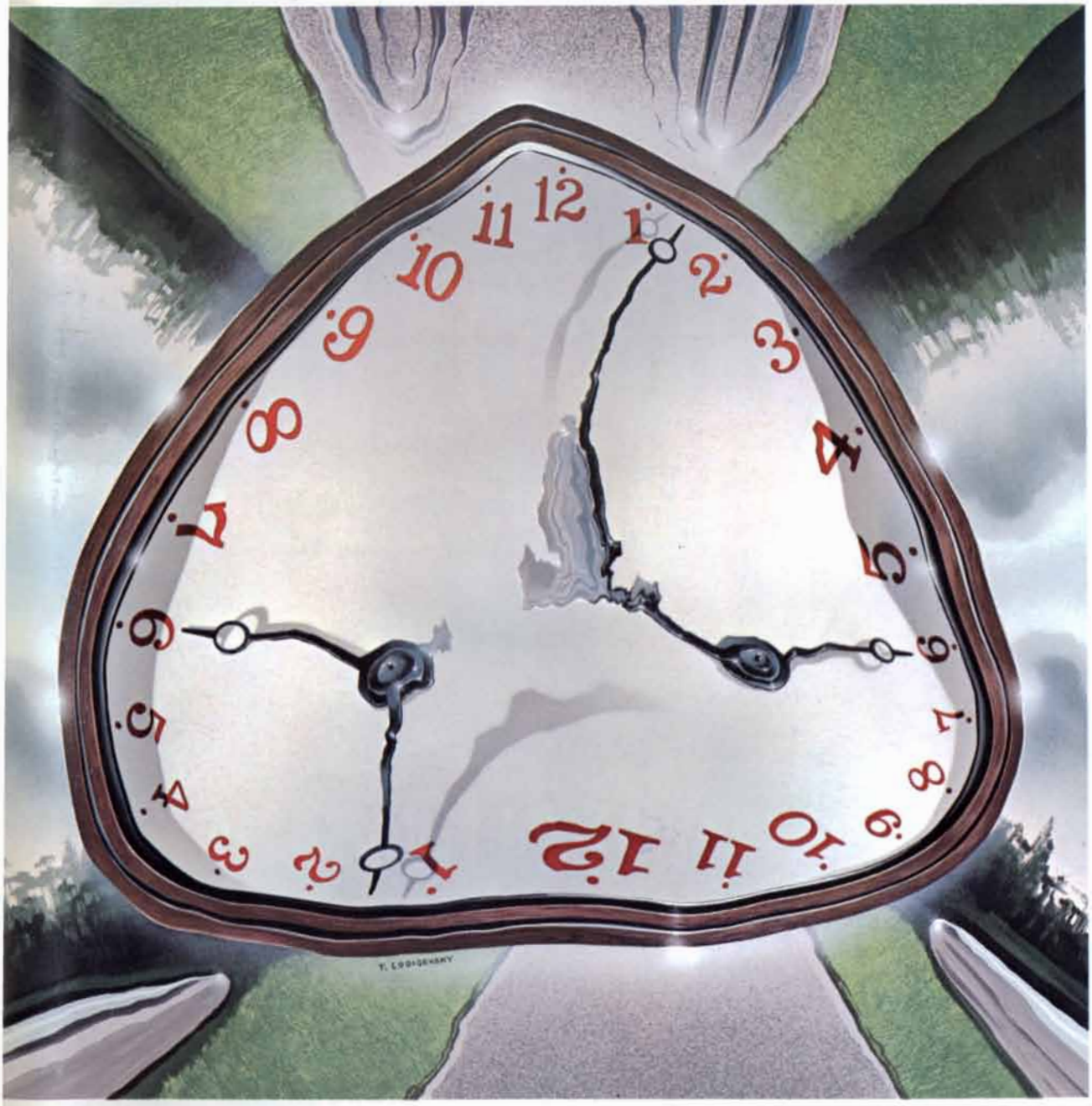
SCIENTIFIC AMERICAN



MIRROR IMAGES

$2.00

December 1980

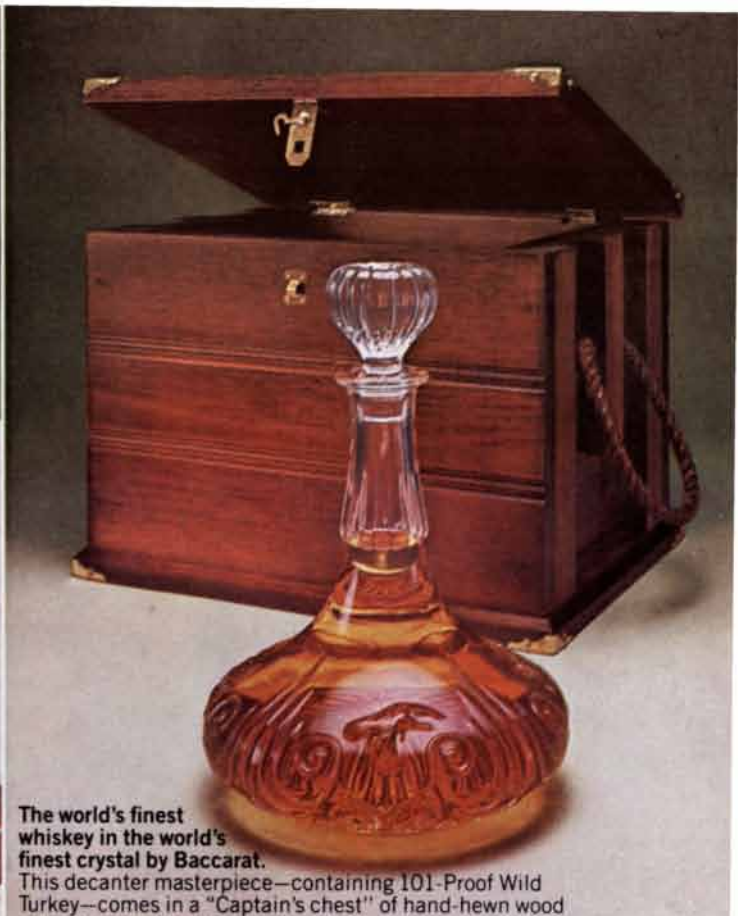
This Holiday Season, Give A Masterpiece.

Your friends will enjoy a toast of "Turkey" for the holiday celebration. At 101-Proof, Wild Turkey® is a recognized masterpiece — America's finest native whiskey. You'll find it dressed for the holidays in an elegant gift carton.

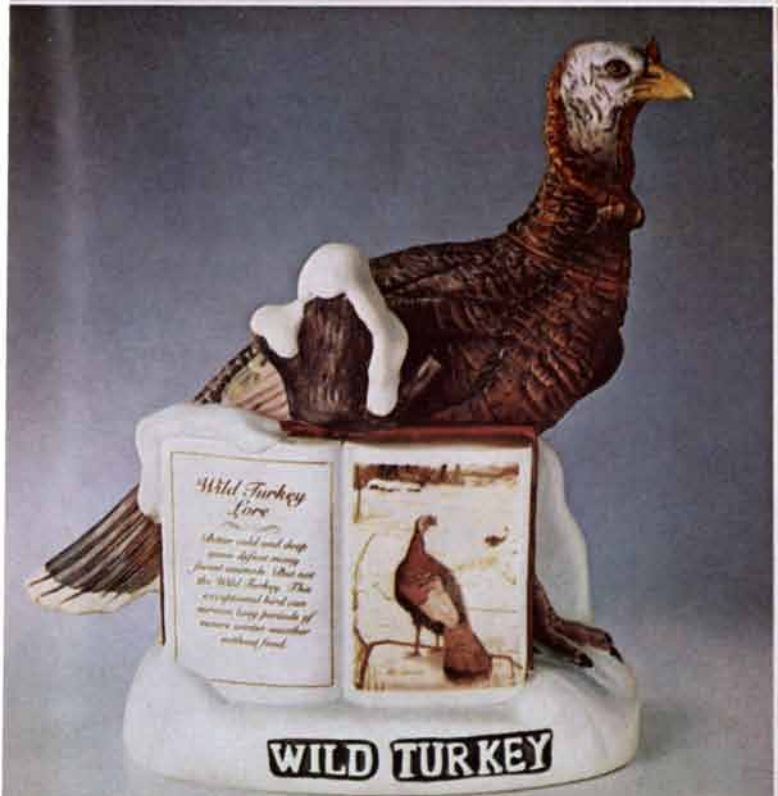
To send a gift of Wild Turkey call toll-free: 800-327-0243. (two bottle minimum)

Void where prohibited by law.

Another before-dinner treat for those who prefer America's finest whiskey at a lower proof—86.8-Proof Wild Turkey. It's also packaged ready for giving, in a striking holiday carton.

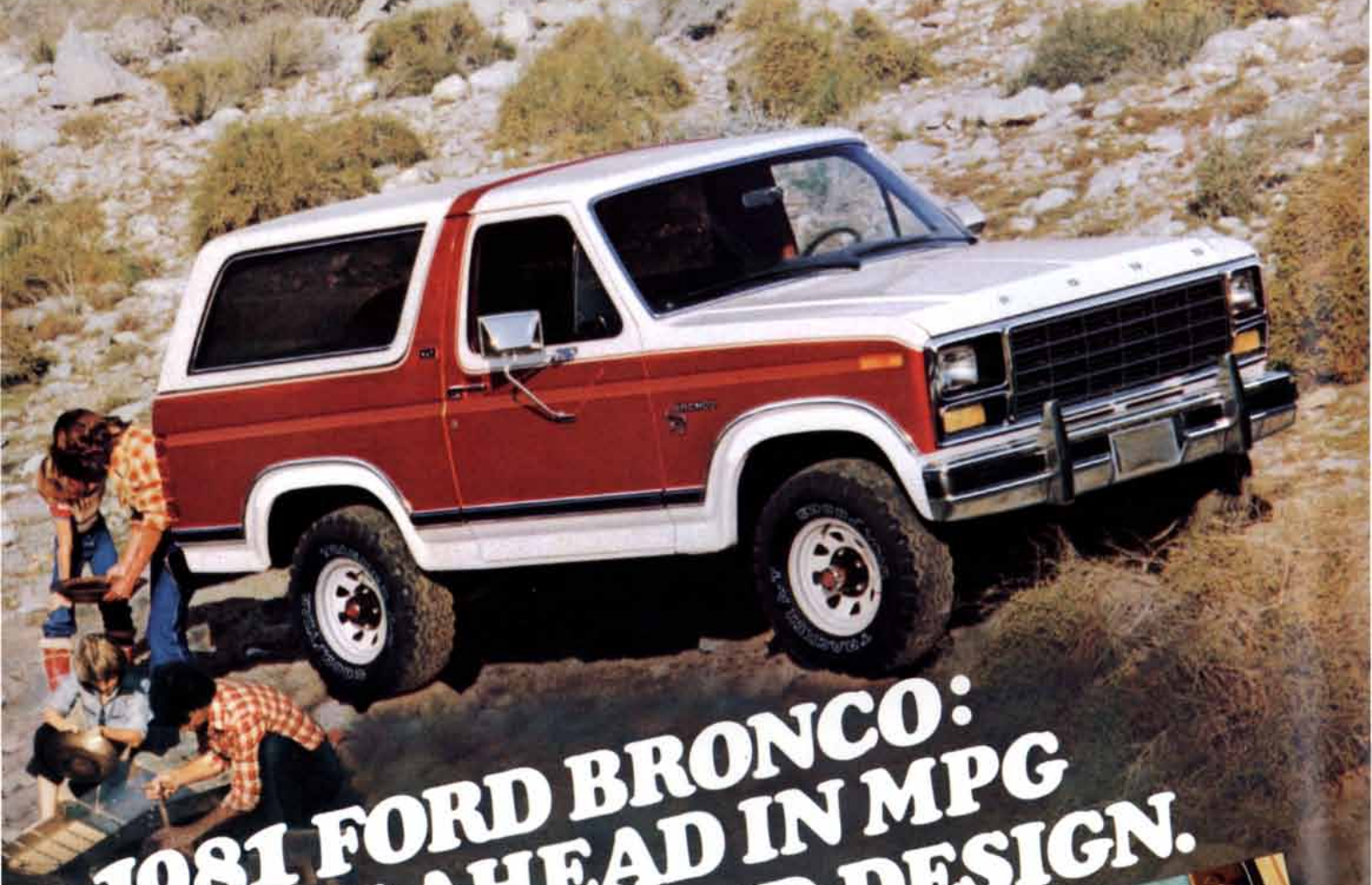


The world's finest whiskey in the world's finest crystal by Baccarat. This decanter masterpiece—containing 101-Proof Wild Turkey—comes in a "Captain's chest" of hand-hewn wood with a hand-rubbed finish. Inspired by early American decanters, it's a true family heirloom. About $250.* (For further information, call toll-free 800-228-5000. Nebraska residents call 800-642-8777.) *Price may vary by state.



For collectors of Americana (and connoisseurs of Wild Turkey), America's great native bird is commemorated in this limited-edition ceramic decanter filled with 101-Proof Wild Turkey. It's a handsome "conversation piece" and an ideal holiday gift. Beautifully boxed.

After dinner, savor the "Sippin' Sweet Cream" taste of Wild Turkey Liqueur. Of the world's great liqueurs, only one is made in America–Wild Turkey Liqueur. Now you can serve Turkey after dinner too! Elegantly gift-packaged. 80 Proof.



1981 FORD BRONCO: MILES AHEAD IN MPG AND ADVANCED DESIGN.

Bronco, the 4-wheel utility economy champ. It's the family 4-wheeler totally redesigned last year for the needs of the 80's. The only one that can give you advanced features like tough, independent front suspension and optional 4-speed overdrive transmission to boost fuel economy, particularly at highway speeds. Any way you figure, you're ahead in a tough Bronco!

Built Ford Tough

BEST SIX UTILITY MPG

18 EPA EST. MPG* 24 EST. HWY.*

Standard 4.9L (300 CID) Six with 4-speed overdrive transmission option.

20% Better gas mileage for the '81 Bronco over last year's 6-cylinder estimated MPG.

ROOMY Interior comfort. Bronco can seat six with optional bench seats, yet keeps its trim outer size.

*Compare these estimates with others. Your mileage may differ depending on speed, distance and weather. Actual highway mileage will probably be less. California estimates lower.

NEW OPTION 4-speed overdrive For Ford Bronco. Helps improve fuel economy.

NEW OPTION Automatic locking hubs Front hubs run free on highway; lock automatically when you shift to 4WD.

TOUGH Twin-Traction Beam Independent front suspension to step over bumps for a stable ride.

FORD

FORD DIVISION Ford

Established 1845 **SCIENTIFIC AMERICAN** December 1980 Volume 243 Number 6

ARTICLES

DEPARTMENTS

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THE COVER

The painting on the cover shows the image of a clock face reflected in a mirror with three lobes, or hills, and three valleys. A single, continuous image is formed but the clock face is doubled, so that it spans a total of 24 hours. If the image were observed for 12 hours, while the hour hand of the real clock made a full revolution, each of the two hour hands in the image would make just half a revolution. Only after 24 hours would each hour hand complete a full turn. The reflecting properties of various surfaces can be analyzed in terms of a few basic curved mirrors and the boundaries that join them (see "Mirror Images," by David Emil Thomas, page 206). The forms around the clock face are a distorted image of the artist's lawn, where the mirror and the clock were set up.

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Cover painting by Ted Lodigensky

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0.00% switching distortion. 0.00% FM drift. Two reasons Technics has a lot to say about nothing.

Technics SU-V8 amplifier with New Class A circuitry eliminates switching distortion. The ST-S7 quartz synthesizer tuner eliminates FM drift. And as you'll discover, the more we eliminate, the more we add.

Take the SU-V8. You won't hear any switching distortion because, unlike most of today's amplifiers, its output transistors don't switch on and off as the input waveform goes from positive to negative. The reason: Technics synchro-bias circuitry. What it does is employ high-speed diodes that constantly send minute amounts of current to the transistor not in use. And since the transistors are always on, switching distortion is eliminated.

And there's nothing minute about the SU-V8's power output: 110 watts per channel from 20 Hz to 20 kHz into 8 ohms with no more than 0.005% THD. The results: Music that's rich, crisp and bursting with dynamic range.

In concert with the SU-V8 is the ST-S7. With its quartz-crystal oscillator, only the broadcast frequencies you select can be received. And since both frequencies are quartz-synthesized, the tuner can't drift. That means any station you tune is perfectly in tune.

And the ST-S7's microprocessor allows you to preset eight AM and eight FM stations and even turn the power on and tune three stations all by itself.

Discover Technics new amps and tuners. When it comes to New Class A and quartz, Technics gets an A plus.

Technics
The science of sound

LETTERS

Sirs:

Thomas Gold and Steven Soter, the authors of "The Deep-Earth-Gas Hypothesis" [SCIENTIFIC AMERICAN, June], expressed the opinion that "our present attempt to formulate a relatively simple hypothesis... will doubtless turn out to be in places oversimplified or overstated." They were optimistic. Much of the analysis presented in support of their hypothesis is more than oversimplified; it is fundamentally incorrect.

1. "Carbon is much more abundant in sediments than it is in the igneous rocks from which the sediments derived."

The authors were referring in particular to limestone. Limestone is less abundant than other sedimentary rocks containing much less carbon, such as shales and sandstones. Furthermore, much of the earth's limestone is derived not from igneous rocks but from the biological action of marine plants and animals that extract calcium carbonate from water. When the organisms die, the calcium carbonate is deposited as a sea-floor sediment.

2. "If all the reduced sedimentary carbon originated from degassed carbon dioxide, a corresponding excess of oxygen should be found in the sediments and the atmosphere. That much oxygen does not seem to be present."

Excess relative to what? The atmospheric abundance of oxygen *is* far in excess of the abundances of most other elements common to the igneous rocks to which the authors refer.

3. "Another line of evidence connecting nonbiological hydrocarbons with such features [deep crustal fissures] is the striking correlation between the major oil and gas regions and the principal zones of past and present seismic activity. Oil fields often lie along active or ancient fault lines.... The fact is that oil and gas fields show a distinct association with such earthquake-prone regions."

This latter "fact" exists only in the minds of the authors. Their own illustration on pages 158–159 shows no such correlation. The illustration shows the locations of 29,000 epicenters, originally plotted by Muawia Barazangi and James Dorman (*Bulletin of the Seismological Society of America,* Vol. 59, No. 1, pages 369–380; February, 1969). The reader should judge for himself what fraction of these earthquakes occurred in the most famous oil-producing areas, such as the Arabian Peninsula, the North Sea, the Alaskan North Slope and the Gulf Coast. Furthermore, the fact that oil and gas fields tend to lie along fault lines is related more to the economics of petroleum exploration than to the origin of the oil. Regardless of where or how hydrocarbons form, they will "migrate," or move, until they are "trapped" and concentrated under impermeable rock. Faults often form such "traps." Thus wherever the oil or gas originates, millions of years after it forms, a "trap" produced by faulting is a good (economically) place to look for it.

4. "Seismologists have long recognized a difficulty in accounting for deep earthquakes.... Yet earthquakes have been recorded from depths of as much as 700 kilometers.... The presence of deep-earth gas could resolve this contradiction."

The authors' knowledge of geophysics is 20 years out of date. Deep-focus earthquakes are now known to be associated with subduction zones. (See, for example, "The Subduction of the Lithosphere," by M. Nafi Toksöz; *Scientific American,* November, 1975.) In such zones earthquakes occur in near-surface rocks forced downward, not "deep rocks."

5. "The total energy ascribed to the earthquake, as judged by the radiated seismic energy, is only between 10 and 100 times that of [a tsunami] wave. One cannot ascribe a much larger energy content to the earthquake without far exceeding the maximum elastic-strain energy the rocks could have stored."

It is well known, from research aimed at discriminating underground nuclear tests from earthquakes, that only a small fraction (about 1 percent) of the energy released by an earthquake goes into radiated energy. The remainder goes into deforming and heating of the rock. Therefore the total energy released by the quake *must be* "tens of thousands of times more than the energy resident in the sea wave." Regarding the elastic-strain limit, rock that has not been stressed far beyond this point does not fracture and cause earthquakes. Earthquakes are not an elastic phenomenon. (See, for example, "The Motion of the Ground in Earthquakes," by David M. Boore; *Scientific American,* December, 1977.)

6. "It is usually assumed that [tsunamis] are generated by a sudden displacement of an... area of the sea floor... more than 100 kilometers across.... A different mechanism seems to be needed to account for the large tsunamis.... An earthquake energy only about 10 times larger than the energy of the tsunami then appears to be a possibility."

The wavelengths of tsunamis in the open sea are typically 10 to 100 kilometers. Since the wavelength of a wave produced by an impulsive source is approximately equal to or less than the linear extent of the source, the source *must* have been of this size. (See "The Generation of Tsunamis and the Focal Mechanism of Earthquakes," by Kumizi Iida, in *Tsunamis in the Pacific Ocean,* edited by William Mansfield Adams; University Press of Hawaii, 1970.) How gas, escaping from fractures only a few meters across (the source proposed by the authors), could expand horizontally hundreds of kilometers to produce the required source size is not explained by the authors. They also do not explain how such a huge bubble could go unobserved through all recorded history.

7. The authors express the hope that their hypothesis will lead "perhaps to the discovery of large new sources of fuel and in any case to an improvement in the understanding of the earth."

Even if the deep gas exists, it will never be a significant source of fuel for a variety of economic, ecological and political reasons dealing with oil and gas production. (See "World Oil Production," by Andrew R. Flower; *Scientific American,* March, 1978.)

Any improvement in the understanding of the earth will have to come in spite of the authors.

ROBERT H. MCEACHERN

Frenchtown, N.J.

Sirs:

1. The average carbon content of the crust is about 3 percent in sedimentary rocks and .05 percent in igneous plus metamorphic rocks. Since the sediments are derived from the weathering of igneous and metamorphic rocks, this "excess" carbon must have been added, via the atmosphere, by outgassing from the deep interior, as was first shown by Wil-

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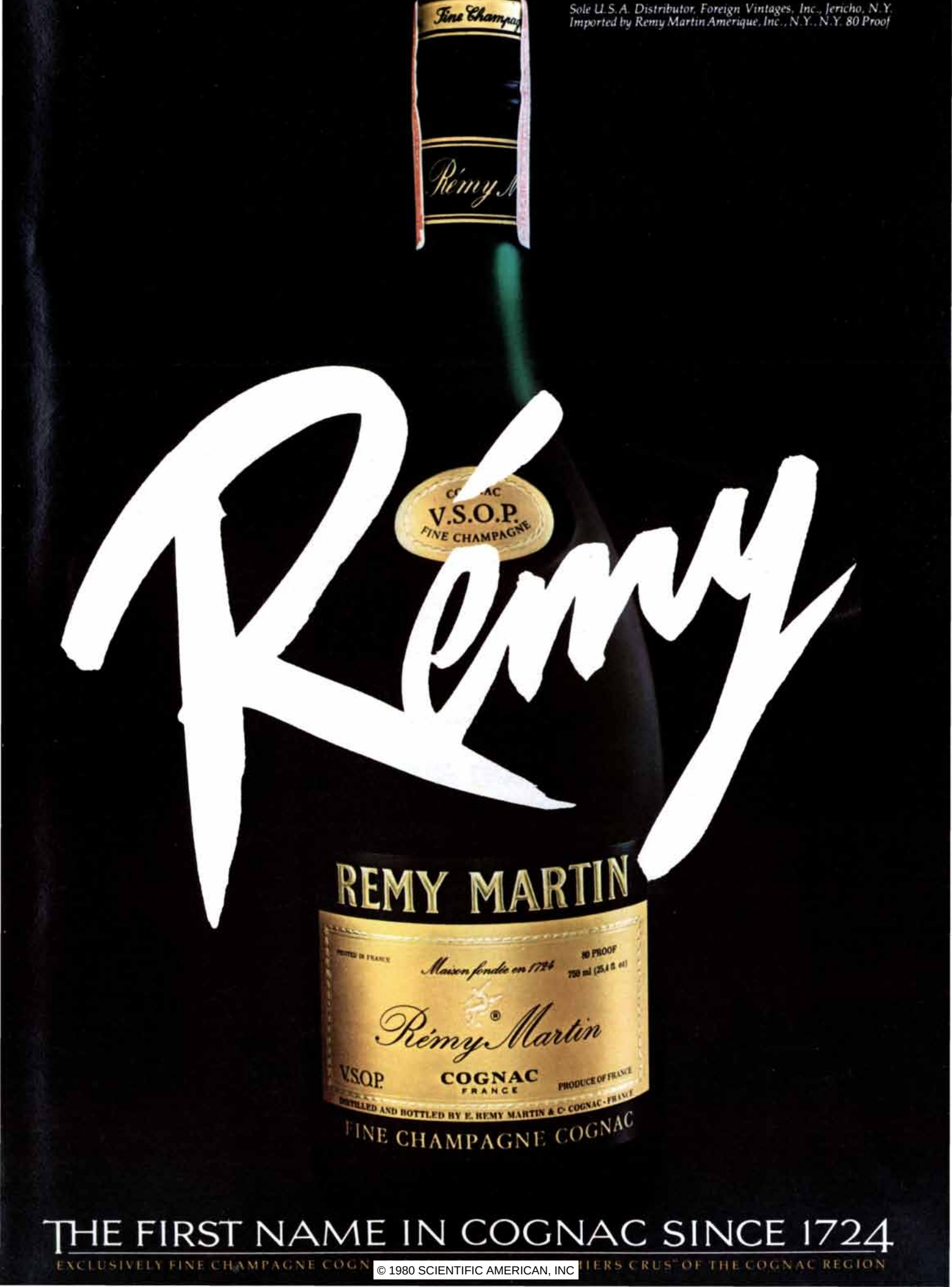
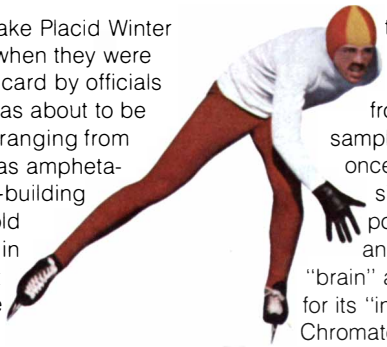


Olympic lab gets results in record time

Athletes at the Lake Placid Winter Olympics knew when they were handed a green card by officials that their urine was about to be tested for drugs ranging from stimulants such as amphetamines to muscle-building steroids. With gold medals hanging in the balance, test results had to be fast and reliable.

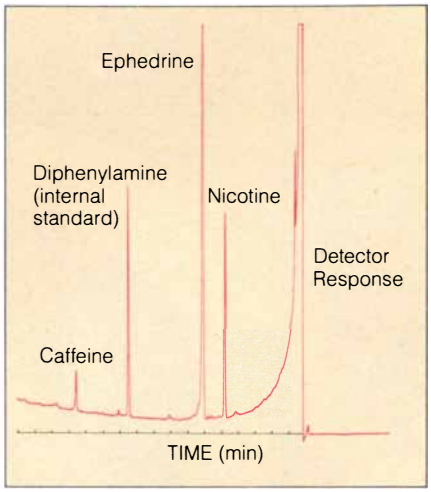


Much of the drug screening was carried out by chromatography, a technique for separating mixtures of compounds so they can be identified and measured. To handle the heavy volume of test data, the Olympic laboratories were automated with a dozen Perkin-Elmer gas chromatographs linked to six Perkin-Elmer SIGMA 10 Chromatography Data Stations.

By bringing the power of the small computer into the laboratory, the SIGMA 10 makes it possible to collect and analyze data from a number of samples in less time than it once took to perform a single analysis. With a powerful microcomputer and memory for its "brain" and versatile software for its "intelligence," a single Chromatography Data Station can guide the operator and handle up to four simultaneous analyses.

At Lake Placid, data stations controlled operation of the chromatographs, processed the data generated, and printed the final reports. In other environments, they also can function as part of a network of "distributed intelligence," trading data with a computer and interacting with other "intelligent" laboratory instruments.

Write to Perkin-Elmer for a free booklet about laboratory data handling and automation systems



Chromatogram reveals presence of ephedrine, which dilates respiratory passages to increase oxygen intake. Other peaks indicate smoking and coffee drinking.

Data station automates trace metal search

How much sulfur is in this coal? Does this canned milk contain lead? Is this well water too high in iron?

To answer such tough questions, analytical chemists turn to atomic spectroscopy, a method of measuring traces of metals in concentrations as low as one part per billion.

The three most common atomic spectroscopy techniques are flame

atomic absorption (for rapid determination of up to six elements), graphite furnace atomic absorption (for trace and microsample analysis), and the newer inductively-coupled plasma emission (for multielement analysis and for elements that can't be readily determined by atomic absorption).

In the new ICP/5000 System, all three techniques are combined for the first time, automated by microprocessors and controlled by a Perkin-Elmer intelligent data station. It can answer those tough questions by using the best analytical technique for each: inductively-coupled plasma emission for analyzing sulfur in coal, graphite furnace for measuring lead in canned milk, and flame for analyzing iron in well water.

Once optimum parameters have been recalled from memory by the analyst, the data station takes over. It selects wavelengths, calibrates, tells the operator when to analyze the sample, indicates any error, displays and prints the results. With its Autosampler, the ICP/5000 System can also sequentially analyze as many as 50 samples for up to 20 elements automatically.

The results will tell you whether the coal is harmful to the environment, whether the milk is safe for your child, and whether you should drink the water.

For your copy of a free brochure on the ICP/5000 System, write to the address below.

Perkin-Elmer computers speed lab data to doctors

The clinical laboratory of Houston's M.D. Anderson Hospital and Tumor Institute, one of the largest cancer centers in the world, performed more than two million tests last year. Data from these tests and thousands more on file must be instantly available via CRT terminals to doctors throughout the hospital.

But as the volume of tests climbed over the two million mark, the computer in the clinical laboratory began to blink "overload." In a comprehensive reliability study to choose new computers, the hospital ran extensive equipment tests. Two Perkin-Elmer 32-bit "supermini" computers were chosen on the basis of reliability, cost/performance factors and the ability to handle the hospital's growing needs.

Using system software developed by the hospital, lab data is input via 44 CRT terminals and 18 on-line instruments in the laboratory. The computers output data to the medical staff through 97 CRT terminals throughout the hospital.

Medical team views terminal outside operating room to check patient's test file stored in lab computer.

With 512 K bytes of memory each, the computers have increased total system memory tenfold. Capacity of the patient data file has been increased from 6,000 to 42,000 patients

Despite this major upgrading in performance, the new equipment is easy for the staff to use: a few simple instructions are all that's required to enter or retrieve data from the computers.

For a free booklet about 32-bit computers, write to the address below.

For more information

If you would like to learn more about these Perkin-Elmer products for Computer Aided Chemistry, please write: Corporate Communications, Perkin-Elmer, Main Avenue, Norwalk, CT 06856.

PERKIN-ELMER

Responsive Technology

liam W. Rubey in 1951. That some of this carbon was processed through marine organisms is entirely irrelevant to the question of its ultimate origin.

2. If all the reduced sedimentary carbon (about 12 units, where we define a unit as 10^{15} tons) was derived from carbon dioxide through reduction by photosynthesis, then the corresponding quantity of oxygen (about 32 units) must somehow be accounted for. The atmosphere contains only 1.2 units of oxygen. According to the calculations of Michael H. Hart (*Origins of Life,* Vol. 9, No. 4, pages 261–266; September, 1979), the oxidation of sedimentary ferrous iron to ferric iron and of sulfides to sulfates could have taken up at most eight units of oxygen. That leaves an "excess" of 22.8 units. It could not have escaped into space, nor could any other crustal element have absorbed such large quantities of oxygen. Only a part of this "excess" oxygen could have been taken up in the oxidation of a primordial reducing atmosphere, because most of the reduced sedimentary carbon is of post-Cambrian age. The discrepancy disappears, however, if we assume that a substantial fraction of the sedimentary carbon was derived from the outgassing of methane rather than carbon dioxide.

3. The correlation between young faults (as delineated by earthquakes) and oil seeps is based on the excellent work of R. D. Wilson, P. H. Monaghan, A. Osanik, L. C. Price and M. A. Rogers (*Science,* Vol. 184, No. 4139, pages 857–865; May 24, 1974) and is established beyond doubt. Furthermore, most of the oil-producing regions of the world are associated with Mesozoic and Tertiary fold belts and rifts, and hence with geologically recent faulting. Our critic first declares that the correlation exists only in our minds, and then he explains why it is to be expected anyway: faulting makes oil traps. It is true that a static fault can make a trap, but a lurching fault (during an earthquake) is the opposite of a trap. Is it loss by seepage, or storage in traps, that is facilitated in such regions? Oil, and particularly gas, should not be concentrated in regions of active faults, unless the rate of supply from below is comparable to the loss through seepage. The enormous rate of seepage in some areas implies a high rate of supply. (Incidentally, a general correlation is not invalidated by examples of its absence.)

4. Rocks at a depth of hundreds of kilometers must be at lithostatic pressure. Whether or not the rock was subducted from the surface is entirely irrelevant.

5. The part of the earthquake energy not associated with the seismic disturbance (but with internal friction) is not instrumental in creating a tsunami. The displacement of a sufficiently large slab of ocean floor to create tsunamis of the observed height and duration would require a very large change in the potential energy of the slab. We compared that with the maximum strain energy the rock could have borne and delivered to the earthquake as elastic rebound.

6. The duration of one phase of a tsunami is given by the velocity of wave propagation (for example 500 kilometers per hour for a depth of two kilometers) and the size of the exciting region, if the excitation is brief. If it is not, then the duration is a factor in determining the length of the wave. Gas injected on the floor of an ocean two kilometers deep will rise in the form of small bubbles, requiring tens of minutes to ascend. Even if the upwelling gas is confined to a narrow source region, it will produce a wave of tens of minutes' duration. Incidentally, bubbling of the sea on a large scale has often been observed associated with earthquakes.

7. If enormous reservoirs of deep gas are found to exist at depths of between five and 15 kilometers, then they will probably be tapped. Moreover, some of these reservoirs may be nearer the places requiring energy than currently known fields. In that case a few "vertical pipelines" to those depths might well be preferable "for a variety of economic, ecological and political reasons" to the use of overland and undersea pipelines hundreds of kilometers long and of sea routes 10,000 kilometers long.

THOMAS GOLD

STEVEN SOTER

Center for Radiophysics
and Space Research
Cornell University
Ithaca, N.Y.

Sirs:

Allow me to correct an error in my recent article "The Physiology of the Koala" [SCIENTIFIC AMERICAN, July]. The koala in the full-page color photograph at the beginning of the article is sitting not in a eucalyptus tree, as the caption states, but in a golden wattle. I submitted several illustrations with the article but did not have an opportunity to proofread the caption against the illustration chosen.

Incidentally, the illustration is a genuine photograph of a wild koala in nature. In fact, I have seen and photographed koalas in oak trees (in the Canberra district) and in kapok trees (in northern Queensland). I am sure that the range of trees frequented by koalas includes nonfood trees.

ROBERT DEGABRIELE

Riverina College of Advanced
Education
Wagga Wagga
New South Wales, Australia

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

DECEMBER, 1930: "Ever since the discovery of the new planet Pluto it has been eagerly observed. More than 100 accurate observations of its place in the heavens have been secured, and from them a rich harvest of knowledge has been reaped. The numerous observations of March, April and May improved our knowledge of the orbit so much that, figuring backward, the position of the planet in past years could be calculated, and images of it, in some cases very faint, were thus identified on photographs taken at the Yerkes Observatory in 1927 and 1921 and at the Mount Wilson Observatory in 1919. With these observations available the observed arc of the planet was multiplied twentyfold. The mean distance of Pluto from the sun is 39.60 astronomical units, but the eccentricity of the orbit is so great that the distance at aphelion is 49.7 astronomical units and at perihelion 29.55. One revolution of Pluto takes 249.17 years."

"China from ancient days has been an agricultural country, and it is still essentially agricultural. Certainly less than 10 percent of the population of 400 million are found in the large cities, and even they are mainly engaged in trade or industry involving agricultural products. The majority of the people eat what they raise. There is absolutely no margin or reserve. A famine in China is primarily a violent disturbance of the delicately balanced economic *status quo*—so violent that the common people find it difficult or impossible to buy food."

"One of the most important problems engaging the attention of airplane designers today is that of metal covering instead of fabric covering for both the wings and the fuselage of an airplane. Fabric covering has the disadvantage of poor maintenance and durability. Metal covering is unfortunately very heavy, even if the thinnest sheet is employed. Since the airplane is under strict weight limitations, it is only desirable to use metal covering provided the covering itself contributes to the strength. Unfortunately thin metal sheet will not develop anything like its theoretical strength because of local failure termed 'crinkling' when the sheet is in compression. The Navy Department and the Army Air Corps are both giving much attention to the problem of the metal-covered fuselage, and in time efforts of various designers should lead to more accurate knowledge. The large airplane for the future should have a structure similar in some respects to the structure of the ocean liner, in which the metal plating is so thick that it can be confidently taken into account in the calculations of strength."

"It is only X rays that can tell us the internal arrangement of a crystal, and it is only by becoming expert in the use of X rays that we can hope to unravel further the marvelous complexity of the relations between structure and properties. The X rays often surprise us by showing that crystalline structure exists where we had not expected it, for example in cotton, silk, stretched rubber, bone and so on, and we may be quite sure that the crystalline tendency is part of the plan and contributes to the desired character of the structure. We have a new field of knowledge, a new branch of science that is in fact a physics and chemistry of the solid."

DECEMBER, 1880: "The transmission of power by electricity is still in its infancy, and it might at first appear that the conversion of power into electricity, and then its reconversion into power, could not be managed economically. Electricity, however, possesses the marvelous capability of being conveyed a great distance along a conductor with hardly any loss of intensity, so that if it was desired to utilize power at a very great distance from its source, there is no doubt that electricity would afford the best and probably the only means of effecting it. Whether the vision of the future that Sir William Thomson pictured by means of the waste coal at the pit's mouth, thus saving the carriage of the coal, should, as he expects, be shortly realized, it at any rate indicates what a wonderful power of economical transmission to almost indefinite distances is possessed by the electric current."

"Volume VI of Behm and Wagner's *Bevölkerung der Erde,* just issued, gives a mass of well-digested information on the population of the countries of the world. We give an abstract of these new figures: Europe, 315,929,000; Asia, 834,707,000; Africa, 205,679,000; America, 95,495,500; Australia and Polynesia, 4,031,000, and the polar regions 82,000. The total is 1,455,923,500. The most populous cities in the world are London (3,630,000), Paris (1,988,806), New York (with suburbs, 1,890,000), Canton (1,500,000), Berlin (1,062,008) and Vienna (1,020,770)."

"At the fall meeting of the National Academy of Sciences, Prof. Henry Draper read a paper titled 'Photographing of the Nebulae in Orion.' After distributing copies of photographs taken by him, Prof. Draper said: 'The gaseous nebulae are bodies of interest because they may be regarded as representing an early stage in the genesis of stellar or solar systems. Matter appears to exist in them in a simple form, as is indicated by their simple spectrum of three or four lines. It is desirable, therefore, to ascertain what changes occur in the nebulae, and to determine, if possible, the laws regulating their internal movements.' In taking the photographs Prof. Draper used a triple achromatic objective of 11 inches aperture made by Clark & Sons for correcting the rays especially for photography. The photographic plates were bromo-gelatine and about eight times as sensitive as the wet collodion formerly employed."

"Philadelphia newspapers report that the American Union Telegraph Company are about to try in that city the experiment of putting their wires underground. The plan works well enough in European cities, and there would seem to be no reason why it should not succeed here, save the indisposition of the companies to bear the first cost of making the change. For some months the Western Union Telegraph Company has had the matter under consideration, but they will probably wait until pressed by a rival company before they undertake the more serious task of taking down their forest of poles and shrinking the wires that contribute so much to the prevailing ugliness of our streets."

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THE AUTHORS

KEVIN N. LEWIS ("Intermediate-Range Nuclear Weapons") is a member of the professional staff of the Rand Corporation. His work has been largely concerned with the effects of nuclear war, with defense budgeting and with problems of arms control. He received his B.S. in operations research at Yale University in 1977, his S.M. degree in defense policy at the Massachusetts Institute of Technology in 1979 and his Ph.D. from M.I.T. this year. Lewis' article "The Prompt and Delayed Effects of Nuclear War" appeared in SCIENTIFIC AMERICAN for July, 1979.

STILLMAN DRAKE and CHARLES T. KOWAL ("Galileo's Sighting of Neptune") are respectively emeritus professor of the history of science at the University of Toronto and a member of the astronomy department at the California Institute of Technology. Drake was educated at the University of California at Berkeley. He joined the Institute of History and Philosophy of Science at Toronto in 1967. He retired in 1978. Kowal got his B.A. in astronomy at the University of Southern California in 1963, and in the same year he moved to Cal Tech. Even before then, however, he had worked as a research assistant at the Mount Wilson and Palomar Observatories. His major observational accomplishments include the discovery of 81 supernovas, among them the very bright supernova of 1972. In 1974 he discovered the 13th satellite of Jupiter, and in 1977 he discovered Chiron, a planetoid between the orbits of Saturn and Uranus. He has also found several unusual asteroids and three comets, and he has "recovered" several lost comets and asteroids. In 1979 he received the James Craig Watson Award of the National Academy of Sciences. Kowal is currently conducting a survey of the outer region of the solar system.

FRANK WILCZEK ("The Cosmic Asymmetry between Matter and Antimatter") is professor of physics at Princeton University, currently on leave at the Institute for Theoretical Physics of the University of California at Santa Barbara. He received his B.S. in mathematics at the University of Chicago in 1970 and his Ph.D. in physics from Princeton in 1974. In the latter year he joined the Princeton faculty. From 1976 through 1978 he was an Alfred P. Sloan Foundation Fellow, and in 1977 and 1978 he was a fellow of the Institute for Advanced Study in Princeton. He is a member of the High-Energy Advisory Committee of the Brookhaven National Laboratory. Wilczek writes that he has an amateur interest in astronomy and physiological psychology.

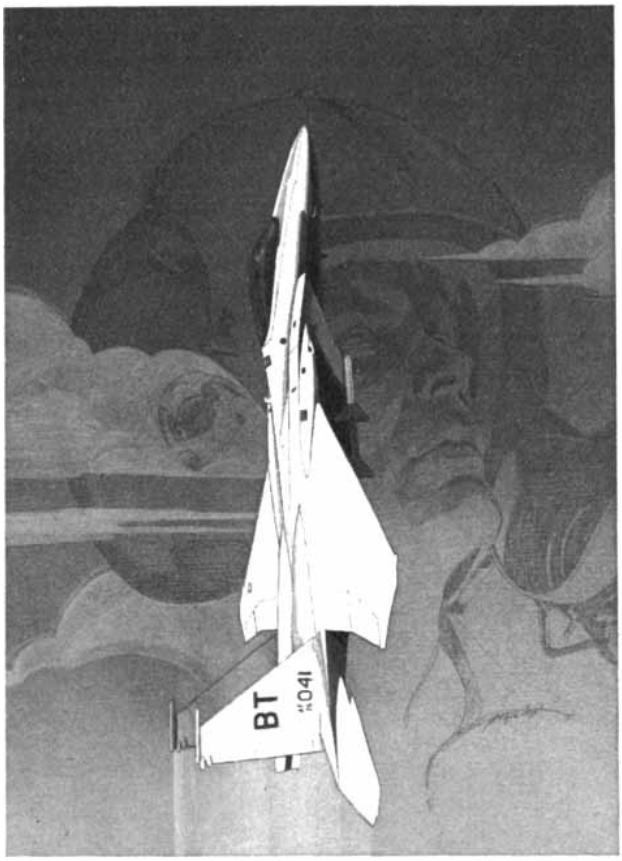
RICHARD P. NOVICK ("Plasmids") is chairman of the department of plasmid biology at the Public Health Research Institute of the City of New York. He got his B.S. at Yale University in 1954 and his M.D. at the New York University School of Medicine in 1959. While he was in medical school he took a year off to work with Werner K. Maas at the N.Y.U. School of Medicine on genetic regulation in bacteria, which was his introduction to molecular genetics. Thereafter he spent a year at Yale as an intern and two years working with Martin Pollock at the National Institute for Medical Research in Britain. There he discovered plasmids in the bacterium *Staphylococcus aureus,* and in so doing he developed an interest in these extrachromosomal loops of DNA. Still uncertain whether or not he wanted to do basic research or work in medicine, he then spent a year at Vanderbilt University as an assistant resident in medicine. Following that he spent two years as a postdoctoral fellow with Rollin D. Hotchkiss at the Rockefeller Institute for Medical Research (now Rockefeller University). He joined the staff of the Public Health Research Institute in 1965. Novick writes: "Although the study of plasmids has been a fascinating and challenging exercise in molecular genetics, at the same time it has a disquieting undercurrent relating to the spread of plasmids and the consequent diminution in the efficacy of antibiotics. Since this situation has been caused in large measure by the overuse of antibiotics in medicine and agriculture, my enthusiasm for the pure science has been seasoned by a sense of social responsibility, and I have found it imperative to speak out, sometimes rather loudly, as often as possible on this issue."

RICHARD S. DAVIS, VADIM A. RANOV and ANDREY E. DODONOV ("Early Man in Soviet Central Asia") are respectively a lecturer in the department of anthropology at Bryn Mawr College, head of the section of archaeology and numismatics in the Institute of Archaeology of the Tadzhik S.S.R. Academy of Sciences and a member of the staff of the Institute of Geology in the Academy of Sciences of the U.S.S.R. In 1977 Davis was in Tadzhikistan in Soviet Central Asia for six months on the interacademy exchange program between the National Academy of Sciences and the Academy of Sciences of the U.S.S.R. During that time he worked with Ranov and Dodonov on Paleolithic archaeology. Last year he continued his work with Ranov when Ranov visited the U.S. on an exchange program between the International Research and Exchanges Board (IREX) and the Soviet Academy. Davis received his A.B. at Columbia College in 1966 and his Ph.D. from Columbia University in 1974. Ranov has since 1953 been actively involved in numerous excavation and survey projects in Soviet Central Asia, ranging from the desert plains near the Amu Darya to the highland valleys of the eastern Pamirs. He has discovered and excavated numerous sites from all periods of the Paleolithic. Dodonov is a geologist who has worked on several occasions with Ranov on problems of interpreting deposits that contain artifacts.

VINCENT P. DOLE ("Addictive Behavior") is professor at Rockefeller University and Senior Physician to the Rockefeller University Hospital. He got his A.B. in mathematics at Stanford University in 1934 and his M.D. at the Harvard Medical School in 1939. In 1941 he joined the staff of the Rockefeller Institute for Medical Research. In recent years he has been mainly interested in the problem of narcotic abuse and in scientific and clinical aspects of the methadone treatment of addiction, which is the major theme of his article. Earlier he had a particular interest in the metabolism of free fatty acids and adipose tissue. Dole writes: "The most important item not mentioned in my curriculum vitae is my great debt to Marie Nyswander, my close professional associate and my wife. She taught me how to see addicts as patients and not simply as problems."

JEFFREY M. CAMHI ("The Escape System of the Cockroach") is associate professor of biology at Cornell University. He received his B.A. in biology at Tufts University in 1963 and his Ph.D. from Harvard University in 1968. He joined the faculty of Cornell in 1967. In 1973 and 1974 he was a visiting scientist at the University of Oxford. The main theme of his research, which is reflected in the work described in his article, is the role of individually identified nerve cells in behavior.

DAVID EMIL THOMAS ("Mirror Images") obtained two bachelor's degrees (in mathematics and physics) and a master's degree (in mathematics) at the New Mexico Institute of Mining and Technology. His master's thesis concerned the optics of arbitrarily curved mirrors. In 1978 he was awarded U.S. Patent No. 4,116,540 for a series of nonreversing mirrors. His other interests include the differential geometry of surfaces, geometric mappings and projections and the cylindrical perspective of the Dutch artist M. C. Escher.



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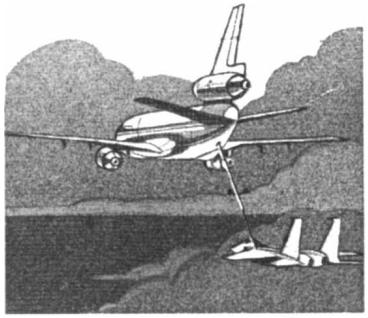

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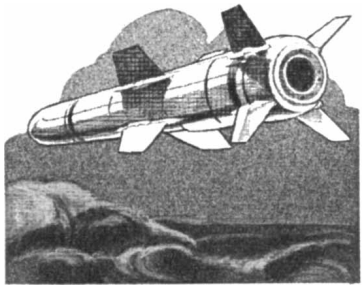

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MATHEMATICAL GAMES

Patterns in primes are a clue to the strong law of small numbers

by Martin Gardner

Let us now praise prime numbers
With our fathers that begat us:
The power, the peculiar glory
of prime numbers
Is that nothing begat them,
No ancestors, no factors,
Adams among the multiplied
generations.

—HELEN SPALDING

"The Strong Law of Small Numbers" is the provocative title of an unpublished paper by Richard Kenneth Guy, a mathematician at the University of Calgary. For many years Guy has edited the "Research Problems" department of *The American Mathematical Monthly*. He is the author of numerous technical papers and is coauthor with John Horton Conway and Elwyn R. Berlekamp of *Winning Ways*, a long-awaited mammoth book of new mathematical recreations that will be published by Academic Press this coming year. The material that follows is taken almost entirely from Guy's paper.

"We think of mathematics as an exact science," Guy begins, "but in the field of discovery this is not at all the right picture. Two of the most important elements in mathematical research are asking the right questions and recognizing patterns."

Unfortunately there is no procedure for generating good questions and no way of knowing whether an observed pattern will lead to a significant new theorem or whether the pattern is just a lucky coincidence. In these respects the research mathematician is in a position strangely like that of the scientist. Both ask questions, do experiments and observe patterns. Will an observed pattern be repeated when new observations are made, with new parameters, leading to the discovery of a general law, or will counterexamples turn up that contradict a hypothesis? It is true that mathematicians can do something scientists cannot: they can prove theorems within a formal system. Until a proof is found, however, a mathematician relies on fallible empirical induction in much the same way a scientist does. This is particularly true in combinatorial problems that involve infinite sequences of numbers.

In examining cases involving small numbers a striking pattern may be encountered that strongly implies a general theorem. It is this implication Guy calls the strong law of small numbers. Sometimes the law works, sometimes it does not. If the pattern is no more than a set of coincidences, as it often is, a mathematician can waste an enormous amount of time trying to prove a false theorem. The law can also mislead in an opposite way. A few counterexamples may cause the mathematician to prematurely abandon a search for a theorem that is actually true but slightly more complicated than expected.

Today's computers are a big help because they often can quickly explore cases of higher numbers that will either explode a hypothesis or greatly increase the probability of its being true. In many combinatorial problems, however, the numbers grow at such a fantastic rate that the computer can examine only a few more cases than can be examined by hand, and the mathematician may be left with an extremely intractable problem.

One could fill many books with examples of how the strong law of small numbers has led to significant theorems, or has misled investigators into looking for theorems that are not there, or has misled them by suggesting a theorem is not there when it is, or has suggested theorems that may be there but resist all efforts to prove them. In the ragbag of examples that follow we shall limit our attention to positive prime numbers.

Primes are the natural numbers larger than 1 with no factors except 1 and themselves: 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31,... All are odd except 2, which has the reputation, Guy points out, of being the "oddest" of all the primes. No polynomial formula can generate primes; indeed, it has been shown that no polynomial has only prime values. As the second stanza of Helen Spalding's poem goes:

None can foretell their coming.
Among the ordinal numbers
They do not reserve their seats,
arrive unexpected.
Along the line of cardinals
They rise like surprising pontiffs,
Each absolute, inscrutable,
self-elected.

Euclid proved that the primes are infinitely many, but the higher they go the larger the gaps between them are. The same is true of the prime powers. Apart from 6 every natural number smaller than 10 is a power of a prime, and more than a third of all numbers smaller than 100 are prime powers. Yet it would be folly to conclude from these small primes that the density of prime powers has a lower bound. They thin out so rapidly as the numbers get larger that their density can be made as low as one likes.

In the beginning where chaos
Ends and zero resolves,
They crowd the foreground prodigal
as forest,
But middle distance thins them,
Far distance to infinity
Yields them rarely as unreturning
comets.

Primes offer rich examples of remarkable patterns that are entirely accidental and lead nowhere. Consider the following sequence of primes: 7, 37, 337, 3337, 33337, 333337,... One is tempted to think the pattern will continue, but it fails in the next case: 3333337 is composite (nonprime) with the prime factors of $7 \times 31 \times 15361$. Indeed, in all cases of patterns of this kind it is a safe bet that the pattern will not continue to yield primes.

Several years ago Reo F. Fortune, an anthropologist at the University of Cambridge (who was once married to the late Margaret Mead), noted a curious pattern involving small primes. Starting with 2, take the product of a set of consecutive primes. Add 1. Find the

$2 + 1 = 3$	$5 - 2 = 3$
$(2\times3) + 1 = 7$	$11 - 6 = 5$
$(2\times3\times5) + 1 = 31$	$37 - 30 = 7$
$(2\times3\times5\times7) + 1 = 211$	$223 - 210 = 13$
$(2\times3\times5\times7\times11) + 1 = 2311$	$2333 - 2310 = 23$
$(2\times3\times\ldots\times13) + 1 = 30031$	$30047 - 30030 = 17$
$(2\times3\times\ldots\times17) + 1 = 510511$	$510529 - 510510 = 19$
$(2\times3\times\ldots\times19) + 1 = 9699691$	$9699713 - 9699690 = 23$

Fortune's conjecture

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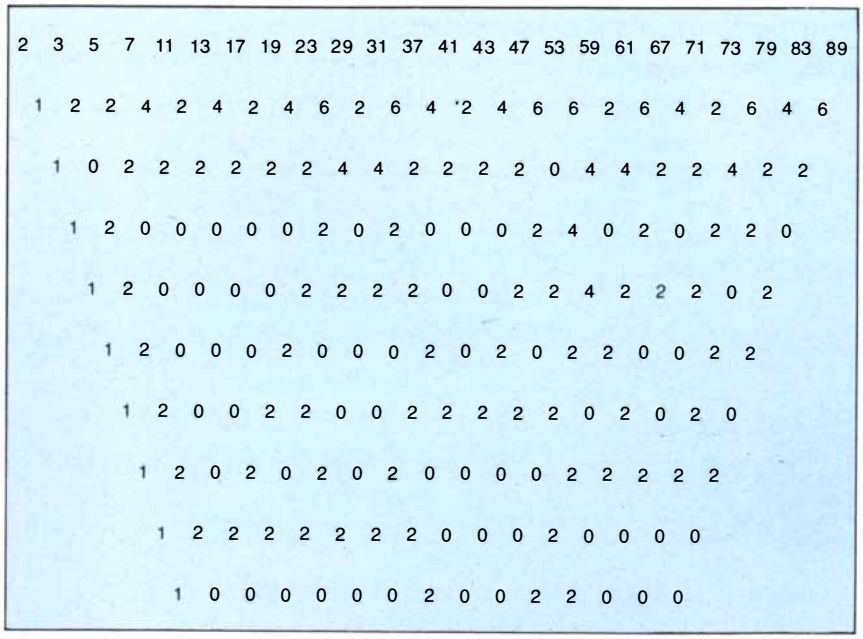

Gilbreath's conjecture concerning successive absolute differences in the sequence of primes

next-largest prime and from it subtract the product of the consecutive primes. Is the result always a prime? The chart on page 18 shows the procedure applied to the first eight cases and gives the eight "fortunate primes" that are generated.

Fortune conjectures that the result is always a prime. Most number theorists believe this is true, but no proof has been found and there seems to be little hope, Guy says, of finding one in the foreseeable future. Perhaps some reader of this column can "cook" (falsify) the conjecture by finding what one might call a "fortune cookie." Note that in the chart the first five numbers at the right side of the equation on the left are primes. Is this always the case? No, it fails for the next three numbers. Mark Templer in his article titled "On the Primality of $k! + 1$ and $2 * 3 * 5 * \cdots * p + 1$" has shown (*Mathematics of Computation,* Vol. 34, No. 149, pages 303–304; January, 1980) that one more than the product of primes up to p is prime for the first five primes and for $p = 37$, $p = 379$, $p = 1019$ and $p = 1021$, and for no other p less than 1032.

Another strange hypothesis, not yet proved, is known as the Gilbreath conjecture after Norman L. Gilbreath, an American mathematician and amateur magician who proposed it in 1958. Write the sequence of primes in a row and under them list the differences between successive primes. Under that second row list the absolute values of the differences, and continue the procedure for as long as you like. The illustration above shows a table of nine rows of differences for the first 24 primes. Note that each row begins with 1. Will every row begin with 1? Gilbreath guesses that it will. This has been verified by Ray B. Killgrove and Ken E. Ralston up to the 63,419th prime (*Mathematical Tables and Other Aids to Computation,* Vol. 13, No. 66, pages 121–122; April, 1959).

"It does not seem likely," writes Guy, "that we shall see a proof of Gilbreath's conjecture in the near future, although the conjecture is probably true." Guy adds that the truth may have nothing to do with the primes as such. Hallard Croft has suggested the conjecture may apply to any sequence beginning with 2 and followed by odd numbers that increase at a "reasonable" rate and with gaps of "reasonable" size. If this is the case, Gilbreath's hypothesis may not be as mysterious as it first seems, even though it may be enormously difficult to prove.

One of the most notorious of all unsolved prime conjectures is that there are an infinite number of twin primes. These are pairs of primes that differ by 2. The smallest instances are 3 and 5, 5 and 7, 11 and 13, 17 and 19, 29 and 31, 41 and 43, 59 and 61, and 71 and 73. Many giant examples are known. Until recently the largest example was a pair of 303-digit primes found by Michael A. Penk in 1978. It was surpassed in 1979 when A. O. L. Atkin and Neil W. Rickert found two larger pairs: $694503810 \cdot 2^{2304} \pm 1$ and $1159142985 \cdot 2^{2304} \pm 1$. In the larger twin pair each number begins 4337..., ends with 17760 ± 1 and consists of 703 digits.

The twin-prime conjecture generalizes to prime pairs that differ by any even number n. (Apart from 2, no two primes can have an odd difference because that would make one number even and hence composite.) It can be further generalized to certain finite patterns of numbers separated by specified even differences. For example, the following triplets of primes all fit the pattern k, $k + 2$ and $k + 6$: 5, 7 and 11; 11, 13 and 17; 17, 19 and 23; 41, 43 and 47, and 101, 103 and 107.

It is believed that for any such pattern not forbidden by divisibility considerations there are infinitely many examples. (The pattern k, $k + 2$ and $k + 4$ has only one solution in primes, 3, 5 and 7, because any larger triplet of this pattern would contain a number divisible by 3.) Quartets of the form k, $k + 2$, $k + 6$ and $k + 8$ (the smallest example is 5, 7, 11 and 13) are thought to be infinite. For some patterns no example is known, or only one. R. E. Crandall has called attention to the pattern exhibited by the octet 11, 13, 17, 19, 23, 29, 31 and 37. There are surely other instances of this pattern, but so far none has been found.

The Mersenne numbers—numbers of the form $2^n - 1$, or one less than a power of 2—have fascinated number theorists since classical times, particularly because of their connection with perfect numbers: numbers that are the sum of their divisors, including 1 but not the number itself (6, 28, 496,...). If a Mersenne number is prime, it automatically leads to a perfect number by way of Euclid's formula $2^{n-1}(2^n - 1)$, where the number in parentheses is a Mersenne prime.

It is easy to show that a Mersenne number cannot be prime unless the exponent n is prime. If n is prime, will the Mersenne number be prime? The strong law of small numbers suggests it will, because it is true when n equals 2, 3, 5 and 7. The law fails for $n = 11$, however, because $2^{11} - 1$ equals 2047, which equals 23×89. It holds for $n = 13$, $n = 17$ and $n = 19$, then fails again for $n = 23$. From here on successes rapidly become rarer. At the moment only 27 Mersenne primes (hence only 27 perfect numbers) are known. The 27th Mersenne prime, $2^{44497} - 1$, was discovered in 1979 by a computer program written by David Slowinski with the assistance of Harry L. Nelson at the Lawrence Livermore Laboratory of the University of California. The number starts 854..., ends ...671 and has 13,395 digits. No one knows if the number of Mersenne primes is infinite, or even if there is a 28th one.

Fermat numbers have the form $2^{2^n} + 1$. For $n = 0$, $n = 1$, $n = 2$, $n = 3$ and $n = 4$ the number is prime (3, 5, 17, 257 and 65537). Pierre de Fermat thought all numbers of this form are prime, but he overlooked the fact that $n = 5$ yields 4294967297, which has the prime factors 641×6700417. No Fermat primes other than the five known to Fermat have been found, and no one knows whether or not others exist.

Here is a curious pattern involving factorials and primes. Factorial n, written $n!$, means $1 \times 2 \times 3 \times \ldots \times n$. Note

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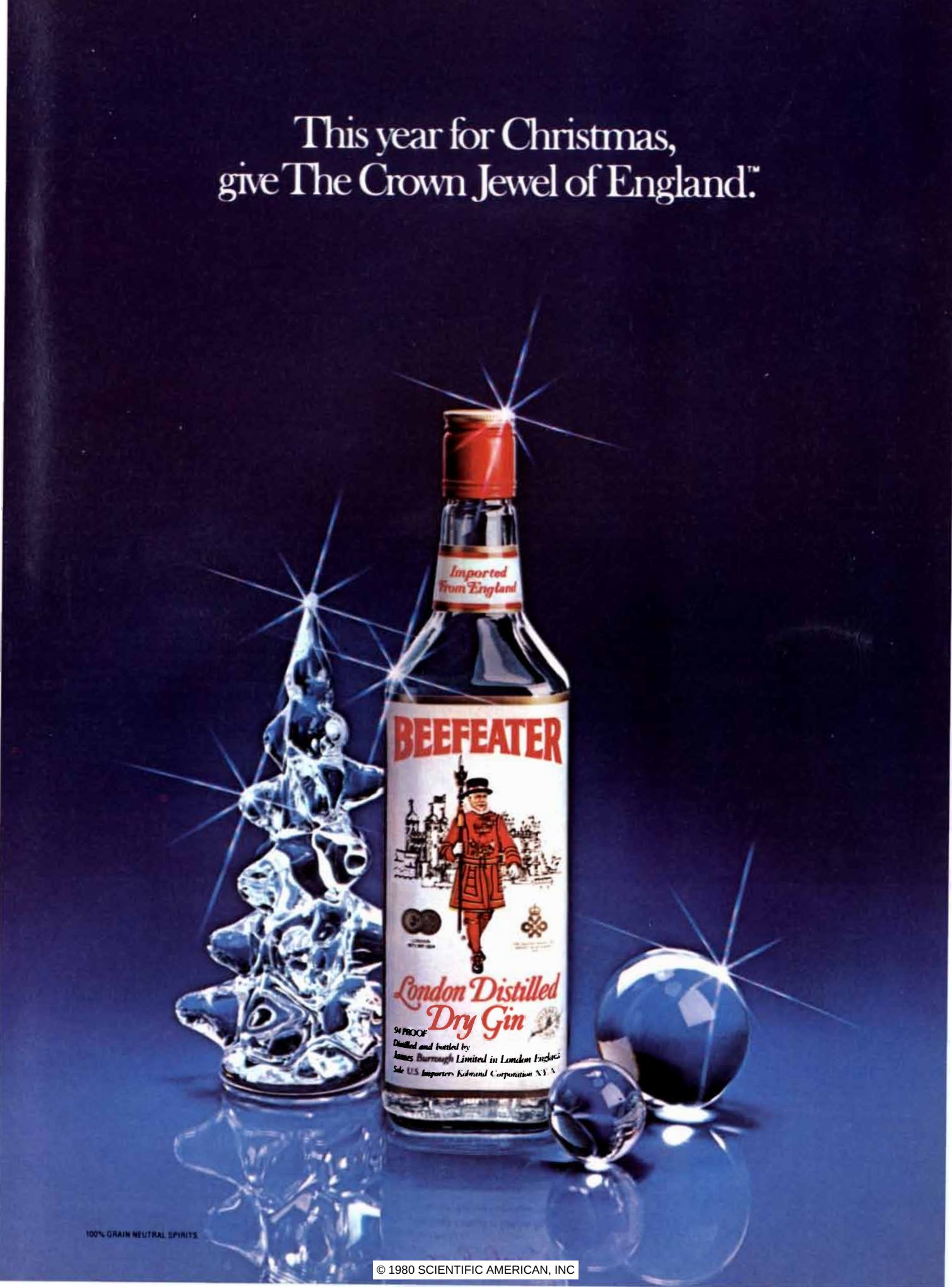

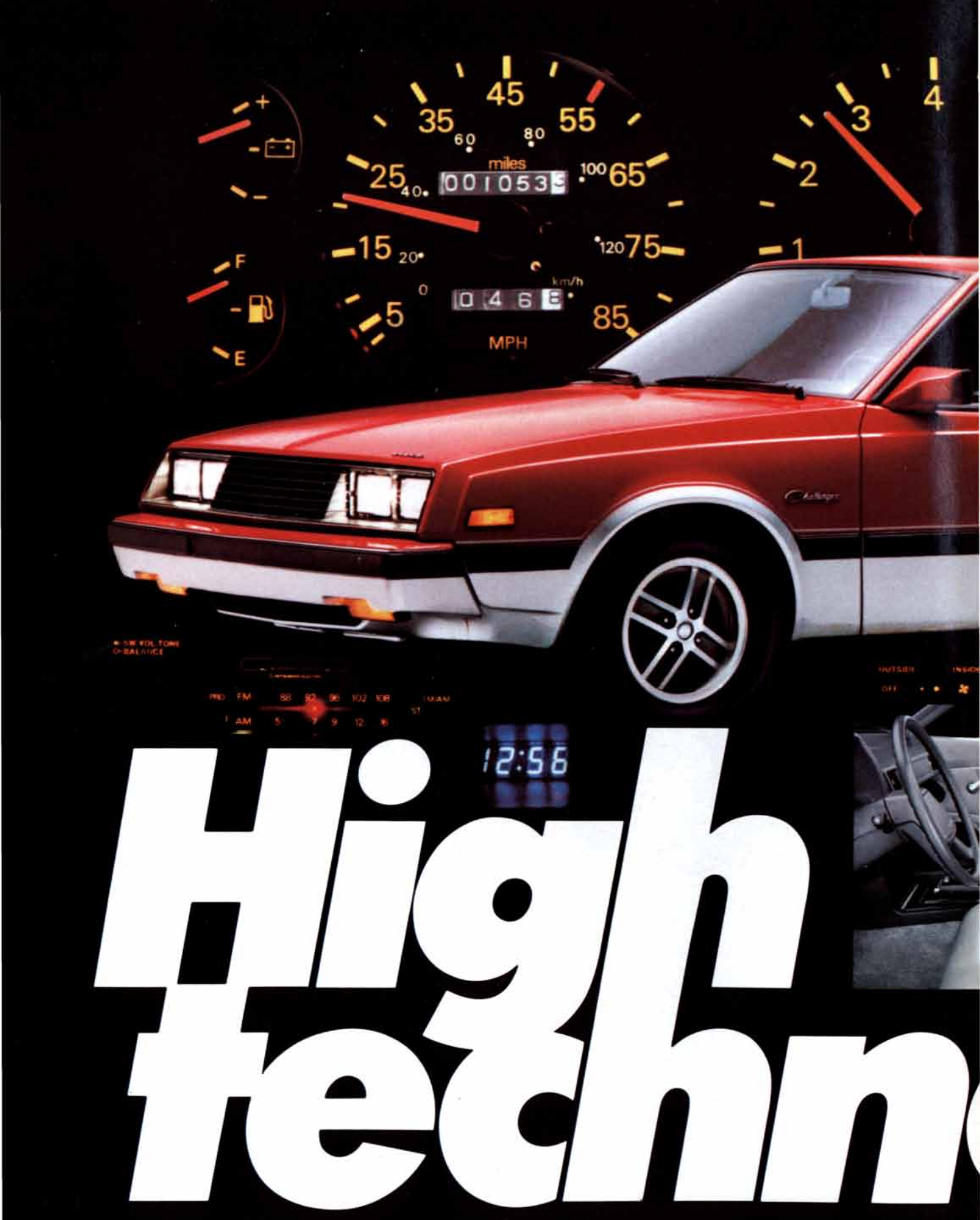

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1	1,1	2
2	1, 2, 1	3
3	1, 3, 2, 3, 1	5
4	1, 4, 3, 2, 3, 4, 1	7
5	1, 5, 4, 3, 5, 2, 5, 3, 4, 5, 1	11
6	1, 6, 5, 4, 3, 5, 2, 5, 3, 4, 5, 6, 1	13
7	1, 7, 6, 5, 4, 7, 3, 5, 7, 2, 7, 5, 3, 7, 4, 5, 6, 7, 1	19

Leo Moser's prime triangle

how plus and minus signs alternate in the following pattern:

$3!-2!+1!=5$
$4!-3!+2!-1!=19$
$5!-4!+3!-2!+1!=101$
$6!-5!+4!-3!+2!-1!=619$
$7!-6!+5!-4!+3!-2!+1!=4421$
$8!-7!+6!-5!+4!-3!+2!-1!=35899$

In each case the number on the right is prime. Alas, the strong law of small numbers fails on the next step. It yields 326981, the product of primes 79 and 4139. The next primes result when n equals 10, 15 and 19.

The chart shown below is formed as follows. We start with 41, then add 2 to get prime 43. To 43 add 4 to get prime 47. To 47 add 6 to get prime 53. Continue in this manner, bringing each prime down as the first number of the next row, and adding numbers from the sequence 2, 4, 6, 8,... In every case on the chart the result is a prime. Does this success continue forever or does it fail at some point? I shall give the answer in my next column.

The Canadian mathematician Leo Moser constructed the curiosity displayed in the illustration above. A study of the pattern shows that each sequence is formed from the one above it by inserting n, the row number, between all pairs of numbers that add to n. On the right k stands for the number of numbers in each sequence. Note that the first six k numbers are the first six primes. The next k number skips 17, but 19 is a prime. Are all k numbers prime? What is the formula for finding the nth k number? I shall give the answers to both questions in my next column.

EVEN NUMBERS		PRIMES
41	+ 2	= 43
43	+ 4	= 47
47	+ 6	= 53
53	+ 8	= 61
61	+ 10	= 71
71	+ 12	= 83
83	+ 14	= 97
97	+ 16	= 113
113	+ 18	= 131
131	+ 20	= 151
151	+ 22	= 173
173	+ 24	= 197
197	+ 26	= 223
223	+ 28	= 251
251	+ 30	= 281
281	+ 32	= 313
313	+ 34	= 347
347	+ 36	= 383
⋮		

How long does this continue to give primes?

Except for 2, all primes have the form $4k \pm 1$, which means that every prime except 2 is one more or one less than a multiple of 4. (This follows trivially from the fact that every odd number is one more or one less than a multiple of 4.) Write the odd primes in consecutive order, putting the $4k - 1$ primes in the top row and the $4k + 1$ primes under them:

3 7 11 19 23 31 43 47 59 67 71 79 83
5 13 17 29 37 41 53 61 73

At this point the top row is "winning the race." If we continue the two sequences, will the top row always be ahead? You should not waste time trying to settle this empirically, Guy advises, because you have to go a long way before the second row gets ahead, and even then you will not have proved anything. The eminent Cambridge mathematician John E. Littlewood showed that the rows alternately lead infinitely often.

Above 5 all primes have the form $6k \pm 1$. If we race these two "horses," they too change lead infinitely often. Other prime-number races have been investigated, such as the four horses in the $8k \pm 1$, $8k \pm 3$ race. Although it is far from established, most number theorists believe that in all such races, regardless of the number of horses, every horse is ahead infinitely often in the long run.

Primes of the form $4k + 1$ (the bottom row of the $4k \pm 1$ race) can always be expressed as the sum of a unique pair of distinct square numbers. Hence 5 equals $4 + 1$, 13 equals $4 + 9$, and so on. This was proved by Fermat and is known as Fermat's two-square theorem. It is an excellent example of a pattern for which the strong law of small numbers is not deceptive but leads to a genuine theorem. Many ways to prove the theorem have long been known, but in 1977 Loren C. Larson of St. Olaf Col-

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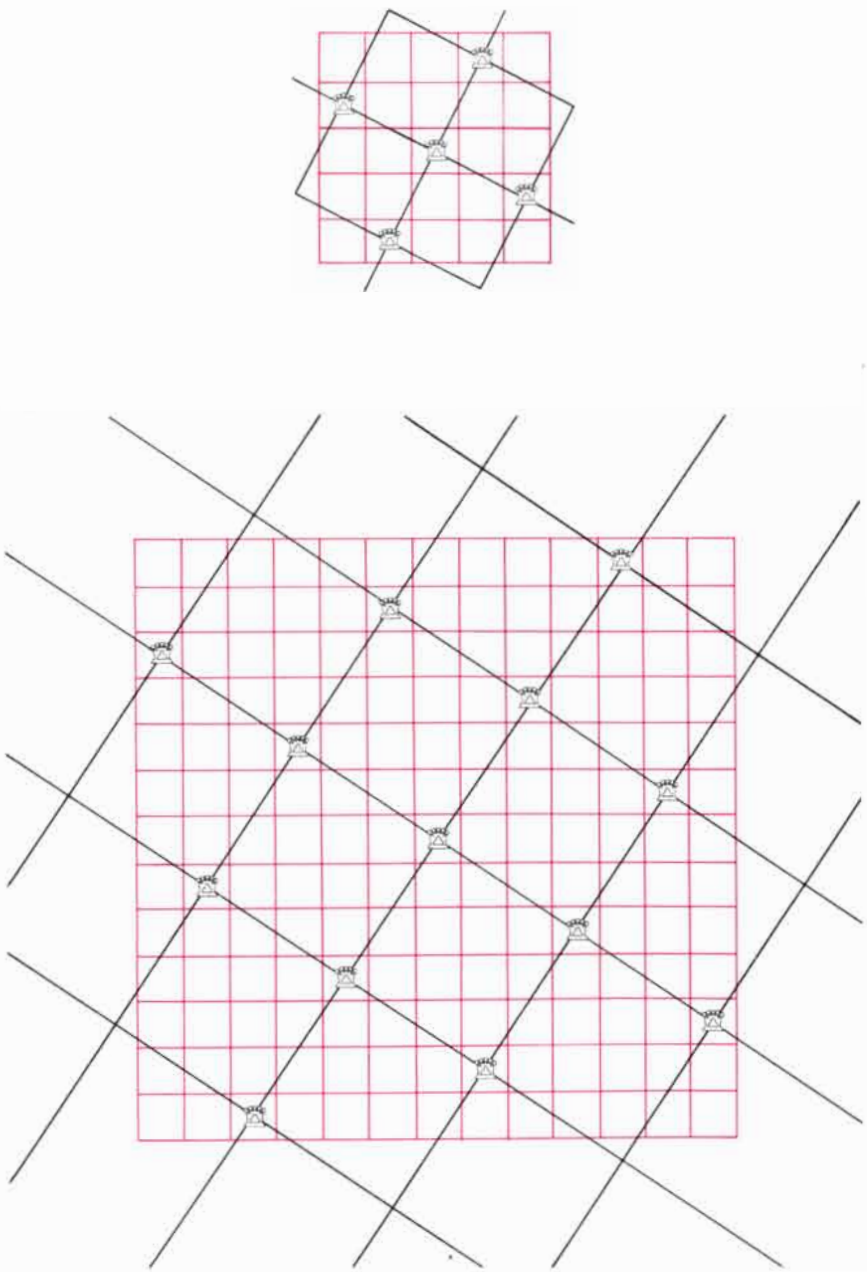
GENERAL ELECTRIC

lege in Minnesota published a delightful new proof based on the familiar problem of placing n queens on an n-by-n chessboard so that no queen attacks another.

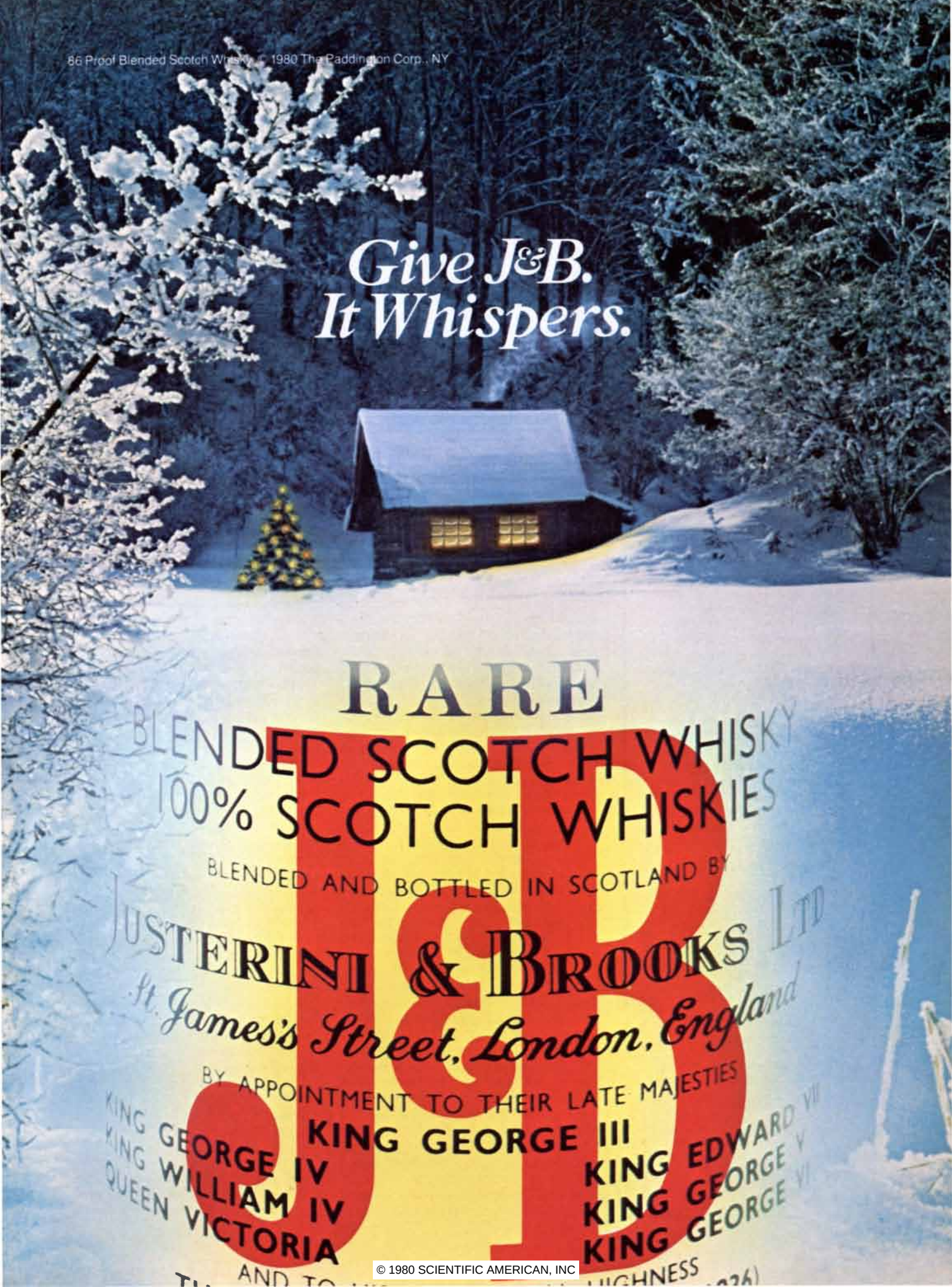
The figure at the top of the illustration below shows the smallest solution for the queens problem that displays the following properties: (1) there is a queen on the center square, (2) all other queens are reached from the center by a generalized knight move of m cells in one direction followed by n cells in a direction at right angles to the first (where m and n are distinct integers) and (3) the final pattern has fourfold rotational symmetry (is unchanged by 90-degree rotations). The next-largest solution with all these features is shown at the bottom of the illustration: 13 queens on a 13-by-13 board.

Apart from the center queen, for all such solutions each quadrant of the board obviously must hold the same number of queens. The number therefore will have the form $4k + 1$. Larson shows that solutions of this type can be constructed if and only if the number of queens is a prime of this form.

In all such solutions the board can be divided into identical smaller squares in the manner shown by the slanting lines in the two examples below. If we imagine the board formed into a torus by joining the top and bottom edges and the left and right edges, we see that each



Chessboard proof that $4k + 1$ primes are the sum of two distinct squares



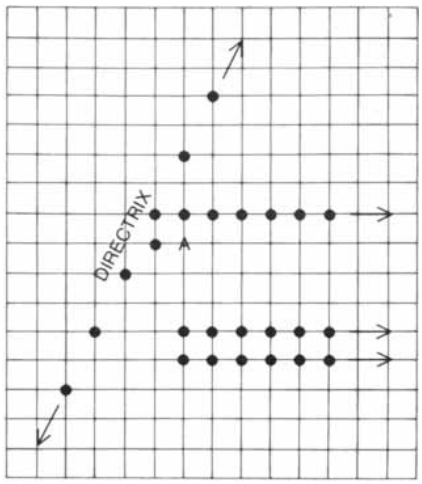
board of side p is made up of p tilted squares. Since the board has an area of p^2, the area of each small square is $\sqrt{p}$. Since p is the hypotenuse of a right triangle with sides equal to m and n (the two components of the generalized knight move), it follows from the Pythagorean theorem that p (the area of the square on the hypotenuse) must equal the sum of the squares of m and n. And since p is any prime of the form $4k + 1$, it follows that every such prime is the sum of two distinct squares. I have given Larson's proof, based on earlier work by George Pólya, in highly abbreviated form. For more details see his article "A Theorem about Primes Proved on a Chessboard" (*Mathematics Magazine,* Vol. 50, No. 2, pages 69–74; March, 1977).

The fourth and last stanza of Spalding's poem gives a fitting conclusion:

O prime improbable numbers,
Long may formula-hunters
Steam in abstraction, waste
to skeleton patience:
Stay non-conformist, nuisance,
Phenomena irreducible
To system, sequence, pattern
or explanation.

My description in September of my visit with Dr. Matrix contained a number of errors. I misspelled "Istiklal," a street in Istanbul, and when I referred to the "Asian sector" of the city, I really meant the Old City. Dr. Matrix' parting words to me were simply "Gule gule," literally "Go with laughter." I am indebted to Robert F. Scott, Boris Gilode and George Gibson, who were the first to write me in this connection.

There were also two mathematical errors. I reported Dr. Matrix as saying that the set of no-rep emirps (primes without duplicate digits that are different primes when they are written backward) had not been proved finite. Consulting my notes, I see that Dr. Matrix spoke only of the set of emirps. It was foolish of me not to realize that any emirp of more than 10 digits would have duplicate digits. Moreover, as Harvey P. Dale and many others noted, no number of even 10 digits can be a no-rep emirp because the 10 digits will have a sum of 45, and so any permutation of them will be a multiple of 9. According to Dale, the highest no-rep emirp is 987653201. I should not have listed 11939 as a cyclic emirp because the permutation 19391 is a palindrome. It appears as if the only cyclic emirp is the six-digit one Dr. Matrix gave, although it may never be possible to prove it. As John Baum made clear, my memory of Dr. Matrix' remark about a recent paper by Paul Erdös was faulty. Erdös' finding concerns the number 70, but the number whose property I described is 60. What Erdös actually proved was that if you start with n and write a sequence of integers greater than n such that each is relatively prime to all the preceding integers in the sequence, then 70 is the largest number for which such a sequence contains only primes and squares of primes.



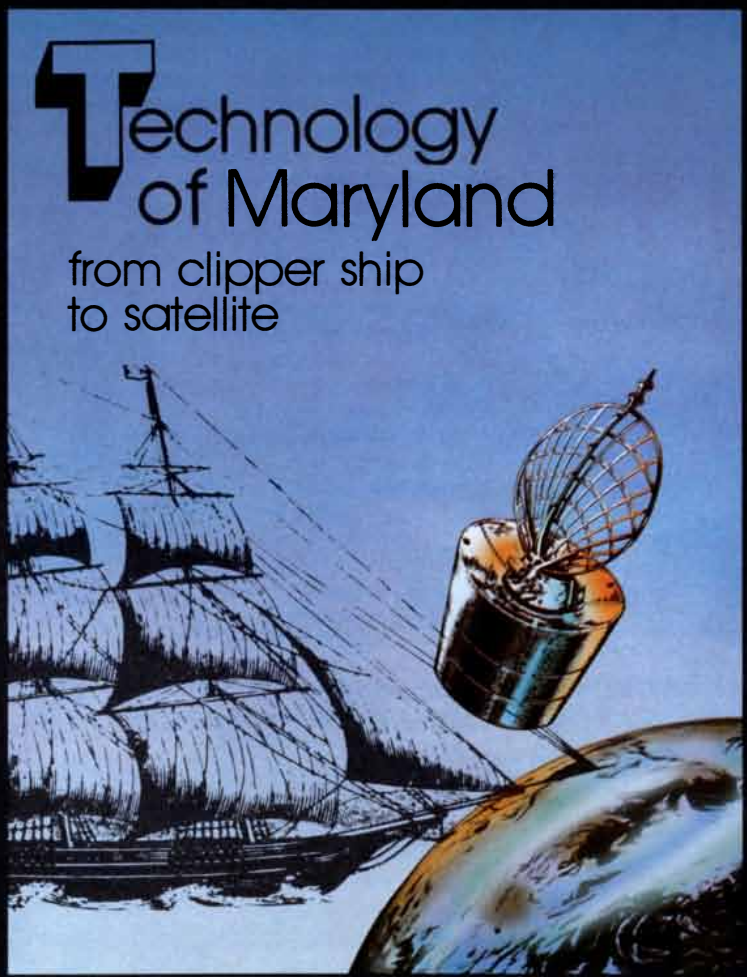
Solution to taxicab-parabola problem

In October, when I gave the answer to Dr. Matrix' question about cutting a cube into three congruent parts, I said I knew of no other way to accomplish the trisection. As many readers were quick to point out, I could not have been wronger. John E. Morse sent the most general solution. If you hold a cube so that its corner points toward you and the outline appears to be a regular hexagon, you will see the cube's 3-symmetry. This symmetry is too complicated to explain in detail, but it makes it possible to slice the cube into three congruent parts in an infinite number of ways. The surfaces of the parts may be flat or curved in any manner, and it is easy to design weird trisections for which the parts are so intricately interlocked that they cannot be separated.

Michael O'Donnell told me that the ballad about Abdul Abulbul Amir had been written in 1877 by Percy French, an Irish music-hall entertainer. A London publisher printed the song without acknowledgment, and to this day its author is listed in anthologies as Anonymous. For the best version I know see Sigmund Spaeth's 1926 anthology *Read 'em and Weep—the Songs You Forgot to Remember.*

Bennett Battaile wrote to suggest an alternative to the problem of labeling the corners of a cube with the integers 0 through 7 so that the sum of every pair of numbers sharing an edge is a prime. Try to make each sum a composite number. This problem too turns out to have a unique solution, apart from rotations and reflections.

The solution to last month's problem of constructing a taxicab parabola with a given focus A and a given directrix is shown in the illustration above.



This is one in a series of special reports on advances in high technology throughout the United States, written by Peter J. Brennan, writer on international business, finance and development in concert with Development Counsellors International, Ltd.

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These together form the popular conception of our seventh state. Mention Maryland and people envision not a modern center of space, communications and medical technology but country gentry living on memories of a prosperous but not particularly notable past.

There Is Much More...

But Maryland has always had far more than Fort McHenry, oyster stew and terrapin soup. One of the original 13 colonies, it has history and a culture uniquely its own. It has ocean beaches on the Atlantic, innumerable sheltered harbors and bays, rolling farmland, steep valleys and mountains. And it has an enormous base in technology that stretches from early clipper ship to modern space shuttle.

West, the Alleghenies that once formed a staunch barrier to expansion now yield coal and other minerals. Further east, fertile rolling land that provided fortunes for the original proprietary landowners now makes prosperous the generations of farmers that followed them. Across Chesapeake Bay lies the Eastern Shore, flat farmland that is as much a part of the sea as of the land. Like a great life-bearing artery to the heart of the state, the rich waters of the Bay itself open the area to the world while its innumerable tiny harbors and gunkholes beloved of sailors, yachtsmen and fishermen are playland, resource and basis of technology.

Advanced Technology —1840 Style...

Technology came early to Maryland. And as it largely still is, it was technology in support of commerce.

The oystermen of Chesapeake Bay in the 18th Century developed a fast sailing vessel with fine lines and large sail area. Others with need for speed adapted the design to ever larger ships. These led directly to the most efficient sailing machines ever built, the Baltimore Clippers and their successors.

The revolutionary clippers were high technology for their day. The design problem in reconciling weight, sail area, sea-keeping ability, capacity, stability, strengths of materials and balances of forces were at least the equal for the time of an aircraft design problem today. Though the type flourished for only twenty years and Baltimore soon lost the lead as designer and builder, these products of Maryland technology briefly made the U.S. merchant marine supreme.

The clippers' ocean crossings set record after record, not surpassed until well into the age of steam. But steam and imitative foreign competition started a long slow decline in 1855, soon hastened by war.

The clippers faded to romantic symbols remembered still today in the oyster boats of Chesapeake Bay. But Maryland was not done with advanced technology. Its burgeoning steel yards, refractory and chemical plants produced basic materials and its shipyards launched vessels. At Annapolis, the U.S. Naval Academy pioneered in oceanography and St. John's College, chartered in 1784, has with its unique curriculum set an extraordinary level of academic excellence. And slumbering on the southern edge the U.S. Government began to spill across the arbitrary border. Neighboring Maryland became de facto part of Metropolitan Washington.

Two poles at either end of a forty-mile corridor took shape. With one pole firmly planted in industrial technology and the other in the business of government, it was inevitable that they should interact.

In time, lesser poles have appeared. Along route 270 to the Northwest the authentically charming ante-bellum city of Frederick balances the boutiquely charming capital on the Bay at Annapolis. The result is a technology trapezoid of sorts wherein government, commerce and industry—the SciCom—synergistically intermingle to form an enormous and disparate region of advanced technology.

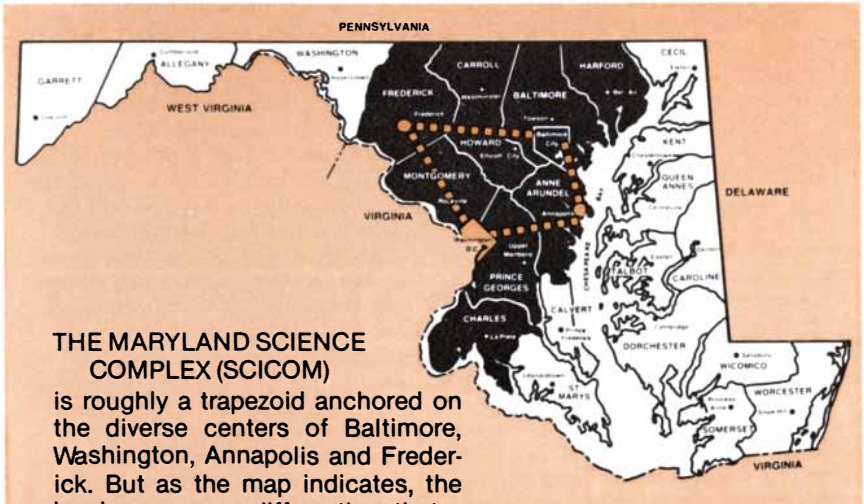
The region has no firm boundaries either in territory or in types and levels of technology. If there is a distinguishing element, it is that the technology, whether government or private, is hands-on, practical and applied rather than theoretical and administrative.

How it got That Way...

Always a border state between the industrial democratic North and the agrarian aristocratic South, Maryland had the elements of both. Conservative and tolerant, the early colony was among the first to guarantee religious freedom and to evolve representative government. The state participated in the founding of the Confederation that became the United States of America. No firebrand like Massachusetts, Pennsylvania and Virginia but compromiser, Maryland actively supported a Constitutional Convention. The planning group first met in Annapolis, then reconvened the next year at Philadelphia.

Congress chose Maryland as the site for the permanent capital of the new nation when the District of Columbia was carved out of Maryland and Virginia. All that is now the District was formerly Maryland. The economic effects for Maryland of that proximity have been enormous.

Embedded in the fabric of the nation, south of the Mason-Dixon line, which indeed is its border with Pennsylvania,



THE MARYLAND SCIENCE COMPLEX (SCICOM)
is roughly a trapezoid anchored on the diverse centers of Baltimore, Washington, Annapolis and Frederick. But as the map indicates, the borders are more diffuse than that.

Maryland's heart was in Dixie. But its head was in Yankeeland. In the War Between the States Maryland largely escaped the vicious turbulence that rent many another border state.

Before World War I, the Baltimore region had become one of the nation's most important industrial centers. Heavy industries gave the city the red-brick, smoke-stacked look so common to older industrial areas. Testifying to the industrial roots, one can often see on the same property low-rise buildings of modern design and construction and the sturdy ruins of a still older structure, green with ancient ivy.

Spectrum of Diversity...

Advanced technology in Maryland is not confined to any one area or sector. The roots bedded in the state's industrial past and present are too deep to allow a government contract or two to dictate the location of the work site. Those same roots also mean that though Government has always been an important source of funding, much has always been and remains commercial.

Indeed, the state got an early start on modern advanced technology when the Glenn L. Martin Co. set up an airplane factory north of Baltimore in 1926. Electronics soon followed when the Bendix Corp. and Westinghouse Electric both established their radio manufacturing divisions near Baltimore in the late 1930s.

Today, the region of advanced technology occupies several hundred square miles in the ten-county SciCom, a trapezoid roughly centered on the Baltimore-Washington axis. Many high-technology companies north of Baltimore can trace their origins to the Martin aircraft plant and the prewar electronics industries. In Baltimore County, many more companies grew out of the area's long established heavy industry and the city's world-renowned university and medical center, Johns Hopkins.

East toward Chesapeake Bay, Annapolis and its environs have more companies, many engaged in marine and ocean technology. A second axis has developed along Route 270 running northwest from Washington to Frederick. Here in the cities of Rockville, Gaithersburg, Germantown and Frederick, many advanced technology companies have sprung up, often government-oriented. Closer to Washington in Silver Spring and Bethesda many older companies thrive on government and academic research, development and supply contracts.

In the new town of Columbia, a few miles southwest of Baltimore; near the Baltimore-Washington International Airport; in numerous industrial development and science parks near both the Washington and Baltimore Beltways and places in between; adjacent to major installations like the NASA Goddard Space Flight Center, the National Bureau of Standards, the National Institutes of Health, the Department of Energy, the University of Maryland, the Department of Agriculture numerous companies have established themselves either to service the larger installations or to benefit from them, or both.

Hands-on Technology...

The more than 500 private companies listed in the state's recent Directory of Science Resources are overwhelmingly hardware-oriented. They emphasize application and the increase of practical knowledge through the reduction of theory to practice. Systems support and service contract companies whose output is paper rather than products are much less common in Maryland than elsewhere.

This practical emphasis derives from the industrial base around Baltimore and from the Government facilities around Washington. The Government agencies, too, are primarily practical. Typical is one of the oldest, the Beltsville Agricultural Research Center of the Department of Agriculture, established in 1910. Here, 2,700 employees in 65 laboratories do basic and applied research. Here were developed the all-white-meat turkey and the four-drumstick chicken.

The National Institutes of Health have numerous laboratories and offices in Bethesda, Rockville and Frederick. The Navy has the National Naval Medical Center and the Naval Medical Research Institute, both at Bethesda. The Navy has many other facilities including the Naval Ordnance Station, the David Taylor Naval Ship Research & Development Center, with laboratories in Annapolis and Bethesda, the Surface Weapons Center, and the Naval Electronics Systems Engineering Activity.

The Department of the Army has a Bioengineering Research and Development Laboratory at Fort Detrick, near Frederick and numerous additional research and proving facilities at Aberdeen Proving Ground. The Department of Commerce runs the huge National Bureau of Standards at Gaithersburg and the National Oceanic and Atmospheric Administration (NOAA) at Rockville.

The Department of Energy (DOE) carries out much of its nuclear program at a large facility in Germantown, formerly headquarters of the Atomic Energy Commission (AEC) now part of DOE. And NASA at the Goddard Space Flight Center in Greenbelt has 3,500 people conducting basic and applied research and development and building satellites. Goddard does much of the hardware and communications work for the Space Shuttle.

The U.S. Postal Service has in Rockville its Research & Technology Group adapting the latest materials-handling and communications technology toward putting the ZIP in ZIP-code.

Given the old-line industries that have always had substantial R&D capability, the strong universities, the long-established Federal R&D presence, it is no surprise that the private companies are similarly hands-on oriented. Nor is it any surprise that the technology seemingly includes every topic man's curiosity or need has uncovered. The state's directory lists more than 800 categories ranging from acoustic emmission to zeolites.

People as Resource...

Maryland has more than 4-million people. Some 80% of these live in the technology trapezoid, many in the suburbs of both Washington and Baltimore to which they commute. But increasingly, these areas are less bedroom communities and more places to work as well as live. Greater dispersal of Federal agencies and initial establishment of new agencies in suburbs is partly responsible. So is the greater number of high technology companies established far from the old industrial centers. Smaller communities find that the flow of commutation is changing. As many people come from elsewhere to work in them now as out-commute.

More scientists and engineers live and work in the Washington-Baltimore area than any other region in the country, some 58,000. The state's 172,000-plus professional, technical and support employees represent 10% of the non-agricultural work force and are a higher percentage of the total work force than any other state. The educational level is correspondingly high, averaging 11.8 years for all levels. Over 44% of high school graduates go on to college and Maryland ranks second in the percentage of its population with four or more years of college. The diversity and depth of the state's industrial roots provides skilled and versatile people who can switch from ship building and steel making to computer frames and satellites.

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Medical and Biomedical Technology...

In Walkersville, Md., near Frederick, is 32-year old M.A. Bioproducts. Since 1970 a unit of the California conglomerate Whittaker Corp., the company employs 240 chemists, biochemists, biologists, virologists and the like to produce clinical test kits and tissue culture research products.

One of the company's more unusual products has made one of nature's more unusual and hitherto useless (to man) creatures useful. The product is limulus amebocyte lysate (LAL) which is derived from the blue blood of the horseshoe crab, a very odd creature. The substance gives the most sensitive test for the presence of toxins in injectable medications such as insulin. The readily available material—the crabs have plenty of blood and promptly regenerate their losses—replaces an expensive rabbit test that was neither as convenient nor as sensitive.

In Rockville, Litton Bionetics among other things runs a $6-million a year clinical sample analysis business servicing 95% of the nursing homes in the Washington area. The company also performs biosafety evaluation tests, runs a screening program for mutagens and carcinogens, develops better ways to determine pesticide residues, maintains a large animal facility and cultures human cells. The rapidly growing unit of the international conglomerate also operates for the National Cancer Institute its Cancer Research Institute at Fort Detrick near Frederick.

But the booming biomedical field by no means belongs solely to the big. Also in Rockville is tiny Biotech Research Laboratories, Inc., a spinoff of sorts from Bionetics. Founded in 1973 to service the National Institutes of Health (NIH) in Bethesda, the fast-growing privately-held company conducts biomedical research in immunology, biochemistry, microbiology, cytogenetics and virology. Its 32 people also produce cell cultures and tumor viruses for use in animal research. As with other such firms, the local sectors of the NIH are the major customers, though the firm also does increasing amounts of contract work for the Environmental Protection Agency (EPA), Food and Drug Administration (FDA) and even the Department of the Interior's Fish and Wildlife Service.

Environment as Market...

Environmental contamination by the effluvia of modern society is no longer a point of contention. Government, industry and public all agree that it exists as a universal and growing problem. They all further agree that we must control the problem in future and repair damage already done. The only contention now is to what degree, at what cost and in what manner we will control contaminants and clean up past contamination. No small part of the answer lies in defining the question.

There is much business and demand for the life sciences and many of the physical sciences for these and other firms in performing the environmental, chemical and biological analyses and long-term monitoring that must be done to define acceptable limits, devise control methods and develop decontamination systems.

Geomet Technologies, Inc., a Route 270 company in Gaithersburg, was founded in 1967 in Rockville to serve the growing environmental market through the appropriate government agencies in the area. The company is now heavily involved with both industry and Government in defining, understanding and addressing the problems of the environment as affected by man-made materials. With 185 people, 25 of them Ph.D.s, the firm works in such varied but interelated disciplines as toxicology, biology and chemistry as well as meteorology, mathematics and computer sciences. A specific contract is a four-month crash program to monitor air, water and soil at the infamous Love Canal site in New York.

Many other Maryland firms work in the life sciences. American Bio-Chemical Lab, Inc., of Baltimore works with food products as well as chemicals and pesticides. The American Type Culture Collection in Rockville, founded in 1925, is a non-profit organization that literally collects germs. It has over 28,000 strains of bacteria, fungi, protozoa, viruses and cells available to the scientific community.

BBL Microbiology Systems in the Hunt Valley Business Community north of Baltimore, founded in 1935, services the industry with microbiological and diagnostic reagents and equipment. The Benedict Estuarine Research Laboratory keeps a biological eye on Chesapeake Bay and the Patuxent and Potomac Rivers. And then there are: the Biomedical Research Institute, specializing in cryobiology; Biospherics

Educational Resources

In the Maryland region there are a number of institutions of higher learning —four-year colleges and universities—as well as numerous two-year junior colleges and technical institutes. Not all of these are actually in the state of Maryland. Several are in Washington which, because there is no geographical boundary between the District of Columbia and the adjacent Maryland suburbs, makes these schools as accessible to Maryland residents as to Washington and, for that matter, Virginia residents.

Major four-year universities in Maryland with engineering and science programs are the University of Maryland, with the main campus at College Park just outside Washington and additional campuses in Baltimore city and Baltimore County; Johns Hopkins University at Baltimore; and of course the U.S. Naval Academy at Annapolis.

The University of Maryland has graduate and undergraduate programs with strong ones in the sciences, engineering and medicine. The school granted 11,215 degrees in 1979.

Johns Hopkins has 100 departments within seven divisions, including engineering, medicine and international studies. The campus for the latter is in Washington, D.C. It also has a strong evening college that awarded 972 degrees in 1979 alone, many of them technical. The school operates the Applied Physics Laboratory and the Chesapeake Bay Institute.

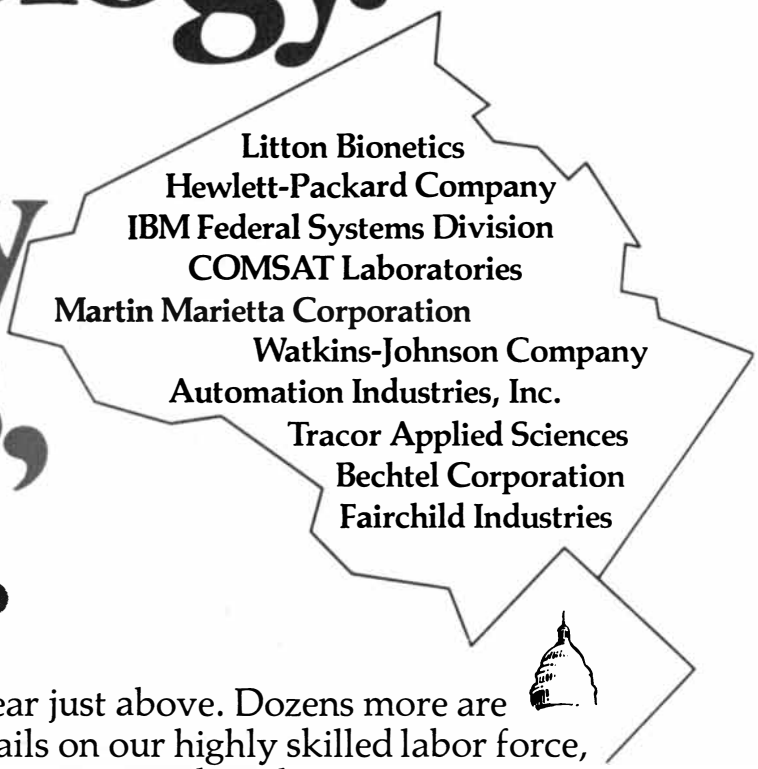
In Washington and accessible to Maryland residents are the George Washington University, with 16,000 on-campus students and strong technical programs; the Catholic University of America, which has highly regarded schools of architecture and aeronautical engineering as well as other technical programs; the American University, with significant programs in physics and chemistry, biology and mathematics.

Other four-year colleges and institutes include St. Johns College at Annapolis, a liberal arts school with the unique Great Books curriculum; Hood College at Frederick, with radiologic technology; the Capitol Institute of Technology at Kensington, which grants degrees in electronics technology.

Among the two-year institutes in the state in virtually every area are the many community colleges, most of which offer extensive courses in vocational technology.

In Montgomery County, we have a name for high technology.

Many names, in fact.



An outstanding few appear just above. Dozens more are here. For the inviting details on our highly skilled labor force, quality of life, transportation network and strong economy that have attracted the most significant names in high technology, write... Office of Economic Development, GBS Building, 51 Monroe Street, Suite 1600, Rockville, Maryland 20850. Or call (301) 279-1462.

MONTGOMERY COUNTY, MARYLAND
People and business. Like nowhere else.

Inc., for environmental analytical services; and Biotronex Laboratory, Inc., which makes medical electronic equipment.

Communications and Space...

In 1962, Congress passed the Communications Satellite Act, which authorized the formation of a new private company to represent the United States in the international satellite system. Only the first Atlantic cable more than a century earlier had as profound an effect on communications techniques and technology.

The Communications Satellite Corporation, more familiarly known as COMSAT, came to life in 1963. By 1964, after a public stock offering, the company was ready to start its business by encouraging the formation of an international consortium, INTELSAT, jointly to own satellites. In early 1965, it began commercial operation with the Early Bird satellite in synchronous orbit 22,300 miles high. There have been many birds in the sky since then, most of them still operating.

COMSAT's laboratories at Clarksburg, occupied in 1969, leave one in little doubt as to their function. The view from Route 270 is of a huge grounded metallic spaceship liberally decorated with dish antennas. Here, more than 500 people advance the state-of-the-art in satellite communications. In physical, chemical and electronic laboratories supplemented by high-bay construction areas, space environmental test facilities and extensive computer backup, the varied and talented crew of scientists and engineers works at the very edge of all applicable technologies. Programs now span five generations of communications satellites and seven ground stations owned by COMSAT.

Since COMSAT Labs is exclusively a research and development organization, it manufactures very little. It will build what are essentially production items in "onesies and twosies" as needed to support corporate and contract programs. But usually, others build its operational satellites and most of the other specialized equipment its networks need after COMSAT people have developed a technology and built one or two. Among these are many types of light and efficient solar cells for space use, an echo canceller for telephone circuits that finally solved a problem as old as long-distance phone transmission, and a type of nickel/hydrogen battery that is so long lived through repeated charge/discharge cycles that the scientists have not yet determined its failure mode. A set has been running a Navy satellite for three years with no sign of diminished capacity.

COMSAT as Parent...

Among COMSAT's successes are the new companies that its presence in the area and its work on the far fringes of technology have spawned. Many of these firms were founded by former COMSAT employees.

COMSAT is sanguine. Its progeny become both its customers and suppliers. The corporation recognizes that as a large organization with a specific mandate, there are areas that interest some of its employees that the company itself cannot exploit. These employees will then leave and do it on their own. As a COMSAT spokesman says: "We miss them. They have great talent. But the corporation wasn't ready to manufacture the technology they developed and we wished them well."

The Offspring...

Among COMSAT's progeny are Solarex, Digital Communications Corporation, Satellite Systems, Inc., Comtel, Future Systems, Inc. and others.

Digital Communications Corp. occupies a striking new building on a large site in Germantown. Founded in 1971 by former COMSAT employees, the firm now has over 500 people and does $35 million a year in sales, and growing at 20% to 30% a year.

Though the company is primarily a manufacturer of high technology communications, satellite and computer equipment, the advanced nature of its products of necessity requires much research and development. Over a hundred of its staff are in some form of R&D, of which much is done for customers. COMSAT is one of the company's best customers. Others include GTE Telenet, other specialized common carriers, and firms with extensive communications networks of their own such as Atlantic Richfield Co.

The company, which recently merged with the publicly-held M/A-COM, Inc., can get enough trained people locally at the intermediate level but suffers from the nation-wide shortage of professional telecommunications people. While it always has openings, business has never suffered. Software, the company believes, is the largest growing area of need because hardware is more and more software driven.

Also in communications and across the street in Germantown is American Satellite Co., a joint venture between Continental Telephone Corp., and Fairchild Industries, Inc., also headquartered there. American Satellite, and for that matter the parents, settled in the area because so much of the company's business is with the government, because communications companies are increasingly moving into the region to be near the regulatory agencies that govern them and because COMSAT is there. NASA Goddard was also a magnet since it is an important customer.

American Satellite began in 1974 as a specialized common carrier providing dedicated satellite communications services to businesses and government. It is a growing business accelerated by the trend to ever larger and more powerful satellites that conversely has made feasible smaller and less complex earth receivers.

Complementing American Satellite is Fairchild's Space and Electronics Co. division, which builds the hardware, particularly satellites. A current project is a standard multimission modular spacecraft (MMS) for NASA.

At Hagerstown, former site of the company's headquarters, Fairchild has the only airplane assembly plant in Maryland with 2,500 people who make the A-10 tactical fighter plane.

Computers and Services...

Not all Maryland companies are so much hardware oriented. The output of many is paper and manpower rather than products. Even these, though, get closer to the hardware than their counterparts elsewhere.

A diversified example is TECH PARK 270, a multi-phased office park development located in the Gaithersburg area of Montgomery County's I-270 Corridor, which is already a preferred location for a number of high technology firms. It is oriented to the functional needs of larger office, engineering, research, laboratory and light assembly users.

Another is NUS Corporation, now part of Halliburton, located on Route 270 in Rockville. Founded in 1960 as Nuclear Utility Services to help public utilities then undergoing the difficult transition to nuclear power, the company today supplies engineering, support and consulting services for varied clients. Only 15% of its $50-million business is Government and only 45% of its work today is nuclear, though the Three Mile Island incident increased that demand.

Typically, for a new plant, utility or

manufacturer, the company will identify the characteristics of the site, plan an operating program that will make the plant compatible with environmental conditions, do environmental engineering of plant systems, and design, specify and procure waste handling facilities. NUS also manages and operates plant training simulators. For refineries, they engineer water recycling facilities. The company is one of 24 qualified by the Environmental Protection Agency to perform all wet chemistry on priority pollutants. And keeping up with new trends, the company is ready to work with coal conversion technology.

Another service firm is Sperry Divison of Sperry Rand Corp. which here works mainly for the military and NASA. For NASA, Sperry Support Services has offices onsite at Goddard engaged in reliability testing of electronic devices for space. NASA's reliability requirements are uniquely high. Where commercial devices with a mean time between failure (MTBF) of 100 hours are good and military devices with a MTBF of 1000 hours are acceptable, NASA wants MTBFs measured in years. At that level the term is meaningless. So the approach is 100% inspection, destructive testing, and even operational observation under electron microscopes to determine the precise mode of failure of sub-microscopic components.

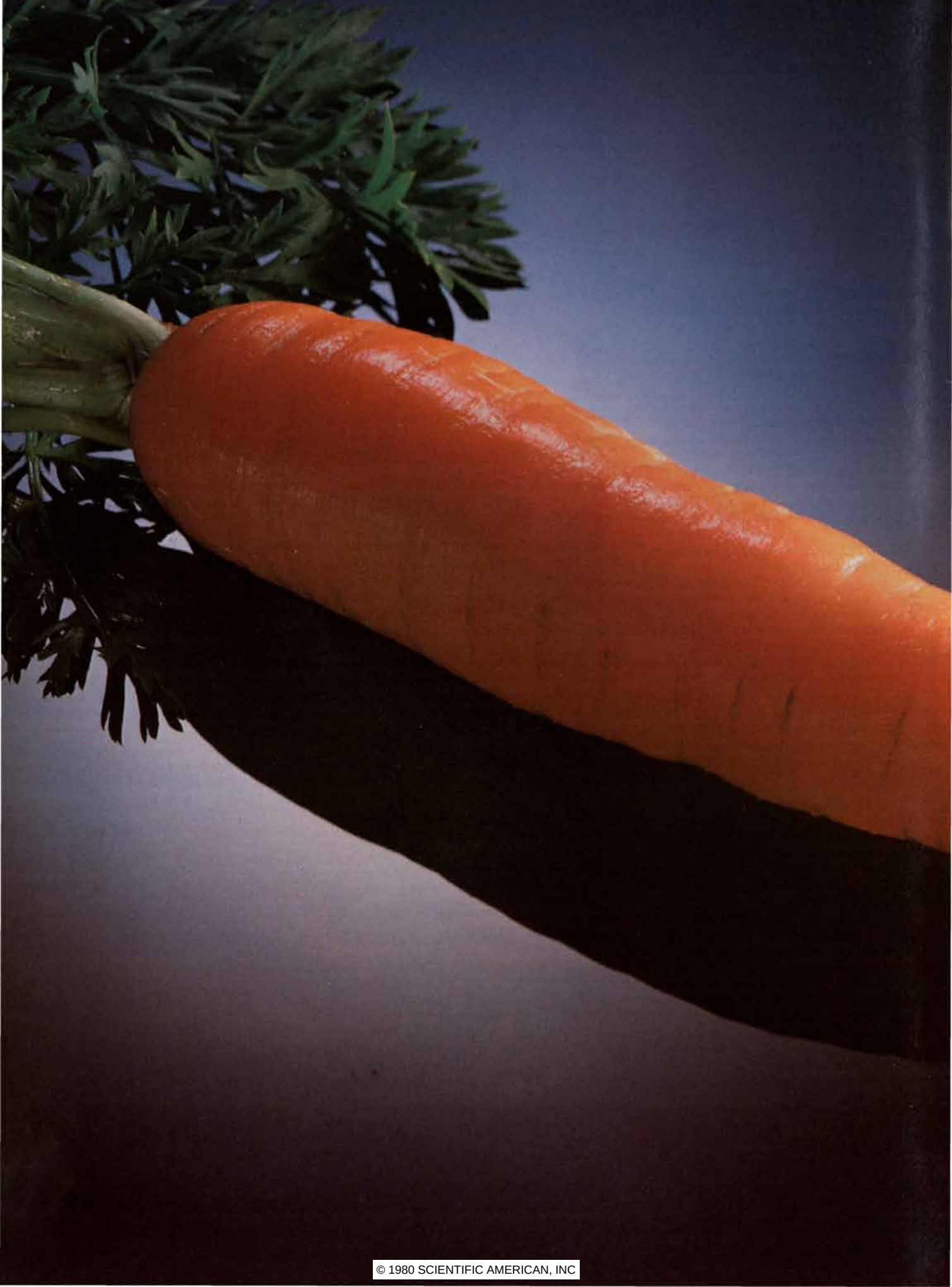
Sperry's work for NASA has important commercial application. Most earthbound devices can accept some failure, but implanted medical devices cannot. Sperry's work has detected failure modes in cardiac pacemakers. So Sperry also does work of the same type for the Food and Drug Administration.

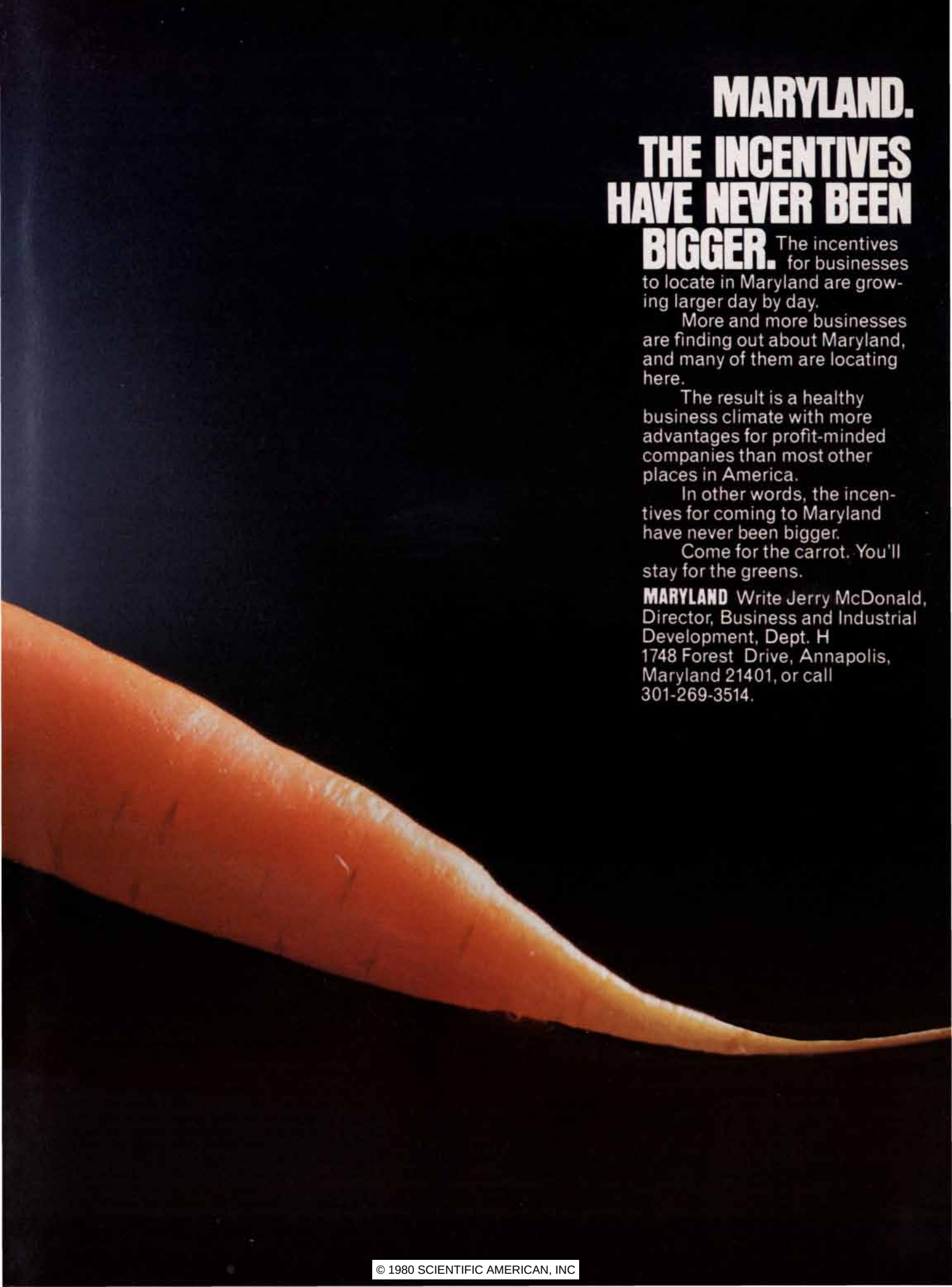
A much larger support organization is Bendix Field Engineering Corp., a subsidiary of Bendix Corp. headquartered at the new town of Columbia.

Bendix also has its Communications Division in Baltimore, where it was one of the early high technology companies. And the corporation has just announced that it will establish its main research and development center at Columbia. This new facility will have some 200 scientists onsite within the next two years.

The company has about 3,000 people involved with the space program, some 800 of them onsite at Goddard. The organization provides engineering support and operational control for the maintenance and operation of NASA-Goddard's data acquisition and space tracking functions.

The staff leans heavily toward lots of mathematics, computer science, electrical and mechanical engineering. The work, which is service rather than product oriented, is not edge of the





technology but application of recently developed technology.

Computers per se...

Where there is advanced technology today, there certainly are computers and computer manufacturers. It is an area of great opportunity for entrepreneurs and established firms alike. And both are active in Maryland where Government and industrial advanced technology make tremendous demands on computational capacity.

Control Data Corporation has a large service organization in Rockville with about 800 people. The company's total employment in the Technology Trapezoid is about 4,000. At the site, Control Data has nine large computers in a cluster center to handle communications and time-sharing operations for its many customers and, not least, to operate its PLATO computerized instruction system.

PLATO, developed at the University of Illinois, is a worldwide teaching facility. There are some 12 such networks of which Control Data has five with 5,000 terminals and 6,000 hours of course material.

A lot smaller but no less ambitious is five-year old Digital Systems Corporation of Walkersville. Started by a lawyer and his engineer brother, the company now builds computers for medical and commercial use that sell in the $100,000 range. The company has doubled in size in the last 14 months and expects to keep on doing so. Its niche is membership and trade associations for which its programmers develop special software and for which it needs more software designers.

Other computer companies include Severn Systems Corp. of Pasadena, on the Baltimore-Annapolis road; Scientific Time Sharing Corp. of Bethesda and Computer Sciences Corp. of Silver Spring; Comten Inc. of Rockville and Amdahl Corp. of Columbia. Indeed, there is so much computer activity in the region that there is at least one firm that provides business consulting services to the local computer industry. Computer Careers Incorporated of Bethesda.

A Place Apart...

APL does not fit easily into any category. Begun as a laboratory for the Navy in Silver Spring in 1942 to develop

How Maryland Looks At Itself...

Some comments from The Honorable James O. Roberson, Secretary of Economic and Community Development, State of Maryland.

Jim Roberson is a cabinet officer in the two-year old new-broom administration of Governor Harry Hughes. His Department now actively seeks new investment for Maryland and has gone to the other side of the world to find it.

New investment means more jobs, particularly in science and engineering as the state aggressively expands its technology base through the more than sixty institutions of higher learning in the region, through the huge base of Federal research and development and through the hundreds of advanced technology companies already there.

"I feel very strongly that Maryland is going through a bit of a rebirth. You can see that physically in Baltimore and sense it elsewhere in the state where faith in the future is at an unprecedented level. We are now on the start of a new cycle.

"We don't take a back seat to anyone in brain power. Our universities—Maryland, Johns Hopkins, Georgetown, George Washington, Catholic University and the other some 60 colleges in the region have excellent programs.

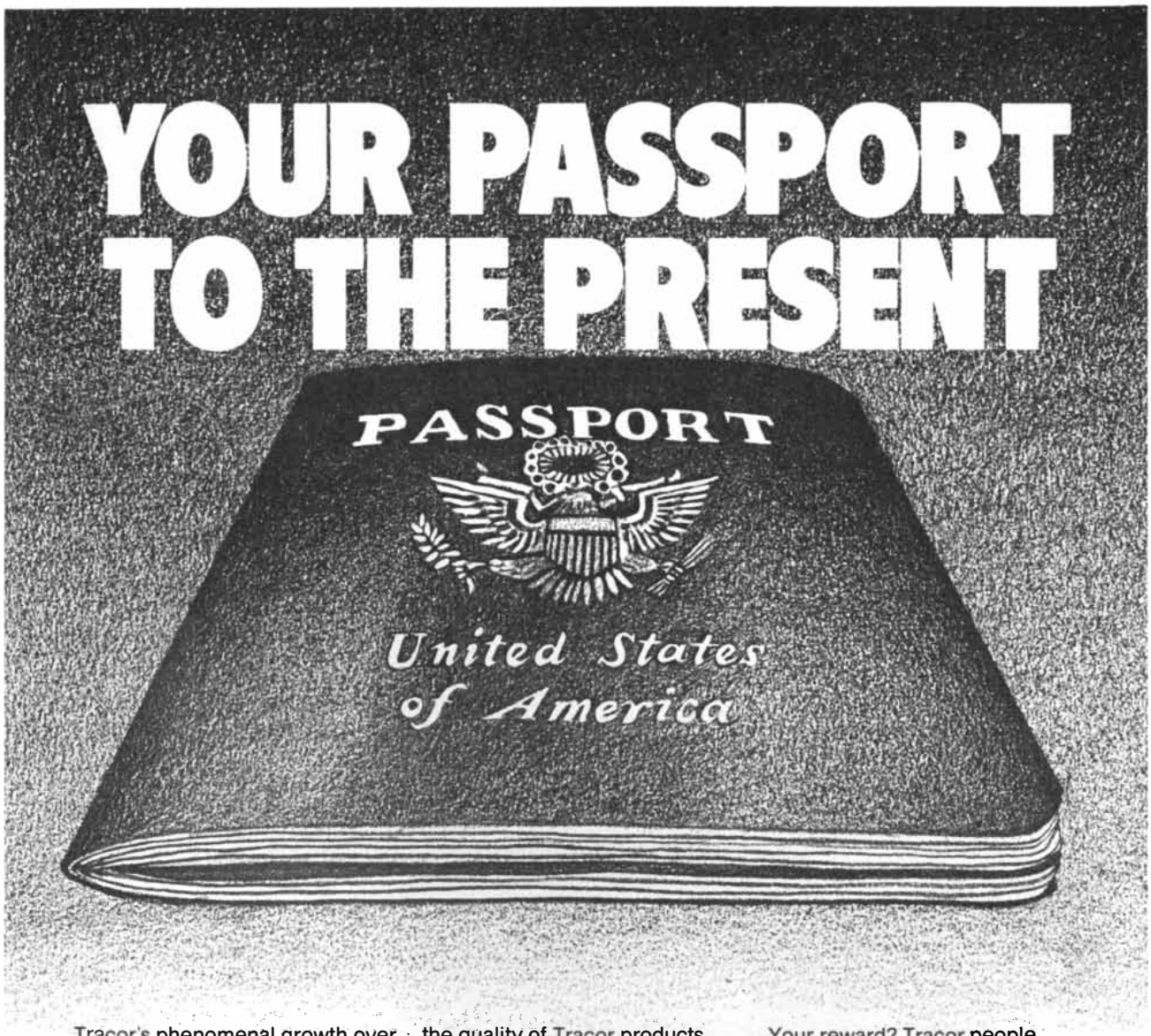
"The University of Maryland and the Johns Hopkins in particular have made great strides in Engineering. The Applied Physics Laboratory is roughly comparable to the Jet Propulsion Laboratory though it is not as well known and doesn't have the same image. But the things APL is doing are just as exciting and innovative as the work JPL does. And in computer software, the University of Maryland is probably the best in the world.

"With such a base of educated people already here, others should find the state attractive. Such people attract like people. They are relatively highly educated and interested in quality education for themselves and for their children. They seek recreational opportunities, which Maryland has in plenty.

"While they might wish to live in the suburbs or country, they want access to urban centers with museums, theaters, restaurants and all the things you would hope and expect from a city. In that respect, Maryland is unique. We really have the only place in this country where you have two huge urban areas close together—Baltimore and Washington.

"We want more advanced technology firms such as semiconductor makers. But we don't have ambitions to steal their headquarters from where they are. All we want is for them to look at Maryland when they are going to build a plant this side of the Mississippi. And we welcome the engineers and scientists who will design and manage them. We have the skilled people to run them."

YOUR PASSPORT TO THE PRESENT



Tracor's phenomenal growth over the past 25 years has resulted in a remarkably successful and diversified present. And we're growing faster every day.

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ONE REWARDING CAREER AFTER ANOTHER

Tracor Applied Sciences

An Equal Opportunity Employer

a radio proximity fuse, the Lab has long since outgrown its original mandate. Still associated with Johns Hopkins—the director has the status of a Dean—APL now occupies 365 acres in the rolling countryside near Columbia. Many consider it the Eastern equivalent of California's better-known Jet Propulsion Laboratories.

APL's 2,600 employees still do 80% of their work for the Navy and the rest for other Government agencies, particularly NASA Goddard, universities and the like. APL accepts no contracts from industry.

APL has been out front in the space age. The Laboratory developed and flew the world's first successful ramjet engine in 1945 and has since had a hand in many Naval missile systems. But APL considers its greatest achievement after the proximity fuze to have been the navigational satellite, which it invented and continues to improve.

While it conducts a broad range of basic research from solid state physics to lasers, photovoltaics and biomedical engineering, Prototype hardware has often been the output. The facility has actually built some forty-eight space satellites since 1959. Today, though APL maintains considerable hardware capabilities in its nine shops, the focus is more on systems engineering.

The Laboratory has taken on difficult problems in many advanced technology areas, notably biomedical engineering. It developed in concert with Johns Hopkins Medical School a rechargeable implanted cardiac pacemaker, a new type of wheelchair, laser surgical devices, a three-dimensional X-ray device and a prosthetic control system. Other programs include research and development in transportation and energy systems and, for the State of Maryland, environmental assessment of proposed sites for power plants.

The staff of the not-for-profit public benefit organization is largely professional and academically oriented. More than 800 area students and staff members are enrolled in graduate courses at an onsite section of the University's Evening College. There are about 230 Ph.D.s and 500 M.S.s among the 1,200 senior staff. These include electrical and mechanical engineers, physicists and mathematicians, a few chemists and one biologist and, of course, sub-specialties.

Societies and Associations...

Maryland is home to many organizations. And of course dozens of national scientific and technical groups are in easy reach in the District of Columbia.

At Columbia is the International Association for the Exchange of Students for Technical Experience (IAESTE), which operates exchange programs with 48 countries for students in science and technology.

At Mt. Rainier is Volunteers In Technical Assistance (VITA), which finds individual volunteer technical people to help solve specific problems in developing countries.

Many local groups provide forums for topics of regional interest.

The Big One...

Very much for profit is Maryland's second largest employer, the Westinghouse Electric Corporation's Systems and Technology Divisions. Headquartered near Friendship Airport, the four Divisions employ some 14,000 people at three locations. About 3,500 are professional, mostly engineers, more engineers even than at the main research center near Pittsburgh, Pa.

These Divisions descend from World War II torpedo manufacturing and early work in radar. Virtually 100% of the Divisions' work is still for the Department of Defense, most of it in some way associated with advanced electronic detection technology. Working in areas where off-the-shelf does not exist, the Divisions have of necessity delved deeply into basic electronics to discover the principles then design and develop components. It has great expertise in semiconductors, charge-coupled devices (CCD), memories, sensors, integrated optics and microwave technology.

Research is the pedestal of production. These divisions define the military problem, develop the systems solutions, then build them in quantity. The Airborne Warning and Control System (AWACS), for example, was first envisioned in 1961 but the technology did not exist. It took sixteen years from concept to operation in 1977. Along the way, Westinghouse engineers learned and developed a lot about antenna theory and practice, high stability receivers, signal processing, communications and the like.

The Divisions have produced look-down radar for AWACS planes, rendevous radar for Gemini space missions, a host of radar systems for all types of military aircraft, systems for fire control, ground-based early warning and control, air traffic control, communications and space and, far from least,

ocean systems ranging from sonar and ship-borne radar to life support, submersibles and acoustic flow meters.

The technology spills over to logistic support. Computers, communications and electronics are being applied to training, data processing, automatic testing, even writing and editing. The Divisions have developed a machine that will read a paragraph of scientific jargon and rewrite it into standard English. Company spokesmen, however, make no great claims for its literary merit.

Another company of unusual organization and very much in advance technology is Aeronautical Radio, Inc., or ARINC, and its subsidiary, ARINC Research Corporation. Founded in 1929 "to serve aircraft, dirigibles, and all other vehicles propelled in the air, in transmitting and receiving by radio...", ARINC is now at Annapolis. The 55 stockholders in the not-for-profit firm are mainly the airlines. Others may also own stock provided they operate aircraft.

Before World War II, the company was mainly a coordinating facility. But in 1946, it got a contract to study the reliability of radio tubes in aircraft communications. Out of that grew ARINC Research Corp., spun off in 1958 as a profit making company. The parent company remains a service organization and is the operator and licensee of VHF voice radio stations providing en route air-ground-air facilities for civil aviation. The company also maintains avionics maintenance centers around the world and provides the secretariat for the Airlines Electronics Engineering Committee (AEEC).

The research company has a much broader mission, its chief clients being government agencies. The research company thinks of itself as an architect that works with the client to design, specify, provide and assemble the parts of a system. Neither company manufactures. But the research company has extensive laboratory and shop facilities that make prototypes and analyze vendor equipment.

Yet another company that makes hardware and provides support services is AAI Corp., in the northern Baltimore county suburbs. Founded thirty years ago as Aircraft Armaments Inc. by four engineers from the Glenn L. Martin Co., AAI is now a subsidiary of United Industrial Corporation.

The aircraft armaments business didn't develop but other things did. The company is now a diverse research and development, support services and manufacturing entity with about 2,000 people and expecting to do $100 million of business in 1981, up from only $39 million in 1977. As a company spokesman put it, the firm is growing so fast it will hire just about anybody—entry level, experienced, particularly in computer sciences, software and design. However, though there are many engineers with MS degrees, the shop-floor oriented company has few Ph.D.s.

AAI covers the military spectrum: ammunition design, armored vehicles, tanks, ordnance, subcontracts on major missile systems, materials handling and the like. But for all the heavy work, 75% of the projects are in electronics, specifically automatic test equipment and training simulators. These latter simulate aircraft, vehicle and ship operating environments with uncanny realism.

Sun Power...

Though AAI's work is 90% Government, it has been breaking ground in civil work, too. The company has a solar energy program that has already produced several commercial installations.

Solar energy seems to be the best way to beat the energy crunch and AAI's efforts have centered on systems that they believe will provide the quickest and best answers. The level of research has spurred interest and production to come up with practical solutions.

AAI's solar systems are concentrating-type collectors. The challenge lies in reducing the cost and increasing the efficiency of a basically well-known technology. Working the same street from another side is Solarex Corp. of Rockville.

Photovoltaic cells—solar cells—based on high-purity silicon technology are the sources of continuing power for space satellites, for which they must be built to exacting standards with the least weight. The very costly cells give the birds that blue-tiled look. Relatively low efficiency and high cost have limited their ground use.

Solarex was founded in 1973 by former COMSAT people who believed cheaper cells could be made for less demanding applications. Efficiency *per se* is not the factor; cost per watt is. Present cost of Solarex cells is about $10 per watt but the company hopes to meet the DOE goal of $0.70 by 1986, which will take an annual production of 500 megawatts cell capacity. Solarex seems determined to do that all by itself.

The company has the largest photovoltaic research facility in the world with about 60 people, mostly Ph.D. physicists, chemists, physical chemists and metallurgists. Total employment in

the parent company and a subsidiary formed to make cell-grade silicon is about 400. But the company needs more people to keep up with its growth in this area of wholly new technology.

Solarex plans a new plant in Frederick that it calls a solar breeder. Solar cells on the roof and facades will generate the 200 kilowatts needed to turn out 5-MW worth of new cells annually. Cost effective? No. But somebody has to start.

Earth to Space...

No one makes flying boats at Baltimore anymore. But the successor to the Glenn L. Martin Company, Martin Marietta Corp., a multi-industry conglomerate headquartered in Bethesda, still makes airplane parts there. Martin Marietta Aerospace makes jet engine reversers, structural components and subassemblies for commercial, defense and space craft.

The company's main research laboratories are also in the state, just south of Baltimore. Here a staff of 200 people, some 30% of them Ph.D. level, conduct basic research for the company's diverse activities as well as for outside clients. The laboratory pursues advanced technology in some very down to earth (literally) industries. Efficient production of aluminum, cement and refractories require the solution of complex and elusive technical problems at the most basic levels. Its scientists use high-speed photography developed for nuclear reactions to appraise the performance of explosives in quarrying. Scanning transmission electron microscopes show why adhesives work or don't. Physical chemists examine the mechanisms of textile dying. Computerists model smoke-stack plumes. The diversity allows many types of scientists to bring unusual disciplines to bear on unusual problems.

Enclaves...

When Martin built whole airplanes, it needed a whole airport and acres of buildings. The airport and the buildings are still there. But now the facility is an industrial park, called Chesapeake Park, in which the Martin Marietta Aerospace Baltimore Division is but one of many tenants.

The industrial park is common in Maryland. Most of them have been assembled by private developers in cooperation with the state and local industrial and economic development agencies. Some, like the Chesapeake Park, are subsidiaries of corporations that for one reason or another had large amounts of land now available for new uses. Others result from deliberate expansion and others still are pure real estate development companies.

McCormick & Co., Inc., the spice people who have been bringing the exotic spices of the Indies and elsewhere to America through Baltimore since 1889, have a subsidiary, McCormick Properties, Inc. This company has developed several industrial parks in the state. One is north of Baltimore near Cockeysville, on the edge of a delightful rural valley. This Hunt Valley Business Community is now the site of many advanced technology companies. South, the company plans another 230-acre site at Inglewood on the Washington Beltway and, north of Hunt Valley, another tailored to R&D firms, Loveton Center.

South of Baltimore near the airport is the appropriately named Parkway Industrial Center. The park is local operations center for such firms as Motorola, General Automation, Microdata, Ford Aerospace and Communications, Inc. Parkway people note a trend away from the initial thrust of many of these sites, as warehouse and distribution centers, to offices, manufacturing, and research and development sites. Indeed, many companies have asked the developers to convert to offices or laboratories buildings that were built as warehouses.

A large new research park is under development outside Frederick, in part because of the proximity of the Cancer Research Institute. The developers will have their own research lab on the site.

The planned community of Columbia, a residential city founded in 1967 that now has over 50,000 people, has several planned industrial areas. Some forty high-technology companies now employ over 25,000 people. Among the firms are General Electric, Amdahl, American Computer and Bendix.

Around both the Baltimore and Washington beltways, near Annapolis, along the major highways that lace the region, in the vicinity of such major Federal installations as Goddard Space Flight Center, along the routes of the Washington Metro and the new Baltimore subway, many more such sites are developing.

County Competition...

Maryland has 23 counties. At the state level, they cooperate. Intrastate, the counties compete vigorously for both people and industry. Each of course believes it has the most to offer prospective employers and employees. And each of course is right in one way or another for each is unique.

Among the SciCom counties, Frederick offers the mountains, lower living and real estate costs. Howard has Columbia and many unspoiled older once-industrial towns along steep river valleys. Baltimore is a new-old city, revitalized in heart and spirit, a place of culture and history that has rediscovered itself and its confidence in itself.

Anne Arundel has the state capital at Annapolis and Chesapeake Bay. Montgomery has booming but environment-conscious growth along Route 270 and 29. Prince Georges shares with Montgomery proximity to Washington and termini of the Washington Metro.

Whatever. No part of the Technology Trapezoid is more than an hour or so from any other part. And beyond its corners across the Chesapeake Bay Bridge on the Eastern Shore to the Atlantic beaches, out toward Cumberland, up to Havre de Grace and Elkton at the head of Chesapeake Bay lie pleasant lees indeed.

Though Maryland touches on one of the highest-cost living areas in the country, Washington, the state itself reflects national patterns. Areas close to Washington of course reflect Washington. But the state's own diversity in the SciCom, and the multiple variety of its towns and cities assure affordable and ample housing in all price ranges. Cost of housing does not preclude any level of the work force from living within easy reach of the workplace.

Not By Bread Alone...

West, from atop a little mountain with a marvelously appointed state park, a land all green and gold stretches away to the East, past Frederick. Below, an interstate highway eases up the valley headed West where once the early settlers cut their way through to new lands and new lives.

East, a diamond-bright October day on Chesapeake Bay, the Bay Bridge and Annapolis's 18th Century buildings etched sharp, in generational contrast with the immense, bulky but graceful supertankers stolidly anchored. No tall and many-sparred clippers appear but hundreds of multi-hued spinnakers, butterflies skimming leisurely across the sparkling estuary in a last outing before winter folds their wings. The quality of light, the colors of the sails and of the autumn foliage along the shore, the whisper of many hulls in the silence of a propulsion technology that may yet return, the felt rather than known camaraderie of many like souls.

It is world enough. And more.

Quality: *distinctive properties or character as of merit or superiority.*

At Westinghouse Defense and Electronic Systems Center, quality goes beyond the production line. It permeates everything we do. We look for people with those distinctive properties of merit or superiority that add up to an industry elite...and we give those people the type of environment in which they can flourish. That means challenge on the leading edge of their discipline. It means technological leadership that will support their vision. And it means a consistent quality in concept, design, production and support for our land, sea, air and space electronic systems.

We are actively seeking engineers in such areas as VHSIC/LSI, electronic warfare, software, microwave components, analog circuits, digital systems, power supplies, mini-computer systems and many others. If you'd like to know more about the future we can offer, just send your resume stating present salary, to: R. A. Richmond, Dept. 800, Westinghouse, P.O. 1693, Baltimore, Maryland 21203.

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And you'll discover why Vitro's employees enjoy the Challenge, Growth, Recognition and Opportunity we can offer!

For over thirty years, Vitro has been revolutionizing state-of-the-art standards, and playing an integral part in the innovation and maintenance of national programs. Vitro is a broadly competent systems engineering and management support organization for defense, civil and energy programs; and incidentally, one of the largest high-technology employers in Maryland.

Almost all of our projects are of a high visibility nature. Consequently, so are our career opportunities. As one of the leading firms of our kind, we can offer some unique combinations — the wealth of our background experience plus the latest in computer engineering, documentation and publications capabilities — long term project stability plus a wide diversity of projects in-house — the support facilities of an organization with a staff of nearly 5000 and "special team" structure for projects, which allows you to work with others on a one-to-one basis — a highly professional atmosphere, and first-name informality.

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- ☐ Fire Control Systems
- ☐ Sonar Technology
- ☐ Scientific Programming
- ☐ Configuration Management
- ☐ Data Management
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BOOKS

A conspectus of books about science and technology for younger readers

by Philip and Phylis Morrison

It is a good year for children's books on science and on themes closely related to it. One feature stands out: among these books of high quality a dozen or more not only deal well with their subject but also open direct paths to further exploration.

The Fight against Gravity

BUILDING: THE FIGHT AGAINST GRAVITY, by Mario Salvadori. Drawings by Saralinda Hooker and Christopher Ragus. Atheneum ($10.95). EXPERIMENTS IN FORM: A FOUNDATION COURSE IN THREE-DIMENSIONAL DESIGN, by Peter Pearce and Susan Pearce. Van Nostrand Reinhold Company ($9.95). UNBUILDING, by David Macaulay. Houghton Mifflin Company ($9.95). The model of a tent has a drinking straw for a pole, anchored by string stays held with thumbtacks to a slab of Styrofoam insulation, and a paper skin. The aim is not just to make a tent; rather, it is to display clearly the tension and compression (you can feel them in your muscles too) that allow the analysis of every structure. Rulers and a sponge, glued paper strips, handkerchiefs, tongue depressors and cunningly folded paper appear in clear line drawings on nearly every page of the wonderful little Salvadori book. All of them and more are assembled into models of structure achievable by kids; not one model is a mere look-alike, made to simulate only the surface appearance of something at full scale. Every one is the structural counterpart of a real building, every one a start at taking part in the fight against gravity that human beings have waged ever since the first tents and rope suspension bridges.

Among these drawings of models dwell a dazzling muster of drawings of architectural wonders: the Sears Tower, tallest in the world; the Pantheon; the Leaning Tower of Pisa; the 20-acre tent of Frei Otto in Munich; the intricate church of the Jesuit University of San Salvador, whose creased-barrel roof of reinforced concrete spans 100 feet with a marvelously light structure; the New River Gorge Bridge in West Virginia, the world's longest steel arch; the tuned mass damper vibrating unseen up there under the slant roof of Manhattan's Citicorp Center Building, where a 400-ton weight slides back and forth to soak up the tower's sway. It is all woven together, models and reality, with the elements of genuine understanding of structure. There are no equations, only a few numbers to explain the loads. A serious reader, young or old, will nonetheless come away with a lively sense of how structures work.

This is a splendid book, and its origin is exemplary. Professor Salvadori has spent a lifetime as an innovative structural designer, and he has long been known as well for his texts on structure for students of architecture. All of this he has distilled into a children's book, but he does not simply offer young readers a new book spun out of that rich experience. Instead he took his fascination and his knowledge of structure into the public schools, where for years his classes and he mutually learned how to answer in a simple way the tough question of why buildings stand up. He includes a warm acknowledging line "to the children of Harlem, who joyfully started me on a new career." Children far and wide, and adults too, will benefit from that collaboration.

At the level of college students of design Peter Pearce and Susan Pearce, two California teacher-designers, extend the utility of the paper model beyond architecture and beyond qualitative structural analysis to a set of related exercises in successive optimizations. How many bricks can a tower made of one sheet of paper support? A good performance is 24 pounds. About a third of the book offers clever problems and solutions along that line. A variety of forms of the real world, from snowflakes to the Crystal Palace and the Porsche, are presented in images with sharp evaluative captions. It is agreeable to note that photographs of the same steel-arch bridge and the same big tent Salvadori figures appear here, and that both books show the remarkable sculptural-structural inventions of Kenneth Snelson: incredibly airy frames of cable tendons and steel struts "in which tensile and compressive forces can be physically differentiated."

What goes up, we well know, must come down. With meticulously accurate fancy David Macaulay, whose detailed ink renderings of construction have amazed and delighted readers for a decade, looks ahead. He imagines that in 1990 the "renowned New York firm of Krunchit and Sons" have won the job of taking down the Empire State Building, to turn the block into a public park, the structure to be rebuilt as headquarters tower for a petroleum institute over in Riyadh. The task takes three years, with a rather small crew; the building had gone up 60 years before in the just about record time of 18 months. Once the last tenant had left, the sidewalk sheds, the outside scaffolding and the big wood vertical rubble chutes were built. The housewreckers first take out the interiors, their air hammers pounding up the masonry inner walls and the concrete floors; the ironworkers then cut away and delicately remove the steel frame, member by member; meanwhile the operating engineers run the cranes, dozers, hoists and compressors that power all the work aloft.

The trucks circulate below to claim the pieces. The cut limestone, the stainless steel and the cast-aluminum wall panels characteristic of the famous building are all carefully removed; from the interior only the most decorative metalwork and marble is to be saved. Down it all comes in order, the floors dwindling away week by week, at first hardly noticeable on the skyline. The many details are logical and fascinating; for example, the steel frame is not to be saved but scrapped. The rivet holes have stretched over the years, and the structure will have to be redrilled, even without planning any changes. The delightful open park appears on time, with that great mooring mast saved as a central monument, a couple of hundred feet of landmark. Unfortunately the tanker that sails off with all the pieces hits a water-supply iceberg off the Arabian coast and is lost, although all hands are saved. The insurers are notified, and Krunchit prepares its estimate for the demolition of the Chrysler Building!

MOVING HEAVY THINGS, written and illustrated by Jan Adkins. Houghton Mifflin Company ($6.95). Archimedes published first, it may be, but masterful riggers and boatswains long antedated his treatise on simple machines. "The idea that Stonehenge and the Pyramids of Egypt and the Americas couldn't have been done without the unidentified fork lifts and flying backhoe saucers of space travelers is an insult.... It can be done and no doubt *has* been done. You can unstick a car, move a piano, install a refrigerator, haul a boat, hoist an engine or carry a friend." This little book is an engaging, ingenious, beautifully drawn primer of engineless moving, set in the ambience of New England but as universal as the stars.

All the work begins with muscle and bone, and a valuable four pages tell and

picture how to use the body efficiently and safely, including the movers' straps, the tumpline and the two-person carry. Adkins is no dilettante; his aim is effect, and so he does not fail to remind the reader that "a big, powerful friend" is no mean ally and that sometimes the rollers will scratch the floor; sometimes too it is cheaper to call in the engines and be done with it. When the case is clear for moving by hand, however, the rigger's path to prowess is made clear with good sense and directness.

Friction is the mover's foremost obstacle. Winter ice can overcome it, and so can tarpaulins, travoises and waxed floors under a square of old carpet. Carved stone blocks are slid on ice cubes, whose melting can neatly place the unwieldy load. Heavy sheet-metal flats are managed on baseballs, and coffins are rolled into vaults on simple and expendable marbles. Boats are launched with rollers, as indeed the pyramid stones may have been moved. There is the case of one garage boatbuilder who remembered that the garage door set the maximum size he could build; in his zeal he allowed just half an inch all around for clearance. Wheels or rollers could not work at all, but the ingenious novice was undismayed. His craft came smoothly out on bacon rinds.

Next we learn about line, rope, cable and chain and how to stress and use them, about apt knots and ruling turns, cleats and belays. Here are technical maneuvers, such as swigging and tailing on, and a careful introduction to block and tackle, theory and practice, word and detailed image. No reader about the days of sail can afford to remain vague about whip and purchase, gun tackle, kedging off, parbuckling round drums and the Spanish windlass. Here too is the Johnson bar (the heavy lever with an angled end and small wheels), the come-along (a ratcheted block on a cable) and the hand truck, all valued newcomers to the old leverage arsenal of peavey, pry bar, crowbar and cant hook.

Perhaps the best advice of all is general: 16 concise precepts, compounded of experience with heavy loads and the principles of right reason. "Murphy: 3—Home Team: 0.... Don't put your hand under it unless you've got it blocked; get the Ming vase out of the room, all the way out.... Expect disaster and have a back-up plan to minimize it.... Moving heavy things is more a way of thinking than a job.... It is always surprising how quickly... small bids haul a boat into the eelgrass before the sun is over the yardarm.... Be careful, worry over it a bit, and in all probability you and your friends can...heave it in place yourselves." Any reader, young or old, who aims to act on the real world or to know the working past, or who has practical aims ashore or afloat or takes pleasure in physics, will enjoy this brief, rich, delightful book.

Other Technologies

THE FANTASTIC BICYCLES BOOK, by Steven Lindblom. Houghton Mifflin Company ($8.95). Would you look neat upon the seat of a bicycle you had built for two! Scrounging and recycling, shopping and coaxing, working carefully with hand tools, a simple electric drill and penetrating oil, an interested young person in the upper grades or beyond can build a tandem, a racing bike, a dirt bike, a ski bike for snow, a period-piece sidecar and a good deal more. This book is an invaluable starter. It will, however, take not weeks or months but a year to gain enough experience, skills and know-how to complete the job well.

The central resource is the great tide of junked bikes and parts, new and used, that floods our land, where every year a couple of million bikes are discarded. This book, like all good technology, tells as much about the culture of these technical resources as it does about the mechanical and structural problems themselves. It is full of workshop wisdom, learned the hard way by the author, a trained designer and a young veteran of bike building and bike racing. "Adults know a great deal. However, there is even more they don't know.... Find out for yourself!" "Very little ever goes wrong on a three-speed" hub, and a used one is easy to find. Dérailleurs (the heart of the 10-speed system) "get out of whack in mysterious and aggravating ways. Here the best solution may be to throw it out and get a new one. Why am I going against everything I've been saying in this book to tell you this? Simple.... The better low-priced Japanese dérailleurs are probably the biggest bargain in cycling today."

In the back of the book are pieces on maintenance and construction, everything from welding (get it done by a specialist) to ball bearings, whose ubiquitousness in all the moving parts of the bicycle will surprise the layman. It is the light, strong steel-tubing structure, the admirable wire-spoked wheels, ball bearings and the well-evolved crankset and transmission that make the modern bicycle the fine machine it is. They all offer plenty of scope for the upgrading and reworking style of this practical and philosophical guide.

SUN UP TO SUN DOWN, by Shawn Buckley. McGraw-Hill Book Company ($6.95, paper). This admirable book tells what a Trombe wall is, and even an oil-blocked thermic diode. It has much in common with a great many other introductory treatments of passive solar-heating systems and their design. It has no numbers and no equations, no account of welding or cements; its aim is clearly not at design or construction but at understanding, for young readers and for those who would buy such devices rather than build them for themselves.

Those are the book's limits; what distinguishes it from the run of the shelves is its consistent, expressive and profound use of a precise, quite intuitive analogy to explain heat flow qualitatively but in detail. That analogy is the one between heat flow and water flow, which relates a difference in temperature to effective depth. The analogy includes resistance and leaks, storage capacity and latent heat, and the effects on flow of material, path and area. The straightforward text and simplified but careful line drawings are well fitted. Of course, the analogy must be transcended to allow the understanding of radiation.

The latter half of the book leaves off the general analogy and describes in the same pedagogic spirit the cycle of the day for a variety of practical solar-heating systems, up to some sophisticated ones indeed. A final chapter weighs water as an analogy to the problems of capital costs and income, all in a very few pages. A glossary and an index close the book, which is an example of how well a first-class engineering analyst can explain through prose and picture, once he chooses to leave equations behind with his M.I.T. students who can use them. "Simply by adding appropriate equations for concepts I have discussed in prose, this book could become a college engineering text." It is serious reading for high school kids or their parents.

THE WEAVER'S GIFT, by Kathryn Lasky. Photographs by Christopher G. Knight. Frederick Warne ($8.95). The gift was for Max, who is not two yet. He had never felt anything like the springy, thrilling, soft, warm wool blanket, now all his own. It is the weaver's September gift to her young friend.

The blanket grew under Carolyn's skillful and hardworking hands between spring and fall. The wool came from a Merino sheep. Years ago that sheep had been born, a tiny lamb, like the newborn lamb Carolyn helped to revive in her icy barnyard on that March morning after a night of freezing Vermont rain. The lamb was saved, and Carolyn happily heard the ewe making her special sound, the "hey hey hey" ewes make only when their newborns arrive. The grown sheep must be shorn for their fleece; one spring day Rob Burroughs came to do that, a rugged man with a body that seemed to be "forever curved around a sheep for shearing." The fleeces are sorted, washed in warm water, patiently carded into rolags: "puffs of smoke." (Max was watching.)

Then the wool was spun with rhythm and skill onto the wheel-turned bob-

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bin. Carolyn wound the spun yarn into skeins on her kniddy-knoddy. Once the yarn was stored, she turned her mind to color. The plants of summer offered dyestuff, the right plants, rightly collected and used. Then the yarns must be woven together. First there is the idea: white wool from Henry, gray wool from Strawberry and dark brown wool from Amy—stripes of bold color for Max but no dye. The loom is carefully dressed in a pattern of plain weave, hundreds of heddles threaded, until midnight saw the work complete. Next day Carolyn at the loom wove the blanket in one long day's work. By now the baby lamb, like the small boy with the new blanket, also has a warming coat: a thickened fleece has grown on the lamb, ready for winter.

This story of varied craftsmanship is well illustrated with photographs of the steps in the work and of the people who did it. The entire story could have been matched fairly well 300 years ago or more; it is a look mostly at the sunny side of the demanding crafts of the self-reliant farm of a slower and less populous world.

MAX, THE MUSIC-MAKER, by Miriam B. Stecher and Alice S. Kandell. Lothrop, Lee & Shepard Books ($6.95). Max sings back to the subway grate, clicks a stick against the uprights of a wrought-iron fence, taps empty jars and shakes some filled ones. Once he crashed potlids to make a mighty noise, but even his ears were hurt by that. Then he found that tapping the potlids very lightly together made a singing sound. He helped to make himself a rubber banjo, and he sings, sometimes glad songs, sometimes sad ones. Max cheerfully beating a drum hat on his head is certainly the most winning of all the photographs of this small music-maker, who is quite naturally and seriously making creative music before any lesson at all in the strict forms of other people's music had come his way. It is a fine little introduction to a new friend for many a musical kid who might very well come to emulate Max.

Journeys

COSMIC LANDSCAPE: VOYAGES BACK ALONG THE PHOTON'S TRACK, by Michael Rowan-Robinson. Oxford University Press ($12.95). "But for me," our author says, "the essence of landscape is that there is a human being at the center who experiences it." So directed, we enter these voyages of the mind and the ingenious hand, not merely to the moon, there to plant a flag in mimicry of Captain Cook, but spectacularly far beyond, out into that universe which is in no way separate from us but a complete and complex unity of which we ourselves are an integral and evolving part. In this vein, with up-to-date and expert understanding, always in simple if specific accounts, we make six voyages and take a final reflective look at ourselves. The voyages are into distant landscapes seen by way of visible light, radio waves, ultraviolet, X and gamma rays, infrared and microwaves (much the most distant of signals), back to the first fireball.

There is a little history, a little physics, a lively appreciation and a first-order explanation of wonders such as the jet of the galaxy M87, the dusty filaments of M82, the molecular clouds of the Milky Way, the radio hiss of Io, the lightning of Jupiter and the rest of the remarkable display. It is shown us by the "all-frequency light machine" that our cultural evolution, and not the slow work of Darwinian evolution, has recently made. With a sure but always light touch the author, a young cosmologist and astronomer from Queen Mary College in London, has prepared a splendid introduction to the cosmic view of our day. His writing is clear and engaging; he has evoked a universe without a single photograph or diagram or formula. Any serious reader, young or old, could benefit from this brief, simple book; one hopes the next step would be to look at some maps or photographs of the remote landscapes themselves. The text is well printed; a few evident misspellings add an endearing note of fallibility.

HOW TO DIG A HOLE TO THE OTHER SIDE OF THE WORLD, by Faith McNulty. Pictures by Marc Simont. Harper & Row, Publishers ($8.95). Once you get through the topsoil the hole is five or six feet deep. You need a friend to pull up the bucket of clay or gravel as you keep digging. Then there are rocks aplenty, all kinds, and maybe bones too. Then you get to the granite skin of the earth, and you badly need an air drill. If you hit water, a diving suit is also de rigueur. Black, gooey oil? Give up the hole and start over again somewhere else; this marvelous imaginary voyage is no place for grubby commercialism. Keep drilling; it gets hot enough so that you will have to acquire an asbestos suit. Then comes the basalt. Then follows glowing melted basalt, the magma. Beware of volcanoes here. Now you need a jet-propelled submarine, strong and well cooled. Here is its blueprint, full of kids' detail, including lemonade and cookies. Keep drilling. Now your long shaft is a radius of the entire earth. Finally you are at the center. Every way is up. Go straight ahead. Once you get out to the cool Indian Ocean you will be pretty safe, even among all those sharks. Stay in the sub. Surface, open the hatch and sail home. What a story you have to tell!

These two partners, author and artist, have told it pretty straight as a guide for cool kids. Easy to read and very colorful to look at, the book will inform and delight any reader in the early grades who has a sense of whimsy and a bent for adventure. The familiar textbook diagrams are here transformed into lively pictures, much enriched by the physical texture of the imaginary voyage and not at all diminished by the playful, hyperbolic treatment.

PADDLE-TO-THE-SEA, written and illustrated by Holling Clancy Holling. Houghton Mifflin Company ($9.95). Paddle-to-the-Sea was a carved wood paddler kneeling in a canoe a foot long, looking like a "big birchbark loaded with packs and supplies for a journey." He was painted with care, kept upright by a lump of lead for ballast and on course by a tin rudder. Many days work to fulfill the dream had made Paddle a person, and the carver who made him was a young Indian boy on the shores of Lake Nipigon north of Lake Superior, where the outflow begins, to pour at last into the ocean far to the east at the end of the Gulf of Saint Lawrence. Paddle was set on a snowbank as the geese returned; the snowmelt set him free, on his way past brook and beaver pond into the fierce ice break-up and logjam downstream. An alert lumberjack saved him from the band saw that might have split him like a fish, by Jo! The lumberjack might have taken Paddle home to little Henri, but Paddle was no mute, helpless float; on the bottom of the canoe you could read: "Please put me back in water. I am Paddle-to-the-Sea."

The yearning was evident to all who could read, and so Paddle, on his voyage down "the Great Lakes, the biggest lakes in the world... set like bowls on a gentle slope," links a chain of volunteers as he descends, now held in a marsh, now reddened by sifting ore as he bumps the pilings of an ore dock, now netted and lost again by fishermen, now witness to a shipwreck and a daring rescue. The coastguardsman at Whitefish Bay renews Paddle, and even adds a copper plate to replace the lost lead ballast, with a longer message and an invitation to those who help to add the place where they met the Paddler. Past forest fire and through the great locks at Sault Ste Marie he goes, afloat or aided by fellow voyagers, on a dogsled, on an ore boat, even on a little girl's lap in a motorboat down Lake Huron to Detroit.

As Paddle goes we meet the people and see the places he encounters, in careful and colorful paintings, and in neat, detailed marginal pencil drawings that map and explain locks, sawmills, freighters, ice fishing, the ore trade, great Niagara and Davy Jones's locker. Paddle hurtles over the turbulent American Falls, and he does reach the sea. On the Grand Banks he is picked up in a dip net by a French fishing boat. He is taken overseas to far-off France, but "Paddle never showed surprise. For four years he had been what he was supposed to be, a Paddle-to-the-Sea." The long loop magically closes; the fisherman shows him to his town newspaper in France,

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the French-Canadian lumberjack who saved Paddle from the saw recognizes his photograph in the French paper he is pleased to read whenever his cousin remembers to send him one from France, and the quiet Indian who had made Paddle, no boy now but a tall and strong young man, took "one long look over the Frenchman's shoulder" and paddled off himself "with a song in his heart."

Happy is he who, like Ulysses, makes a good voyage. Paddle's voyage is a tiny odyssey; his tale is not one of monsters or sorceresses but of reality, geographic, economic and human; it is a work of clarity, warmth and quest rewarded, which remains after 40 years fresh and true. Diesels are more likely now to drive the ore boat and the fisherman than is steam or sail, and there are other big flows of ore. But Paddle's voyage could be made today. (He portaged the rocky stretch of river that is now the smooth Saint Lawrence Seaway.)

ANNO'S MEDIEVAL WORLD, by Mitsumasa Anno. Adapted from the translation by Ursula Synge. Philomel Books, Putnam Publishing Group ($9.95). In almost 20 two-page spreads, each a carefully painted scene within an intricately illuminated frame, this original artist from Japan once again engages and surprises the reader. There is a text this time, a paragraph or two on most frames. What we see first is a small, flat land, where simple people fish and plow with oxen. As the pages turn and the years pass, the land holds more people and bigger structures, until at last we see the Leaning Tower of Pisa, obelisks, mines, galleons, chess players, big mill wheels and an alchemist's crocodile. By this time the earth has become round, and the words have told us how people came step by step, never directly, to understand that their world was a spinning ball in orbit around the sun. There is a wonderfully anachronistic Foucault pendulum toward the end, and finally a very brief chronology of what happened when. From the opening stained manuscript pages to the library seal stamped on the last leaf (or is it all on marble?) Anno has painted and explained something of the growth of the modern world view in his usual witty and poetic way, a piece of the history of ideas enriched for readers in the early grades.

STONES: THEIR COLLECTION, IDENTIFICATION, AND USES, by R. V. Dietrich. W. H. Freeman and Company ($12.95). It is not easy to define a stone. The geologists nonetheless try; for Professor Dietrich a stone is a loose object made of rock materials, set loose by natural processes. Addressed to collectors, this nontechnical but serious guide is a fine introduction to the study. Stones are sized on a conventional scale, as clear to tyro as it is to expert: a big stone, more than 10 inches in diameter, is a boulder, then follow cobble, pebble, granule and sand grain. A sand grain, less than a tenth of an inch across, is often excluded from stonehood, but such microstones may be of eye-opening beauty under the microscope. Stones are to be found wherever rock has been loosened from its natural bed: beaches, streams (present-day or ancient), glacier edges, in the rubble of collapsed cavern roofs, at the bottom of weathering cliffs. There are stones that slide windblown out into the desert, stones that are rafted by plants or by ice, stones pitched down from orbit, stones thrown by volcanoes.

The substance of stones—the rock materials of which they are made—defines another way to look at them. The chapter here on the origins of parent rocks is a little introduction to petrology. How far one can go is exhibited by a picture and its caption of a boulder collected from a glacial deposit near Mount Pleasant, Mich. (where the author teaches geology). Eight steps can be made out from the stone fabric, from its first sedimentation into the type of rock called graywacke through no fewer than six stages of deformation and intrusion to the final transport. The last chapter is a droll account of the uses of stones, from stone soup (perhaps for the lichen on the stones, the author suggests a little tentatively) to the adding of weight to anything from a beehive to a sailing ship, to skipping, hopscotch and slingshot, to a stuttering cure (for Demosthenes), to ritual, to clappers and hammers and firestones. Many birds depend on gizzard stones for the internal grinding of seed coats.

There are several useful appendixes, including a piece on kinds of collections. For example, there are collectors who assemble sets of ventifacts, which are stones shaped by the wind, or of gemstones found as beach stones, or of official state stones, each found in the proper state, or of imitative stones, whose forms by chance resemble a person, an animal, a bird. There is considerable whimsy in this instructive book. The author asks readers for news about any other distinctive collections of stones; there must be plenty of ideas left.

Logic and Illusion

THE SECRETS OF ALKAZAR: A BOOK OF MAGIC, by Allan Zola Kronzek. Illustrations by Tom Huffman. Four Winds Press ($9.95). BODY MAGIC, by John Fisher. Illustrated by Derek Lucas. Stein and Day/Publishers ($10). All of us have long experience in Newtonian mechanics; we know that a continuous causal chain governs the position of every tangible object. Alkazar offers theory and specific example as a guide to the magic of today's magician. Through the author he explains with interesting and convincing pedagogy how to intervene in 15 different chains of cause to produce a baffling result. It is mainly continuity the magician attacks, either in time or in space. The four rope ends dangle from the hand, the coin is placed in the cupped palm, the performer is mummy-wrapped by his assistants as you watch, the saltshaker is concealed casually by the napkin. Or is it so? It is not, but the little interval of space or time you have missed is not apparent. That depends on misdirection: by words, by carefully elaborated mime, by delays and by subtly belied assumptions.

In *The Secrets of Alkazar* it is all put together in language and props within the reach of theatrically minded and hardworking kids from junior high up. Among the effects described are some suitable for closeup work before a small group, some for a living-room show, a few even for performance on a modest stage. It is true that most of the effects involve one act of deftness, or one apparently familiar object in fact patiently modified, but most of the mystery is contained not in how the chain is broken but in how the event appears. We all know that cards never speak to us, that cut ropes do not mysteriously mend, that you cannot wrap the magician and then unwrap a quite different person, but so it appears. How disbelief is sent into hiding is what the book tells, only in elegant detail. Alkazar's wisdom about means and ends opens a way to the creative extension of the individual acts set forth. We do not quite learn who this master magician is, but we read his notebooks and hear his admonitions, genuinely revealing about the nature of inference. It seems possible to infer with good probability that for all his Levantine name Alkazar is an intimate of the author's family on Long Island.

Body Magic is quite different, both in style and in content. It is much more demanding in that it does not offer detail for the theater but concentrates on effects and something of their causes. It has more than 100 rather brief chapters. For most of them the effect is not the result of a causal chain carefully linked by the conscious actions of the magician. Rather, the effect is the result of an inherent functional response of the human body to some carefully specified input. How it all works often remains within the black box of the human senses, the nervous system and the mind, although some responses are simple results of the skeletal and muscular structure we all possess.

The effects discussed range from the familiar and simple, such as optical illusions and the swift fall of the dollar bill past and out of the ready fingertips, to less commonplace matters such as the remarkable results of muscle reading, a trained contact able to perceive the subject's unvoiced intentions, and the

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schemes by which a slight person can nullify the muscular effort of a heavyweight. A century ago Annie Abbott, the Little Georgia Magnet, made a national reputation by defeating the efforts of anyone to lift her from the floor. Even Thomas Edison felt there was some new force involved. You can rival the Little Magnet after some practice. The Ouija board, magical pendulums, table tilting and other Victorian marvels are similarly made repeatable. Here too are mnemonics and the edges of hypnosis and karate. It does not sound easy or sure, but it presents a starting point for determined young people of high school age and beyond; the book is much to the point in today's credulous climate as one to read and muse on.

THE TURN ABOUT, THINK ABOUT, LOOK ABOUT BOOK, text and graphics by Beau Gardner. Lothrop, Lee & Shepard Books ($6.95). Square pages each contain a brightly colored pattern of bold forms, at a glance suggesting cutouts by Matisse. Every page can be examined from each of its four edges, and there is a different caption on each edge. A diverging set of red and white stripes against a blue ground looks from the bottom of the page like a circus tent, but from one side it is a red-and-white striped wall, from the top it is a giant balloon and from the other side it is a fantasy of candy-cane breath. Fourteen such pages make up the book; aimed at all ages, it could be reread by any apprentice reader who had heard the captions read aloud. It is an original and witty study in the ambiguities of form.

COUNT ON YOUR FINGERS AFRICAN STYLE, by Claudia Zaslavsky. Illustrated by Jerry Pinkney. Thomas Y. Crowell ($8.95). Could you convey your price of eight shillings for produce to a customer who did not speak your language? Well, you might easily hold up two hands, four fingers on each, thumbs folded. That is what the Taita farmer did in front of snowy Kilimanjaro. Not far off a Masai trader waved his right hand, four fingers up, once back and forth. The Kamba fruit seller grasped with his right hand the three small fingers of his left. All had said eight.

Sometimes words retain old ideas. The Zulu still hold up the right thumb to show six; the Zulu word for six is *isithipa,* which means "take the thumb." An old echo still rings in English: the words eleven and twelve seem to contain the Old English for "left over"; they might have meant one or two left over after counting 10 fingers. In this book for young readers or those read to, who hope to learn to count well or who like far travel by way of books, we visit African markets to see the sights. Daily many people use fingers for arithmetic, a practical method when a common language is lacking. After all, ours is the time of digital mathematics; here are its origins. The detailed and evocative pencil renderings from life are the pleasure of these pages; they show striking costumes and animated crowds in the varied marketplaces of Africa, East and West, where one little Mende girl can count on her fingers nimbly up to 20 while her experienced mother carries out big sums swiftly in her head.

Living Forms

FOX FAMILY: FOUR SEASONS OF ANIMAL LIFE, by Minoru Taketazu, photographs and text. Translated and adapted by Richard L. Gage. John Weatherhill, Inc. ($25). The red fox is found all around the northern Temperate Zone, as widespread as any wild species of the dog family. The foxes thrive from seashore to timberline, but it is likely they prefer the scrubby undergrowth at the forest edge, so that the clearings people make for small-scale agriculture turn out to be ideal for foxes. "The fox diet is inclusive": rabbits, mice and chickens might make up half of a fox's food, but fish, fowl and the afterbirths of cows and pigs support many a fox family. Farmers benefit from a foxy control of rodents and can often tolerate the tribute of a few chickens.

In the folklore of Japan the red fox is an enchantress, and this book, as colorful and as intense as the fox itself, confirms the tale. The enthralled author-photographer (the volume is adapted from two books of the 1970's in Japanese) is a veterinarian in the northernmost part of Hokkaido, among forests, fields, streams and shore, open to blizzards from the Sea of Okhotsk. There nearly 20 years ago he came to help the farmers, but his deepest interest was captured by the wildlife. "Living proof that a license does not make a veterinarian," he somehow or other became a satisfactory animal doctor and then was won by the foxes. He has spent 12 years afield with a hundred dens of the beautiful wild creatures, and the life he came to know so well is here displayed in 90 strikingly reproduced photographs in color, the choice among 70,000 shots he has taken.

Here is the round of the vulpine year. Winter is the time of pair forming, an idyll of unrestrained romance, vixen and male running side by side daylong through the deep snow, without appetite for food. In time the cubs come, born in the innermost den, burrowed in the "southern slope of a hill in the grassy plains." The vixen nurses them in their early myopic play. Soon enough they are fed by whatever the parents can win from the land. Hungrier, they search their mother's mouth for food even when they have left the lair and have begun to snap at butterflies and grasshoppers. Summer finds the cubs sleek and voracious, their tired parents molting and unsightly.

The cubs begin to follow the foraging across the green fields in their russet coats. Play steadily turns to serious hunt, and "by the end of July, cub droppings are made up almost entirely of the hard wings of insects." Almost full-grown by early fall, the cubs first lose a father; his task ended, he goes off. Then one day the mother drives them out with wild threats and bites. Even a feint of food bringing can be staged; when one female cub appeared to claim that last offer of mother's care, she was driven away unfed, now "only an unwanted intruder." Snow returns in season, and with it the rifles of man. "The cruelest season for the foxes, and all I can do is scream to them to run! run!"

This extraordinary narrative has four levels: the bright images themselves, their detailed captions as a careful gloss, a personal essay of his experiences by the author and a compact factual account of red fox life. Any of them can be enjoyed alone; it is a wildlife book for any age and condition of reader, or even for a young nonreader. Taketazu is candid; his book is a "love lyric relating eight years of adventurous contacts between a veterinarian and the foxes." The red fox can form narrow or extended families but never runs in packs; perhaps that is why the species remains entirely undomesticated. But their untamed closeness and wild beauty are manifest.

SUNFLOWER!, by Martha McKeen Welch. Dodd, Mead & Company ($6.95). This magnificent sunflower is so tall that you need to stand on a ladder to look at the big flower head up top. There is a hole in a leaf. Why? The sunflower is not alone. True, we can find the seeds and plant one, first of all germinating it in plain sight on a damp blotter. The tiny seed leaves sprout, and the plant grows apace. (Disarmingly saying nothing of measurement, the author has photographed a ruler next to the vigorous young plant.) Plenty of insects come and go; there is even an infestation of white flies. The mature main stem is a thick, strong handful for the young grower. The many seeds can feed the birds, and still they allow a new planting in the spring. And that is not the whole story. The big plant withers, dies, falls "in a great big mess" and slowly goes back to the soil, sheltering a tiny animal or two, even in its ruin. The thoughtful, simple text and the clear, strong black-and-white photographs add up to a genuine example of the life cycle in context, more convincing than many efforts at formal ecology. One looks forward next

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season to many a stand, city or country, of a single sturdy sunflower.

HORSES AS I SEE THEM, pictures by Ugo Mochi, text by Dorcas MacClintock. Charles Scribner's Sons ($9.95). Ugo Mochi saw horses lovingly all his life. At 10 he modeled in clay a great bronze horse of Donatello's that carries the figure of a famous Venetian general; the model won the boy admittance to the Florentine Academy of Fine Arts. An animal sculptor of promise, Mochi had always made paper cutouts of the animals he admired. By and by he gave himself over to that technique, in which he is clearly unmatched: a small, sharp knife, a piece of heavy black paper, his own rough sketch to follow and a glass surface on which to cut. The silhouettes that result, always cut out of one piece of paper, small or large, are as lively and as intricate as any pen drawing. They stand strikingly on the page like living shadows; the clouds, bushes, bulk, motion and even the wriggly line of the bridle are evocative of reality and yet are only that terse, strong shadow. Mochi died a couple of years ago in his eighties; here are some of the horses he long admired and artfully represented in paper.

They come with carriages, with riders, standing still, bucking, engaged in a neck-to-neck encounter at polo. Here are the horses of cave days, the Greek figures and the Chinese; here too are the huge shire horse and the tiny Shetland pony. Close to 100 outlines are found in this book, arranged to illustrate the knowing text by an American author who has always loved horses and tells about them clearly and personally. She describes the gaucho and his bola, the five-gaited show horse and the skillful young woman who rides it, with assurance and accuracy, and just about every other relationship between human beings and their horses worldwide. It is a brief but inclusive text, a synopsis of horses, their breeds and uses, over space and time. There are other such outlines of the lore of horse, no doubt, but none so distinguished graphically or so much a celebration of a lifelong gaze at those two close-knit species.

DEAR PARROT: PERTAINING TO THE CARE, NURTURE & BEFRIENDING OF MAN'S OLDEST PET, by John Phillips. Illustrations by William Bramhall. Clarkson N. Potter, Inc., Publishers. Distributed by Crown Publishers ($4.95). In the elevated style of its subtitle, with a vocabulary that extends your dictionary out to *eiton* and *kvetching,* an intimate of parrots tells what he has learned, "based less on banal fact than on Subjective Truth." It is a small, funny work, really an article with drawings, invoking Aristotle and Scripture, some shaky paleontology and much fond observation.

The African Gray, dressed almost in the colors of the Confederacy, is the best-talking parrot. The Gray is "at ease in all earthly and celestial tongues" and commands a brimming repertoire of sounds, from hounds on a summer night to burping, snoring and a woman laughing. There are a few elite parrots that refuse to play the talk game, even cusswords. If you try hard enough, there in a dark room, teacher perched on your shoulder, you might in time learn "a rude *patois* of [Parrot]," and if you are favored by fortune, you might come, no longer a mere pupil but now a disciple, to speak the "mystic tongue-click language that long ago the Parrot taught the apricot-skinned Bushman nomads who wander the Kalahari."

For a little-known apocryphal account of what really happened after that dove came back with a leaf ("Big deal.... You're some stupid Dove," said Noah, overwrought) you will have to consult this book itself.

Tales

EDWARD S. CURTIS IN THE LAND OF THE WAR CANOES: A PIONEER CINEMATOGRAPHER IN THE PACIFIC NORTHWEST, by Bill Holm and George Irving Quimby. University of Washington Press ($19.95). Three great war canoes, richly carved and decorated, a dozen paddlers in each, speed toward the shore. On a platform in the bow of each there dances in spectacular mask and costume one of the three personages: Thunderbird, Wasp and Grizzly Bear. As they near the shore war songs give way to lighter dance; it is a captive the flotilla seeks, but not a captive of war. The ceremony is put forth as part of the lavish display of an ancient chieftainly Kwakiutl wedding. It is all there in a sepia print, a sight too magnificent and archaic to be expected in a 20th-century photograph. The plate is one of the 700 big rotogravure pictures in *The North American Indian,* a 20-volume work by Edward Curtis published in costly portfolios between 1907 and 1930.

It was not easy to travel to the Hopi and the Arikara, to befriend them and pose them, to represent them in sympathetic images on such an aristocratic scale. The scheme was grand, too grand to be quite real, although the gifted and obsessed artist who was Edward Curtis completed the project. The 20 volumes had promised to cover "all the tribes of America, both North and South," but in the end they could not treat more than a handful of the tribes of the American West. During the time spent among the Kwakiutl for Volume 10 there came to Curtis a still larger scheme: an entire library of motion-picture films that would forever document the everyday and ceremonial life of each Indian culture. He actually began the task, starting in 1913 among the richly theatrical Kwakiutl, with their great canoes and spectacular carved house poles, but he finished only that single operatic film.

The wonderfully staged sequence of the speeding canoes with their breathtaking dancers is alive today, optically stretched to 24 frames per second, the opening shot of the new sound version of Curtis' Kwakiutl film. The picture is only one still taken from the film; the film itself had opened in 1914 to one enthusiastic review and had then disappeared without a trace. In 1947 a collector gave to the Field Museum of Natural History in Chicago a brittle, scratched, 35-millimeter nitrate film, parts tinted in sepia, green and red to fit the mood of the action, the only copy known. The film clearly was a lost treasure; George Quimby, curator at the Field, dreamed that one day the technology and the means for restoration would arrive. In the mid-1950's Bill Holm began research among the Kwakiutl, a student of their art and their artists. The old people were full of tales of filmmaking long ago, although none of them had seen the film. In 1962 Holm, seeking word of the lost work, met Quimby. They knew that their "mutual dream of restoring the film... was finally realizable."

Here is the story, well documented and full of pictures, with the letters of Curtis and his cameraman. We see the activities of George Hunt, the Kwakiutl carver, interpreter and informant who was an indispensable assistant to Curtis as he had been before him to Franz Boas, the central source of what we now know of the old troubles and glories of the Kwakiutl. Here are bills for masks and costumes, false façades of the houses, the entire anatomy of a remarkable event in the history of film. It is a tale worthy of the high drama in which the Northwest world, the Kwakiutl and Edward Curtis will always dwell, a life somehow larger than we others lead, far from the abundant shores of clever Raven and noble Thunderbird.

ITALIAN FOLKTALES, selected and retold by Italo Calvino. Translated by George Martin. Harcourt Brace Jovanovich, Inc. ($25). Half a dozen brilliant works of fantasy, wit and invention by the novelist Italo Calvino are fully at home on the shelves of every reader who enjoys the writers of our time. This volume of 200 stories that Calvino first produced 25 years ago in Italian, reaching us now in a clear, bright translation, may help us to understand some deep-lying sources of his ingenuity and wonder. He has here acted as the Italian counterpart of the Brothers Grimm. When printers were still new in Venice and Naples, Italian folktales were collected and elaborated by the writers of the time. By the end of the Enlightenment it was plain that the old stories of foxes and grapes had evolved into an elegant and artful genre, far from its

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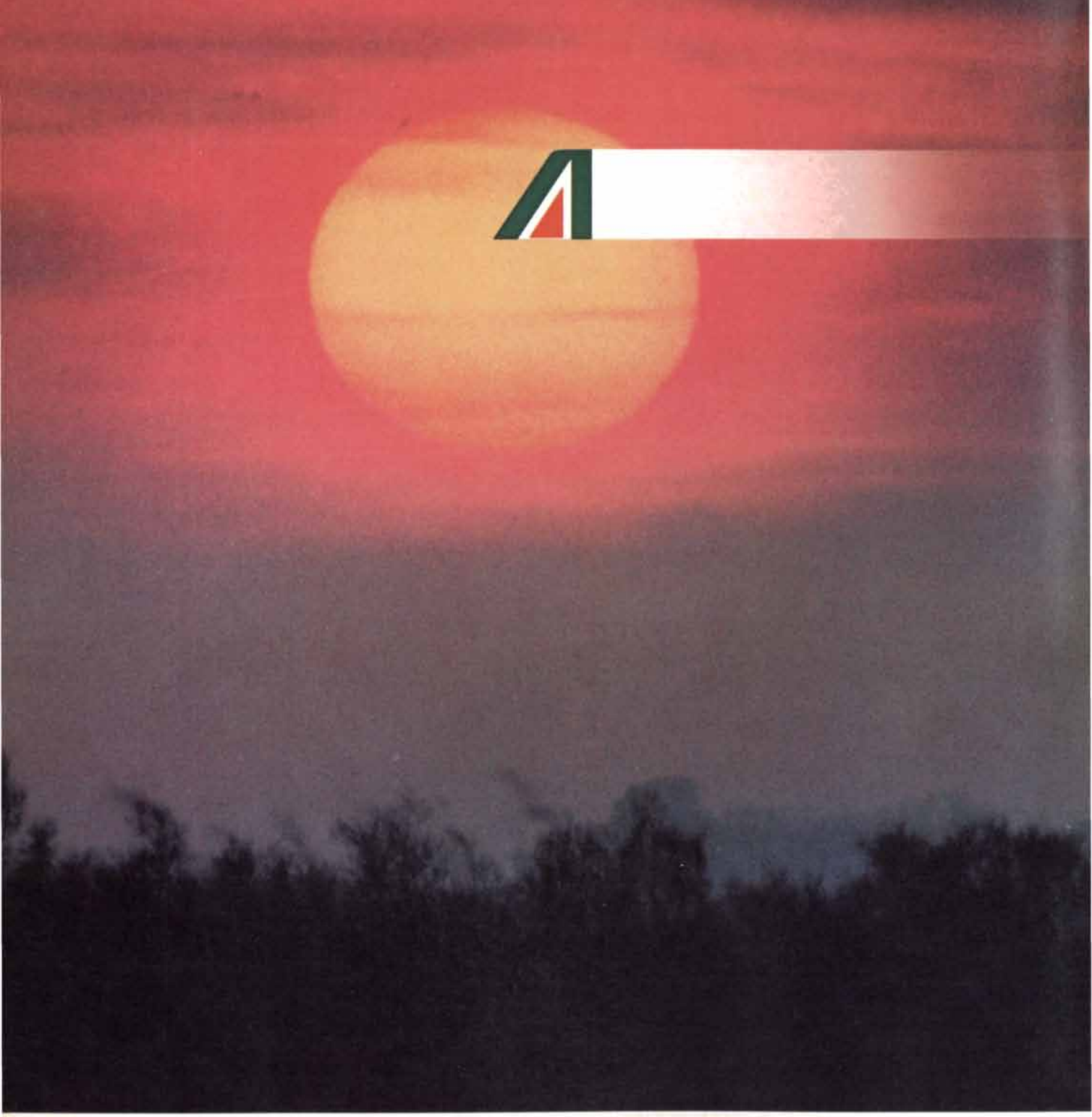

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AT HOME IN THE SKY

simple origins. Then came the Romantic work of the Grimms, who felt they were working at timeless roots of the Germanic mind in the stories they touched up and integrated.

That event of 150 years ago had no clear echo across the Alps. The folklore of Italy has been well collected during the past 100 years, but as part of a science of folklore. Since that time collectors worldwide have become even more scientific, sticking close to the oral texts, thirsty for ethnographic marvels of classification and the comparison of themes. Calvino himself was caught, he admits, by that typology, its system as developed and as logical now as the taxonomy of beetles. "I would have given all of Proust in exchange for a new variant of the 'gold-dung donkey.'"

After his tour de force of an introduction Calvino limpidly retells and annotates for us a Grimms' worth of tales, with kings and farmers' daughters, magical apples, prophetic mirrors, articulate donkeys, princes bewitched into frogs and restored by love, the full, intricate machinery of the European folktale, some familiar, some wonderfully unexpected. All regions are represented, Tuscany and Sicily most richly. There is the deep stamp of the medieval, and no little of the Oriental world, but time has gone by, we are in more sophisticated, less isolated southern lands, and the tales show it. Even a certain cynicism is found: one story is called "Money Can Do Everything." But "The Love of the Three Pomegranates" (or oranges), a chain of dazzling transformations across metaphor (blood and ricotta to rose red and snow white), may stand for the especially Italianate qualities in this cargo of wonders. The climate of sun and civility somehow brightens even the terrible punishment of the Ugly Saracen, who condemned herself. It is a new natural resource: a reading-aloud or enjoy-in-silence volume good for all who love tales and tale books.

WORLD FOLKTALES: A SCRIBNER RESOURCE COLLECTION, by Atelia Clarkson and Gilbert B. Cross. Charles Scribner's Sons ($20). Here is a useful gate to the world of the scholars of the folktale. It is first of all an anthology of more than 60 worldwide tales, reprinted from many collections, gathered into 10 broad classes. The system of motifs and tale types exhaustively elaborated by the scholars of Helsinki and Indiana over the decade is sketched, with the exhibited tales categorized, compared and annotated. The scholarly literature is well listed and introduced, and there are explicit guides, with sample student papers, for teachers in school and college classrooms. With this weight of apparatus the book acquires a certain textbook-like heft, but a reader who loves folktales will find it irresistible. The subject is certainly more accessible here than in

the sources to which the book points the devotee. There is a rich bibliography.

The one-page story dubbed Tale Type 980, here taken from the Grimms, is in itself a shaft of light on life and death. A very old man has become trembling and uncertain. He can hardly hold his spoon. His son and his son's wife at meals put him in the corner to eat. There they feed him out of a crude wooden bowl, which cannot break if it falls from his faltering hands. One day after dinner his grandson, only four, begins to gather some bits of wood. "I am making a little trough," he explains, "for father and mother to eat out of when I am big." The pitiless story is found in Korea, Brazil, Greece, Russia, Japan. Diffusion? Or common humanity?

BEAT THE STORY-DRUM, PUM-PUM, retold and illustrated by Ashley Bryan. Atheneum ($10.95). THE ADVENTURES OF NANABUSH: OJIBWAY INDIAN STORIES, compiled by Emerson Coatsworth and David Coatsworth. Illustrated by Francis Kagige. Told by Sam Snake, Chief Elijah Yellowhead, Alder York, David Simcoe and Annie King. Atheneum ($10.95). In the first of these books we hear the accounts of Nigerian storytellers, north and south, retold from collections and translations made some time back. In the second book, again based on scholar's collections of the past, we read a cycle of stories of the "mighty magician, Nanabush," a personage well known to the storytellers of the Rama Ojibway band in central Canada. Each work has been given a unity of style by its illustrator, the Nigerian book showing fine strong blocks, mainly of animals, and the Ojibway stories illuminated by bright and strongly outlined paintings in the idiom of a self-trained and powerful Ojibway painter. There are no princes, mirrors or apples in these tales. From Nigeria we hear mainly of animals, whose relationships are not so distant from our own lives. Frogchild and Snakeson used to play together, but their mothers had another wisdom. Mama Snake said, "Frogs are delicious people!... Ah, for true!" and Mama Frog warned that snakes are "Bad, too bad!" Since then Frog and Snake have never played together.

Nanabush is a more complex figure. He hunts, transforms, speaks with the beasts and arranges the world as it has come to be. Indeed, the very moss that grows on the once barren rocks of the northland is a memorial set by Nanabush for his lazy brother, who was so indolent that when at last he was turned away from the wigwam, where for a long time he had been fed and sheltered as a guest, he could not hunt for himself and starved by the barren rocks. Guests since then are always welcome, but they must not in laziness stay too long. These are fine books, for grade school readers or beyond.

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Intermediate-Range Nuclear Weapons

Systems of this kind, also known as long-range theater nuclear forces, fall into a "gray area" between tactical and strategic nuclear forces, adding a new dimension to the nuclear-arms race

by Kevin N. Lewis

Last December the governments of 14 of the 15 member states of the North Atlantic Treaty Organization agreed in principle to a plan for the modernization of NATO's force of intermediate-range nuclear weapons stationed in Western Europe. The NATO plan, which is intended to counter a similar modernization effort undertaken by the U.S.S.R., calls for the deployment by 1985 of 572 advanced nuclear-armed missiles: 108 Pershing II extended-range battlefield-support ballistic missiles and 464 ground-launched cruise missiles (GLCM's). The new weapons would be supplied by the U.S., at a cost officially estimated at $5 billion.

At the same time that the NATO decision was announced the diplomatic and military representatives of the 14 nations concerned, meeting in Brussels, indicated their willingness to enter arms-control negotiations with representatives of the Warsaw Pact in an attempt to limit the deployment of the new generation of intermediate-range weapons on both sides. The U.S.S.R. has since then responded favorably to the NATO initiative, and preliminary discussions on the issue are under way in Geneva. Pending the outcome of the talks the government of at least one NATO nation, Belgium, has postponed a decision on whether or not it will allow the new missiles to be installed on its territory.

According to the NATO plan (as it now stands), the U.S. would send home from the European theater of operations 1,572 tactical nuclear weapons, or approximately a fourth of the U.S. stockpile of such weapons now stationed in Europe. The first 1,000 would be withdrawn within a year of the final NATO deployment decision, and the rest would be recalled on a one-for-one basis as the new warheads began to arrive in 1983. The planned deployment would therefore entail a net reduction of 1,000 U.S. nuclear weapons in Europe.

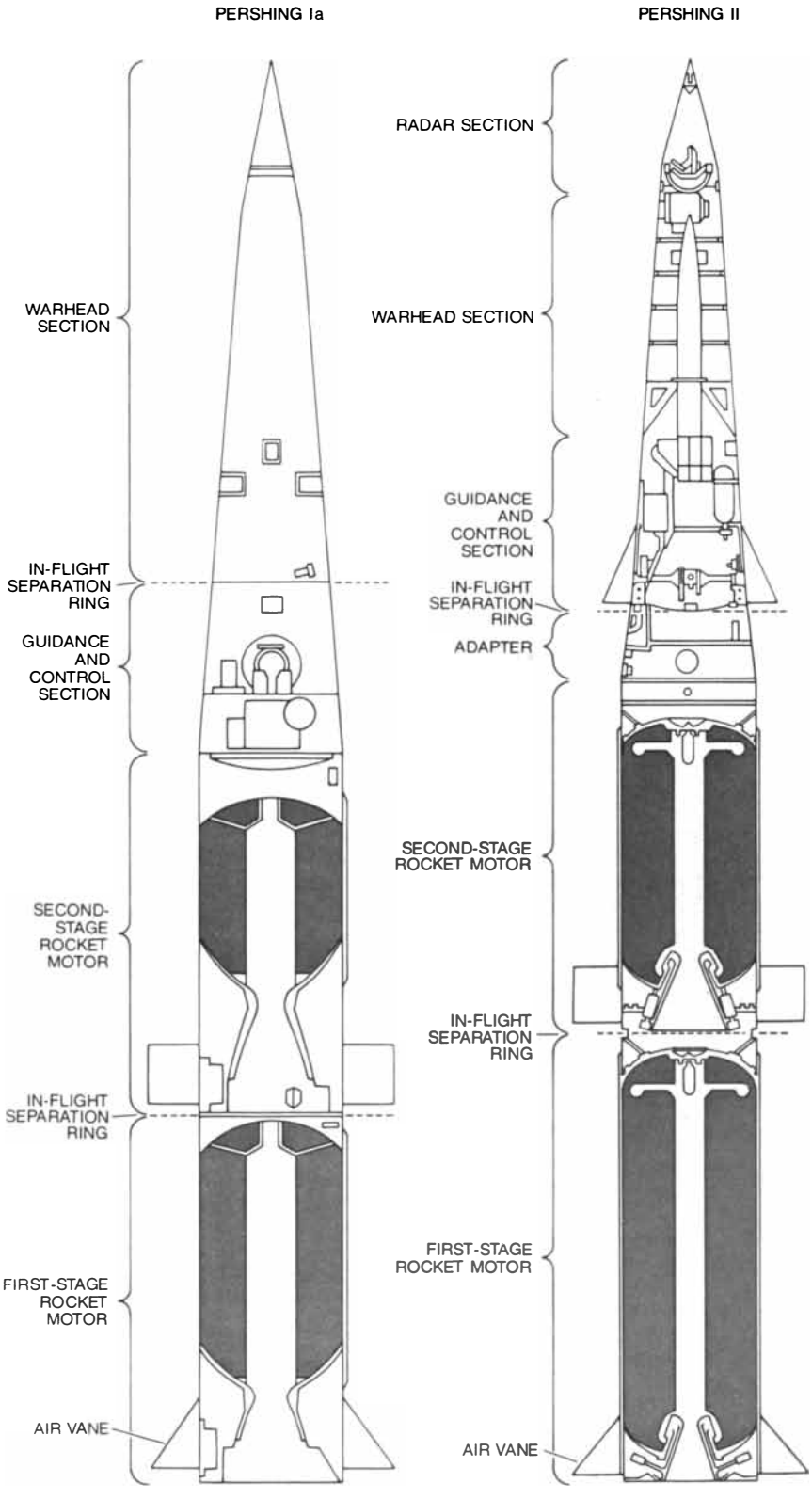
The weapons to be deployed, however, would differ in several important ways from the ones they would replace. Among other things, they would be more accurate than existing nuclear missiles, and they might be armed with modernized nuclear warheads, making them more appropriate for certain missions. What has contributed most to the emergence of the plan as a major point of international contention, however, is the fact that the new weapons would be the first new U.S. land-based missiles in Europe in two decades that would have the capability of reaching targets in the U.S.S.R.

The debate that immediately preceded the announcement of the NATO plan was intense both in the U.S. and abroad. The issue is a complicated one, and the scope of the discussion was initially quite broad. Within a few months after the controversy began, however, most points of view represented in the debate on the Western side seemed to coalesce into a consensus that the planned deployment was the best way for NATO to deal with the Russian intermediate-range bomber and missile force, which may now be approaching the final stages of its buildup.

Following the NATO endorsement of this premise attention was focused primarily on certain political aspects of the issue. As a result other considerations, in particular the basic military rationale for the deployment, have largely escaped scrutiny. Here I shall review some of the military and other consequences of the NATO plan. Notwithstanding the importance of the political issues involved, both domestic and international, the deployment of such weapons must in the final analysis be judged on the basis of their contribution to the security of the Western European nations. It is my conclusion that the military case for the NATO plan provides little support for going ahead with it.

Over the past 30 years or so the specific missions for which nuclear weapons have been considered appropriate have varied widely. In an effort to treat the problems of nuclear war systematically some strategic analysts invoke a conceptual spectrum of capabilities to describe the various properties of the weapons and their assigned roles. At one end of the spectrum are the strictly tactical nuclear forces. These consist of nuclear explosives and delivery systems suited for use in a battlefield setting in roughly the same way as non-nuclear munitions are. For example, one side might fire a nuclear artillery round to destroy a concentration of enemy tanks, or it might explode a nuclear mine to create a barrier in a mountain pass. At the other end of the spectrum are the central strategic forces, those nuclear-weapons systems that are assigned a specific set of long-range missions, including all-out attack on military, economic and other targets in the homeland of an adversary.

Between these two extremes are what are referred to in military argot as long-range theater nuclear forces. Although such forces may be able to attack targets inside the territory of the other side, they are designed primarily for objectives related to the progress of a battle within a given operational theater. For example, the Russians might plan to employ medium-range nuclear-armed bombers or



PERSHING II, the new U.S. intermediate-range ballistic missile scheduled for deployment with the forces of the North Atlantic Treaty Organization in Western Europe, is compared here with the missile it would replace, the Pershing Ia. Both missiles are designed to be fired from mobile field launchers and both have a solid-fuel two-stage propulsion system. The advanced terminal-guidance system of the Pershing II, however, makes it much more accurate than its inertially guided predecessor. The improvement in accuracy has made it possible to greatly reduce the explosive yield of the new missile's nuclear warhead, creating more room for fuel and helping to increase the weapon's range: from approximately 650 kilometers for the Pershing Ia to 1,500 kilometers for the Pershing II (long enough to reach the U.S.S.R.).

missiles to attack a NATO ship convoy unloading American reinforcements at a European port such as Amsterdam. Similarly, British medium-range bombers might be assigned to drop nuclear explosives on one of the points where the rail gauge changes along the border between the U.S.S.R. and Poland. Since nuclear weapons of these types and in these roles are strictly speaking neither tactical nor strategic, they are sometimes called "gray area" forces. I shall refer to them simply as intermediate-range systems, that is, those with ranges between 1,000 and 5,000 kilometers.

Both the U.S. and the U.S.S.R. have long deployed intermediate-range nuclear weapons of various kinds. For example, both nations have for some time fielded not only light and medium bombers but also certain tactical aircraft capable of striking distant targets with nuclear weapons. The two sides have also deployed a variety of ground-launched and sea-launched missiles (both ballistic missiles and cruise missiles), whose primary mission has been to carry out nuclear attacks on targets in the countries of the major opposing alliances along the periphery of the Soviet bloc. (In addition many of the strategic nuclear weapons in the arsenals of both sides can attack targets at less than the full range technically possible for such weapons.) Over and above these formidable superpower arsenals the secondary nuclear powers—Britain, France and China—have developed and maintained nuclear weapons capable of striking targets at ranges of as much as a few thousand kilometers. A competition among gray-area nuclear arms has therefore been in effect for more than two decades not only in Europe but also in other operational theaters.

The recent controversy was set off by what has been perceived as an abrupt shift from a long-standing state of inertia in the area of intermediate-range systems resulting from the deployment by the U.S.S.R. of greatly improved intermediate-range missiles and bombers. Some comparatively vulnerable Russian missiles installed almost 20 years ago are in the process of being replaced and augmented by what seems to be a much superior system, the mobile SS-20 missile, which carries three independently targetable nuclear warheads. In addition an advanced Russian medium-range bomber, the Tu-26 (code-named Backfire by NATO intelligence agencies), has been entering service in growing numbers.

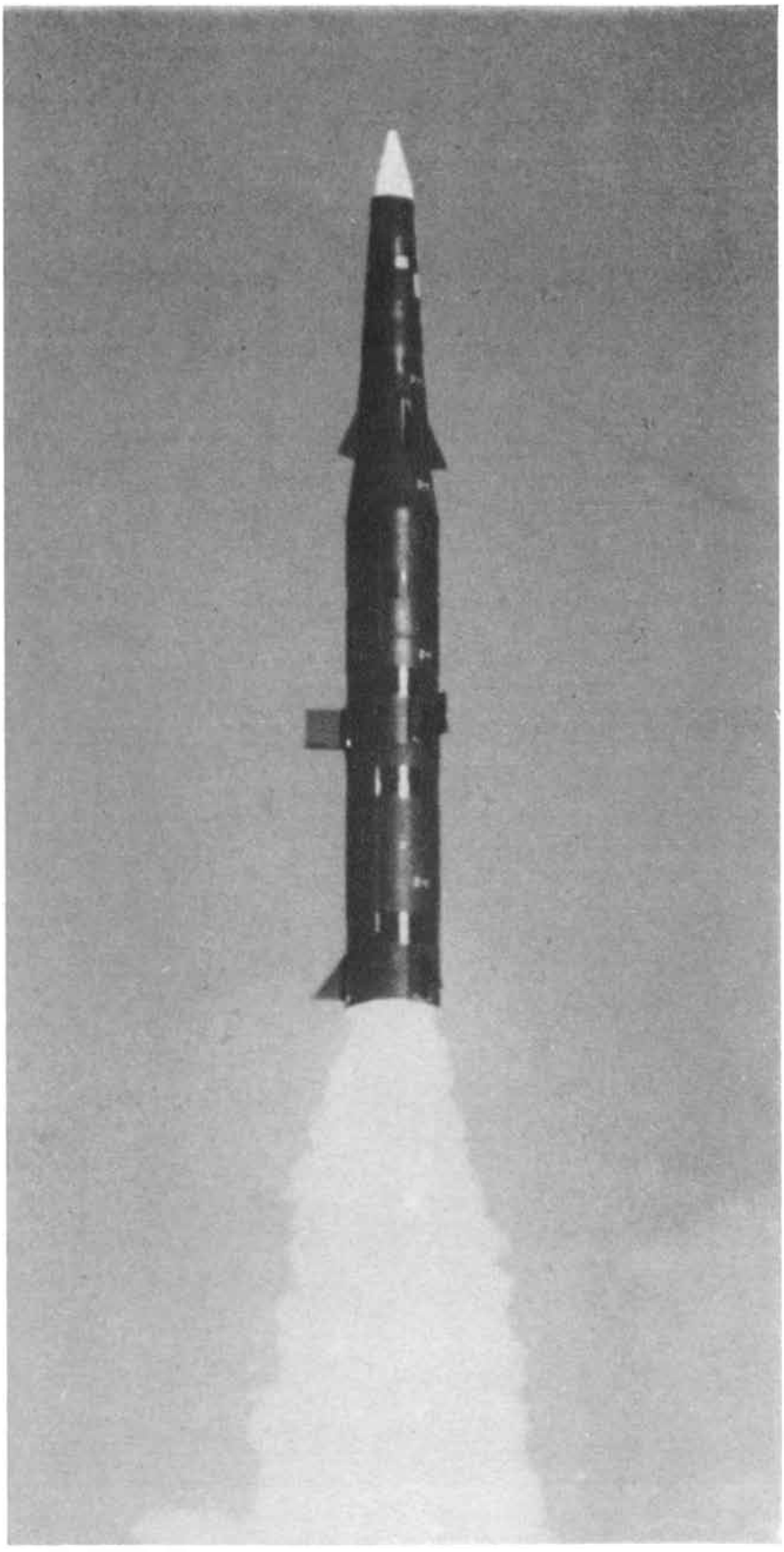
The new U.S. intermediate-range missiles are under consideration, then, partly because it is thought they can to some degree duplicate the capabilities of the new Russian intermediate-range weapons (even though the ranges of the Pershing II and the GLCM are much short-

er than those of the SS-20 or the Backfire). The GLCM is identical in certain respects with the air-launched cruise missile (ALCM) soon to be deployed with U.S. strategic forces. The Pershing II, a modernized version of a 1960's-vintage nuclear missile named the Pershing Ia, has increased range and improved accuracy. The proposed NATO systems represent no great revolution in weapons design or in operational role. What is novel about them is the stated rationale for their deployment.

In order to understand the debate about the deployment of the new intermediate-range nuclear weapons it is necessary to examine its historical background. The current controversy has revived many of the issues of nuclear strategy and diplomacy with which the NATO alliance has been concerned throughout its history. The current issues, like the historical ones, extend far beyond strictly military considerations, and the new U.S. plan is bound up with difficult political questions. The most important is the question of what kinds of enemy action a given type of nuclear weapon is supposed to deter. In this respect the key question is: Can U.S. nuclear power prevent the Russians from perceiving any advantage from an attack on Western Europe?

Ever since the establishment of NATO in 1949 the unified defense strategy of the members of the alliance has implied an affirmative answer to this question. It has seemed to many analysts that American nuclear forces could play an important, and perhaps pivotal, role in plans to deter or defeat an attack by the U.S.S.R. on Western Europe. This role could be achieved either by the strategic bombing of war-supporting facilities in the U.S.S.R. or by direct attack on invading Russian land forces and their lines of communication.

Through 1948 there were not enough nuclear weapons in the U.S. stockpile to spare any for tactical purposes. By about 1950, however, the U.S. stockpile had become large enough to consider the possibility of deploying some nuclear weapons in the European theater. Such a diversion of weapons would, it was thought, give the U.S. an opportunity to exploit its much superior fission-bomb technology and much larger fission-bomb stockpile. More important, it was thought nuclear weapons would provide NATO with the heavy firepower needed to oppose the otherwise seemingly invincible Russian armies. In December, 1949, President Truman ordered the Strategic Air Command (SAC) to include "retarding" nuclear attacks in its war planning. In such attacks atomic bombs would be dropped to impede the advance of Russian forces into territory along the borders of the



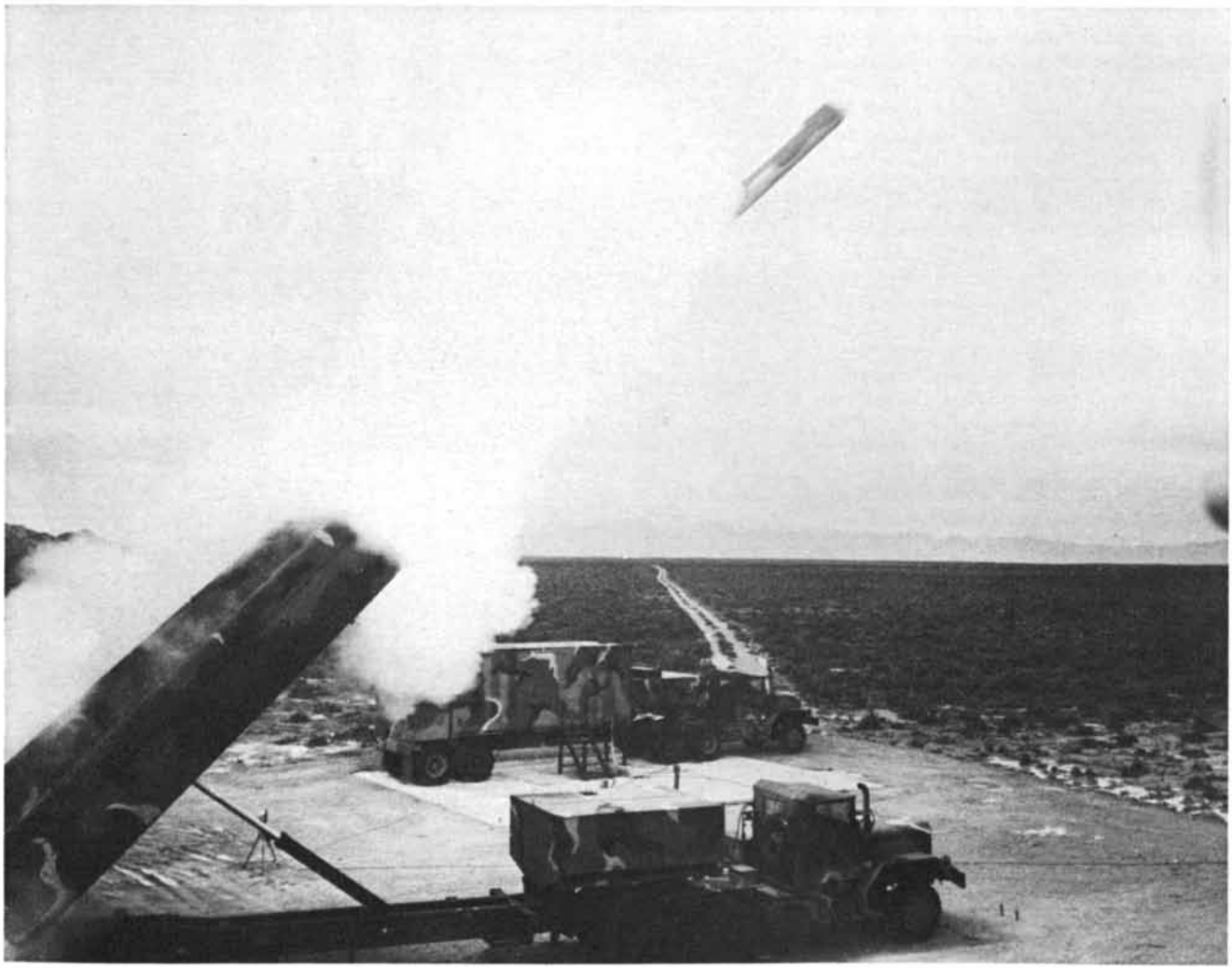
SUCCESSFUL TEST LAUNCH of a Pershing II missile was photographed at White Sands Missile Range in New Mexico. The Pershing program is managed by the U.S. Army Missile Command at Redstone Arsenal in Alabama. Prime contractor is Martin Marietta Aerospace.

U.S.S.R. Another proposal advanced at that time was the development and deployment of tactical nuclear weapons.

The Korean war prompted a sharp rise in U.S. defense spending. Although there had been, in 1949–50, recommendations to substantially enhance NATO's conventional war-fighting capability, U.S. nuclear forces took the lion's share of the augmented postwar budget. American disenchantment with the progress of the ground war in Korea and other factors (mainly economic) led President Eisenhower to conclude that U.S. security interests worldwide should be defended by means of forces armed with nuclear weapons rather than by a balanced combination of air, ground and naval forces. Accordingly in January, 1954, Secretary of State John Foster Dulles publicly enunciated the new U.S. defense policy of "massive retaliation," which reserved for the U.S. the right to use nuclear arms to defeat aggression at times and places of its own choosing. At the same time President Eisenhower authorized the Joint Chiefs of Staff to include both strategic and tactical nuclear weapons in their defense plans. It was this decision that led to the first emplacement of U.S. nuclear weapons in Europe.

In the early 1950's the U.S. began a general buildup of nuclear forces of all types. Many of these weapons would now be considered gray-area nuclear systems because they could strike at the U.S.S.R. only from forward bases. Although SAC had limited numbers of intercontinental-range bombers (the B-36 and early versions of the B-52) in the early and middle 1950's, most of the U.S. strategic-bomber force consisted of medium-range aircraft. The mainstay of SAC throughout the 1950's, the B-47, did not have sufficient range to attack the U.S.S.R. from the continental U.S. without multiple air refuelings or ground staging at forward bases. Tanker aircraft were in short supply, and so if SAC was to be able to strike at targets in the U.S.S.R. in the 1950's, it would need a large network of bases in countries surrounding the U.S.S.R. Tactical Air Force fighter-bombers and Navy carrier-based strike aircraft were also oriented generally toward the nuclear mission. As for unmanned systems, the U.S. emphasized intermediate-range ballistic missiles (such as the Thor and the Jupiter) and cruise missiles (such as the Mace, the Matador and the Regulus), partly because of expected technical difficulties in the development of longer-range missile systems.

By the mid-1950's some American strategists began to recommend the development of alternatives to the policy of massive retaliation. Interest in more



GROUND-LAUNCHED CRUISE MISSILE (GLCM) is seen here at the Utah Test and Training Range being launched for the first time from its transporter-erector-launcher (TEL) vehicle. The GLCM, a variant of the Navy's Tomahawk sea-launched cruise missile (SLCM), is being developed for the Air Force by the Convair Division of the General Dynamics Corporation. A typical GLCM unit would have four such vehicles, each capable of firing four missiles. The unit would also have two launch-control-center vans; a mockup of one of them is in the background. The current NATO plan calls for the deployment of 464 GLCM's in Western Europe by 1985.

refined strategies was stimulated mainly by the U.S.S.R.'s acquisition, after 1952, of a sizable and growing nuclear arsenal of its own. Moreover, in 1953 the Russians exploded an experimental thermonuclear device, and in 1955 Russian bombers apparently comparable to the then brand-new American B-52 were displayed at Aviation Day parades in Moscow. The U.S.S.R., it appeared, would soon be capable of presenting a serious threat to U.S. cities, raising the prospect that a massive American reply to anything short of an all-out Russian attack would guarantee the reciprocal destruction by the U.S.S.R. of urban centers in both Europe and the U.S. Alarm over the Russian nuclear threat intensified in the late 1950's, when the U.S.S.R. not only demonstrated the technical capability of producing intercontinental ballistic missiles (ICBM's) but also expressed the intention of deploying tactical nuclear weapons with its forces in the Warsaw Pact nations.

Looking beyond the question of the threat to the civilian populations of the U.S. and its allies, some analysts argued that the new Russian programs might soon make possible a surprise attack that would destroy U.S. nuclear forces, which were then dependent on bases near the borders of the U.S.S.R. Subsequently the U.S. adopted several measures to reduce the vulnerability of its deterrent forces, including a modernization of strategic-weapons systems with emphasis on the survivability of retaliatory forces. The U.S. retaliatory forces in the 1960's included advanced versions of the B-52 heavy bomber, which with tanker support could fly from bases in the U.S. to targets in the U.S.S.R. and be recovered safely, U.S.-based ICBM's in hardened silos and missile-carrying Polaris submarines, which were protected by their mobility and concealment in the oceans. As the intercontinental-range forces expanded, B-47's were retired in large numbers. In 1961 Air Force and Navy tactical land- and carrier-based aircraft began to be released from the strategic mission, and in 1963 intermediate-range missiles, including the Thor, the Jupiter and the Mace, also began to be retired.

The same Russian progress that prompted this U.S. effort caused considerable concern in Europe. As the U.S.S.R. presented an increasingly serious threat to American cities, could NATO, seemingly dependent on the American "nuclear umbrella," continue to rely on the expectation that the U.S. would reply to a Russian attack with an all-out counterstrike? As President de Gaulle asked: Would the U.S. risk New York for the safety of Paris? The credibility of a massive U.S. response to a Russian attack on Western Europe came under more intense scrutiny, and with it the nuclear keystone of the NATO security pact.

Worse still, from the perspective of Western Europe, the U.S.S.R. began in the mid-1950's to deploy large missile and bomber forces within range of targets in Western Europe. The U.S. had been concerned that the U.S.S.R. would move vigorously to present a threat to North America, but neither the predicted "bomber gap" nor the later "missile gap" ever materialized. These predictions went wrong in assuming that the U.S.S.R. would devote the bulk of its considerable industrial capacity for producing airplanes and missiles to building a force that could attack the U.S. directly. Instead the Russians concentrated on the construction of intermediate-range and medium-range bombers and missiles, presumably targeted against their neighbors. Whereas by 1962 the U.S.S.R. had deployed fewer than 40 ICBM's and roughly 200 long-range bombers, it could field more than 1,200 medium-range bombers of various types and almost 600 SS-4 and SS-5 intermediate-range ballistic missiles (IRBM's).

As the U.S. withdrew some of its forces to the other side of the Atlantic and its nuclear guarantee became in a sense less visible, the U.S. conferred with its European NATO allies to develop strategies to deal with the problem. Strategists were particularly interested in formulas for sharing the risk of military emergency. The allies wanted to establish beyond doubt the linkage between European and intercontinental contingencies.

Accordingly in 1959 President Eisenhower asked Secretary of State Christian A. Herter to look into the question. In December, 1960, only weeks before a new administration representing a new political party was to come into office, Herter proposed a multilateral nuclear force to consist of jointly manned cargo ships carrying medium-range ballistic missiles. The rationale was that such a force would allay European concerns about the credibility of the American response and avoid the more dangerous alternative of each NATO nation's procuring its own nuclear deterrent. (The latter path had already been chosen by Britain and France, and the choice was essentially unopposed by the Eisenhower Administration.) The prospect of including West Germany, which had only joined NATO and begun to rearm in 1955, in a joint nuclear command was unacceptable to almost everyone concerned, even given President Eisenhower's determined efforts to provide less expensive nuclear alternatives to a strong conventional defense in NATO.

With these developments under way the Kennedy Administration took office and promptly initiated a major review of U.S. nuclear policy. The new strategy that emerged, largely under the direction of Secretary of Defense Robert S. McNamara, turned on three assumptions.

First, reliance on nuclear weapons to the exclusion of other options was held to be imprudent. Such an approach could preclude appropriate and effective American response to crises where deterrents based mainly on the threat of nuclear attack might not be credible. Moreover, it was thought that the member states of NATO were not so weak and poor that the alliance could not hope to muster an effective conventional defense of its own territory.

Second, many in the Kennedy Administration agreed that the proliferation of nuclear weapons was an extremely dangerous prospect and should be prevented if possible. The spread of nuclear weapons among NATO countries might undermine efforts to build a strong conventional defense and might also increase the likelihood of war.

Third, it was deemed necessary to introduce more flexibility into U.S. nuclear-war planning. In planning for the European-war scenario, McNamara and others believed the U.S. should not be compelled to either launch a massive retaliatory strike against the U.S.S.R. or do nothing; the U.S. should be ready to reply on whatever level was appropriate. This, it seemed to McNamara, was probably the only way nuclear weapons might be integrated into the defense of Western Europe without foreordaining large-scale civilian destruction in all the nations concerned.

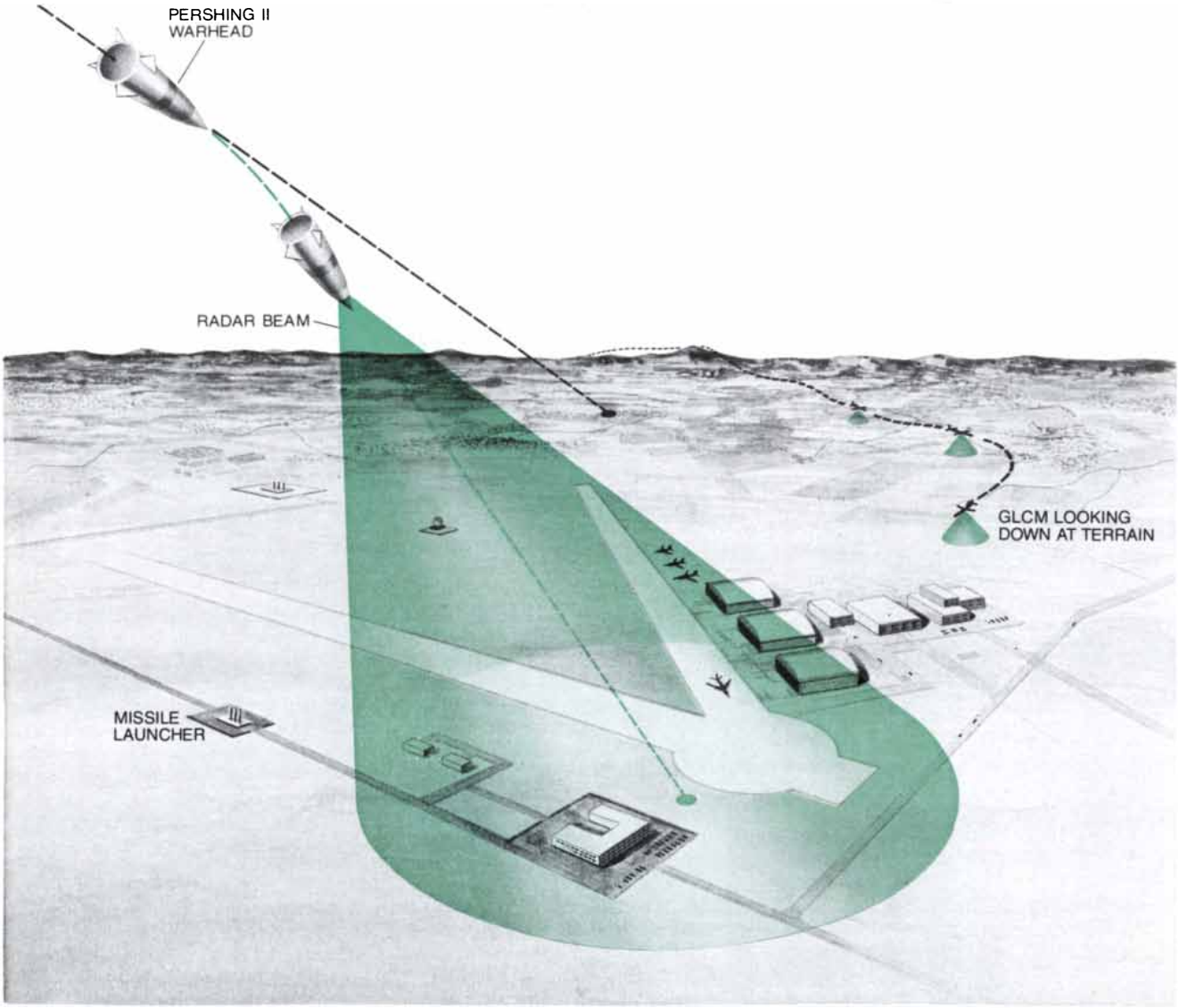
Working from these assumptions, President Kennedy and his advisers were inclined to reject plans for the sharing of nuclear weapons and for independent deterrent forces. Instead, they decided on a policy of increased flexibility in the makeup of the U.S. deterrent force and a determined buildup of non-nuclear forces.

McNamara outlined the new strategy before an audience of senior NATO officials in a secret meeting in Athens in May, 1962. A few weeks later he put the matter before the public in a speech at Ann Arbor, Mich. McNamara's ideas were received skeptically by many in the U.S. and Western Europe, largely because the plan called for increased reliance on non-nuclear weapons. Such reliance not only would be expensive but also could bring about the "decoupling" of the traditional U.S. retaliatory nuclear deterrent and the requirements of possibly having to fight a non-nuclear war against an attacker; in other words, it could sever the defense of Europe from the security of the U.S.

For a time the Kennedy-McNamara

initiatives met with little success. The multilateral nuclear force was abandoned in 1965, although the British and French continued to develop their own deterrent forces. The U.S. created a coordinative Nuclear Planning Group in the early 1960's, but France withdrew from the Military Committee of NATO in 1966. These and other events led to the adoption by NATO in 1967 of the U.S.-sponsored "flexible response" strategy and thereby to the acceptance, at least in formal terms, of the essence of McNamara's proposed strategic doctrine. Nevertheless, NATO's basic defense policy remained fundamentally unchanged from that of the early 1960's: the shift in strategy was not complemented by a material change in weaponry or by any new developments in operational planning.

In fact, NATO began to plan for more varied war contingencies only in 1973 and 1974, when Secretary of Defense James R. Schlesinger tried to introduce the option of fighting a limited nuclear war into U.S. strategic-weapons-targeting policy. Schlesinger's strategy for flexible nuclear-weapons employment gave NATO a number of options other than a massive nuclear reprisal in the event of a Russian attack. The logic behind the new policy was that such a strategy filled a gap that had always existed in what might be imagined to be a spectrum of NATO planning contingencies between a strictly non-nuclear defense and a more or less general nuclear war. With this new U.S. strategy, proponents of the plan argued, the U.S.S.R. could no longer rely on the assumption that the U.S. might be "self-deterred"



HYPOTHETICAL ATTACK by U.S. intermediate-range nuclear weapons on an airfield in Eastern Europe is depicted in this idealized scene. Both the Pershing II and the GLCM are distinguished not only by their extended range but also by their greatly improved accuracy compared with current NATO systems. The reentry vehicle of the Pershing II, which carries the nuclear warhead, is terminally guided by a radar-based area-correlation technique that compares the live radar return from the target area with a stored radar image of the area. Continual automatic comparisons of the two images generate control signals to maneuver the reentry vehicle, bringing it in with pinpoint accuracy on the assigned target. (The accuracy of the terminal-guidance system is independent of the range.) The reentry vehicle is too small and travels too fast for it to be shot down by current air defenses. The GLCM is equipped with an advanced terrain-contour-matching guidance system (called TERCOM), which is capable of directing the missile over a circuitous flight path to the target. The TERCOM system employs a radar altimeter to measure the altitude of the terrain along preselected segments of the route. The information from the altimeter is compared with stored data to signal appropriate changes in course and altitude. Here the GLCM is approaching the target area from the rear in order to avoid local air defenses. GLCM is designed to fly low, in effect hiding in the terrain.

from escalating a conventional conflict into a nuclear one in order to spare U.S. cities from Russian retaliation. Now there would be steps in between the extremes of holocaust and surrender.

The theory behind the Schlesinger plan did not differ fundamentally from that of the plan put forward by McNamara in the early 1960's. The European NATO leaders tended to accept the new Schlesinger doctrine more readily, however, because (among other reasons) he deliberately set out to neutralize the source of their concerns. For example, in 1974 Schlesinger explicitly stated that all U.S. central strategic forces would from that point on have some intermediate-range nuclear capability. He also took pains to brief the West German leadership on U.S. strategic capabilities and plans, and Europeans attached to U.S. planning organizations were able to verify that overall U.S. nuclear preparations were essentially consistent with the support of NATO objectives. Moreover, when the U.S. equipped many of its missiles with multiple independently targetable warheads (MIRV's) in the early 1970's, it resulted in a much larger arsenal of warheads and facilitated much wider targeting not only in intercontinental strategic planning but also in European-theater planning. At the same time Schlesinger ordered vigorous U.S. initiatives aimed at improving NATO's non-nuclear forces. The European members of NATO were impressed with Schlesinger's evident interest in problems of great concern to them.

The main theme of this historical review can be summarized as follows. The U.S. first deployed intermediate-range nuclear systems in Europe chiefly because it expected to encounter difficulties in developing longer-range systems. As the American deterrent was withdrawn to its homeland, and as the Russian nuclear forces were enlarged and improved, the European members of NATO became concerned about the linkage of the massive American retaliatory nuclear force and the non-nuclear defense of Europe. From the start U.S. policy planners have recognized that the confidence of the NATO allies in the connection between the two could be sustained by any of several means. Nevertheless, a recurring lesson has been that European concern with the linkage of NATO defense and the U.S. nuclear umbrella may be related more to Western European perceptions of the resolve and ability of the American leadership than to the available military power.

The stage was now set for the most recent act in the drama. In October, 1977, Chancellor Schmidt of West Germany gave an address at the International Institute for Strategic Studies in London, where he contended the principle of parity required that NATO match the capabilities of the Warsaw Pact forces at every level. Given the threat presented by a new and potent generation of Russian intermediate-range nuclear forces, Schmidt argued, what has come to be known as a "Euro-strategic" balance should be established and maintained. New NATO forces would clearly be necessary if the threat presented by upgraded Russian intermediate-range nuclear weapons was to be neutralized.

Why did Schmidt make those remarks at the time and in the way he did? As the preceding historical review suggests, the American nuclear guarantee to Europe has been only as good as the confidence Western European leaders have had in the American leadership. The revival of the linkage problem can to some degree be attributed to European concern with the Carter Administration's foreign policy. At that time the allies were worried about the U.S. handling of Russian and Cuban activities in Africa, about President Carter's abortive invitation of the U.S.S.R. into the Middle East peace talks in the fall of 1977 and about his seeming inability to organize progress on U.S. economic and energy problems.

On the military side the West German leadership was particularly disturbed by disclosures that an early Carter Administration analysis of NATO strategy recommended trading off much of West Germany for a securer defense perimeter closer to the Rhine. President Carter's disagreements with the West German government on the subject of West German sales of nuclear technology abroad and his handling of the "neutron bomb" issue also did not enhance his popularity in Europe, particularly in West Germany. Schmidt and others were worried about rumors current before the signing of the SALT II agreement in 1979 that President Carter was prepared to bargain away the cruise missile, abandoning a weapon system that Schmidt and others believed could revolutionize the defense of NATO against a Russian attack.

The NATO plan for the deployment of intermediate-range nuclear missiles has thus come to be discussed largely in political and psychological terms. Furthermore, the arms-control aspect of the plan has at times seemed more important than the deployment itself. For example, more has been said about the complexities of multilateral negotiations than about the intended military role of the missiles. As a series of political episodes has unfolded, the military and strategic aspects of the missile plan have been overlooked, both in official circles and in the public forum.

In my own view the military rationale for the new systems remains to be proved. To begin with, the relative value of the deployments must be evaluated in the larger context of the U.S. defense program. Such an analysis should be conditioned by the other pressures on the U.S. budget. Although the deployment of the Pershing II missile and the GLCM was originally estimated to cost roughly $5 billion, some program costs have already escalated by an order of magnitude. Every dollar invested in these forces is one that cannot be spent on other U.S. programs, including improvements in strategic forces. Is the military case for the new intermediate-range weapons so strong that their deployment should outweigh these other programs?

The planned deployment of the Pershing II and the GLCM could be supported by the demonstrated value of the two weapons in one of two military roles. First, the weapons might add some new military potential to the NATO arsenal by providing a new technological capability. Second, they might be justified by the special military conditions and prerequisites of deterrence.

What new role could the two U.S missiles play that could not be satisfied by existing or improved U.S. strategic systems? The new missiles are remarkable weapons, but neither provides substantively new capabilities or options. The GLCM would function exactly as air-launched and sea-launched land-attack cruise missiles do and would differ only in the details of its storage and basing. Similarly, the Pershing II could not carry out any tactical mission that cannot be done by weapons now in the U.S. arsenal. The only possible advantage to be gained by having Pershing II missiles in Europe is a strategic one: the weapon could arrive so quickly and so accurately on targets in the U.S.S.R. that it could be a valuable adjunct to central strategic forces in some kinds of strategic nuclear war. The U.S. does not seem to have designed the Pershing II missile or scaled the overall program with this aim in mind, however, and the same military advantage could probably be gained in other ways.

Whether or not the technical characteristics of the new intermediate-range missiles are novel, one question that should be asked in any evaluation of the proposed deployment is what new targeting possibilities would be opened up to the NATO commanders. Again, even though NATO's military planners may perceive a warhead shortage, the size of the strategic nuclear stockpile is such that U.S. strategic forces, particularly the invulnerable sea-based missiles, can reach any targets of interest in Europe, except for a limited number of hard targets that might call for warheads delivered by bomber or ALCM.

One assertion made in support of the

planned deployment is that the new NATO nuclear missiles might be needed as a counterforce to the Russian missiles deployed opposite them. In this respect the intended role of the new forces would be identical with that of the U.S. Jupiter, Thor and other systems deployed two decades ago. Unlike those 1960-era missiles, the new missiles are meant to avoid being attacked while they are still on the ground by means of their mobility; they would escape destruction by being constantly moved about the countryside. Even if the weapons could survive as well as their proponents say, however, they still might not be able to attack some of their designated targets effectively because their Russian counterparts are also mobile and have a longer range as well.

On both sides, the concentration of nuclear weapons and delivery systems at heavily guarded installations might negate the advantage of mobility before war starts. Given the political constraints, the new intermediate-range nuclear force would presumably be deployed only in the gravest emergency; indeed, weapons might be retained at storage facilities to avoid the provocative escalation of a crisis. By the time NATO's missiles had been deployed, however, many of their intended targets—mobile missile launchers and aircraft capable of operating from numerous airfields in the western U.S.S.R.—could have similarly "disappeared."

So far no reliable means of locating mobile targets in the U.S.S.R. has been found that is capable of withstanding all the technical and organizational rigors of combat. Perhaps targets could occasionally be found by both sides, but unless the responsibility for making decisions to use nuclear weapons against targets appearing spontaneously was delegated to field commanders, any knowledge of the whereabouts of those targets might be perishable. Moreover, the U.S. is committed to conferring with its allies before releasing nuclear weapons, an obligation that would add delay. Except in extreme cases such as one side or the other's failing to disperse its forces or the U.S. or the U.S.S.R.'s choosing to escalate quickly to a nuclear exchange, the ability of both sides to conduct coherent and integrated operations with mobile nuclear systems would presumably diminish with time. Furthermore, before such operations could be set in motion some missiles might be destroyed by non-nuclear attack or might lose their effectiveness through a lack of field support.

Some additional operational points have been raised in favor of the new deployments over the retargeting of some strategic forces for these missions. It has been argued that basing the missiles in Europe is necessary for purposes of command and control. On the contrary, if war were to break out in Europe, the command-and-control arrangements for the new nuclear forces would be less reliable than those for U.S. strategic systems, since the latter are connected and controlled by communications systems that would not be disrupted by a land conflict. Some U.S. strategic weapons can in principle be quickly re-aimed, and by virtue of their more advanced design and their location in the U.S., the central strategic systems could have much better intelligence and reconnaissance support during a war than European-based intermediate-range systems would.

It has also been argued that the new missiles are necessary because U.S. strategic systems committed to NATO could, without the European allies' knowledge, be retargeted in a way that would betray their interests. Such an argument surely ignores the realities of nuclear targeting: since the McNamara years the allied military services have maintained formal liaison with U.S. tar-

NEW RUSSIAN BOMBER, the medium-range, swept-wing Tu-26 (also known in the West as the Backfire), is seen in a photograph supplied by the Swedish Air Force. The probe projecting from the nose is for in-flight refueling, which some Western analysts believe gives the bomber a strategic, or intercontinental, capability. Without refueling the aircraft could not attack the U.S. from the U.S.S.R. and return to a base in the U.S.S.R.; it could reach the U.S. and go on to land in, say, Cuba, but only if it flew subsonically. The Tu-26 was not included in the SALT II limits on strategic weapons. Photograph was made earlier this year by a Swedish Air Force surveillance plane.

geting officials and are fully aware of U.S. nuclear-war plans, at least insofar as they apply to contingencies that have to do with European security.

In short, it is hard to think of any sound military reason for pursuing the new deployments that would justify the high cost of the two programs. Funds invested in improved strategic forces would benefit both the strategic and the intermediate-range nuclear missions as opposed to only the one. The new intermediate-range forces would seem to be justified only if some theoretical distinction could be drawn between strategic systems and intermediate-range systems in terms of their deterrent value. In recent debate that distinction has been provided by the new strategic concept of "sanctuary war."

Many people in the NATO nations, including some strategic analysts, have recently become concerned with the strategic implications of NATO's failure to explicitly counter the expansion of Russian military forces. These concerns have led to the popularization of the concept of sanctuary nuclear war. For example, some military analysts have warned of the serious asymmetry created by the failure to counter Russian intermediate-range forces with similar NATO weapons. If the U.S.S.R. were to launch nuclear strikes at neighboring countries from bases within its own borders, NATO could not respond without relying on U.S. strategic weapons, which, it is said, the U.S. would be less likely to use (and, more important, which the Russians might believe the U.S. would be less likely to use) given the circumstance of strategic parity. Hence the U.S.S.R. would be a sanctuary from which nuclear attacks could be launched against Western Europe.

What is now required of NATO, according to this line of reasoning, is to bridge the widening gap in the escalation spectrum by means of the Pershing II and GLCM missiles. The rationale for this requirement rests on several assumptions, none of which is immediately apparent.

First, how sound is the notion of a sanctuary in a European-theater nuclear war? Does the current lack of the Pershing II and GLCM missiles signal a material asymmetry between the combat capabilities of the NATO forces and the Warsaw Pact forces? There are many reasons to believe the "escalation gap" is not, at least with respect to the European military balance, a meaningful concept. There can be no doubt that there is a distinction between an attack by, say, U.S. Minuteman ICBM's and an attack by a shorter-range system. The notion of an escalation gap assumes that NATO does not now have, and could not improvise, a counterstrike with existing forces.

Actually several options are open to NATO between the extremes of long-range and intermediate-range systems. The U.S. currently operates about 60 FB-111A aircraft and some 300 tactical fighter-bomber variants of that airplane (two wings of which are now based in Britain). Moreover, the U.S. has earmarked about 75 B-52D's for potential service in the European theater. The U.S. could also call on its large force of Poseidon submarine-launched missiles to attack targets that aircraft could not strike. The U.S. now allots several hundred Poseidon warheads to NATO contingencies, and this commitment could be increased. In short, there is no reason to believe the U.S. military would find itself without a range of optional responses even if systems such as Minuteman were not to be used.

A related problem with this line of reasoning is the existence of the independent British and French deterrent forces. A sanctuary would exist in the U.S.S.R. only if the Russians could persuade the British and the French that their territory too could be a sanctuary. Otherwise a Russian attack on British or French forces might lead to independent retaliation and perhaps escalate the conflict in the process. The U.S.S.R. would almost certainly not be able to convince Britain and France that they were sanctuaries, particularly if non-nuclear fighting preceded nuclear war. Both Britain and France maintain personnel in West Germany and Berlin, and both would be involved immediately if war broke out. Moreover, the U.S.S.R. could have little assurance that Britain and France would accept its pledge that they would remain sanctuaries. (Indeed, many of the targets the U.S.S.R. presumably would strike with SS-20's or Backfires are air bases and other installations in Britain.)

The consideration of self-deterrence, which underlies the sanctuary-war concept, could be imputed to British and French decision makers by Russian theorists once war with the Warsaw Pact had broken out. Thus by holding back a substantial force capable of annihilating each country the U.S.S.R. might be able to deter independent retaliation by Britain or France. This possibility represents no major change from the conditions that have informed British and French planning, and if their forces have any deterrent power today, modern Russian intermediate-range forces do not materially change that fact. Moreover, the very existence of the British and French forces must complicate all Russian nuclear-war planning, and potential incentives for both Britain and France to launch nuclear weapons if a Russian occupation of Western Europe seemed imminent remain compelling.

The most important assumption required by the sanctuary-war concept is the least convincing. The concept demands that the Russians be particularly sensitive to the location of the sites from which nuclear warheads landing on their territory were launched. If the Russians did not care where the warheads came from, there would be no need for specialized medium-range nuclear forces: the U.S. could simply draw from its strategic arsenal and avoid the costs, the political liabilities and the other drawbacks of forward-based systems. The crucial question is whether the Russians care where an attack originates.

In U.S. strategic theory tactical nuclear warfare and strategic nuclear warfare are separated by fine distinctions. Although Russian military doctrine has its ambiguities, it has always considered such distinctions artificial. To a large extent the difference between American and Russian thinking on the subject is conditioned by the different geographies and historical traditions of the two nations. From the American point of view it is easy to discriminate between Russian weapons arriving in Europe, Japan or China and weapons arriving in, say, North Dakota. To the Russians there is less difference between a U.S. weapon exploding at a SS-20 base in the U.S.S.R. and one exploding at an ICBM base that might be only a few kilometers away. Attacks on other gray-area forces, such as Russian long-range bombers or missile submarines, are subject to even greater ambiguity.

Finally, there are those people who, even while agreeing with the points above, would argue that the new weapons are necessary for political and psychological reasons. Indeed, that is why the issue became the widespread controversy it is today. Should the political pressures for such a deployment overrule the military case against them?

At stake in this latter context are two issues. The first is the issue of U.S. leadership in the NATO alliance. At one point, before the NATO meeting of last December, the deployment of new intermediate-range nuclear missiles was seen as an opportunity for the U.S. to restore the confidence of its allies in American foreign policy and to provide the focus for a unified NATO stand in the face of Russian actions. With the approval of the modernization plan by the NATO governments this issue has been settled.

The second issue is whether the deployment is a prerequisite for meaningful limitation of those nuclear forces that have not so far been considered in the SALT talks. It is the official position of the U.S. that negotiations to limit long-range theater nuclear forces should proceed from, at the very least, a position of equality, even if the basis for

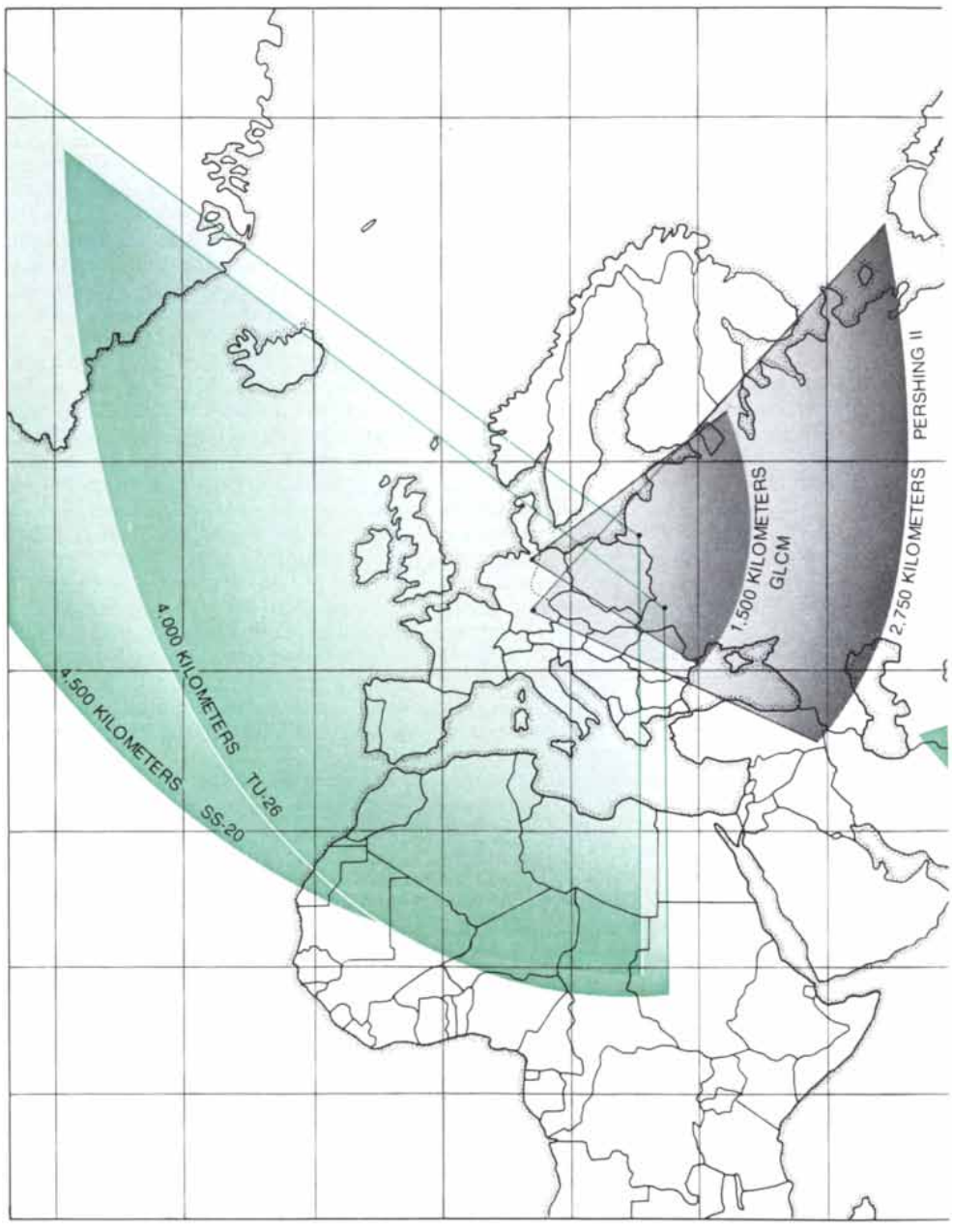
that equality is defined only in principle and not by equivalence in numbers and capabilities of launchers and warheads. The reasoning behind this position is that the U.S.S.R. will have no incentive for arms control if NATO has no leverage for compelling Russian participation in a treaty to regulate these systems. If NATO pursuit of the Pershing II and the GLCM is the only way to invite meaningful Russian participation in talks, then this fact alone may overrule the military and economic case against the new missiles. Here one must briefly speculate on the course of the deployment and on the likelihood that a reasonable arms-control forum can be established. In this regard three facts should be noted.

First, the Russians may finish their deployment of the SS-20 and the Backfire bomber before NATO's counterdeployment even begins. Moreover, the Russian deployment would inevitably represent, in terms of numbers of warheads on launchers, a force at least twice as large as the proposed NATO deployment, even if all the aging and redundant Russian systems are withdrawn as new forces go in. An interesting characteristic of the impending talks on the limitation of intermediate-range weapons, then, is that the U.S. and its partners will be trying to counter existing Russian systems with future NATO ones.

Second, the Russian leadership, if one may judge by precedent, will ultimately attempt to link its specialized long-range bombers and missiles to those NATO aircraft, based on land and on aircraft carriers, that are "dual-capable" (that is, can carry either non-nuclear or nuclear weapons). Again judging by precedent, however, the U.S.S.R. will not allow its own dual-capable aircraft to be included in the reckoning of theater nuclear-arms-control ceilings. Given that virtually all front-line ground-attack aircraft now being deployed by the U.S. with NATO forces can carry nuclear bombs, restrictions on dual-capable aircraft would impose severe constraints on NATO's non-nuclear defenses. For this reason, unless the U.S.S.R. is willing to accept the negotiating principle of "reciprocity," there can be little hope for gray-area arms control. Reciprocity means simply that forces must be counted against like forces and not against other capabilities.

Third, given that both sides could deploy intermediate-range nuclear missiles elsewhere and then quickly airlift them into Europe and that not only the military allies of the U.S. and the U.S.S.R. but also other nations, such as France and China, have aircraft and missiles analogous to those under debate, there may be a need to integrate all pertinent forces into talks if a treaty is to have any practical effect. It makes little sense to limit the numbers of American and Russian missiles in the European area when the Russians can easily augment their capability with fresh equipment flown in from the central or eastern U.S.S.R. Similarly, whether or not the U.S.S.R. suspects that China, say, is in league with NATO, the Russian leadership will consider the threat arrayed against the U.S.S.R. as a whole, and it may insist that all pertinent forces that conceivably could threaten the U.S.S.R. be counted against Russian capabilities. This, of course, would be unacceptable to NATO.

Other serious difficulties with the course of intermediate-range nuclear-arms control could be added to the list, but these few instances will suggest that the negotiations will be problematic indeed. Presumably the talks will stretch out toward the time the U.S. deployment is scheduled to begin. Even so, there seem to be major opportunities in the negotiations. The U.S.S.R. is obviously concerned about the proposed U.S. systems. It may be that the Russians' fear of the Pershing II and the GLCM will motivate an early agreement. The beginning of negotiations on

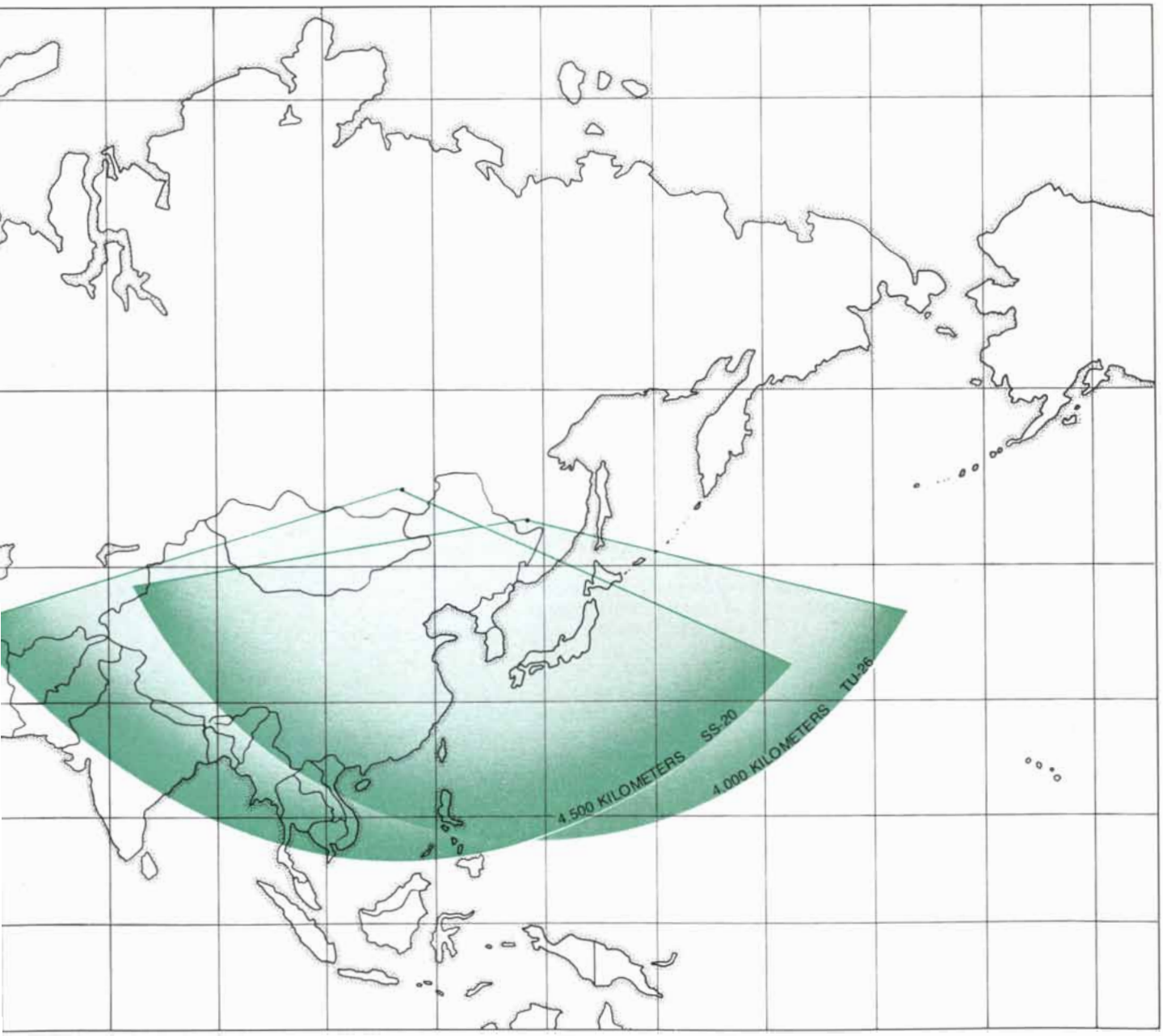


APPROXIMATE RANGES of two American and two Russian intermediate-range nuclear-weapons systems are indicated by the fan-shaped areas on this map. The SS-20 missile and the Tu-26 bomber could probably reach targets throughout the European and Far Eastern military theaters of operation from the hypothetical launching points shown (*colored areas*). Sim-

the issue undoubtedly brings the questions raised by intermediate-range nuclear weapons, which have been skirted so far in the SALT sessions, to world attention. A corollary development might be progress in the continuing talks on conventional-force reduction in the rival European blocs.

However this may be, strategic planners must deal with military and financial difficulties in addition to political ones. If the political rationale for the new intermediate-range NATO forces is not very strong, the forces should certainly be abandoned. A decision to commit vital resources to new weapons of less than obvious military value should be entertained only if there is no political alternative.

The final decision to deploy the new weapons must therefore rest on NATO's joint determination that the plan is so necessary for policy reasons that other, and possibly more important, military programs should be undercut. Probably the only development that would make the new forces sufficiently attractive would be the possibility of promoting wide-ranging arms-control agreements on intermediate-range nuclear forces and even conventional forces in Europe. It would surely be more in the interests of stability and deterrence, however, to direct attention toward the political and strategic causes of concern with the present arms-control stalemate between the U.S. and the U.S.S.R., and not to devote so much effort to a program that addresses only the symptoms of that concern. If the will and ability to explore such a negotiated resolution of the gray-area arms race does not exist, the new programs should be terminated at once.



ilarly, the Pershing II and the GLCM, although their ranges are shorter than the ranges of the two Russian systems, could reach targets in the U.S.S.R. from the hypothetical forward-based launching points shown (*gray areas*). Many of the U.S. GLCM's will be based farther to the rear, however, and no Pershing II or GLCM deployments are planned for the Far East. The maximum ranges of the four systems are estimated here for comparative purposes only. Circular arcs indicating maximum ranges are distorted in this Mercator projection.

Galileo's Sighting of Neptune

He first observed it in 1612 and thought it was a fixed star, some 234 years before it was discovered to be a planet. His data cast doubt on the accuracy of modern orbital calculations for Neptune

by Stillman Drake and Charles T. Kowal

Galileo Galilei first trained his telescope on the heavens in 1609. He saw the mountains and valleys of the moon, and over the next year he discovered the satellites of Jupiter, the curious shape of Saturn and the phases of Venus. Now we have found in one of his journals the record of another observation that may turn out to be of use to modern astronomers: the first sighting of Neptune. Although he did not identify it as a planet, he first saw it in December, 1612, some 234 years before it was recognized as the eighth planet by Johann Gottfried Galle, a young astronomer in Berlin.

Our examination of Galileo's journal turned up another unexpected result: about a year before his sighting of Neptune he developed an ingenious measuring instrument for charting celestial objects. It has sometimes been assumed that Galileo could not have employed a micrometer with his telescope and hence could not have made accurate measurements. Our work shows that his observations were remarkably accurate as early as the second year of telescopic astronomy.

The reliability of Galileo's observations makes his sighting of Neptune much more than a historical curiosity. His observations call into question the accuracy of the modern calculated orbit of Neptune. The orbits of the first seven planets are known with great precision; indeed, the accuracy with which planetary positions can be calculated has made celestial mechanics the paradigm of the exact sciences. It may therefore come as a surprise that the orbit of the eighth planet might have to be recalculated because of observations made with primitive instruments more than three and a half centuries ago. One reason for the uncertainties in the orbit is Neptune's long period of revolution of 165 years; since its discovery as a planet in 1846 it has not yet completely circled the sun. Even so, the orbit deduced from observations made since 1846 should be quite accurate, and discrepancies between the theoretical positions of Neptune in 1612 and 1613 and the positions recorded by Galileo stand in need of explanation. One possibility is that an undiscovered planet is perturbing Neptune's motion.

Our discovery of Galileo's sighting of Neptune came about through an attempt to refine the orbital calculations. An early observation is valuable in such an endeavor because any error in the orbit will generally grow larger and hence more conspicuous with the passage of time. One observation of Neptune before Galle's was already known. Joseph Lalande, a French astronomer who catalogued some 50,000 stars, charted its position in 1795, although he assumed that it was a fixed star. The position given by Lalande turns out to be west of the calculated one by seven arc seconds, or one five-hundredth of a degree. The discrepancy may seem small, but telescopic astronomy was already a precise science by the end of the 18th century, and the difference cannot automatically be charged to observational error.

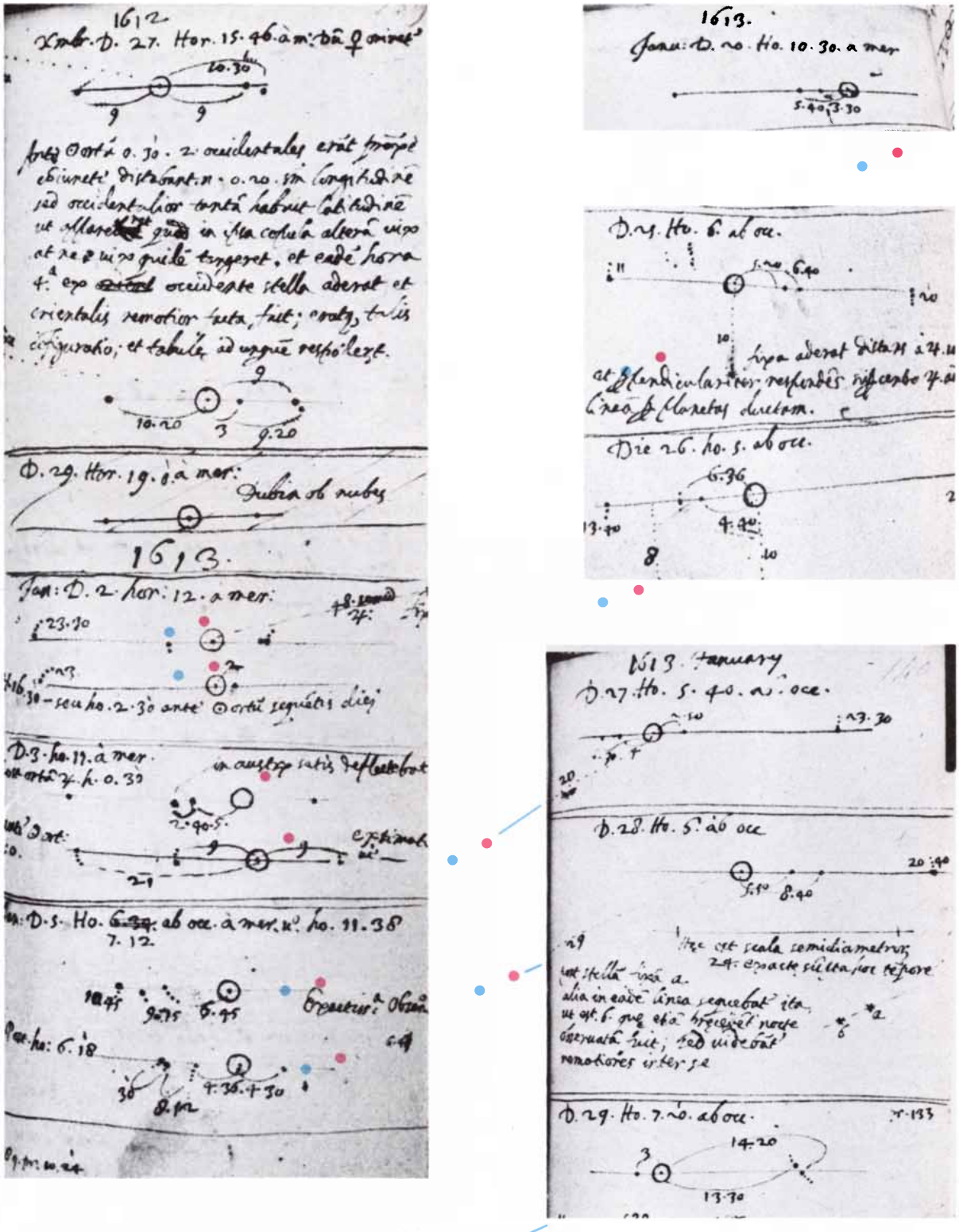
In order to evaluate better the accuracy of Neptune's orbit one of us (Kowal) hoped to find other early sightings of the planet. In 1979 Steven C. Albers published a list of all the occultations of one planet by another as seen from the earth for the years 1557 through 2230. In this period of almost 700 years there are just 21 such events; third on the list was an occultation of Neptune by Jupiter in January, 1613. Galileo had been methodically observing the satellites of Jupiter then, and he might have seen Neptune, which he would have taken to be a faint fixed star, at about the time of the occultation. Indeed he did see it, as our examination of his journal has revealed.

Like Lalande, Galileo marked positions of Neptune that are to the west of where the theoretical orbit would put it. The discrepancy may be as large as one arc minute, or one sixtieth of a degree. We have concluded that most of the difference must be attributed not to primitive instrumentation or to observational error by Galileo but to inaccuracy in the calculated orbit.

It may seem odd that we have such high regard for observations made in the very first years of telescopic astronomy. Why we do should become clear when we discuss the format and content of Galileo's journal, his methods of measurement, the properties of his telescope and the nature of some of his satellite observations and tables, whose accuracy can be determined by comparing them with modern data.

By April, 1611, Galileo had constructed tables of the motions of the four brightest satellites of Jupiter (Io, Europa, Ganymede and Callisto), which are now called the Galilean satellites. In the journal in which the sightings of Neptune are recorded he kept only observations that might help him to refine the tables. The journal, which is preserved in the National Central Library in Florence, is a narrow volume 29 centimeters by 9.5 centimeters. It includes many diagrams of the Jovian system, most of them in the same format. Typically, Jupiter is at the center of the page and a distance representing 24 Jovian radii is on each side. Each margin leaves room for an additional 10 Jovian radii. Regardless of the actual orientation of the plane of the satellites, Galileo drew it as a horizontal line with east to the left. The positions of the four satellites are plotted as dots along the line, and they are usually distinguished one from another by a system of supplementary dots above or below the line. Io, the innermost satellite, has no additional identifying dots, Europa has one, Ganymede two and Callisto three. The elongation of a satellite (its apparent distance from the center of Jupiter) is expressed in units of the Jovian radius. Occasionally Galileo defined the scale of the diagram by citing the distance between two satellites instead of the elongation of the farthest one.

Long before the telescope was invented astronomical calculations were carried out not only in arc minutes but also in small fractions of an arc second. Regardless of the numerical precision of the calculations, however, astronomical observations were rarely more accurate than an arc minute, and sometimes they



GALILEO'S NOTEBOOK ENTRIES for selected nights in December, 1612, and January, 1613, include diagrams of Jupiter and its four largest satellites. In each diagram Jupiter is at the center and a distance representing 24 Jovian radii is on each side. The four satellites (Io, Europa, Ganymede and Callisto) are represented by dots along the horizontal line and are distinguished from one another by supplementary dots above or below the line. Io has no additional dot, Europa has one, Ganymede two and Callisto three. Distances between Jupiter and a satellite and between two satellites are marked in units of Jovian radii. On December 28, 1612, and on January 28, 1613, Galileo observed Neptune, which he thought was a fixed star. His data show that Neptune was perhaps one arc minute west of where its modern theoretical orbit would put it. The authors have calculated from these data where Neptune (*red dots*) would have appeared on the nights Galileo did not chart it. The blue dots give the position according to the currently accepted theoretical orbit. The notebook entries, which were provided by the Central National Library in Florence, are reproduced at 80 percent of the original size.

TWO TELESCOPES thought to have been made by Galileo are preserved at the Institute and Museum for the History of Science in Florence. The instrument at the left has a magnification of 14, a resolving power of 20 arc seconds and a field of view of 17 arc minutes. Instrument at the right has a magnification of 20, a resolving power of 10 arc seconds and a field of view of 17 arc minutes. The actual telescope employed by Galileo in his observations of Neptune (which has not been preserved) had a magnification of 18 and a resolving power of 10 arc seconds; the field of view was probably 17 arc minutes.

were still less accurate. Tycho Brahe, who was perhaps the most accurate observer without a lens system, estimated that the visual diameter of Jupiter and the diameters of bright stars were as great as two or three arc minutes. Galileo realized that Brahe's estimates for stars were in error by as much as 3,000 percent.

How did Galileo make measurements of small angles that are still of use today? His method of employing the telescope as a measuring instrument has remained largely unknown because he did not publish much about it. Moreover, it is usually supposed that accurate astronomical measurements began only with the cross-hair micrometer, which was perfected after Galileo's death. No such micrometer could be employed with the Galilean telescope, which, like the opera glass, generates a virtual image. The cross-hair micrometer requires a real image such as the one provided by the Keplerian, or astronomical, telescope. Nevertheless, Galileo was able to develop a kind of micrometric instrument that worked reasonably well with his telescope.

On the last day of January, 1612, when Galileo had measured the diameter of Jupiter as being about 41 arc seconds, he wrote in his journal that he had begun using "an Instrument for taking the exact intervals and distances—not that the instrument is yet very accurately made." Although he did not describe the instrument, which has not survived, his disciple Giovanni Alfonso Borelli mentioned it in 1666.

According to Borelli, the micrometric instrument was a precisely ruled grid on which Galileo optically superposed the telescopic image. The idea may seem implausible but actually it is quite workable. The reader is invited to try a similar technique. Hold a sheet of graph paper next to the end of a small telescope and look at the paper with one eye while looking through the telescope with the other eye. It is easy to see the magnified image superposed on the paper. It will be apparent at once how, with a little effort, accurate measurements could be obtained by employing this principle.

Neither Galileo nor Borelli explained in detail the construction of the micrometric instrument. Nevertheless, from various comments of Galileo's and from our comparison of many of his measurements with modern calculations, we are fairly sure the instrument was constructed along the following lines. There was a circular grid with a diameter of 10 centimeters and a spacing between rulings of about two millimeters. The grid had a pin through its center by which it was attached to a rod ending in a ring that fitted snugly around the tube of the telescope. When Galileo looked through the telescope with his right eye, he looked with his left eye at the grid and optically superposed Jupiter on the central pin. The grid was then rotated to align a horizontal ruling with the plane of the satellites. Finally, the grid was moved toward or away from the eye until the magnified disk of Jupiter fit exactly between two vertical rulings, with a third ruling vertically bisecting the disk. Since the space between any two adjacent rulings then represented one Jovian radius, it was an easy matter to measure the position of a satellite in units of Jovian radii by counting the number of rulings between it and the pin. The rulings could also provide the coordinates needed to determine the angles made by objects outside the satellite plane.

With the micrometric instrument Galileo could compute the apparent angular radius of Jupiter's disk in units of arc seconds. Suppose on a particular night the distance between his eye and the grid was one meter. On the assumption that the spacing between the grid rulings was two millimeters, the radius of the magnified disk of Jupiter on that night would be two millimeters. From these measurements and a table of sines Galileo could have calculated that an angle of .115 degree was subtended at the eye by the radius of Jupiter. Dividing .115 degree by the magnifying power of the telescope, 18, yields an apparent radius of 23 arc seconds.

In this calculation we have relied on assumptions about the spacing between the grid rulings and the distance between the grid and the eye. Galileo's journal actually provides not these measurements but their ratio. Whatever the measurements were, it is clear that he could draw an accurate scale of apparent visual Jovian radii for any night. The scale would change from night to night, however, as the distance between the earth and Jupiter changed. Galileo could choose some distance from the grid to the eye to serve as a benchmark length. On any night he could find the ratio of the elongation of a satellite in grid units, with the grid at the benchmark length, to the elongation of the satellite in Jovian radii. The ratio would provide a scale for 24 Jovian radii (or any other distance) that could be compared with the scale on other nights or could be employed to find the distance of other objects seen on the same night.

In January, 1612, Galileo found Jupiter's diameter to be about 41.5 arc seconds. Four months later, when the earth and Jupiter were farther apart, he measured it as being 39.25 arc seconds. Modern calculations of the diameter on the two days he cited reveal a similar ratio of visual reduction. This similarity strengthens our confidence in his measurements and in our reconstruction of his procedures.

Although the ratio measured by Galileo is accurate, the Jovian diameters are

not because his lens system gave Jupiter a fuzzy edge. From the journal entries, however, we can deduce the extent of the distortion. Galileo recorded the radius of the orbit of the outermost satellite he could observe as being 24 Jovian radii; the modern value is about 26.4. His telescope made the radius of Jupiter appear to be about 1.1 times (26.4 divided by 24) its actual size. When the correction factor of 1.1 is applied to his satellite positions, they are close to the correct values. The correction factor remains the same regardless of where Jupiter is with respect to the earth, since Jupiter carries its satellites with it.

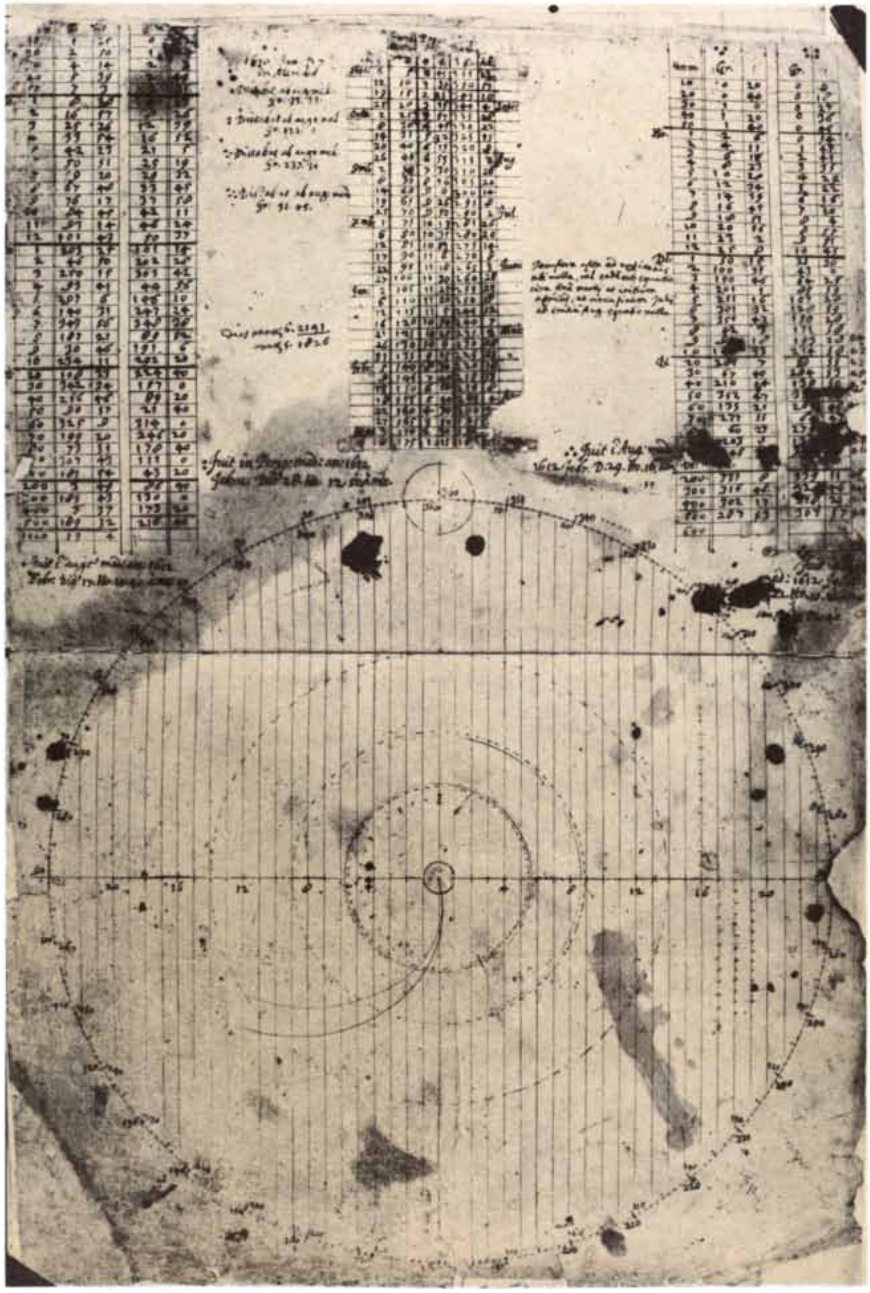
It is fortunate for modern attempts at reconstruction that Galileo chose a physical object such as the variable disk of Jupiter as his unit of measurement. If he had adopted a fixed theoretical unit of measurement such as the average visual diameter of Jupiter's disk and employed it every night in recording the position of each satellite, his measurements would have been much less reliable. A value of 40 arc seconds would have been a good average value for the diameter, but on a particular night the actual diameter could vary from that average by as much as 25 percent.

By relying on the actual visual radius of Jupiter as it varied from night to night, Galileo made it possible for us to determine exactly what he measured and to compare that with the satellite observations he recorded. In this way we have determined the typical margin of observational error in his measurements. By taking into account the correction factor for the true edge of Jupiter, we know the range of observational error in his journal entries. From modern tables we have calculated numerous satellite positions for the dates and times stated by Galileo. We have concluded that his measurements in 1612 and 1613 were often correct to better than 10 arc seconds and rarely wrong by as much as 20 arc seconds.

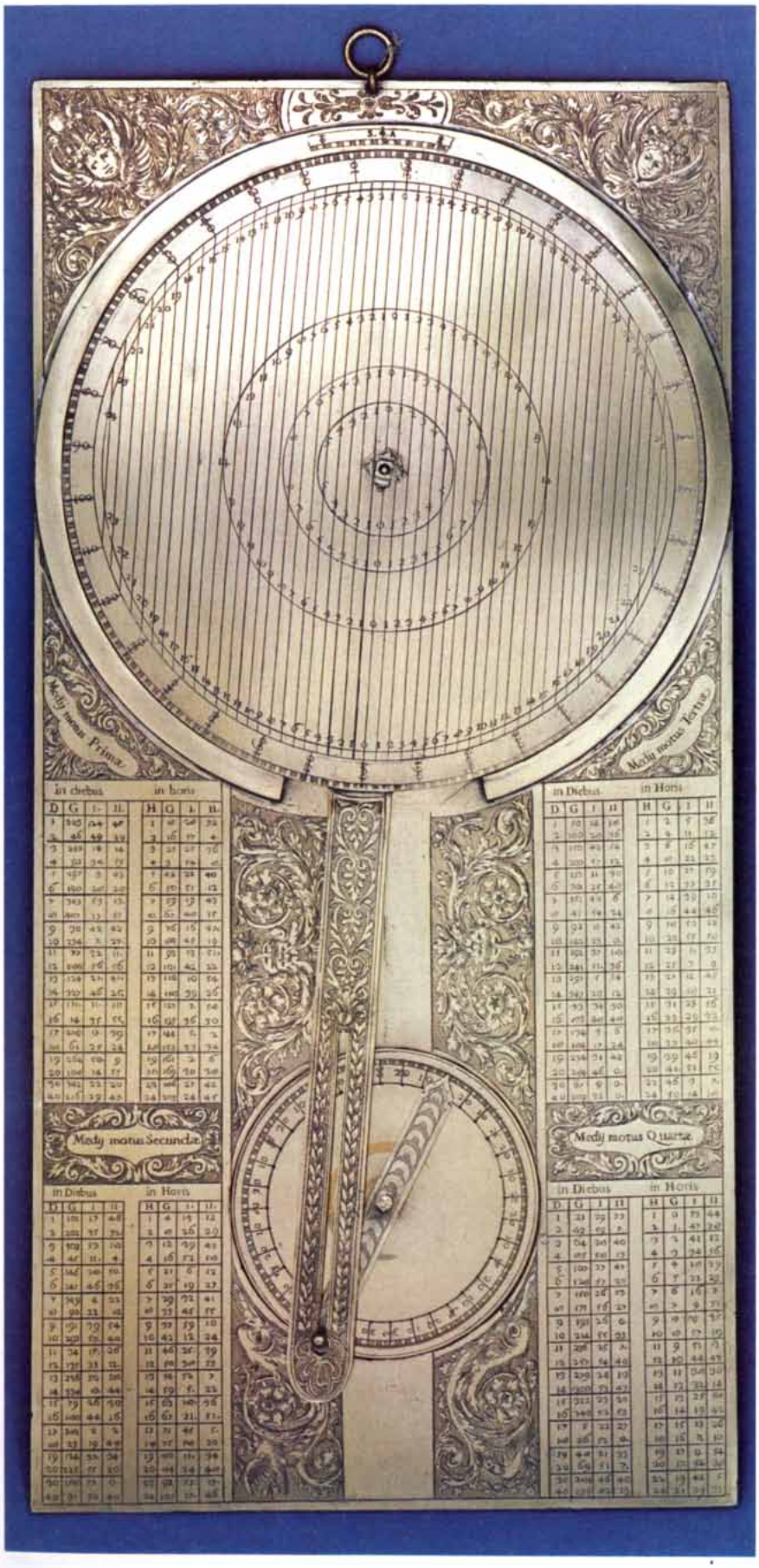
The telescope with which Galileo observed Neptune apparently had a magnification of 18 times and a resolving power of 10 arc seconds; the field of view was probably 17 arc minutes, or a little more than half the diameter of the full moon. The resolving power of 10 arc seconds was inferred from our investigation of his measurements and is confirmed by two telescopes and an objective lens thought to have been Galileo's that are preserved at the Institute and Museum for the History of Science in Florence. That is the maximum resolving power, and it could be attained only when observing bright points in a dark field. For observations near Jupiter the brightness of its disk considerably reduced the resolving power. Galileo could seldom make out a satellite until it was 25 arc seconds, or more than one Jovian radius, from the edge of Jupiter.

The precision of an astronomical observation is limited not only by the accuracy of angular measurements but also by the accuracy with which it is timed. The times Galileo recorded were sometimes approximations, although a comparison of his positions of satellites and calculations made from modern tables shows that the times he cited were often exact and can at least be trusted to within 15 minutes. In most cases a small error in the recorded time would not significantly affect the position of a satellite. The same would be true of a time given for a position of Neptune.

Such were Galileo's methods of mak-



PAPER JOVILABE was devised by Galileo to save himself the trouble of making trigonometric calculations when he predicted positions of satellites from tables of their motions. The Jovilabe is one that Galileo employed in 1612 and 1613. The outer circle, with a radius of nine centimeters, represents the orbit of Callisto. The circle is graduated in degrees and the horizontal diameter is divided into 48 equal parts, each of which represents one Jovian radius. The orbits of the three inner satellites are given by the next three smaller circles. The small circle at the center is Jupiter. With the Jovilabe the tabulated position of a satellite, expressed in degrees of rotation about Jupiter, can be converted into an elongation in units of Jovian radii. In order to make such a calculation a thread was passed through the center of the Jovilabe and knotted behind the paper. The thread was stretched along a line corresponding to the calculated degree of rotation. From the intersection of the thread and the orbit of the satellite a perpendicular was dropped to the horizontal line. The elongation in units of Jovian radii could then be read from the line. The tables above the Jovilabe indicate the positions of the satellites at intervals of 10 minutes, an hour and a day. The entries in the tables are close to the currently accepted values.



BRASS JOVILABE was constructed for Galileo in about 1617. The brass Jovilabe works on the same principle as the paper Jovilabe shown in the photograph on the preceding page.

ing astronomical measurements. At about 3:45 on the morning of December 28, 1612, he made a diagram of the Jovian satellites and added to it a broken line at an angle to the satellite plane. Near the edge of the page he drew a star at the end of the broken line and marked it *fixa* (the Latin designation for a fixed star). The marked object, which was east and south of Jupiter but north of the steeply tilted satellite plane, was not a fixed star but the planet Neptune. It was then virtually stationary with respect to the background of stars because its apparent motion as seen from the earth was changing from direct to retrograde. Later that morning Galileo made another observation of the satellites and again he recorded the same object.

How can we be sure the object Galileo labeled *fixa* was Neptune? First, there is no question that he could have seen the planet if his telescope was trained on it. Neptune has a visual magnitude of 7.8, and Galileo had plotted the positions of stars much fainter than that. Second, there is also no question that Neptune was within his field of view. It was at the same angle to the satellite plane as the fixed star he had drawn. Third and most important, there was no fixed star anywhere along that line from the satellite plane he could have observed through his telescope.

That night was the first time Galileo drew a broken line in his journal entries. Presumably he made the line a broken one in order to indicate that it represented not distance but direction. Neptune was then 41 Jovian radii east of Jupiter, and it would have been off the narrow page if he had plotted it to the same scale as the satellites.

In the hundreds of recorded observations that Galileo made before December 28, 1612, we can find only a few instances where he added a fixed star to a diagram of the Jovian moons. It is clear why he charted these stars and not others. In each case he first noted the star when it was being approached by Jupiter and was about to be overtaken by the planet. By following the motion of Jupiter on the few nights that a star remained in the field of view with Jupiter, Galileo had an independent method of checking his measurements of the visual diameter of Jupiter. The stars served as mileposts that helped him to investigate not only the relative motions of Jupiter and its moons but also the absolute motions. Hence there was precedent as well as reason for including an object such as Neptune in his diagrams of the Jovian moons.

Galileo's next observation, however, included something that was without precedent and that never appeared again in the records of his observations. From December 28 through January 1 the skies were too overcast for relia-

ble sightings. On January 2 the sky had cleared and he made the unprecedented observation at midnight. He recorded a fixed star to the west and north of Jupiter that could scarcely have aided him in his study of Jupiter's motion because the planet had already passed the star. The star was so far from Jupiter that he could hardly put the two of them in the same field. (Indeed, five hours later he was unable to do so.) Consequently he must have made a special effort that resulted in his finding the star.

There is no other record of Galileo's having searched for a fixed star already passed by Jupiter. Why had he done so this time? The question can best be approached by considering where he would have expected to see the fixed star of December 28 (namely Neptune) when he next looked for it five days later. He had originally found Neptune to the east of Jupiter, at a distance twice the maximum elongation of Callisto. Because a fixed star usually required four or five days to move that far with respect to Jupiter, he must have expected Neptune to be quite close to Jupiter on January 2. In fact it was, but for some reason Galileo apparently did not see it. He may have spotted a fixed star far to the west because he was searching the sky for Neptune. The fixed star was brighter than Neptune and was at a similar distance north of the satellite plane. In any event, the fixed star he saw that night (now designated SAO 119234) would come to have an important role in his next recorded sighting of Neptune.

Why Galileo did not record Neptune on January 2 is a matter of much debate between us. Perhaps the cloud cover was such that he could see SAO 119234 but could not make out the fainter Neptune. (From a canceled entry for a night in December, 1612, that includes the phrase "doubtful by clouds," it is evident he attempted satellite observations even in doubtful weather.) Another possibility is that Neptune was too near Jupiter or one of its moons to be distinguished. There is no evidence for this possibility; in fact, both the calculated orbit and Galileo's next sighting of Neptune make it likely the planet could have been seen on January 2. Since the calculated orbit is called into question by Galileo's observation, however, the possibility that Neptune was obscured by one of the bodies in the Jovian system should not be ruled out even though it is an unlikely one.

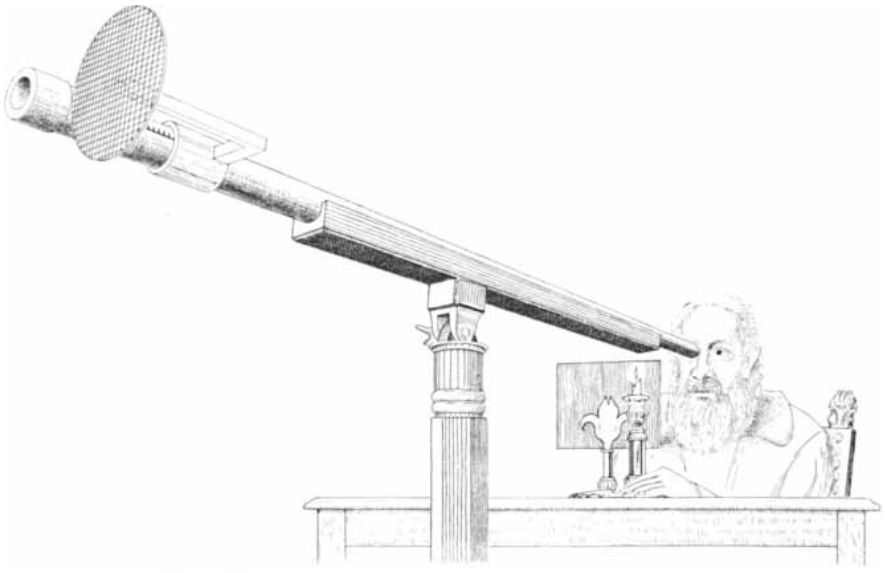
From January 6 through January 19 the weather again seems to have prevented Galileo from making observations. He was unable to see Jupiter's motion change from east to west on January 14. A week later Jupiter, which was moving north as well as west, again overtook Neptune and SAO 119234, which were thereafter south of the satellite plane.

On January 20 Galileo resumed his observations and on January 25 he again recorded the positions of SAO 119234. He first noted seeing it 10 Jovian radii below Jupiter on a line perpendicular to the satellite plane. Because it is easy to judge straight lines and right angles, he often noted perpendicular alignments. The recorded position agrees with where modern calculations would put the star. Galileo could also have put Neptune in the field of view with Jupiter and SAO 119234, but the planet was faint, farther from Jupiter and in no special right-angle or straight-line arrangement.

From January 25 through January 27 Galileo charted the position of SAO 119234 each night. On the 28th he placed it 29 Jovian radii (or 32 Jovian radii after the correction factor is applied) from Jupiter's center. In both distance and direction from Jupiter the recorded position of the star conforms quite closely to calculations based on modern data.

At 11:00 that night Galileo charted the position of Neptune for the last time. He took note of it because it was lying beyond SAO 119234 on a straight line drawn through the star and the center of Jupiter. He had also noticed Neptune the night before but had not recorded its position. On the 28th he commented that the night before Neptune and SAO 119234 had seemed farther apart. Since no overnight change is possible in the relative positions of fixed stars, he must have been puzzled by his recollection. He had good reason to trust his memory. Having charted the relative motions of the Jovian satellites for three years, he had become particularly alert to overnight changes in position. Our calculations show that from January 27 to January 28 Neptune moved 2.5 Jovian radii closer to SAO 119234. On the 27th the separation between the planet and the star was 6.25 Jovian radii, and so the overnight approach of 2.5 Jovian radii amounted to a change in separation of 40 percent.

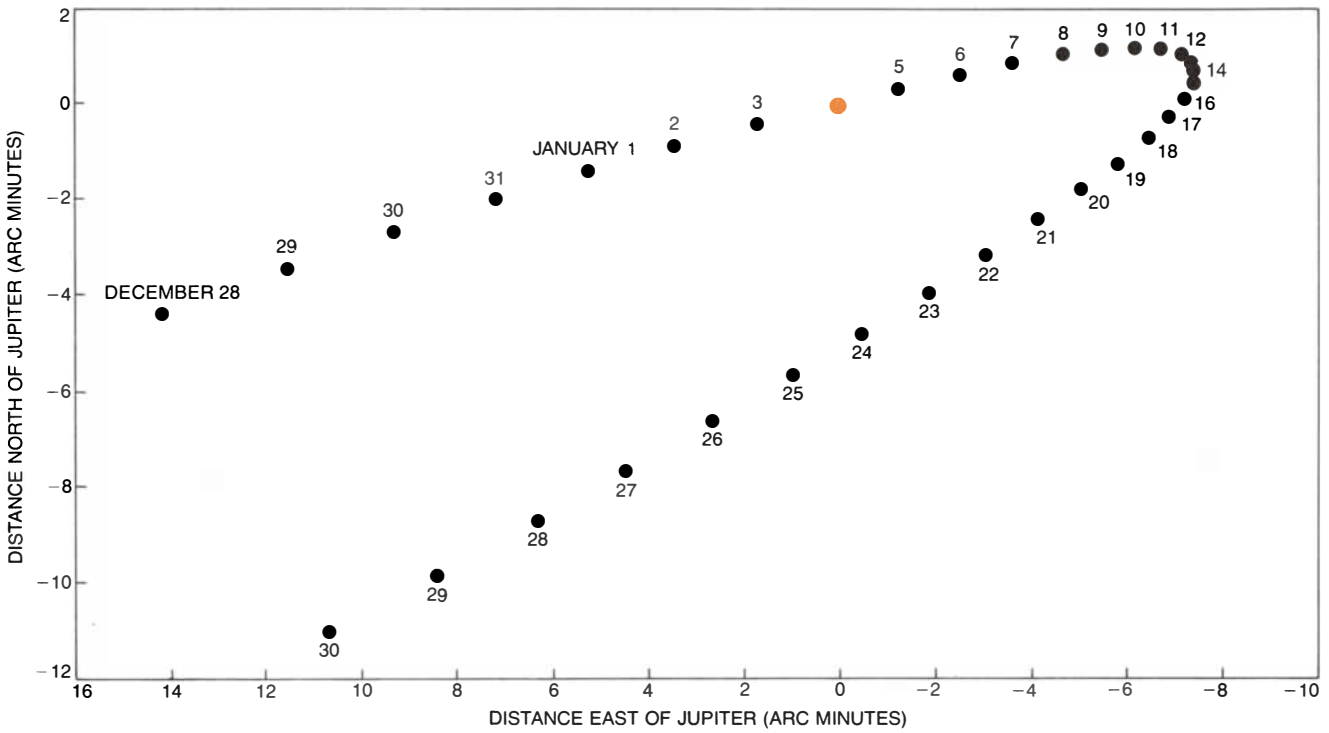
On the 28th Galileo made a detailed drawing of the positions of Jupiter and its satellites. He included SAO 119234 in the diagram, drew a line connecting it to the center of Jupiter and indicated the distance. Then for the first time in the journal he drew an "exact scale" of 24 Jovian radii. The scale of 24 Jovian radii is 47 millimeters wide, which supports our reconstruction of the grid lines as being two millimeters apart. Galileo did



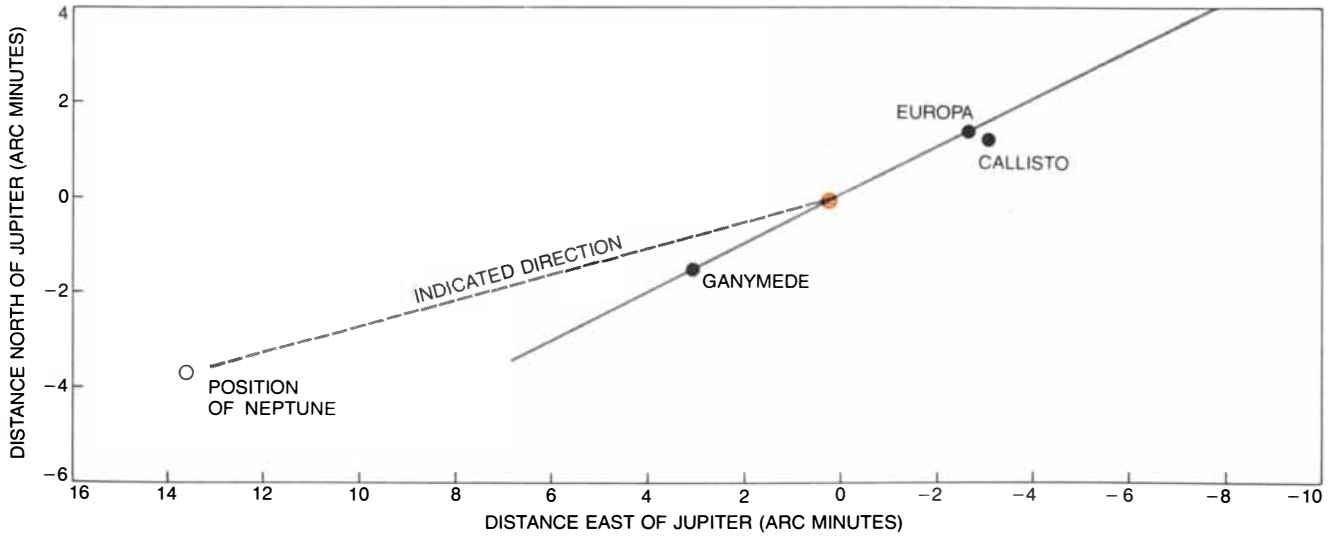
MICROMETRIC INSTRUMENT constructed by Galileo in January, 1612, increased the accuracy of his telescopic observations. The micrometer, which has not survived, was hardly mentioned by Galileo, but it probably worked like the one shown. The micrometer was a circular grid that was mounted next to the end of the telescope. The grid was ruled with equal spaces between the lines. Galileo looked through the telescope with his right eye while he looked at the grid with his left eye and optically superposed Jupiter and its satellites on the grid. Then the grid was rotated to align a horizontal ruling with the plane of the Jovian satellites and was moved either toward the eye or away from it until Jupiter appeared to fit exactly between two vertical rulings, with a third ruling vertically bisecting the planet. Since the space between any two adjacent rulings was thereby made equal to one Jovian radius, the elongation of a satellite in units of Jovian radii could be found by counting the rulings between the satellite and Jupiter. The distance between the grid and the eye was given by a strip on the side of the telescope. The grid was attached to the telescope by a clamp that could be moved along the graduated strip. The space between the markings on the graduated strip was twice the space between the rulings on the circular grid, and so the space was equivalent to the diameter of Jupiter.

not try to put Neptune in the diagram because it would not fit on the page to the same scale. Instead he made a separate (parallel) drawing of SAO 119234 and Neptune to the same scale, in which they are 3.75 radii apart. To this drawing he appended a note that summed up his observation: "Beyond fixed star *a* another followed in the same line, as [does] *b*, which also was observed on the preceding night; but they [then] seemed farther apart."

The trouble Galileo took to make a scale diagram of Neptune and SAO 119234 suggests to one of us (Drake) that he planned to follow up his impression of apparent relative motion with observations on subsequent nights. Yet he did not. The suggestion that he planned to make a follow-up study is cast in doubt by the absence of any record of SAO 119234 on the next night, when modern calculations show that he could still have put Neptune, SAO 119234 and Jupiter in his field of view Of course, the position of Neptune based on modern calculations cannot be trusted completely as long as any uncertainty remains about its exact orbit. Perhaps bad weather interfered again. Galileo saw satellites that night, but they are considerably brighter than Neptune and SAO 119234, which might have been obscured by cloudy skies. In any event, the night of January 28th was his last chance to observe them, because af-



CALCULATED POSITIONS OF NEPTUNE are shown for December 28, 1612, through January 30, 1613. The black dots are Neptune and the colored dot is Jupiter. On January 4 Jupiter occulted Neptune. The next such occultation was not until September, 1702.



FIRST SIGHTING OF NEPTUNE was on December 28, 1612. Galileo drew a broken line to represent the direction of what he thought was a fixed star but which turns out to have been Neptune. He marked not the position but the direction because the planet would have been off the narrow page of his notebook if he had plotted it to the same scale as the satellite positions. From Galileo's data the authors have determined where he must have seen Neptune that night: about four arc minutes north of Jupiter and 13 arc minutes east of it.

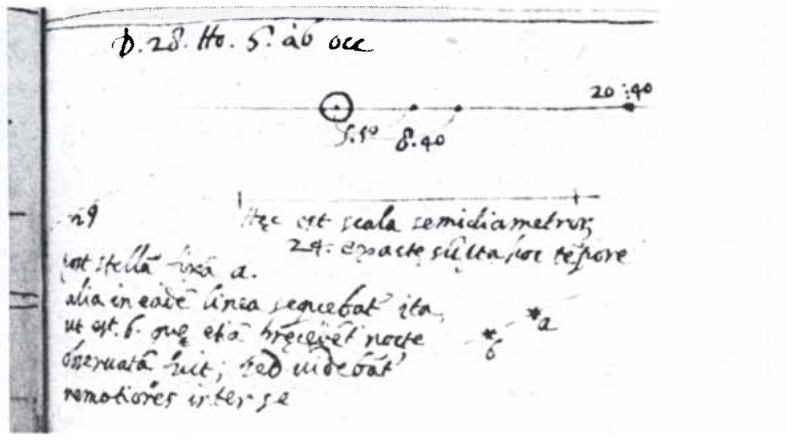
ter that he could no longer have put the three objects in the same narrow field of view. Without a graduated mounting for his telescope, and without Jupiter to serve as a guidepost, he would hardly have been able to find a planet and a fixed star that are not visible to the unaided eye, let alone determine their motions.

If it were not for Galileo's pioneering method of turning his telescope into a measuring instrument, his sighting of Neptune would have no bearing on modern astronomy. By recording distances in Jovian radii and by making precise diagrams, he has provided a reliable 17th-century position of Neptune.

In Galileo's diagram the distance between Neptune and SAO 119234 is a little more than one arc minute. The currently accepted orbit of Neptune puts it about two arc minutes from the star. The possible discrepancy of almost one arc minute between Galileo's reported position and the theoretical one is a large difference by the standards of celestial mechanics. After every reasonable adjustment and allowance for observational error, the discrepancy is still large enough to cast doubt on the accuracy of the accepted orbit. It suggests that some unidentified mass may be perturbing the motion of Neptune. One possibility is the presence of an undiscovered planet. The new planet would have to be beyond Neptune because otherwise it would significantly affect the orbits of the inner planets.

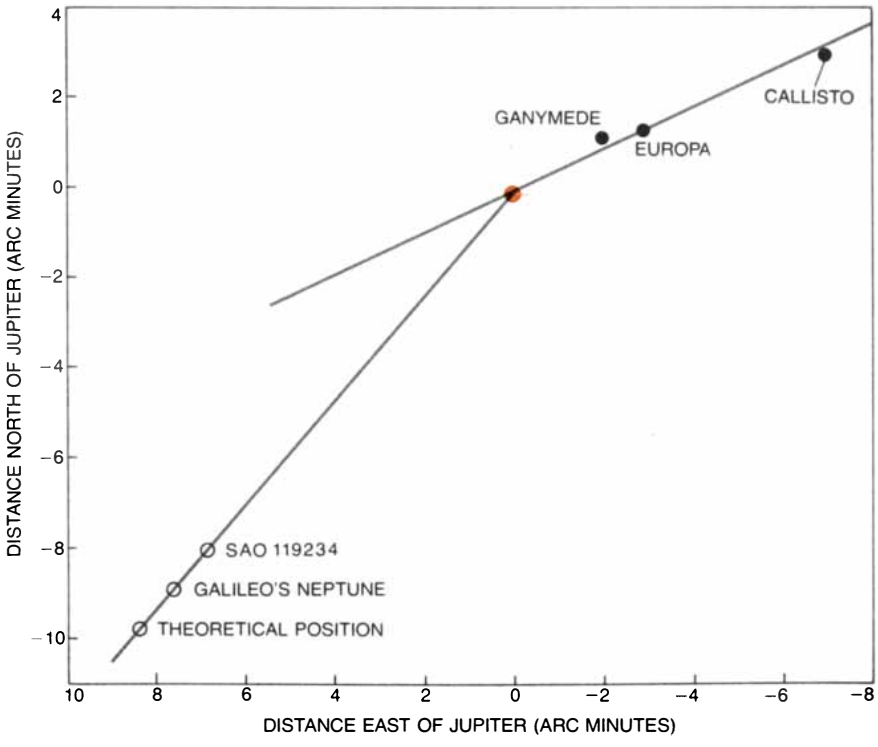
Curiously, the 19th-century detection of Neptune was itself inspired by an orbital irregularity. Uranus, discovered in 1781, had exhibited over the next half century departures from its predicted orbit that could not be accounted for by the gravitational forces of the known planets. It was suggested that an undiscovered planet might be attracting Uranus and hence perturbing its orbit. The planet would have to be beyond Uranus, so that it would scarcely affect the orbits of the first six planets. The possibility of a new planet was investigated by John Couch Adams in England and by Urbain Jean Joseph Leverrier in France. They made similar starting assumptions and their investigations led them to almost the same conclusion about the probable mass of the unknown planet, its distance from the sun and the region of the sky in which astronomers should first search for it.

Adams sent his work to George B. Airy, the Astronomer Royal of England, who put it aside and took no action. Meanwhile Leverrier got cooperation from the Berlin Observatory, where a new series of star maps had just been completed. Galle, who worked there, searched for any unmapped object in the region of the sky suggested by Leverrier. The first night Galle looked he detected such an object and the following night he found that it had moved a little. The object was of course Neptune.



NOTEBOOK ENTRY FOR JANUARY 28, 1613, shown actual size, indicates that Galileo had detected an overnight change in the relative positions of Neptune and a nearby fixed star (now designated SAO 119234). The note at the bottom left reads: "Beyond fixed star *a* another followed in the same line, as [does] *b*, which also was observed on the preceding night; but they [then] seemed farther apart." Notebook entry was provided by Central National Library.

News of the discovery of Neptune spread quickly and caused an international sensation, much like the one that had followed Galileo's first announcement of the new "planets" seen through his telescope in 1610. In his day all wandering stars were called planets and these new ones were the Jovian satellites. Because the satellites were not expected, their discovery caused much excitement. The detection of Neptune caused a sensation for the opposite reason: because the existence of the planet was expected as a consequence of Newton's laws of motion and gravitation and the most precise measurements, its discovery was a spectacular demonstration of the success of celestial mechanics. The task now is to check Galileo's careful measurements by recalculating the orbit of Neptune.



SECOND SIGHTING OF NEPTUNE (that of January 28, 1613) brings out the discrepancy between Galileo's observation and the modern calculated orbit. There is little reason to doubt the accuracy of his sightings and there are grounds for thinking the orbit may be in error.

The Cosmic Asymmetry between Matter and Antimatter

It seems the universe today is almost entirely the former. Evidence from both cosmology and particle physics (the study of the universe on the largest scale and the smallest) now suggests an explanation

by Frank Wilczek

All the fundamental constituents of matter come in matched pairs: for every kind of particle there is an antiparticle that is identical in mass but opposite in other properties, such as electric charge. The symmetrical pairing of particles and antiparticles is required in order to unite the two great theories of 20th-century physics: relativity and quantum mechanics. The symmetry has been well verified by experiment. Since 1932, when the positron, or antielectron, was discovered, the catalogue of antiparticles has grown apace with the catalogue of ordinary particles. Indeed, a particle and its antiparticle have often been discovered simultaneously when the two were created as a pair by a high-energy collision in a particle accelerator. Such collisions always seem to yield matter and antimatter in equal quantities; indeed, it was long assumed that the laws of nature express no preference for matter or antimatter.

And yet in the world outside the laboratory antimatter is almost never encountered. The atoms composing the earth consist of neutrons, protons and electrons, but never their antiparticles. Does this asymmetry prevail throughout the universe? That is, does the entire universe consist predominantly of matter, with very little antimatter? If it does, has the asymmetry always existed, or did the universe begin with equal numbers of particles and antiparticles and somehow develop an imbalance later?

Recent findings in cosmology and particle physics suggest answers to these questions. They suggest that in the first instant after the big bang, when the universe was much hotter and denser than it is now, there were equal amounts of matter and antimatter. Before the universe was 10^{-35} second old, however, violent collisions among particles created conditions that led promptly to an asymmetry between matter and antimatter. The asymmetry has been locked into the universe ever since. The road leading to this conclusion is still unpaved in places, but I shall try to show that the route is the right one.

How can one be sure the universe consists entirely of matter? It is easy to demonstrate that matter and antimatter cannot be mixed homogeneously. Whenever a particle and the corresponding antiparticle come together, they annihilate each other and their mass is converted into energy. Hence a star made up of half matter and half antimatter would immediately disappear in a titanic explosion. The possibility remains, however, that matter and antimatter might coexist in the universe if each was confined to isolated regions separated by empty space.

One line of evidence for the preponderance of matter over antimatter is provided by cosmic rays, the high-energy particles that arrive from space. They seem invariably to be particles of matter such as protons and electrons and atomic nuclei made up of protons and neutrons; antiparticles are not observed. Although the origin of cosmic rays is not yet fully understood, they certainly come from throughout the galaxy, and some of them may have a still more distant origin. It therefore seems established that the Milky Way consists entirely of matter, and it is only a little less certain that the group of galaxies of which the Milky Way is a member is also all matter.

Ascertaining that more distant galaxies are composed of matter is a more difficult problem. Merely looking at a galaxy offers no hint of whether it is made up of matter or antimatter. "Looking at" a galaxy implies the detection of photons, or quanta of electromagnetic radiation. The photons include not only those of visible light but also those of radio waves, X rays, gamma rays and so on. The problem is that the photon is its own antiparticle, and there is no way to distinguish a photon emitted by matter from one emitted by antimatter. As a result the light from an antimatter galaxy would be identical with that from a matter galaxy, even in the detailed structure of the spectrum. For example, the characteristic emission lines of the hydrogen atom would be duplicated exactly in emission lines of the antihydrogen atom.

There is one circumstance in which photon observations might indirectly reveal the presence of antimatter. If an antimatter galaxy were close to a matter galaxy, the boundary region between them would be the site of frequent particle-antiparticle annihilations. The energy of each such annihilation would eventually appear in the form of photons at gamma-ray wavelengths. The border region would therefore be a place where gamma radiation is copiously emitted. Astronomical sources of gamma radiation are known and are under investigation, but no source with the proper characteristics has been found. This argument is of no consequence, however, if empty space separates the matter from the antimatter. At best the failure to observe strong gamma emissions suggests that clusters of galaxies must consist entirely of matter or entirely of antimatter, not a mixture of the two. The clusters are pervaded by intergalactic gas, and any difference in composition within a cluster would give rise to gamma radiation.

In the future the question of whether any substantial aggregations of antimatter exist in the universe may be answered by the advent of telescopes that detect not photons but neutrinos. Unlike the photon, the neutrino has a distinguishable antiparticle. Neutrinos and antineutrinos would be emitted in different proportions by nuclear reactions in matter and antimatter. A star composed of matter radiates mainly neutrinos, whereas a star composed of antimatter would give rise chiefly to antineutrinos. The issue has not been settled yet by

neutrino observations because building a neutrino telescope is a formidable project. Neutrinos have negligible mass and hardly interact at all with other matter; their detection is problematic.

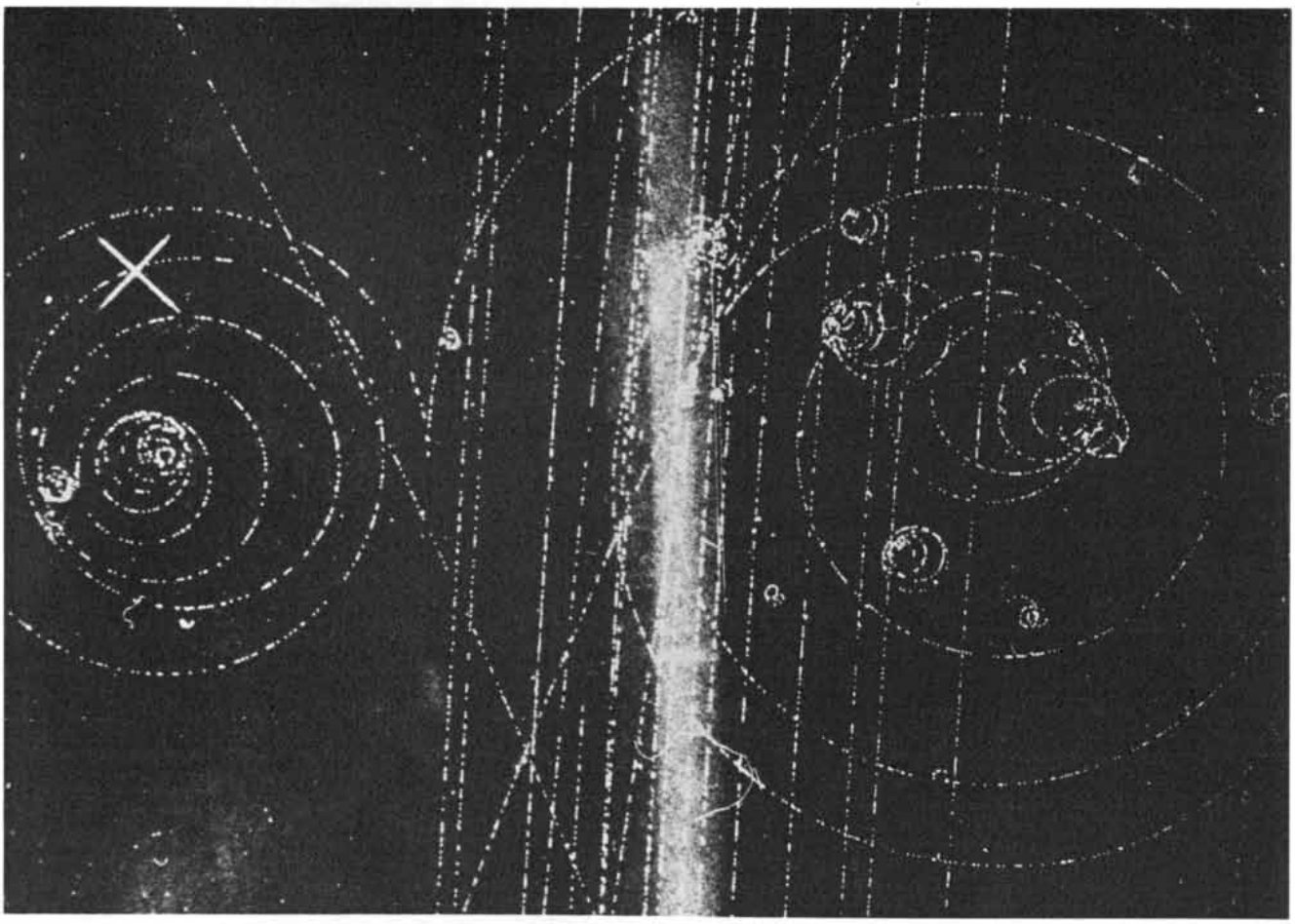
For now at least, the prevailing opinion among astronomers and astrophysicists is that matter dominates over antimatter in the present universe. As I have suggested, the evidence in support of this view is not compelling, although there is a notable lack of evidence for the existence of antimatter. What ultimately seems decisive is the difficulty of imagining how matter and antimatter in the early universe could have become segregated into distinct regions. It seems more likely they would have simply annihilated each other everywhere.

If the universe is now mostly matter, one is moved to ask how this asymmetry came about. One possibility is that the preference for matter was built in at the start, that the primordial material issuing from the big bang was predominantly matter. This hypothesis cannot be disproved, at least for now, but it is rather unsatisfying. Virtually any composition of the universe could be explained in the same way. Moreover, the primordial-imbalance hypothesis accords fundamental status to a set of initial conditions that have no apparent rationale; any number of alternatives seem equally plausible. If a theory consistent with established physical principles could be constructed in which the universe was initially symmetrical, it would be more appealing. It is just such a theory that is offered by the conjunction of cosmology and particle physics.

A crucial event in modern cosmology was the discovery in the 1920's by Edwin P. Hubble that distant galaxies are receding from the earth with speeds proportional to their distances. The recession of the galaxies implies that the entire universe is expanding. Extrapolating backward in time leads to the conclusion that roughly 10 billion years ago the material that now forms the galaxies emerged explosively from a highly compressed state. Indeed, following the backward evolution to its mathematical limit suggests that the entire universe was initially a dimensionless point.

At the instant of the big bang the density and the temperature of the universe were infinite. The temperature fell rapidly, but throughout the first minute it was greater than 10^{10} degrees Kelvin. Under those conditions any atoms that may have formed were immediately torn apart; even atomic nuclei could not survive but were decomposed into their constituent particles. In other words, the universe in its first moments was a hot plasma of free particles, many of which, such as the electrons and the protons, were electrically charged. Because charged particles in motion give off electromagnetic radiation, the early universe was rich in photons.

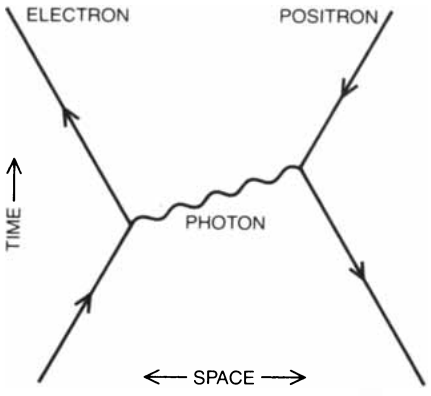
The expanding universe cooled much



CREATION OF ANTIMATTER becomes visible in a chamber in which the trajectory of any particle that has an electric charge is marked by a trail of bubbles in liquid helium. Here the antimatter is a positron, whose clockwise spiraling path fills the right two-thirds of the photograph. The smaller counterclockwise spiral represents the path of an electron. The positron is the antiparticle of the electron: the two are identical in mass, but in several other ways, such as electric charge, their attributes are opposite. The positron and the electron were created as a pair by the decay of a photon, or quantum of electromagnetc radiation. The photon's path cannot be seen because photons have no electric charge and do not give rise to bubbles in the helium. A magnetic field was applied to the chamber to bend the trajectories of the particles. In high-energy experiments the creation of particle-antiparticle pairs is common, yet the universe in the large appears to consist predominantly of matter. The photograph was made by Nicholas P. Samios of the Brookhaven National Laboratory.

as an expanding gas cools, and by about three minutes after the big bang protons and neutrons began to combine to form the nuclei of helium atoms. The remaining unbound protons would eventually become hydrogen nuclei. (All the heavier elements, which are quite rare on a cosmic scale, have been built up out of hydrogen and helium in the cores of stars and in supernova explosions.) By making the simplest assumptions about the conditions in the early universe that are consistent with known physical laws, one can calculate that the ratio of helium to hydrogen was about one to three by weight. The value is in good agreement with the ratio estimated for the universe today. The success of this prediction is testimony to an understanding of what the universe was like a few minutes after its birth.

After roughly 10,000 years of expansion the universe was cool enough for the last of the free charged particles to be incorporated into atoms. Each atom is electrically neutral because it has equal numbers of positive and negative charges. Photons interact only weakly with neutral matter, and so from that time forward the matter and the electromagnetic radiation in the universe were essentially uncoupled. Since then the radiation has freely followed the expansion of the universe, cooling all the while. How can radiation cool, and how can it have a temperature in the first place? If the radiation is regarded as a gas of photons, then it cools by expansion, somewhat like a gas of material particles, as the average energy of the photons decreases. If the radiation is regarded as a wave, then the expansion of space brings an increase in the distance between any two successive wave crests. The longer wavelength corresponds to a smaller photon energy.



ELECTROMAGNETIC FORCE can be represented as acting through the exchange of a photon by two electrically charged particles. The interaction is depicted in a Feynman diagram, in which time advances from the bottom to the top and a single dimension that represents space runs from left to right. The line at the lower left represents an electron. The line at the lower right represents a positron. Arrows show the direction in which charge flows. (In the mathematical description of the interaction a positron moving forward in time is equivalent to its antiparticle, an electron, moving backward in time.) The exchanged photon alters the trajectory of each particle.

In 1964 it was discovered that microwave radiation is striking the earth evenly from all directions. The radiation corresponds to a photon gas that fills the universe to a density of about 300 photons per cubic centimeter. The temperature of the radiation is 2.7 degrees K., a value much reduced from the temperature of about 10,000 degrees at the time of decoupling. The presence of the radiation is further evidence that this theoretical reconstruction of the early universe is correct. Emboldened by these successes, one can attempt to extrapolate back to the earliest moments of the universe to see if the extreme conditions then prevailing might account for the present asymmetry between matter and antimatter.

In the first few seconds of the universe the particles of the hot primeval gas had an average energy that exceeds the capabilities of even the largest modern particle accelerators. Interactions of particles at those energies may have been qualitatively different from all those that can be observed now. Even if the events in the early universe differed in character from those accessible today, however, the laws of nature governing the events can be assumed to endure unchanged. What is needed, then, is a theory that will predict how particles act at very high energy on the basis of natural laws deduced from events at much lower energies.

Among the natural laws in question are conservation laws applied to quantum numbers. A quantum number is essentially a bookkeeping convenience, adopted as an aid to keeping track of the various properties of particles. For example, electric charge can be expressed as a quantum number: the proton is assigned a value of $+1$, the electron a value of -1 and the photon and all other neutral particles a value of zero. The conservation law that applies to electric charge states that the total charge quantum number cannot change in an interaction; the sum of all the charge quantum numbers after the event must be equal to the sum before the event.

It is important to note that the conservation of electric charge does not forbid a change in the number of charged particles. An electron and a positron can annihilate each other, diminishing the number of particles by two; the total charge, however, is zero both before the annihilation and after it. The opposite process, in which an electron and a positron are created out of pure energy, obeys the conservation law for the same reason. Indeed, any particle can be created or annihilated simultaneously with its antiparticle, and all quantum numbers will automatically be conserved.

A quantum number called baryon number is of notable interest in tracing the source of the cosmic asymmetry between matter and antimatter. The baryons are a large family of particles whose most familiar members are the proton and the neutron; as basic constituents of atomic nuclei, the baryons clearly have an important role in the structure of ordinary matter. The proton, the neutron and all the many related baryons are assigned a baryon number of $+1$. For the antiproton, the antineutron and other antibaryons the baryon number is -1. All other particles, including the pions, the muons, the neutrinos, the electron, the photon and their antiparticles, have a baryon number of zero.

The conservation of baryon number is the assertion that in any reaction the baryon number of all the particles in the initial state is equal to the baryon number of all the particles in the final state. Again the number of particles can change, as when a proton and an antiproton are created or annihilated as a pair, but the net baryon number remains unaltered. Suppose, for example, two protons (with a total baryon number of $+2$) collide at high energy. The final products might include four protons, a neutron, three antiprotons and a number of pions; adding up the baryon numbers shows that the total remains $+2$.

Electric charge is a quantity that is thought to be conserved under all circumstances. The absolute conservation of baryon number is less certain, and indeed there is now strong suspicion that the law is occasionally violated.

The most compelling evidence for the conservation of baryon number is the stability of the proton. As the least massive particle whose baryon number is $+1$, the proton cannot decay into any set of lighter particles without violating the conservation law. Detection of a proton decay would therefore constitute direct evidence that the law is not always enforced.

No one has yet seen a proton decay, and even crude calculations suggest that its lifetime is long. If protons decayed, for example, in human bone, the energy released would increase the incidence of cancer. On this basis the lifetime of the proton must be greater than 10^{16} years. If protons decayed on Jupiter, the energy would contribute to the luminosity of the planet. On this basis the lifetime is greater than 10^{18} years. Systematic experiments suggest that the lifetime is actually greater than 10^{29} years. In contrast, the age of the universe is only 10^{10} years. Evidently if the proton does decay, it is an exceedingly rare event. If the actual lifetime should turn out to be 10^{30} years, then in 100 tons of matter (a sample of 10^{31} protons) an average of

10 would decay in a year. The low rate suggests both the stringency of the law of conservation of baryon number and the difficulty of mounting experiments to search for violations. Several such experiments are nonetheless under way.

Saying that the universe has an excess of matter over antimatter is equivalent to saying that it has a positive baryon number. If the law of conservation of baryon number were absolute, the number would have been constant through the eons. There may have been more of both baryons and antibaryons once, but the number of baryons minus the number of antibaryons would have always been the same.

Consider the state of the universe when it was a hundredth of a second old and had a temperature of 10^{14} degrees K. For any given temperature there is an equilibrium mixture of different kinds of particles such that for each kind the number of particles being created by collisions or decays balances the number being destroyed. In the early universe, at 10^{14} degrees, the equilibrium mixture included about a billion protons and a billion antiprotons for every proton in the present universe. If the baryon number of the universe was the same then as it is now, the ratio of protons to antiprotons must have been roughly 1,000,000,001 to 1,000,000,000, and so the asymmetry would have been scarcely noticeable.

Later almost all the protons were annihilated by encounters with antiprotons. Only the conservation of baryon number forestalled a total annihilation of all baryons and antibaryons. In this view all the present protons, and therefore all the present galaxies, stars, planets and sentient beings, are the residue of a one-part-in-a-billion imbalance. It is the small imbalance, the early manifestation of the cosmic asymmetry between matter and antimatter, that stands in need of explanation. Once the excess of matter has been established the subsequent evolution of the universe is comparatively straightforward: the source of the original asymmetry is a deeper mystery. In particular, if the universe evolved from an initial state that was fully symmetrical between matter and antimatter (a state having a baryon number of zero) into an asymmetrical state in which the baryon number is greater than zero and protons outnumber antiprotons, then the conservation of baryon number must have been violated at some stage.

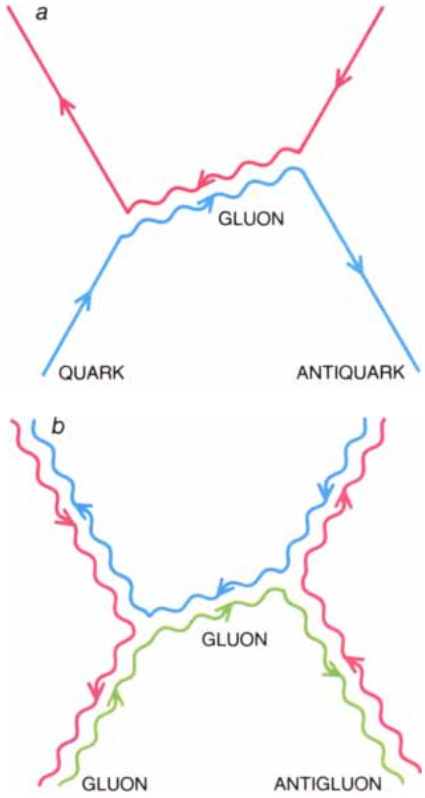
The first indication that the conservation of baryon number cannot be exact came from a distantly related field of inquiry: the theory of the black hole. A mathematical analysis demonstrated that the only properties of a black hole measurable by an outside observer are its mass, its angular momentum and its electric charge. Notably absent from the list is the baryon number. Hence a black hole created by the collapse of a star would be indistinguishable from one created by the collapse of an antistar with the same mass, angular momentum and charge. Yet the baryon number for the star is positive, whereas the number for the antistar is negative. Clearly there is no way to assign a baryon number to a black hole and be certain that the baryon number of the universe is conserved.

The putative violation of the conservation law by black holes suggests that a similar mechanism on a microscopic scale might lead to proton decay. In this hypothetical process a proton is absorbed by a virtual black hole: a minute, short-lived fluctuation in the geometry of space-time, which in principle could arise anywhere and at any time. The virtual black hole promptly decays into a positron and a gamma ray. In these particles the mass or energy of the proton reappears and so does its positive electric charge; its baryon number, however, is irretrievably lost. Although the details of the hypothetical process are uncertain, estimates suggest that it implies a lifetime for the proton on the order of 10^{40} years. If the conservation of baryon number is violated in this way, the violation is feeble indeed.

A second indication that the conservation of baryon number is only approximate is slightly less exotic and also more powerful in its effect on the lifetime of the proton. This second possible mechanism is an outcome of revolutionary developments in the theories describing interactions among elementary particles. To be specific, it is an outcome of the understanding, achieved only in the past decade, that the "strong" force responsible for holding together the nuclei of atoms and the "weak" force responsible for most radioactive decays are quite similar to electromagnetism.

How could improved understanding of these forces, which do not violate the conservation of baryon number, lead to theories predicting such a violation? A more detailed discussion of the forces must precede the explanation.

Of the three forces only electromagnetism is routinely evident in the macroscopic world that people perceive directly. The electromagnetic force acts only between particles that have an electric charge; the interaction can be described as the exchange of a third particle, namely a photon. The photon is said to be a vector particle, a designation given to any particle whose spin angular momentum, when measured in fundamental units, is equal to 1. Perhaps the most fundamental characteristic of electromagnetism is that it can be described by a gauge-invariant theory. In a theory of this kind the origin of the force is related to a conservation law; in this case the conservation of electric charge. The coupling of vector particles to a conserved charge is characteristic of gauge theories.



STRONG FORCE can be represented as the exchange of a gluon by two particles that have the property called color. In *a* the particles are quarks; the one at the left is blue, the one at the right antiblue (note the direction of the arrow). The strong interaction changes the trajectory and also the color of each quark. In order to conserve color throughout the interaction the gluon must have both a color and an anticolor; as a result the gluons themselves are subject to the strong interaction. The scattering of a gluon and an antigluon is shown in *b*. The strong interaction binds together the protons and the neutrons in an atomic nucleus. It also binds together the quarks that are thought to make up each proton and neutron.

In all these respects the strong interaction is similar. The force arises from a gauge theory, and a strong interaction can be described as the exchange of a vector particle by two other particles that have a certain kind of charge. The vector particle is not the photon, however, but a hypothetical entity called a gluon, and the charge is not electric charge but a property called color. The color charge of course has nothing to do with color in the ordinary sense. The word charge in this context is less fanciful. The word is apt because color charge plays much the same role in the strong interaction as electric charge does in the electromagnetic interaction.

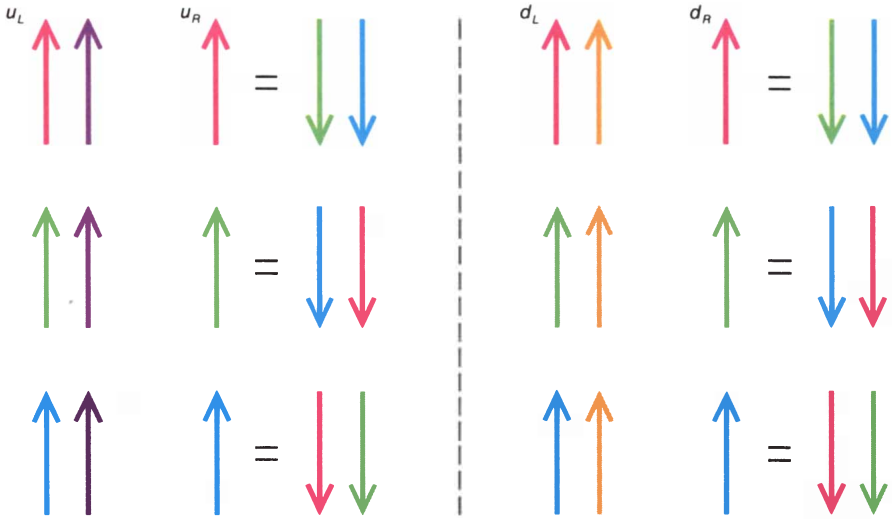
One difference between electromag-

netism and the strong interaction is that electromagnetism has only one kind of charge, whereas in the strong interaction there are three, labeled *R*, *G* and *B* for red, green and blue. The colors are carried by the fundamental constituents of all strongly interacting particles: the quarks. Each quark has a single color, denoted by an assignment of the three color quantum numbers. For red quarks *R* equals +1 whereas *G* equals 0 and *B* equals 0. Similarly, for green quarks *G* equals +1 and for blue quarks *B* equals +1 and the other color quantum numbers are zero. Eight kinds of gluon are required by the theory. Six kinds change a quark of one color into a quark of a different color in all possible ways, namely red into green, red into blue, green into red, green into blue, blue into red and blue into green. The other two gluons resemble the photon in that they carry a force between "charged" particles but do not alter the charge.

A property of color charges is that they can cancel one another. For example, the combination of one red, one green and one blue quark is a colorless composite particle, to which gluons do not couple. (Similarly, particles with opposite electric charges can combine to form a neutral composite.) It is only such colorless combinations of quarks that seem to appear in nature. All baryons consist of three quarks, one quark in each of the three colors. The mesons, which make up another category of strongly interacting particles, each consist of a quark and an antiquark.

A second difference between the strong interaction and electromagnetism is that the gluons themselves are charged, whereas the photon is not. For example, the gluon that is absorbed by a red quark and transforms it into a green quark has *R* equal to −1, *G* equal to +1 and *B* equal to 0; with this combination of colors and anticolors color charge is conserved throughout the interaction. Since gluons couple to colored particles and since gluons themselves are colored, gluons couple to one another. In contrast, the photon is electrically neutral and does not couple to other photons. The difference has a profound dynamical consequence: at short distances the strong interaction loses strength. Quarks bind only feebly when they are close together, but their binding becomes quite powerful when they are somewhat farther apart. (In the present context a long distance is 10^{-13} centimeter.)

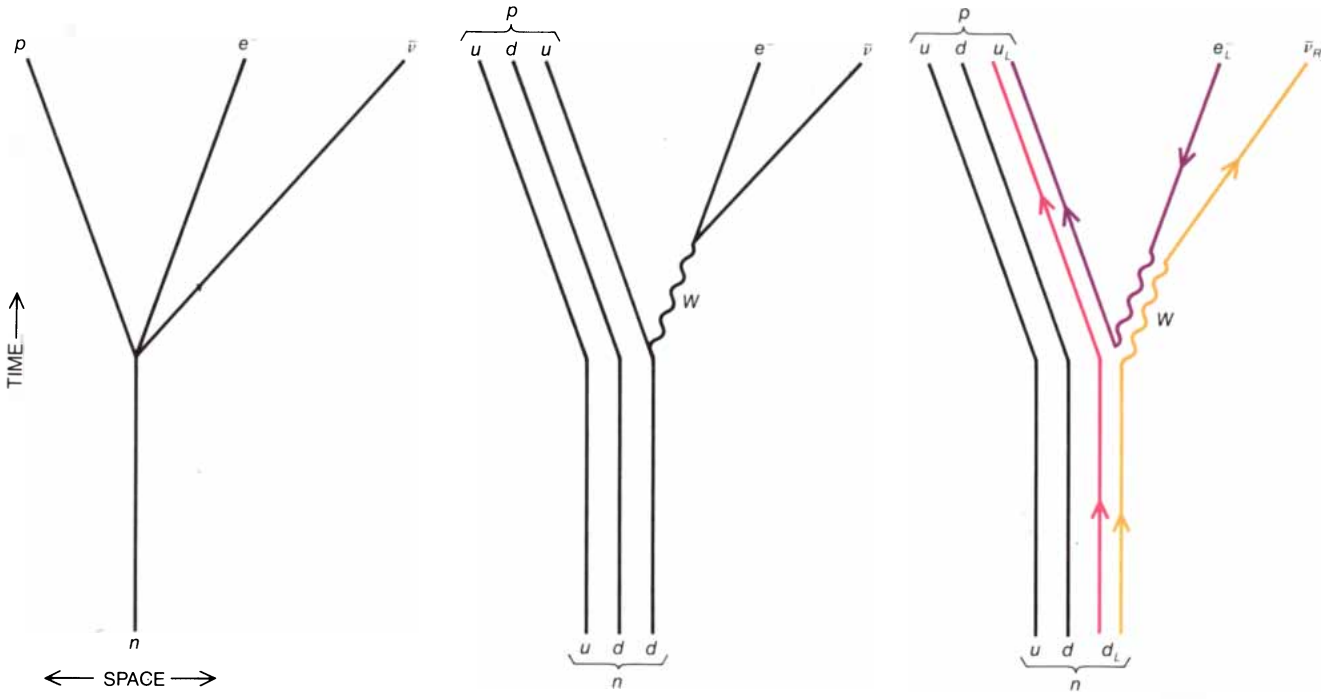
This paradoxical force law explains a great deal. It has been known since the mid-1960's that the properties of strongly interacting particles could be accounted for by the quark model, but no one has ever observed an isolated quark. Furthermore, the utility of treating a strongly interacting particle as a composite of quarks rests on an approximation in which the quarks are essentially noninteracting particles inside a communal "bag." It was puzzling that strongly interacting particles such as quarks could successfully be described as noninteracting. The notion that the strength of the strong interaction among quarks decreases when the quarks are close together neatly explains why the quarks inside a "bag" interact only feebly with one another and yet cannot be pulled far apart. It may be impossible to isolate a quark. The gauge theory of the strong interaction that underlies the quark model leads to many experimental predictions, which so far have proved very successful. The theory is gaining almost universal acceptance.



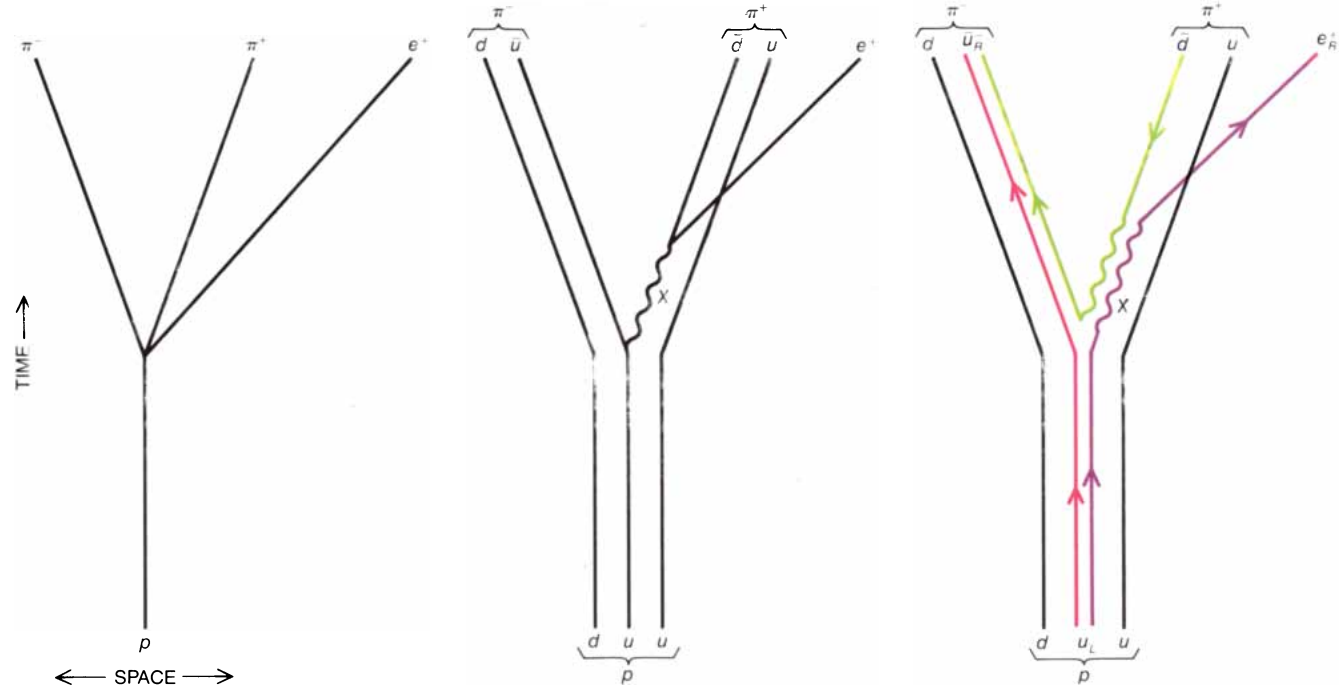
FAMILY OF 12 QUARKS is depicted as the 12 would appear in Feynman diagrams. Each quark has four salient attributes. First, each quark is called up (*u*) or down (*d*). The *u* quarks have an electric charge of +2/3, the *d* quarks an electric charge of −1/3. (The charge of an electron is −1, that of a positron or a proton +1.) Second, each quark has a color with respect to the strong interaction: red, green or blue. Third, each quark has a spin whose axis is aligned with the particle's direction of motion (subscript *R*, for right-handed particles), or is opposite to that direction (subscript *L*, for left-handed particles). Finally, the left-handed quarks have a color with respect to the force in nature called the weak interaction, which mediates most radioactive decays. The color is purple for *u* quarks and orange for *d* quarks. Curiously, the weak force does not affect right-handed particles or left-handed antiparticles. In the mathematical formalism of the strong interaction a quark with a given color is equivalent to a quark without that color but with the other two anticolors. An equivalence is shown for each right-handed quark. Reversing the arrows (not shown) transforms a quark into the corresponding antiquark.

WEAKLY INTERACTING PARTICLES include the left-handed neutrino; its antiparticle, the right-handed antineutrino; the left-handed electron, and its antiparticle, the right-handed positron. The particles do not interact strongly, and so they are shown without strong color charges. The fifth particle is the right-handed electron. It is given two weak color charges, a configuration that is equivalent to a state with no weak color charge (*black line without arrow*).

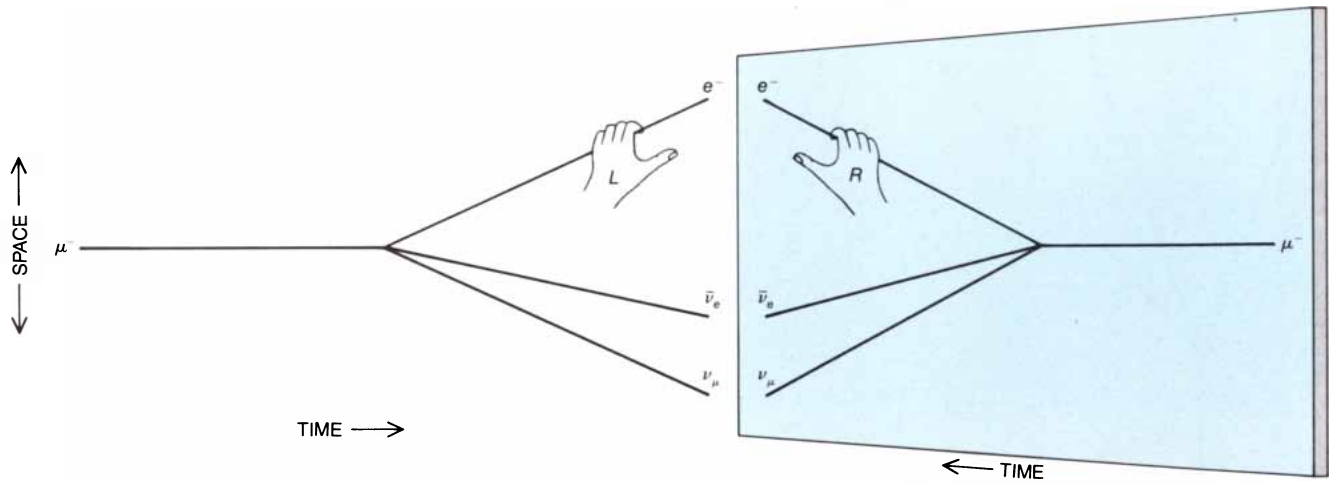
The weak interaction can be described in much the same way as the electromagnetic and the strong interactions, but it has a few twists of its own. First, there are two kinds of charge, analogous to the three color charges of the strong interaction. I shall call them *P* and *O*, for the colors purple and orange. Three vector particles, called W^+, W^- and *Z*, mediate the interaction. These particles have large masses, unlike the photon and the gluons, which are massless. A particle with a large mass can arise spontaneously only as a short-lived fluctuation; if it is short-lived, it cannot go far, and as a result the weak interaction has a very short range. A more surprising characteristic of the weak force is that it acts only on particles with certain geometric properties. Quarks, electrons, neutrinos and a few other particles can be classified as right-handed or left-handed according to the relative orientation of their spin angular momentum and their linear motion. A right-handed particle has its spin axis pointing parallel to its direction of motion, a left-handed particle antiparallel. The weak interaction affects only left-handed particles and right-handed antiparticles. In sum,



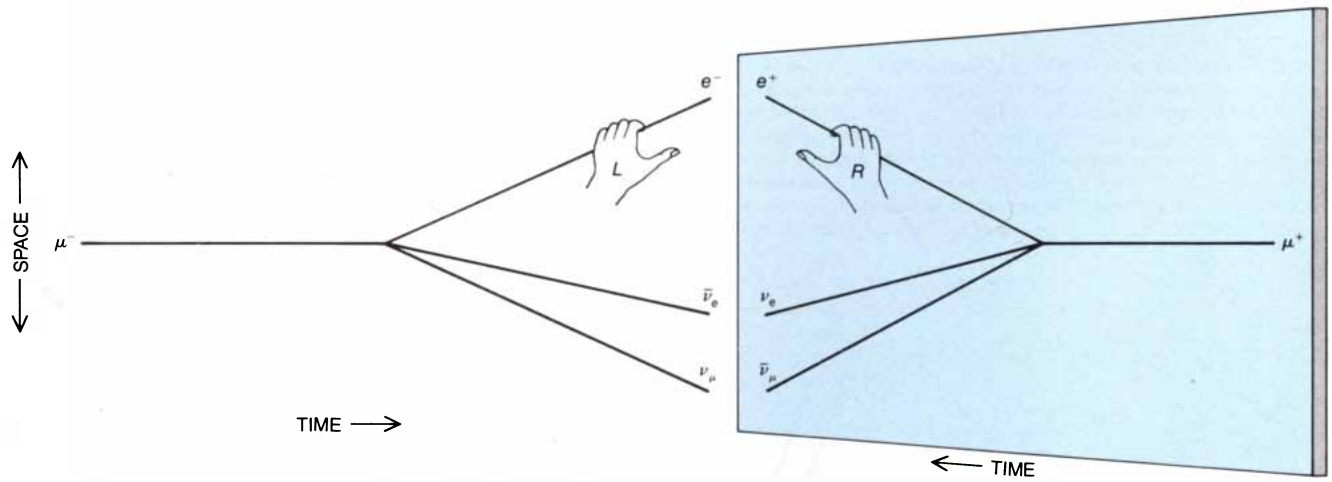
DECAY OF THE NEUTRON is a weak interaction that allows the particle a lifetime of only some 15 minutes on the average if it is not bound in the nucleus of an atom. In the broadest view (*left Feynman diagram*) the decay transforms the neutron (n) into a proton (p), an electron (e^-) and an antineutrino ($\bar{\nu}$). In a finer analysis (*center*) the neutron consists of three quarks, and only a d quark, placed arbitrarily at the right, is affected by the decay. A left-handed d quark (d_L) decays into the less massive left-handed u quark (u_L), the electron and the antineutrino. The d_L quark was red with respect to the strong interaction and orange with respect to the weak one. The orange charge is transformed by a short-lived (or virtual) particle (W), which is orange and antipurple. Only weak colors are changed. (As before, arrows show the direction of flow of the color charges.) A weak interaction of the kind diagrammed here is typical not only of neutron decay but also of most other kinds of radioactive decay. The colors of the unaltered quarks do not appear in the diagram at the right.



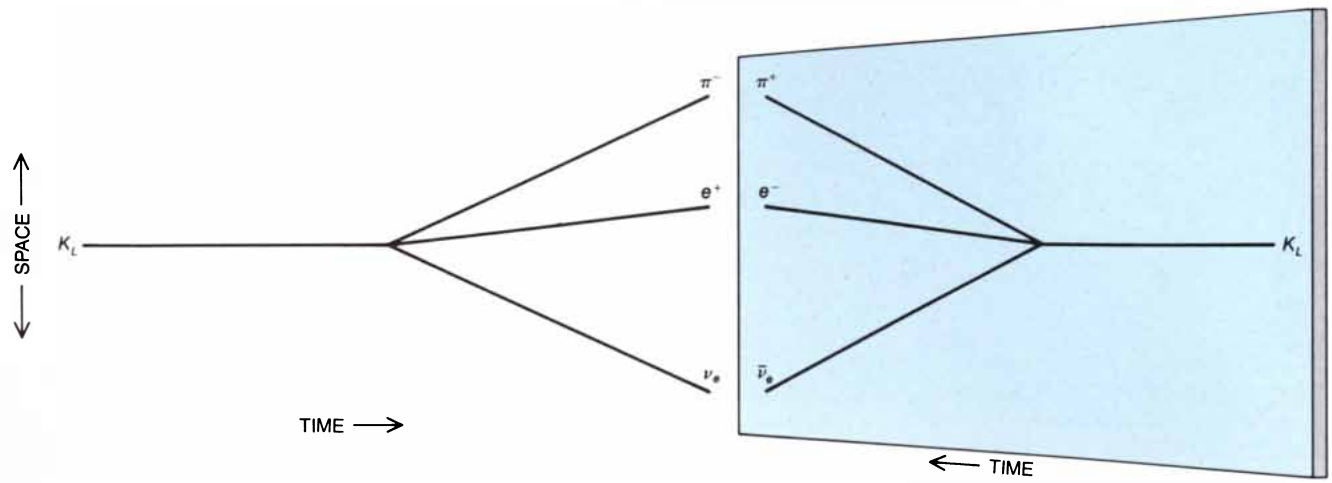
DECAY OF THE PROTON is predicted by theories that unify the strong and the weak interactions. The theories posit the existence of a virtual particle (X) that has both strong and weak color and that mediates the decay. Its spontaneous creation is rare, and so the proton is thought to survive for an average of 10^{31} years. In the mode of decay shown the proton (p) is transformed into two charged pions (π^+ and π^-) and a positron (e^+). The microscopic event responsible for the decay is the transformation of a single quark into two antiquarks and the positron. Again, the left diagram shows the overall decay, the center diagram decomposes the particles into quarks and the right diagram shows the flow of color charges for the quark that is transformed. The proton is the lightest member of the class of particles called baryons. If the proton can decay, it is not a law of nature that the number of baryons in the universe is constant. This law must have been broken at some era in the history of the universe if an asymmetry between matter and antimatter evolved in the early universe.



VIOLATION OF PARITY CONSERVATION was the first in a sequence of discoveries to show that the laws of physics are not indifferent to the distinction between matter and antimatter. Parity, or P, conservation holds that every physical process would remain invariant if it could be transformed into its mirror image. The process shown is the decay of a muon (μ) into an electron (e^-), an electron-type antineutrino ($\bar{\nu}_e$) and a muon-type neutrino (ν_μ). The electron is left-handed. In the mirror reflection of the decay the electron is right-handed. Actually parity is not conserved in this process: left-handed electrons appear more than 1,000 times as often as right-handed ones.



CP CONSERVATION proposed a symmetry that might be observed even if parity conservation is violated. CP conservation asserted that the symmetry broken by a mirror reflection could be restored by replacing all particles with their antiparticles. (The *C* stands for charge conjugation.) In muon decay CP conservation holds true: the decay at the left and the decay at the right appear to be equally common.



CP VIOLATION was demonstrated in the decay of the long-lived neutral *K* meson (K_L). The decay of this particle into π^-, e^+ and ν_e is commoner than decay into the antiparticles π^+, e^- and $\bar{\nu}_e$. (The long-lived neutral $\bar{K}$ meson is its own antiparticle.) If CP symmetry were never broken, the ratio of baryons to antibaryons would be fixed and no asymmetry could develop between matter and antimatter.

the strong and the weak interactions require five kinds of color charge (red, green and blue for the strong and purple and orange for the weak), along with vector particles that transmute some of these colors.

In the theories I have outlined here the strong force is a mechanism for changing the red, green and blue colors of quarks. The weak force works similar changes on the purple and orange color quantum numbers of particles. If these theories are to be truly unified, one would expect some additional force to transform the strong colors into weak colors and vice versa. In addition to being aesthetically attractive, a scheme that incorporates such a new force accommodates all known particles quite neatly. Moreover, it makes definite predictions. For example, it predicts the mass of the W, a particle that has not yet been detected.

It is by postulating a new force that the unifying theories compromise the conservation of baryon number and allow the proton to decay. New color-changing vector particles are introduced as bridges between particles with strong color, such as the quarks composing a proton, and particles with only weak color, whose baryon number is zero. I shall designate such vector particles X. The unifying theory predicts that the X has a mass that is 10^{15} times the mass of the proton (and is roughly comparable to the mass of a flea), compressed into a volume only 10^{-27} centimeter across. Because the X particle is so massive, its spontaneous creation is extremely rare. Accordingly it is estimated that the mean lifetime of the proton is long but not infinite; the lifetime should be on the order of 10^{31} years.

To be sure, a lifetime of 10^{31} years implies that in the universe today the violation of the conservation of baryon number is slight. As I have noted, however, the matter-antimatter asymmetry observed today corresponds to merely a one-part-in-a-billion asymmetry in the early universe. Moreover, a mode of decay that requires the creation of an unstable heavy particle may well have been commoner in the earliest moments of the universe, when heavy particles could be freely created by ultrahigh-energy collisions.

I turn now to the idea that physical laws are indifferent to the distinction between matter and antimatter. The history of the idea is a series of upset expectations. Until the mid-1950's it was generally thought the laws of physics would remain unchanged if experiments were repeated in a mirror-reflected world. In other words, it was thought no absolute distinction could be made between left and right. A variety of experiments then revealed, however, that mirror-reflection symmetry is badly broken by the weak interactions. An example is provided by the decay of the muon into an electron, a neutrino and an antineutrino. In more than 999 decays in 1,000 the electron is found to be left-handed: its spin axis points in the direction opposite to its direction of motion. Thus the decay of the muon furnishes an absolute standard of left v. right.

Theorists next proposed a more comprehensive symmetry that seemed to be respected by all interactions. This second hypothesis was that the laws of physics would be unchanged by the mirror reflection of an experiment if at the same time all the particles in the experiment were replaced by their antiparticles. The symmetry is called CP for charge conjugation and parity, or mirror reflection. CP symmetry predicts that in the decay of the antimuon a positron should emerge instead of an electron and the positron should almost always be right-handed. In the case of muon decay exact CP symmetry is observed.

If CP symmetry were absolute, a preponderance of matter or of antimatter could not evolve from a primordial equality between the two. For every process that creates a particle, an equally likely mirror process would create the antiparticle.

The concept of absolute CP symmetry survived for about seven years. Then it was observed that the long-lived neutral K meson, which is its own antiparticle, decays more often into a negative pion, a positron and a neutrino than it does into a positive pion, an electron and an antineutrino. If CP were an absolute symmetry, the two decay modes would have to be equally likely. No violation of CP symmetry has been found except in K-meson decay, but such violations might have a more prominent role in nature at ultrahigh energies.

The developments I have described suggest that both the permanence of certain particles, as formalized in the law of conservation of baryon number, and the indifference of physical laws to the distinction between matter and antimatter, as formalized in the principle of CP symmetry, are not exact but only approximate. It is true the principles hold quite accurately today, but this may not have been the case in the very early universe. Indeed, given even a small violation of these principles one can construct a specific chain of events leading from a universe in an initial state of symmetry between matter and antimatter to a universe with a preponderance of matter over antimatter.

The chain of reasoning begins with the observation that the temperature of the universe has been falling steadily since the big bang. The higher the temperature, the higher the average speed and energy of the particles that make up the universe, and hence the greater the energy available in a collision for the creation of other particles. At a temperature greater than 10^{28} degrees K. the typical energy of a particle was comparable to the rest-mass energy of an X particle. Until about 10^{-35} second after the big bang the universe had such a temperature, and so one can propose that it had a great density of X particles.

As the universe expanded and cooled, the probability of creating an X particle declined rapidly; meanwhile the existing particles were rapidly decaying. Suppose the decays did not conserve baryon number. An X particle might then decay into any of several final states with differing total baryon number. The average might be, say, $+2/3$. If the universe had equal amounts of matter and antimatter before it was 10^{-35} second old, it would include equal numbers of X's and $\overline{X}$'s, where the $\overline{X}$ is the antiparticle of an X. It might seem, therefore, that every decay mode of an X would be counterbalanced by the decay of an $\overline{X}$, which would yield particles with an average baryon number of $-2/3$. In that case the total baryon number of the universe would remain zero at all times. Actually, since CP symmetry may not have been observed exactly in the decay of the X and the $\overline{X}$, one cannot conclude that the two decay sequences always yielded symmetrically opposite sets of particles. The $\overline{X}$ might give rise to particles whose average baryon number was not $-2/3$ but rather, say, $-1/3$.

In this way a universe that had equal numbers of X and $\overline{X}$ particles would have evolved into a universe with a positive baryon number and a corresponding preponderance of matter. It could have been a universe, for example, with a one-part-in-a-billion imbalance favoring matter. After the first 10^{-35} second or so the temperature and the typical energy per particle throughout the universe would fall below the threshold for the creation of an X and an $\overline{X}$. The processes that violate baryon number would then become insignificant, and the preponderance of matter over antimatter would be frozen in. The universe would still have many more baryons and antibaryons than it has now, but most of them would eventually annihilate one another, leaving the residue of matter observed today.

Several aspects of this argument are highly speculative, and the explanation of the cosmic asymmetry between matter and antimatter may seem more mythical than scientific. To an extent that is unavoidable, since the extreme conditions of the early universe cannot be reproduced in a laboratory. What distinguishes scientific speculation from myth is its logical consistency and the amenability of at least some of its elements to experimental test. I have described how the inner logic of particle physics leads to unified theories in

which baryon number is not conserved, and I have noted that future developments both in neutrino astronomy and in the search for the decay of the proton will test the theories. If these difficult experiments give results consistent with theoretical expectations, they will bring much closer the scientific understanding of a mysterious asymmetry. Even now, calculations carried out in accordance with the unified theories suggest that the average density of matter in the universe today is consistent with the primordial course of events the unified theories imply. Because of uncertainties about the mechanisms of CP violation it is difficult to make the calculations precise, but the qualitative picture is satisfying.

A further question remains. I have described how the universe could have begun with symmetry between matter and antimatter and then have grown asymmetrical. Why was the universe symmetrical in the beginning?

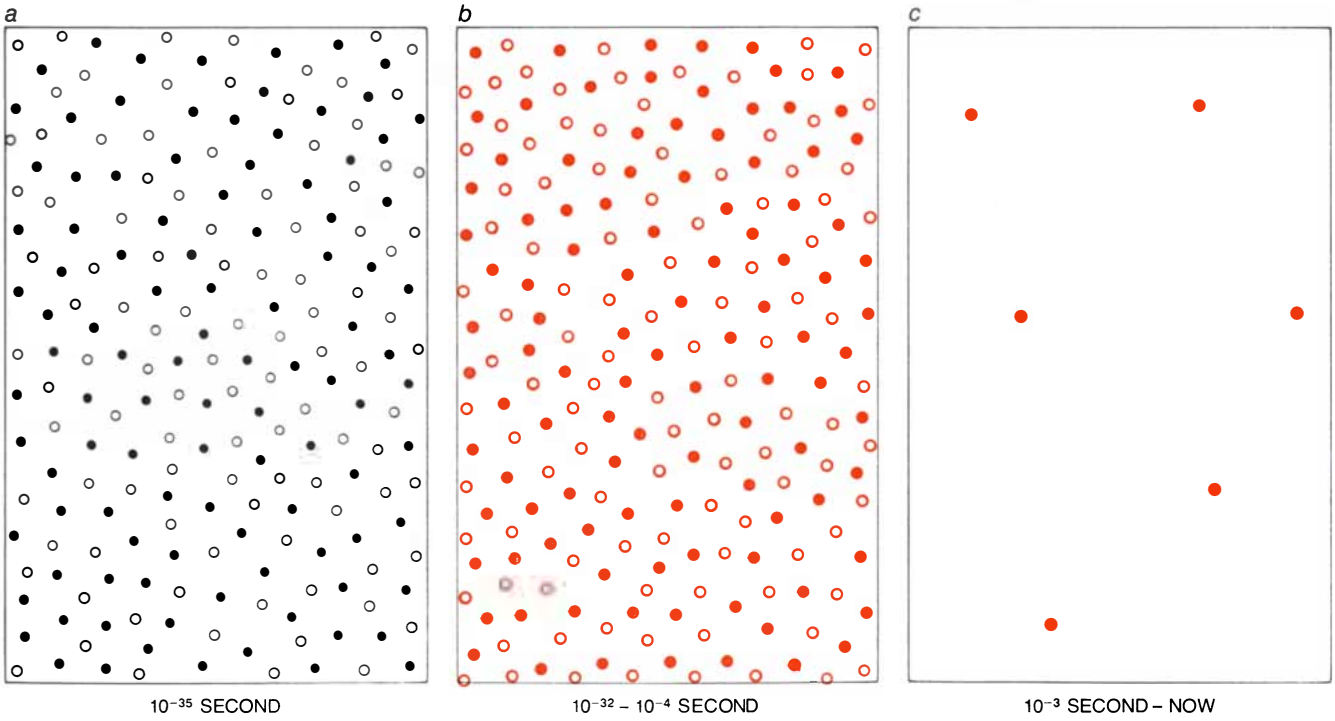
At one level this question can be answered statistically. Even if interactions that violate baryon number were frequent in the early universe, the most likely universal condition, which would be attained at equilibrium before 10^{-35} second, is one in which the amount of matter equals the amount of antimatter. Unified theories therefore enforce initial symmetry automatically; it need not be postulated separately. After 10^{-35} second the decay rates of the X's and $\overline{X}$'s would have been slow compared with the expansion and cooling rate of the universe. Under that condition equilibrium could no longer be attained.

At a deeper level I do not find this explanation fully satisfying. It fails to explain why the universe should have begun in an explosive event. It also fails to explain why the universe is symmetrical in several other ways: it is electrically neutral on the average and it seems to have no net angular momentum.

I shall now describe an idea that may lead to an understanding of these questions. It is by no means well established, but it does suggest a program of research. Indeed, it was the original motivation for my own work on the matter-antimatter asymmetry.

Modern theories of the interactions among elementary particles suggest that the universe can exist in different phases that are analogous in a way to the liquid and solid phases of water. In the various phases the properties of matter are different; for example, a certain particle might be massless in one phase but massive in another. The laws of physics are more symmetrical in some phases than they are in others, just as liquid water is more symmetrical than ice, in which the crystal lattice distinguishes certain positions and directions in space.

In these theories the most symmetrical phase of the universe generally turns out to be unstable. One can speculate that the universe began in the most symmetrical state possible and that in such a state no matter existed; the universe was a vacuum. A second state was available, and in it matter existed. The second state had slightly less symmetry, but it was also lower in energy. Eventually a patch of the less symmetrical phase appeared and grew rapidly. The energy released by the transition found form in the creation of particles. This event might be identified with the big bang. The electrical neutrality of the universe of particles would then be guaranteed, because the universe lacking matter had been electrically neutral. The lack of rotation in the universe of matter could be understood as being among the conditions most favorable for the phase change and the subsequent growth, with all that the growth implied, including the cosmic asymmetry between matter and antimatter. The answer to the ancient question "Why is there something rather than nothing?" would then be that "nothing" is unstable.



EVOLUTION OF COSMIC ASYMMETRY between matter and antimatter is diagrammed in accordance with the predictions of the theories that unify the strong and the weak interactions. Panel *a* symbolizes the universe 10^{-35} second after the big bang. The panel shows equal quantities of X particles (*black dots*) and their antiparticles, $\overline{X}$'s (*open black circles*). In the newborn universe such particles were copiously produced by ultrahigh-energy collisions. Panel *b* shows the universe from 10^{-34} second through 10^{-4} second. The X's and $\overline{X}$'s have decayed in ways that do not always conserve baryon number and CP symmetry. The result is a slight imbalance favoring protons (*colored dots*) over antiprotons (*open colored circles*). The panel shows six more protons than antiprotons; actually the imbalance was much smaller, namely one part in a billion. Although the proton is less massive than the X by a factor of 10^{15}, the proton is shown as being larger because according to quantum mechanics mass is inversely proportional to uncertainty in position. Panel *c* shows the universe from 10^{-3} second through the present. Each encounter of a proton and an antiproton has caused the annihilation of both particles, and only the excess protons survive. They contribute to the apparent preponderance of matter over antimatter observed in the universe today.

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SCIENCE AND THE CITIZEN

The Nobel Prizes

The 1980 Nobel prizes in the sciences were awarded to three immunologists for showing that the molecules enabling man and other animals to recognize and repel invasive agents at the cellular level are genetically determined, to two physicists who found that nature is not indifferent to the direction of time's arrow, to three biochemists whose discoveries underlie the techniques of gene splicing and genetic engineering and to an economist whose mathematical models of national economies are in worldwide use. This year's prizes have a value of about $210,000.

The prize in physiology or medicine was awarded jointly to George D. Snell, 76, who retired six years ago from the Jackson Laboratory in Bar Harbor, Me., to Jean Dausset of the University of Paris and to Baruj Benacerraf of the Harvard Medical School. The origins of their work can be traced to the 1920's, when it was observed that skin grafts survived longer when the grafts were made between members of the same inbred line of mice or guinea pigs than when they were made between members of different inbred lines. The rejection of the grafts was traced to molecules called histocompatibility antigens that are unique to each individual (except for identical twins) and that enable the recipient of a graft to recognize the graft tissue as "foreign," so that it can be destroyed. Such antigens were first described in 1937 by Peter Gorer of the Lister Institute of Preventive Medicine in London.

In 1942 Snell set out to develop highly inbred strains of mice in the hope of tracing the histocompatibility antigens to particular sites in the genetic material of the mouse. Ultimately he found that the two antigens most strongly associated with graft rejection arise from two genes in a short segment called the *H*-2 region of the mouse's chromosome No. 17. It is now known that each of the "strong" *H*-2 genes exists in 100 or more variant forms, each of which codes for a unique protein antigen. The antigens serve as distinctive markers on the cell surface, enabling the individual to distinguish between "self" and "not self."

In Paris in the early 1950's Dausset suspected that some of his patients with low counts of white blood cells might be suffering from an autoimmune reaction elicited by foreign antigens introduced into their system as a result of multiple blood transfusions. By developing agglutination techniques to identify and classify human white-blood-cell types he showed that his patients indeed harbored antibodies to antigens carried on the white cells of blood donors. Reasoning from Snell's work with mice, Dausset suggested that the antigens arose from a single region in human chromosomes. Independently Jan van Rood of the University of Leiden and Rose M. Payne of Stanford University showed with Dausset's agglutination technique that pregnant women develop antibodies to antigenic markers on the white cells of the fetus. Van Rood and Ruggiero Ceppellini of the University of Turin demonstrated that the rapid rejection of grafts made between human subjects depends on a single locus on chromosome No. 6. The site is designated human leukocyte locus *A,* or *HLA,* and it is analogous to the *H*-2 locus in mice.

Although it was clear by the early 1960's that a complex genetic mechanism could hardly have evolved with the sole function of rejecting grafts and organ transplants, no one had yet perceived a linkage between the histocompatibility antigens and an organism's broader capacity to mount a defense against invading viruses, bacteria and foreign antigens in general, a defense expressed by the immune system. The crucial connection was established in 1967 by Hugh O. McDevitt of the Stanford University School of Medicine, following studies of the immune response of mice to synthetic polypeptide antigens, which had been synthesized by Michael Sela of the Weizmann Institute of Science. McDevitt showed that the immune response, or *Ir,* genes could be traced to the middle of the *H*-2 complex. Benacerraf, who had been observing similar immune responses in guinea pigs, confirmed McDevitt's findings and, with his co-workers, developed a wealth of information about the nature and function of *Ir* genes and the complex cellular interactions required for their expression.

The prize in physics was shared by James W. Cronin of the University of Chicago and Val L. Fitch of Princeton University. In 1964 Cronin, Fitch and two colleagues, James H. Christenson and René Turlay, studied the decay of neutral *K* mesons as a sensitive test of the CP part of the theorem called CPT. The theorem states that the laws of physics would remain the same if all particles were replaced by their antiparticles (an operation designated C, for charge conjugation), if an event were reflected in a mirror, reversing left and right (an operation called P, for parity), and if the direction of time (T) were reversed. In 1956 two of these presumed symmetries of nature, C and P, were shown to be inexact. In one of several related experiments it was found that electrons arising from the decay of radioactive cobalt atoms placed in a magnetic field emerged preferentially in one direction, in violation of P, or mirror-reversal, symmetry. The symmetry of nature was salvaged when it was recognized that atoms of anticobalt would emit antielectrons in the opposite direction. In other words, nature appeared to observe the symmetry of C and P taken jointly, so that the direction designated "left" in the world of matter would become "right" in the world of antimatter.

Cronin and Fitch sought to test CP symmetry, and indirectly T symmetry, by observing the decay mode of one of the two states of the neutral *K* meson, the state K_L^0, which is called "*K* nought long" because it has a longer lifetime than its companion state, K_S^0, or "*K* nought short." It was then thought that the K_L^0 state would be antisymmetrical if it were reflected in a CP "mirror," a hypothetical device that would simultaneously convert matter into antimatter and interchange left and right. If CP symmetry were invariably observed, the antisymmetrical K_L^0 meson would always decay into another antisymmetrical state; an example of such a state is a set of three pi mesons, or pions. A decay into two pions, which constitute a symmetrical state, would be disallowed. Cronin and Fitch observed that about one in 500 of the K_L^0 mesons decayed into the "forbidden" two-pion state.

After the Cronin and Fitch experiment the only way to salvage CPT symmetry was to assume that the violation of CP symmetry is compensated for by a violation of T symmetry. It follows that nature is not indifferent to the direction of time. Subsequent detailed studies of *K*-meson decays confirmed that time-reversal invariance is indeed violated. Physicists remain confident that CPT symmetry taken as a whole is inviolable.

A number of theorists, including Andrei D. Sakharov among the earliest, have found in the CP violation an opportunity to explain why the big bang that created the universe resulted in a world made of particles rather than antiparticles or a mixture of the two. The assumption is that initially matter and antimatter were equally abundant but that when the two classes finished annihilating each other, a small number of matter particles were left over. Everything else had been converted into photons, or quanta of electromagnetic radiation. In the observed universe photons outnumber the residual material particles by a factor of a billion. In 1967 Sakharov offered a detailed mechanism to explain this ratio, based in part on CP violation. Other theorists have made alternative proposals (see "The Cosmic Asymmetry between Matter and Antimatter," by Frank Wilczek; page 82).

Half of this year's prize in chemistry was awarded to Paul Berg of Stanford;

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the other half is to be shared by Walter Gilbert of Harvard University and Frederick Sanger of the University of Cambridge. Sanger won a Nobel prize in chemistry in 1958 for determining the structure of insulin. Berg has been in the forefront of the international effort that has clarified how the genetic information coded in DNA is transcribed into RNA and ultimately translated into protein molecules. About 10 years ago he foresaw the possibility of employing tumor viruses to insert new genes into animal cells. In 1972, with the help of gene-splicing techniques worked out by Peter Loban and A. Dale Kaiser of Stanford, Berg and his co-workers opened and then joined into a single hybrid entity the circular DNA molecule of an animal tumor virus, SV40, and the circular DNA molecule of a bacterial virus. This was the first recombinant-DNA molecule derived wholly from living organisms. At that point, concerned about safety, Berg abandoned plans to insert the hybrid DNA molecule into bacterial cells to see whether it would be accepted by the cell. (There is now reason to believe the hybrid would not have been acceptable to a bacterial host.)

Within a year a collaborating group from Stanford (Annie C.-Y. Chang and Stanley N. Cohen) and the University of California School of Medicine (Herbert W. Boyer and Robert B. Helling) announced the construction of a biologically functional DNA hybrid by a different approach and with genes less worrisome than those employed by Berg. The new hybrid combined genetic information from two strains of the bacterium *Escherichia coli*. When it was inserted into other *E. coli* cells, the hybrid DNA was replicated and the replicas expressed the genetic information of both parts of the hybrid molecule.

In 1974 the National Academy of Sciences, concerned about the "potentially biohazardous consequences" of some of the hybrid DNA molecules that might be made with the new gene-splicing techniques, called on Berg to form an advisory committee to review the matter. After an international meeting in 1975 at the Asilomar Conference Center in California strict guidelines were issued for recombinant-DNA experiments. The early fears have now largely subsided and gene splicing is being exploited on a commercial scale to manufacture such substances as human insulin and interferon.

These developments in genetic engineering would have been impossible without methods developed independently by Gilbert and Sanger for rapidly identifying the sequence of nucleotides, or genetic-code units, that endow molecules of DNA with their distinctive properties. The code employs four nucleotides, built on four bases: adenine, thymine, cytosine and guanine. Each gene is defined by a unique sequence of at least several hundred nucleotides. With the methods worked out by Sanger and Gilbert (with their respective collaborators Alan R. Coulson and Allan Maxam) a sequence of 200 or more nucleotides can be determined in a few days. With earlier methods the task would have required years. The new method enabled Sanger and his coworkers to establish the complete sequence of 5,375 nucleotides in a small bacterial virus, ϕX 174. Gilbert and his colleagues have exploited the rapid sequencing methods to find control points in the DNA molecule that determine whether a gene is actively translated into protein or is "repressed."

The Alfred Nobel Memorial Prize in economics was awarded to Lawrence R. Klein of the University of Pennsylvania "for the creation of econometric models and their analysis of economic fluctuations and economic policies." Klein says he was attracted to economics because he was "a child of the Great Depression." He received his doctorate in economics from the Massachusetts Institute of Technology in 1944 and two years later had developed a primitive econometric model that contradicted widespread predictions that the depression of the 1930's would resume after the war. In the early 1950's, in collaboration with A. S. Goldberger at the University of Michigan, he developed the Klein-Goldberger model, the first to be used regularly for forecasting the business cycle. Subsequently his methods were adopted in the construction of econometric models for a number of countries, including Canada, Japan, the U.K., India, Mexico and the Sudan. Recently Klein has helped to design an econometric model of the U.S.S.R.

After moving to the University of Pennsylvania, Klein began work with Michael Evans on the construction of the Wharton econometric model, which is now in its fourth version. The Wharton model is recognized as the premier instrument for forecasting the U.S. economic outlook. At present Klein is deeply involved in Project Link, centered at Pennsylvania, in which model builders from all over the world have access by means of computer to econometric models of 13 developed, market-economy countries, of developing regions and of the U.S.S.R. and its close allies. Project Link is in regular use for predicting world trade and for testing the consequences of alternative policies.

Death Watch

The confidence with which the worldwide eradication of smallpox was proclaimed last May seems to fly in the face of the common knowledge that it is difficult, if not impossible, to prove a negative proposition. The world was declared to be free of the disease only after a 22-year campaign coordinated by the World Health Organization. Still, how can one be sure that smallpox no longer exists anywhere in the world? Might there not be an undetected case somewhere in a remote region of one of the scores of countries where the disease was endemic not long ago?

The certainty of the eradication is soundly based on the characteristics of smallpox. Man was the only known reservoir of the variola, or smallpox, virus, and there are no asymptomatic carriers; for the disease to survive it had to be transmitted from one afflicted person to a susceptible contact, and from that person to another in an unbroken chain. The breaking of the chain everywhere in the world was attested to by a succession of WHO commissions that visited regions where the disease had been endemic and confirmed that intensive surveillance had discovered no smallpox cases for at least two years. Specimens from some 10,000 suspected cases were examined in the laboratory, but not one of them contained the variola virus. After evaluating these results a Global Commission for the Certification of Smallpox Eradication confirmed the success of the campaign and recommended that vaccination be discontinued everywhere (except for the few investigators continuing to work with the variola virus and with related orthopox viruses). Stocks of freeze-dried vaccine sufficient for 200 million vaccinations will be maintained to deal with any recurrence of the disease.

If the disease is dead, how might it recur? There appear to be three possibilities. One is that live virus maintained in the laboratory could cause infection; such an accident has already happened. Only six laboratories worldwide, however, are now working with the orthopox viruses. Each maintains stringent safety precautions and is checked periodically by WHO inspectors. In two years, when the variola projects now under way should be completed, a decision will be made whether variola virus will be retained anywhere.

A second possibility is that there is indeed a hitherto unknown animal reservoir of the smallpox virus. That is very unlikely: in all the years of the campaign no evidence was found linking a single smallpox outbreak to any source but man. There was concern that an animal reservoir had been discovered in the summer of 1970, when what appeared to be smallpox turned up in a region of Zaïre where human transmission of the disease had been interrupted for more than a year. Workers in a Moscow laboratory collaborating with WHO found, however, that what had been discovered was the first known case in human beings of monkeypox, an animal disease that had been identified in zoo and laboratory animals but was thought not to be transmitted to man.

Clinically, human monkeypox resem-

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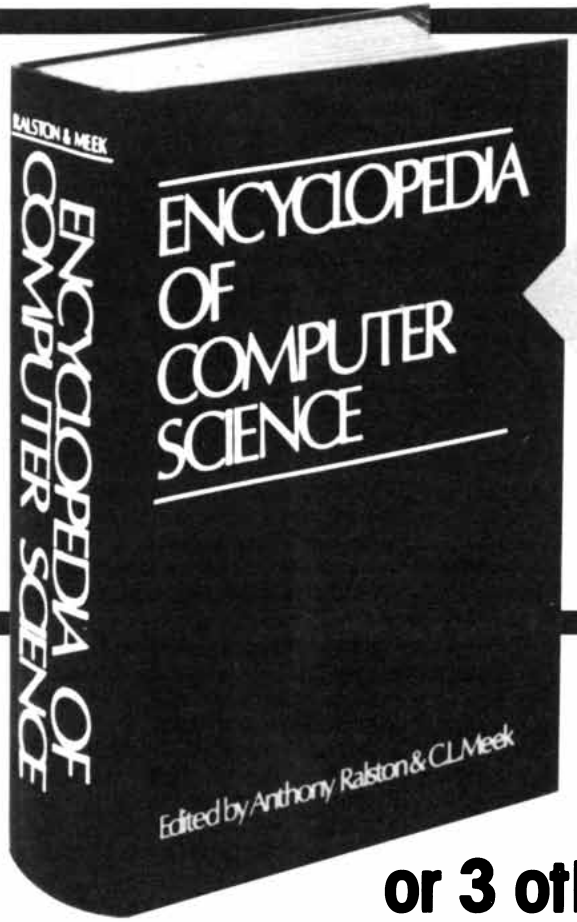

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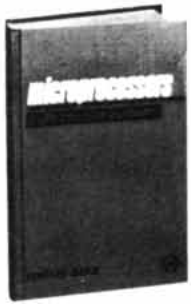

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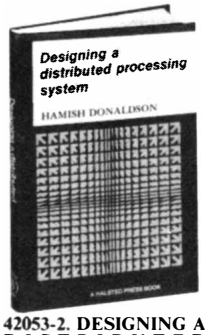

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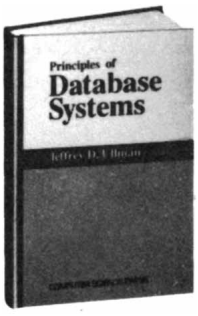

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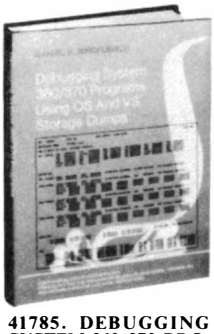

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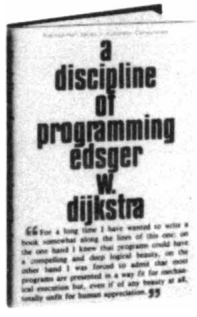

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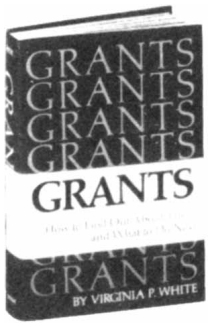

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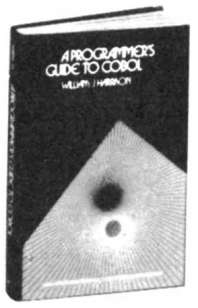

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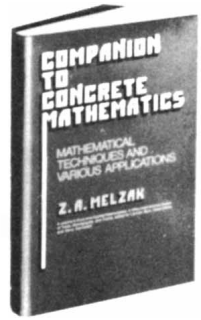

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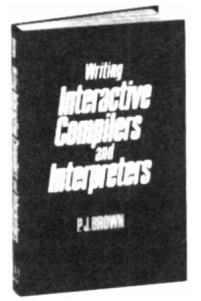

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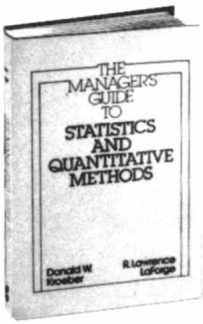

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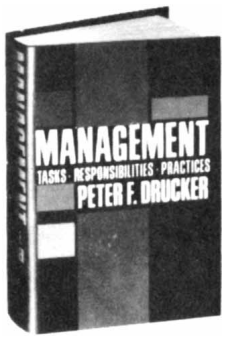

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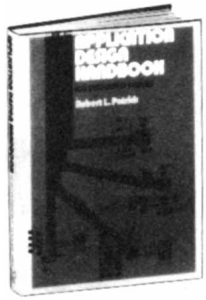

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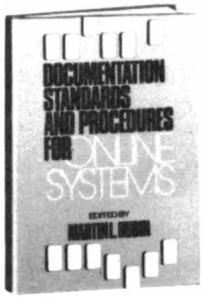

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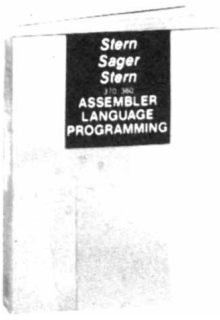

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bles smallpox, with similar skin lesions and residual scars and with a fatality rate of about 15 percent. Epidemiologically, however, human monkeypox is very different. It is a sporadic and infrequent disease, and so far it has been detected only in small villages in the rain forest of central and western Africa. Some 48 cases had been recorded as of last winter. They are reviewed in the *Bulletin of the World Health Organization* by J. G. Bremen of the U.S. Center for Disease Control and five colleagues.

Bremen and his colleagues found only four possible instances of person-to-person transmission of monkeypox. They calculate the secondary attack rate (which is defined as the number of instances of interhuman transmission divided by the number of contacts between monkeypox patients and susceptible persons) as 3.3 percent. The corresponding rate for smallpox ranges from 25 to 40 percent. Monkeypox is apparently an animal disease that is only rarely transmitted to humans, usually to young children or women who handle animal carcasses. Since vaccination against smallpox largely protects human beings against monkeypox, the incidence of monkeypox may increase as vaccination immunity declines, but the disease is not thought to represent a significant public-health hazard.

There remains the possibility that smallpox virus might reemerge by mutation from the monkeypox agent. The Moscow laboratory has reported several instances in which that seemed to have happened. Six cultures originating either in laboratory monkeys or in forest animals appeared to yield some virus that caused white pocks (characteristic of variola virus) when inoculated into the outer membrane of chick embryos, rather than the reddish pocks of monkeypox virus; the whitepox virus could not be distinguished from the variola virus by biological or chemical tests. More recently Svetlana S. Marennikova of the Moscow laboratory reported that passing the monkeypox virus through hamsters yielded some mutants that gave rise to white pocks and were indistinguishable from the variola virus.

The similarity of the presumed mutants to the variola virus has been confirmed, but not the derivation from monkeypox virus. Workers in two other laboratories generated a large number of monkeypox mutants and compared their DNA to that of the variola virus by analysis with restriction enzymes; none of the mutants was very similar to the smallpox virus. Direct comparison of the restriction-enzyme maps of the Moscow mutants with maps of the monkeypox virus from which they were thought to be derived suggested that the monkeypox virus could not in fact have given rise to the variola-like virus. The most likely explanation seems to be that the monkeypox preparations were contaminated with smallpox virus present in the same laboratory, but such contamination cannot be proved. The most comforting evidence against mutation is epidemiological: intensive surveillance of the region where monkeypox seems to be prevalent continues to turn up nothing but monkeypox.

Third Carbon

Carbon is responsible for more diversity in the structure of molecules than all the other chemical elements combined, yet it was long thought to bond to itself to yield only two kinds of crystal. In diamond, which forms at high temperature and high pressure, each carbon atom makes a single bond with each of four neighbors in a three-dimensional array. Each bond represents the sharing of a pair of electrons. In graphite, which forms at low temperature and low pressure, the carbon atoms lie in planes that consist of flat, six-carbon rings in which single and double bonds alternate. Each double bond represents the sharing of two pairs of electrons. There is no sharing of electrons between

carbon atoms in adjacent planes; hence the crystal lattice of graphite is weak, and graphite is notably soft.

In 1968 a third crystalline form of carbon was discovered almost simultaneously in the U.S. and the U.S.S.R. Although its crystal structure has not yet been fully elucidated, it now appears to be a set of forms in which carbon atoms are linked by a mixture of single and triple bonds. In each triple bond three pairs of electrons are shared.

The new crystalline forms have been given the name carbyne, *-yne* being the standard suffix for triply bonded carbon. The forms range in hardness from soft to superhard, or almost as hard as diamond. They tend to condense from gaseous carbon at high temperature and low pressure. The pressure can, however, approach a million pounds per square inch, the minimum pressure required for the formation of diamond. Carbyne has now been found in the midst of ordinary graphite from several natural deposits, and it has been synthesized in the laboratory. It is known to be a constituent of meteorites and of the dust in interstellar space. Far from being rare, carbyne may turn out to be as common in the universe as graphite.

The existence of carbyne in space was first surmised two years ago, when certain features of infrared radiation from space were identified by Adrian S. Webster of the University of Cambridge as being the emission of molecules that include a chain of from nine to 11 carbon atoms joined by alternating single and triple bonds. The molecules each had only a single hydrogen atom. It was hard to imagine how a molecule that is so complex and yet so poor in hydrogen, which predominates in the universe, could be built up in space. Webster hypothesized that it was a fragment broken off from a carbyne crystal.

Many reports in the scientific literature now concern the presence of carbyne in the meteorites known as Allende and Murchison. Both are rich in carbon and both are thought to be ancient: they have apparently undergone no alteration by melting or collision since the time the solar system formed. Three techniques have been brought to bear on the meteorites to reveal the presence of carbyne. In one technique, employed by A. Greenville Whittaker and his colleagues at the Aerospace Corporation, electrons are scattered from crystals in samples of the meteorites; the scattering angles reveal the positions of atoms in the crystals. The results suggest that parts of the samples have a structure posited for carbyne. The method has also been employed to detect small regions of carbyne in terrestrial graphite.

The other two techniques detect the carbyne more directly. They are practiced by Whittaker's group and by Ryoichi Hayatsu, Robert G. Scott and Martin H. Studier of the Argonne National Laboratory and by Roy S. Lewis and Edward Anders of the University of Chicago. Molecular fragments are liberated from the meteorites by heat or by bombardment with a beam of particles. During the first few seconds the fragments prove to be abundant at masses that are multiples of the mass of a carbon atom. This implies that the fragments are chains of carbon atoms. The even multiples predominate over the odd, a result that is taken to reflect the alternation of single and triple bonds in the fragments. The triple bonds are more resistant to breakage. If the carbon were in the form of graphite, fragments six times as massive as a carbon atom would be common. If the carbon were organic, hydrogen would be present and the fragments would have masses different from those of carbon atoms alone.

A recent result is the discovery that the carbyne in the Allende and Murchison meteorites has apparently absorbed trace amounts of inert gases, among which xenon has particular importance. Typically the gases accumulate because the nuclei of heavier atoms in the meteorite break up either through radioactive decay or from the impact of a high-energy cosmic ray. On the hypothesis that the cloud of gases that condensed to form the solar system was homogeneous, the proportions of the various isotopes of an inert gas should be the same in any sample of the solar system's substance. Conversely, an unusual mixture of isotopes suggests two possibilities: the material in which the isotopes lie is not broadly representative of the solar system, or perhaps it originated somewhere else.

The nine isotopes of xenon all turn out to be present in the carbyne of the Allende meteorite in unusually high concentration. The enrichment in the heavier isotopes implies an origin in the radioactive decay of an extremely heavy element. In the Allende meteorite, however, no element fits the pattern. The investigators hypothesize that the element may have been a superheavy one not found in the solar system today.

The origin of the xenon in the carbyne of the Murchison meteorite may be even more exotic. Here the pattern of relative concentration of the isotopes of xenon suggests the radioactive decay of nuclei that were built up by a slow capture of neutrons. The pattern corresponds in particular to models of slow neutron capture in red-giant stars, which have exhausted their hydrogen and glow instead by the fusion of helium. In changing their nuclear fuel such stars develop an extended gaseous envelope.

The history of the carbyne in the Murchison meteorite would then begin in the atmosphere of a red-giant star, where carbyne might have condensed from gaseous carbon several billion years ago. The carbyne would take up traces of the matter in the star. It would be matter that had been synthesized in part by slow neutron capture, and in time the radioactive decay of the matter would yield isotopes of xenon. Somehow the carbyne would be swept into the cloud of gas that condensed to form the solar system, where it was incorporated into a matrix that eventually fell to the earth.

The Uri Awards

James Randi is a professional magician who takes a particular interest in credulousness about paranormal phenomena, notably the uncritical acceptance of the remote bending of spoons and stopping of clocks by the Israeli magician Uri Geller. Recently Randi announced his first annual "Uri Awards." Each award is a bent spoon mounted on a plastic base. Awards were given in several categories.

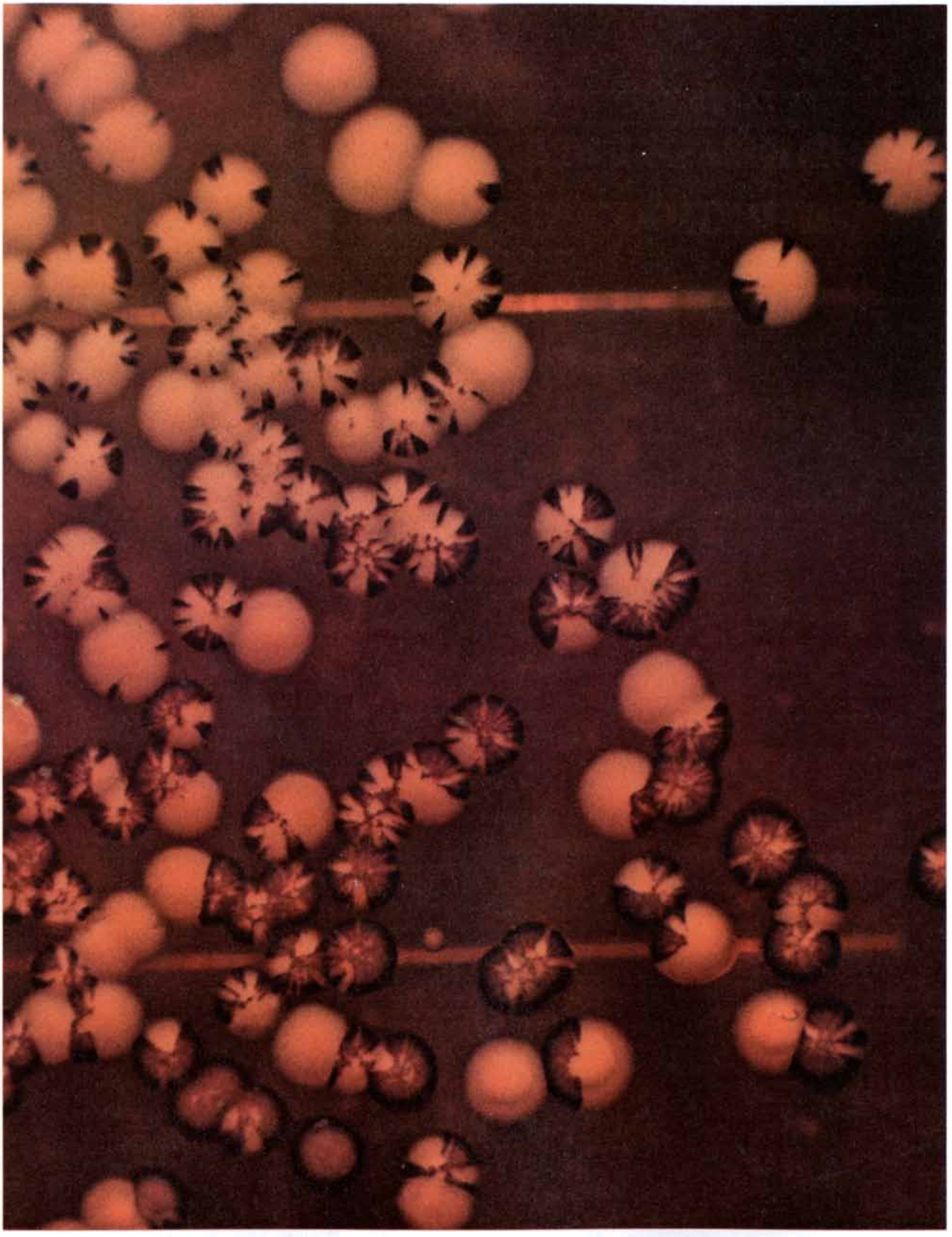
The award in the academic category ("to the scientist who says the dumbest thing about parapsychology") was given to William Tiller of Stanford University, "who declared that even though the experiments of the parapsychologists and the experimenters themselves may be subject to doubt, there is so much evidence produced for the paranormal that the sheer volume indicates that there is something there, regardless of the poor quality of the data."

The award in the funding category ("to the funding organization that awards the most money for the dumbest things in parapsychology") was given to the McDonnell Foundation, which gave $500,000 to Washington University for the investigation of psychics. According to a parapsychologist at the university, the money "was to be devoted primarily to the investigation of children who bend spoons and keys."

The award in the performance category ("to the psychic who takes in the most people with the least talent") went to Philip Jordan, "a conjuror who does the table-tipping trick and was appointed an officer of the court in Binghamton, N.Y., to assist defense attorney Robert L. Miller in selecting jurors according to the color of their 'auras.'"

The award in the media category ("to the news organization that supports the most outrageous claims of the paranormalists") was given to Prentice-Hall and American International Pictures, "who sold the public the 'true story' of *The Amityville Horror* via 15 hardcover printings, millions of paperback sales and a highly successful motion picture. It was a fabrication based on the barest of evidence and perfectly ordinary events."

News of the awards was presented in the journal *The Skeptical Inquirer,* which reports Randi as saying that recipients were notified of the honor by telepathy and were "free to announce their winning in advance, by precognition, if they so desired." Randi intends to repeat the awards next year.



PRESENCE OF PLASMIDS in bacteria and their autonomous behavior are revealed in a photograph, made by the author, of colonies of *Staphylococcus aureus* growing on a temperature gradient: from 30 degrees Celsius at the bottom to 40 degrees at the top. Most of the cells originally plated on the agar contain a plasmid with a gene coding for penicillinase. Cells that have the plasmid and produce penicillinase stain purple; those without the plasmid, lacking penicillinase, stain orange. The plasmid's replication (but not the host cell's) is temperature-sensitive, so that the higher the temperature is, the more often cells lacking the plasmid and penicillinase are generated. When a plasmid is lost from a cell, the cell's progeny stain orange rather than purple, giving rise to colonies with radial purple and orange sectors.

Plasmids

These accessory genetic elements in bacteria, best known as carriers of resistance to antibiotics and as vehicles for genetic engineering, are actually subcellular organisms poised on the threshold of life

by Richard P. Novick

The living cell is the only natural environment within which the intricate chemistry of life can proceed. As such it is the fundamental unit of biological organization for multicellular organisms as well as for unicellular ones. It is also an ecological niche occupied by a variety of subcellular, submicroscopic organisms—organisms whose structures and reproductive dynamics are so profoundly different from those of cellular forms that they should probably be assigned to a new taxonomic kingdom.

The best-known of these curious life forms are the viruses: elegantly symmetrical particulate structures composed essentially of a molecule of nucleic acid encapsulated in a protein coat. They can exist outside the cell, but there they are inert. Once inserted into a cell, however, their nucleic acid (RNA or DNA) reprograms the cell's metabolic apparatus to the service of the virus; the nucleic acid replicates and is encapsulated, in the process destroying the cell and releasing a new crop of virus particles.

There is a less familiar class of subcellular organisms: the plasmids, found for the most part in bacteria. Plasmids are simpler in organization than viruses. They have no protein coat and no extracellular phase; they are no more than circular molecules of double-strand DNA that multiply independently within host cells and are inherited in a regular manner as those cells proliferate. For a time after their discovery about 30 years ago plasmids were thought to be something of an oddity. Now they are known to be extremely common. Plasmids are found in virtually all bacterial species; they are probably present in most individual bacterial cells. They are not essential to the everyday metabolism of the host cell, and so it is almost always possible to isolate a variant of any plasmid-carrying strain that no longer has any plasmids. The loss is permanent: the cell cannot regenerate a new plasmid but can only acquire it from another bacterium. The information encoded in a plasmid (or in any other DNA molecule) can be developed only through the prolonged and tortuous process of organic evolution.

Plasmids account for only a small part of a cell's genome: typically between a fraction of 1 percent and 2 or 3 percent. That small fraction of the cell's hereditary information, however, codes for important accessory genetic traits that are not ordinarily encoded by the bacterial chromosome. Plasmids alone carry the information for conjugation, or "mating," between bacteria. They are uniquely responsible for several diseases of plants and animals. They enable their bacterial hosts to utilize many complex substances as nutrients. And they confer on their host cells the ability to resist a wide variety of toxic agents, including antibiotics.

It was the importance of these genetic traits, and in particular the clinical importance of antibiotic resistance, that first drew the close attention of biologists to plasmids and led to some understanding of their role in bacterial genetics. In the past five years plasmids have been intensively investigated, dissected and manipulated for another reason: they were found to be ideal vehicles for introducing nonbacterial genes into bacteria by the techniques of molecular cloning and thereby purifying and greatly amplifying the foreign genes. The molecular cloning of DNA has already revolutionized genetic analysis and, because the bacteria can sometimes be induced to manufacture nonbacterial proteins, is the basis of a new "applied genetics" with great promise for medicine and industry.

Plasmids as Organisms

In a broader perspective plasmids are significant because they force biologists to reappraise the essential nature of living things. Plasmids are poised at the very threshold of life, between the inanimate and the animate. Are they merely bits of DNA that are integral parts of the cell's genome, contributing a little extra genetic information? Or are they independently evolving subcellular organisms more or less on a par with the viruses? The second view is strongly supported by a number of significant observations.

In the first place, each plasmid autonomously controls its own "copy number": the number of replicas of the plasmid present in a host cell. Moreover, conjugation between bacterial cells can lead to the exchange of plasmids between different species, and even genera, that are quite unable to exchange chromosomal genes. Finally and most significant, this exchange can result in the transfer from one species to a competing species of a plasmid carrying genes that enable the recipient to survive at the expense of the donor. In other words, the plasmids have evolved the ability to survive regardless of the fate of their host species—something that would be inconceivable, within the framework of evolution through natural selection, for an element that was merely a component of a particular organism's genome.

These observations imply that plasmids are indeed independent organisms, members of a hierarchy of subcellular life. Within that hierarchy animal viruses such as those that cause poliomyelitis or yellow fever and bacteriophages, or bacterial viruses, such as T4 can be regarded as predators because they always kill the cells they infect. "Temperate" phages and certain animal viruses, which sometimes kill the host cell but also sometimes coexist stably within the cell without apparently harming or benefiting it, can be considered subcellular parasites. Plasmids, then, can be regarded as endosymbionts: they exist stably within the host cell and often perform a service by supplying the host with adaptive genetic functions, the quid pro quo of the symbiotic state.

The notion that naked molecules of DNA are organisms cannot be squared with the conventional cell-based concept of life. What is common to all living things is that they respond independently to evolutionary forces and duplicate their genetic material autonomously. Any nucleic acid system that controls its own replication should therefore be regarded as an organism. An examination

of the details of the molecular processes that determine the life cycle of plasmids should advance understanding of the very essence of the living state and hence illuminate the borderline between the animate and the inanimate.

The Discovery of Plasmids

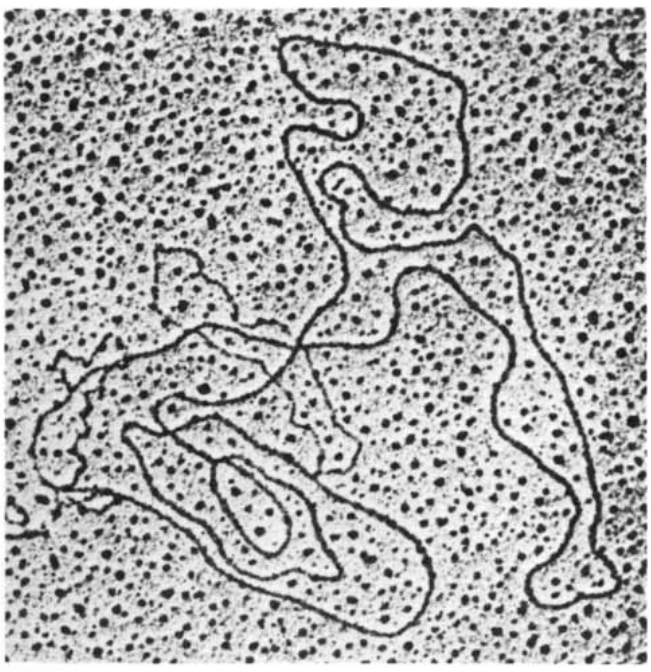
In the early 1950's, soon after the discovery of conjugation in the bacterium *Escherichia coli* by Joshua Lederberg, it became clear that there were two genetically determined "mating" types and that genetic information was physically transferred from a "male," or donor, type to a "female," or recipient. The genetic character of "maleness"—the F (for fertility) factor—was transferred far more often than any other trait. Moreover, the F factor was transferred independently of any other known donor genes: it was not "linked" to any of them. In the case of a eukaryotic cell (a higher cell with a nucleus and with its DNA organized in discrete chromosomes visible under a light microscope) such a finding would have meant that the trait was encoded by an extrachromosomal gene. Lederberg saw that the F factor was somehow similar to extrachromosomal genetic elements in the cytoplasm of higher organisms, and in 1952 he coined the word plasmid to refer to all such extrachromosomal genetic systems. The structural organization of the genome in bacteria was not well understood at that time, and so the precise significance of the absence of linkage was not entirely clear.

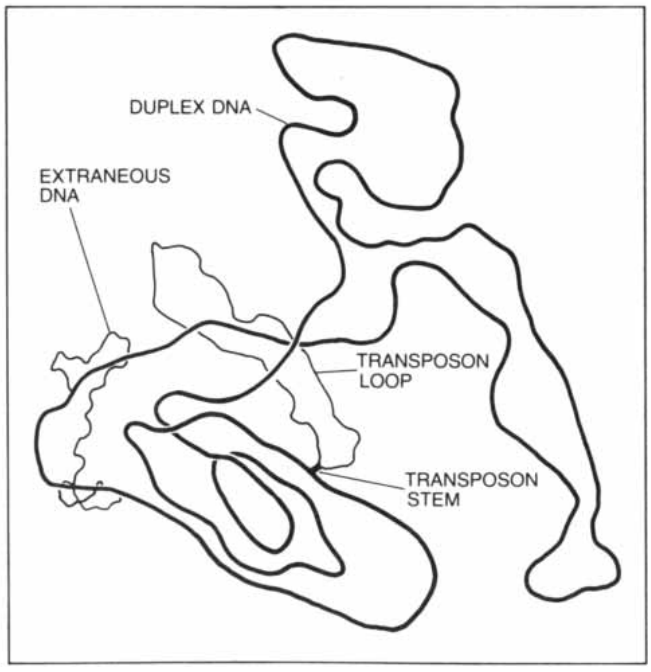
It was soon clarified, however, by further investigation of the F factor. In 1953 William Hayes, who was then working at Hammersmith Hospital in London, discovered that under certain circumstances the F factor could in fact become linked to standard markers and could thereupon bring about their sequential transfer during conjugation. It developed that most of the genes of *E. coli* are arrayed along a single continuous structure that behaves in formal genetic terms like a closed loop—the bacterial analogue of the eukaryotic chromosome. The F factor is physically attached to this structure at a specific site; the loop opens at the site of F attachment during conjugation and passes as a linear structure to the recipient cell. It was also observed that the attached F factor could occasionally become detached, sometimes entraining a segment of the loop near its attachment site. Given a bacterial chromosome, it was now possible to consider the F factor to be a specifically extrachromosomal element that sometimes became integrated into the chromosome.

At the Pasteur Institute in Paris François Jacob and Elie L. Wollman noted similarities between the behavior of the F factor and that of a temperate bacterial virus, phage lambda, and another plasmid, ColE1 (which encodes a colicin, a protein that kills *E. coli*). They coined a new term, episome, for a genetic element that could be replicated in either of two states: attached to a host-cell chromosome or free in the cytoplasm.

For a time phage lambda, the F factor, ColE1 and one or two other elements remained the only known episomes. Then in about 1959 a remarkable discovery was made in Japan in the course of a study of patients with bacterial dysentery who did not respond to treatment with ordinarily efficacious antibiotics. The causative bacteria, *Shigella dysenteriae,* contained genes that made them resistant to several antibiotics at once, and the resistance genes were transferred to other intestinal bacteria in much the same way as the F factor [see "Infectious Drug Resistance," by Tsutomu Watanabe; SCIENTIFIC AMERICAN, December, 1967]. These R (for resistance) factors, as they came to be called, had several properties in common with the F factor, including the ability to promote their own intercell transfer by conjugation; some have since been shown to have partial DNA sequences in common with F. Whereas the F factor had been considered a rather special entity, genetically very interesting but not necessarily widespread, the discovery of R factors made it suddenly clear that extrachromosomal genetic elements were important components of the bacterial microcosm, with clinical significance as well as scientific.

Soon after the discovery of R factors in the enteric bacteria I found similar factors in staphylococci. They carried a gene for an extremely potent enzyme, penicillin beta-lactamase (penicillinase), that broke down penicillin, and they were responsible for the resistance to penicillin that was compromising treatment of "hospital staph" in many parts of the world in the early 1960's. The staphylococcal R factors are apparent-





PLASMID HETERODUPLEX is seen in an electron micrograph made by Marjorie M. Schwesinger in the author's laboratory. Plasmids pI258 and pI6187, identical except that the former carries a transposon specifying resistance to erythromycin, were denatured and the separated strands were allowed to reanneal. The heteroduplex has one strand from each of the plasmids. The two strands match perfectly except for the sequence constituting the transposon. As the drawing indicates, the two strands therefore form a double-strand molecule with a single-strand loop: the transposon, which is attached by a short double-strand stem formed by its "inverted repeat" termini.

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ly unable to promote their own transfer by conjugation. They are transferred passively by transduction: a process in which a bit of bacterial DNA is encapsulated in a phage particle (in place of the phage's own DNA) and then introduced into another cell infected by the phage. A substantial proportion of the R factors of enteric bacteria are similarly unable to promote their own conjugative transfer and rely instead on transduction or on mobilization by another, conjugative plasmid that is present in the same cell.

By the mid-1960's it was apparent that most of the R factors in staphylococci and the enteric bacteria (and ColE1 too) were different from the F factor and lambda in that they remained extrachromosomal instead of undergoing reversible integration into the chromosome, and so they did not fit the restrictive definition of an episome. It seemed to me the requirement of reversible integration made it impossible to group together a wide range of clearly related extrachromosomal genetic systems, and in 1963 I suggested that Lederberg's more general term was more appropriate; other workers in the field agreed, and gradually over the next 15 years these mobile extrachromosomal genetic elements in bacteria came to be generally known as plasmids rather than episomes.

Gradually too it became evident that plasmids are responsible for a remarkably wide range of biological activities in bacteria. Appreciation of the role of plasmids (and of some other extrachromosomal genetic systems that have come to light even more recently) has produced a rather dramatic shift in biologists' thinking about genetics. The traditional view was that the genetic makeup of a species was about the same from one cell to another and was constant over long periods of time. Now a significant proportion of genetic traits, not only in bacteria but also in higher organisms, are known to be variable (present in some individual cells or strains, absent in others), labile (subject to frequent loss or gain) and mobile (transferable between individual cells or transposable from one site to another in a cell)—all because those traits are associated with plasmids and other atypical genetic systems.

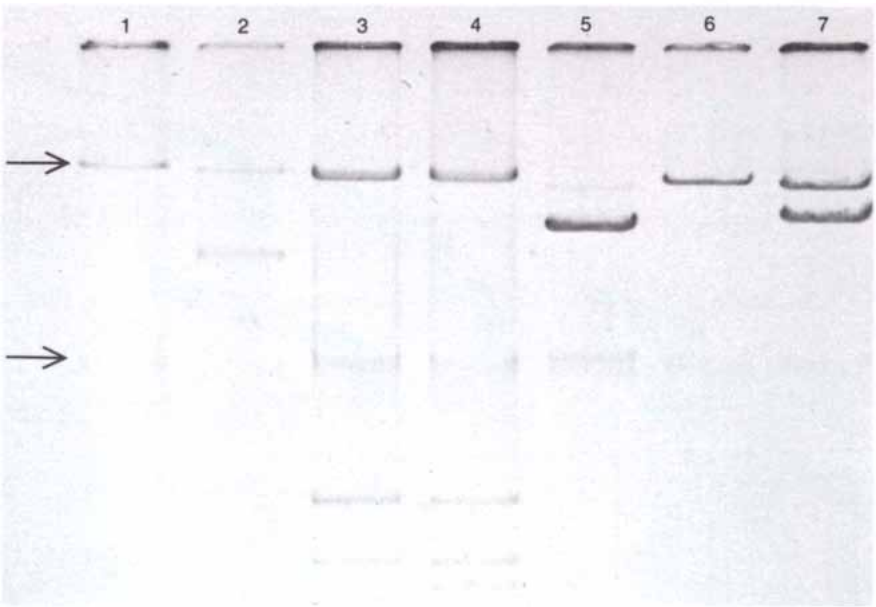
The Variety of Plasmids

In 1964 Mark Richmond and Eric Johnston of the National Institute for Medical Research in England showed that the staphylococci responsible for an outbreak of postsurgical "suture line" infections carried a plasmid enabling them not only to destroy penicillin but also to grow in the mercury-based disinfectant used to sterilize the sutures. In my laboratory at the Public Health Research Institute of the City of New York, Christine Roth and I found that our staph plasmids carried genes for resistance to penicillin and mercury compounds and also to a variety of other heavy-metal compounds lethal to staphylococci: salts of cadmium, bismuth, lead and antimony and the ions arsenate and arsenite. Various heavy-metal resistance genes have since been found on some *E. coli* R plasmids.

Many other kinds of specialty genes are carried by plasmids rather than by the bacterial chromosome, including the genes for some human diseases such as traveler's diarrhea and staphylococcal impetigo, for the fermentation of milk by lactic acid bacteria to produce cheese and for much of the metabolic versatility of the pseudomonads, soil bacteria that can degrade a variety of complex hydrocarbons (and may have applications such as cleaning up oil spills and converting petroleum into edible proteins). Plasmids give rise to a curious gas vacuole in salt-loving bacteria; they are thought to control the synthesis by *Bacillus thuringiensis* of an insecticide widely applied to control the gypsy moth and tent worms.

Apart from the rather special nature of many of their functions, plasmid genes are not basically different from other genes. For the most part they encode proteins that are active enzymes, and these proteins are synthesized by the same metabolic machinery—supplied by the cell—as other proteins.

The most intensively studied of the plasmid-derived behaviors has been resistance to antibiotics and other substances toxic to bacteria. It was the first widespread plasmid-carried property to be encountered; it presents a grave medical problem; it is a convenient selective trait for experiments in bacterial genetics and in molecular cloning, and analyzing it sheds light on the origin of plasmids and on how they accumulate a variety of genes.



GEL ELECTROPHORESIS reveals the presence of plasmids in bacteria. Daniel A. Portnoy and Stanley Falkow of the University of Washington at Seattle prepared cell-free extracts of seven strains of the bacterium *Escherichia coli,* eliminated most of the chromosomal DNA and placed samples in slots at one end of an agarose gel slab. Application of an electric current caused the negatively charged DNA molecules to migrate toward the positive electrode at a rate inversely proportional to the logarithm of their size. The DNA, labeled with a fluorescent dye, is visualized as a set of linear bands. The top band represents material still in the origin wells. The next band (*top arrow*), representing a plasmid responsible for traveler's diarrhea, is common to all samples except No. 5—a strain that does not cause the disease. The other distinct bands correspond to various plasmids, some of which specify antibiotic resistance. The faint, more diffuse bands (*bottom arrow*) correspond to segments of residual chromosomal DNA.

Resistance to Antibiotics

At least three different strategies have evolved by which plasmid-associated genes resist toxic substances, including those we know as antibiotics. The simplest is outright destruction of the antibiotic. This is the case for resistance to penicillin, chloramphenicol, aminoglycoside antibiotics such as streptomycin, and mercury compounds. Another strategy involves blocking access of the toxic substance to its particular target in the cell. The macrolide antibiotics, such as erythromycin, act by binding to the cellular organelles called ribosomes and thereby blocking the synthesis of proteins; Bernard Weisblum and his colleagues at the University of Wisconsin Medical School have shown that the plasmid-borne resistance genes attach a methyl group to the ribosomal RNA and so prevent the binding of the antibiotic. Tetracycline is apparently kept out

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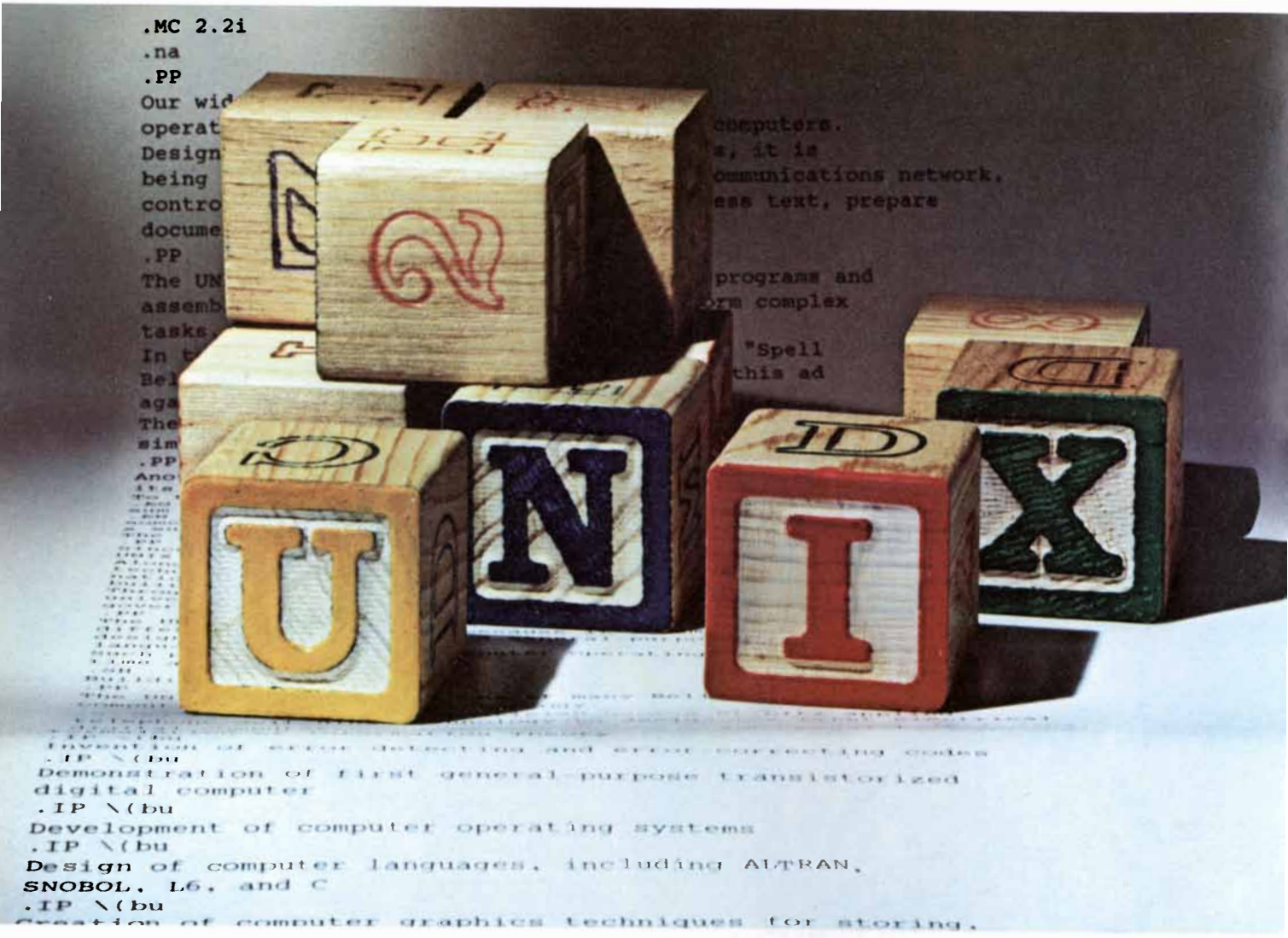

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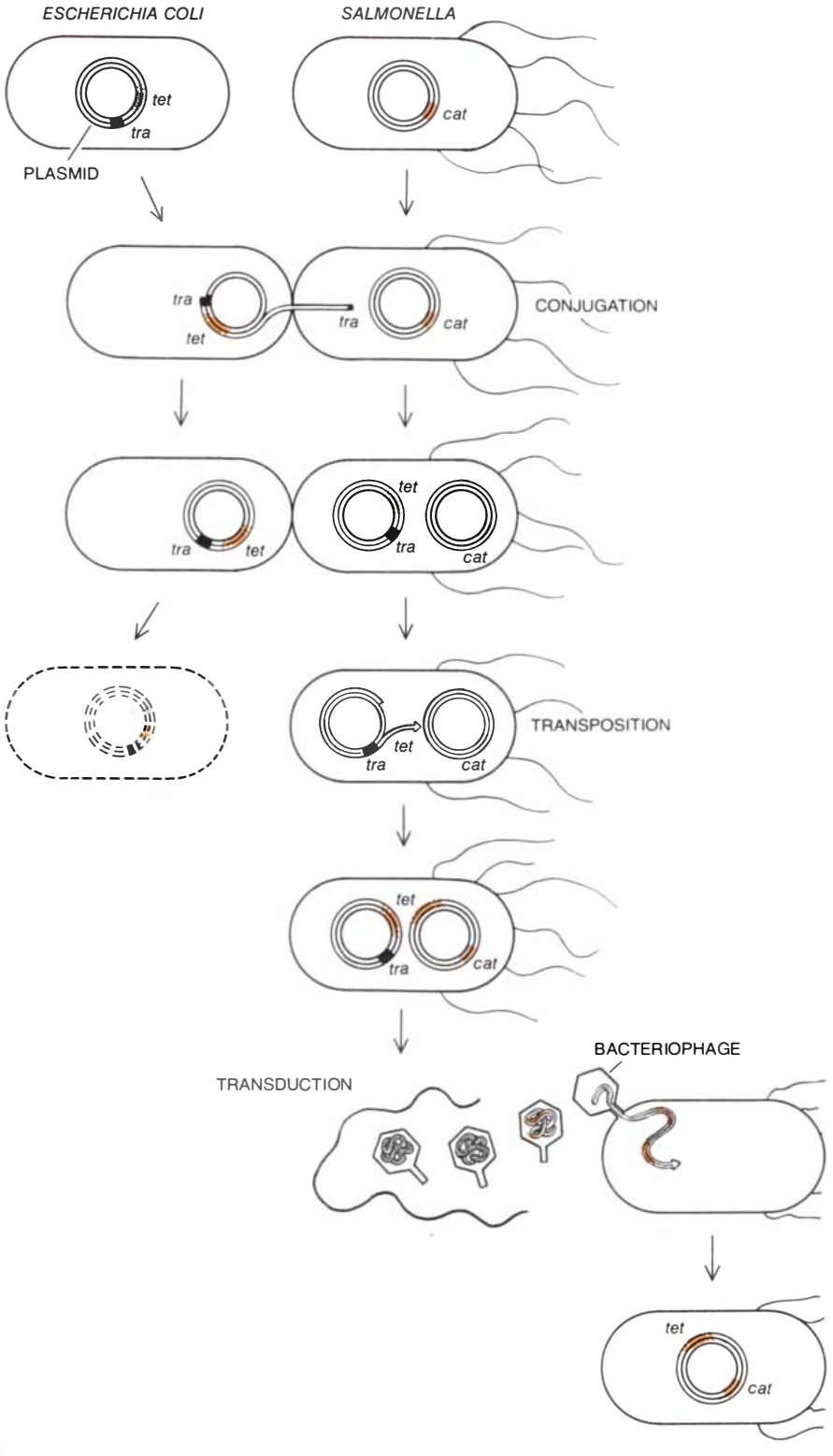


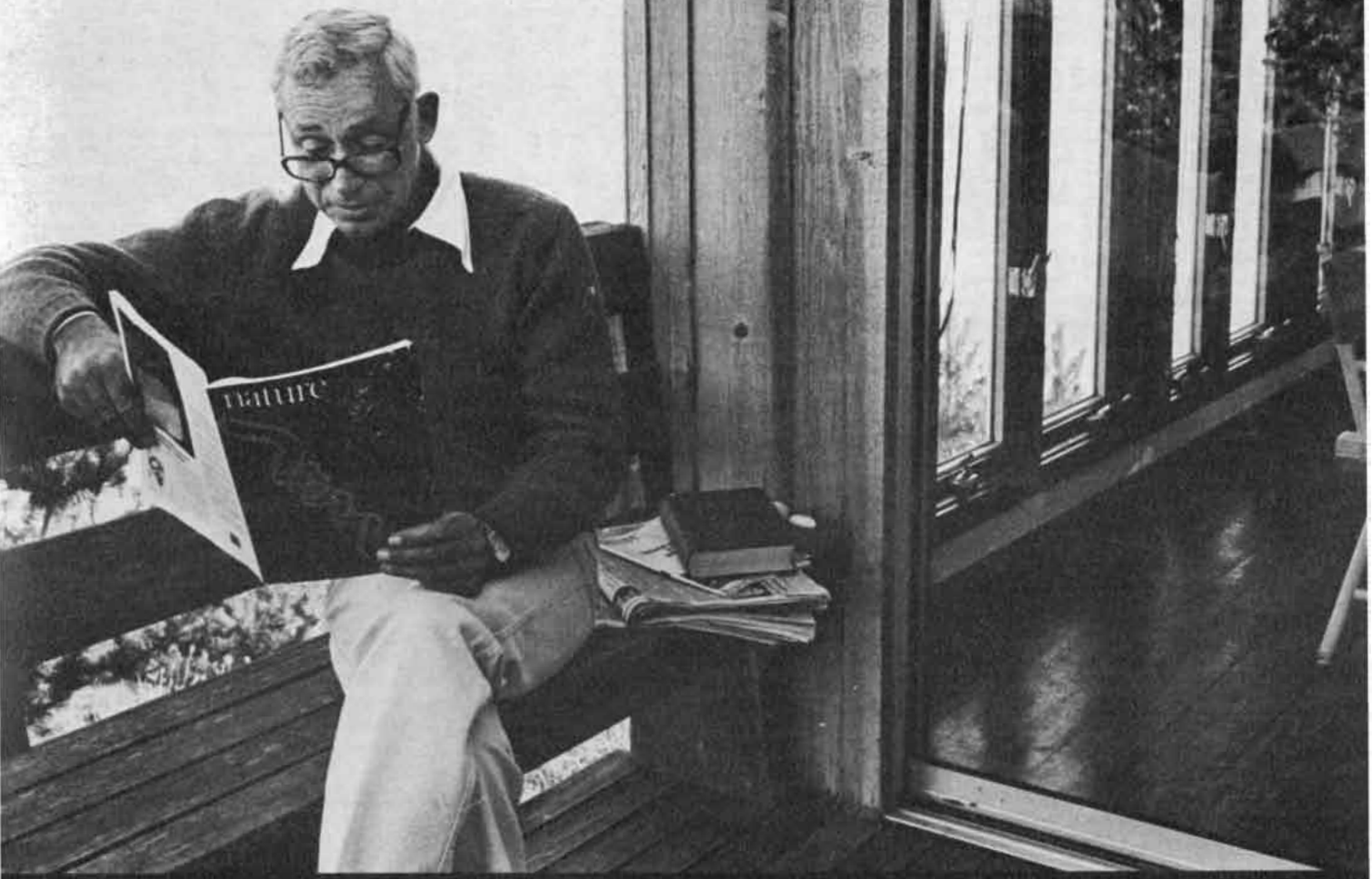
GENES FOR RESISTANCE to antibiotics are collected by plasmids and are transferred from one bacterial cell to another by various mechanisms, sometimes enabling a plasmid to survive the death of its host. Here two bacteria are depicted (*top*): an *Escherichia coli* cell containing a plasmid with genes for transmission by conjugation (*tra*) and for tetracycline resistance (*tet*) and a *Salmonella* cell with a plasmid carrying a gene for resistance to chloramphenicol (*cat*). The two cells conjugate and the *tet*-carrying plasmid is transferred to the salmonella, rendering it resistant to tetracycline as well as to chloramphenicol. In an environment containing both antibiotics the *E. coli* die, but their plasmid survives in the successful host. The *tet* gene is on a transposon that subsequently moves from one plasmid to the other, which then carries genes for resistance to both antibiotics. Finally the double-resistance plasmid may be transferred again, by transduction. A bacterial virus infects the salmonella and proliferates, killing the cell; one phage particle incorporates the plasmid instead of viral DNA and transfers it to new cell.

of the cell by plasmid-encoded proteins that modify some specific transport system in the cell envelope. Simon D. Silver of Washington University has found that staphylococcal resistance to the arsenate ion is the result of an active pumping process somehow mediated by plasmid genes; the ions enter the cell without difficulty but are pumped out again as fast as they get in.

The third strategy, substitution of a bypassing process for a process inhibited by the antibacterial agent, provides resistance to the sulfa drugs and trimethoprim, which act by inhibiting bacterial enzymes required for the synthesis of the essential vitamin folic acid. (Human beings, unlike bacteria, are unable to synthesize the vitamin; they depend on dietary sources, which provide too little folic acid to sustain infecting bacteria.) Plasmid-borne resistance to these drugs involves the substitution for the drug-inhibited enzyme of another enzyme that has the same function but is insensitive to the inhibition.

Clearly such genetic strategies as these could not have developed overnight; they must have arisen in the slow course of organic evolution, and their existence must predate the clinical application of antibiotics by millions of years. As a matter of fact an examination of bacteria isolated and stored long before the antibiotic era, or isolated recently in remote places unlikely to have been exposed to antibiotics, often reveals the presence of fully developed R plasmids.

I should make it clear that plasmids are not the only source of bacterial antibiotic-resistance traits. Mutations in chromosomal genes can also give rise to such traits, and for several years chromosomal mutations were mistakenly assumed to be responsible for clinical antibiotic resistance. The confusion arose from laboratory experiments in which pure strains of bacteria were challenged by an antibiotic. If a spontaneous mutation arose on a bacterial chromosome and fortuitously enabled a cell to resist the drug, that cell proliferated as the other cells died. Such a mechanism could not, however, explain the naturally occurring resistance to several drugs that appeared simultaneously in bacteria infecting a person being treated with a single antibiotic. Moreover, the resistant mutants isolated in laboratory experiments were shown to grow poorly in the absence of the particular antibiotic that had selected for them. Chromosomal resistance mutations modify the antibiotic-sensitive cellular target—say a ribosome or the cell wall—in a way that reduces its general efficiency; the resistant mutants are evolutionary cripples, and under natural conditions they rapidly die out. Plasmid-determined resistance traits, in contrast, have evolved over time to be exquisitely specific: they



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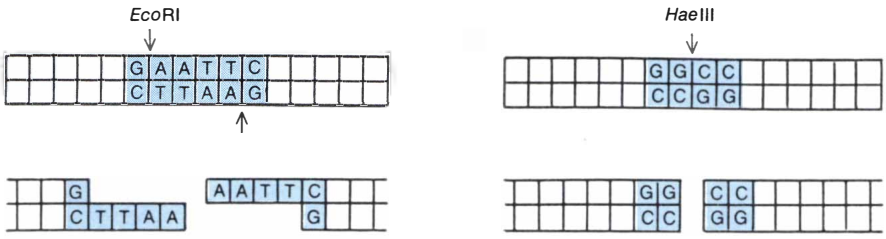


RESTRICTION ENDONUCLEASES are enzymes that cleave DNA at sites determined by the sequence of the DNA's component nucleotide bases *A, G, T* and *C*. Each enzyme (two of which are illustrated here) recognizes a particular palindromic sequence of base pairs and cuts each DNA strand between specific bases of that sequence. If the sites are offset from each other as in the case of *Eco*RI (*left*), the cleavage yields fragments with complementary, overlapping single-strand ends. Such "sticky end" fragments join readily with other fragments generated by same enzyme and are particularly suitable for making new combinations of fragments.

protect the antibiotic's target in the cell without significantly reducing the cell's general adaptivity. That is the key to their success.

Evolution of Plasmids

How and why did the resistance genes of plasmids evolve? Julian E. Davies of the University of Wisconsin, noting that antibiotics are manufactured by bacteria and fungi, has suggested that the same microorganisms evolved resistance genes to protect themselves from their own products. He and his co-workers have shown that *Bacillus circulans,* which produces the aminoglycoside antibiotic butirosin, synthesizes an enzyme that inactivates butirosin and several other aminoglycosides, including neomycin. The gene specifying the enzyme can be transferred to *E. coli* by recombinant-DNA techniques, rendering the *E. coli* resistant to neomycin.

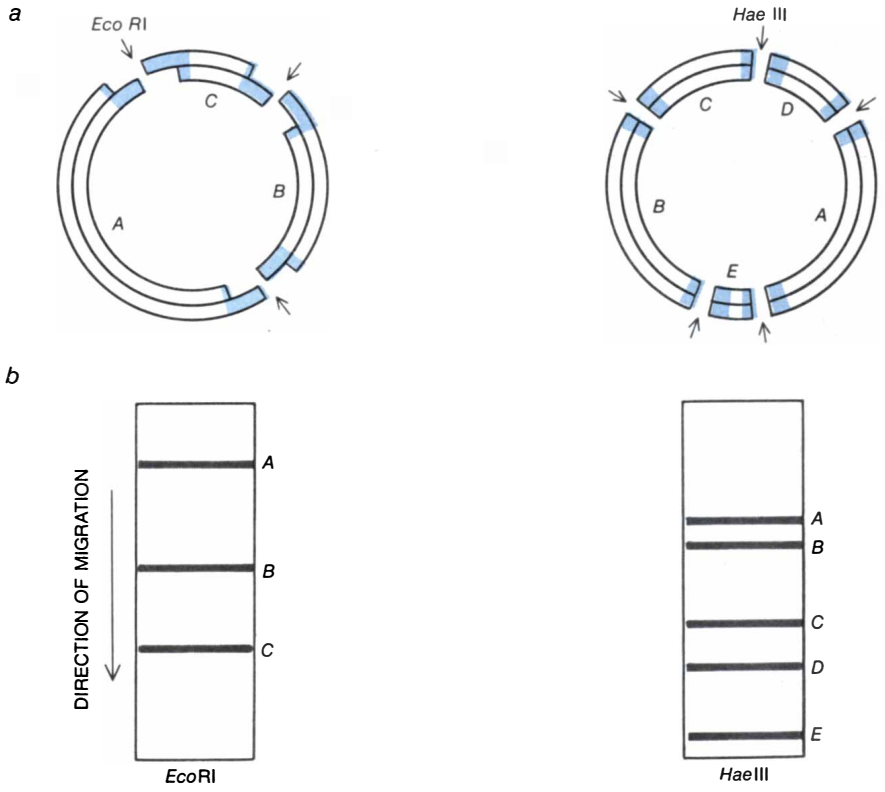
In my own view there is an additional possibility. Antibiotics are manufactured by organisms in the soil, which also contains traces of toxic heavy metals. The presence of these compounds in the soil (even at low concentrations) could have evoked the evolution of resistance genes among sensitive soil bacteria, as primary plasmid genes or as chromosomal genes that were later transferred to plasmids. In either case the genes would have made their way to nonsoil bacteria that cause infections in animals.

This view is supported by the fact that although penicillin is manufactured by fungi (which are eukaryotes, not bacteria), many nonpathogenic soil bacteria synthesize a penicillinase similar to the enzyme responsible for penicillin resistance in pathogenic animal bacteria. Plasmids specifying penicillinase have been found in staphylococcus strains isolated before the discovery of penicillin. And plasmids specifying resistance to tetracycline have been found in several species of soil bacteria. In my laboratory June Polak has shown that one such plasmid can be transferred to *Staphylococcus aureus,* which thereupon becomes resistant to tetracycline; the plasmid is almost identical with a plasmid that is native to staphylococci and specifies resistance to kanamycin. The implication of this soil-bacteria hypothesis is that the large-scale application of antibiotics in medicine and agriculture has disrupted a very old ecosystem in which a balance had been achieved between producers of antibiotics and target organisms with resistance genes.

When R plasmids were first discovered, they commonly carried one or two resistance traits. Today it is not uncommon to find a plasmid carrying genes for resistance to as many as 10 antibiotics. The rather frightening clinical implication of this accumulation of resistance genes is that treating a patient with a single drug can promote the selection of an organism resistant to everything in sight. Analysis of this phenomenon has revealed another astonishing property of plasmids and related genetic systems: genetic transposition.

At first it was assumed, by analogy with the F factor's behavior, that chromosomal mutations specifying resistance had been "picked up" by R plasmids temporarily integrated into the chromosome, which later emerged entraining a segment of chromosomal DNA. It was impossible, however, to find DNA sequences on plasmids that matched sequences on their host-cell chromosomes, as would have been expected if the plasmids had picked up significant amounts of the chromosomal DNA. Moreover, if the plasmids could routinely acquire chromosomal genes, how had they apparently been able to choose only resistance genes? Even if some selective force was responsible, surely some sequences on each side of the resistance genes would have been picked up. Actually, as it has turned out, many R plasmids do not insert themselves into the chromosome in the manner of F factors.

The real answer to multiple antibiotic resistance came only in 1974, first from Alan E. Jacob and Robert W. Hedges



PLASMID IS CLEAVED by different restriction enzymes at sites peculiar to each enzyme, yielding a set of fragments (*a*). The length of those fragments (and thus the cleavage sites for the enzyme) can be determined by gel electrophoresis. After migration through the gel the DNA is dyed, revealing a pattern of bands (*b*), each one composed of fragments of the same size. The distance of each band from the origin gives the size of the fragments making up that band.

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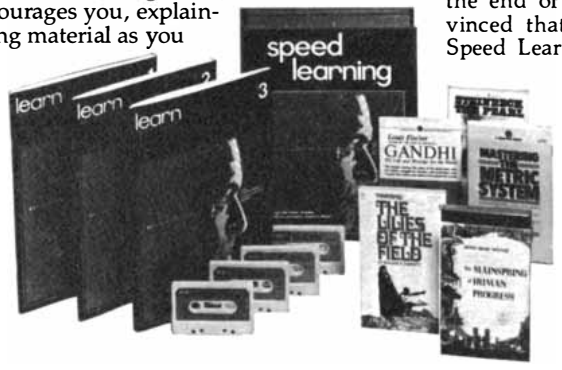

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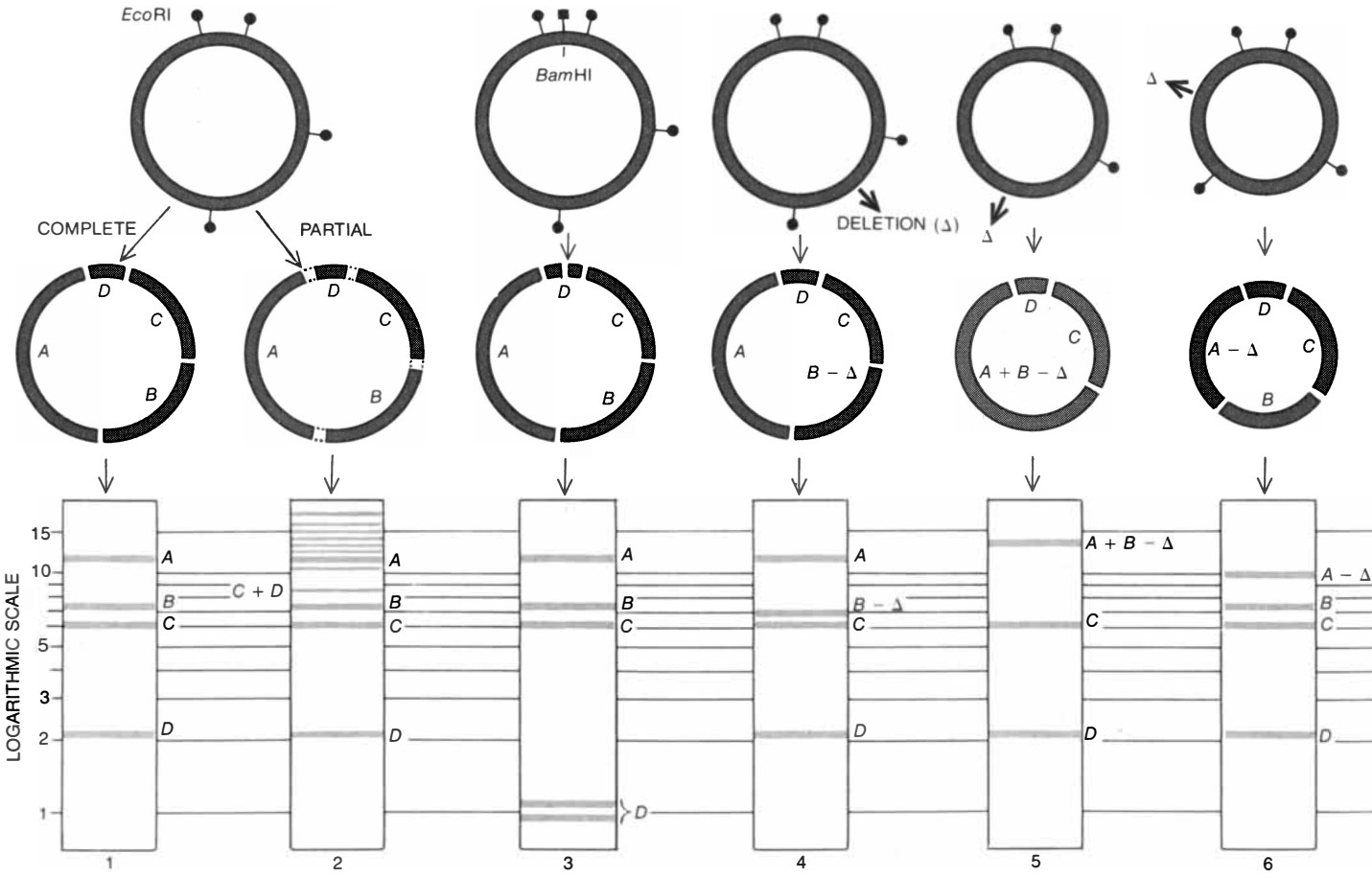
of the University of London Royal Postgraduate Medical School and then quickly from at least five other investigative groups. The resistance genes in question, it developed, were on novel genetic elements that can transfer themselves bodily from one genetic location to another in a cell; they do so without benefit of the enzymes that mediate more typical recombination mechanisms and without any need for the matching DNA base sequences required by those mechanisms. These new genetic elements, known as transposons, are responsible not only for the accumulation by plasmids of multiple resistance genes but also for gross genetic rearrangements in bacteria and apparently in eukaryotes too [see "Transposable Genetic Elements," by Stanley N. Cohen and James A. Shapiro; SCIENTIFIC AMERICAN, February]. Probably the prevalence of resistance genes on the transposons discovered so far will turn out to have the same basis as the prevalence of R plasmids themselves: the radical change in the processes of evolution brought about by the wholesale dissemination of antibiotics.

The Structure of Plasmids

Plasmid genes seem to be arranged so as to ensure hereditary stability and at the same time allow great structural flexibility. Unlike viruses, plasmids can acquire new genes and grossly rearrange old ones to maintain a store of genetic information consistent with the needs of their current host organism—all without compromising their own replicative efficiency. To appreciate the plasmid's genetic strategy one needs to know a little about the experimental analysis that has revealed it.

Plasmids do not readily yield their organizational secrets to the mapping techniques that have revealed the structure and function of genetic systems in animals, plants and even viruses. Those techniques are based on tracking gene mutations in genetic crossing experiments. In plasmids it is hard to isolate mutations affecting replication functions, and the analysis of genetic recombination is discouragingly complex. Plasmids have, however, turned out to be well suited to some recently developed techniques of molecular genetics, in particular the application of gel electrophoresis to the analysis of DNA and the dissection and cloning of DNA sequences with enzymes, known as restriction endonucleases, that are synthesized by bacteria.

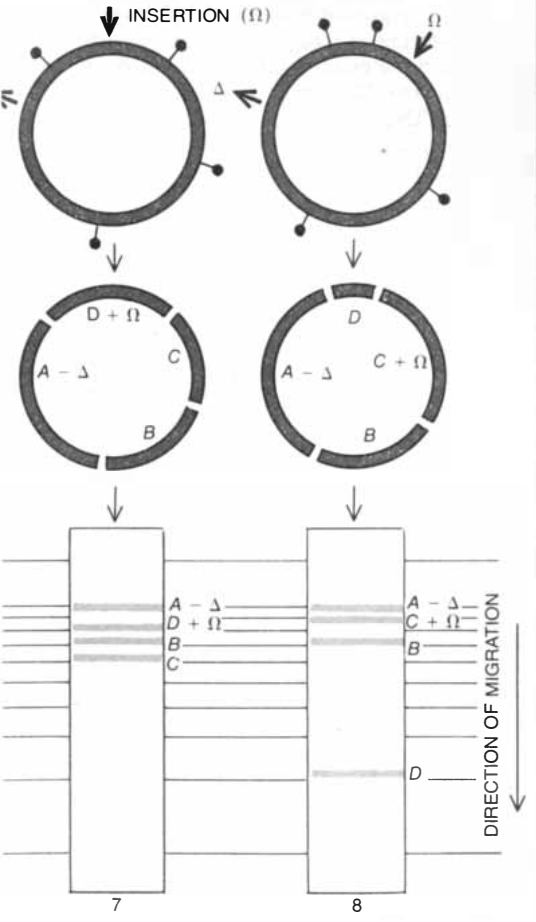
A plasmid, like most other DNA molecules, is a double helix each strand of which is a linear array of the four nucleotide bases adenine (*A*), guanine (*G*), thymine (*T*) and cytosine (*C*). The sequence of bases on one chain is complementary to the sequence on the other chain: *A* always pairs with *T* and *G* pairs with *C*. Each restriction enzyme recognizes a specific short sequence of bases and cleaves DNA at a particular site within that sequence wherever it may be in any DNA molecule. Given a large



DATA FOR MAPPING plasmid pI258 are obtained by cleaving the plasmid and variants of it with restriction enzymes and analyzing the fragments by gel electrophoresis. The plasmids are shown in the top row with cleavage sites indicated; the cleavage products are shown in the next row. Below each set of fragments is a schematic representation of the track on a gel that establishes the size of each fragment. Track No. 1 shows that enzyme *Eco*RI cuts the plasmid into four fragments, *A, B, C* and *D,* that are respectively about 13, seven, six and two kilobases (thousands of base pairs) long. The sequence of the fragments around the loop is determined by "partial digestion," in which not all the plasmid molecules are completely cleaved. The presence in track No. 2 of uncleaved fragments comprising *C* and *D* (but not any combining *B* and *D*) establishes the sequence: *A, B, C, D.* To make smaller fragments for detailed mapping the mixture of fragments can be treated with another enzyme. Track No. 3, for example, shows that enzyme *Bam*HI cuts *D* into two pieces, establishing the location of the single site of *Bam*HI cleavage on this plasmid. Track No. 4 is for a plasmid in which a deletion mutation has disrupted a sequence encoding penicillinase; the penicillinase gene must lie at least partly in *B,* because the *B* band is now smaller (it travels farther). In track No. 5 a different deletion (eliminating resistance to arsenate and arsenite ions) has joined fragments *A* and *B,* confirming the adjacency of *A*

collection of identical DNA molecules, such as a pure sample of plasmid DNA, each molecule will be cut by a particular endonuclease at precisely the same sites, yielding as many subsets of identical molecular fragments as there are cleavage sites on the original molecule. These subsets of fragments can be conveniently separated from one another according to size (or molecular length) by gel electrophoresis. The cleaved DNA is placed in a rectangular slot near one end of a slab of gel; an electric current is applied and the DNA molecules migrate through the gel toward the positive electrode at a rate inversely proportional to the logarithm of their molecular length. Each subset of identical fragments forms a narrow horizontal band whose position can be visualized by soaking the gel in a fluorescent dye such as ethidium bromide (which binds to DNA) and photographing it under ultraviolet radiation.

By dissecting a plasmid with several restriction enzymes, separately and in



and *B* and locating the resistance genes at or near the *A-B* junction. A transposon carrying erythromycin resistance has been deleted in the plasmid of track No. 6; it must have been in *A* because the *A* band now travels farther. Two secondary insertions of the transposon, one in fragment *D* (track No. 7) and the other in fragment *C* (track No. 8), both abolish resistance to mercury disinfectants. The gene responsible for that resistance must therefore be partly in fragment *D* and partly in *C*.

combination, one can generate various sets of fragments that can be pieced together to form a fragmentation map. The location of the plasmid's genes can be determined in several ways, including the analysis of plasmids with structurally identifiable mutations such as deletions and insertions. Some idea of the procedure can be gained by considering the first steps in the analysis of the staphylococcal R plasmid pI258, which has an overall length of some 28,000 base pairs and carries genes for resistance to erythromycin and penicillin and to a number of toxic metal compounds.

The plasmid is first cleaved, by the restriction enzyme *Eco*RI, into four fragments, which track No. 1 of the gel shows to be respectively about 13, seven, six and two kilobase pairs (thousands of base pairs) long [*see illustration on preceding two pages*]. The actual sequence of those fragments around the circle is determined by a "partial digestion," shown in track No. 2. The sites at which other enzymes cut the plasmid can be determined by a large number of experiments such as the one shown in track No. 3. The remaining tracks show the fragments obtained when derivative plasmids are dissected from which segments bearing known traits have been deleted or into which a transposon has been inserted. Examination of a plasmid with a deletion affecting a particular gene shows which segment has been shortened by the deletion, thereby locating the deleted gene. The insertion of a transposon lengthens a fragment and disrupts the function of any gene into which it is inserted, thus pinpointing the site of the inactivated gene.

By examining only these few physical rearrangements of the plasmid DNA one can get a great deal of information about the structure and genetic organization of the plasmid. By combining the results of a larger number of electrophoresis experiments with the direct determination of a plasmid's entire base sequence (which has been accomplished only for much smaller plasmids) one can hope to obtain the detailed information needed for a complete understanding of the plasmid as a genetic entity.

Plasmid Autonomy

Since plasmids represent the ultimate stage of symbiosis, being dependent on the host cell for all life-support systems except the "autonomy functions" (those that are most intimately linked with its claim to being an organism and that serve to define its individuality), the identification and analysis of those functions reveal the minimal essential components of the living state. Put another way, every plasmid must contain in its genome a solution to the problem of how a nonessential genetic system can be stably inherited and how it can control its own replication and the distribution of its copies so that a constant relationship with its host is maintained. What are those solutions?

The basic theoretical foundation for considering this question was developed in 1963 by Jacob, Sydney Brenner and François Cuzin. They proposed that for any given "replicon," or replication unit, whether it is a bacterial chromosome, a segment of a eukaryotic chromosome, a virus, a plasmid or some other form, replication begins at a specific point (the origin) and proceeds in a sequential and linear manner to another specific point (the terminus), where it stops; an "initiator" substance, encoded by the replicon itself, acts at the origin to trigger replication. They proposed that in bacteria all autonomous replicons are permanently attached to the inner surface of the cell membrane at a site near the cell's equatorial plane; the attachment is essential for replication and for partitioning, or copy distribution. At a particular stage of the cell cycle, then, a new attachment site would be formed for each replicon on the side of the equatorial plane opposite the existing site, triggering a replication cycle during which the newly synthesized DNA molecule would become attached to the new site. The growth of a division septum along the equatorial plane would allot one of the two DNA molecules to each daughter cell. This brilliant theoretical synthesis, years ahead of its time and formulated on the basis of scanty evidence, has served to guide virtually all research on the control of bacterial replication and on the genetics of plasmid autonomy.

The theory predicted that very few genetic functions—only a small part of any plasmid—would be required for autonomy. This was confirmed by the isolation of derivative plasmids from which large segments of DNA had been deleted but that were still viable. In a study of deletions affecting the staphylococcal R plasmid pI258 I found that as much as two-thirds of the plasmid could be deleted without affecting the plasmid's autonomy functions. No other type of genome can survive deletions nearly as large as that. More important, there was a small "forbidden" region of the viable plasmids that was never affected by deletions and that turned out to carry all the autonomy functions; deletion of any part of this region destroyed the plasmid's viability.

Similar results have been obtained for many other plasmids, and it is now well established that plasmid autonomy genes are clustered in what Ken-ichi Matsubara of Osaka University has termed a "replication drive unit." In 1966, when my experiments were completed, molecular techniques had not yet advanced to the stage allowing precise determination of the size of the replication drive unit. More recently it has been found that the unit cannot be larger

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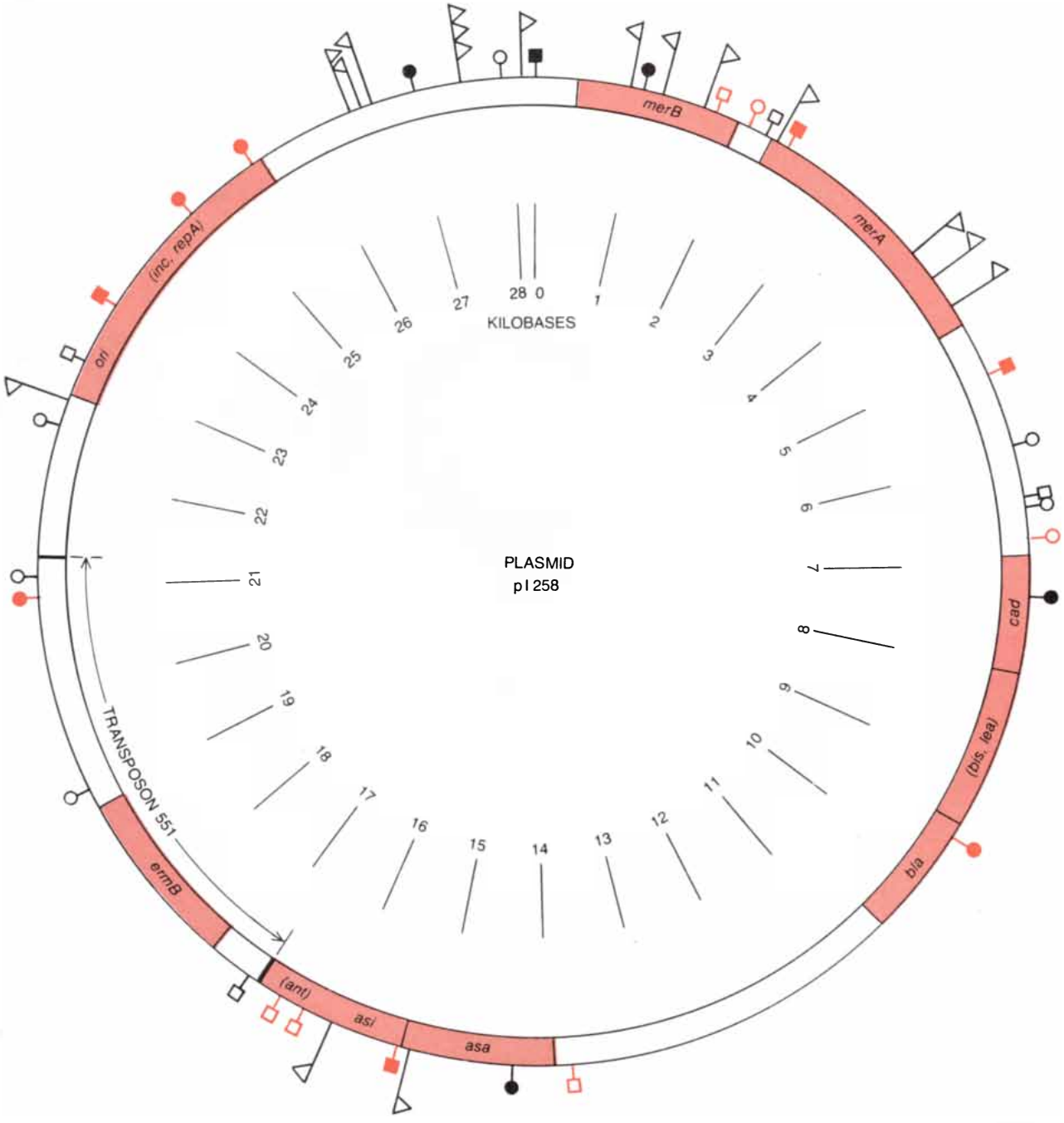
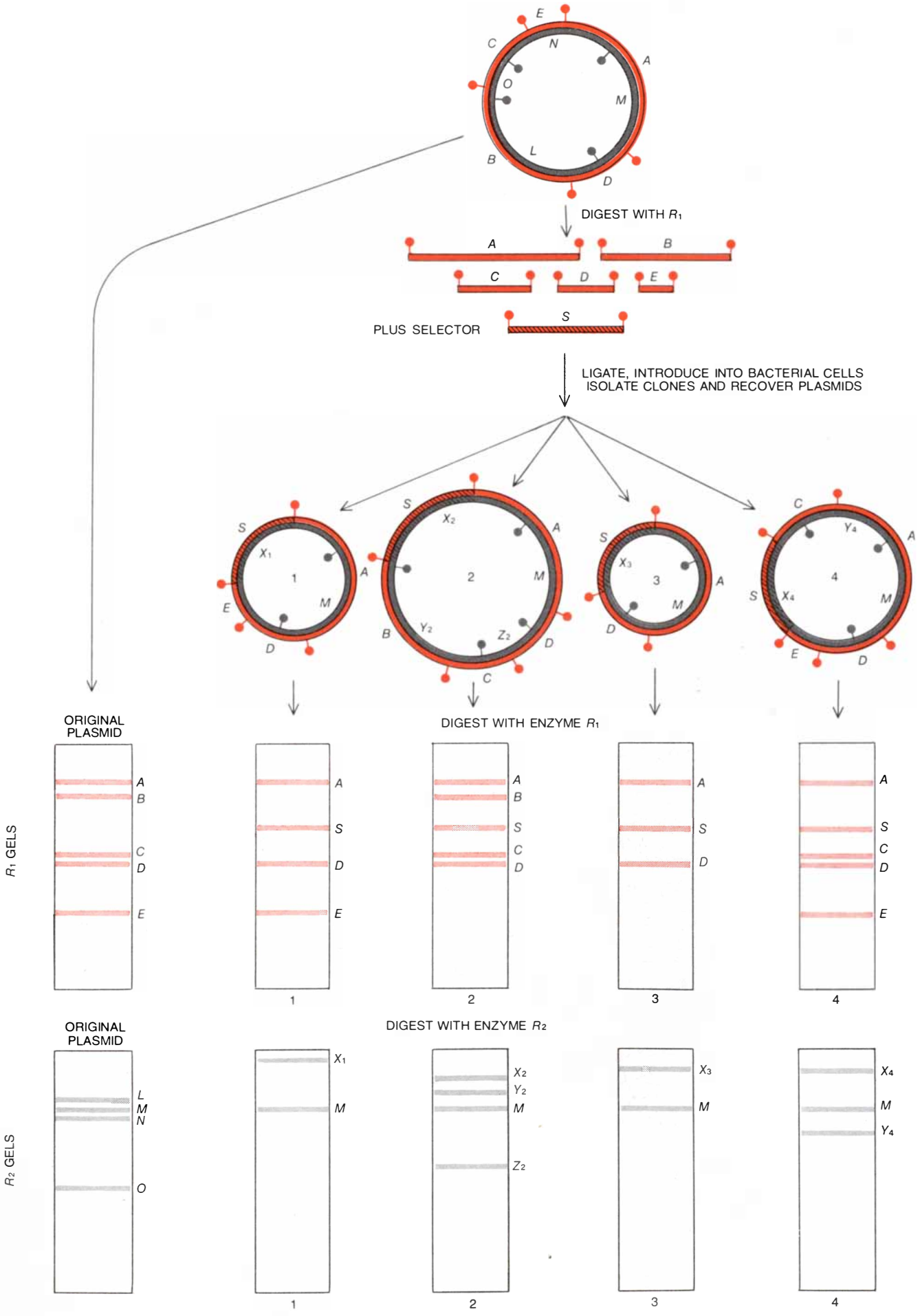
than about 3,000 base pairs, or just over a tenth of the pI258 plasmid.

Recent molecular-cloning experiments have defined more precisely the replication drive units of several *E. coli* plasmids. In these experiments a plasmid is digested with a restriction enzyme and the collection of fragments is mixed with a nonreplicating "selector" segment of DNA generated by the same endonuclease and containing a known marker gene. Since all the fragments are cleaved from DNA by the same enzyme, they have matching and symmetrical unpaired bases at their ends ("sticky ends") and can therefore combine with one another, in any number, order and relative orientation, by base pairing. When the mixture is treated with the enzyme DNA ligase, the base-paired fragments form new, scrambled plasmids: random rearrangements of the original plasmid. When these are introduced into recipient cells, only those that contain the region or regions required for autonomous replication are able to replicate and only those that also contain the selector can be recovered. Treatment with the original endonuclease shows which of the original frag-



EcoRI
BamHI
Bg l II
Hpa I
Xba I
Pst I
Sma I
Sal I

PHYSICAL-GENETIC MAP of plasmid pI258 reflects the results of many experiments of the kind shown in the preceding illustration. Locations are given by the kilobase scale, which indicates the distance from the single site at which the restriction enzyme *Bam*HI cleaves the circular molecule; the symbols (*see key*) mark the recognition sites for different restriction enzymes. Pennants represent various alternative sites at which transposon 551 has been mapped and indicate the orientation of the transposon. Plasmid genes that have been mapped include those for resistance to penicillin (*bla*), arsenate (*asa*), arsenite (*asi*), antimony (*ant*), erythromycin (*ermB*), inorganic mercury (*merA*), organic mercury (*merB*), cadmium (*cad*), bismuth (*bis*) and lead (*lea*) as well as for the replication origin (*ori*), the initiator protein (*repA*) and incompatibility (*inc*). Genes whose precise location is still not certain are indicated in parentheses.



ments are present and analysis with a second endonuclease establishes their sequence and relative orientations.

If all replication-function genes are contained within a single original fragment, then that fragment is always found to be present in viable new plasmids. Kenneth N. Timmis, Felipe Cabello and Stanley N. Cohen of the Stanford University School of Medicine found that to be the case for two large *E. coli* plasmids, F and R6. In both cases a single fragment about a tenth as long as the original plasmid was found to contain the entire replication drive unit and thus to ensure autonomous replication in the same way as the full original plasmid. Further reduction in size of the derivative plasmids indicated that a DNA segment of no more than 2,000 base pairs encompasses the entire replication drive unit of plasmids more than 50 times as long.

If two fragments each contain independently necessary replication functions, both are always found to be present in the new plasmids, without constraint on their relative location. If a restriction-enzyme site falls within the confines of a required gene, again two of the original fragments are always recovered from the new plasmids, but in this case they are always adjacent and in the same orientation as in the original.

Replication Drive Unit

Four elements of a typical replication drive unit have so far been defined experimentally: the origin (the site of initiation of replication), the initiator substance, the genetic functions controlling copy number and those that ensure partitioning, or the distribution of replicas to daughter cells. The central element of the autonomy system is the replication origin, a unique sequence of bases within which the actual "start site" for each replication cycle is situated. A replication origin is defined functionally as the smallest DNA sequence that can serve as the start of a replication cycle.

An extension of the fragment-scrambling experiment makes it possible to isolate the origin sequence. As before, one ligates a mixture of restriction-enzyme fragments with a selector. Now, however, the new plasmids are introduced into a specially engineered bacterial strain. It contains a second, unrelated plasmid to which has been attached a fragment of the first one that is known to encode whatever diffusible substances, such as the initiator protein, are necessary for its replication. As before, the experiment pinpoints a fragment whose presence is required if a scrambled plasmid is to be viable. In this case, however, the required fragment need not include the entire replication drive unit because the diffusible substances encoded by that unit will have been supplied by the complementary plasmid already present in the recipient cells. Therefore any fragment that is always present in viable new plasmids must specifically contain the DNA that constitutes the origin sequence. In this way Donald R. Helinski of the University of California at San Diego and his colleagues isolated the origins of the *E. coli* plasmids R6K and RK2, and similar methods have been applied to isolate the origins of other plasmids.

In each case the origin region has been found to be several hundred base pairs long. Within that region the synthesis of a new DNA chain always begins at essentially the same base pair. The rest of the origin region presumably contains specific sequences to which various proteins (and perhaps other large molecules) adhere to influence the initiation process. For example, it now appears that the first step in the replication of plasmid (and other) DNA is the traversal of the origin sequence by the enzyme RNA polymerase. This interaction not only synthesizes an RNA chain that primes the replication of the DNA but also separates the two DNA strands, perhaps allowing intrastrand loops to form; these loops may attract the enzymes and other proteins involved in the actual biosynthesis of new DNA.

The first hint of the existence of plasmid genes required for replication came when Jacob, Brenner and Cuzin isolated F-plasmid mutants that were unstable at high temperatures, apparently because they were defective in replication. We isolated similar mutants of various staphylococcal plasmids that we could show were indeed unable to replicate at an elevated temperature at which the host cells grew perfectly well [*see illustration on page 102*]. These plasmids were enabled to replicate when they were complemented by other copies of the same plasmid carrying the nonmutant allele (variant) of the temperature-sensitive gene. This meant the mutant gene encoded a diffusible protein (generally assumed to be the initiator) that was supplied by the nonmutant plasmid. The mutants were not enabled to replicate by a different but closely related plasmid, establishing the high degree of specificity of this protein-DNA reaction and fulfilling the prediction of a specific initiator for each replicon. Manabu Inuzuka and Helinski have demonstrated that such a protein, encoded by plasmid R6K, is required for replication of the plasmid in cell-free extracts of *E. coli*.

At first it was assumed that there would be found to be as many copies of a particular plasmid in a cell as there were chromosomes, with plasmid replication coupled to and regulated by chromosomal replication. That is not the case. In the plasmids studied to date there appears to be a continuum of copy numbers from one or two per cell to more than 100; in general the larger the plasmid, the smaller its copy number. And plasmid replication is generally regulated independently of chromosome replication. Since different plasmids present in the same host can have very different copy numbers, the copy number must be determined by a plasmid-encoded regulatory system. The first such system was discovered in 1972 by Kurt Nordström, now of Odense University in Denmark, for the *E. coli* plasmid R1, and similar systems have been revealed for other plasmids, in staphylococci as well as in *E. coli*. In R1, at least, copy number appears to be controlled by a protein or proteins inhibiting replication, fulfilling a 1968 prediction by Robert H. Pritchard, Peter T. Barth and John F. Collins of the University of Leicester that replication is controlled negatively, that is, by a repressor.

When in the course of the cell cycle do plasmids replicate, and what determines the sequence in which particular copies of a given plasmid will replicate? There might possibly be a precise moment when all plasmid molecules replicate in synchrony, but there are indications that the replication events are instead random ones, distributed throughout the cell cycle. An elegant experiment reported in 1967 by Robert H. Rownd of Wisconsin showed that all the copies of a particular plasmid act as members of a homogeneous pool, with copies chosen for replication by random selection without respect to their recent replication history: the regulatory system does not discriminate between "new" and "old" DNA. Other workers have shown that plasmids replicate throughout the cell cycle. One simple interpretation of these observations is that at any constant host-cell growth rate there is a corresponding constant concentration of a repressor that fixes the probability of plasmid replication in any time period.

How two elements, a positive initiator

FRAGMENT-SCRAMBLING experiment defines the region responsible for plasmid autonomy functions. A plasmid is diagrammed (*top*) to indicate the sites at which hypothetical restriction enzymes R_1 (*colored symbols*) and R_2 (*gray symbols*) cleave it. The plasmid is first digested with R_1 and the fragments (*A–E*), mixed with a "selector" fragment (*S*) having matching ends, are ligated to make a variety of new plasmids, which are cloned in bacteria. Viable plasmids (those containing the autonomy functions) replicate in the bacteria and can be recovered if they also contain the selector. Digestion of the scrambled plasmids with R_1 reveals that each contains a different set of fragments, but all of them have the selector and also fragments *A* and *D;* the last two must between them contain all autonomy functions. Dissection of the original plasmid with enzyme R_2 yields a different group of fragments, *L, M, N* and *O;* scrambled plasmids yield *M* and variety of new fragments. Because only *M* is always present in viable plasmids it must include autonomy functions; its constant presence shows *A* and *D* are adjacent and in same relative orientation in all viable scrambles.

and a negative repressor, might interact to regulate the rate of replication is not yet clear. It is probably different in different systems. A repressor could control either the rate of synthesis of the initiator protein, the rate at which the initiator interacts with the origin or the frequency with which the origin region is transcribed by RNA polymerase. Any such copy-control mechanism is quite different from the one predicted by Jacob, Brenner and Cuzin, which formally implies the presence of only a positive regulatory element, consisting of a limited number of structural sites to which a replicon must attach to be replicated.

Partition

Jacob, Brenner and Cuzin recognized that if a nonessential genetic element present in a limited number of copies in each cell was to maintain its hereditary stability, there would have to be a mechanism to ensure the equal distribution (partition) of the copies of the element among daughter cells. Such a mechanism has not yet been clearly identified, but the first direct evidence that there is one came from a study in our laboratory of the plasmid mutants that have a temperature-sensitive initiator. As the host cells divide at the elevated temperature the plasmids originally present in them are not destroyed, but neither are they replicated; they are assorted among the dividing cells until no cell has more than one plasmid.

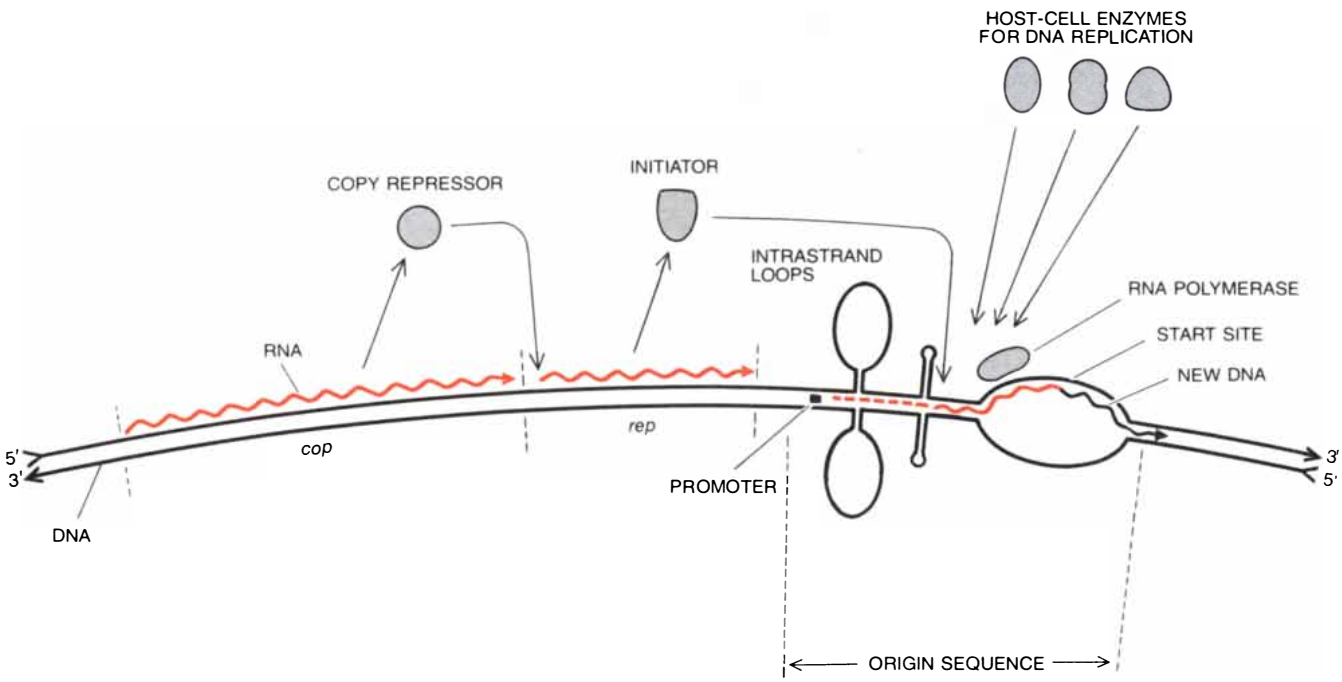
We did a statistical analysis of this assortment in the case of two different plasmids, one with an average copy number between two and three and the other with about 30 copies per cell. In both cases the copies originally present were divided approximately in half at each generation until there was one copy per cell. Thereafter at each cell division one daughter cell had a single plasmid and the other cell had none. We concluded that at least these two plasmids do contain a specific equipartition mechanism. Here again the mechanism is likely to have at least two components, an effector molecule and a recognition site, and the cell envelope is probably involved.

Nordström and Rownd independently have recently found that when a particular segment of an R plasmid is excised by recombinant-DNA techniques, the plasmid becomes unstable and is inherited in an apparently random way; the tentative interpretation is that the deleted segment must be implicated in equipartition. In collaboration with Carmen Sanchez-Rivas of the University of Paris we have studied plasmids in staphylococcal protoplasts: bacteria from which the tough cell wall has been removed, leaving only the thin cell membrane. When staphylococcal protoplasts regenerate a cell wall, many of the regenerated cells fail to inherit plasmids that were originally present. The plasmid DNA is not physically expelled from the protoplasts and it can replicate normally, and so the failure to inherit must be related to a series of cell divisions that take place during cell-wall regeneration. Because the normal location of the plane of division is determined by the cell wall these divisions are abnormal, often resulting in "cells" without a chromosome (which of course cannot survive) or cells without any plasmid.

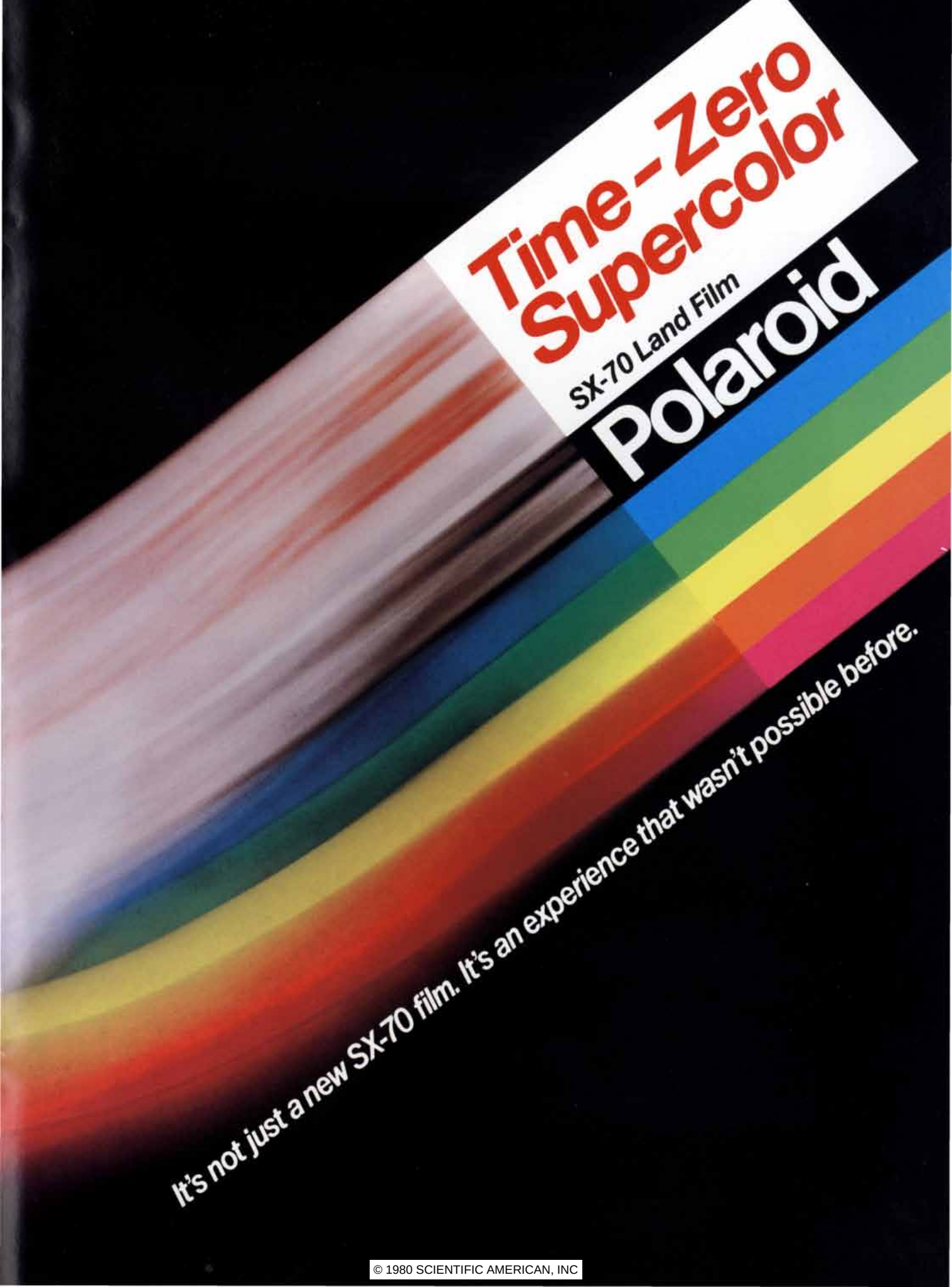
This result implies that the intact cell wall is intimately involved in the coordination of division and partitioning, in keeping with the theory of Jacob, Brenner and Cuzin. The theory, however, specified that after replication the two copies of a replicon are automatically separated, one to each daughter cell. It is now clear that this cannot be true for plasmids because of a phenomenon, unique to plasmids, known as incompatibility.

Incompatibility

Pairs of closely related plasmids usually cannot be stably maintained together in a single cell line: they are "incompatible." It may be possible to develop a line containing two such plasmids, but it is difficult to keep them both present. As the cells proliferate, subclones with only one or the other of the two plasmids are continually generated; the culture approaches, asymptotically, a state in which it consists of two pure sublines, one for each of the original plasmids. Frank C. Hoppensteadt of the University of Utah and I have shown, by statistical analysis of experiments done in our laboratory and in Nordström's, that the process is clearly stochastic: the results



PLASMID REPLICATION might be controlled as is suggested by this model. An initiator protein is encoded by a replication gene (*rep*) whose activity is controlled by a repressor protein that is specified by a copy-control gene (*cop*). The initiator recognizes loops in the two strands of plasmid DNA; the loops form (by intrastrand base pairing) when the strands are dissociated as the enzyme RNA polymerase traverses the origin sequence, beginning at the promoter, to synthesize an RNA transcript that will serve as a primer for DNA replication. The resulting complex of the initiator and the intrastrand loops attracts a number of host-cell enzymes, including DNA polymerase, that mediate the synthesis of DNA; these proceed to attach new nucleotide bases to the RNA primer, starting a new replication cycle.



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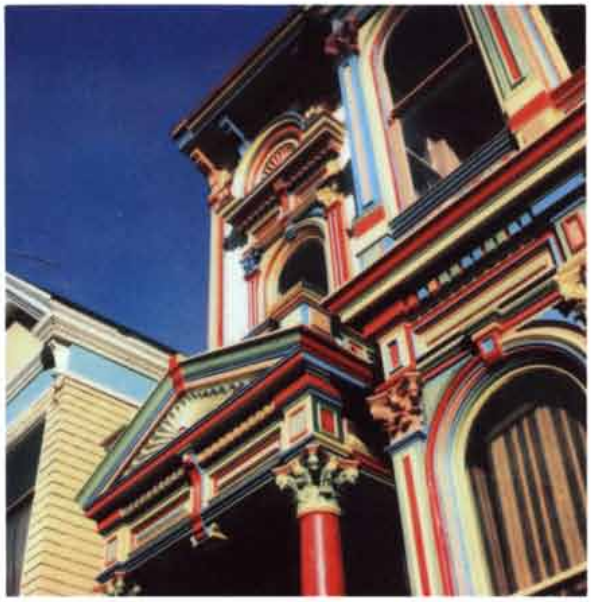

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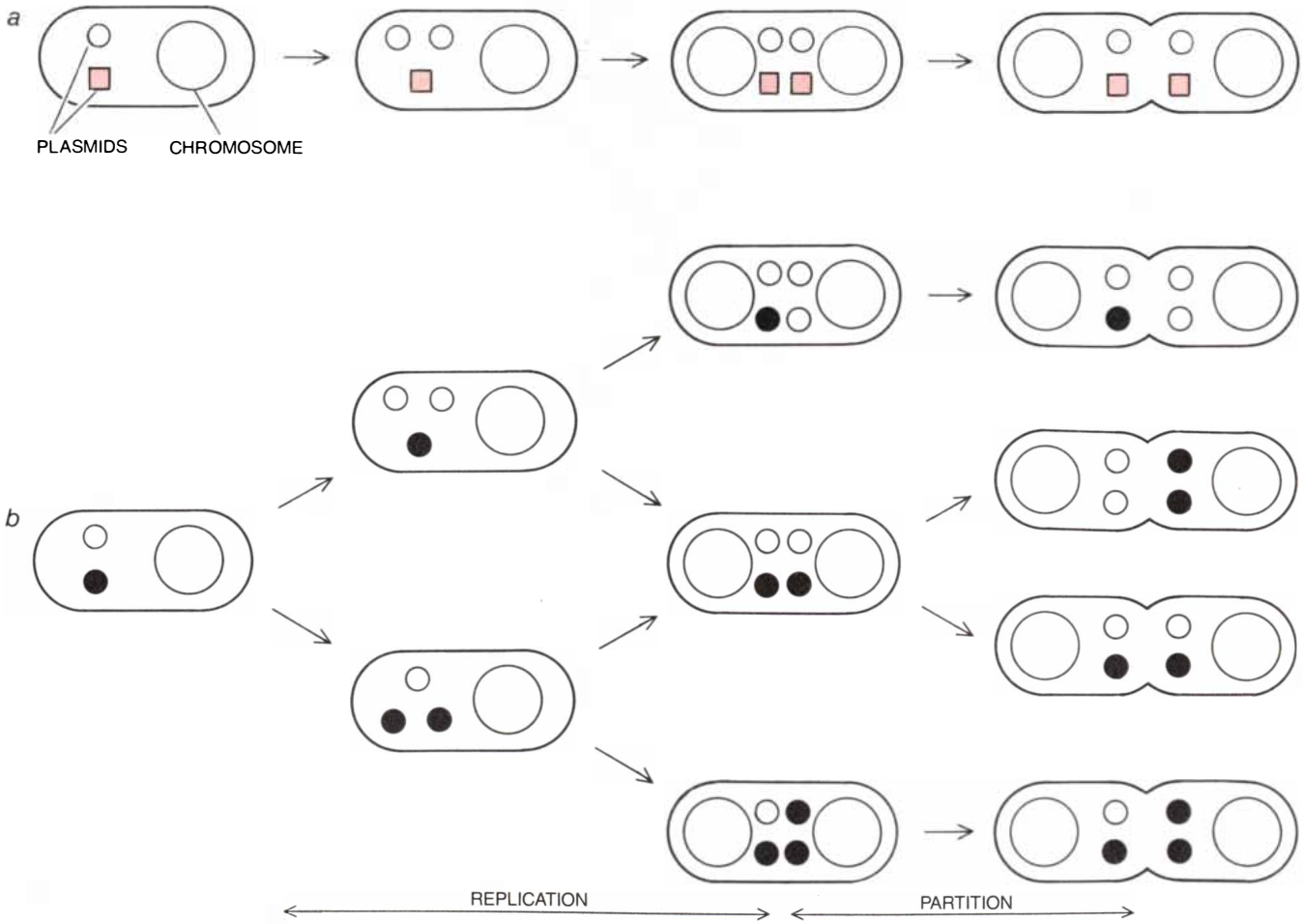
can be interpreted as the net effect of random replication and random assortment. Two incompatible plasmids *A* and *B* in the same cell form a common pool from which individual copies are chosen at random for replication until the total number has doubled; then they are again chosen at random for partitioning, with half of the total going to each daughter cell. The relative numbers of *A* and *B* will therefore vary from cell to cell in a mathematically predictable way, even though the sum of *A* and *B* remains constant. Since the two plasmids have similar or identical replication drive units, they are not recognized as being different by the plasmid and cellular systems that regulate replication and partitioning. And so the disproportions persist, giving rise (at a predictable rate determined by the overall copy number) to progeny cells having only *A* or only *B*.

In contrast to plasmids with similar or identical drive units, pairs of unrelated plasmids can be maintained together in a cell and are regarded as being compatible; naturally occurring bacteria are quite commonly observed to have as many as seven or eight different plasmids. The contrast between compatibility and incompatibility indicates a high degree of specificity in the interactions between cells and plasmids. There must be specific gene loci on a plasmid that are responsible for the differing behavior of compatible and incompatible plasmids. Perhaps plasmid partition is specific for each incompatibility type, in that any two incompatible plasmids share the same partition apparatus. In that case there must be at least as many different partition systems as there are different groups of mutually incompatible plasmids, and a substantial number of such incompatibility groups have already been identified in several bacterial species. All of this suggests that the specificity of the partition system is determined solely by the plasmid.

Consideration of plasmid partition and incompatibility bears directly on the essence of the symbiotic state. For most of its needs a subcellular endosymbiont presumably exploits a host structure, metabolic pathway or other function for the same purpose as the host itself does. For example, a plasmid presumably depends on a host RNA polymerase to transcribe its DNA and on host DNA polymerases for DNA replication and repair. Alternatively a subcellular organism can subvert a host function to serve a need peculiar to itself. For example, the system whereby a bacterial cell transports the sugar maltose across its membrane is exploited by bacteriophage lambda for a very different purpose: as its site of attachment to the wall of a cell it is infecting. In other cases, such as the control of copy number, there is presumably no appropriate cellular function to be exploited, and the plasmid itself apparently encodes whatever control molecules are required.

What about partition, where a variety of plasmids must each be able independently to develop a specific structural interaction with the host cell? I would suggest that each plasmid may have "learned" to attach itself to a different structure in the cell (perhaps on the interior of the cell membrane or even, as suggested by Bruce C. Kline of the Mayo Clinic, on the chromosome itself) by evolving a protein that binds to a specific site. If this notion is correct, the isolation and study of such systems should help to clarify the special kind of symbiosis at the molecular level that is the hallmark of the plasmid way of life.



REPLICATION AND PARTITION of compatible plasmids (*a*) are contrasted with the same processes in incompatible plasmids (*b*). Unrelated plasmids are "compatible" and can be maintained together in a cell. They may replicate at different stages of the cell cycle, but both types replicate and the copies are assorted equally during cell division. Closely related plasmids are "incompatible." One or the other is chosen at random for replication (*middle columns*) and at cell division they are randomly assorted (*right*), that is, sister plasmid copies are not always separated from each other. The result is that cell lines lacking either one plasmid or the other are inevitably produced.

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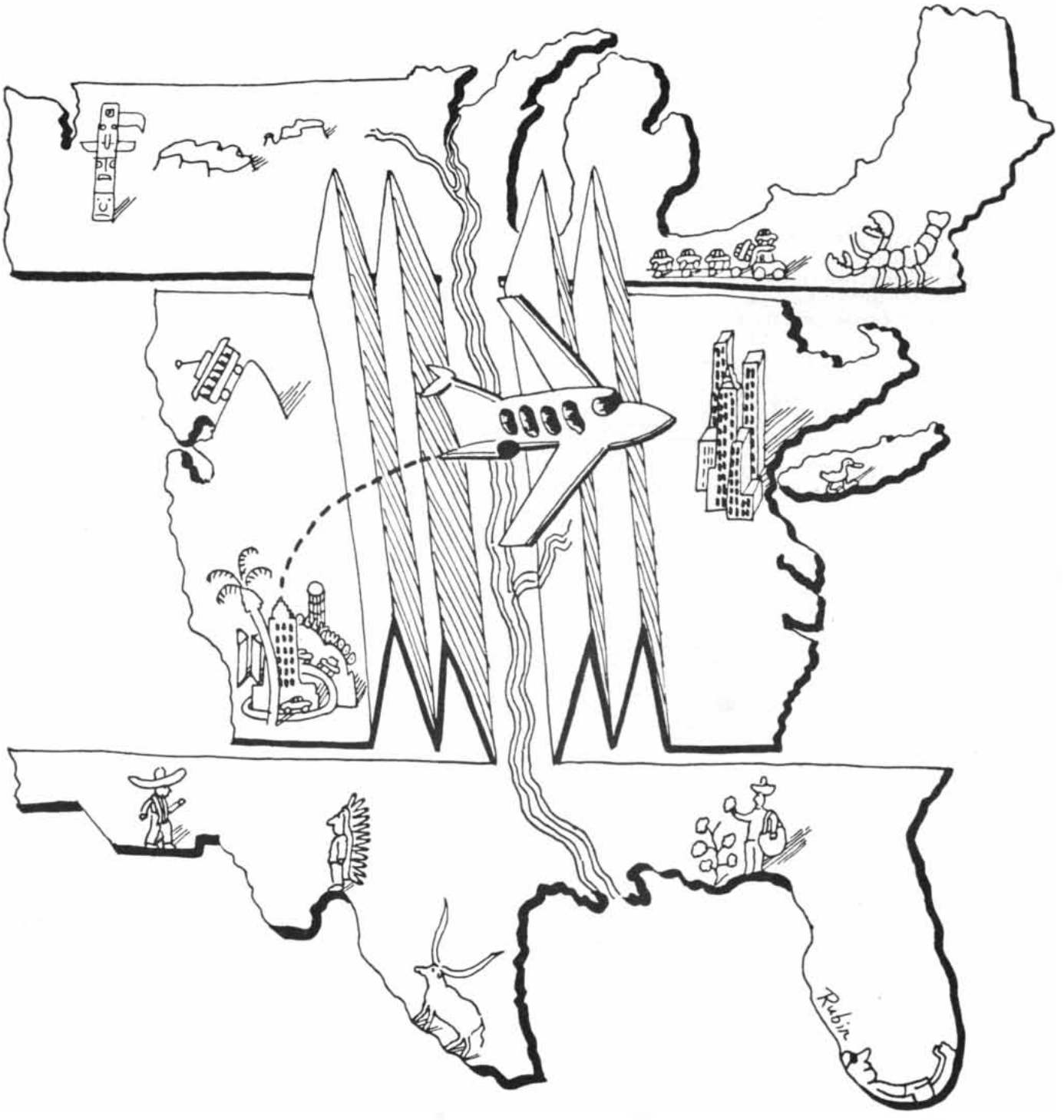

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Early Man in Soviet Central Asia

In the Tadzhik S.S.R. deep deposits of loess have accumulated over a span of two million years. Stone tools embedded in them were made by hunter-gatherers of the Lower Paleolithic some 250,000 years ago

by Richard S. Davis, Vadim A. Ranov and Andrey E. Dodonov

The record of early man in much of Asia is not at all clear. To be sure, it was in Asia that *Homo erectus* ("Java man") was first discovered and in Asia that the habitation site of Choukoutien was excavated, revealing an unequaled amount of skeletal remains of the same species ("Peking man"). Nevertheless, large areas of Asia are blank spots on the archaeological map. For example, until only a few years ago the region extending from east of the Euphrates, across the Plateau of Iran and on through central Asia was almost without an example of a site of early Paleolithic man that could be reliably dated on the basis of its geological context. Hence little was known about early hunter-gatherers and their ways of life in this large, arid zone of interior Asia.

Recently archaeological sites have been discovered in the Soviet Central Asian republic of Tadzhikistan that are covered by more than 60 meters of windblown loess. Several lines of evidence date these traces of human activity to approximately a quarter of a million years ago, a time that falls in the later Lower Paleolithic. In addition to their archaeological content the loess deposits of Tadzhikistan have revealed much else of interest. They contain evidence of an apparently continuous sequence of warm-to-cold climatic oscillations that span the past two million years—the entire Pleistocene epoch. The combination of the archaeological and the climatic information stored in the loess provides a glimpse of early human adaptations to a continental, highland environment in Lower Paleolithic times.

Loess (from the Swiss German *lösch,* "loose") is primarily a windborne sediment. It is characteristically yellow, calcareous and porous and is composed of silt-size particles. In nonglacial regions it is generally formed under relatively dry conditions in areas where vegetation does not fully shield the soil, so that the surface is vulnerable to erosion.

Deep deposits of loess are found along the Yellow River in China, on the Potwar Plain in Pakistan, in the Ukraine, in central Europe and in the Upper Mississippi basin. The deposits along the Afghan-Tadzhikistan border are not as well known, but they surely constitute one of the great loess areas of the world. Most loess deposits are unconsolidated but are resistant to slumping; stream erosion, for example, can cut nearly vertical bluffs in them. In southern Tadzhikistan these deep cuts are common, and they expose long-term records of Pleistocene events.

Tadzhikistan in Soviet Central Asia includes a tectonically active highland area, created by the upthrusting and faulting of the Gissar, Pamir and Hindu Kush ranges in late Cenozoic times, a consequence of the collision of the drifting subcontinent of India with Asia. An area of subsidence related to these upthrusts is the Afghan-Tadzhik Depression. For millions of years the depression has been a catchment area for the materials eroded from the mountains that surround it. In several parts of the depression thick loess deposits were formed during the Pleistocene. Many are 100 meters deep, and some are as deep as 200 meters.

A large-scale investigation of the Tadzhikistan loesses was begun late in the 1960's by scholars from the Institute of Geology of the Academy of Sciences of the U.S.S.R. and from the Tadzhikistan Academy of Sciences. The work is still in progress, and the loesses are being analyzed by students of climate, of soil and sediment formation, of minerals and of plant pollens. The age of the deposits is being assessed by the paleomagnetic dating of fine particles of the iron ore magnetite in the loess, by the thermoluminescence dating of particles of quartz (a major constituent of the loess) and by stratigraphic correlation. Archaeologists and paleontologists are also studying the artifacts and fossil remains that have been uncovered. Already there are many results to report.

One immediately apparent feature of the Tadzhikistan loess exposures is the alternation of thick layers of unaltered loess and distinct "horizons" of soil. The soil horizons were formed when the surface of the loess was altered in periods of relatively moist and warm climate. In many places the soil structure is complex, and two or even three horizons overlap, reflecting the dynamic interaction of two simultaneous processes: sedimentation and soil formation. Typically the soils buried in the loess are reddish brown, contrasting with the yellow of the loess; they are three to five meters thick and have a heavy crust of calcium carbonate near the base. The most intense zone of weathering is usually in the 1.5 meters of soil above the crust.

The physical and chemical properties of the buried soils are analogous to the "chestnut" soils (*kastanozemy* in Russian usage) that are formed under semiarid steppe conditions today. The plant pollen and snail species found in the loess, however, indicate that it accumulated when the climate was considerably cooler and drier than it is today. Thus the alternating layers of loess and soil are evidence of major climatic oscillations in the region. It is assumed these oscillations reflect the climatic changes that in more northerly latitudes controlled the advance and retreat of the continental ice sheets throughout the Pleistocene.

Paleomagnetic dating is based on the fact that the north and south magnetic poles of the earth reverse over periods of tens of thousands or hundreds of thousands of years. As the fine particles of magnetite are deposited with the loess they tend to come to rest lined up with the magnetic polarity prevailing at the time, and their orientation can be measured with a sensitive magnetometer. The dates of the major reversals of polarity, and of briefer reversal episodes, are known from independent evidence such as the radioactive dating of volcanic rocks. Hence it is possible, once the sequence of reversals in the loess is identified, to assign appropriate dates to the identified strata.

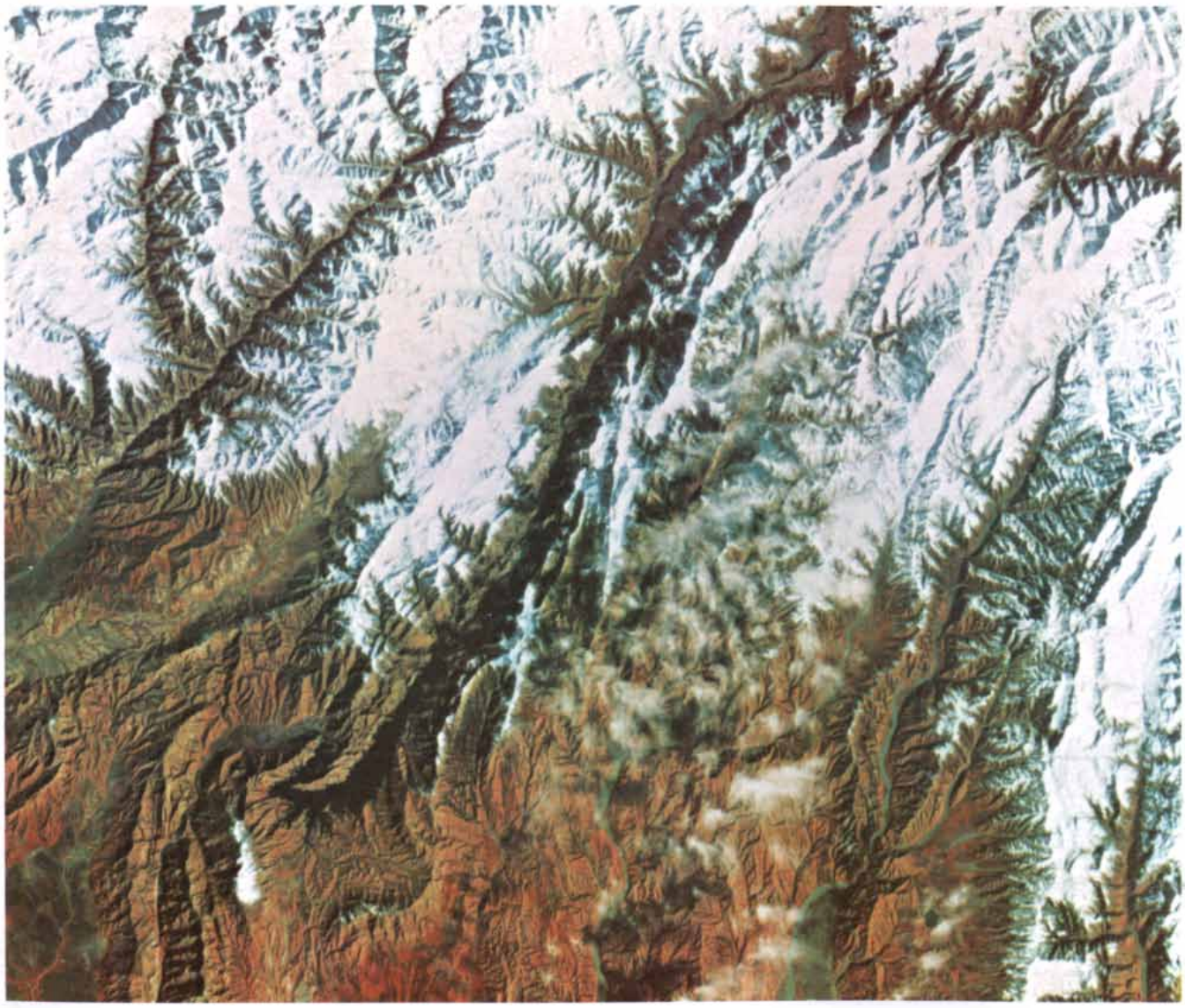
STEEP LOESS HILLSIDE at Karatau in Tadzhikistan descends more than 1,100 meters to the Vaksh River. Four narrow trenches are visible to the left of a wider trench that passes through the excavation, to the right of center, that exposed a buried soil complex where stone tools were unearthed. The soil, which is 67 meters below the surface today, may have developed as long as 250,000 years ago.

EXCAVATION AT LAKHUTI uncovered another buried soil that held stone tools. This was the fifth of nine soil complexes at Lakhuti I, all of them situated above the level in the Tadzhikistan loess deposits where paleomagnetic evidence indicates the shift from reversed magnetic polarity of 700,000 years ago (Matuyama) to the normal polarity of today (Brunhes). Some 450 stone artifacts were found here.

Various paleomagnetic events are detectable in the loess of Tadzhikistan, the most important one being the transition some 690,000 years ago between the Matuyama magnetic period, when the earth's magnetic polarity was the opposite of what it is now, and the Brunhes period of today. In the Tadzhikistan loess sections currently being studied the total number of buried soil complexes varies, the maximum being 37. In the six sections where the Matuyama-Brunhes boundary has been detected, however, nine of the soil complexes consistently lie above it. The number of soil complexes above the Matuyama-Brunhes boundary in Tadzhikistan corresponds fairly closely to the number above the boundary in the loess of central Europe. The number of soil complexes is also in agreement with the record of climatic oscillations preserved in deep-sea sediments.

Pollen analysis, which is being done under the direction of M. M. Pakhomov of the Tadzhikistan Academy of Sciences, indicates that in addition to the climatic oscillations attributable to the advance and retreat of the Pleistocene ice sheets the climate in this part of Tadzhikistan has gradually become drier over the past million years or so. Early in Middle Pleistocene times a forest cover of birch predominated; ferns grew in the river valleys and pines at the higher elevations. With the passage of time the forest cover gradually diminished, to be replaced by the grasses typical of more arid conditions. The trend continues today.

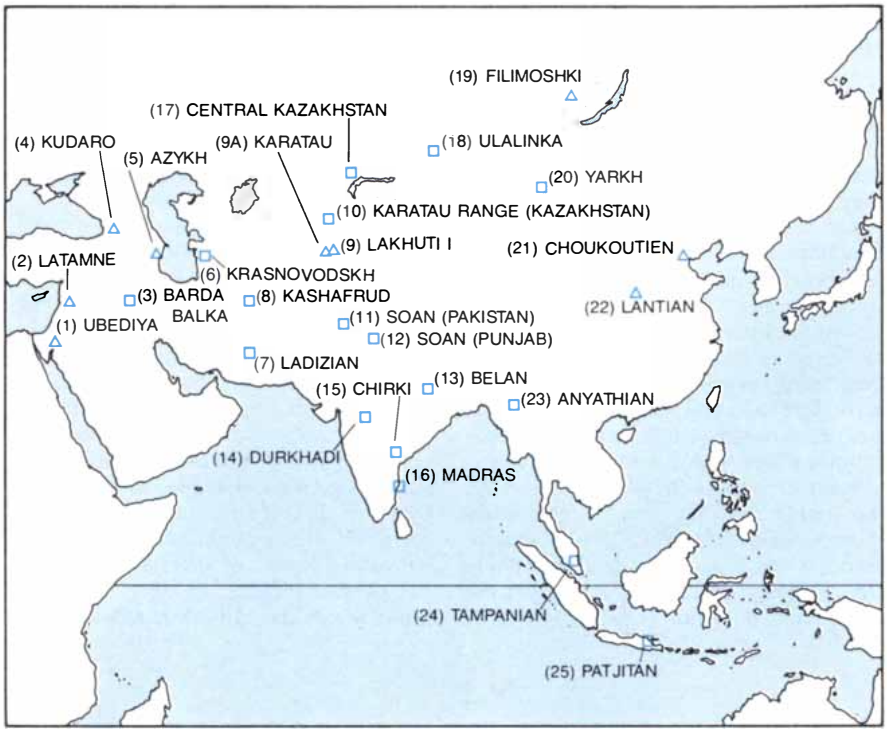
The stone tools that demonstrate man's presence in the area are all associated with buried soils that lie above the Matuyama-Brunhes paleomagnetic boundary. Specifically they have been found in the fifth, sixth and seventh soil complexes (counting from the surface down). Their position above the boundary means that the tools are less than 690,000 years old. But how much less? Fortunately another paleomagnetic datum, the Blake event, helps to narrow the possible range. The Blake event, a brief reversal of the Brunhes polarity, occurred about 110,000 years ago; evidence of it is present in the loess above



WIDESPREAD DEPOSITS OF LOESS lie below the mid-February snow line in this satellite image of the Afghanistan-Tadzhikistan border area east of Dushanbe produced by the EROS Data Center of the U.S. Geological Survey. The data for the image were acquired at an altitude of 915 kilometers by the earth-resources satellite *Landsat 2* in the winter of 1978–79. The deeply carved deposits of loess in the area have been under scientific study since the late 1960's. Evidence of the presence of early men in the harsh environment of this steppe region has been noted at 12 deep sections exposed by erosion and has been confirmed by archaeological excavations at two of the sections. The area covered by the satellite image is indicated by the colored rectangle that appears in the map at the bottom of the opposite page.

the fifth buried soil complex at three of the 12 soil exposures where tools have been found. Clearly a substantial length of time was needed for the successive accumulations of loess and the development of the soils that lie between the seventh and the fifth buried soil complexes. It therefore seems reasonable, if not conservative, to estimate the age of the three soil complexes where tools are found as being somewhere between the late Middle Pleistocene and the early Upper Pleistocene. In terms of absolute chronology that would be between 250,000 and 130,000 years ago; in the terminology of Old World archaeology it is the latter part of the Lower Paleolithic.

Thermoluminescence dating is based on the fact that a number of crystalline solids, such as the quartz particles of the Tadzhikistan loesses, store energy from background ionizing radiation after they are buried and release it in the form of light when they are heated. The intensity of the light they emit is proportional to the length of time they have been buried. Such solids do not store energy while they are exposed to the sun's ultraviolet radiation at the surface; they are therefore set at zero, so to speak, until they are buried.

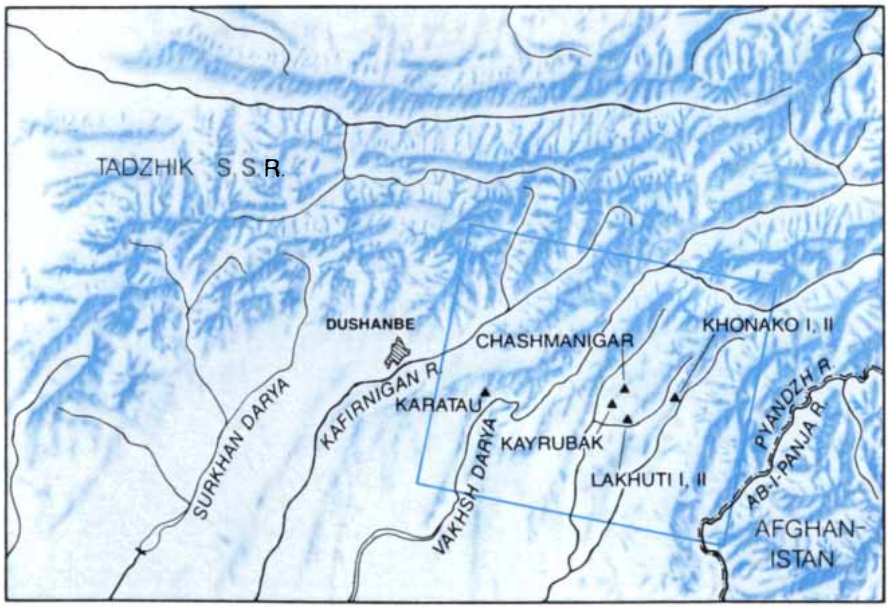


MAJOR EARLY PALEOLITHIC SITES in Asia appear in color on this map. Triangles, such as the ones marking Choukoutien in northern China and Latamne in Syria, indicate that the estimated age of the site is based on good geological data. Rectangles, such as the ones marking Patjitan in Java and Barda Balka in Iraq, indicate the absence of a good geological context. Of the 26 sites that appear on the map only nine fall in the first category. Two of the nine, Karatau and Lakhuti I, are in the loess region of the Afghan-Tadzhik Depression.

A pioneering attempt by the Ukrainian geologist V. N. Shelkoplyas to apply thermoluminescence dating to the quartz particles in the Tadzhikistan loesses provides at least preliminary support for the age estimates arrived at by paleomagnetic dating. Shelkoplyas has calculated dates at five of the loess exposures. The earliest date, from loess more than 150 meters below the surface today, was 880,000 ± 98,000 years B.P. (before the present). The latest date, from loess about 10 meters below the surface, was 21,000 ± 9,000. The thermoluminescence dates relating to the stone tools (that is, the dates indicating the age of loess deposits above or below the buried soils where the tools have been found) range from a minimum of 110,000 ± 13,000 (loess above and therefore younger than Soil No. 5 at the site Khonako II) to a maximum of 280,000 ± 48,000 (loess below and therefore older than Soil No. 7 at Khonako I).

Shelkoplyas' findings are necessarily tentative, but their rough agreement with the paleomagnetic dates strengthens their credibility. For example, the thermoluminescence date of a loess layer at Kayrubak, placed by paleomagnetic methods at the Matuyama-Brunhes boundary (690,000 B.P.), is 650,000 ± 78,000, and the thermoluminescence date of the same boundary loess at Lakhuti is 720,000 ± 82,000. It has been observed that thermoluminescence determinations tend to underestimate the age of quartz samples progressively with increasing age. One can therefore reasonably expect that the actual age of the buried soils where the Tadzhikistan stone tools were found is greater than the thermoluminescence dates suggest and is thus closer to the initial estimate of between 250,000 and 130,000 years.

Two of the 12 locations where the buried soils have been found to contain stone tools, Lakhuti I and Karatau, have been excavated. The work began in 1973 under the direction of one of us (Ranov)



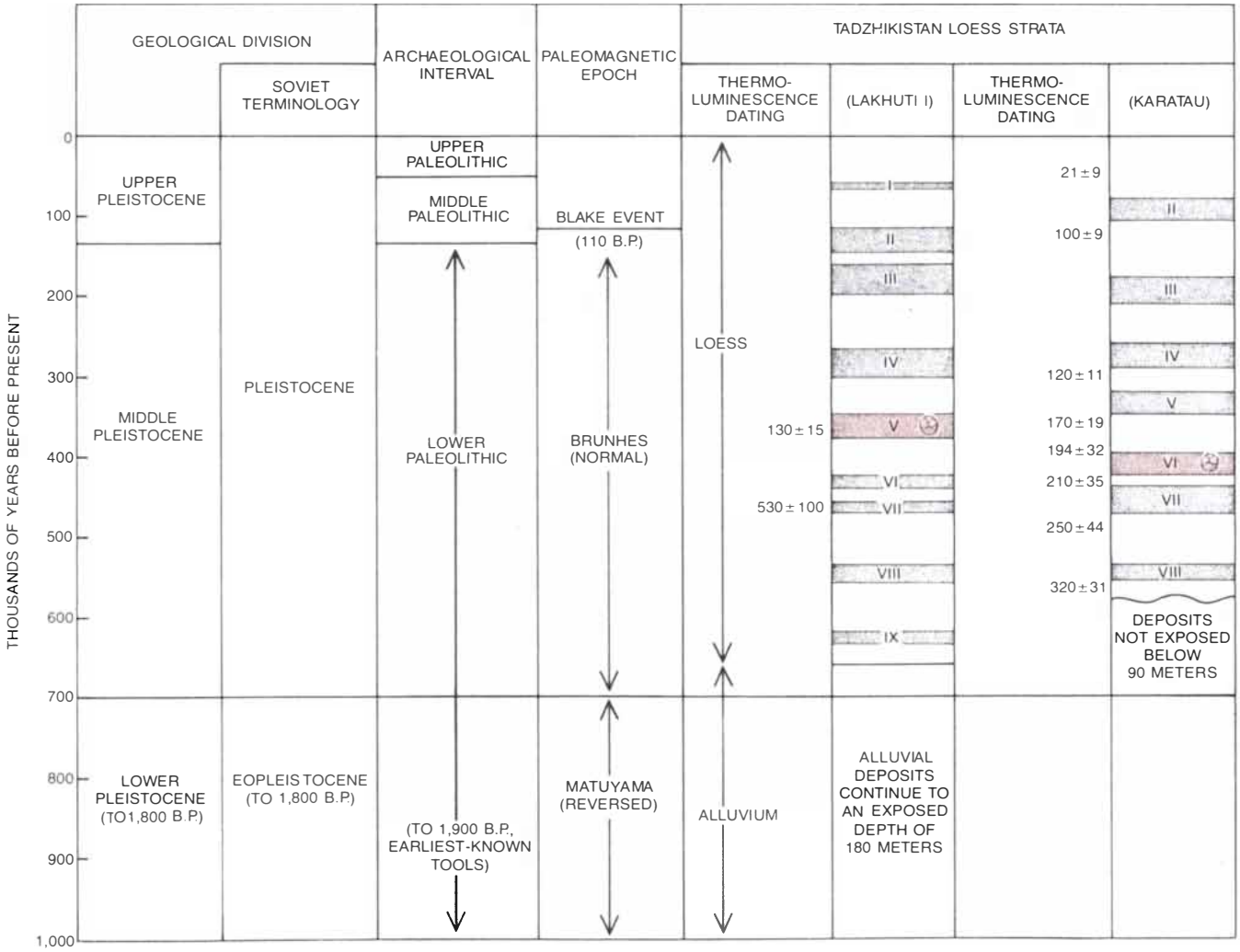
SOUTHEASTERN AREA OF THE TADZHIK S.S.R. abutting the Afghanistan border is noted for deep loess deposits that hold a two-million-year record of changes in Pleistocene climate and environment. Five of the places (*color*) where stone tools have been found are named.

and is still in progress. Up to now 276 square meters of Soil No. 5 at Lakhuti I and 124 square meters of Soil No. 6 at Karatau have been cleared. At both of the excavated sites the tools were within a soil horizon; the same is true of the other 10 locations. At the excavated sites they were found mainly in the 1.5-meter zone of most intense weathering that lies above the carbonate horizon. This position indicates that hunter-gatherers occupied the sites only at times of optimum climate, when conditions both of temperature and of precipitation were most favorable for plants and animals. The tools were made out of metamorphic rock that had been worn into pebbles and cobbles in stream beds.

Some 200 artifacts were found at the Karatau site. They are of two basic classes: cores and flakes. Core tools were made by modifying the original pebble only slightly, detaching a few small flakes from one end. These simple tools are nonetheless divisible into two categories: choppers and chopping tools. The distinction is as follows. With a chopper the working edge was formed by removing flakes from only one side of the pebble. With a chopping tool the working edge was formed by removing flakes from both sides.

The second class of tools, flake tools, appear to have been made by two methods. The commoner method was to strike the pebble a direct blow that detached a single flake; it frequently yielded flakes that had a wedge-shaped cross section, like a segment of an orange. The other method was to prepare a "striking platform" at one end of the pebble by removing one or more small flakes. The subsequent blow that produced the flake tool was directed at this prepared platform. Of all the unbroken flakes from Karatau 70 percent still have the original pebble surface on one side at the point where the blow was struck to detach them. This is evidence that even though a striking platform was sometimes made, the toolmakers more commonly struck the flake from the pebble without preliminaries.

Soil No. 5 at Lakhuti I was formed somewhat later than Soil No. 6 at Karatau. Among the 450 artifacts unearthed at Lakhuti I the proportion of flake tools with striking platforms is considerably higher than it is at Karatau. A few disk-shaped pebble cores were also found at the site, indicating the practice of detaching several flakes from a single pebble. The proportion of flake tools to pebble choppers and chopping tools is also higher at Lakhuti I than it is at Karatau, and one gets the impression of a greater refinement in the secondary retouching of the flakes. These differences could indicate that the occupants of the more recent site had a more developed stone-tool technology.



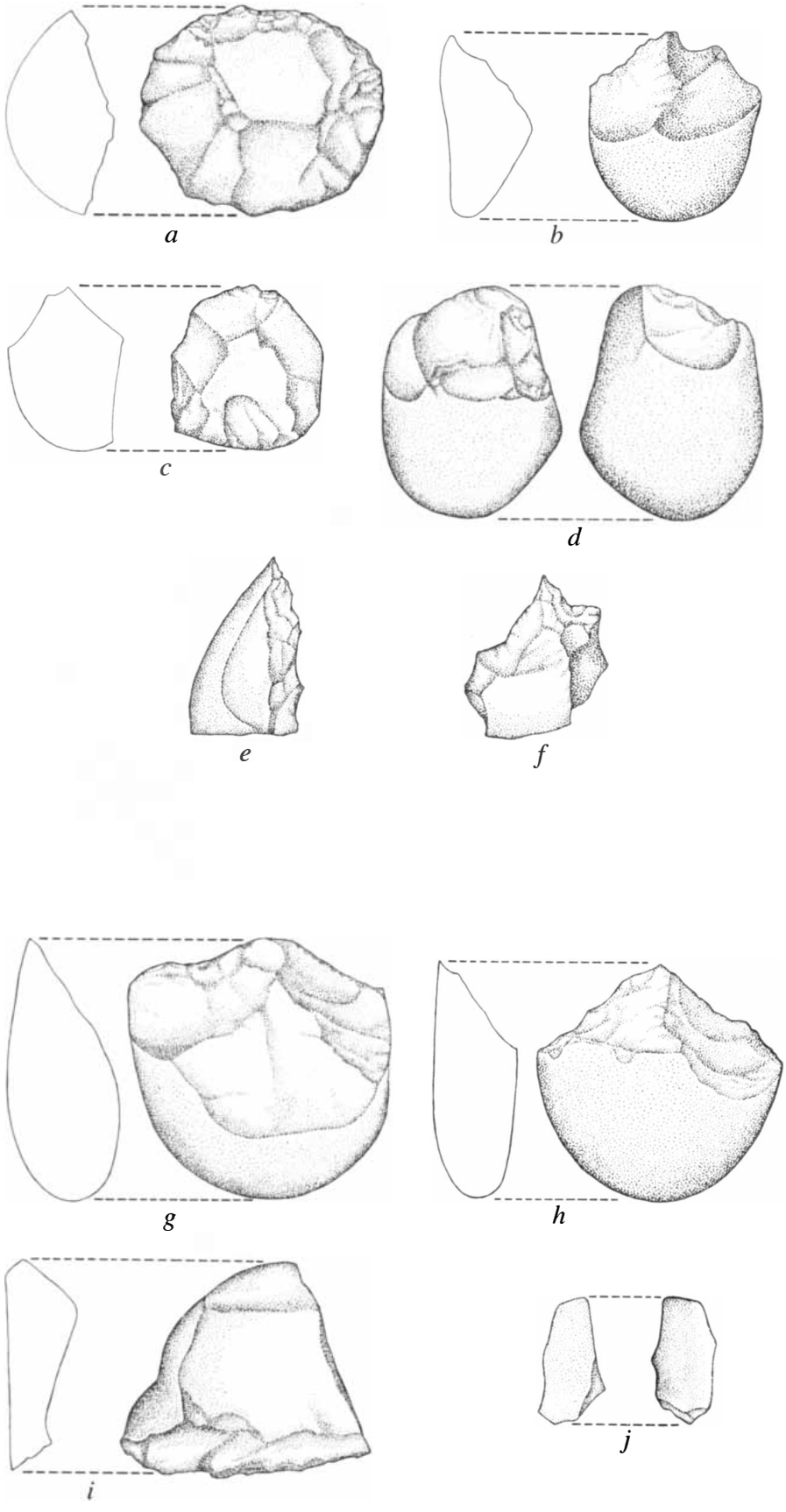
BURIED SOILS at the two loess exposures where stone tools have been excavated (*right*) are shown in this diagram in relation to two special time scales. The first is based on the paleomagnetism of magnetic particles in the loess. The second is based on the thermoluminescence of quartz particles in the loess. Dates are given in thousands of years before the present (B.P.). Both the geological divisions of the Pleistocene and the archaeological intervals of the Paleolithic also appear. Eight buried soils (*Roman numerals*) at Karatau and nine at Lakhuti I are younger than 690,000 B.P. The excavated stone tools are from Soil No. 6 at Karatau and Soil No. 5 at Lakhuti I (*color*).

When the overall technology is as simple as it is at both sites, however, it is notoriously difficult to identify cumulative and progressive changes.

Although at both sites it is possible to distinguish between the two kinds of core tools, that is, choppers and chopping tools, the flake tools do not fall into uniform categories. They can be described only in general terms as flakes with lateral retouching, notched flakes and bifacial fragments: small tools that were shaped by detaching smaller flakes from both sides. (The last are extremely rare, and the stone-tool industries at both sites can in no sense be construed as typical bifacial industries such as those that turned out the well-known Chellean and Acheulean hand axes of the Lower Paleolithic.)

Among the finds at Lakhuti I are a few bits of animal bone. They have been identified as the remains of gazelles and a variety of deer. Grazing ungulates such as these may have been relatively abundant on the open steppe, but beyond this the picture of the hunter-gatherer economy in central Asia at that time, late in the Middle Pleistocene, is not yet clear. The landscape would have included piedmont in addition to steppe, and the difference in altitude between the faulted mountain ridges and the river valleys below was substantial. Today the Lakhuti I site lies close to the Obi-Mazar River. In contrast, Karatau is more than 1,000 meters above the nearest major river, the Vaksh. On balance it seems likely that the pattern of human activity consisted of the exploitation of the region by wide-ranging bands of foraging hunter-gatherers that entered the Afghan-Tadzhik Depression in climatically favorable interglacial periods to occupy small temporary camps.

What kind of men were these hunter-gatherers? Until skeletal remains are uncovered the question cannot be answered with any precision. It is known that the earliest hominid inhabitants of Asia, with only one possible exception, belonged to the species *Homo erectus,* whose remains in Java and China date back some 1.5 million years and possibly 1.9 million. (The possible exception is *Meganthropus,* represented by a jaw fragment from Java that has been placed by some in the genus *Australopithecus.*) What led populations of *Homo erectus,* or successor populations, out of the low-latitude savanna into the deciduous forests of the north and the semiarid steppe beyond? With respect to the Afghan-Tadzhik Depression in particular, until recently many prehistorians maintained that early men did not inhabit such arid and climatically rigorous regions of central Asia until perhaps 100,000 years ago, at the end of the Lower Paleolithic and the beginning of the Middle Paleolithic. This conclusion was based primarily on the assumption



SIMPLE STONE TOOLS from Lakhuti I (*upper group*) and Karatau (*lower group*) appear at half actual size. The distinction between chopping tools (*c, d*) and a chopper (*b*) is that flakes were struck off both sides of a water-worn pebble to make a chopping tool but struck off only one side to make a chopper. The two pointed and retouched flakes (*e, f*) may have been used for piercing. One pebble (*a*) shows the scars caused by the removal of several flakes, perhaps for use as tools themselves. The artifacts from Karatau include two choppers (*g, h*), a flake tool (*i*) that was laterally retouched and an unretouched primary flake (*j*), raw material for a tool.

that any earlier hunter-gatherer populations would have been unable to adapt to steppe conditions.

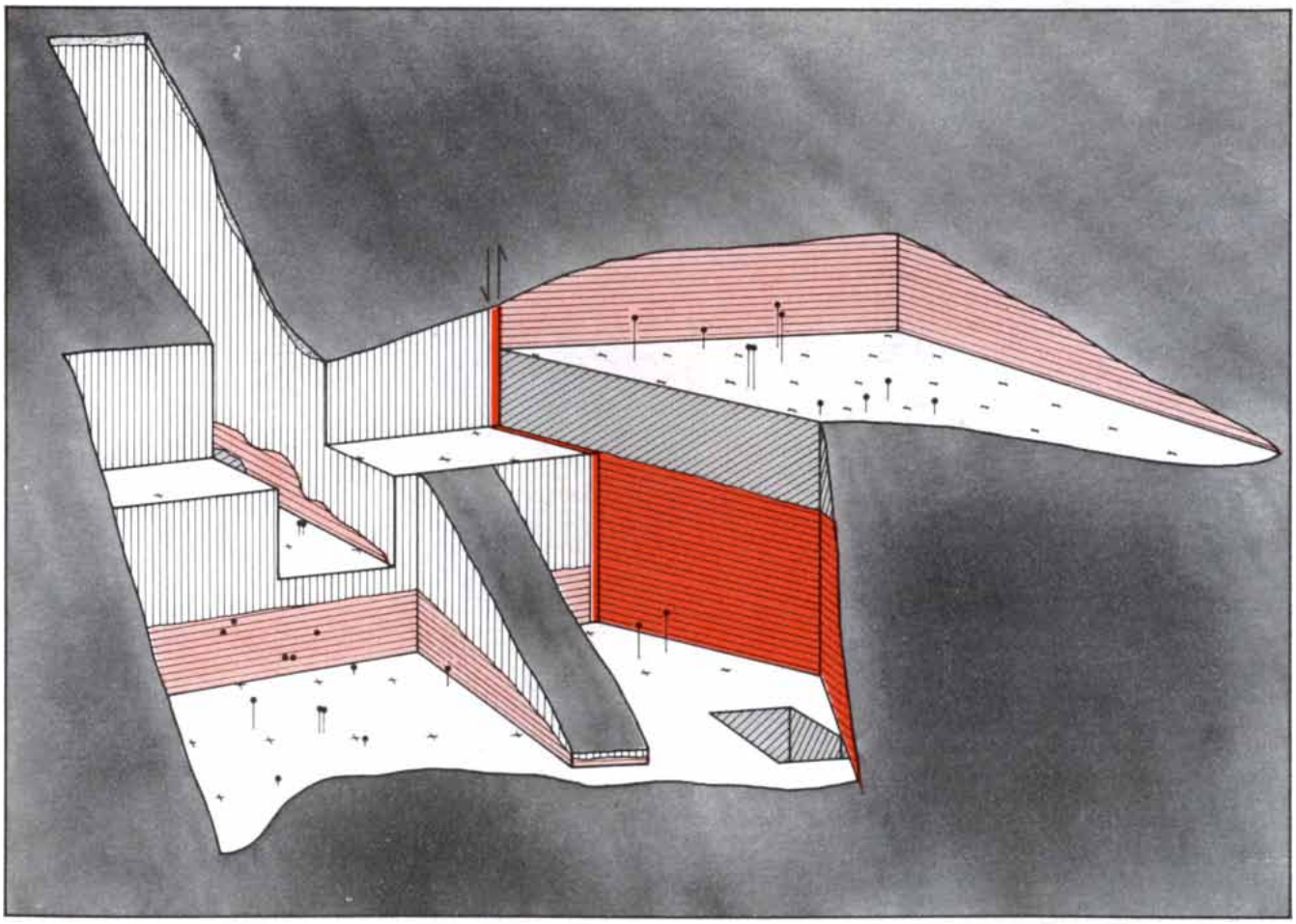
The archaeological findings in Tadzhikistan demonstrate that this assumption is not correct. Instead, some 250,000 years ago and quite possibly even before then certain early hunter-gatherers, attuned to fluctuations in the availability of scarce resources, were living in the Afghan-Tadzhik Depression. They obviously had managed to adapt to these harsh semiarid uplands. Nowhere else in the Old World at this time is a similar cultural adaptation known.

One must conclude that the adaptive competence of these hunter-gatherers was greater than has generally been recognized. Indeed, one can predict that evidence of the presence of Lower Paleolithic hunter-gatherers will be uncovered in many parts of Asia where it has not been expected that it would be found. For example, several reported finds of bifacial hand axes in central Kazakhstan could be explained as reflecting a more northerly penetration of early hunter-gatherers than has heretofore been recognized. In this connection finds at Korolevo in the Carpathian Mountains of the Ukraine by V. N. Gladilin of the Kiev Archaeological Museum indicate that the hunter-gatherers of late Middle Pleistocene times could deal with severe and prolonged winters. This is a fact not widely recognized by scholars concerned with the period.

The stone tools found at Lakhuti I and at Karatau are very simple; some prehistorians might even describe them as crude or primitive. Their presence in Tadzhikistan some 250,000 years ago, however, is incontrovertible evidence that a simple core-and-flake assemblage of tools was sufficient to meet the adaptive requirements of a demanding habitat. The tools apparently did what was needed—in terms of pounding, cutting, scraping, piercing and so on—for the central Asian hunter-gatherers' survival under these conditions. The lesson here is that a simple technology does not necessarily reflect a limited potential for adaptation.

If, as it appears, early man inhabited the Afghan-Tadzhik Depression mainly in interglacial times, then not only this region but also other large areas of Asia may have been the scene of human population movements in response to climatic oscillations over long periods of time. Such movements ought to have precluded any long-term isolation of regional populations in Asia. If that is the case, however, it disagrees with a view of Asia in Paleolithic times that has long been held and is still widely held. This view maintains that in Asia during the Middle and Upper Pleistocene there were two long-standing and mutually exclusive stone-tool technologies representing two isolated populations: a chopper-and-chopping-tool industry and a bifacial-hand-axe industry.

The conventional view is that the chopper-and-chopping-tool tradition is the original technological heritage of



EXCAVATION AT KARATAU, cutting back into the loess slope high above the Vaksh River, exposed an area of 124 square meters. The block diagram shows the southern part of the site; a fault (*dark color*) had offset the sixth soil complex here by a distance of about three meters, leaving the left side of the soil lower than the right. The soil complex consists of three divisions: a weathered upper soil (*light color*), a thick crust of calcium carbonate (*gray*) and the parent material of the soil (*dark color*) under the crust. All 25 artifacts uncovered in this part of the site (*black dots*) were in upper soil. Karatau site held some 200 choppers and flake tools.

the earliest hominids who spread out from Africa across the Old World. That tradition was characterized by relatively simple pebble tools showing a minimum of modification. In contrast, the bifacial-hand-axe tradition, which is usually considered more advanced, was also thought to have spread out from Africa and Europe but to have penetrated Asia no farther than the subcontinent of India. The chopper-and-chopping-tool tradition was thought to have remained in isolation in Asia: a kind of cultural backwater confined to the southern flanks of the Himalayas, Southeast Asia and the Far East that contributed little to the mainstream of human development.

The conventional view presupposes the existence of cultural or natural isolating mechanisms that separated the two traditions for hundreds of thousands of years. Further, it sees the patterns of stone-tool technology as reflecting two distinct cultural traditions. In a sense such a two-culture hypothesis supports the notion that the differences between the peoples of the East and those of the West are extremely early in origin, arising in Lower Pleistocene times.

The discoveries in Tadzhikistan, and other recent finds as well, show a geographic overlap of the two tool traditions that has laid the conventional view to rest. The view that is emerging to replace the two-culture one rejects the concept of long-term regional isolation in Asia while recognizing that with respect to tool technology there was considerable regional variability and diversity throughout middle- and lower-latitude Asia. This diversity could have had a number of causes. Among them can be included short-run adaptive responses to local environmental changes, functional requirements related to seasonal tasks and similar specific activities, cultural "drift" and even population movements. At the same time a significant flow of genes between human populations that came in contact would have served to prevent any substantial long-term genetic isolation.

It follows that assigning the Lower Paleolithic artifacts of Tadzhikistan to one component of a no longer tenable two-culture hypothesis would be an exercise in futility. The Tadzhikistan core-and-flake industry must be evaluated not in broad generalities but on a more regional basis, and the influences that molded its characteristics must be sought locally. This is equally true of whatever other surprises the loess of central Asia may hold. There could well be in the loess a record of human activity in the interior of Asia going back to the beginning of Middle Pleistocene times, a record that might provide the key to an understanding of the biological and cultural evolution of our early Paleolithic ancestors in Asia.

Addictive Behavior

Whether the addiction is to drugs, alcohol or tobacco, the problem is self-destructive behavior. One treatment that has succeeded in restoring health is the maintenance of heroin addicts on methadone

by Vincent P. Dole

The grave social and personal problems resulting from addiction, particularly to drugs but also to alcohol and tobacco, are notoriously difficult to deal with. The failure rate of "detoxification" and rehabilitation programs is high. A program that does work, provided it is done properly, is the maintenance of heroin addicts on methadone, an analogue of heroin. The methadone-maintenance program in New York City, in which I have participated as a physician and an administrator since it began, is an example of such a program. It also provides a basis for reflections on addiction and the problems of dealing with it.

No one really understands addictive behavior. Children and animals are not born with a desire for narcotics, sedatives, alcohol, tobacco, amphetamines, cocaine or caffeine. Many people, including those who later become drug addicts, alcoholics and smokers, react to their first dose with nausea and dizziness. It is therefore strange that some people not only learn to tolerate these poisons but also go on to develop an irresistible craving for them.

Theories are abundant. Popular wisdom holds that addicts take drugs for gratification. The statement is undeniable but incomplete. How do these initially aversive substances become gratifying, and why do only certain people become addicted when many are exposed? Do the addicted minority react differently to the drugs or do the nonaddicted majority have less need for gratification?

The older medical textbooks attributed addiction to an addictive personality, a defect of character diagnosed from the fact that the subject had become addicted. Little was said in this circular explanation about the reasons for the specificity of addictions. Narcotics users crave narcotics, alcoholics alcohol, cigarette smokers cigarettes. Even with people who have multiple addictions the various cravings retain their specificity. Why is this so?

Matching the psychological explanations in inadequacy were theories based on purely pharmacological arguments. An oversimplified theory pictured the addict as a person trapped in his habit of taking drugs by the punishment of stopping. When the effect of an addictive drug wears off (the argument went), symptoms of abstinence appear, compelling the addict to seek relief in another dose. This explanation was plausible and accounted for the recurrent desperation of drug-seeking behavior, but it failed on the major point of explaining why most addicts relapse after the acute pharmacological need for the drug has been removed.

The oldest treatment of addiction is detoxification (a term left over from an obsolete theory that addicts suffer from an accumulation of toxins in the body). In this treatment the drug is withdrawn under supervision. The symptoms during the withdrawal period depend on the particular drug, the extent of prior usage and the kind of supportive services provided during withdrawal, but with sufficient control of the patient detoxification is always possible. Thereafter he can abstain without severe discomfort. To employ the technical phrase, he has been relieved of his physical dependence.

Some investigators have equated addiction with physical dependence, but this view ignores the most difficult part of the problem: drug-seeking behavior. Physical dependence is simply an adaptive consequence of taking certain chemicals repeatedly. Many drugs administered in medical practice (for example steroids) give rise to a physical dependence in the pharmacological sense without creating a desire for the substance. Similarly, the forced administration of narcotics and alcohol to animals makes them physically dependent but usually fails to make them behave addictively. The people taking steroids and the animals given narcotics or alcohol stop or substantially reduce their consumption when the intake is made optional.

The distinction between dependence and addiction is most clearly demonstrated by the usual failure of detoxification to cure addicted human beings. If this treatment ended the habit, addiction would be only a minor medical problem, but most users relapse after they have been freed of their dependence. In an effort to reconcile this result with the pharmacological theory some experts have invoked the concept of psychological dependence, a term based on the notion that detoxification has removed the physiological determinants of addictive behavior but has left a psychological need. Like the theory of addictive personality, the concept of psychological dependence has the quality of being inferred from the very behavior it seeks to explain.

An alternative psychopharmacological theory of habitual drug taking identified relapse with conditioned responses. Abraham Wikler, working at the Public Health Service Hospital in Lexington, Ky., noted that addicts who had been discharged from the institution as being cured might be seized with an intense craving when they returned to their old neighborhood. He found that environmental cues associated with the taking of heroin could serve as triggers to reactivate craving. Even the physical aspects of acute withdrawal could reappear in these circumstances.

This observation raised the hope that the addictive cycle might be broken by reverse training, which entails dissociating the cues from the rewarding effects of the drug. Unfortunately attempts to apply this principle have had little success. Potent medicines have been available to block the action of narcotic drugs, but the prescription of these medicines has not extinguished drug-seeking behavior in a significant number of addicts. Although the negative results do not necessarily invalidate the theory, they cast doubt on its practical value.

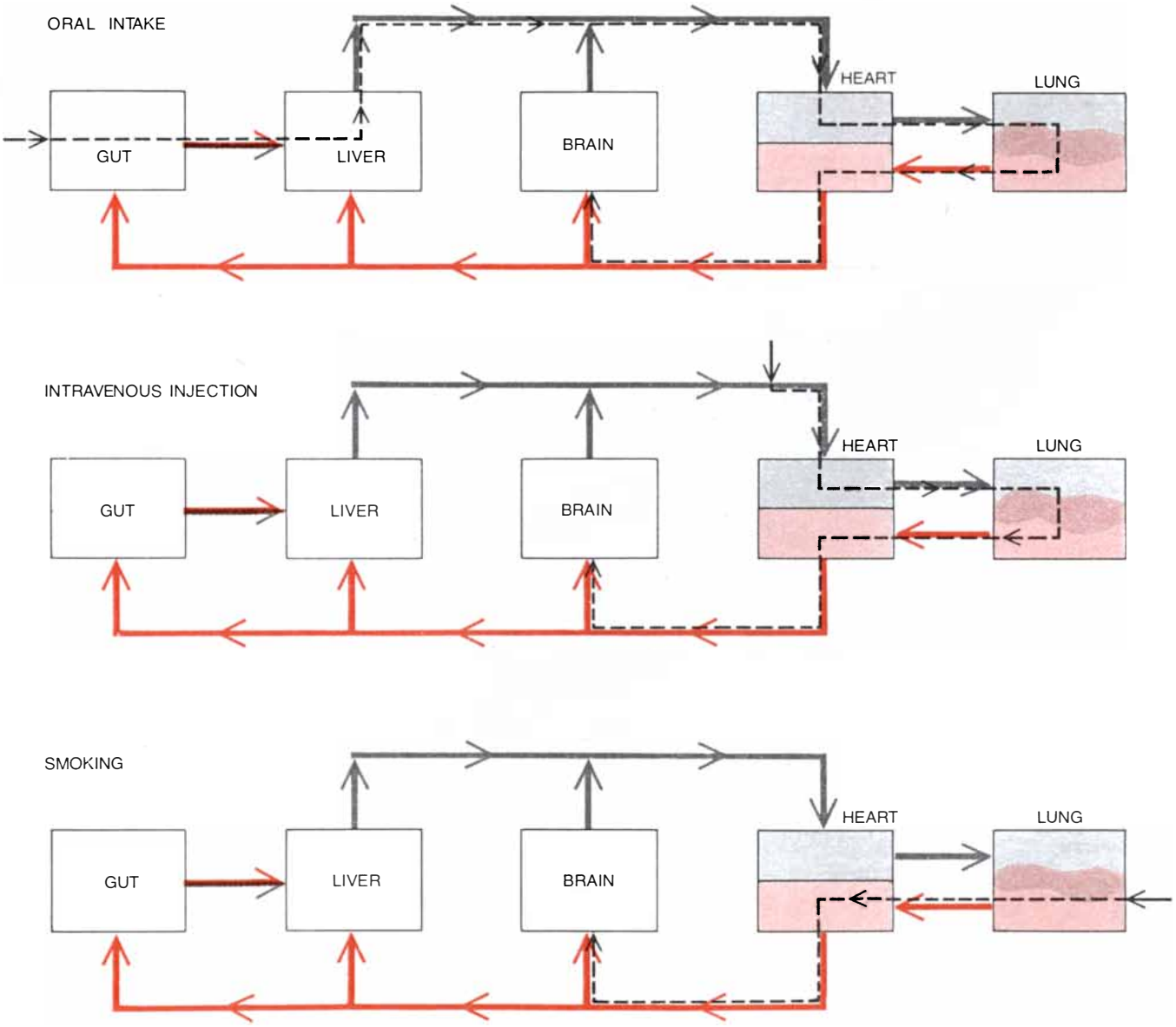
A broader sociopsychological theory,

ADDICTION TO ALCOHOL is portrayed in *Gin Lane,* an engraving by William Hogarth. The scene reflects in a somewhat overstated way the epidemic of alcoholism that developed in England some 250 years ago when alcohol in a concentrated and cheap form became widely available in "geneva" (gin). On the steps a drunken woman lets her baby fall to his death; below her an alcoholic appears to be dying; to the left people pawn items to get money for gin, and in background several people are drinking or suffering the consequences.

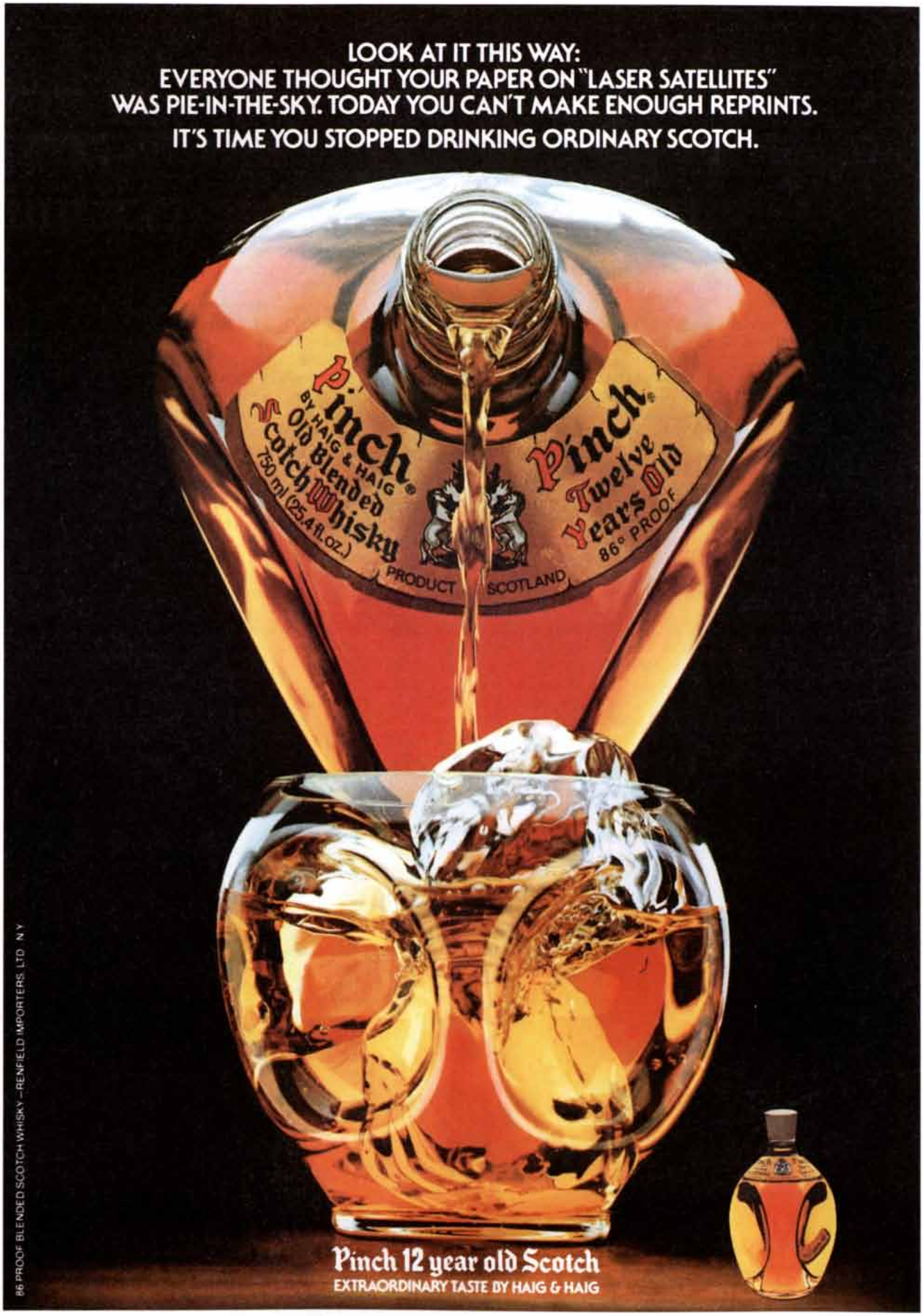
incorporating some elements of the conditioning theory, is currently popular. Recognizing that drug addiction and alcoholism are found in epidemic proportions in crowded slums, many socially conscious people have interpreted addiction as being a means of escape from an oppressive environment. In this view all medical treatment is superficial, at best only palliative and at worst counterproductive to the fundamental task of reforming society. The political appeal of the theory is powerful, linking as it does the prevention of addiction to the worthy goals of eliminating social discrimination, poverty, unemployment, crowding and poor education.

Apart from the practical difficulties of preventing drug abuse by abolishing poverty the sociopsychological theory provides no treatment for people already addicted and no explanation of differences in susceptibility. Even in bad environments most people avoid addiction. In fact, it is the availability of drugs rather than the quality of life that seems to be the most important factor in determining the prevalence of drug abuse. Heroin has spread to suburbs and small towns, which were once thought to be immune. Addiction to alcohol and cigarettes, which are universally available, affects all strata of society. A place that has escaped a narcotic epidemic may owe its good fortune more to a scarcity of drugs than to social privilege.

As a practical matter most authorities concerned with the control of addiction agree on the need for a comprehensive approach: the enforcement of laws to limit the availability of dangerous drugs, the pursuit of measures intended to prevent addiction (the improvement of social conditions, education and placement in jobs) and a reduction in demand through the treatment of people who have become addicted. Meanwhile the lack of a basic understanding of the addictive process becomes obvious to anyone who examines the confusion of programs seeking to deal with



ROUTES OF DRUGS to the brain by way of the bloodstream are depicted for oral ingestion, intravenous injection and inhalation in these schematic diagrams of the human circulatory system. If a drug such as heroin is injected or inhaled, it reaches the brain in a high concentration after a delay of only a few seconds. Alcohol taken by mouth similarly goes into the circulation quickly if a strong drink is gulped, because it is absorbed rapidly from the stomach and intestines and passes through the liver with little delay. If methadone is given orally, however, it is only gradually absorbed from the intestinal tract and is further delayed in entering the bloodstream by uptake in the liver. Because the absorption of methadone by the liver and other tissues is reversible, the concentration of drug in the bloodstream is buffered against sharp rises or declines. A heroin addict can therefore be stabilized and made functional with a daily oral dose of methadone.



the drug epidemic. As with efforts to control plagues in the Middle Ages, today's governmental policies toward addiction are politically determined, contradictory and ineffective. The situation is not likely to improve until the biological factors underlying addiction have been discovered.

It is noteworthy that most animals cannot be made into addicts. Experimenters looking for animal models of addiction have either failed or have succeeded under such special conditions as to cast doubt on the relevance of the model to the human problem. Although the pharmacological effects of addictive substances injected into animals are quite similar to those seen in human beings, animals generally avoid such drugs when they are given a choice. The toxic effects of various drugs have been well defined, but the fundamental question of why human addicts dose themselves repeatedly remains unanswered. Perhaps, as the psychological theories assume, the self-destructive ingestion of addictive substances is a peculiarly human problem arising from cognitive processes not shared by animals. Or perhaps the right combination of experimental animal, metabolic disturbance and environmental stress has not been found. The question is tantalizing, and it can be answered only by more research.

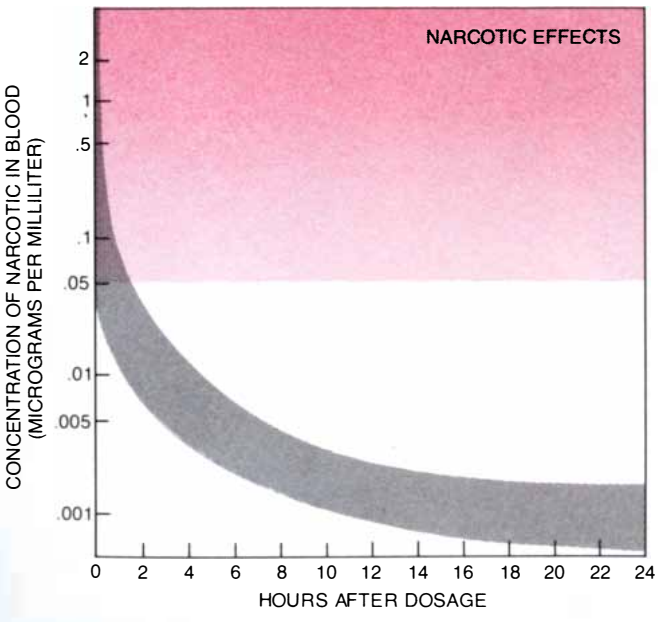
As often happens in studies of human disease, work on the clinical problem of addictive behavior has led to discoveries of general importance while the original question remains unanswered. Studies of opiate drugs in several laboratories revealed the presence of specific binding sites in various tissues; further study identified the native ligands for those sites as various polypeptides, or short chains of amino acids. It is now clear that the significance of the binding sites and ligands is much broader than their role in narcotic action. They may also figure in a variety of chronic diseases. Speculations cover the range from obesity to schizophrenia. As far as is now known, however, addictive behavior is not caused by an excess or a deficiency of the binding sites or the ligands. There is no evidence that they are abnormal in susceptible people before addiction or in detoxified narcotic users before relapse. Nor does any firm evidence link them to alcoholism or other kinds of addiction. At present, therefore, the biochemical work provides no theoretical guidance for the treatment of addicts. As with other chronic diseases of unknown cause addiction must be managed without an understanding of the fundamental processes. The only reliable basis for decision is an analysis of clinical experience.

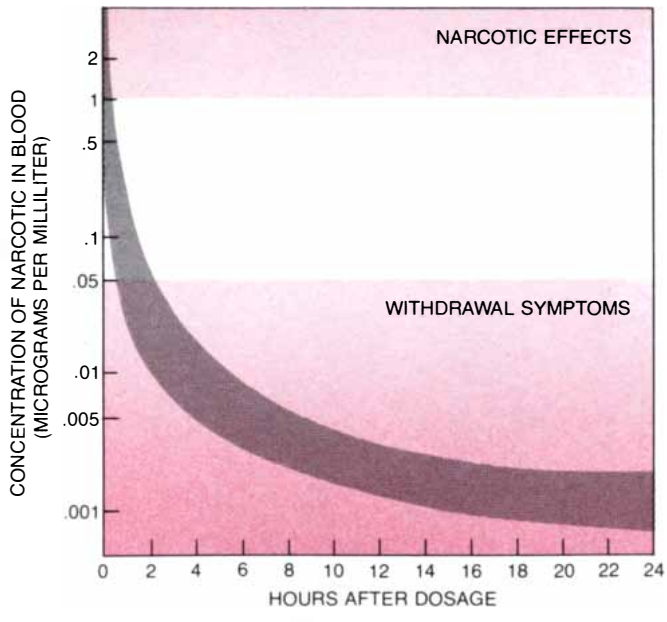
This was the point of view Marie Nyswander and I shared when we began our joint work on narcotic addiction 16 years ago. Then as now theories were abundant but had little practical value. The traditional methods of treatment—detoxification, psychotherapy and punishment—had already failed with many thousands of heroin addicts. The Public Health Service Hospital in Lexington, which was recognized as the national leader in treatment policy, provided only jail and psychotherapy. The rate of relapse after the addicts were returned to their communities was 90 percent. In the next decade the states of California and New York replicated the failure of jail and psychotherapy on an even larger scale. There was a need for empirical tests of other methods of treatment and for reliable, long-term statistics on the results.

Fortunately the hospital in Lexington had attracted clinical investigators of unusual ability. With a population of prisoner addicts available, they had done detailed studies of the short-term effects of addictive drugs. Their observations provided a sound pharmacological classification and gave precise definitions of the concepts of tolerance and physical dependence.

Of particular assistance to us as we planned our approach was their finding of differences in the effects of various narcotics. Although drugs of the opiate category are pharmacologically related, they have a wide variety of chemical structures with significant differences in the site and the duration of their action. This variation opened the interesting possibility that addicts who had been disabled by heroin might function better while taking a more benign narcotic. Unlike alcohol, which is the same drug whether it comes in gin or in bourbon, narcotics differ in absorption, metabolism, subjective effects and dangers. We reasoned that the behavioral symptoms of addiction might also depend on the particular narcotic being taken.

This question had not been much explored, since prison is a poor place in which to judge behavior. Good conduct in confinement is not proof of rehabilitation, nor is the alienation of a prisoner reliable evidence that he is psychopathic. For a fair test of social functioning observations should be made of the sub-





CONCENTRATION OF MORPHINE in the blood and its functional effects following an intravenous injection of 10 milligrams are shown for a nonaddict (*left*) and an addict (*right*). The concentration (*gray*) is approximately the same in each case, but the functional effects are quite different because of the addict's tolerance and physical dependence. The period between the disappearance of the narcotic effect and the onset of withdrawal symptoms is short for the addict. The body rapidly produces morphine from heroin after an injection.

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ject in his own community and should be continued for a longer period than a five-month sentence in a prison hospital.

We therefore began systematic comparisons of different narcotic drugs given to long-term heroin addicts in the metabolic ward of the Rockefeller University Hospital. The understanding was that the subjects could give up the study at any time. As the work progressed they were allowed to sign in and out almost every day to visit friends or hold part-time jobs. Samples of urine were analyzed frequently to detect illicit drugs taken outside the hospital. Much time was devoted to undirected discussion, mostly listening to the patients. It was our good fortune to be joined in this study by Mary Jeanne Kreek, a talented young investigator in clinical pharmacology. She participated in the early work and has continued as an independent investigator. In recent years her studies of differences in the metabolism of narcotic drugs have clarified the practically important distinctions between methadone and other narcotic drugs.

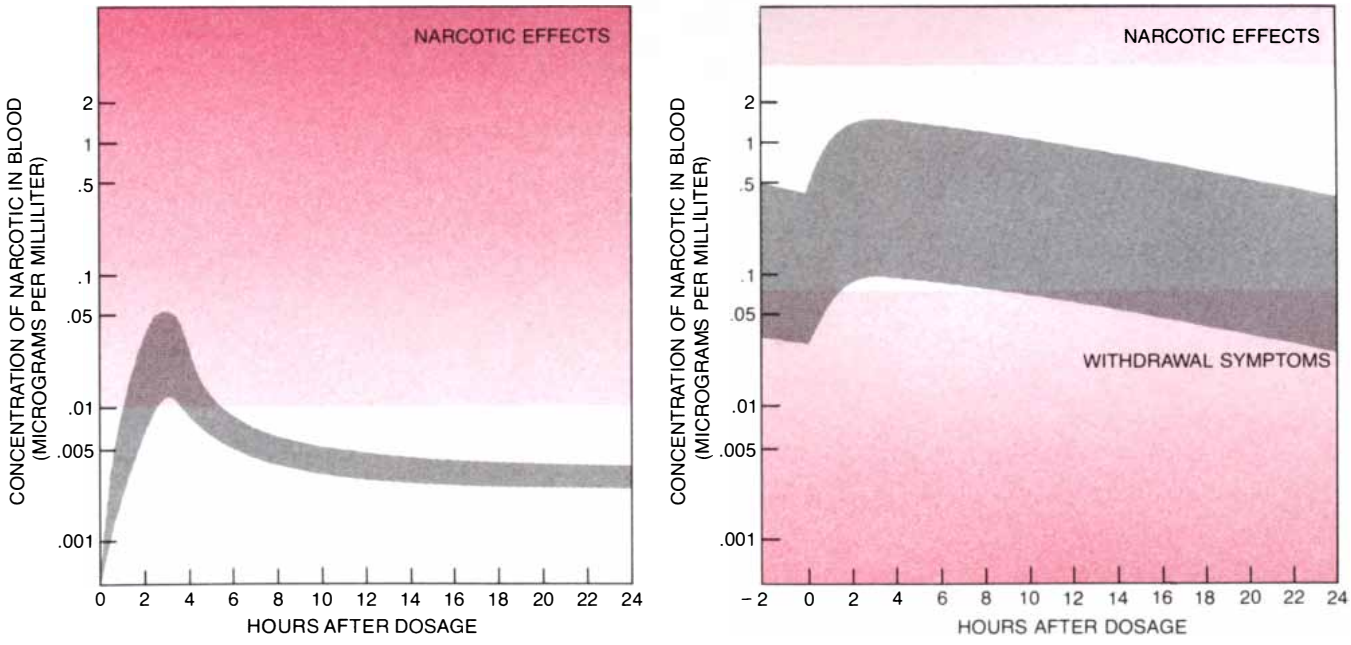
Our first trials of maintenance, involving a variety of narcotic drugs (morphine, heroin, oxymorphone and others), were discouraging. As the experts at Lexington had predicted, the patients were not satisfied with the treatment for more than a few days. They became irritable between doses, demanding larger amounts of drug and becoming obsessively preoccupied with the schedule of injections. Even five minutes of delay of a dose could create a disturbance. The patients certainly had not become candidates for social rehabilitation.

A different attitude developed after the patients entered the methadone phase of the study. We had not anticipated this effect and had no theory to explain it, but proceeding in ignorance we gradually increased the dose of methadone until it reached a constant and relatively high level: from 80 to 120 milligrams, given once per day orally. In this stabilized condition the patients appeared medically and functionally normal. They were not made euphoric by the medication as they had been by morphine and heroin. They passed tests of vigilance and coordination that had been designed for pilots of jet aircraft in the Navy. (The tests were administered by Norman Gordon of Yeshiva University.) Most important, their craving for narcotic drugs subsided. They became involved in correspondence courses and part-time work.

As the study progressed over the next eight months the subjects were allowed to use the ward as a residence, remaining for scheduled tests but otherwise free to leave during the daytime hours. There was relatively little abuse of narcotics after the first three months. Most of the patients had tried heroin on their first trips away from the hospital and had found it to be ineffective, since the tolerance induced by the daily dose of methadone blocked the usual narcotic effects of the illicit drugs. Further systematic tests, in which known doses of heroin and other narcotics were injected intravenously, showed that this tolerance also blocked the effects of all narcotics. In these stabilized patients the large daily dose of methadone was not producing a narcotic "high."

Here, then, was a quite remarkable phenomenon: a potent narcotic given every day to addicts did not narcotize them. Their specific tolerance to narcotics was high enough to eliminate narcotic effects, and their craving for heroin had disappeared. For the first time in many years they were able to behave like normal citizens, returning to their neighborhoods without involvement in illicit drugs. Now, it seemed, these people had become candidates for social rehabilitation.

The work therefore branched into two parts: (1) the development of rehabilitation services for medically stabilized patients and (2) continued research into the basic pharmacology. The treatment programs, which I shall not discuss in detail, have over the past 15 years enabled many thousands of otherwise intractable addicts to live as normal, noncriminal members of society. Interested readers can find an abundance of publications showing how the treatment programs must provide comprehensive



EFFECT AND CONCENTRATION of methadone are shown for naive subjects (*left*) and methadone-maintenance patients (*right*) after an oral dose. In the naive subject taking a 10-milligram dose the gradual absorption of the drug from the intestinal tract and the buffering effect provided by absorption in the liver before the methadone enters the bloodstream prevent the concentration of the drug in the blood from rising rapidly. This smooth course of action makes methadone useful for relieving pain in medical and surgical patients. In maintenance patients stabilized on an adequate daily dose (usually from 50 to 100 milligrams) the concentration of methadone in the blood is kept at all times above the threshold for withdrawal symptoms. (In a few cases a higher dose may be required if the elimination of methadone is unusually fast.) The peak concentration in a stabilized patient remains well below the threshold for narcotic effects. When a maintenance patient is stabilized on a correct daily dose of methadone, he is functionally normal, protected from narcotic effects by his pharmacological tolerance of the drug and from withdrawal symptoms by the constant presence of methadone in his bloodstream.

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services in addition to methadone. With this help and effective maintenance the patients have exhibited a remarkable potential for rehabilitation. All the patients admitted to the early studies had criminal records, lacked steady jobs, were without secure homes and family and had lost self-respect. Today most of them are living responsibly, supporting families and maintaining homes. Many of them are still taking methadone.

On the theoretical side we wondered how a potent narcotic drug could relieve craving without giving rise to undesirable narcotic effects. Some years later we found the answer in the stability of the level of the drug in the blood. Unlike heroin and other short-action drugs, methadone (when it is given orally in the proper dose to a stabilized patient) holds the concentration of narcotic in the blood at a fairly constant level for about 24 hours. Two conditions must be met: the daily dose of methadone must be adequate and the subject's tolerance must be high enough to block the narcotic effects of that dose. The conditions are met easily if the pharmacology is understood. Beginning with a small amount and gradually increasing the daily dose as tolerance develops over a period of from four to six weeks, a competent physician can stabilize an addict patient on methadone as easily as he can maintain a cardiac patient on a constant daily dose of digitalis.

The pharmacology merits a closer look. With repeated administration of a fixed dose methadone loses its sedative and analgesic powers. The subject becomes tolerant. If the dose is increased gradually to the fixed maintenance level, the effects are never large because this specific tolerance to narcotics grows with the dose.

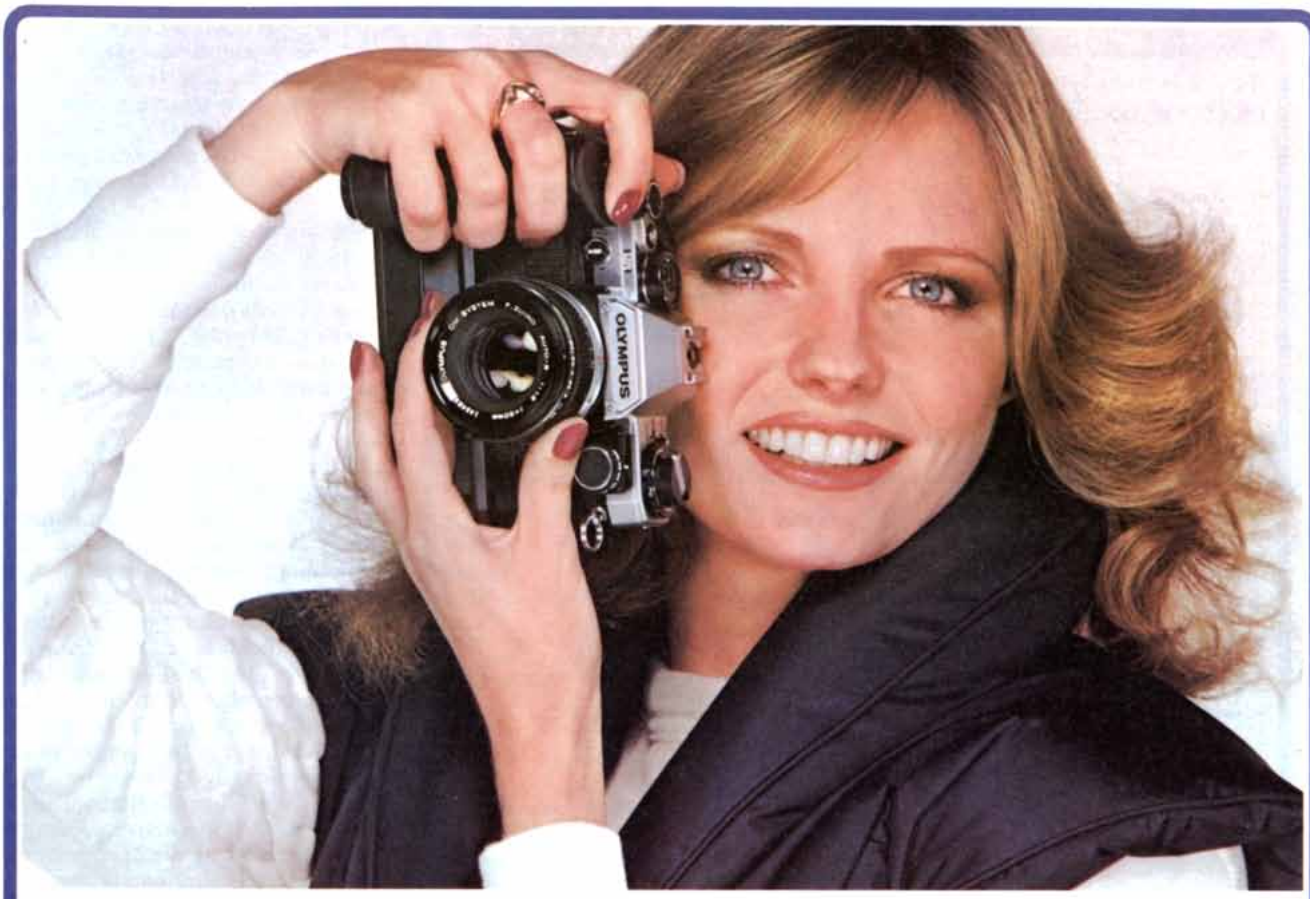
At the same time, however, the subject becomes adapted to the presence of a narcotic drug in his nervous system. He now needs to keep the concentration above a critical minimum to prevent symptoms of withdrawal. He has become physically dependent. Between the limits of narcosis and abstinence there is a functional zone. If the concentration of circulating methadone remains below the level that gives rise to narcotic effects but above the threshold for withdrawal symptoms, the subject will be both alert and comfortable. The discovery in the study of methadone was the possibility of relying on the medication to hold a patient consistently in this normal state. Such a result is not possible with medically administered heroin, morphine or similar narcotics. Further study showed why.

When an addict injects a concentrated solution of heroin into a vein, the first event is a sharp impact of the drug on the nervous system. From studies of circulatory dynamics by physiologists injecting inert tracer substances it can be estimated that the initial concentration of heroin entering the addict's brain is enormous, perilously close to a lethal exposure. If he survives the impact, it is because of the tolerance carried over from previous doses and because of the brevity of the narcotic pulse. For example, if he injects 20 milligrams, a pulse of heroin with a peak concentration perhaps as high as 40 micrograms per milliliter of blood will reach his brain and other organs within about 10 seconds. It will remain in contact with susceptible cells for a period of from one second to three seconds. In this short time the drug has been swept with the venous blood through the right side of the heart, through the lungs, back again to the heart and from there has been pumped in arterial blood to the susceptible tissues. On this first pass the drug is only slightly diluted by body fluids, and the liver has no opportunity to remove it. As the blood recirculates, the concentration of drug falls rapidly. Five minutes after injection it may be below .5 microgram per milliliter; two hours later, below .05 microgram.

The addict has delivered to his nervous system a pharmacological hammerblow, which is followed by a rapid withdrawal that sensitizes his brain for the next dose. Such transient effects appear to be an important part of the addictive process; they are sought by all addicts, not only by those who inject narcotics but also by people addicted to sedatives (who inject their drug when it is possible for them to do so), alcoholics (who gulp drinks) and heavy smokers (who inhale cigarette smoke deep into the lungs). Rapid changes in the concentration of a drug maximize the pharmacological effects.

At the time of our early work analytical methods were not available to follow the concentration of a narcotic drug in the blood, but Kreek and I could observe the acute functional effects of injected narcotics delivered cautiously into the veins of addicts. About 10 seconds after the beginning of an injection of heroin the subjects had a typical narcotic "rush," including a wave of euphoric feelings, visceral sensations, a facial flush and a deepening of the voice. Following this immediate effect, which lasted for only a few minutes, they became calm, contented and detached. They appeared to be quite uninterested in external events during the next hour but were able to answer questions.

Between two and four hours after the injection their restlessness reappeared. They felt uncomfortable and wanted another injection. Heroin had disabled them both with its initial narcotic effect and with the subsequent symptoms of withdrawal. No one who had witnessed



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experiments such as these would recommend attempts to maintain addicts with heroin or other self-administered, quick-acting, injectable narcotic drugs. Addicts using drugs in this way could not live and work as normal people, nor could their daily dose be kept constant.

In contrast the blood level of methadone, when it is given by mouth in therapeutic doses to stabilized patients, never exceeds one microgram per milliliter or falls below .1. For most patients the range is even smaller if the dose has been carefully adjusted. In the average patient the concentration remains between a maximum of .5 microgram per milliliter and a minimum of .2. At the maximum the concentration is well below the level required to cause narcotic effects in tolerant subjects, and at the minimum it is safely above the threshold for withdrawal. Moreover, the changes in concentration are quite slow: the peak is not reached until from two to four hours after the dose is taken.

After the absorption of methadone about 98 percent is removed from the blood and held in an inactive state. At any moment only 2 percent is in the circulation, reaching cells that are sensitive to narcotics. As this active portion is excreted bound drug dissociates from the reservoir in tissue, enters the bloodstream and sustains the circulating level. The net effect is to stabilize the exposure of nervous tissue. The intestinal tract and the liver provide further protection against surges in the concentration.

It should also be noted that oral ingestion makes for a slower entry of a drug than intravenous injection. Before the drug reaches the general circulation it must travel through the wall of the gut and then pass through the liver, where about 85 percent of it is removed on a single passage. The drug is then slowly released as blood recirculates through the liver. Hence although the daily dose of methadone is ingested in one swallow, it is delivered to the bloodstream over a period of two hours or more.

Other known narcotic substances do not have the same combination of long action and safety for maintenance treatment. Morphine and related drugs are poorly absorbed after oral ingestion and are insufficiently bound by the tissues to stabilize the concentration in the blood over a 24-hour period. Acetylmethadol, a drug chemically related to methadone, has an even longer period of action than methadone but gives rise to highly toxic metabolites. The metabolites of methadone are pharmacologically inactive, and so the only concern in maintenance treatment with this drug is to provide a daily dose that replaces the amount eliminated by metabolism.

This theoretical understanding has come quite recently. Therefore many patients have been improperly treated

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with methadone over the past 15 years. Some programs have given inadequate daily doses (30 milligrams or less). Their patients probably have had recurrent symptoms of withdrawal when the concentration of circulating drug became too low; such a patient is tempted to supplement the dose with illicit narcotics. Some programs have given ampules of injectable methadone to addicts; the result is the loss of the smoothing-out process brought about by the intestine and the liver with oral doses, and the brain again receives a hammerblow like the one from injected heroin.

Even methadone maintenance has its limitations, which were shown in a follow-up study that Herman Joseph and I recently conducted. From the list of some 70,000 people who had entered methadone programs in New York between 1965 and 1976 we drew a random sample (appropriately structured to reflect the age and sex of the people who had entered such programs) of 1,513, representing people who entered early in the program (1966–67) and later (1972). Of the sample group 667 were still in treatment and 846 were not. Over the next three years a trained group of field workers examined agency records and interviewed or otherwise accounted for 1,427 (94 percent of the sample).

From the mass of data collected the most striking conclusion was the failure of social rehabilitation to cure narcotic addiction. Although maintenance had markedly reduced the use of illicit narcotics and the criminal activity associated with them, and a majority of the patients became productively employed while they were in treatment, they generally relapsed to the use of illicit narcotics after maintenance on methadone was terminated. In contrast the group still in treatment showed no tendency to relapse.

This finding was not what had been hoped for in the early days of methadone research, but the facts cannot be ignored. No program treating people with a record of serious narcotic addiction has had more success in rehabilitation than the methadone-maintenance clinics in New York. No program (maintenance or drug-free) that has treated addicts of comparable severity and followed them for three years or more after discharge has presented any evidence of better long-term results. Although a minority of subjects with a history of serious addiction can remain abstinent after discharge from treatment (or become so without treatment), most cannot. For the majority continued maintenance is needed for normal functioning.

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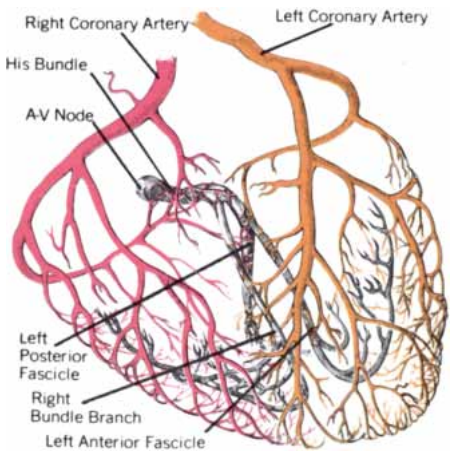

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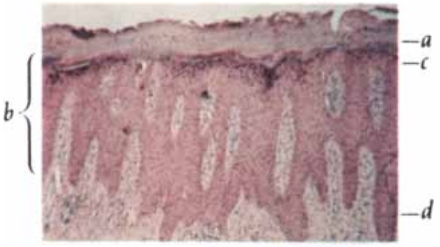

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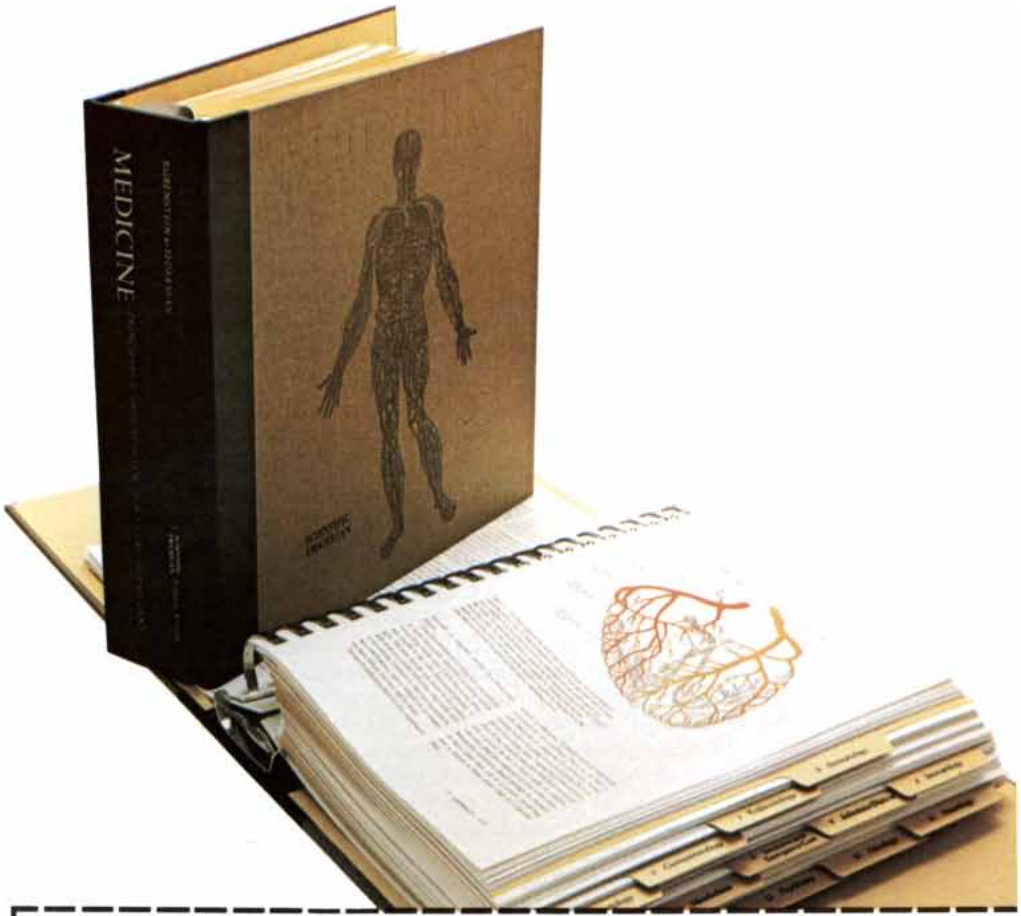

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maintenance patients have failed to reveal any common trait that could be identified as an addictive personality. As addicts using illicit drugs, the people who came to maintenance programs had similar experiences and in some respects similar attitudes, but the experiences and the attitudes apparently were consequences of addiction rather than causes. With medical treatment and social rehabilitation these people became as diverse psychologically as their unaddicted peers.

We also found that it was not possible in pharmacologically stabilized patients to detect the abnormal pleasure-seeking, reality-escaping traits that have been associated with addicts. Whatever euphoria the addicts had enjoyed in the use of heroin prior to treatment, they lost the opportunity for it when they were stabilized on methadone, and yet in most cases the treatment was welcomed. Addicts with a history of two years or more of slavery to heroin have seemed to be quite willing to sacrifice the occasional euphoria for a continuing feeling of normality. This finding suggests that the addictive behavior of chronic users of narcotics stems less from pleasure seeking than from a need to relieve a recurring discomfort. The same may also be true of people unable to stop other harmful practices such as smoking and excessive drinking.

To the extent that an addiction is a symptom of dysphoria, the harmful practice can be stopped by an alternative medicine to relieve the symptoms—provided, of course, that the alternative is safe and acceptable. Although this strategy falls short of absolute cure, it can save thousands of lives while investigators look for a complete theoretical understanding of addictive behavior. Moreover, the remarkable difference in effect between methadone and heroin in continuous use provides a clue that I think is relevant to the fundamental problem: The nervous system responds mainly to changes in the concentration of neuroactive chemicals in the bloodstream and tends to lose its response when the concentration remains steady. Addicts seek to use drugs in ways that bring a sharp pulse of the substance to the brain, since it is the pulse that causes the "high." The introduction of gin in the 18th century was followed by an epidemic of alcoholism, the introduction of the hypodermic needle in the 19th century by an epidemic of narcotic addiction and the introduction of the cigarette in this century by an epidemic of smoking. In technical terms future research must take into account the pharmacokinetics of addictive drugs—the time variable—because the responsiveness of the nervous tissue changes rapidly with exposure.

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The Escape System of the Cockroach

How does the insect evade the swipe of a hand or the lunge of a toad? The mechanisms by which it does so are a simple model of those that mediate more complex forms of behavior

by Jeffrey M. Camhi

The householder observes that the cockroach on the kitchen shelf is highly adept at escaping a killing blow. The naturalist observes that the cockroach on the forest floor more often than not escapes the flick of a toad's sticky tongue. How are such behavioral acts initiated and controlled by the insect's nervous system? Ultimately a question of this kind can lead one to speculate about the neuronal basis of behavior in more complex animals, including man. Daunted, however, by the complexity of the human brain, many investigators have been attracted to much simpler experimental subjects: crustaceans, mollusks and insects. Such animals have relatively few neurons, or nerve cells, many of which are large and individually recognizable. As a result one can sometimes determine the role individual neurons play in a behavioral act, important information that is almost impossible to obtain in studies of mammalian brains.

As an example of the techniques used in such experiments, the investigator impales a neuron with a glass micropipette electrode that makes it possible to record the voltage signals arising on the membrane of the cell. One type of signal is the action potential, a voltage change that propagates down an axon (the long fiber of the neuron) and serves for long-distance communication in the nervous system. In addition one can record synaptic potentials, the voltage changes that arise locally at a synapse, a point of functional communication between two neurons.

To learn whether or not any two neurons communicate with each other the investigator impales both cells with microelectrodes and determines whether an action potential in one cell is consistently followed by a synaptic potential in the other cell. The synaptic potential can be either excitatory, increasing the probability that the second cell will itself fire an action potential, or inhibitory, momentarily decreasing the probability that the second cell will fire. By repeating the experiment on different pairs of neurons that give rise to a behavioral act one ultimately gets the information needed to draw a circuit diagram: the pattern of synaptic interactions among identified neurons mediating the behavior. Such a diagram is much like an engineer's drawing of the electrical components and their connections in a radio or an electronic calculator. The neuronal circuit diagrams for a few patterns of behavior in invertebrate animals have now been worked out.

Much of this type of work has placed more emphasis on the neurobiology underlying behavior than on the behavior itself. This is unfortunate because for certain kinds of behavior carefully considering the animal's natural acts as they unfold under natural conditions can illuminate important features of the control of behavior. The study of an animal's behavior under natural conditions conjointly with the neuronal control of its behavior has come to be called neuroethology.

For the past six years my students, postdoctoral associates and I at Cornell University have been taking a neuroethological approach to the study of a particularly favorable subject, the cockroach *Periplaneta americana*. The insect is a native of tropical Africa, but in the past few centuries its habitat has expanded to include most of the tropical, subtropical and temperate regions of the world. It is all too familiar as a joint tenant of human dwellings. We have been examining the system of sensory receptors and the signal-processing networks that enable the cockroach to escape the strike of its natural predators.

Kenneth D. Roeder of Tufts University did the most important early studies of the cockroach's escape system. In the late 1940's he noted that cockroaches run in response to a gentle puff of air and that the response is absent if the insect's two posterior sensory appendages, the cerci, are removed. On the underside of each cercus Roeder observed an array of delicate hairs, about 220 of them in the adult insect. It was later shown that it is their stimulation by wind that causes the cockroach to run.

When one subjects the cockroach to a puff of air, many of the cercal hairs bend in their sockets. This deflection of a hair excites the single sensory neuron at its base. Each sensory neuron is connected to the central nervous system by its axon. Roeder showed that when the sensory cells of the cerci are excited, they in turn excite a group of particularly large nerve cells called giant interneurons. An interneuron is a nerve cell that is found only in the central nervous system, where it serves as a functional link between sensory neurons and motor neurons. The *P. americana* cockroach has 14 giant interneurons, each of which can be identified with a microscope in every member of the species.

The cell body of each giant interneuron is in the terminal ganglion. In the central nervous system of invertebrates a ganglion consists of a cluster of cell bodies and their feltwork of short branches, the dendrites, along with axons whose terminals form synapses with the dendrites. Running between neighboring ganglia are cablelike connective structures that contain only axons. The ganglia and the connective structures together make up the insect's central nerve cord. As Micha Spira and Itzhac Parnas of the Hebrew University of Jerusalem have shown, the axons of the giant interneurons run up the nerve cord all the way to the head. The action potentials ascend the axons of the giant interneurons and pass through the thoracic ganglia, where the motor neurons controlling the legs are found.

Roeder suggested that the giant interneurons excite the motor neurons of the cockroach leg either directly or through other interneurons. Roy E. Ritzmann, who worked originally in my laboratory and is now at Case Western Reserve University, showed that when a giant interneuron is stimulated by means of an intracellular microelectrode to generate a sequence of action potentials, motor neurons of the leg are activated. These experiments and related ones have convinced us that the giant interneurons help to elicit running in response to wind stimulation of the cerci. To sum up, it is

now known that the escape circuit involves about 440 cercal wind receptors, 14 giant interneurons and a small number of leg motor neurons.

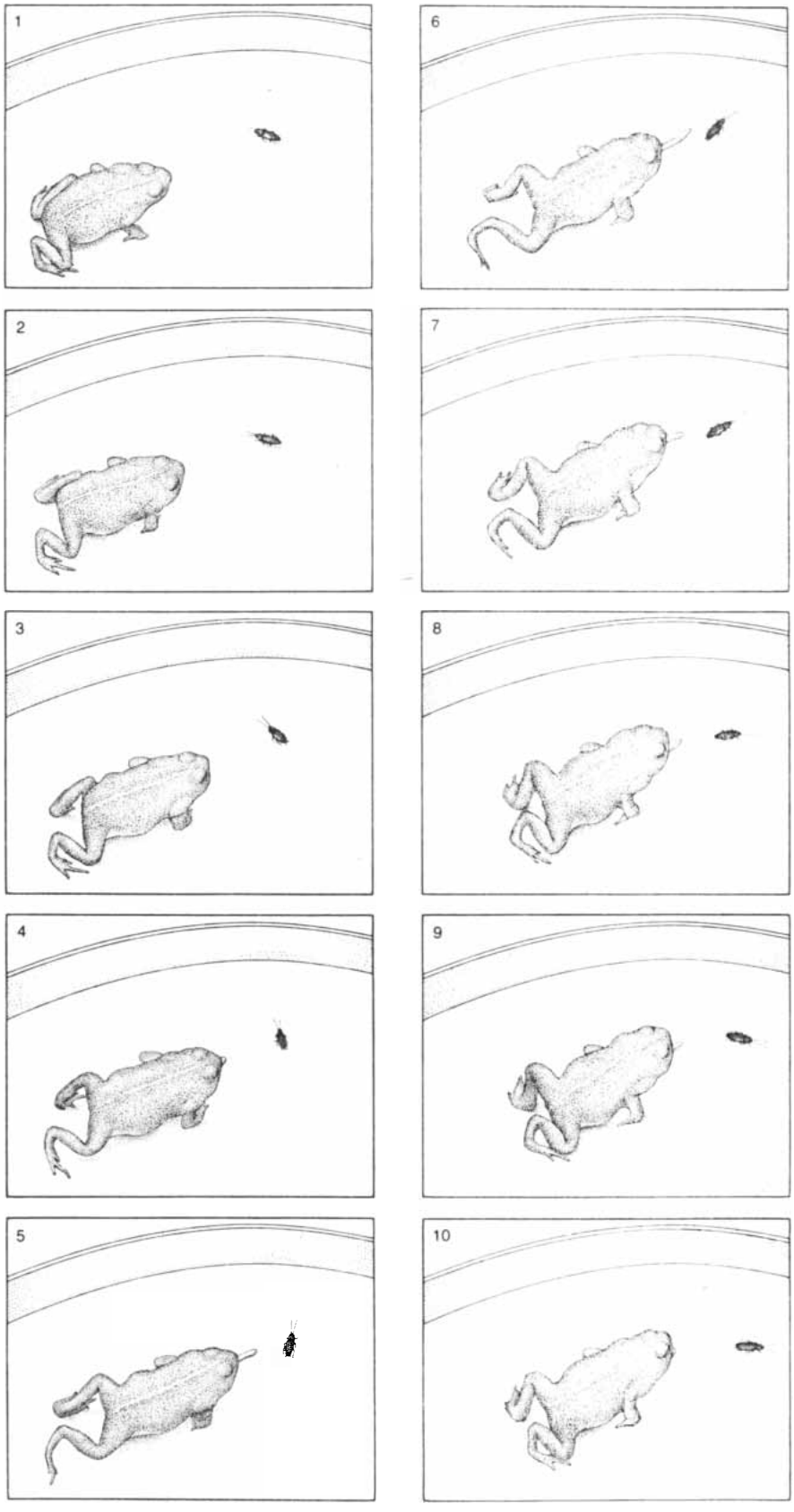
Our goal was to discover how these cells and their interconnections give rise to the wind-evoked running behavior. At the outset, however, almost nothing was known about the behavior except that it occurs. Roeder had originally proposed that it might help the cockroach to escape from predators whose lunge would presumably set the nearby air in motion. We reasoned that if this were the behavior's actual function, it should exhibit directionality, since the insect's best chance of survival would be to flee from the source of the wind.

To test for directionality Winston Tom and I made high-speed motion-picture films of cockroaches subjected to standardized puffs of air delivered from different angles. When we plotted the direction of turning and running in many trials, it was clear that the insects usually did turn away from the source of the wind. Moreover, it was apparent that what was responsible for the oriented response was the wind-receptor hairs on the underside of the cerci. This conclusion was based on several lines of evidence.

When we covered the underside of both cerci with wax, the cockroaches were totally unresponsive to the wind stimuli. When the upper side of the cerci was covered, the directional response was unaffected. If we twisted both cerci clockwise where they were joined to the body, fixing each cercus in place with a dab of wax, we found that the directional response to the wind shifted by roughly the amount of the twist. When we covered one cercus or cut it off, most of the turns the insect made were in the direction away from the intact cercus regardless of the wind direction.

We also tested the escape response in juvenile cockroaches of the first instar, or first molting stage. Although juveniles have only two hairs on each cercus, they turn away from a wind source nearly as successfully as adults. Moreover, as Susan Volman of our laboratory has shown, if the two hairs of one cercus are snipped off, the infant insects turn away from the side with the intact cercus regardless of the wind direction. If the four hairs of both cerci are removed, the insects no longer respond to a puff of air. A variety of control experiments convinced us that the stimulus responsible for the oriented responses is indeed the wind and not visual, auditory or other cues from the wind simulator.

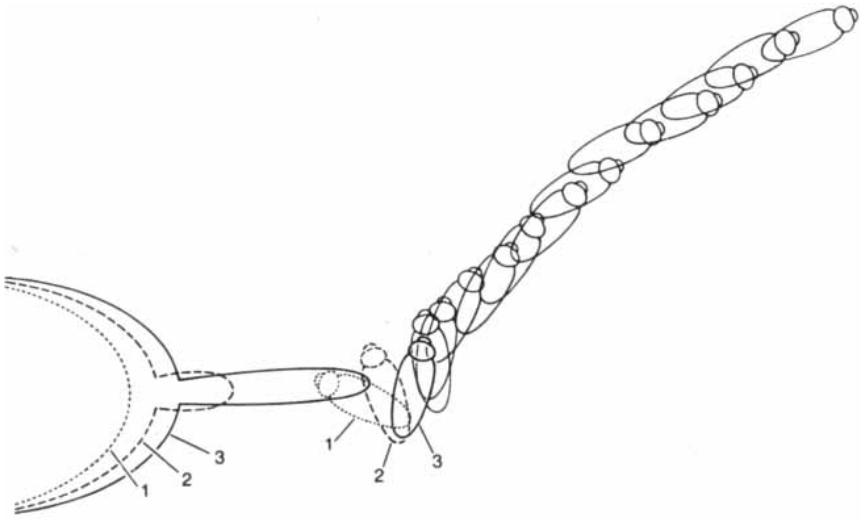
The next step was to satisfy ourselves that cockroaches actually rely on the wind-evoked turning and running behavior to escape from natural predators. The predator we chose to study was the nocturnally active tropical toad *Bufo marinus,* which is known to strike at noc-



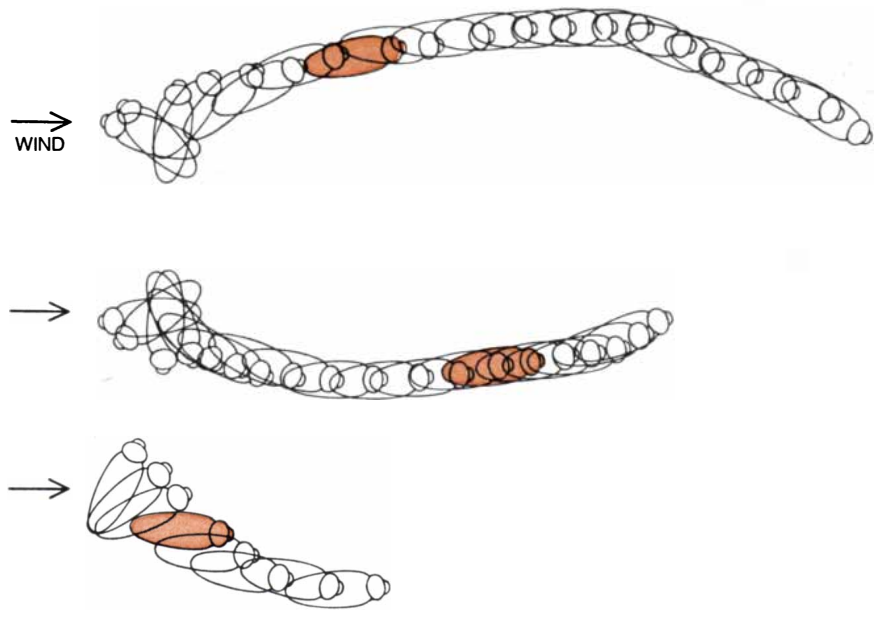
NARROW ESCAPE OF A COCKROACH (*Periplaneta americana*) from an attack by a toad (*Bufo marinus*) is depicted in scenes redrawn from frames of a high-speed motion picture made in the author's laboratory at Cornell University. After making a short lunge the toad attempts to trap the insect with its sticky tongue. The motion of the toad's body creates a sharp puff of air that the cockroach senses by means of hairs projecting from two posterior sensory appendages called cerci. The cockroach responds by turning away from the source of wind and running. Under the most favorable conditions the cockroach's escape response can begin within 11 milliseconds of the time cercal hairs are activated. Sequence was filmed at 64 frames per second.

turnally active cockroaches in its natural habitat. We began by adapting a toad and a cockroach to nocturnal lighting conditions in the laboratory. We then put the cockroach and the toad in a chamber three feet in diameter. As the cockroach wandered about it eventually came close enough (within 15 centimeters) to the toad to evoke a predatory strike: a forward lunge culminating in a flick of the toad's sticky tongue.

By observing many lunges by several toads at many different cockroaches we determined that the insects escaped successfully from 55 percent of the strikes. Cockroaches whose cerci had been covered with wax, on the other hand, escaped only 8 percent of the time. Insects of a control group in which we had covered part of the abdomen but not the cerci escaped from 47 percent of the strikes. Clearly the cerci helped the cockroaches to escape from toads, presumably by virtue of some kind of cercal receptor. Although wind receptors were the likely candidate, at this stage we could not exclude the possibility that there might be cercal receptors capable of detecting ground vibration, sound, odors or other potential signals from the toad.



DETAILS OF A COCKROACH'S ESCAPE from the strike of a toad is plotted from 15 successive motion-picture frames. The sequence begins with the toad's head and the insect at position *1*. In the second frame of the motion picture (*2*) the toad has begun to extend its tongue. By the third frame (*3*) the toad's tongue is fully extended, just missing the turning insect, which continues to run away. The position of the cockroach is shown at 16-millisecond intervals.



DIRECTIONAL RESPONSES of the cockroach's escape system can be seen in three sample trials in which controlled puffs of air were aimed at the insect from different directions. The silhouette at the far left, nearest the arrowhead, shows the cockroach's position just before the stimulus. The succeeding silhouettes show the insect's position at 16-millisecond intervals. The colored silhouette in each trial indicates the insect's position at the moment that its initial turn was completed. Subsequent frames show no additional turning in the initial direction.

In pursuit of the question we made high-speed films of the encounters between the cockroaches and the toads. The films showed unequivocally that the insects respond to toads just as they do to a puff of air, by turning away and then running. We became fully convinced that wind was the crucial signal only when we measured the wind created by the toad's strike and compared it with measured amounts of wind needed to make the insect run.

In order to measure the wind generated by a lunging toad we anesthetized a cockroach with carbon dioxide, tied it to the end of a miniature fishing pole and cast it on the floor of the chamber harboring a toad. (Toads strike only at objects that are moving or have just moved.) As soon as we saw we had caught the toad's attention we moved the cockroach to within a centimeter of the active element of a wind meter that had been put on the floor in the middle of the chamber. When the toad struck, the intensity of the wind of the strike was recorded.

Since we were simultaneously filming the strike, we were able to relate the wind velocity to the distance between the toad and the cockroach at each moment. We had learned from earlier films of toads striking at unanesthetized cockroaches that the insects begin their escape movements on the average about one motion-picture frame, or about 16 milliseconds at a filming rate of 64 frames per second, before the toad's tongue emerges from its mouth. Therefore the intensity of the wind just before this moment was a matter of crucial interest.

In a separate series of tests with controlled puffs from our wind simulator Mark Plummer and I found that in causing the insects to run both a high wind acceleration and a certain critical velocity were important. Specifically, in order to evoke a running response in at least half of the trials the wind must have an acceleration of at least 60 centimeters per second per second combined with a velocity of at least 12 millimeters per second. The mean latency of the response, that is, the mean time from the arrival of the air puff at the cerci to the start of running, is 44 milliseconds.

In our recorded toad strikes at anesthetized cockroaches the wind produced by the toad reached the critical acceleration and velocity at a mean time of 41 milliseconds before the mean time (determined in other experiments) the cockroaches begin to move in response to the toad strike. The agreement between the two values (44 milliseconds for latency and 41 milliseconds before movement) is compelling evidence that

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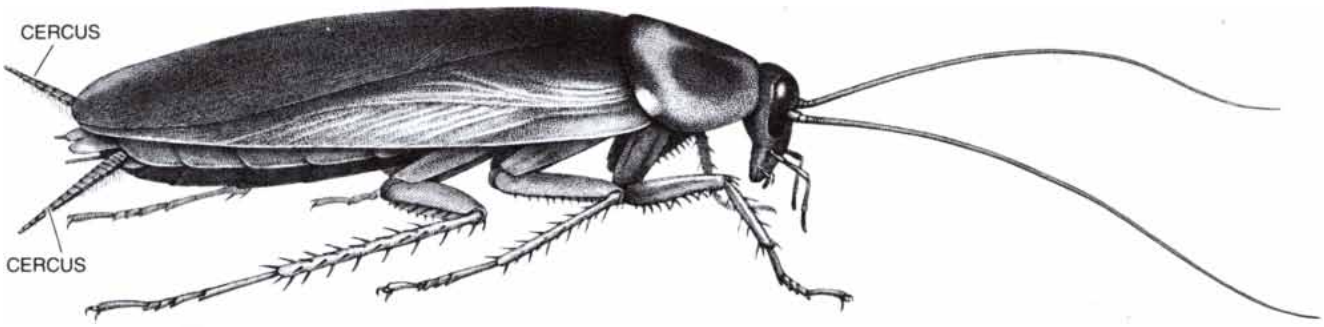
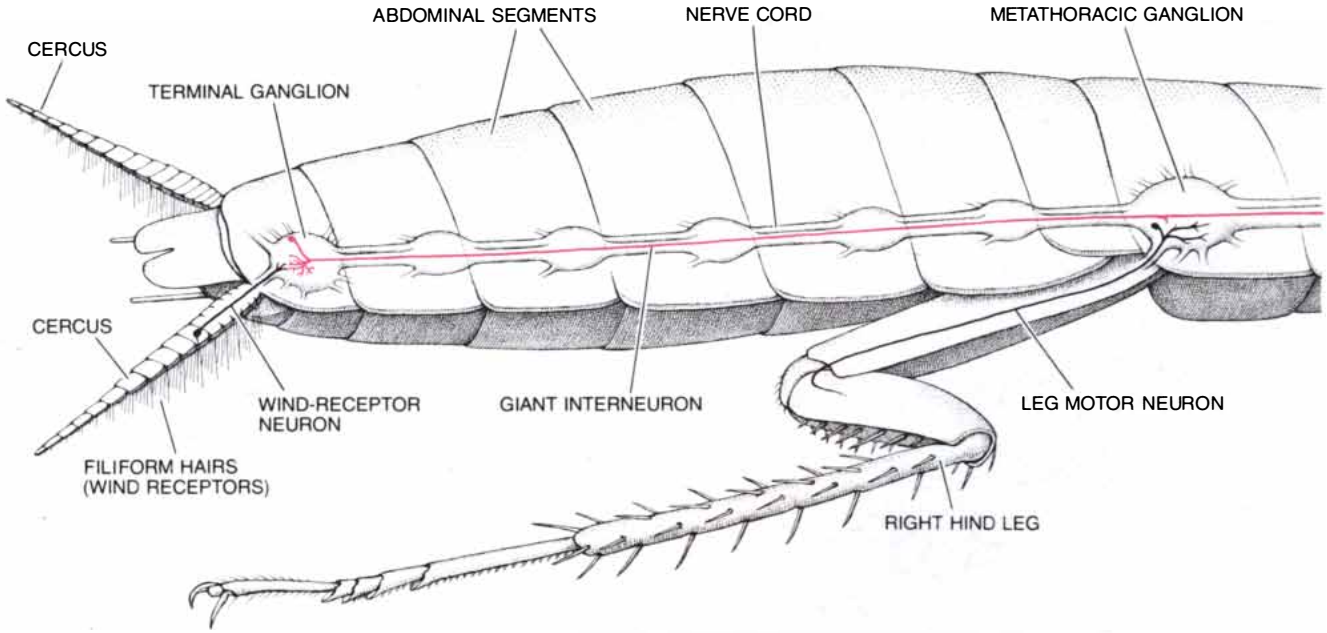


PERIPLANETA AMERICANA, one of the commonest cockroaches found in American and European households, is a native of tropical Africa. The drawing depicts an adult male, whose body is about 40 millimeters long. Wind receptors are some 440 hairs on the cerci.



NERVE CELLS OF THE ESCAPE SYSTEM are organized so that the stimulus provided by a puff of air evokes turning and running. Nerve impulses that originate in wind-receptor neurons are relayed at the terminal ganglion to giant interneurons running up the central nerve cord to the metathoracic ganglion. There the signal processing is completed that leads to the activation of motor neurons in the legs.

the puff of air generated by the toad's strike is sufficient stimulus to trigger the escape response.

We made many attempts to find other effective cues that might be produced by the toad, all of them negative. For example, if we put two thin panes of transparent acrylic between the toad and several moving cockroaches, the insects were oblivious to the sight, sound and vibration of the striking toad's colliding with the barrier less than a centimeter away from them. Other experiments enabled us to rule out olfactory and tactile cues as contributing significantly to the escape response.

Therefore we can say with some confidence that the small but sharp puff of air made by the toad's lunge is the major channel of information, and perhaps the only one, through which the cockroach detects an attacking toad. Although wind is not normally regarded as containing much information, here it both contains and conveys to the insect information about the presence and the direction of a rapidly approaching and life-threatening object.

Information about the direction of a puff of air must somehow be coded in the sensory receptors of the cerci. The basic mechanism was worked out in the late 1960's by R. Nicklaus of the University of Munich. The hairs on the cercus are organized into columns and rows. Each of the 17 cercal segments of the adult, except those at the tip or near the base of the cercus, has a row of nine particularly long hairs. The similarly placed hairs in each segment can be regarded as members of a column running from the front of the cercus to the rear. All the hairs of a given column are mechanically alike in that they can be deflected easily in either of two opposite directions and less easily at right angles to those directions. The directions of maximum pliancy are different from column to column.

By recording the sensory output from a few individual hairs, Nicklaus found that deflection in one of the two most pliant directions evoked a maximum number of action potentials. Deflection in the other most pliant direction (that is, 180 degrees away from the first) produced a maximum inhibition of spontaneously occurring action potentials. The excitatory deflection is thought to stretch the sensory cell's dendrite, leading to the generation of action potentials. The opposite, inhibiting deflection is thought to slacken the sensory cell's dendrite.

Daniel Dagan, who was then working in my laboratory, extended these findings by determining the best excitatory wind direction for each of the nine columns of cercal hairs. His technique was to cover with glue all the hairs except those of one column and then to record responses of the entire cercal nerve to wind from different directions. He found that among them the nine

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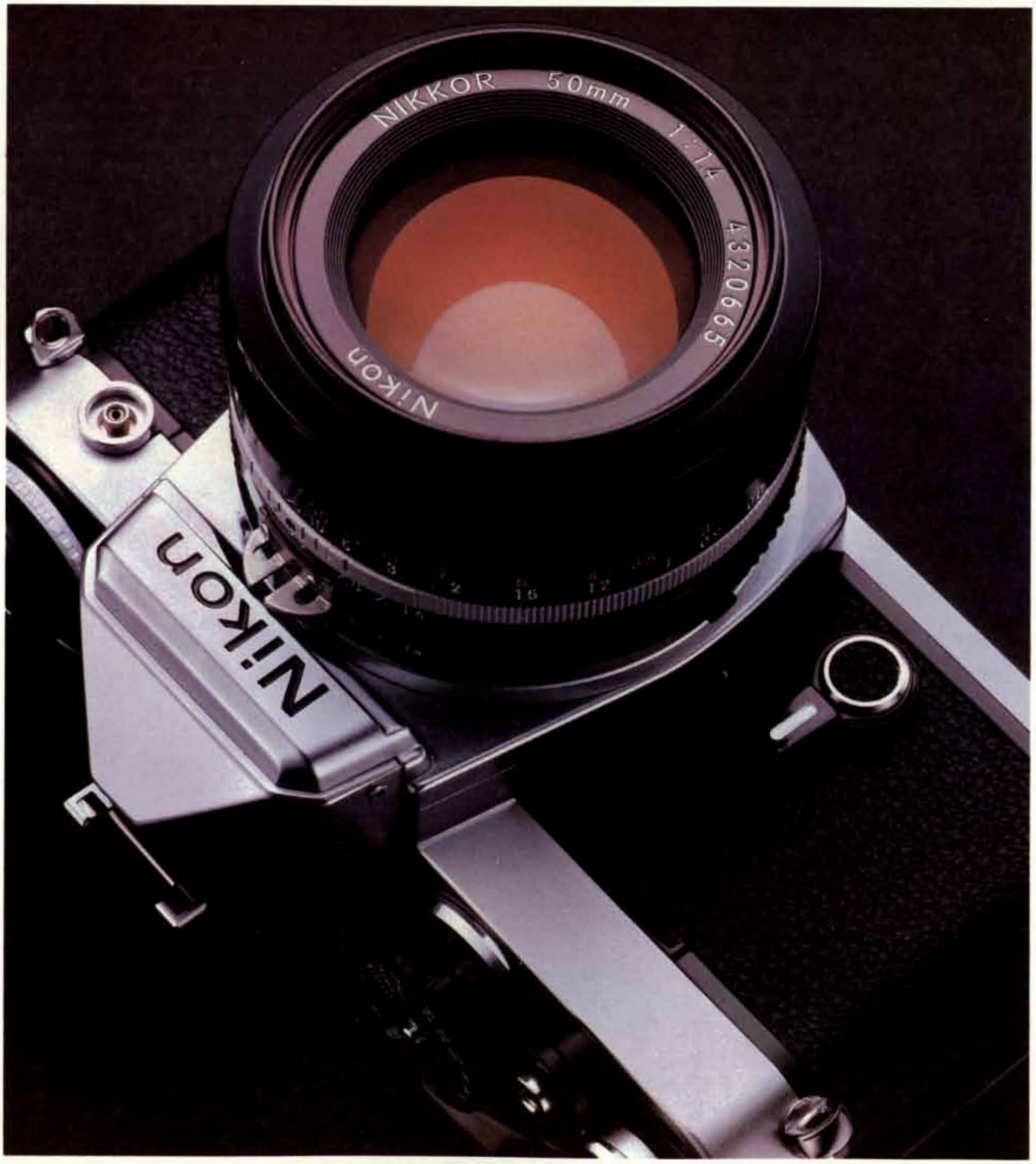

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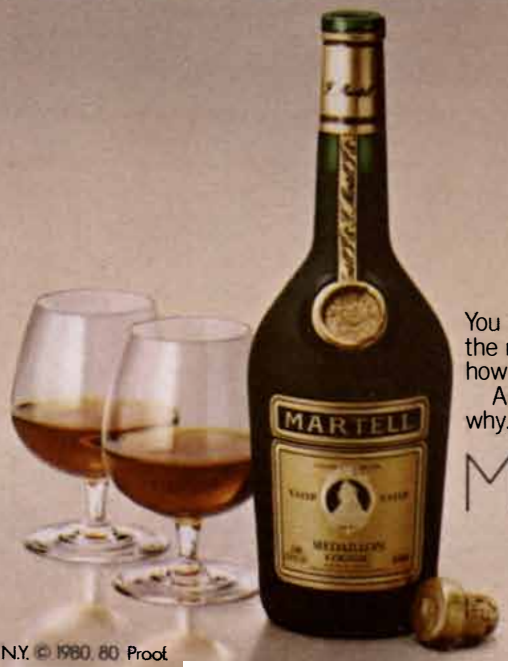

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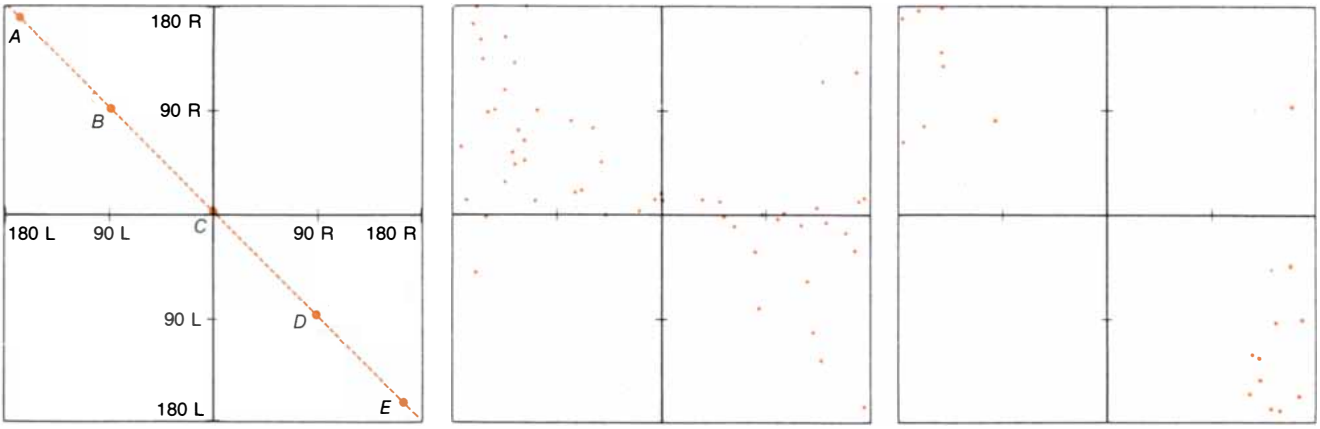
columns effectively box the compass. Meanwhile Joanne Westin, working first in my laboratory and later at Case Western Reserve, made intracellular recordings from single axons carrying sensory impulses from individual cercal hairs. Her results show that each sensory axon responds maximally to a fairly narrow range of different wind directions and also that as a group the hairs provide 360-degree coverage.

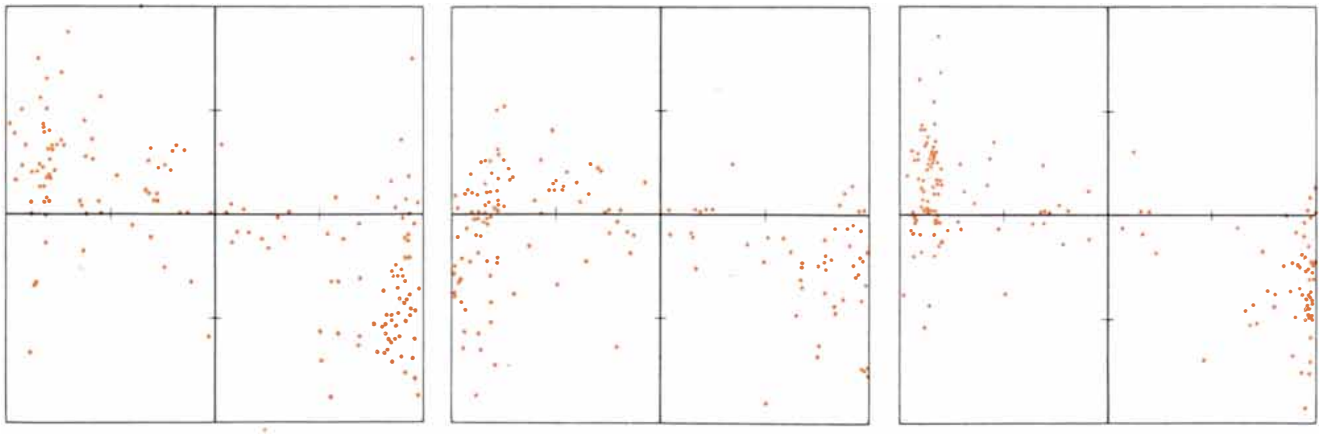
Do the giant interneurons excited by the cercal wind receptors preserve the directional information encoded by the sensory cells? Westin, Jonathan Langberg and I answered this question by making intracellular recordings from individual giant interneurons. After each experiment the particular giant interneuron that had been recorded was identified under the microscope on the basis of its unique anatomical characteristics. The anatomy of the recorded cell was made visible by injecting a dye into the cell through the micropipette electrode that had been used to make the recording. The injected dye (procion yellow, lucifer yellow or cobalt chloride) diffuses through much of the neuron but does not escape outward through the cell membrane.

We found that each giant interneuron responds characteristically to standardized puffs of air directed toward the cercal hairs from different directions. Of the seven giant interneurons on each side of the nervous system (that is, seven pairs in all) two on each side respond about equally well to air puffs from any direction. In the conventional numbering system these two giant interneurons are designated Nos. 2 and 4. Two others on each side (Nos. 1 and 7) respond most strongly to wind striking the cerci on the same side as the one occupied by the axons of the giant interneurons. The three remaining giant interneurons on each side (Nos. 3, 5 and 6) give responses that are more specifically directional [*see illustration on page 170*].

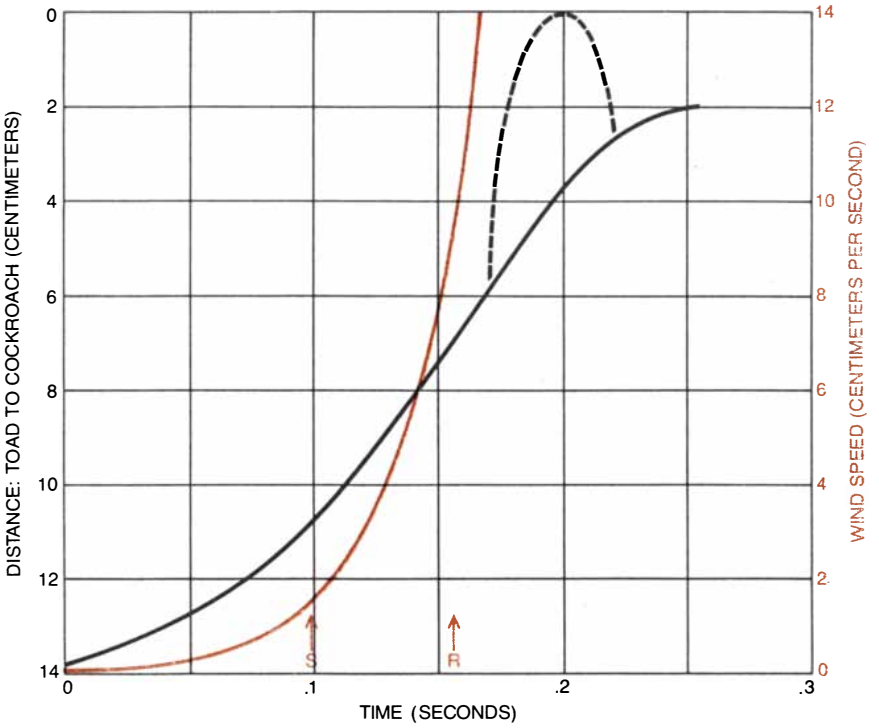
We are currently examining the pattern of connection of particular columns of sensory cells with particular giant interneurons to determine how the directional responses of each giant interneuron are established. We predict, for example, that the two pairs of giant in-

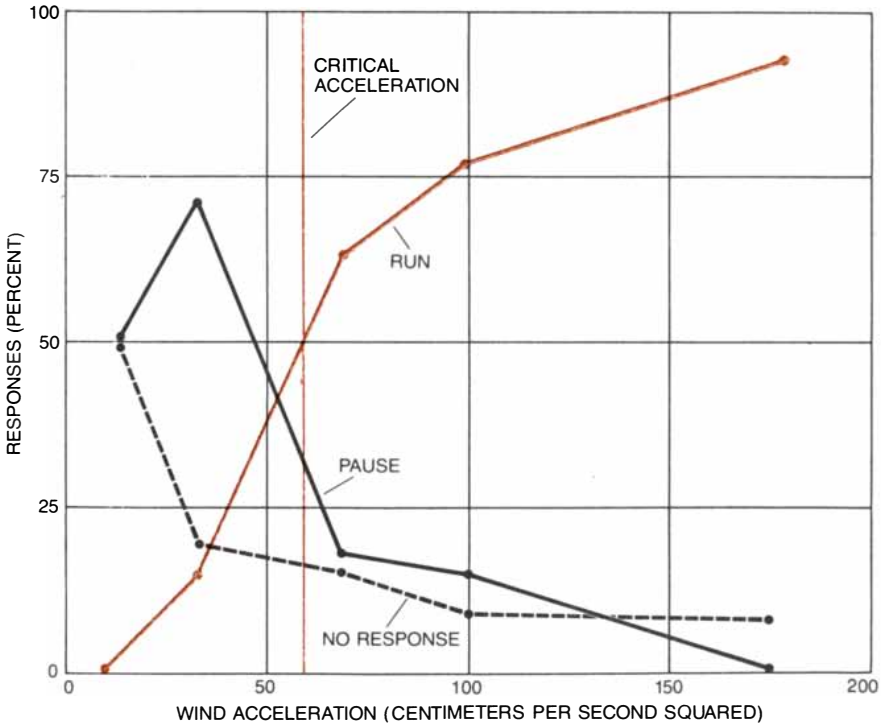


TURNING RESPONSES OF COCKROACHES are plotted in the author's laboratory according to the conventions illustrated at the left. The five insect silhouettes show the wind direction (*solid arrows*) and the direction of the insect's turning (*broken arrows*). A trial in which the wind comes directly from the rear and the cockroach responds by running straight ahead would be represented by point *C* on the graph (stimulus and response both lie at 0 degrees). Wind from 90 degrees left that evoked a 90-degree right turn would be represented by point *B*, and so on. In the graph at the left the slanting line in color represents the locus of points that would result if cockroaches oriented perfectly away from the wind stimulus. The middle graph shows the turning responses of adult male cockroaches to laboratory air puffs. Their tendency to turn away from the wind is highly significant. The graph at the right represents the turning responses of adult male cockroaches to the strikes of toads, as plotted from filmed sequences. Only the turns of insects that survived the strikes are indicated. Slightly more than half escape.



RECOVERY FROM THE REMOVAL OF CERCI can be observed in this set of three graphs. The graph at the left shows the responses of normal nymphal cockroaches in a late stage of development to puffs of air. The graph in the middle shows the responses of nymphal insects whose left cercus had been removed one day before they were tested. The turning responses to puffs of air from the left were randomly scattered. Avoidance of puffs of air from the right remained about normal. The graph at the right shows the results when the same insects were tested 30 days later. They had largely recovered the ability to turn evasively (to the right) away from puffs of air from the left.





WIND OF A TOAD'S STRIKE was recorded with an anesthetized cockroach as a target and a sensitive wind meter. The black curve at the top represents the distance from the front of the toad's head to the cockroach during the course of the strike. The toad's tongue (*broken line*) emerges about .18 second into the strike. The curve in color represents the velocity at the target of the wind created by the toad's strike. The wind reaches a maximum velocity of about 20 centimeters per second (far off the scale) about .2 second into the strike. The arrow *S* represents the first moment when the wind reached a critical acceleration of 60 centimeters per second per second. The arrow *R* marks the mean time in other trials with fully alert insects when cockroaches begin to move in response to toad strikes. (In such trials *R* is measured with respect to the moment of emergence of the toad's tongue.) In this sample trial the time from *S* to *R* is 56 milliseconds. The three curves at the bottom show responses of walking cockroaches to air puffs of different accelerations but all of the same peak velocity: four centimeters per second. Depending on the acceleration, the response is to run, to pause or to ignore the stimulus. Beyond acceleration of 60 centimeters per second per second more than half of insects run.

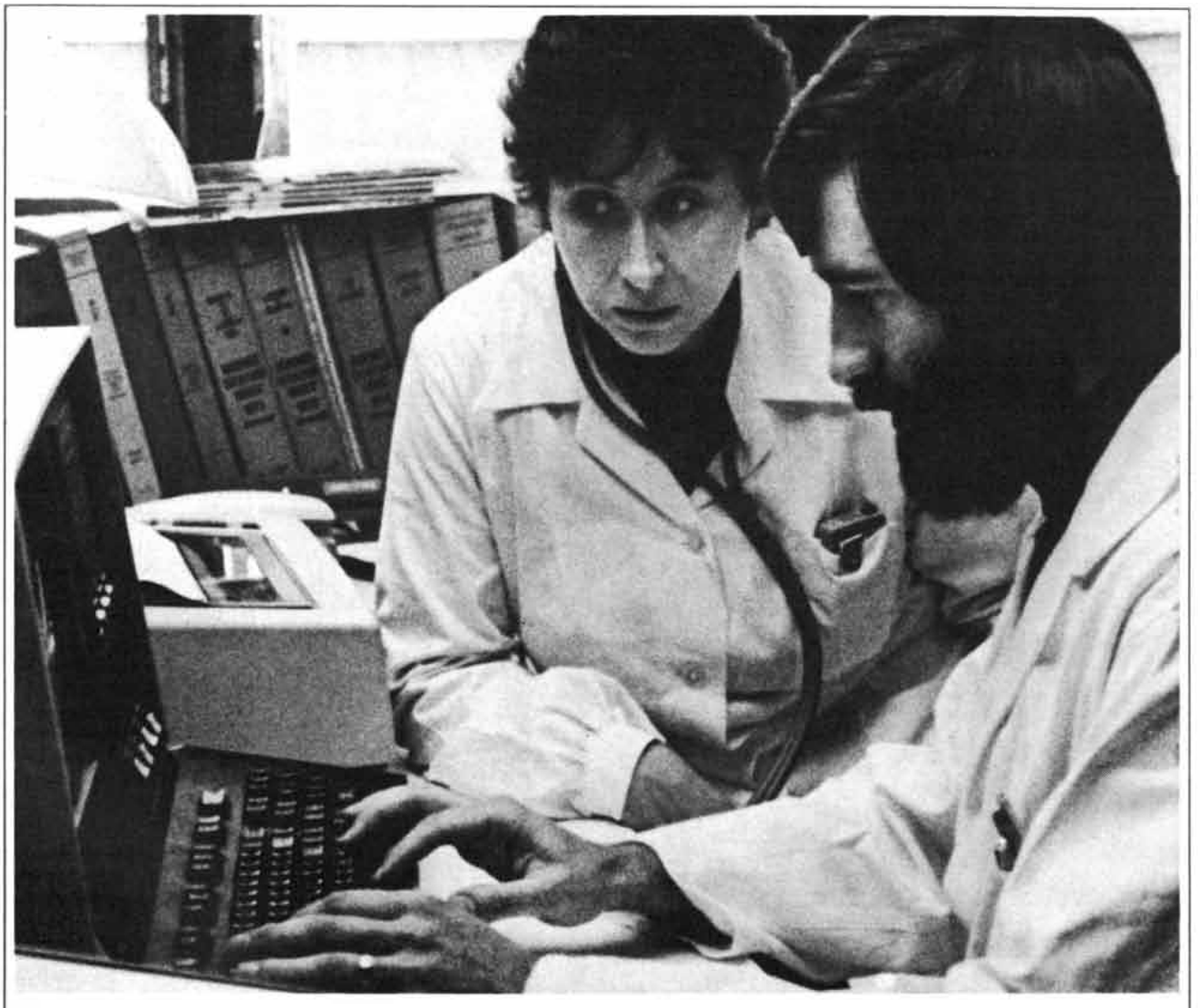
terneurons that respond about equally well to wind from all directions must receive excitatory inputs from several different columns of cercal hairs to account for their broad directional response. In contrast, the three pairs of giant interneurons with rather specific directional responses might each receive excitatory inputs from just a single column of hairs.

On the basis of the responses observed in the giant interneurons one might guess that to determine the direction of a given puff of air the cockroach need only rely on the information carried by one of the three pairs of giant interneurons whose responses are the most highly directional. For example, if the directional giant interneuron on the left side designated No. 5 responds with its maximum number of action potentials, the wind must be from the rear quadrant between 30 and 60 degrees to the left of center.

The response of each giant interneuron, however, depends not only on wind direction but also on instantaneous wind velocity, from which acceleration can be derived. As a result there is no fixed relation between a single cell's rate of firing and the direction of the wind. To obtain absolute directional information the cockroach must somehow "compare" the firing rates of two or more of the giant interneurons. Since all the giant interneurons have a characteristic firing rate for a particular wind velocity, a comparison of the actual firing rates should reveal differences that are uniquely related to wind direction.

Although it is not yet known which giant interneurons are most important in providing such comparative information and in evoking the appropriate behavior, one attractive hypothesis is that the left and right units Nos. 1, 2 and 3 mediate the initial behavioral response and specify the initial direction of turning. (Since unit No. 2 has an omnidirectional response, it may be that only Nos. 1 and 3 specify direction.) It also happens that the axons of these three pairs of giant interneurons conduct action potentials faster than any of the other axons, an important advantage for initiating rapid escape behavior. Moreover, action potentials in response to puffs of air are initiated in giant interneurons Nos. 1, 2 and 3 about five milliseconds earlier than they are in any of the other four. Since the escape behavior can begin as soon as 11 milliseconds after an air puff of particularly high acceleration reaches the cercal receptors of a slowly walking cockroach, the five-millisecond firing advantage appears to rule out as initiators of the behavior all giant interneurons other than Nos. 1, 2 and 3, at least under these special conditions of minimum latency.

In an extension of this hypothesis, af-



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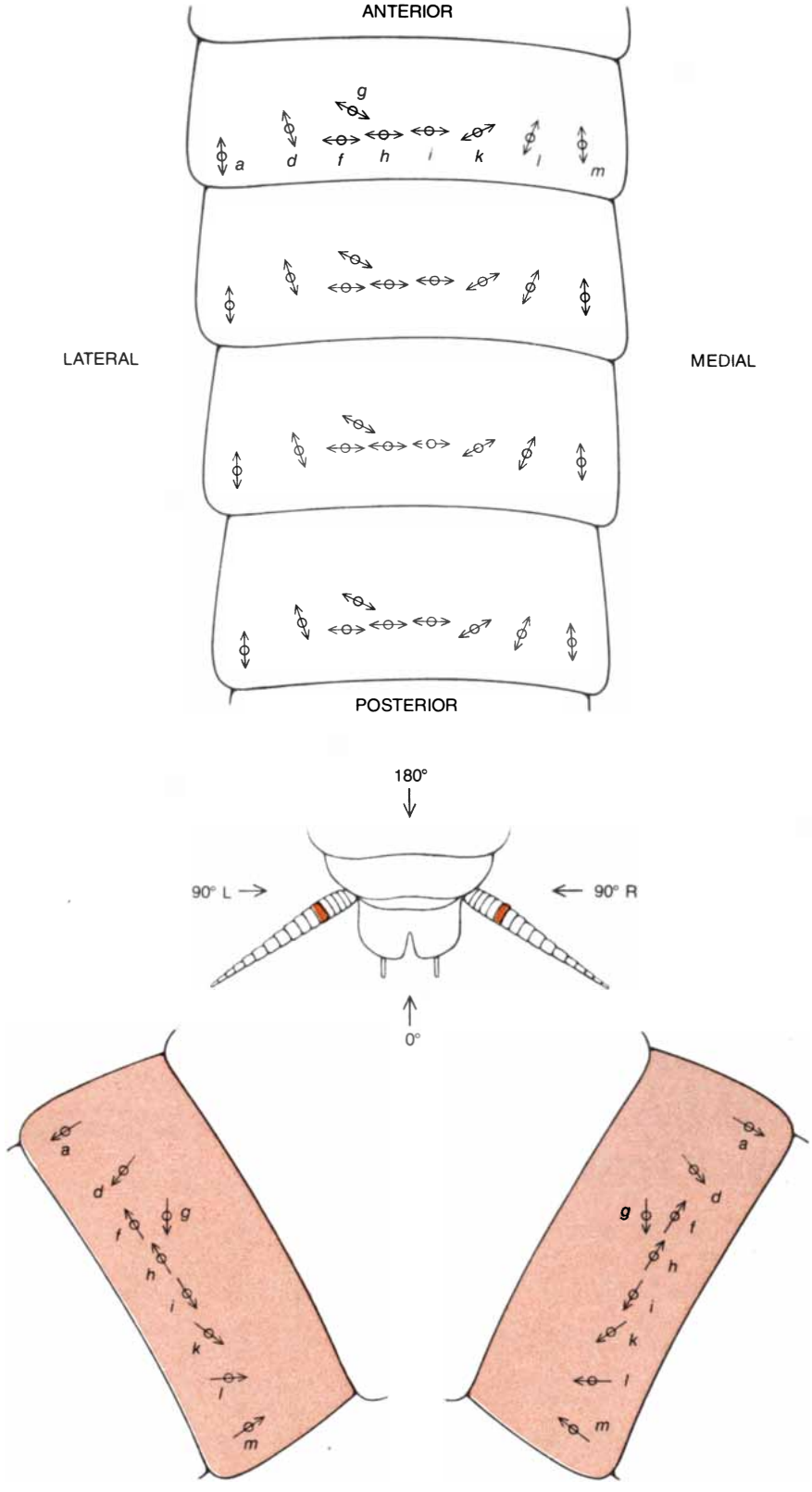


WIND-RECEPTOR HAIRS are found primarily on the lower surface of a cockroach's two cerci. The drawing at the top identifies the longest hairs on four segments of one cercus of an adult cockroach. Each segment has an identical set of nine hairs (*a, d, f, g, h, i, k, l, m*), which bend back and forth more easily in one direction than in any other. The double-headed arrows show the most pliant back-and-forth directions for each hair. One of the two opposite directions of least resistance also corresponds to the direction of maximum excitatory response to puffs of air. In the drawing at the bottom the single-headed arrows show the direction of maximum wind response for each hair in two cercal segments, one on the left, the other on the right. The cerci are drawn as if they were transparent, with the hairs seen from above. Wind striking a hair from a point opposite to the direction of the arrow produces a maximum inhibition of any action potentials, or nerve impulses, that might otherwise arise spontaneously.

ter the avoidance action of the cockroach has been initiated giant interneurons Nos. 5, 6 and 7 may take over the direction of the escape response. Here no specific role is provided for giant interneuron No. 4, which resembles unit No. 2 in being omnidirectional but does not exhibit unit No. 2's high conduction velocity and rapid start-up capability.

Recently we have turned our attention to the question of plasticity in the escape system: the adaptive changes that take place in the cockroach's behavior and neural functioning as a result of altered sensory experience. In one of our early experiments we had snipped off the left cercus of each member of a group of cockroaches and had observed that the insects then turned predominantly to the left regardless of the wind direction. Because we find many cockroaches in our colonies in which part or all of a cercus is missing (probably bitten off in rivalries among cockroaches) we suspected that injured insects in natural populations might frequently make inappropriate turns, often with fatal results, unless adaptive mechanisms developed rather quickly to alter their turns.

Noga Vardi of our laboratory has tested the ability of cockroaches with one missing cercus to correct their initially incorrect turns. She used late-instar cockroach nymphs whose turning behavior is normally as precise as that of adults. When the nymphs were tested one day after removal of the left cercus, they often turned to the left in response to air puffs from the left. Thirty days later, however, the handicapped nymphs were performing significantly better, although not fully as well as normal insects. Moreover, the nymphs did not have to be subjected to testing before the 30th day to show such improvement. Over the 30-day period most of the insects had not regenerated a new left cercus or any new wind-receptor hairs. A few individuals, however, had molted and had regenerated a new cercal bud with at most a few hairs. Such buds were removed within a day of their appearance.

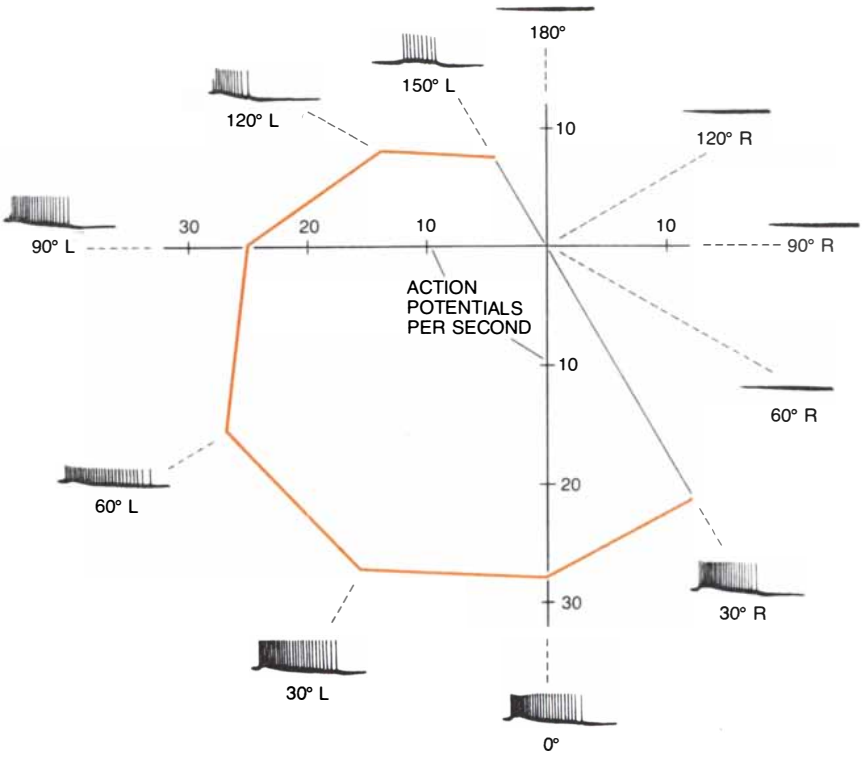
In one group of cockroaches, after we observed the behavioral correction on the 30th day we removed the remaining right cercus and retested the insects' behavior the next day. Only rarely did the insects lacking both cerci show even a slight response to wind from any direction. In this respect they behaved just like insects both of whose cerci had been freshly removed. We concluded that over the 30-day period after the removal of a left cercus the nervous system of the cockroach comes to utilize the directional information from the sensory hairs of the right cercus to make a significantly higher proportion of correct turns than it does on the first day after the removal. Comparable results would

be expected, of course, if we removed the right cercus of test insects.

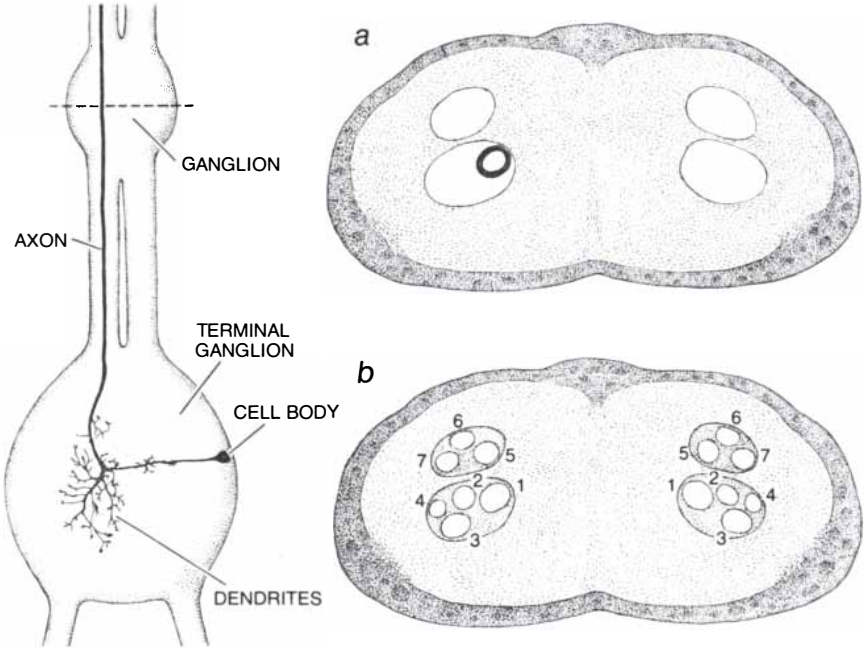
How can this improvement be explained? When the left cercus is removed, many of the giant interneurons on the left side become virtually unresponsive to wind from any direction. Giant interneurons on the right side, however, continue to respond just about normally, which means that they respond in some degree even to wind coming from the left. Evidently the responses of the right-side giant interneurons to wind from the left are responsible for the (incorrect) turns to the left on the first day. By the 30th day the left-side giant interneurons have recovered between a fourth and a third of their normal number of action potentials. The right-side units show no significant change in the same period. As a result there is a partial restoration of the normal ratio of left-to-right activity. All the giant interneurons are now driven by receptors of the right cercus. (Covering up that cercus blocks all responses to wind.)

There is still much to be learned about the enhancement in activity that takes place in left-side giant interneurons over the 30-day period after the removal of the left cercus. Rodney K. Murphey and his co-workers at the State University of New York at Albany have found a similar enhancement in activity of left-side giant interneurons following the removal of the left cercus of crickets. These insects have cercal receptors and giant interneurons similar to those of cockroaches. (Elizabeth Sherman of our laboratory has found that crickets, like cockroaches, show turning responses to air puffs and to strikes by toads.) In their cricket studies Murphey and Rick Levine found that a major part of the enhanced interneuronal activity results from a reduction in the strength of synaptic inhibition delivered to the left giant interneurons from the right cercus without a concomitant reduction in the level of synaptic excitation. We have no evidence as yet whether it is this mechanism or some other one that is responsible for the enhanced responses of the left giant interneurons that coincide with the cockroach's behavioral improvement over a 30-day period.

Whatever the cellular mechanism is that underlies the recovery of the left giant interneurons, there remains the question of what kind of signal activates this mechanism when a cercus is removed. The removal of a cercus leads to degeneration of the cercal nerve, and one possible signal would be some chemical by-product of the degeneration. Behavioral experiments suggest, however, that the absence of activity only in the left sensory cells, without nerve degeneration, is sufficient to initiate the processes resulting in behavioral correction. For example, when we merely cover the left cercus with an adhesive

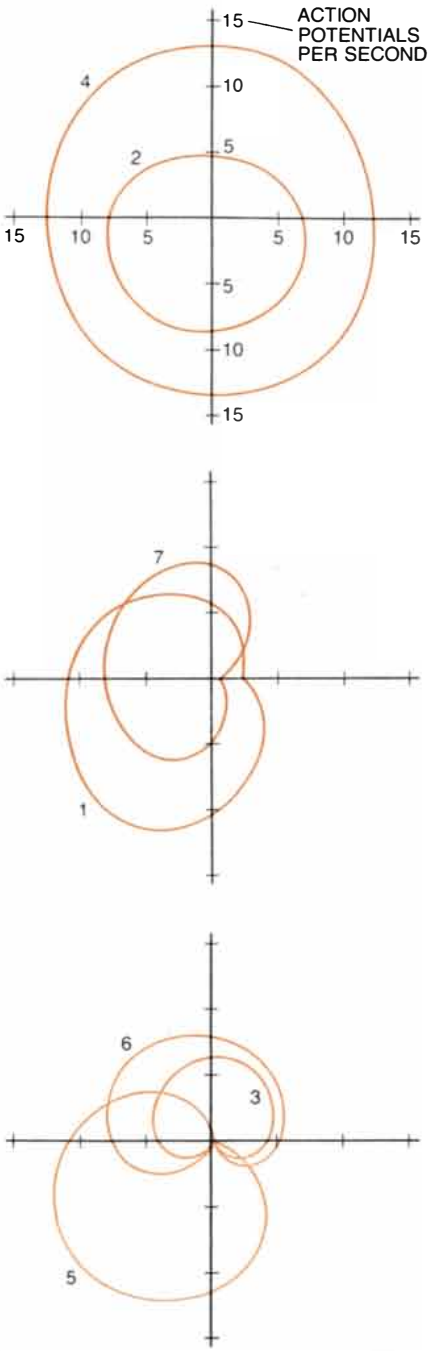


RESPONSE OF INDIVIDUAL WIND-RECEPTOR CELL can be monitored by intracellular recording from the cell's axon, or long fiber. The responses of a cell of the left cercus are plotted in polar coordinates for puffs of air from 12 directions 30 degrees apart. Bursts of action potentials were evoked by puffs from seven of the 12 directions, with maximum response evoked by puffs between 30 and 60 degrees from the left. Samples of intracellular recordings are shown for the seven directions. Polar plot presents mean response for several trials.



GIANT INTERNEURONS receive inputs from cercal wind-receptor cells and relay them to higher centers in the cockroach's nervous system. The drawing at the left represents a whole-mounted nerve cord in which one of the insect's 14 giant interneurons, giant interneuron No. 1 on the left side, has been made visible by being filled with the dye cobalt chloride. The cell body lies to the right of the "tree" of dendrites, which receive most of the incoming signals. Other giant interneurons have different dendritic morphologies. The long vertical cable is the cell's axon, which carries the cell's own signals. The detailed drawings at the right, made from photomicrographs, show sections of a ganglion that had been treated in two ways. In *a* the giant interneuron No. 1 on the left stands out, having been filled with the dye procion yellow. In *b* all 14 of the interneurons, seven on each side, can be identified in a section stained conventionally.

instead of removing it, we see a similar pattern of incorrect turns on the first day and a statistically significant correction by the 30th day. An electron-micrographic study of the sensory nerve, and a limited amount of intracellular recording from the sensory axons after the



DIRECTIONAL RESPONSES of seven left giant interneurons to standardized puffs of air have been plotted. Interneurons Nos. 2 and 4 (*top*) respond almost equally well to puffs from any direction. Interneurons Nos. 1 and 7 (*middle*) respond generally to puffs striking the receptors from the left side. Interneurons Nos. 3, 5 and 6 (*bottom*) show responses that are somewhat more specifically directional. The seven giant interneurons on the right side of the central nerve cord of the cockroach give responses that are mirror images of these.

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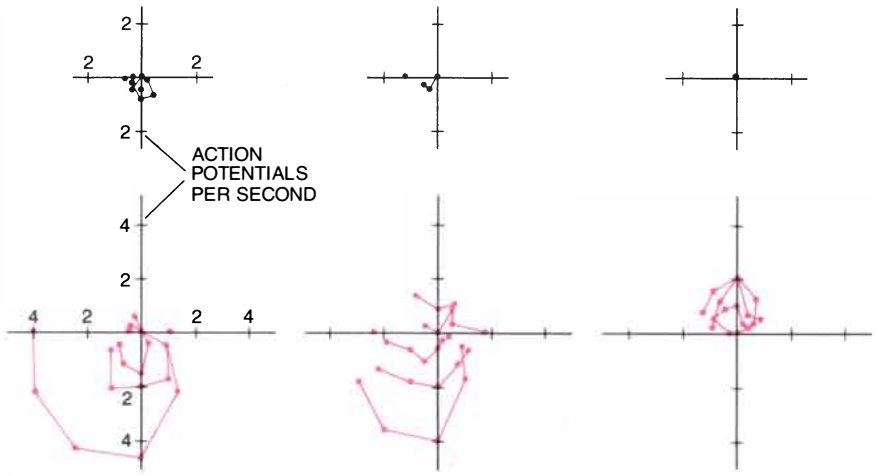
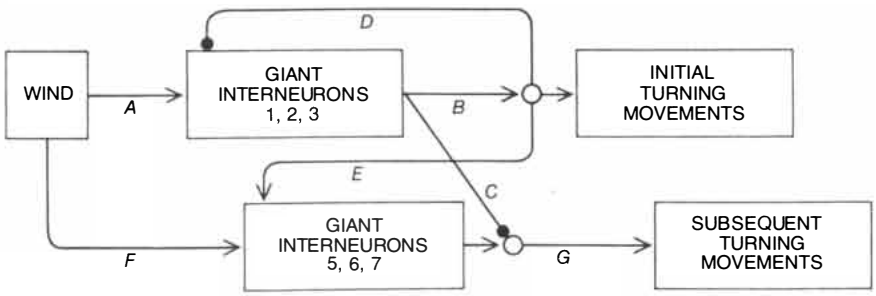


RECOVERY OF ACTIVITY in giant interneurons was observed 30 days after removal of the left cercus of nymphal cockroaches. The three graphs at the top show the average responses in several trials of giant interneurons Nos. 1, 2 and 3 one day after the cercus had been removed. In most of the nymphs tested there was no response to puffs of air from any direction, hence the paucity of points. The three graphs at the bottom show the recovery that had taken place when the insects were tested 30 days later. The three interneurons exhibit response patterns that resemble patterns observed in normal adult insects, as is depicted in preceding illustration.

cercus had been covered for 30 days, indicate that the wind-receptor cells had not degenerated.

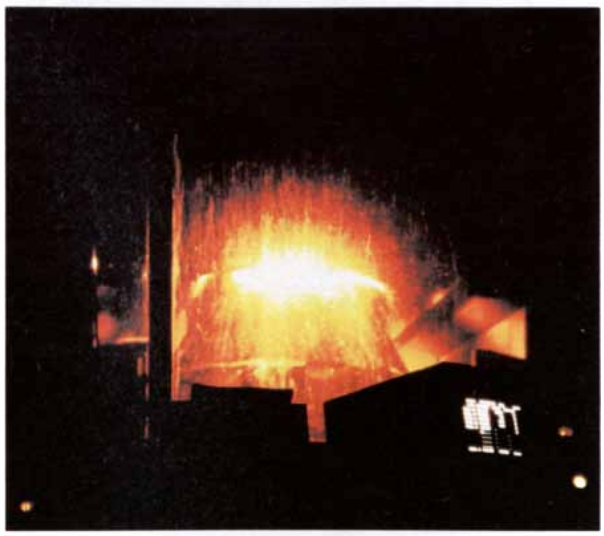
We have shown that the amount of activity in the wind receptors of the right cercus also has an influence on the degree of behavioral correction. This was first suggested by observations of cockroaches that were housed individually over the 30-day recovery period in small plastic cups. The cups shielded the insects almost completely from ambient wind. Moreover, since there was little space for the insects to walk about in, there was virtually no self-generated wind. These confined insects showed significantly less correction than those kept in large screened cages. (Cockroaches with two normal cerci housed in cups for 30 days retained their ability to turn correctly.) In fact, the cockroaches kept in the large cages showed no recovery at all if their left cercus had been removed 30 days earlier and if their right cercus had been covered for the same period and was then uncovered for the behavioral test.

We conclude from these observations and others of a similar kind that the amount of activity in the right cercal nerve of the cockroach is an important determinant of behavioral correction following the removal of a left cercus. In fact, it seems that what determines the extent of behavioral correction is the degree of imbalance between the activity of the left cercal nerve and that of the right cercal nerve over the 30-day period. The nervous system of the cockroach appears to measure this imbalance and to adjust the responsiveness of the giant interneurons accordingly. How that measurement and adjustment are accomplished is still a mystery.



ESCAPE-BEHAVIOR "CIRCUIT" can be inferred by plotting known interactions among sensory cells, giant interneurons and other neurons in response to puffs of air. Puffs striking cercal hairs excite giant interneurons Nos. 1, 2 and 3 through pathway *A* about five milliseconds before they excite interneurons Nos. 5, 6 and 7 through pathway *F*. Moreover, interneurons Nos. 1, 2 and 3, once activated, inhibit the output of interneurons Nos. 5, 6 and 7 through pathway *C*. At first, therefore, units Nos. 1, 2 and 3 probably exert the dominant control over the initial turning movements. Once the turning movements have begun, however, feedback inhibits units Nos. 1, 2 and 3 through pathway *D* and excites units Nos. 5, 6 and 7 through pathway *E*, so that Nos. 5, 6 and 7 may assume dominant control of the behavior. The interactions were established primarily by Roy E. Ritzmann, Joanne Westin, Darryl L. Daley and the author.

TECHNOLOGY



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TECHNOLOGY made in ITALY

Part of Italy's image abroad is that of a land in political turmoil, filled with cultural treasures, and with a continuing tradition of individual craftsmanship. In fact 'Technology: made in Italy' today signifies a totally different and often ignored story – that of developed mastery in the finest points of high technology across a full range of industries. This special report examines the technological innovation and applications in Italy's major industrial sectors. It highlights both the limitations and the many achievements, and focuses particularly on the organization and finance of research and development, through both the public and private sectors of industry.

Foreword by Dr. Luigi Deserti,

President of the Institute for Foreign Trade (ICE)

This report in Scientific American will inform public discussion on the role and importance of technology in the Italian industrial scene and on the concomitant international economic implications. Technology, in today's world, is not just a measure of the novelty or sophistication of products, but is also a fundamental factor in the international division of labor and thus in the relative position of national economies in the world market place. All countries participate in complex international exchanges and all depend on the technical level of their products and on the quality that the foreign buyer requires.

This is why it is significant that this series of special reports in Scientific American on contemporary technology should include one on Italy. A country which after the Second World War has become progressively more industrialized and which has shown great dynamism and an exceptional capacity for expansion.

A diversity of industry and trade is built into the Italian system. The reason for this lies in the co-existence of very large firms with both medium and small sized companies. Together they cover a range of products using both the 'traditional' and the highly sophisticated new technologies. The focus of Italian industry is also directed at exports both to industrialized and developing countries. Furthermore, despite the crisis that affects the industrialized world, our exports continue to grow. They now amount to a quarter of our GNP, and emanate from almost 80,000 firms.

The material that follows should help the reader to gain a clearer impression of the many facets of Italian technology and production. These embody our best traditions for flair, invention and intelligence.

At the time of writing, approximately 830 lire equals one US dollar. A billion lire is thus about $1.2 million.
Front cover photo: 'One of the six L-D converters in Italsider's Taranto Plant' courtesy of Italsider.

OF MONEY AND INITIATIVES: PUBLIC AND PRIVATE

ON THE PUBLIC SIDE

Three public bodies are responsible for initiating and managing scientific research in Italy, whether industrial/applied or basic in intention. At the top, an Interministerial Committee for Economic Planning (CIPE) evaluates and approves budget proposals, setting goals and delegating detailed controls to other bodies. CIPE's acquiescence was crucial, for example, to initiating a change in philosophy at the National Research Council (CNR). This is the main organization for research and was previously geared to pure, but now increasingly toward applied studies. Since 1962 Italy has also had a minister without portfolio for the Coordination of Scientific Research and Technology. This office, without a full Ministry to back it, is now being expanded, indicative of the changes taking place in Italy of late, as the country wakes up to the need to catch up quickly in its technology development.

The CNR is far and away the main clearing house for research sponsored by the State, but, until recently, a continuing criticism of the Council was its distance from industry and the real world. In 1976, out of an over-extended position that yielded little economic gain, the CNR has evolved a new policy. A series of projects were developed aimed at industrial research and oriented to production. The call to bring CNR into collaboration with industry was heeded for the first time. Lasers, informatics and superconductivity were chosen first. The large commitment of public spending for 1979 into these CNR-managed goals is evidence of the new purpose. Widened to include health, environment, nutrition and maintenance of Italy's cultural heritage, the projects have seen their budgets rise fom $24 million to $72 million in the past five years, with some $300 million for the coming five years.

It is easy to point out R&D spending is coming late to Italy, particularly from the public sector. However even without the spin offs and impetus from military budgets national spending has effectively doubled since 1963, but a much greater part has been borne by the private sector compared to the US.

For the second half of the 1970's CNR statisticians calculated that the R&D national spending commitment was the second lowest (to the Republic of Ireland) within the European Economic Community at a level of 0.89% of GNP or about $30 per capita.

Vincenzo Balzamo, Minister for the Coordination of Scientific Research and Technology notes that while it is not enough, central government support for R&D throughout industry rose from $696 million to $840 million in the past two years, and is expected to grow to 2.8% of GNP by 1990.

Italian R&D has suffered not only from lack of funding and bad timing but also from a notorious bureaucracy and even cultural attitudes. The national ideal is still the Rennaissance man of genius. An American style career as a research technologist is only beginning to appeal to the young.

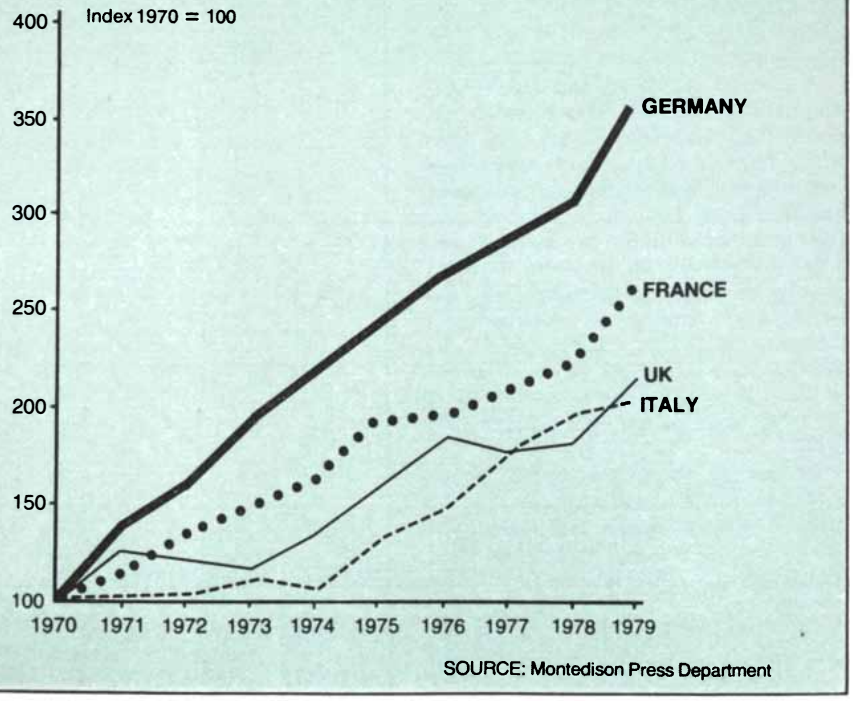
Research is seen as part of industrial development. Industrial development however in Italy's mixed economy is a political decision. Substantial effort has gone for over a decade to remedy the economic imbalance between the North and South of Italy. Legal guidelines now direct research centers to be developed in the South, using both financial incentives and legislation. Government agencies give grants and low interest loans for research projects and are obliged to spend a substantial part of their funds to aid research in the regions south of Rome. Initiatives to bring technologies into the South have also the backing of major industrial firms like FIAT, Pirelli and Montedison.

ON THE PRIVATE SIDE

The continuing viability of small firms in Italy is a source of surprise to visitors, satisfaction to the economists and support for a beleaguered balance of payments. Small companies, faced with less political pressure and fewer union demands are able to compete effectively against the competitive pressure of Japan and the Third World. Many have made a commitment to specialization in developing products of high technological content and have made concomitant expenditures in R&D. And yet, for all their troubles, giants like Pirelli and Montedison and a reflourishing Olivetti account for the major spending for R&D. In fact, according to authoritative sources about 20 firms probably account for 75% of industrial R&D in the private sector.

Without many raw materials, Italy is essentially a manufacturing economy, until recently strongly biased towards heavy machinery, petroleum refining and light, high quality consumer goods. Today, it is aiming to be a supplier of nuclear components, of advanced informatic systems. It is achieving truly remarkable growth figures (8.4% in 1979) and has recently had a positive inflow of population for the first time since the Roman Empire. According to Ministers like Balzamo and Giovanni De Michelis, Minister of State Participations, growth is not being achieved by manipulating prices and labor costs, but by helping an economy with tight social safeguards to become more technologically advanced and less labor intensive.

GROWTH IN R&D EXPENDITURE BY THE PRINCIPAL COUNTRIES IN THE EEC



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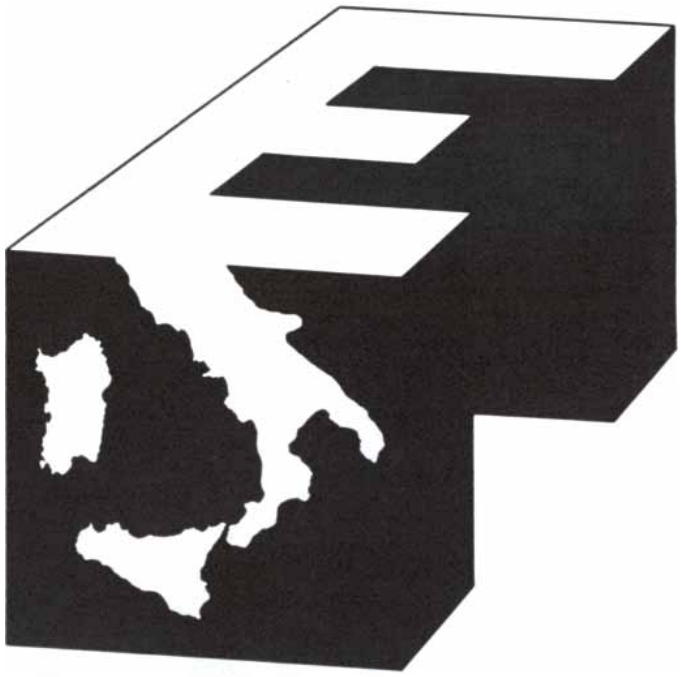

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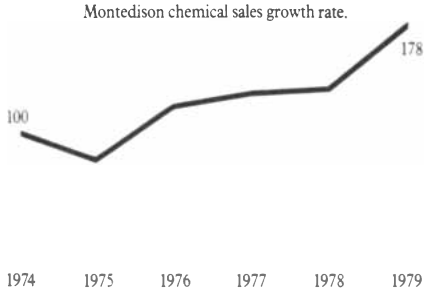
Montedison chemical sales growth rate.



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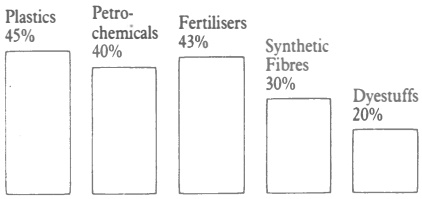

Montedison total sales as a percentage of Italian market

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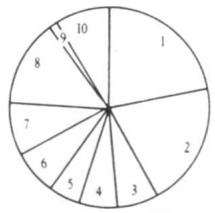
This allows for central co-ordination and policy-making, but in each specialist activity the Divisions and affiliates are autonomous.



The main fields in which the Montedison group operates
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4. Industrial Chemicals 6% 5. Dyestuffs 5%
6. Pharmaceuticals 7% 7. Fibres 9% 8. Retailing 15%
9. Engineering 2% 10. Others 9%

From providing town gas for Milan to cardiovascular drugs; plant construction in USA, USSR and Third World to Polypropylene and Polyurethane manufacture; from the development of the vital new antibiotic Adriamycin to pesticides, industrial chemicals and textile lubricants, Montedison is a force to be reckoned with and in certain areas such as plastics, is a recognised world leader.

Our diversity gives excellent scope for cross-fertilisation of ideas, and the ability to support our extensive research programme, both now and in the busy future.

Montedison may be a quiet giant, but we're far from silent.

WE SHARE OUR ADVANCES

This research and the important technical advances we make include the Nobel prize winning invention and development of the plastics material Polypropylene.

We sell far more know-how than we buy.

Through our Donegani Institute we make available the chemical research also to small and medium sized firms, especially in the South of Italy–the so-called Mezzogiorno.

Although the biggest chemical company in Italy–we have a quarter of the market–our activities are world-wide.

*Fortune August 11th 1980.

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Just a few of the many Italian firms busy developing and selling high technologies are Tecnomare (offshore drilling), Tecnocasa (construction), Tecnofarmaci (pharmaceutical), Tecnotessili (textiles), SAGO (sanitary services), Tecnoalimentari (foodstuffs) and Tecnobiomedica.

Other companies often mentioned for their capacity for innovation include: ARS (Applied Scientific Research) in Milan; SAES-GETTERS, maker of fundamental vacuum units for electronics and the atomic industry; Italsiel, the IRI Group's software house; MaEl, maker of small and medium-sized business computers; Luigi Franchi, a part of the distinguished small firearms industry around Brescia; Pioggia Carnevale, a Mantua firm in automated irrigation systems. Campagnolo means some of the best bicycle components in the world, and like Ferrari, Maserati, Moto Guzzi and Benelli has held its own against the strength of the Japanese and other Europeans by conquering and maintaining the top end of their respective markets.

There are also many successful firms with fewer than 500 employees (for example Officine Meccaniche Vimercati in automotive parts, Corrada for special presses, CCB for numerical controls, Metrel for industrial automation, Norda for robotry and Neofarmed for pharmaceuticals). Many of the companies mentioned are self-financing, have never received help from government or international sources. A good number sell without the backing of aggressive organizations like the Japanese JETRO, though the Italian Ministry of Trade has an Institute for Foreign Trade (ICE) which is now gearing up to help with the sale of Italian technology and know-how abroad, in addition to the more traditional commodities.

The combination of technical expertise, commercial enterprise and judicious government backing should ensure that Italian firms will continue to innovate and gain competitively in world markets.

EVERYTHING STARTS .... WITH ENERGY

Completely dependent on imported energy, Italy has developed a sophisticated technology for refining petroleum products, the backbone of the 1960's 'boom'. In fact, much of the petrochemical and refining industry in the Third World was designed and built on a 'turn-key' basis by Italian firms, above all the associated companies of the National Hydrocarbon Agency, ENI.

ENI is engaged in business and research in hydrocarbons, natural gas, chemicals and nuclear fuels. Its national petroleum company is called AGIP, and ranks as the second largest commercial unit in the Italian economy, vying with FIAT for first place. Because gasoline prices in Italy are government controlled, AGIP's associated 'sister' firms in ENI have concentrated on the development of exportable products, processes and know-how.

The ENI group has virtual monopoly (97%) in Italy in natural gas. SNAM is ENI's entity which builds, owns, and manages the national gas pipeline network. In 1974 it launched a 10 year project to carry a third more product to the Italian system through importation from Algeria.

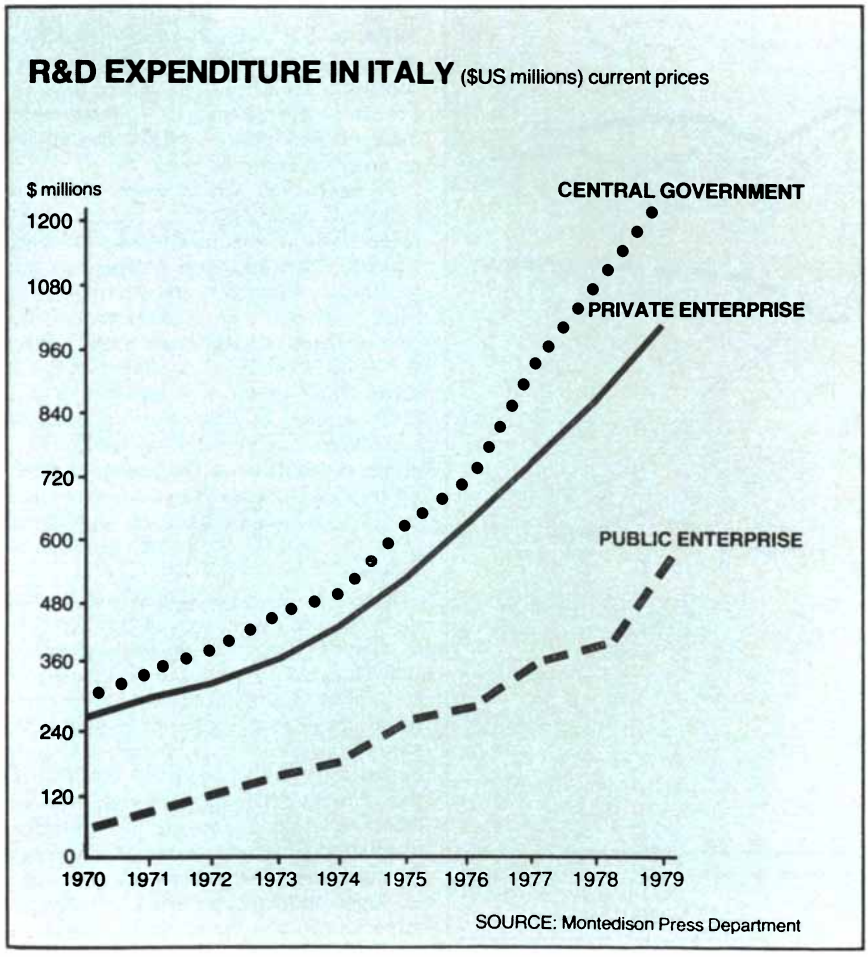
To carry out the project SNAM depended on another ENI affiliate, Snamprogetti, who devised new ultrasonic technologies for undersea relief mapping and underwater gas pipeline laying techniques in order to move natural gas from Algeria to Sicily and connect to the Italian national grid.

The pipeline is being laid by a newly designed $150 million barge – the Castoro 6 – whose technology surpasses that of previous similar vessels. The semi-submersible barge represents five years of research by SAIPEM (also part of ENI). Among the techniques developed for laying the pipeline is new know-how for recovering it for possible repair. While 100 meters ranks as 'deep' for undersea pipeline, this project has worked to a record 608 meters.

Pipelines are not, however, Snamprogetti's only business. Its managing director, Bruno Cimino, says, "Today we have more than 3500 employees and are one of the largest engineering firms in Europe, with about $3 billion orders on our books, 95% of it outside Italy."

Snamprogetti has built over 45 refineries and several hundred process units in the refining, chemical, textile and agroindustrial fields, and laid over 50,000 kilometers of oil and gas pipelines. In petrochemicals the company designs and builds virtually all types of process plant.

The firm has a $10 million annual budget for R&D in process developments, involving 250 people. Today 60% of the world production of MTBE, an octane booster, is made under license from this firm and ANIC. This technology is based on a fixed-bed reactor, using a catalyst which insures a very high yield with low production of by-products. Snamprogetti is also working with Texaco on coal gasification, and with Montedison in fertilizer plants. The firm has recently



developed a 'multiple effect' technology for urea production, using vertical tube evaporators which permit substantial cost reductions in both investment and operation. Snamprogetti has also developed, with Brown Boveri, a new LNG (liquified natural gas) regasification process with the simultaneous production of up to 86,000 KW/hour at maximum capacity.

Other associated companies of Snamprogetti are engaged in far-reaching research projects. Aquater specializes in studies of geothermal energy, produces advanced instrumentation for monitoring the porosity and permeability of rock and manufactures equipment for analyzing water encountered during drilling. Tecneco, a specialist in ecology, water treatment and farm engineering, has devised ways of cleaning the Bay of Naples and developed new filtration materials and techniques.

WEATHERING THE NUCLEAR BATTLE

The Italian nuclear program has suffered from overambitious goals, a well organized opposition and some bad luck. While France is heading towards 1990 with a standardized (all pressurized water reactors) network that will probably yield 40-50% of French electrical power, Italy has only three working reactors with a fourth north of Rome, if siting permission is given. The twelve once envisaged have been shelved, and the country (with 85% of its energy source from petroleum) is second only to Japan in its dependence on OPEC oil.

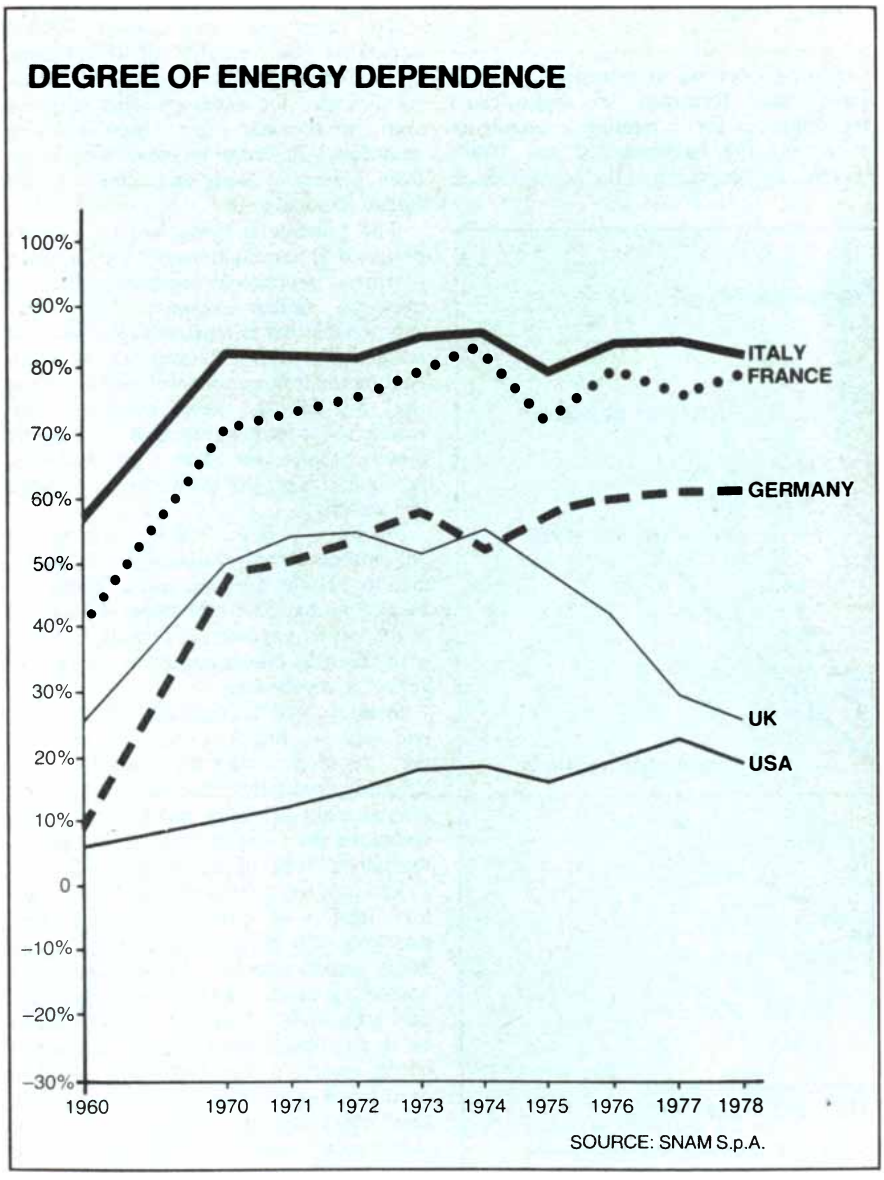
At the start of the 1960's Italy was one of the foremost nations in the world in the construction of nuclear power stations. Today, although effective political opposition has stopped the construction of nuclear power stations, the decision has been made to continue to maintain industrial and technical capability in this field and to sell overseas the know-how unused in Italy.

CNEN is the agency for atomic power and is oriented towards collaboration with industry and increasing European links. With 4,000 employees, CNEN combines several roles: supporting research, building and operating prototypes, maintaining internal contacts and contracts, and acting as the certifying and regulatory agency for all matters concerning safety. In that role, it has kept the Italian nuclear know-how up to par.

Under CNEN an enormously diffused nuclear industry has flourished. Today many operating companies like Ansaldo, Sigen, Sopren and Breda Termomeccanica (all part of the Finmeccanica Group) make components which include reactor vessels and world class equipment for automatic welding of nuclear vessels. Outside these companies, AGIP maintains capacity in nuclear fuels and FIAT-TTG (Termomeccanica and Turbo Gas) is also involved. Sigen and Sopren hold the Westinghouse license for PWR's and Ansaldo's AMN the boiling water reactor (BWR) license from General Electric. CNEN has backed the Ansaldo Group's NIRA in fast sodium reactor research so effectively that this company is lead contractor for the Italian part of the joint French-German-Italian fast-breeder Superphénix project. NIRA also follows up other experimental work.

Probably the single most important industrial grouping on the Italian nuclear scene is the Genoa based complex called Ansaldo. New electrical components and turbines, alternators, transformers and basic design of components for electrification of railways are areas in which the Ansaldo Group of 13 companies is also active. This group of companies, with a 1979 turnover of $800 million and 20,300 employees, is very active in R&D with a group expenditure of $46 million in 1980. Of this R&D expenditure, about one half comes from in-house financing, and the rest through various forms of government support.

In fact the Ansaldo Group is at the core of the economic life of Genoa and fundamental to whatever future the nuclear industry in Italy may have. It is also the most integrated and able to design and deliver everything from forged parts for steam turbine blade mountings to computer controlled systems for reactor vessel management. At CESEN, the Ansaldo Group's central research laboratory, studies on the hydrodynamic magnet as an energy generator are underway. Because Ansaldo is a major industrial user of superconductor materials, it plays an important role in the research program on



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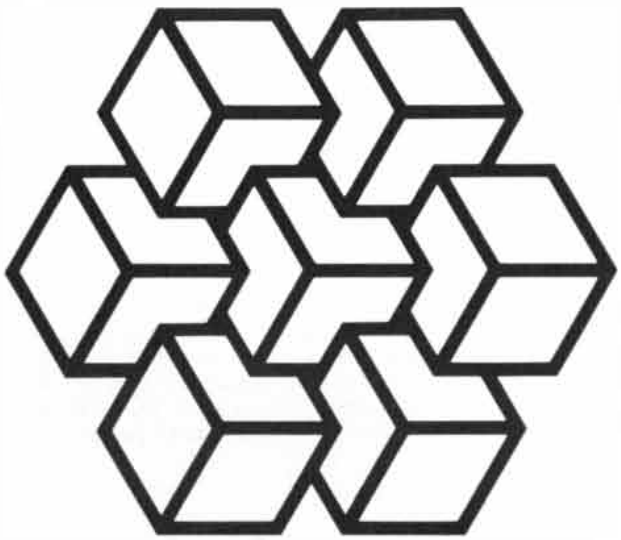

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superconductivity of the National Research Council.

Ansaldo is also in the business of wind energy and the firm has a joint-venture with Grumman to produce vertical axis wind generators in the 15-20 KW range. Ansaldo has sold 50 such wind generators to ENEL and expects no problem in escalating their power output to three times that of the prototype.

A solar power plant installed in Spain and paid for by the EEC will be cooled by a liquid sodium technology thanks to the Ansaldo Group's work on the PEC reactor and the Superphénix , both sodium cooled. Ansaldo's solar experience has grown out of a pilot plant in Sicily along 'central tower and mirrored field' design, with energy receivers able to produce one megawatt of electric power.

DELIVERING ELECTRICITY WITHOUT NUCLEAR HELP

In 1962 electricity was nationalized under ENEL and Italy's challenge was to solve its energy problems starting from nothing. Unlike England with North Sea oil, or Germany and France who have coal, Italy is much more like Japan. The goal can never be complete independence from oil but rather to minimize dependence on it. Stymied in its plan for nuclear construction ENEL strategy is to build new power plants using coal. In the meantime, Italy is expected to consume 38 million tons of petroleum for electric power generation in 1985 as compared to 9 million in France, and 6 million in Germany, a country in which electric power demand is double that of Italy.

Italy's demand for electric power doubles every ten years, and 1979 saw Italy import 6 billion KW. From almost no use of coal a few years ago, ENEL imported 3.7 million tons in 1979 and expects to import 5.2 million in 1980. It is estimated that 20 conventional power stations of 600 megawatts each will be needed, as the plan for ten to twelve nuclear stations of 1,000 megawatts each is fading fast. According to ENEL's president Corbellini, alternative sources like solar and wind power, may make fractional contributions to meeting demand, but possibly not for decades.

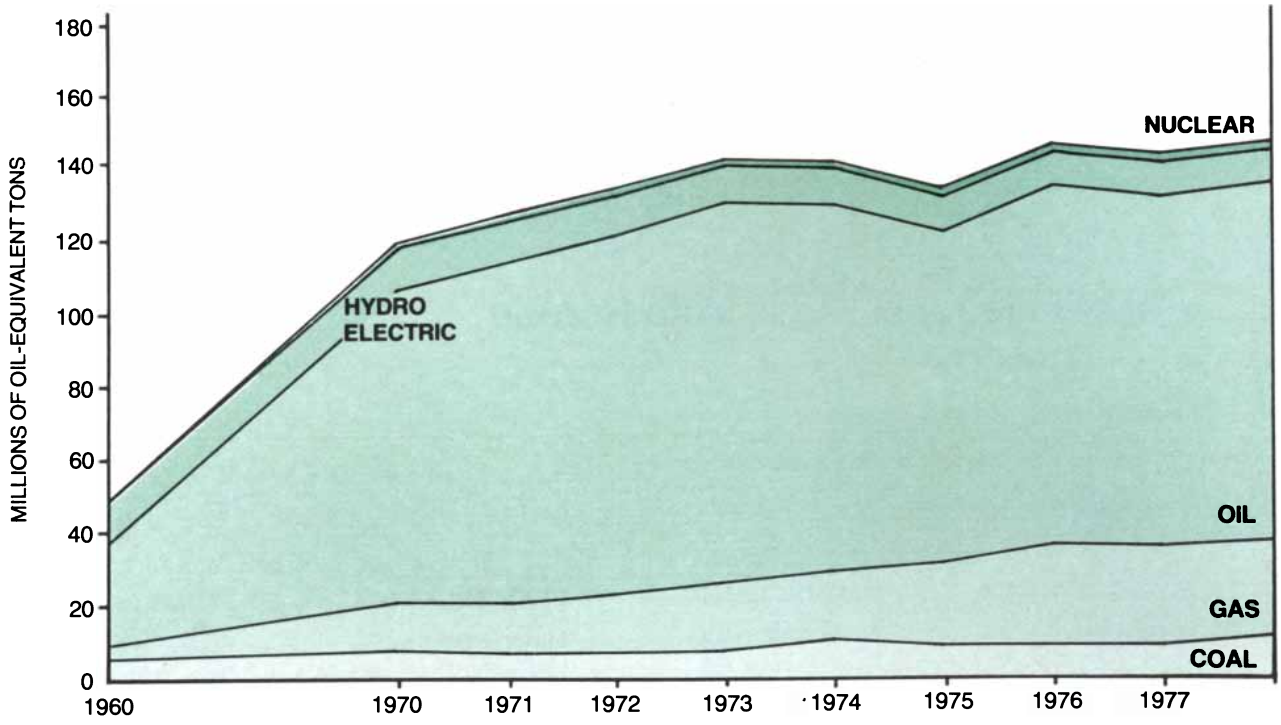
The present 420 KV grid developed during the 1960's needs updating. The new 1,000 KV project is expected to be set up and work beyond the year 2000. The 1000 KV grid (actually 1050) will carry the load of eight 420 KV lines, and use accordingly that much less land.

A program to which ENEL attaches real importance as an energy saving measure is convincing the Italian public and industry to convert to 'mixed' solar heating systems for newly constructed residential hot-water supply. The 'Carp Project' brings Italy into the club of countries involved in ways to use waste heat for agricultural and hydroponic applications. Because conventional and nuclear thermal power stations call for enormous quantities of water for the cooling of steam condensers, properly treated effluent can serve as an inexpensive heat source. Initial experiments and pilot plants already apply ENEL-developed technology toward irrigation, fisheries and crop growing.

A new ENEL plan to certify, measure and report to consumers the electrical efficiency of millions of small motors used in household appliances is expected to have impact. Further, ENEL, and not only car companies, is involved in studies of the urban electric vehicle.

For the period between 1979-1983, ENEL's plan is to substantially increase R&D spending from slightly under $60 million to about $78 million. Priority has been given to solar energy, low-pressure

DEVELOPMENT AND SOURCE OF ITALIAN ENERGY CONSUMPTION



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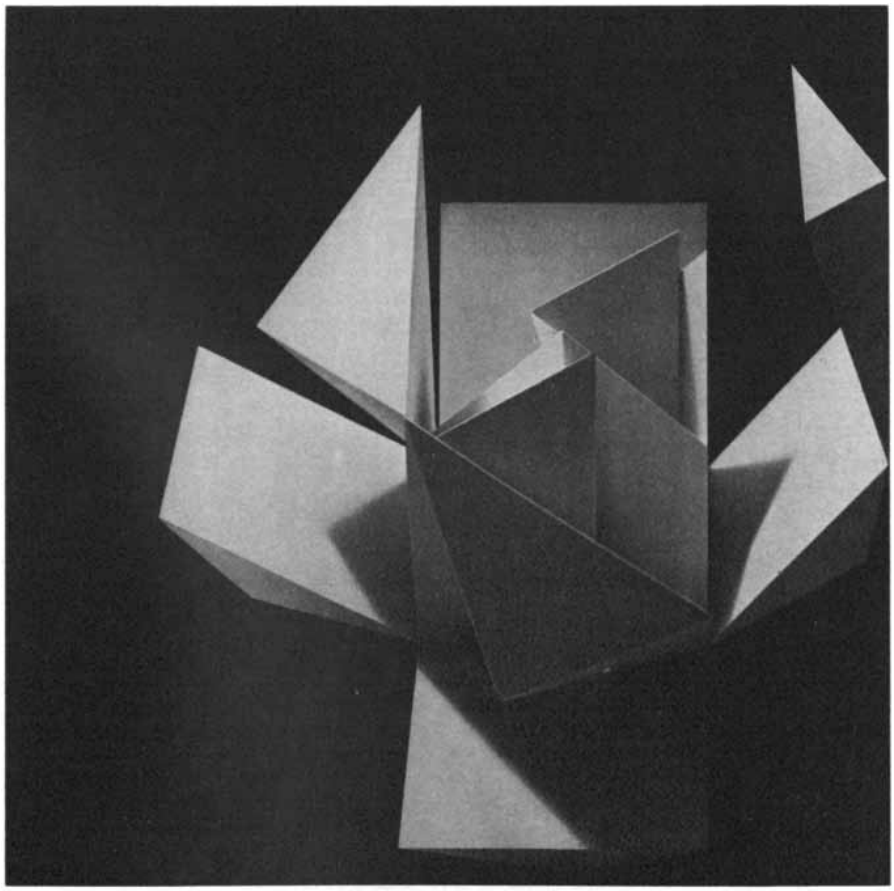
When the readership of scientific publications goes up as sharply as it has today, Olivetti is delighted. Because this means that the number of people interested in scientific research, data processing and therefore in Olivetti, has also increased. If in fact scientific research can progress today at such a fast pace, thanks are also due to data processing. And Olivetti is Europe's leading manufacturer and one of the world's major operators in this field. To understand why, just take a closer look at some of the facts. 2,200 research workers in the Ivrea laboratories – some of the largest in Europe – are designing the future. 55,000 people are working in 28 plants distributed in 10 nations. 32 foreign subsidiaries plus 105 general agents are engaged in direct sales throughout 138 countries. 9,600 servicing technicians, 3,200 software specialists.



By virtue of this Olivetti today offers the widest range existing of distributed data processing systems and equipment for office automation. In fact with its network of terminals and concentrators spreading from the North Pole to the boundaries of the Australian deserts, Olivetti does away with continental distances ensuring the organization and transmission of information. And with the world's most complete line of electronic typewriters Olivetti has recently brought a new dimension into everyday office jobs - the possibility of increasing productivity while helping to make work more creative. So, in 1979 the turnover amounted to 2,237 million dollars. 70% of this is accounted for outside the Italian market. A turnover coming from sales but also from technologies covered by international patents and which Olivetti exports worldwide, U.S.A. and Japan included. And it is this turnover, this presence extending everywhere, the advanced solutions of its technology that make it possible to affirm that Olivetti is wherever there are people who make the future happen.

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steam turbines for nuclear stations and the use of waste heat recoverable for further use.

THE FRONTIERS OF ENERGY RESEARCH

In addition to its three large scale research establishments, CESI, CISE and ISMES, ENEL maintains five other research centers: electric, automation and computing, hydraulic and structural, thermal and nuclear and geothermal.

Italy presently exploits on an industrial basis hydrothermal systems, and first experiments are underway on hot dry rock systems; ENEL has collaborated with AGIP to produce a detailed national geothermal map. In the solar field, thermodynamic conversion and photovoltaic cells are studied by ENEL (jointly with the EEC), and with EEC funding a 1,000 kilowatt solar plant for joint ENEL-Ansaldo operation, is planned in Sicily.

As for geothermal, Italy was for decades the only country to exploit indigenous steam for the use of electricity. While about one third of the world's geothermal output is in Italy (2.5 billion kilowatts supplied in 1975), this represents only about 2% of Italy's electricity output. Research is now underway for exploration below 3,000 meters and in new fields.

Not confined to ENEL's goals, CISE (Italian Center for Research and Experimentation) is an interdisciplinary center, and conducts experiments in physics, chemistry, electronics, technology and engineering, especially geared to energy sources. Entities like CISE have grown up directly under industrial corporations or as legally separate research corporations, at least in part, because Italian universities have had a chronic lack of resources compared to elsewhere in Western Europe, Japan, and the United States.

Outside of nuclear, CISE is involved in alternative and integrative energies and energy-saving. Geothermal probes, and apparatus are among their innovations to measure industrial plant energy waste of internal structures of pressurized water reactor vessels.

Further, acoustic detection techniques have been developed for use in the operation of high pressure processes involved in power generation.

Many of CISE's patented processes and products in a variety of fields can be cited as contributions to world technology: in the nuclear field, instruments for pulsed wave shape analysis; in the medical field, probe equipment for heart potential measurements and ultrasound instruments for measurements of the human blood velocity by a non-intrusive method; in the field of communications, a system for data transmission through optical fibers over distances of hundreds of meters; and in the electro-optical field, a high-accuracy telemeter associated with a semi conductor laser for topographic distance measurements. The payload of the first flight of the European Space Agency Spacelab will include instrumentation developed at CISE allowing for physical experiments to be carried out under micro-gravity situations.

In informatics, CISE has developed software for microprocessors, both basic and application types; the Center has also developed languages and subsystems for large computers.

In late 1977 ENEL, CISE, Montedison and the association of autonomous energy-producing industries, created a Venice task force of scientists and, as explained by the Institite's director, Franco Dalla Valle, "We decided that a more rational use of energy in this dense industrial zone was the key to solving the environmental problem. Heat in the water is one problem among others. The big

industries have installed anti-pollution devices and taken measures which now show positive results; for example, some fish thought eliminated from the Venetian Lagoon, have reappeared."

THE CNR ENERGY PROJECT REPORTS RESULTS

The single largest budget appropriation among 'finalized projects' of the CNR is that dedicated to the Energy Project. Between 1976 and 1979 its appropriations rose (in current figures) from $7.5million to over $20 million; as of 1979 the overall budget for the project is expected to be $86 million. The energy study is divided into ten subprojects: solar, geothermal, use of urban waste, energy saving, use of methanol, energy saving in building heating, and other related projects.

After four years, good results can be reported: research on energy saving engines for use in traction-based transportation is proceeding to a prototype; a reduction by 15% in fuel consumption was achieved through new aerodynamic studies for vehicles undertaken by Pininfarina (the auto-body design firm of sports car fame) and a reduction of 20% by redesign of the cabin shape of trucks and buses; positive results in the development and use of a direct-injection diesel engine with excellent performance regarding emission; and satisfying work on development of a modular engine in combination with a special electronic injection system.

The Energy Project has underwritten development of a new kind of diesel fuel, extractable from petroleum with a simplification in refining. During 1979, the program on use of methanol successfully concluded research on the use of that compound as transport fuel and heating source. Results confirm the possibility of using a gasoline mixed with 20% methanol with economic, technical and environmental advantages.

Important to Italy's steel industry, new kinds of electric furnaces and techniques for desulfurization are being devised. Research in energy saving included a study of 150 buildings a year for four years throughout the country, and results are expected in 1981. Statistical studies are providing a framework for measuring the efficiency of plant producing hot water, often wasted, and helped to develop standards to aid the construction industry to conform with the strict standards of a new law which came into force in the summer of 1978. Pilot studies undertaken at two housing projects (research contracted to FIAT Engineering) showed not only that observance of stringent environmental laws is feasible but that the use of everyday materials allows a reduction in fuel consumption of 60%, with any cost increases absorbed in the normal amortization period.

Research on solar cells has seen synthesis of new polymers for short-term accumulation and needed silicon components; cell prototypes have been built using a new method of 'ionic implant' and improved rubber collectors. Wind-assisted heat pumps have been devised and a solar-powered desalinization plant installed.

In geothermic studies, detailed prospecting has been undertaken and seismic studies connected with problems encountered when water is injected into hot rocks. CNR's Energy Project has initiated plans for a world geothermal data bank.

KEY INDUSTRY SECTORS

RESEARCH SURVIVES AUTOMOBILE MARKET PROBLEMS

FIAT is far and away the largest private presence on the Italian economic scene, a conglomerate of some 11 industrial divisions. Eighty years old, the Group today operates under a holding company based in Switzerland, employs over 350,000 people worldwide, runs 211 production plants (162 in Italy) and shows a 1979 turnover of some $18 billion. This would rank FIAT eleventh among American companies in FORTUNE's 1978 list, and in fifth place, amongst non-American manufacturing companies.

Of FIAT's turnover, less than half is accounted for by automobiles: steelmaking alone generated almost $2 billion with over 2 million ingot tons production. While not nearly so visible as in the auto field, FIAT is a maker of components (almost 50,000 employees, turnover about $2 billion), of machine tools and production systems, a supplier of civil engineering and even land-use planning know-how.

In the automotive area, FIAT's long term plan for answering the predominantly Japanese challenge is to reduce the number of models it produces. FIAT's chairman, Giovanni Agnelli, thinks that the company should concentrate on four models, part of a strategy for making FIAT a leader in creating a European rather than a strictly Italian industry. The first steps are underway. FIAT has recently signed an agreement with British Leyland, Renault, Peugeot-Citroen, Volvo and Volkswagen for a common effort in basic R&D. When the largest single factor on the Italian industrial scene is retrenching, one would expect its R&D expenditure to fall. Not so.

As a center for new techniques and technologies, FIAT is certainly the single greatest source on the Italian scene. Its biomedical group (SOREN) engages in plasma welding of pace-maker cases; Teksid Steel foundries pioneered mould

casting; the automatic systems for serial welding (called Robogate) developed by its affiliated machine tool firm COMAU are applied not only within the gigantic Mirafiori plant at Turin, but in the many FIAT plants elsewhere.

Individual operating sectors conduct research, but a centralized FIAT Research Center responds directly to the parent companies and also works for third parties. The FRC's budget was some $48 million in 1979, representing 15% of the Group's overall R&D expenditure. Dr. Ugo Lucio Businaro, head of FIAT Research Center, explains, "Projects undertaken at the Center do not always bear a direct relationship to production, and can be of a theoretical nature. Major research has been necessary because the automobile business changed completely in the 1970's, and unlike the relatively static technical years, the 1950's and 60's, we are now in a period of revolution in car design, from weight to consumption."

As for manufacturing process technology, the Center has been developing a 'visual sense' in robot automation systems, a natural outgrowth of FIAT's longstanding leadership in the use of robots in car making.

A newly developed prototype robot, now factory-installed, refines a quality control system for checking invisible defects in metal parts, thereby eliminating the undependable human factor.

Four years ago, the FRC set up a team charged with marketing the know-how developed there; among its first sales was that of an anti-skid system to US automakers and it has received research contracts from US government agencies. For example, it is now developing a specialized data-base concerned with the trade-off between fuel consumption and emission. Other US-source contracts fund research on the carcinogenous effects of diesel particle emissions, and on the energy saving 'hybrid car'.

Along with setting a long-range development strategy, the Center's major work comes from the operating divisions: diesel supercharging, alternative materials for car bodies and improved systems for quality control rank high among the Center's interests.

TOTEM is the result of the Center's five year study into alternative energy systems. This is a complete generator, designed to produce heat and electric power using the FIAT 127 car engine working on methane, and an electric asynchronous motor directly coupled to the engine. The unit can supply power or heat: 33,000 Kgcal and 15 KW at 90% efficiency. TOTEM produces electricity more efficiently than a normal generating plant because of heat recovery.

In the field of solar energy, FIAT research devised an air-heating solar panel that uses thin aluminum tubes. "We tried to avoid the solar-panel which produces hot water, of which there are already many makers. We think that for many agricultural purposes, an air warming system has much potential," says Businaro. Under EEC contract, the Center has experimented with heat collecting equipment for underground storage. The reclamation of stored heat is a crucial technology, for without the capacity to recover such energy solar systems are largely seasonal.

In auto R&D, the transition to digital-based auto electronics at FIAT is leading to a total system approach. FIAT now has under study a prototype in which the controls for ignition, fuel injection and gearbox are all connected.

Dr. Businaro in concluding an explanation of what makes the Center's approach to R&D unique notes that his engineers and researchers are far more eclectic than their Japanese and American counterparts.

These research goals are also shared by Alfa Romeo, Italy's tenth largest company by turnover. Alfa Romeo, is among the world's smallest auto makers, with a production of about 220,000 cars in the upper price range. President Ettore Massacesi says, "We have a long tradition of brilliant engines, and as a car maker we are 'motor oriented', but Alfa Romeo recognizes that competition in today's auto market also depends on body styling and efficiency of production. We have a ten year plan which calls for more frequent model changes: a new model every six, instead of twelve years, with 'face-lifts' every third year." Alfa Romeo's major R&D program, bolstered by a $35 million a year expenditure, is oriented toward electronics, and the application of microprocessors to control engine functions. As a result, much greater collaboration between auto maker and component supplier in the design and engineering of the microprocessor is expected. According to Alfa Romeo, the transition will be from auto maker as an assembler of finished components, to systems-designer at an earlier stage in the conception of crucial components.

Massacesi says, "Alfa Romeo's approach to electronic control is gradually to increase the number of individual functions rather than introduce in the market a total integrated system in one fell swoop. While the basic technology is already in hand, the crucial solutions must be in the area of reliability, as once the engine, transmission and other vital functions of the car are integrated into on-board electronic control, if everything works well there is an improvement, but integration also means that a single malfunction can stop the car completely."

MACHINE TOOLS AND AUTOMATION: SHOWCASES OF ITALIAN ACHIEVEMENT

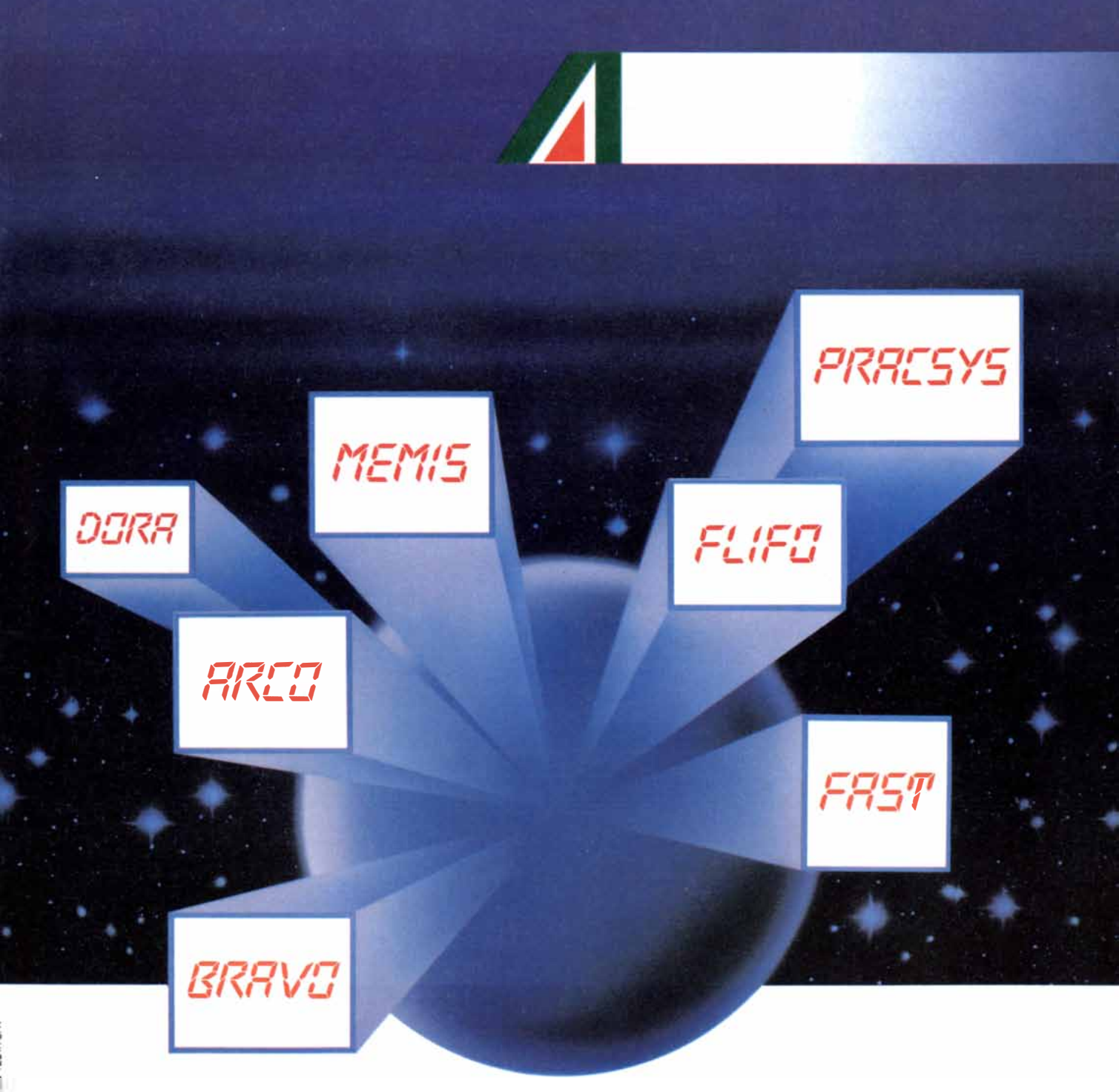
The Italian machine tool industry has a distinguished career, in part thanks to the early development of a large scale automobile industry. Today, spurred in part by the shortage of labor, but mostly responding to available technologies, the Italian machine tool industry has moved well beyond the individual machining center. The idea is total systems, offering flexibility and multipurpose use, integrated assembly systems built on conveyors which can assemble high-precision parts with minimum human intervention and maximum use of the computer. The Italian machine tool industry is at the forefront in applying computer technology of all kinds to machine tool design.

Among the leaders is the FIAT-affiliated firm COMAU of Turin. The largest such complex in Europe, with $350 million in turnover (1979), ten factories and 1,000 design engineers (of 6,000 employees), COMAU undertakes overall responsibility from design through engineering feasibility studies, to plant completion and installation on a turn-key basis. While highly diversified, COMAU's chief customer has been the FIAT group, which has been supplied over the past decade with major innovations in all aspects of production processes for cars, trucks and industrial vehicles, tractors and earth-moving equipment. Speaking about FIAT as a giant laboratory for automation, chairman Agnelli says, "The key point that we have faced before anybody else was the difficult industrial relations in the factory, so I think we have anticipated certain production techniques in areas that are going to be problems to other European auto makers."

With interests in machining, welding, materials handling, storage and industrial washing as well as dies and fixtures, COMAU is probably best known as the firm which devised the 'Robogate' weldingsystem, a complete, flexible, integrated plant for the welding of auto bodies and sub-assemblies.

COMAU's six axis 'Polar 6000' welding robot lends itself to changeover for use on a different car model in about two hours, with replacement of about 30% of components, and the relatively high investment pays off because only 20% of the Robogate's components are tied to any particular car model.

Working to devise flexible instead of rigid systems, with adaptability and lower cost, COMAU also has customers in the thermonuclear, petrochemical and shipbuilding industries. Numerous vertical storage systems with electronic controls have been designed. Automatic warehousing systems require special software for retrieval and delivery of stored



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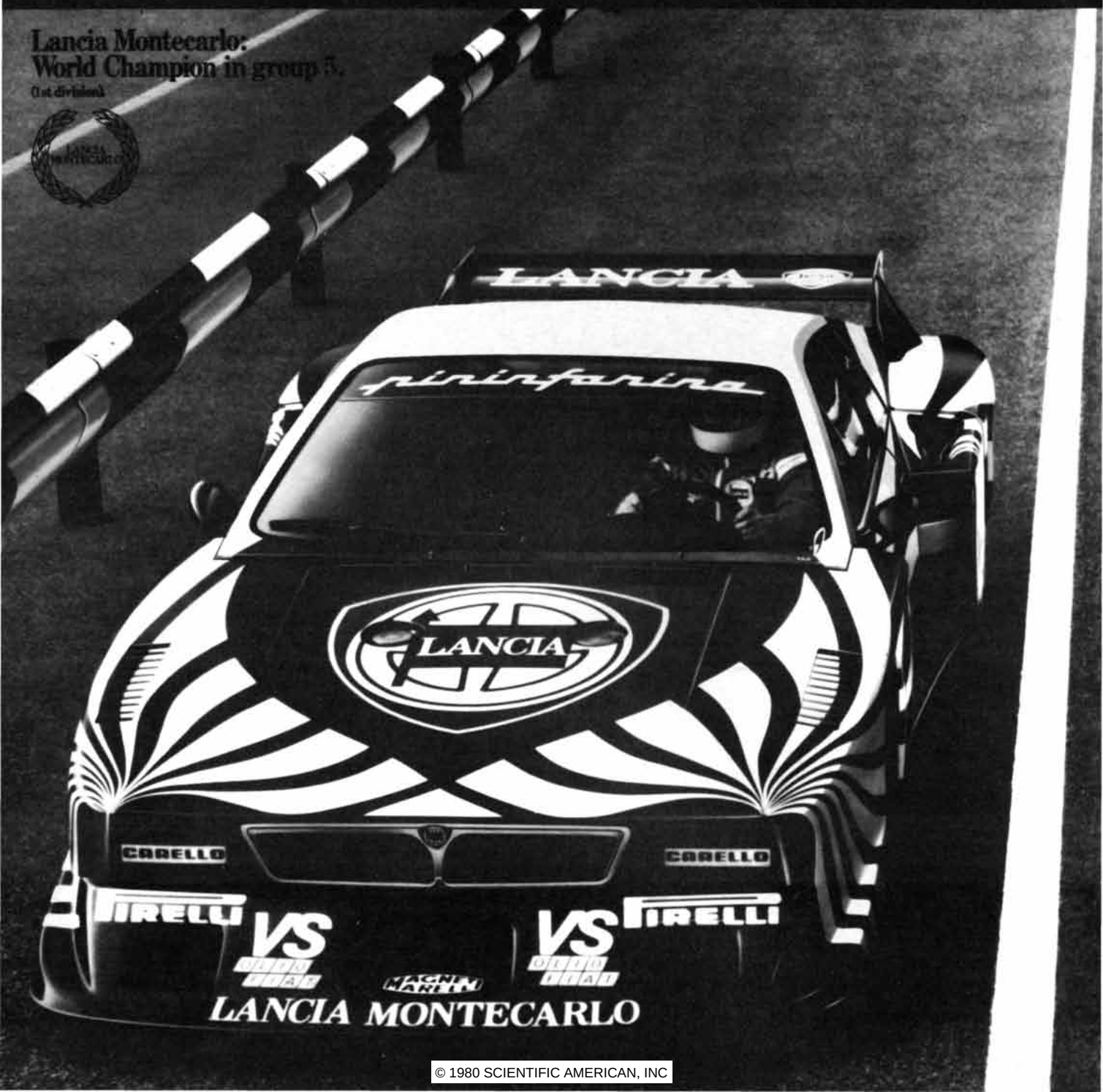
Getting to the top is easy. It's staying there that's difficult. At Lancia we've made our name with a certain unique style: we build cars that stand out from the crowd. But it's in keeping that style, year after year, that the Lancia spirit really comes in.

Well, so far as Lancia has developed and patented over 300 major innovations in car design and engineering — including the first monocoque shell construction — the first front wheel independent suspension — the first 60 degree V-six engine — and the first gran turismo.

All these firsts — plus dozens of other minor ones — go a long way towards explaining the Lancia reputation for high performance. In fact, over the past ten years we've notched up more competition successes than any other manufacturer in rally events with the Fulvia HF and the Stratos and more recently with the turbo-charged



IN ACTION.

Lancia Montecarlo, which won the group 5 first division world Championship in 1979. Don't misunderstand us. We don't build prestige cars like these just for the glory. The reason we put so much effort into tearing around the world's toughest racing circuits is simply that it's the best way there is of proving — and improving — the quality and performance of the car you drive. Our latest demonstration of the Lancia fighting spirit, the spirit that keeps us ahead both on the racetrack and off, is the Lancia Delta.
The first genuinely "big" car in the compact class.

Sensation... confirmation. The Delta has just been nominated car of the year. Way ahead of the rest of the field.

parts to working stations without stopping operations. These are major achievements of COMAU R&D.

The Olivetti Corporation has long been active in the Italian machine tool field. Olivetti Controllo Numerico (OCN), founded in 1973, exports more than 50% of its production which includes machining centers, measuring machines, digital readouts, software service, as well as accessories and industrial robots.

Constituted in 1980, Olivetti Systems for Industrial Automation (OSAI), designs and produces a robot called SIGMA, an automation system consisting of one or more arms that can move in three directions, guided by a computer. Using standard mechanical structures and control units, SIGMA is especially suitable for operations like drilling, tapping, riveting, and welding. Its special sensitivity and a certain 'decision making' capacity allows it to be used also in delicate operations on appliances, record players and electronic components.

ELECTRONICS : THE TURNING POINT

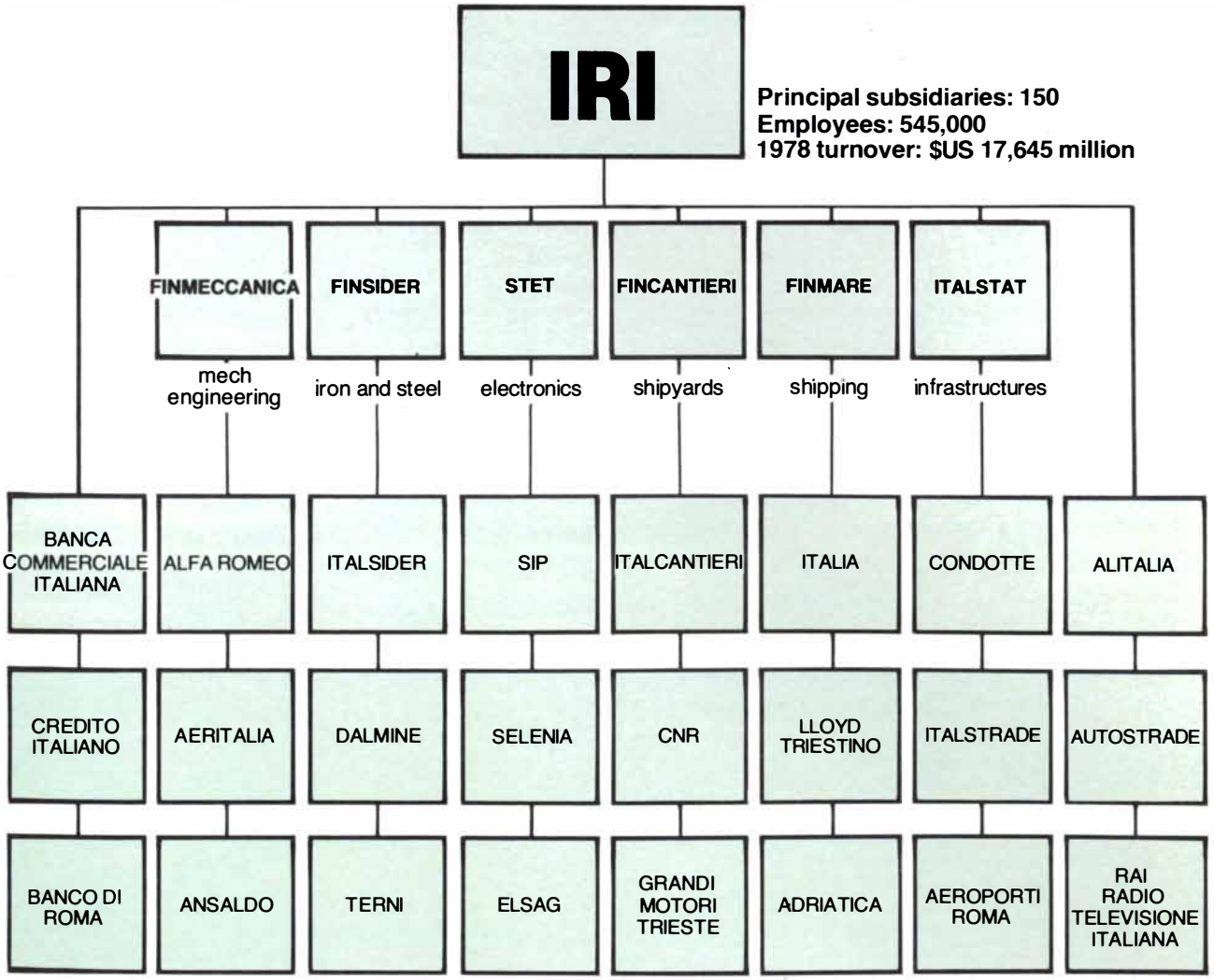
In the heyday of the 1960's economic miracle, Olivetti was a prime success story in the world of office equipment.

But the 1970's found the company with an inflated work force, a large debt burden for an undercapitalized firm and a product line full of 'firsts', but feeling the pressure of new technologies from competitors such as IBM. Under a new chief executive, Carlo De Benedetti, a notable turnaround has been achieved. As operating head and major single shareholder, he had negotiated the participation in Olivetti of the giant French conglomerate Saint Gobain. Some commentators predict great success in the Olivetti/Saint Gobain link-up, as the French government is committed to modernize public administration through projects in which Olivetti is now a prime participant. Typical is the cooperation agreement with the French company Matra; the two companies will jointly design and produce facsimile transmission equipment. Olivetti will develop precision mechanics and printing systems, and Matra the electronic know-how for automatic message transmission.

A Distributed Information Processing Group is responsible for systems, their concept design and production. Today Olivetti is among the most integrated manufacturer in the world with a product range that includes typewriters calculators and accounting machines, reprographic products, word processors, mini computers, business systems, simple and intelligent terminals, equipment for data collection and transmission, telecommunications systems and peripherals. Through subsidiaries, the firm operates in software, electronic circuits, numerically controlled machine tools and robotics.

Chief executive De Benedetti says, "The challenge now is not in the factory, but in

THE STRUCTURE OF THE INSTITUTE FOR INDUSTRIAL RECONSTRUCTION (IRI)



As of 1979

the office – and it is in the electronic office that Olivetti is strongest. Filing, typing and office chores that have not changed in 30 years are a major bottleneck, and the creation of electronic-based systems comes naturally to Olivetti."

In 1979, Olivetti spent approximately $80 million on research, about 3.5% of its revenues, distributed in various fields. Of its total R&D budget, the firm estimated in March 1980 that 77% was committed to Distributed Data Processing, about 11% to Office Products, and 12% to long range system research. In the field of data processing and office products, Olivetti ranks after IBM, Xerox, NCR, Burroughs and Control Data, but is larger than Sperry Rand, Digital, Honeywell and Fujitsu.

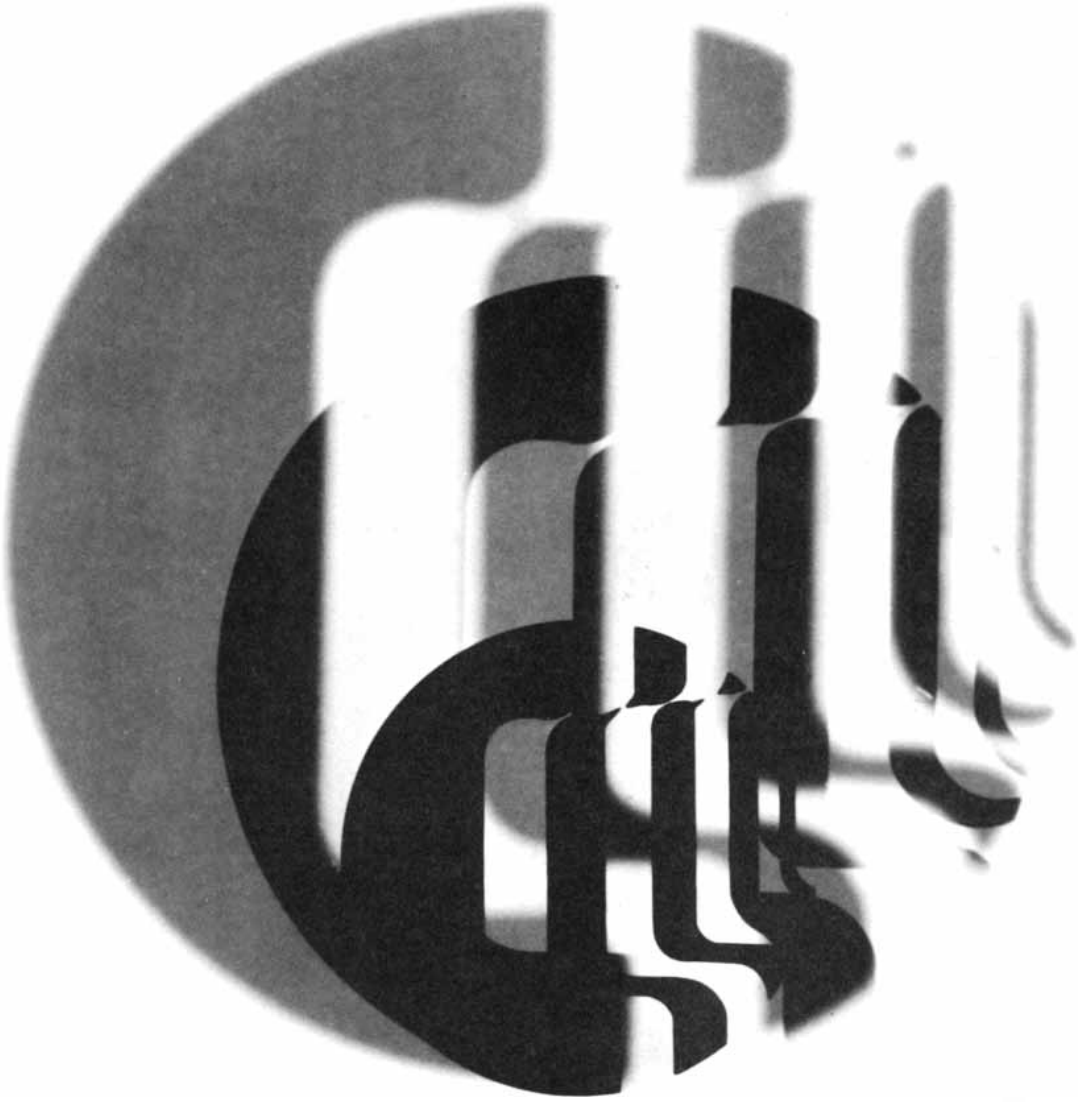
Given the broad spectrum of Olivetti's product line, R&D projects are highly varied on several levels, consumer products, office systems and microelectronics.

One major research goal is to couple the copier and the printer to make a new two function system out of separate units. Competition for the $2 billion market (of the same dimension as that for traditional copiers) includes IBM, Xerox and the Japanese in the technology of dot-based printer heads, fundamental to high speed printing peripherals. In another development, Olivetti has created a dry 'ink' base, expected to be on the market in late 1981, protected by patent. The firm's R&D and management are much concerned with reducing the cost of connecting elements between office equipment units to open the market for private data networks, including the development of performance standards on an international basis.

In the Office Products Group, the breakthrough technology is the 'daisy wheel', a flat, two-plastic disc printer, an interchangeable element used throughout the firm's electronic typewriter line and now throughout the European typewriter industry.

Italy, as the rest of the world, depends on a few giant American and Japanese producers of semiconductors. However, an Italian company based at Milan, called SGS-ATES Componenti Elettronici S.p.A. has made significant contributions to this technology, specializing in analogue circuitry for control of electrical pulses. SGS has become a recognized world specialist in this field, while the major semiconductor manufacturers are oriented toward digital systems.

Today, as the only Italian supplier of semiconductors for the Italian electronics industry, it is a key factor in the national strategy for the electronics industry as a whole. Exporting 75% of its printed circuits, transistors and other microelectronics, SGS cannot count on a captive home market, for Italian



Making the right choice

The world wide energy crisis combined with an increasingly competitive motor vehicle industry have made most dedicated production facilities obsolete.
Dedicated systems cannot adapt to today's rapidly changing market conditions.
The key to successful motor vehicle production in the Eighties is to implement "flexible automation" as rapidly as possible.
Comau has for years been supplying equipment which utilizes new and existing technologies to provide "flexible automation".
Examples are welding systems, machine tools, and materials handling and storage systems, all engineered with central process computer control.

Total systems, including computer software, have been developed, designed and manufactured by Comau.
As a result, complete installation and maintenance services are supplied by Comau.
In the United States and in a number of European countries, Comau has been chosen to supply a wide range of flexible, automated systems.
"BINAFLESS" and **"FMS"** (Flexible Machining Systems);
"ROBOGATE" (Flexible Body Welding Systems);
"N.A.L." (Non Synchronous Assembly Systems).
All provided by Comau.

COMAU

COMAU
10 major manufacturing complexes covering about 2,000,000 square feet.
Annual sales of over $325,000,000
6,000 employees including 1000 design engineers.
5 major technological fields
Dies and Fixtures
Engineering for all areas, including computer hardware and software.
Materials-handling, storage, and industrial washing systems.
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In the U.S.A.:
Robogate Systems, Inc.
and Machine Tool Group
A Comau affiliated company
3040 Outer Drive
Detroit, Michigan 48234 - (313) 368-4280
TWX 810-221-9452 FJS CO DET

The technology of major developments.

telecommunications is expanding and is open to all comers.

SGS, as a source of strategic components for systems-makers (like Olivetti) is doubly important because its customers do not have semiconductor strength in-house. SGS is looked to as the source for circuitry that will permit its customers to compete. SGS's strength is the capacity to collaborate wth system makers to tailor-make components, whereas larger makers usually offer standard components.

SGS today is specialized in integrated circuits oriented to high tension and high current requirements, microprocessors and non-volatile memories. They believe they are at the theoretical limits so far as current is concerned, given the economic realities of silicon.

As for the future, circuits able to unify functions, speed calculation and increase memory are high on SGS's R&D priorities. SGS is collaborating with the Electronics Institute of the University of Bologna, a common enough sort of partnership in America, still rare enough to be noteworthy in Italian R&D.

Digital Electronic Automation is often cited as a supreme example of a small, very successful and flexible high-technology firm. Begun by two former FIAT engineers, the Turin based firm has specialized in electronics and measuring machines. The firm produces equipment sold to the world car industry through its offices in Frankfurt, Tokyo and Detroit. Now a world leader in coordinate measuring systems, the firm in a few years has grown from a single machine to a full line of very sophisticated equipment, for inspection of very large parts at extremely high accuracy.

DEA's president, Luigi Lazzaroni, says, "We are not builders of machine tools, nor software specialists, nor builders of large scale computers. We are experts at the systems which put together all these, combining engineering electronics and informatics."

Another notable success is that of Franco Sartorio, one of DEA's founding pair, who left the firm to launch a series of very small companies. The lead firm, Prima Progetti, and its two sister companies Prima Electronics and Imperial RIV, are working to develop new production and control equipment. Says Sartorio, "In automation, the creation of a working prototype is the hard part, and that is what we do, selling know-how in engineering, electronics, hydraulics, optics and software to third parties."

For example, instead of the conventional (and slow) system for random checking car headlights in a darkroom, Prima Progetti developed an automated system for the Italian subsidiary of Lucas, using the first power laser-plus-robot combination in the moving manufacturing line.

Italy has been criticized as a technological environment so production oriented that insufficient emphasis is put on invention and research. In contributing to the solution of this problem, Sartorio's companies were among the founders of a Consortium for the Development of Electronics and Automation (CSEA), consisting of 23 Turin based firms, with a staff of highly skilled engineers, and together some $36 million in sales of advanced engineering technology.

TELECOMMUNICATIONS PREPARES ITS OWN REVOLUTION

A major problem in the Italian telephone system is that of compatibility. Components made by the nationalized Siemens group, now part of STET, are in competition with imports which freely enter the Italian market. The single most important short and medium term development (fiber optics is the big story for the long term) is the conversion of telephone exchanges to a fully electronic digital system.

Much of STET's R&D force and budget are dedicated to developing the necessary software for the fully electronic exchanges in the Italian telephone network. Some 600 people are involved in this effort, an undertaking under the code name PROTEUS, involving SIT-Siemens, CSELT and SGS-ATES. Beyond the effort to bring Italian communications in line with the most sophisticated, the PROTEUS system is crucial because it represents complete Italian industrial independence, after operating for a long time under license from Siemens of West Germany. The PROTEUS system is expected to come on-line from production in 1982, and while electro-mechanical switching still follows German design, STET has made a major leap toward the American-style digital design.

Alfonso Graziani, a director of STET, explains, "Once the Italian telecommunications chose to follow the path of the most modern digital exchanges, satellite link-up and network adaptable to data transmission, we had to undertake enormous capital investments." Experts at STET expect that the maximum tolerable investment for R&D is of the order of 7-8%, but the ambitious expansion and improvement program will probably require outlays in excess of that amount for the next five or ten years.

Graziani notes, "We expect to move from the experimental stage to significant operating electronic exchanges within two to three years. In 1982, we will begin to install electronic lines, and a gradual phase-out or replacement of the electromechanical lines means no new lines of that type will be placed after 1990." By that time, the SINTRA system will connect telephone exchanges by cables, radio links and optic fibers. Transmission, switching and terminals will all be digital, so that the Italian telephone system will function as an integrated, multipurpose data network.

Studies now underway at SIP, STET's service company, are analyzing the technical and market potentials for data transmission. The problem is the same in Italy as elsewhere: how to use and develop peripherals and how to divide up the responsibilities for R&D in what is now a new field.

Graziani says, "I see no reason to exclude the possibility that STET will act as a consultant, installing a variety of makers' terminals or even act as initiator of private information systems for major clients with large-scale data processing requirements, such as banks."

STET is now studying terminals, printers and the marketing of both soft and hardware in those instances where informatics and telecommunications meet. From the PBX, to memorized dialling codes by a telephone-installed microprocessor, STET foresees its entrance into those services and communications techniques linked with information handling that in the US are very much the concern of AT&T, IBM and Exxon, among countless others.

SIRTI, the cable and exchanges installing company of STET, gives an idea of the range of R&D in the Italian telephone complex.

Top managers Giancarlo Grianti and Francesco Sponzilli foresee a role for SIRTI as a designer of specialized software systems, tailor-made for making compatible hardware systems in data and telecommunications networks. When the Italian government decides whether operating standards for data-transmission systems are the province of the telephone system or of the Ministry of Telecommunications – one of the many hot debates now underway in Italy – SIRTI expects a role in the new game which will open up for both suppliers of components and service systems.

KEEPING STEEL COMPETITIVE

From 1973 to 1977, when world steel production fell by about 26 million tons, Italy was one of the few countries to increase its production, and the only member of the EEC to do so. While this did not mean profits to the giant State-controlled industry, it signals operational capabilities and competitiveness.

The crucial factor for Italy, like all European and American producers, is the

apparently growing tendency for steel making to move to developing countries rich in fuel and raw materials.

The EEC Commission has proposed a reduction of supplies, price increases and protective anti-dumping measures. Restructuring of the European steel industry is under study, but fears of drastic effects on British and French employment slow progress towards this goal.

Over half the Italian production comes from electric furnaces and plant that is generally fairly new and efficient in terms of specific energy consumption. The latter point is important since Italy has no coal sources (save for high-sulfur in Sardinia) and no petroleum. This has been a spur to technological innovation, and one finds examples in the bulk processes and speciality fields. The fast electric arc furnaces use 20% the energy of traditional integrated furnaces, so that Italy's 46% orientation to this technique brings home energy savings.

Steel production was one of the first sectors to be amalgamated into the IRI holding system of State 'participation'. 70% of all production comes from the group called Finsider, the rest is shared among private concerns, among which the largest are the profitable Falck, widely-diversified Teksid (FIAT Group), and dozens of small producers, mostly around Milan. Finsider, created in 1937, was reorganized in 1945 when steel output was one-fifth that of 1938. Today, Finsider is headed by the Genoa-based Italsider operating firm, but also controls companies working for third parties: Italimpianti, a major engineering concern working inside and outside Italy; Innocenti Sant 'Eustacchio, a distinguished maker of machine tools that devised entirely new production systems such as the seamless process at Finsider's Dalmine works.

On the state of Finsider technology, the holding company's managing director Dr. Mario Costa explains, "We have innovations in plant, in process and in product. For example, 'electromagnetic steering' helps eliminate lumps formed during the cooling of molten steel. There is also a project for reduction of mineral inputs that will give Finsider's Italimpianti a technolgy for sale." In product, Dr. Costa says, "Italy is now entering the field of high tensile steels, and as a world leader in wide-gauge tubing, we are well placed to exploit that technology."

The firm, overall, is one of the world's big ten by revenue and had an increase in 1979 of 18% in exports. This record, and substantial reduction in losses, was achieved despite some two million man hours lost through strikes, largely as a result of high yield investments. Other spending at the Genoa works has gone to keep up-to-date in mass production of every kind of flat steel suitable for bending, forming, stamping or coating. In steel, as throughout Italian industry, automation is a major theme, for quality control and to break the labor bottleneck. Use of the OMB (Oxygen Boden Maxhutte) process, for example, brings Italy into the club with Germany, Japan, the US, France and Sweden; its daily production of 6600 tons should bring profits, in part thanks to computer control.

Perhaps the most difficult problems are encountered with large-diameter (up to 56") welded pipes. Technologies for inside and outside welding, for nondestructive hydraulic testing, X-ray, ultrasonic and magnetic sensoring have been developed and applied.

Italsider has developed stress tests for jobs like the 235 km arc-welded Jubail-Riyadh pipeline in Saudi Arabia. Crack propogation and burst testing of welded pipe have taken Italsider researchers into diameters, thicknesses and material types not previously tried. According to Dr.

EEC: PRODUCTION OF STEEL

in 1000's of tons	1974	1975	1976	1977	1978	1979	variation 79/78 %
GERMANY	53.232	40.415	42.415	38.980	41.253	46.042	+12
ITALY	23.803	21.836	23.447	23.334	24.283	24.043	−1
FRANCE	27.020	21.530	23.221	22.103	22.837	23.360	+2
UK	22.379	19.780	22.396	20.409	20.302	21.551	+6
BELGIUM	16.225	11.584	12.145	11.257	12.601	13.442	+7
HOLLAND	5.840	4.826	5.186	4.927	5.590	5.800	+4
LUXEMBURG	6.448	4.624	4.566	4.329	4.790	4.950	+3
DENMARK	535	558	722	685	863	790	−8
IRELAND	110	81	58	48	68	72	+6
EEC	155.592	125.234	134.156	126.072	132.587	140.050	+6

Italsider, 1979 annual report

Michele Civallero, vice director-general of Italsider, "To optimize existing technologies, we should consider fast cooling as well as heat treatments using direct, intermediate or traditional tempering. We understand better all the time the nature of the welded joint."

The FIAT Group's Teksid S.p.A. operates in a variety of metallurgical industries (steel, cast iron, aluminum) and supplied about 875,000 tons of finished product to the FIAT group alone in 1979, about 750,000 tons of steel to other customers and saw a quarter of its output go to export.

In the flat-steel products, intensive research has been conducted to manufacture car body panels that are both thinner and lighter by virtue of their increased mechnical strength.

Professor Sergio Gallo, technical director, points to energy saving as an object of Teksid research, "The goal is to reduce by 20% over the next three years the energy consumption of our electric furnaces for steel. Already we have recovered three megawatts/hour of electrical energy by recycling heat lost through smoke into the atmosphere by adjustments to one furnace alone. Other energy saving ideas concern the recovery of heat and waste gases, converting it into electricity."

Following on a British-invented process for adding manganese in small quantities to graphite cast-iron, Teksid was able to perfect spheroidal cast-iron, with improved fatigue properties and doubled resistance.

Teksid's Foundry Group has an in-house R&D department, which has devised HSLA, or 'high strength, low-alloy' speciality steels, which allow 20% weight saving.

In the special world of seamless steel pipes, the Italian maker, Dalmine, part of IRI's steel consortium, holds its own with some giant's. Dalmine's seamless is so important in this side of the steel industry that it accounts for two thirds of $700 million a year of Italian pipe sold. While Dalmine could supply almost all of Italian demand for seamless steel pipe, it currently exports half of its production, mainly within the EEC.

The previously mentioned Center for Metallurgical Experiments (CSM) is a full scale research and development laboratory near Rome, maintained by the Italian Steel Industry. Its ownership is divided among Finsider, the main partner, with Finmeccanica, FIAT, Falck, SIAS and the ENI-associated engineering firm Snamprogetti. R&D at this center is done at the 'bench-scale' level and pilot plant level, through to direct on-site collaboration with operating staffs within the steel plants.

CSM has pioneered the development and application of computer controls in the steel production process, including satellite link-ups.

Future areas of research are the microscopic behaviour of metals in transition from the liquid to the solid state, and problems related to the protection of surfaces, especially in those cases in which thin-gauged steel is subject to extended wear, such as in domestic appliances and cars.

NEW PROFILES IN TIRES, CABLES AND CHEMICALS

Pirelli Industries is, like a handful of other Italian giants, a holding company with roots in Italy but manufacturing in over 100 factories in 18 other countries with a total of 75,000 employees, and sales worldwide of $5 billion. The Italian holding group alone is a world leader in the tire and related rubber industries, with over 22,000 employees and total turnover of about $780 million. It is divided into three major groups, tires (40%), cables (power) and telecommunications (45%), and diversified products in rubber, metal and plastic (15%).

In addition to products, the tire division is exporting increasing amounts of technology, selling patents, licences for machinery, know-how, production lines, and the design, construction and sale of 'turn-key' plants for all types of tires and vehicle components. On the tire side, in order to achieve energy saving in cars at medium and low speeds, Pirelli has asked their R&D engineers to study wheel resistance, aerodynamics and natural deformation of tires in ordinary use.

Piero Sierra, director of products, thinks this is the proper way for technology to meet the marketplace. "Our market approach is to lead with innovations. After load carrying, comfort, road holding and safety, we believe the next frontier is energy saving."

Just as Pirelli tires were born with the auto industry, so Pirelli, as maker of cables, started early: its insulated wire for telegraphy appeared in 1879. The highest voltage power cables now in operation (525 KV, with advanced studies at 750 KV) rely on an alkylbenzine oil first developed by Pirelli, and since used all over the world. Pirelli technology counts many 'firsts' in telecommunications cables. Its 'micro-coaxial' telephone cable of 1967 allows 2000 conversations to be transmitted at the same time, and is now widely used in the Italian trunk network.

A logical continuation of Pirelli's role as a maker of cables is its current activity in the R&D, production and installation of optic fibers. Under a recent license agreement with Corning Glass, Pirelli will build, in the south of Italy, the first plant for the manufacture of optic fibers. Pirelli's fibers, filaments with a diameter of 0.1 - 0.2 mm, are of pure silica, improved with certain additives.

Special problems associated with submarine cables have been a Pirelli interest since the firm laid its first underwater telegraph line, in the Red Sea, in 1887. In 1966, the firm ceased production of submarine telephone cables, concentrating on high and very high voltage underwater power cables. Projects in hand include the crossing of the Straits of Messina, in Italy, and the linking of Vancouver Island to the Canadian mainland, where the cable design called for is larger than any submarine cable yet made or installed anywhere in the world, at the greatest depth ever.

Beyond tires and cables, the Pirelli Group produces over 2,000 products in 41 factories in Europe and South America: rubber, plastic, mechanical and electromechanical, textile and paper products for transport, agriculture, building, sport and leisure. Rubber components include transmission and toothed belts, brake hoses for cars, hoses for hydraulic systems, rubber flooring and boats. Decentralized research extends from rubber, solar energy panels for heating water, to breakwaters to dampen the effect of waves in ports.

Surveying Pirelli's diversified product line and its research, president Filiberto Pittini says, "We have a tradition as sellers, rather than buyers, of technology of all kinds. We export ten times the value of technology as compared to what we buy."

The Montedison Group is the eighth largest chemical company in the world and the first in Italy, and highly active in R&D. Collaboration between Montedison and Professor Guilio Natta, in 1953, led to the discovery of anion-coordinated catalysis of alpha-olefins, of other polymers, and for the first time allowed researchers to synthesize macromolecular structures having a pre-determined order. From this came industrial production of isotactic polypropylene, marketed by Montedison under the trade name Moplem.

The Natta-Montedison research allowed, for the first time, the possibility to pre-order the spatial structure of the macro-molecules to tailor-make plastic materials ranging from the rigidity of isotactic polypropylene to elastic co-polymer ethylene-propylenes. The new catalysts developed by Natta represented a major advance in the precise synthesis of molecular structure, recognized with a Nobel Prize for Chemistry in 1963.

Montedison was the first in the world to initiate industrial production of isotactic polypropylene and a publication of Montedison research states that 'all factories which today produce polypropylene do so on the base of a patented know-how of Montedison'.

Giovanni Di Drusco, vice-director general for research of the plastics division, says, "We are now working on the third generation catalysts which we hope will yield polypropylene in a new physical form." Third generation plants are expected to eliminate contaminants and effluents, and save substantial energy, a major payoff of Montedison's $54 million plastics research program.

Last year, the division employed 1,600 researchers and had an R&D budget of almost $36 million. This research effort represents 70% of all Italian spending in plastics.

A sophisticated portion of the firm's far-flung chemical activities is represented by the pharmaceutical field. Its Farmitalia Carlo Erba is the largest Italian company and holds a 10% share of the home market for proprietary drugs. $38.4 million, some 16-17% of Farmitalia's overall budget, was dedicated to research oriented overwhelmingly to the identification and development of patentable, original compounds. This distinguishes Farmitalia in Italian pharmaceuticals, an industry often characterized by manufacture in Italy of compounds researched elsewhere. According to Dr. Guilio Maffii, director of Farmitalia's R&D, the firm is most noted for its anti-cancer drugs. "Adriamycin has been recognized as one of the most effective preparations in this field, and we recently opened Adria Laboratories, Inc., with the firm Hercules, to market in North America a wide range of our anti-tumor, cardiovascular, anti-inflammatory, psycho-tropic and anti-fungal drugs."

Montedison is unusual in Italy having founded in 1974 an autonomous research establishment, the Mario Donegani Institute. While the Group's R&D staff numbers 6,000, the Donegani Institute, with a staff of 750, carries out work for Montedison itself, and also research under contract for other parties.

The bulk of Montedison's R&D effort in 1979 was oriented to process and safety improvement, energy saving techniques, reducing pollutants and the consumption of raw materials. At Porto Marghera, an extremely dense industrial zone near Venice, where Montedison alone employs 12,000 workers, the Group has installed equipment for treatment of effluents from nitric plants, recycling machinery for fluosilicic acid from gas and phosphate production as well as pretreatment and incineration for chlorinated organic wastes.

NEW DIRECTIONS IN MEDICAL AND PHARMACEUTICAL RESEARCH

Biomedical and pharmaceutical research has long suffered a second-class status in Italy. Lack of patent protection for new drug compounds led to a highly dispersed

Italsider Genova
Flat hot-rolled, flat cold-rolled and coated mill products - Large and medium diameter welded steel pipes - Hot-rolled bars and sections - Welded sections - Railway superstructures and switches - Railway wheel arrangements and rolling stock - Steel castings and forgings.

Dalmine Milano
Seamless and welded steel pipe for any industrial and civil purposes.

Terni Roma
Electrical and stainless steels, forgings, castings, drop-forgings, concrete rein forcing bars, penstocks, pressure vessels for chemical, petrochemical and nuclear industry.

Acciaierie di Piombino Piombino
Merchant rolled products, rolled bars also in special steel, beams and rails.

Morteo Soprefin Genova
Prefabricated family housing ranging from relocatable mobile homes through permanent units, contractors' site offices, workers' camps, prefabs for use as schools, medical centers, recreation facilities etc., mobile units (caravans), supermarkets, sports-halls, supplied on a turn-key basis - industrial buildings -"alusicc" cladding and roofing -lighting steel columns and poles for overhead lines - iso freight containers - portable garbage containers - safety fencing - Unquote.

C.M.F. Costruzioni Metalliche Finsider Livorno
Study, design, constructions, sale and erection of steel structures for industrial and civil buildings.

C.I.M.I. Milano
Construction and erection of industrial installations (for oil industry, petrochemical and steel industries, thermic and thermonuclear stations, electrical and instrumental installation). Normal and special maintenance work.

Ponteggi Dalmine Milano
Scaffolding and Formworks Storage Racks.

Montubi Milano
Design and construction of installations in Italy and abroad by using steel tubular products: acqueducts, gas pipelines, oil pipelines, penstocks for hydroelectric installations, submarine piping, sea terminals, structures and installations in general.

SIAS acciai Cogne-Breda S. Milano
Special steels for costructional bars, stainless and valve steels, high and tool steels, special parts according to customer's drawing, stamp coins.

INNSE Milano
Design and construction of plants and equipment for steel and non ferrous metals, mill rolls, heavy machine tools and presses.

Italimpianti Genova
Consulting design and construction of industrial plants.

SIDEREXPORT **Head Office:**
Export Sales Organisation Viale Brigate Bisagno, 2 - 16121 Genova

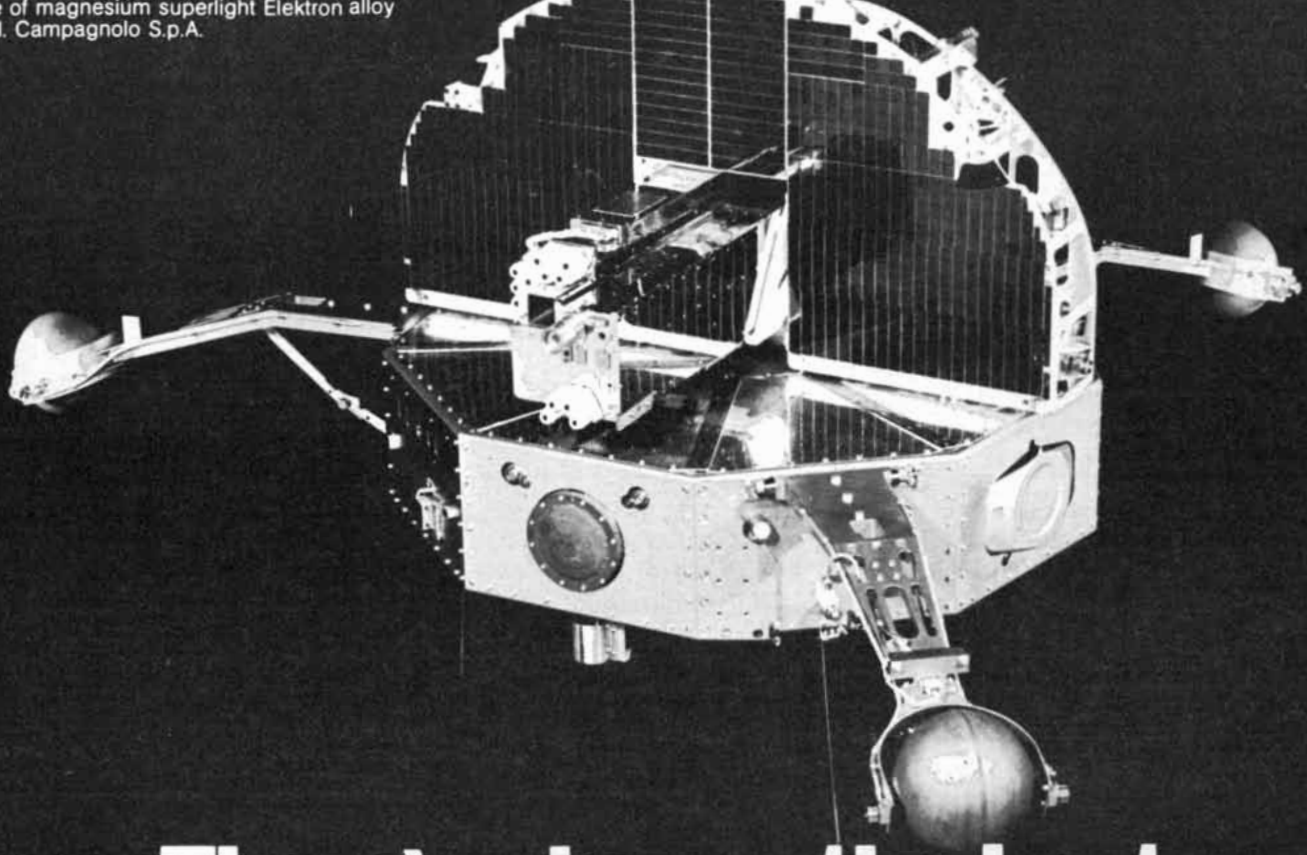
Great Britain:
SIDERITAL LTD. London W1 H7AL - 1 Great Cumberland Place

U.S.A. **Head Office:**
SIDERIUS INC. New York - N.Y. 10019 - 35th Floor - 1301 Avenue of the Americas

PUB FINSIDER

FINSIDER GROUP ITALY

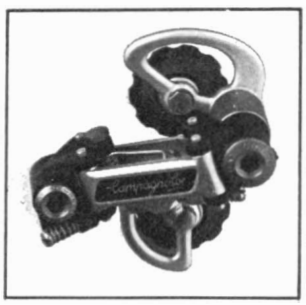
made of magnesium superlight Elektron alloy
by B.I. Campagnolo S.p.A.

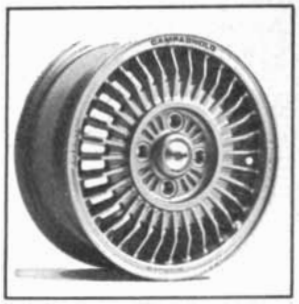


There's always the best way to make a rear derailleur for cycle or an artificial satellite.

Campagnolo knows it.

From the high precision of the rolling mechanisms for bicycles to the new process of the most advanced technology in the magnesium field.





1975: the «Design and Application Award» to B.I. Campagnolo S.p.A. «for their use and advance ment of the low pressure die casting process for making magnesium automobile wheels».

Campagnolo

Brevetti Internazionali Campagnolo S.p.A. 36100 Vicenza (ITALY)

Italian industry of hundreds of tiny companies, concentrating on creating local versions of products often identical to foreign brand names.

Further difficulty in creating and maintaining biomedical research has been the absence of public research entities underwritten by the State, and a chronic undertstaffing and underfinancing within the universities. Even though from 1974-1979 public spending in real terms on human health rose 34%, the absolute amount remains small.

Two recent developments are now changing this picture: one is a program of the National Research Council, managed by Dr. Luigi Donato, which has undertaken to do nothing less than create a national strategy and incentives for strengthening the industrial side of biomedical innovation; the second is a unique foundation named after industrial benefactor Mario Negri, headed for the past fifteen years by Professor Silvio Garattini.

In 1979 almost $2.8 billion was spent in Italy for pharmaceuticals, and in that same period the industry's outlay for research did not exceed $120 million. Garattani says that, "The Italian pharmaceutical industry now finds itself obliged to spend that much more simply to catch up with other countries." A serious problem of the industry is that of scale: some 464 small companies are competing for well under half of the annual sales, with half the market in the hands of the Italian subsidiaries of foreign firms. Pharmaceutical research is so expensive, and of such a longterm, and with such high risks of failure, that only with industrial reorganization will firms be of a sufficient size to be able to afford original R&D. Today, it is estimated that 90% of the sales of Italian-made products are counted for by less than a fourth of the operating firms.

Today, one can detect in the Italian industry two major trends: concentration, in which the high cost and risk for developing new products seems to be putting development success into the hands of only the largest players; and secondly, an urge to diversify, with growing interest in the marketing of hospital and medical equipment such as diagnostic kits, useful for repeated medical procedures, such as equipment for gas chromotography.

Garattini points out that the low national investment in R&D, barely 1% of GNP, is also the case in biomedical research. He estimates that 20% of this 1% of total R&D expenditure goes to biomedical research at its most broadly defined. Garattini maintains, though this is not an official figure, that Italy spends an eighth as much on biomedical research as does Germany, and this is not accounting for private philanthropy, but the State's commitment.

For all its negative features, the picture is improving: the proportion, and the absolute budgets for biomedical research, have been increasing in the past few years. The new law allowing patent protection is beginning to have a stimulating effect on pharmaceutical research, and the Negri Institute has grown from 15 classmates from the University of Milan two decades ago, to over 300 researchers from all over the world, operating under a budget of some $5 million a year.

The situation which has too long continued in Italy, dependence on foreign know-how in the pharmaceutical field, has had its analogue in that of biomedical equipment and instrumentation. Important steps have been underway during the past five years, with a budget of $1.5 million, to bring the Italian medical equipment industry to a leadership position.

Under the National Research Council about 100 different study groups oriented to two dozen themes, each staffed with technical, medical and industrial participants have worked to identify those products which Italian industry can best hope to produce, and sell at home and around the world.

Under coordination of Dr. Luigi Donato, this program has completed its first phase and can report positive results. Now that manufacturers are convinced of the seriousness of the government's effort, the CNR program plans to go beyond the creation of specific technical study teams to implement a financing plan that will channel government money through the CNR, to seed pilot projects aimed for on-line production. The goal is not to become isolated or self-sufficient, even the US equipment scene is characterized by many foreign suppliers, but rather to arrive at a better situation, more equilibrium.

The project's areas of concentration have been the following: imaging equipment, laboratory analysis equipment of various kinds, measurement instrumentation for the neurosensory response (building on a distinguished Italian tradition in this speciality), cardiovascular, detoxification and dialysis. These were identified as sectors in which the international equipment market had gaps – which Italian industry might move to fill, and also ones in which the basic industrial capacity already existed.

AERONAUTICS : PAYOFF IN SPECIALIZATION

While the Italian domestic market for defense and military aeronautics is small, the industry is well developed and among the most consortium minded at point of sale.

On the defense hardware side for composite projects a cooperation among several industries has had notable success. Called 'Club Melara', it includes, among others, Oto-Melara, a La Spezia based maker of naval tanks and artillery, the Cantieri Navali Riuniti, a shipyard of the IRI-Fincantieri Group, acting as lead supplier, the electronics firm Elettronica San Giorgio (ELSAG), and Selenia. Selenia and ELSAG operate a joint Naval Systems Division whose electronic fire control systems, tracking and search radar assemblies for small vessels have been sold as a package overseas by the Club Melara.

Radar traffic control (254 systems installed including 20 channels at Moscow airport) and missile design (especially the multi-role ASPIDE, ground-sea-air series) have been Selenia's main military activity, while components – including multiplexers – for Italy's telephone network also went to the civil market. Dr. Michele Principe, Selenia's president, indicates other areas of the firm's military market R&D achievements: in microelectronic devices, infra-red detectors, solid-state and gas lasers for application in tank warfare, shipborne installations, ground and airborne stations. Interception and jamming of radar signals with digital data analysis in peripheral equipment, called 'Multiscan', are a part of Selenia's program, one which extends from identification of signals to rocket launching using computerized fire control.

Two cases are typical of the matured independence of Italian aeronautics suppliers in technology: a helicopter manufacturer and an aero-engine maker.

The Agusta Group is one of the half dozen leading world helicopter manufacturers, with 1979 revenues of $530 million, 82% export earned. Search and rescue, antisubmarine and executive helicopter sales have doubled in size in the past five years, mostly with its own technology, and not only that of its collaborators Bell, Sikorsky, Boeing-Vertol. Its R&D budget for the coming five years is partly directed toward application of multiplexing systems and microprocessors to effect inflight/firepower coordination. Agusta's president, Dr. Pietro Fascione, says, "The lightweight 129 helicopter we are developing for the Italian armed forces is one we think has NATO applications, and the US Defense Department has also expressed interest in a derivative. Incorporating our in-house technologies, it will fly during the first half of 1982."

Following on joint Anglo-Italian agreements, Agusta will collaborate with Westland to develop a new medium-heavy helicopter, (the 'EH 101') for the two Navies, successor to the present Sea King SH-3D. Military and commercial spin-offs are expected.

Also on Agusta's drawing boards is a new light weight, low cost jet trainer, the S211, a simulator carrying full load navigational

Established in 1872, Pirelli is a 108-year-young company. Throughout its history it has contributed fully to the quality of life and economic needs of the day.

To-day, Pirelli's 77.000 employees and 109 factories in Italy and abroad are making a substantial contribution to progress and the economy of the countries in which they operate. And in the fields of cables for telecommunications and energy transmission, tires, leisure goods and rubber components for major industrial and ecological projects, Pirelli continues to innovate.

With its advanced technology Pirelli makes a realistic contribution to the worldwide success of Italian industry whilst continuously improving the international competitiveness of its products. Such is Pirelli's response to the Eighties.

Ever sensitive to change and the need to move ahead, it is in this way that Pirelli, a 108-year-old company, remains young.

Pirelli è giovane.

and communication equipment for speed and distance specifications reaching combat aircraft threshold.

Alfa Romeo Aviation has been in the aircraft engine business since 1915. Today the firm is the Italian partner of the world's major aero-engine makers, Rolls-Royce, Curtiss-Wright, Pratt and Whitney and General Electric, developing prime expertise for thirty years in the technology of the crucial hot zone of the engine.

Now the days of learning the gas turbine engine under license (turbojet, turboprop, turbofan) are turning to technological self-sufficiency. "Having to work on 25 different engines" explains Filippo de Luca "while unfortunate from the manufacturing point of view, has given us a unique broad know-how base today." Alfa Aviation is continuing its collaborations with international giants. General Electric and Alfa recently agreed to joint venturing for the development and construction of a new turbofan engine, the CF6-32, for the next generation of commercial aircraft, such as the Boeing (and Aeritalia) 767.

The Italian Government acted in 1969 to unify national efforts in aircraft production, reorganizing and merging many famous firms under the new heading Aeritalia. Today, the consortium is the largest presence in Italian aeronautics, producing all parts of the aircraft, excluding engines. Aeritalia's technology has secured international recognition as indicated by its role in the manufacturing pool for the Boeing 767 and the Tornado project.

Aeritalia handles the 12.4% Italian share of the budget for the British-German-Italian Tornado, 100 of which (from a total of 800) are intended for the Italian Air Force. As for Aeritalia's role in the Boeing 767, the wing elevators, vertical stabilizer and all the wing flaps and slats are made by this firm, some 15% of the program for this Boeing competitor of the A310 and DC-8 in the medium-range airline business.

Aeritalia is among the leading Italian participants to the European Space Agency laboratory, and additionally is doing research studies in radio altimeters, software stability for satellites, the use of titanium for wing parts calling for special machine tools, as well as being the leading contractor for the 6222, the first Italian cargo plane with jet engines.

Few airlines changed their technical checking procedures in response to dramatic escalations in maintenance costs that came with the introduction of wide body jets. Alitalia, Italy's national airline, has been among the very first to coordinate maintenance and engineering demands with its own in-house generated computer software. MEMIS (Maintenance and Engineering Management Information System) was developed by the airline's group computer center and has been profitably applied at home and sold to other airlines. The system shortens the time between ordering and issuing of spare parts, reduces and controls out-of-stock situations, avoids duplicate orders, offers a reduction in inventory investment, increases the service level of expendable items and the warehouse turnover rate.

In competitive bidding, Alitalia won the contract to install MEMIS for Saudia, the national airline of Saudia Arabia. South African Airways, Garuda, Korean Airlines and Aerolineas Argentinas have also bought MEMIS; at least $14.4 million have been earned in foreign currency by the sales of this kind of Alitalia-generated software.

Umberto Nordio, Alitalia's president, says, "We are the first airline in the world to implement PARS, the passenger airline reservation system. We invested 130 man years in PO4, and that grew into what we call FAST, our cargo routing and control system since licensed by KLM, TWA, PAN AM (under its own name, Pantrac), Swiss Air, Eastern, British Airways, Singapore Airlines and TAP." This is an airline delivering not only service but software.

TECHNOLOGY TRANSFER, AND SOME PROSPECTS

On the private side, there is no indication that Montedison, Pirelli, Olivetti, FIAT and other large firms expect to cut back on R&D budgets. On the contrary, they all express enthusiasm for the revival and expansion of the government approved Fund for Research, which was of some $160 million in 1980, allocated approximately 40% to electronics, 20% to chemicals and pharmaceuticals, 20% to engineering generally and 15% to food, metallurgy and energy. They all mention the need for keeping R&D spending up, not for prestige motives, but for international marketplace survival.

On the public side, in the State participations sector, one finds Groups like Finmeccanica stepping up their efforts dramatically. When a complex like Finmeccanica commits 5% of its staff and revenues to R&D, this means 4,500 persons and over $200 million. Covering the energy sector from nuclear to steam generation, from solar and desalination to biogas, from industrial air conditioning to water treatment, Finmeccanica has grouped its energy research in a Center for Energy Studies (CESEN) in Genoa. For similar reasons an aeronautics center was set up in Naples, bringing together industry, the universities and the research center.

Over the past 3 years, the Italian Government has also raised the funding for basic research in the universities from $15 million to $50 million and now to $120 million. Besides creating technology, Italy is thinking about its movement. A number of small bodies have sprung up dedicated to the transfer of technology and know-how, and for export as well as for varied application within the country.

At the level of the Confederation of Italian Industry (Confindustria), a project called CNOS Tecnoservizi works under consultancy contract to enter client questions into a data bank. As technical consultants, CNOS also operates a fleet of 'Enerbuses', FIAT 242 vehicles filled with computers, which call on small and medium-sized industries to give analysis of their energy waste and to propose programs of energy savings. Called 'a mobile research center', the bus has received European-wide praise.

SITI WORLDTECH, a consortium of some of the biggest names in Italian private and public industry, connects via Control Data network to the US Department of Commerce National Technical Information Service data bank for the same purpose, acting as source for various kinds of US Government technical data in Italy. This organization operates a technical advisory service to help identify R&D needs and negotiate technology transfer; the search is for an 'appropriate' technology, not simply 'high' technology.

The Federation for Scientific Technical Associations (FAST) has issued fundamental white papers on policy for stimulating crucial sectors like electronics. FAST has also consolidated proposals now before the Research Minister for creating a 'National Technology Center', something new, but along the lines of the French AMVAR or the British National Research and Development Corporation.

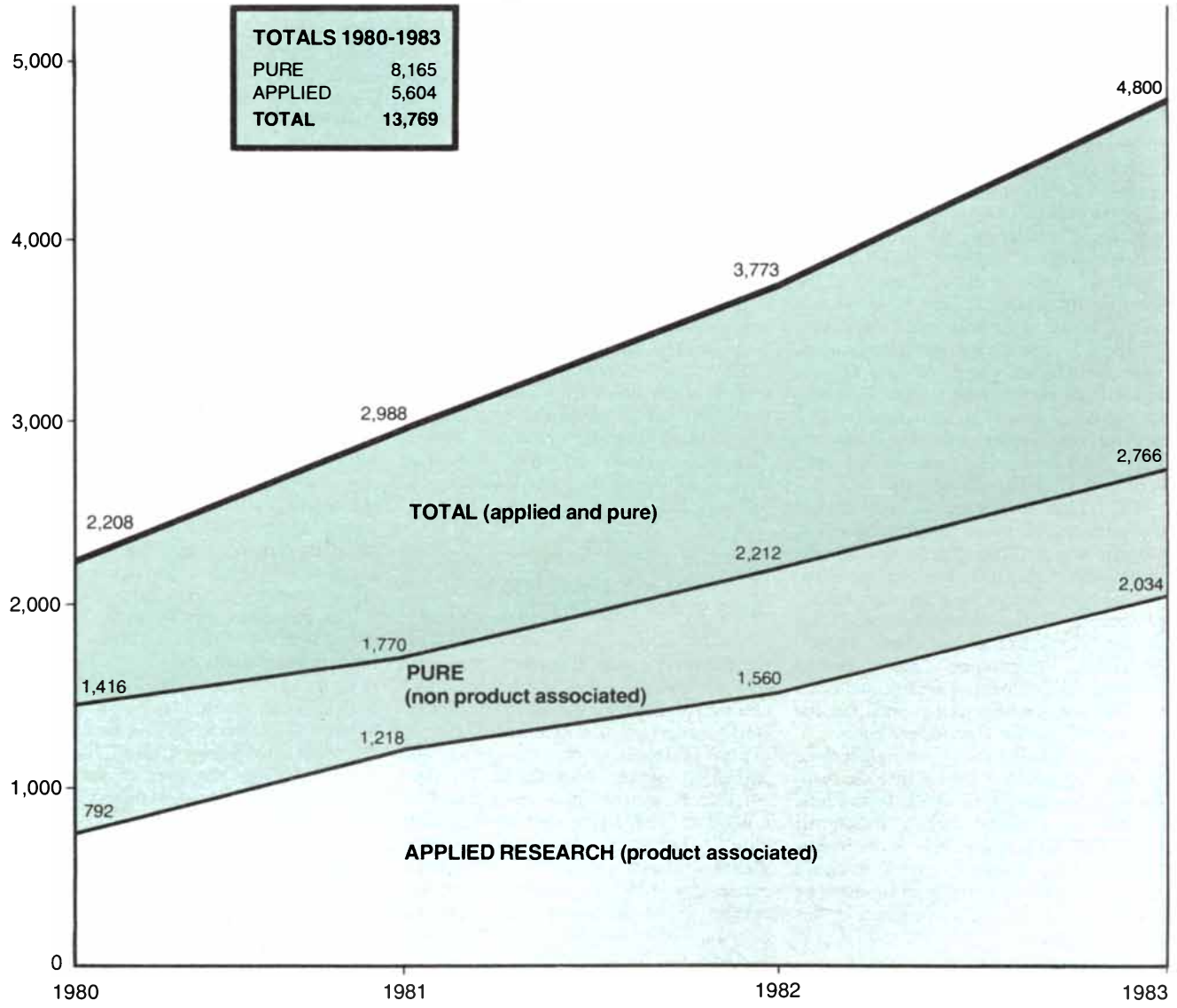
Another group is TECNETRA, a technology transfer organization, which is also pushing the Government to create a 'National Know-how Center' (Centro Nazionale Informativo) and a National Committee for Information and Technology Transfer.

Responsible for the 'innovative technology sector', Professor Claudio Roveda says, "We are in constant touch with the Stanford Research Institute and MIT, looking for ways to move their know-how to Italian industry from licenses, joint-ventures, everything from feasibility studies to technical evaluations."

Much technology enters and exits Italy through official channels like the CNR, and much through initiatives of private and public industry – conferences, papers, licenses. But the Institute for Foreign Trade (ICE) is playing a growing and a changing role. Founded in the late 1920's, ICE has grown from an autonomous organization under the Ministry of Overseas Trade, responsible for ensuring quality of Italian produce, into a major factor for the stimulation of Italian exports around the world. While a third of the

PLANNED PUBLIC SECTOR RESEARCH EXPENDITURE 1980-1983

(current $U.S. in millions)



SOURCE: Ministry for the Coordination of Scientific Research and Technology

Institute's staff still works in the agricultural sector, the rest concentrate on that which makes Italy a modern country: the promotion and export of industrial products, now 96.7% of the country's external sales revenue.

It serves Italian industry in various ways: as a clearing house of information about taxes, customs, export financing and as an intervening leader in opening up and developing markets overseas. Traditionally, the major beneficiaries of the Institute's efforts have been the small and medium-sized companies not equipped to conduct export and promotional programs on their own.

A major initiative at ICE for some years has been increasing the promotion of high technology. "One problem has been that many markets are interested in middle-level technology, products which much of the Third World buys from Italy, and not the special goods which we bring to the marketplace in competition with other Europeans," explains Dr. Fausto De Franceschi, secretary general of ICE.

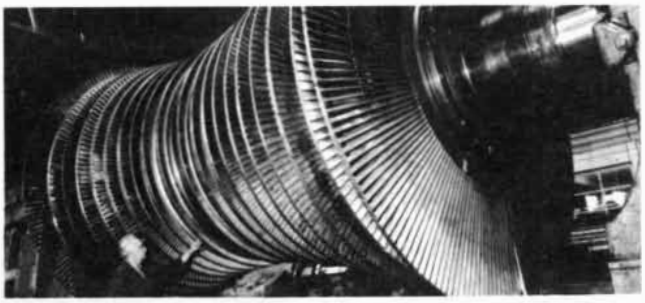
Italian exports go 50% to the EEC, 10% to OPEC countries, 15-20% to industrialized countries outside the EEC, 5% to Latin America, 5% to Eastern bloc countries. De Franceschi says, "Italy is among the world's chief exporters, in relative terms twice as much as the Japanese, a little known fact."

While the so-called 'intermediate' technologies like power stations, telephone networks, tunnels, bridges and roads have become very successful, the crux of the problem is to meet the head-to-head competition of the Japanese, Germans, French and Americans in technologies based on rapidly obsolescing components without unacceptable labor consequences, and to find a place between the sales expertise of other European countries (with long traditions of industrial stability) and Third World manufacturers operating under acquired know-how and measurably lower labor costs.

ANSALDO

Genoa, 1853. ANSALDO is established. And only two years later it has already produced the very first steam locomotive fully designed and built in Italy.

● *1000 kV autotransformer for the Italian electrical network project.*



● *Caorso nuclear power-station work.*

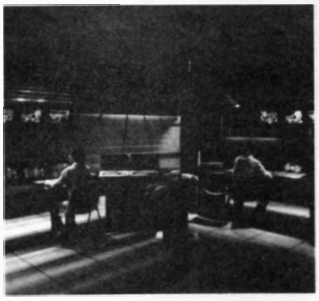
● *Turbine for steam power-station.*

● *The largest solar receiver so far in the world, for the 1 MW pilot station, Adrano, Sicily.*

Today, ANSALDO is the largest thermoelectromechanical and nuclear group in Italy. It counts 12 production plants, 20,000 employees and orders, in 1980, worth US dollars 1.25 billion, over 40% of them for export.
The ANSALDO Group comprises the integrated design, planning, manufacturing, engineering and research resources of the IRI - Finmeccanica Group in the fields of energy, electrified transport, industrial automation and electrical equipment.

● *Automatic welding centre for large joints of pressure vessels.*

● *ALe 804 rapid-transit commuter train.*

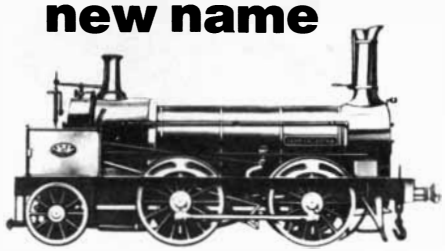


● *Centralized traffic-control room, Genoa railway district.*

● *Saddle-shaped coil winding of a superconducting dipole magnet.*

For more than a hundred years now, ANSALDO has been concentrating on advanced technology and on the quality and reliability of a range of products that is well known and highly esteemed the world over.

an old, new name



IRI - Finmeccanica Group

ANSALDO
Via Pacinotti, 20
Genoa, Italy

MID design / comunicazioni visive Milano

International cooperation is the right step.

Companies of the ENI Group are working for this on all continents.
More than a third of the total revenue of the group comes from foreign sources for supplying goods and services and for activities which, also because of the high degree of technological advance reached by the group, have become enduringly a part of the plans for industrialization and development of almost all countries of the world.

Energy, always presenting a more complex situation, chemicals, mining and metallurgy, mechanical manufacturing, textile machinery and textiles are all sectors of operation of ENI companies.

In some sectors such as engineering and services and mechanical manufacturing, companies of the Group carry on a major part of their activities on behalf of foreign countries.

Eni

Agip AgipNucleare Anic Lanerossi NuovoPignone
Saipem Samim Savio Snam Snamprogetti Sofid

Mirror Images

The mirror image is not always a faithful reflection: it can be inverted, reversed in handedness or distorted in other ways. The transformations are analyzed through a few basic curved mirrors

by David Emil Thomas

The ways in which a plane mirror does (and does not) transform the objects it reflects are familiar to everyone. The image of a right hand appears as a left hand, but its shape and size are unaltered. As a visit to a fun house shows, however, not all mirrors generate such faithful images. Plato observed that a piece of reflecting metal bent into a concave cylinder can form an image of a right-hand glove that is itself right-handed. More generally, by introducing various curvatures into reflecting surfaces it is possible to create mirrors that change the shape, size, orientation and handedness of the objects they reflect in dramatic and disturbing ways.

The number of different curved mirror surfaces is infinite, but they could all be assembled from just a few kinds of basic region. Any small region of a curved surface can be described in terms of its curvature along a pair of perpendicular axes whose origin lies at the region's center of curvature. The directions of these principal axes are determined by the directions of minimum and maximum curvature on the surface. The curvature of each axis can be convex, concave or planar. The axes serve to define six basic types of reflecting surface: each type is a simple mirror whose overall shape is defined by a pair of principal curvatures. These six basic surfaces are the plane mirror, for which both principal axes are planar; the convex mirror, for which both are convex; the concave mirror, for which both are concave; the convex cylinder, for which one axis is convex and one is planar; the concave cylinder, for which one is concave and the other is planar, and the saddle, for which one is convex and the other is concave.

Over the past five years I have been studying reflecting surfaces such as bells and toruses that can be constructed by joining mirrors of these six types. The images created by such compound mirrors are diverse, but I have found that they also have certain striking regularities: underlying traits that can be attributed to the character of the basic components from which the mirrors are created. Indeed, it is often possible to predict the appearance of images reflected in even the most elaborate compound mirrors. In order to understand compound mirrors and the images they generate, then, it is necessary to begin by discussing the light-reflecting properties of the six basic mirrors.

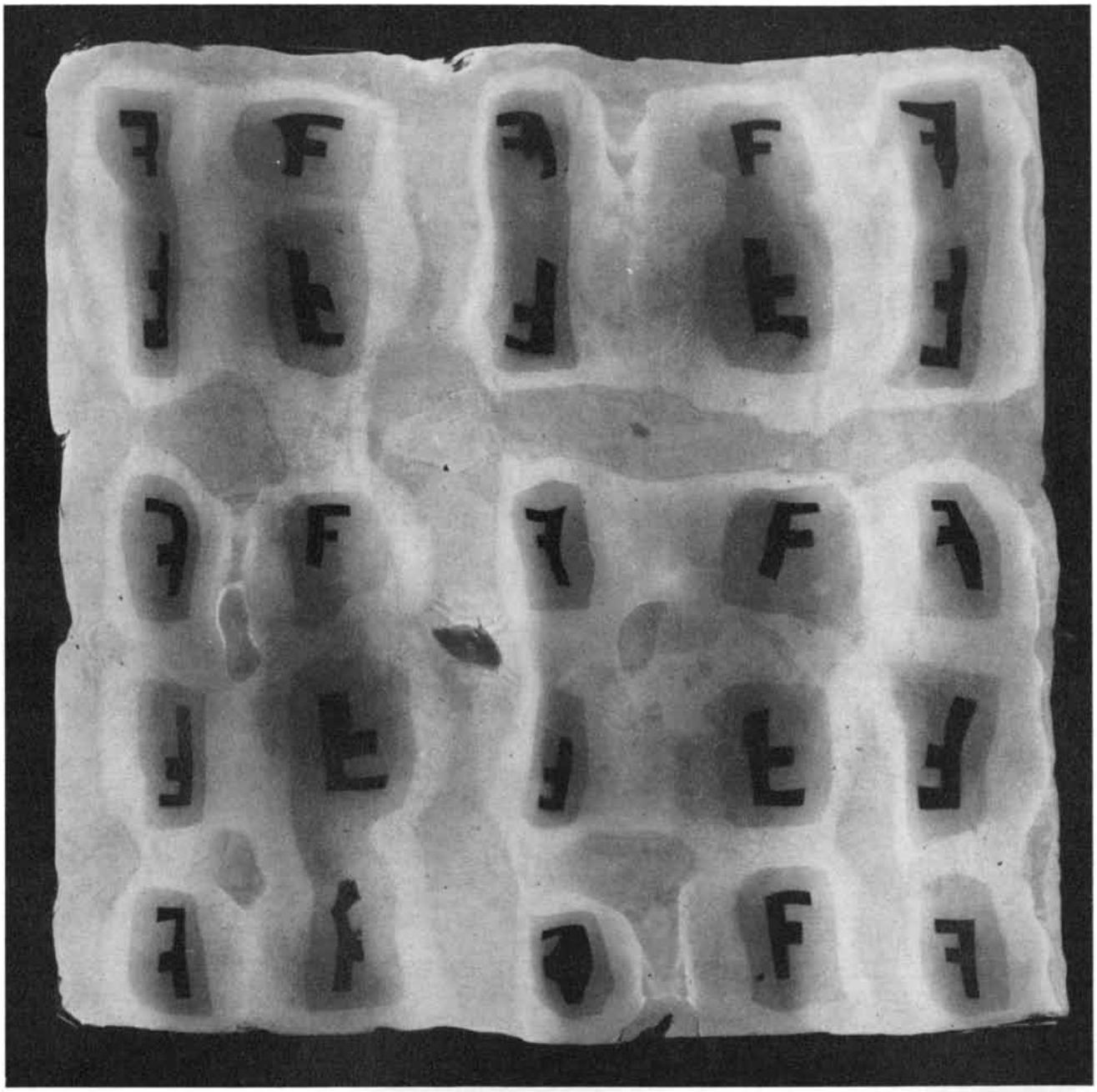
Consider, first, a puzzling and fundamental question about the plane mirror: Why does such a mirror exchange right and left but not up and down? In other words, why is it that when a book is held up to a plane mirror, each letter appears reversed and the sequence of letters runs from right to left, whereas the order of the lines from the top of the page to the bottom is unchanged? This paradox can be traced to the confusion between the handedness of an image and its orientation. Actually for an observer facing a plane mirror the directions right and left are not changed any more than the directions up and down. This fact can be demonstrated by comparing a clock face with its image in a plane mirror.

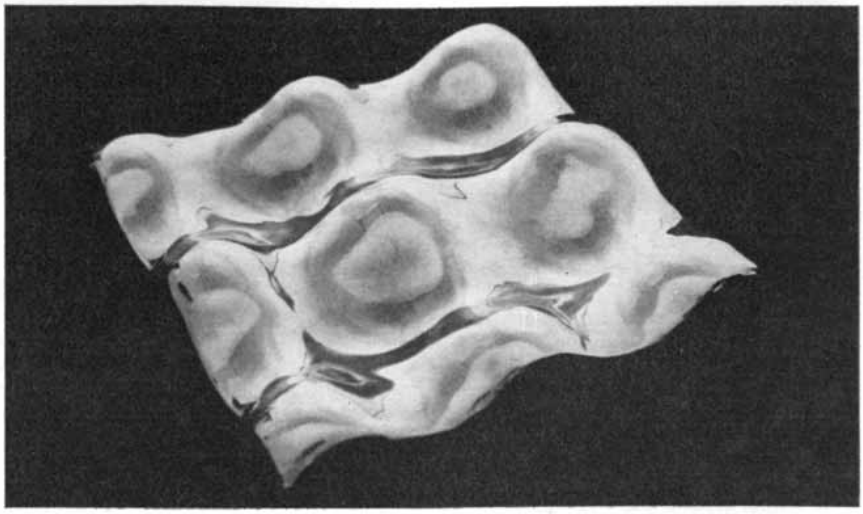
The familiar geometry of a clock face makes it a useful standard object with which to study object-image relations for differently curved mirrors. In my own investigations I rely on a clock face that has the ring of numerals on a transparent plastic backing. An observer holding such a clock face toward a mirror is able to view not only the mirror image but also the real object, at least from the back. Through the transparent backing the observer sees the numerals of the object clock (reversed and running counterclockwise) as well as the images they generate.

The transparent clock face is particularly useful in that its numerals serve to define lateral directions in the plane tangent to the mirror at its center of curvature. For example, 11:00 identifies the direction from the center of the clock face to the numeral 11; similarly, 5:30 identifies the direction from the center of the clock to the point midway between the numerals 5 and 6. (It is assumed throughout this discussion that the observer and the object are close to the axis of the mirror: the line through the mirror's center of curvature that is perpendicular to the tangent plane at that point.)

This coordinate system provides a means of explicitly describing the elusive distinction between handedness and orientation. The numerals in the plane-mirror image of a transparent clock face run in counterclockwise order, just as the numerals viewed through the back of the clock face itself do. Comparing the real object with the image "face to face," then, it is apparent that neither the direction 9:00 (right) nor 3:00 (left) nor 12:00 (up) nor 6:00 (down) is changed by the plane mirror. Because orientation is not changed along any direction in the plane of the mirror, the numerals in the image of a clock face run in counterclockwise sequence. But plane mirrors (and all other mirrors) do invert the directions forward and backward: whereas the actual clock's front faces away from the observer, the image clock's front faces toward the observer. This single inversion creates an image with reversed handedness. It is for the same reason that the image of a right-handed glove is left-handed. To avoid confusion in what follows I shall employ "invert" to describe changes in the orientation of an image and "reverse" to describe changes in handedness.

When an object is held parallel to the surface of a plane mirror, the forward-backward inversion is evident. If a clock face is held perpendicular to the mirror, however, the same transformation has a different result. When the clock face is perpendicular to the mirror and in a vertical position, the forward-backward inversion transposes 3 and 9 (as well as 1 and 11, 2 and 10, and so on), so that right and left appear to be inverted. Similarly, if the clock is held perpendicular to the mirror and in a horizontal position, the forward-backward inversion transposes 6 and 12 (as well





MULTIPLE IMAGES of a single object, in this instance an uppercase *F,* can be viewed in a "matrix mirror" with a complexly curved surface, shown here in top and oblique views. The smoothly connected surface of the mirror consists of convex, concave and saddle-shaped regions, each of which reflects an image of the single, fixed *F.* Owing to the different light-reflecting properties of the various regions some of the images have reversed handedness whereas others are not reversed. The matrix mirror shown is one of an infinite variety of compound mirrors that can be created by joining mirrors of six basic types.

as 1 and 5, 11 and 7, and so on), so that the mirror seems to invert up and down.

A plane mirror creates what is traditionally called a virtual image: an image that seems to be behind the surface of the mirror. In other words, the reflected light waves that form a plane-mirror image appear to emanate from a point behind the mirror. The fundamental optical law of reflection states that the angle of reflection of a light ray must be equal to the angle of incidence. From this law it follows that the image of an object in a plane mirror seems to be as far behind the mirror as the object is in front of it. The image of an object three feet in front of the mirror appears with the same size, shape and orientation (but with the opposite handedness) as an object placed three feet behind the mirror.

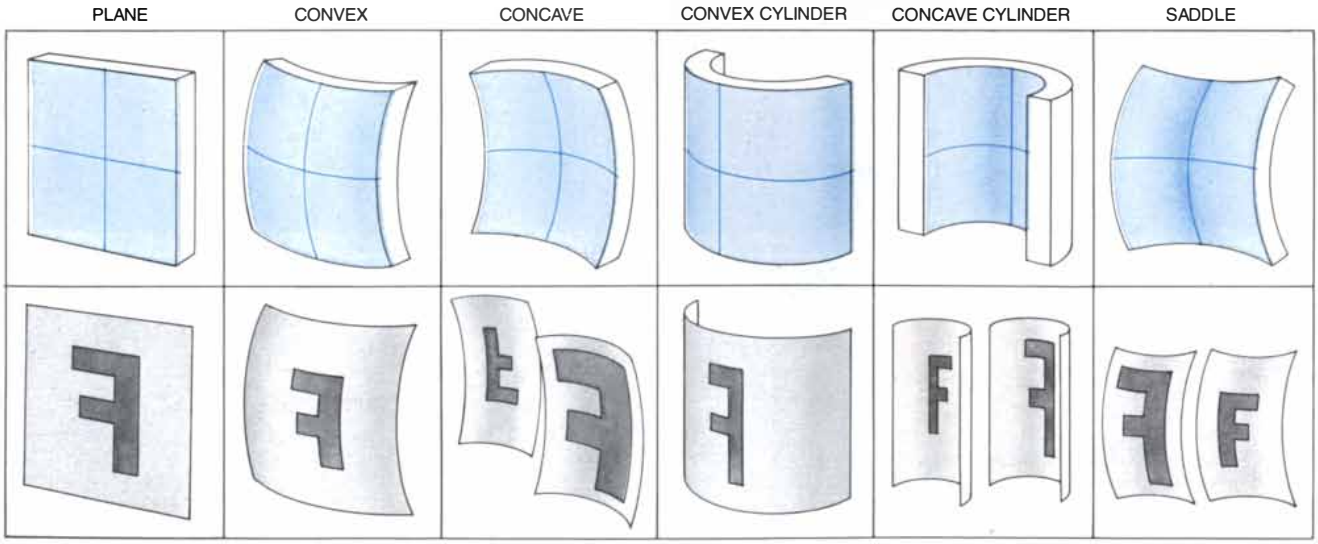
Almost the same analysis can be applied to convex mirrors, which also give rise to virtual images. Like a plane mirror, a convex mirror inverts orientation only along the forward-backward direction and not along any lateral direction; hence it reflects upright, reversed images. Because the surface has a convex curvature, however, the reflected light waves seem to emanate from a point that is not as far behind the mirror as the point where a plane-mirror image is apparently positioned. The convex-mirror image is therefore reduced in size compared with its plane-mirror counterpart.

Any lateral direction along which a curved mirror is planar or convex can be called a noninverting direction. What constitutes an inverting direction? Consider what happens to a wave front of light when it is reflected from the surface of a curved mirror. The incident wave front is spherical and diverging, but after reflection it can be either spherical or asymmetrical, and it can be either diverging (possibly at a rate different from that of the incident wave front) or converging, that is, parts of the wave may be coming together. It is the passing of one part of the wave through another that creates a lateral inversion. The crossing takes place at the point where the mirror focuses incoming light waves to form what is called the real image of the object. The directions along which the mirror causes parts of a wave to converge determine which lateral directions are inverting. If orientation is laterally inverted along both principal axes of a curved basic mirror, an image with reversed handedness is generated. If orientation is inverted along only one lateral axis, a nonreversed image is generated. The lateral inversions are in addition to the forward-backward inversion common to all mirrors. In general if the number of inversions (including the forward-backward one) is odd, the image has reversed handedness; if the number is even, the image has nonreversed handedness.

The position of the observer is an important factor in the formation of mirror images. An observer can see an inverted, real image only if the light reflected from the mirror is brought to a focus at a point between him and the surface of the mirror, that is, the observer must intercept the wave fronts only after they have converged. Plane and convex mirrors, which do not bring wave fronts to convergence, cannot introduce lateral inversions. Moreover, when an observer is close to a curved mirror, no matter what the inverting properties of the mirror are, the image is always similar to a plane-mirror image. The wave fronts do not have space in which to converge before they reach the observer's eye, and so the image is upright, reversed and (compared with a plane-mirror image) neither much magnified nor much reduced. An image similar to a plane-mirror image is also invariably formed when the object (rather than the observer) is close to the surface. The explanation in this case, however, is that for an object up against a mirror the section of the reflecting surface that actually forms the image is almost planar.

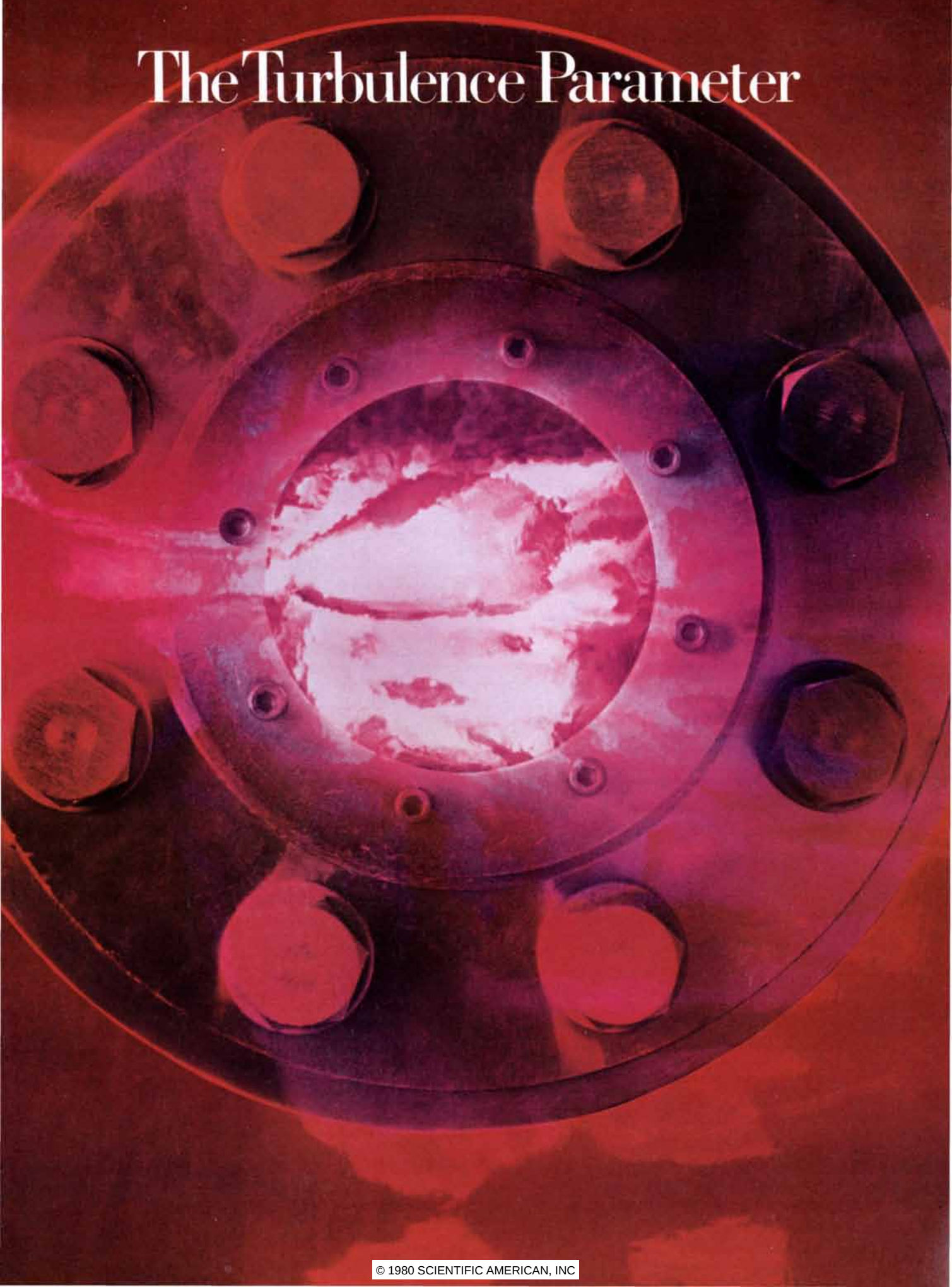
A concave mirror can give rise to at least three distinct kinds of mirror image. To begin with, it can generate either a real or a virtual image, depending on the position of the object with respect to the mirror's focal point: the point where incoming planar wave fronts either converge or appear to diverge. For an object between the focal point and a concave mirror the reflected wave fronts diverge, seemingly from a point behind the mirror, so that the image is a virtual one. For an object placed beyond the focal point of the mirror, reflected wave fronts converge along all lateral directions to focus at a point on the observer's side of the mirror. The image in this case is real.

Therefore when an object is between



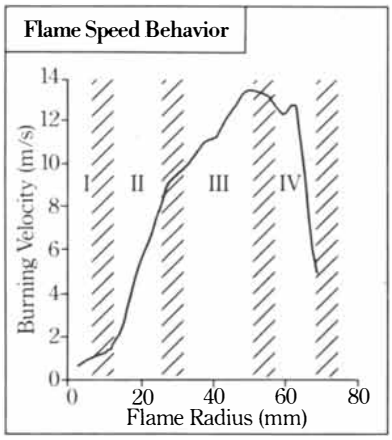
BASIC CURVED MIRRORS from which compound mirrors are constructed are described in terms of a pair of perpendicular axes (*color*) that pass through each mirror's center of curvature. The directions of the principal axes are determined by the directions of minimum and maximum curvature on the surface; the shape of each axis can be convex, concave or planar. The axes serve to define six types of reflecting surface: the plane mirror, for which both curvatures are planar; the convex mirror, for which both curvatures are convex; the concave mirror, for which both curvatures are concave; the convex cylinder, for which one curvature is convex and the other is planar; the concave cylinder, for which one curvature is concave and the other is planar, and the saddle, for which one curvature is concave and the other is convex. The image-forming properties of the mirrors are illustrated in the lower panels, where an uppercase *F* serves as the standard reflected object. In some cases a single mirror can give rise to different images in different circumstances. It is assumed that both the observer and the object are positioned on the axis line: a perpendicular line through the mirror's center of curvature.

The Turbulence Parameter



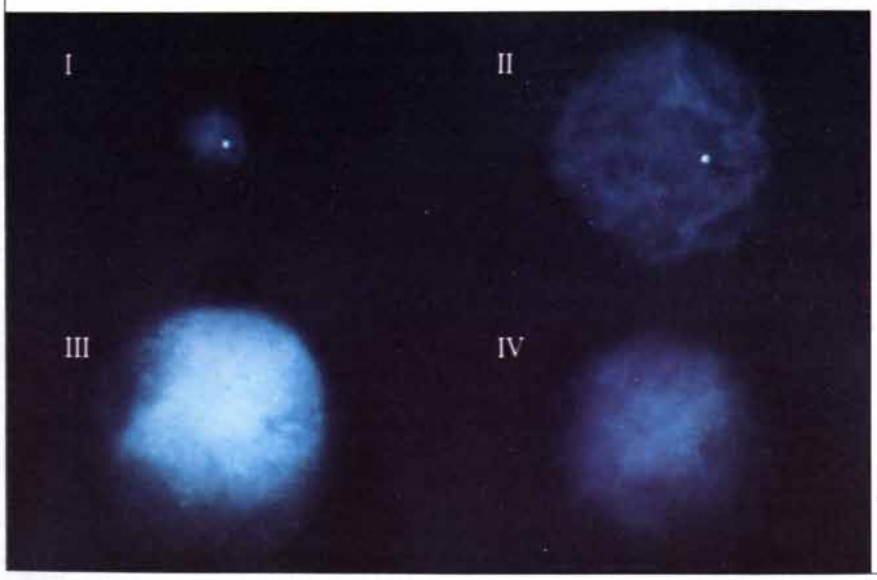
The Turbulence Parameter

Energy-efficient operation of the internal combustion engine requires the highly turbulent movement of fuel and air in the chamber. Recent advances at the General Motors Research Laboratories provide a new basis for determining what degree of turbulence will get the most work from each drop of fuel.



Burning velocity plotted as a function of flame radius. Combustion stages are indicated by roman numerals.

High-speed photographs showing flame evolution (lasting six milliseconds) through four stages: initiation (I); flame growth (II); full development (III); termination (IV).



WITHOUT TURBULENCE, the highly agitated motion of cylinder gases, combustion would take place too slowly for the gasoline engine to function. Predicting combustion behavior in order to design engines with greater fuel efficiency depends upon understanding the relationship between vital, turbulent gas motions and burning rate. The challenge is to quantify this relationship—a complex task made more difficult by the requirements of measuring a transient event occurring in a few milliseconds within a small, confined space.

New knowledge of how turbulence affects flame speed has been revealed in fundamental studies conducted at the General Motors Research Laboratories by Drs. Frederic Matekunas and Edward Groff. Their investigative results have been incorporated into a model that successfully predicts the effect of engine design and operating conditions on power and fuel economy.

The researchers separated their experiments into two phases. In the first phase, they measured turbulence in the engine cylinder; in the second phase, they determined flame speeds over a broad range of operating conditions. Testing took place in a specially designed, single-cylinder engine equipped with a transparent piston to permit high-speed filming of the combustion event.

Hot-wire anemometry was applied to measure the turbulent flows while the engine was operated without combustion. Instantaneous velocities were calculated from the anemometer signals and simultaneous measurements of gas temperature and pressure. More than 400,000 pieces of data were processed for each ten-second measurement period.

The significant measure of turbulence is its "intensity," defined as the fluctuating component of velocity. Because conditions in the cylinder are both transient within cycles and variant between cycles, separating the fluctuating and mean components of velocity is inherently difficult. The researchers overcame this problem by using a probe with two orthogonal wires properly aligned with the direction of the mean flow.

In the combustion phase, tests were performed at over one hundred operating conditions of varied spark timing, spark plug location, engine speed and intake valve geometry. Detailed thermodynamic analyses were applied to the recorded cylinder pressures to calculate flame speeds throughout combustion. High-speed films were analyzed frame by frame to validate flame speeds and to characterize how gas motions influence the initial flame.

The researchers used these measured flame speeds, turbulence intensities, and the conditions under which they occurred to formulate a burning law for engine flames. They divided the combustion event into four stages. The initiation stage begins with ignition and ends as the flame grows to consume one percent of the fuel mass. In the second stage, the flame accelerates and thickens in response to the turbulent field. The third stage exhibits peak flame speed. In the final stage, the thick flame interacts increasingly with the chamber walls and decelerates.

OVER THE RANGE of turbulent intensities encountered in engines, the researchers were able to describe the turbulent burning velocity, S_T, during the critical third stage of combustion with the expression:

$$S_T = 2.0\, S_L + 1.2\, u'\, P_R^{0.82}\, \beta$$

S_L, the laminar flame speed—a known function of pressure, temperature and mixture composition—is the flame speed that would exist without turbulence. The variable u′ is the turbulence intensity. P_R represents a pressure ratio accounting for combustion-induced compression of the unburned mixture. The dimensionless factor β accounts for the effect of spark timing on geometric distortion of the flame which occurs during the first combustion stage and persists into the later stages.

The researchers also observed that the burning velocity in the second stage increases in proportion to flame radius, and that in predicting the energy release rate from the burning velocity equation, it is necessary to account for the finite flame-front thickness.

"The form of our burning equation," says Dr. Matekunas, "shows a satisfying resemblance to expressions for non-engine flames. This helps link complex engine combustion phenomena to the existing body of knowledge on turbulent flames."

"We see this extension," adds Dr. Groff, "as a significant step toward optimizing fuel economy in automotive engines."

THE MEN BEHIND THE WORK

Drs. Matekunas and Groff are senior engineers in the Engine Research Department at the General Motors Research Laboratories.

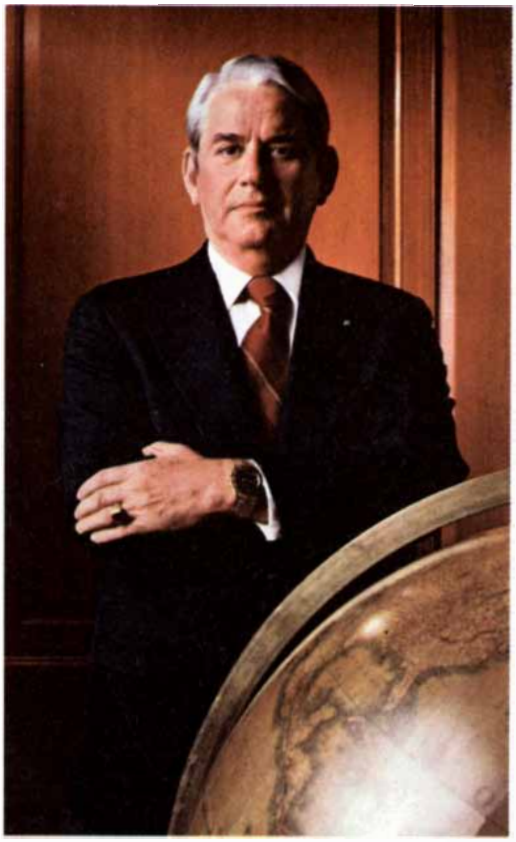
Both researchers hold undergraduate and graduate degrees in the field of mechanical engineering.

Dr. Matekunas (right) received his M.S. and Ph. D. from Purdue University, where he completed graduate work in advanced optics applications.

Dr. Groff (left) received an M.S. from California Institute of Technology and a Ph. D. from The Pennsylvania State University. His doctoral thesis explored the combustion of liquid metals.

General Motors welcomed Dr. Matekunas to its staff in 1973, and Dr. Groff in 1977.

His business is world travel. His watch is Rolex.



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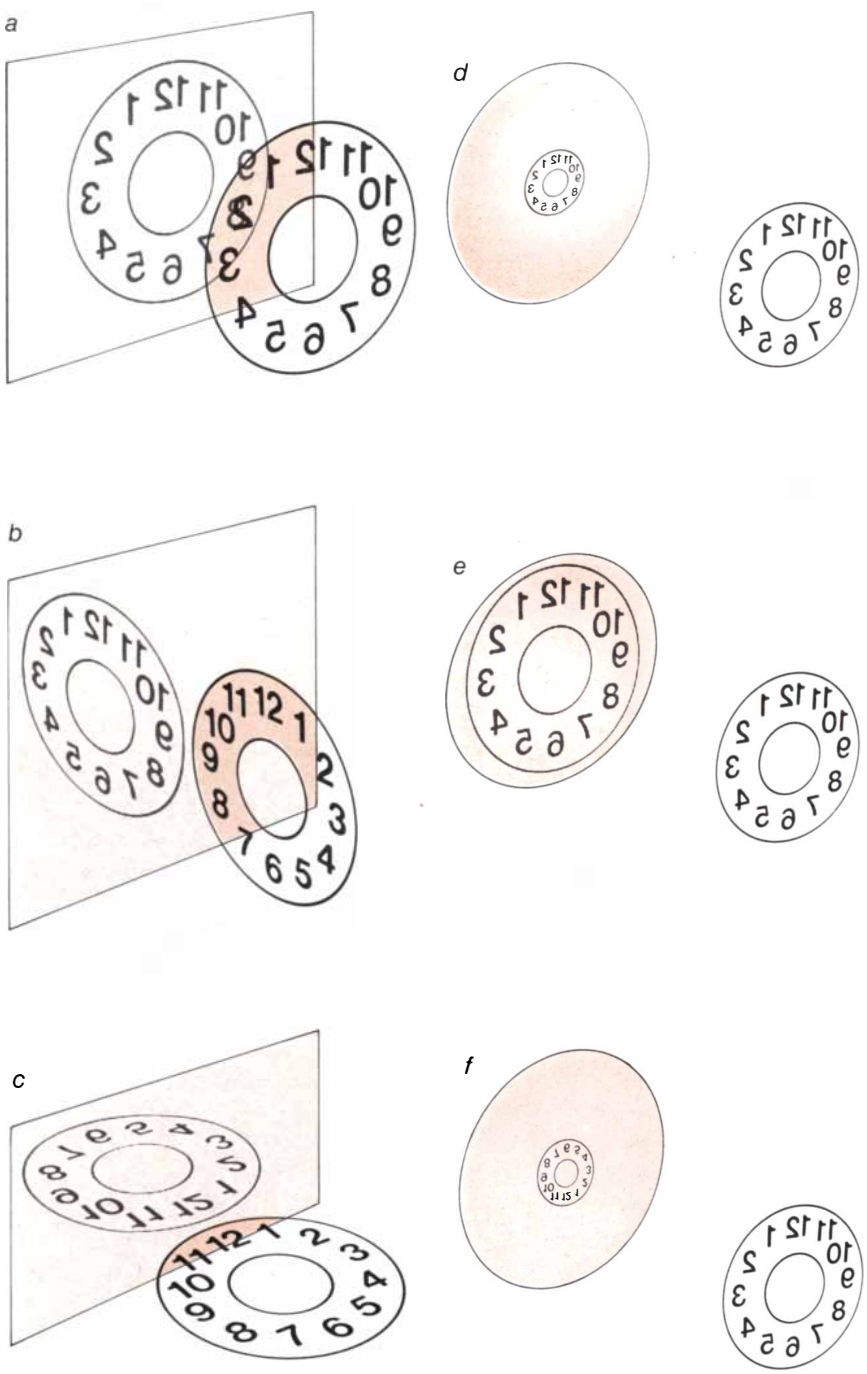
the focal point and a concave mirror, the mirror generates a virtual image for an observer at any distance. The image is an upright, reversed reflection that is magnified compared with a plane-mirror image. When the object is beyond the focal point, there are a number of possibilities. For example, when the observer is between the mirror surface and the point at which the real image is focused, he intercepts the converging wave fronts before they have actually converged. In this case it is the observer who must bring the wave fronts into focus, and the result is a blurred image that is upright, reversed and larger than a plane-mirror image would be.

When the observer is beyond the position of a real image, the concave mirror introduces inversions along all lateral directions. In other words, when both the observer and the object are sufficiently far from the surface of the mirror, a transparent clock face is reflected so that the image of each numeral appears in a position 180 degrees (or six hours) around the clock face. The numeral 1 appears at 7:00 and 7 at 1:00, 2 appears at 8:00 and 8 at 2:00, and so on. Since the directions 12:00 (up) and 6:00 (down) are inverted, the image is upside down. The positions of the object and the observer determine whether the image is magnified, reduced or the same size compared with its plane-mirror counterpart. Since orientation is inverted along all lateral directions, it is inverted along both principal axes of curvature; these two inversions and the front-to-back one make an odd number, and so the image is not only inverted but also reversed.

With a concave mirror and an object placed beyond the focal point it is possible for the observer and the mirror image to be at about the same point on the mirror axis. In this instance the result is a totally magnified image: an unrecognizable image that "lights up" the entire surface of the mirror. The same kind of image can be seen on any curved mirror that can generate a real image.

Curved mirrors that are not sections of a sphere generally reflect images that are transformed in an asymmetrical way. For example, the mirror images observed in oblate convex and concave mirrors are, compared with the corresponding plane- or spherical-mirror images, elongated or shortened in certain lateral directions.

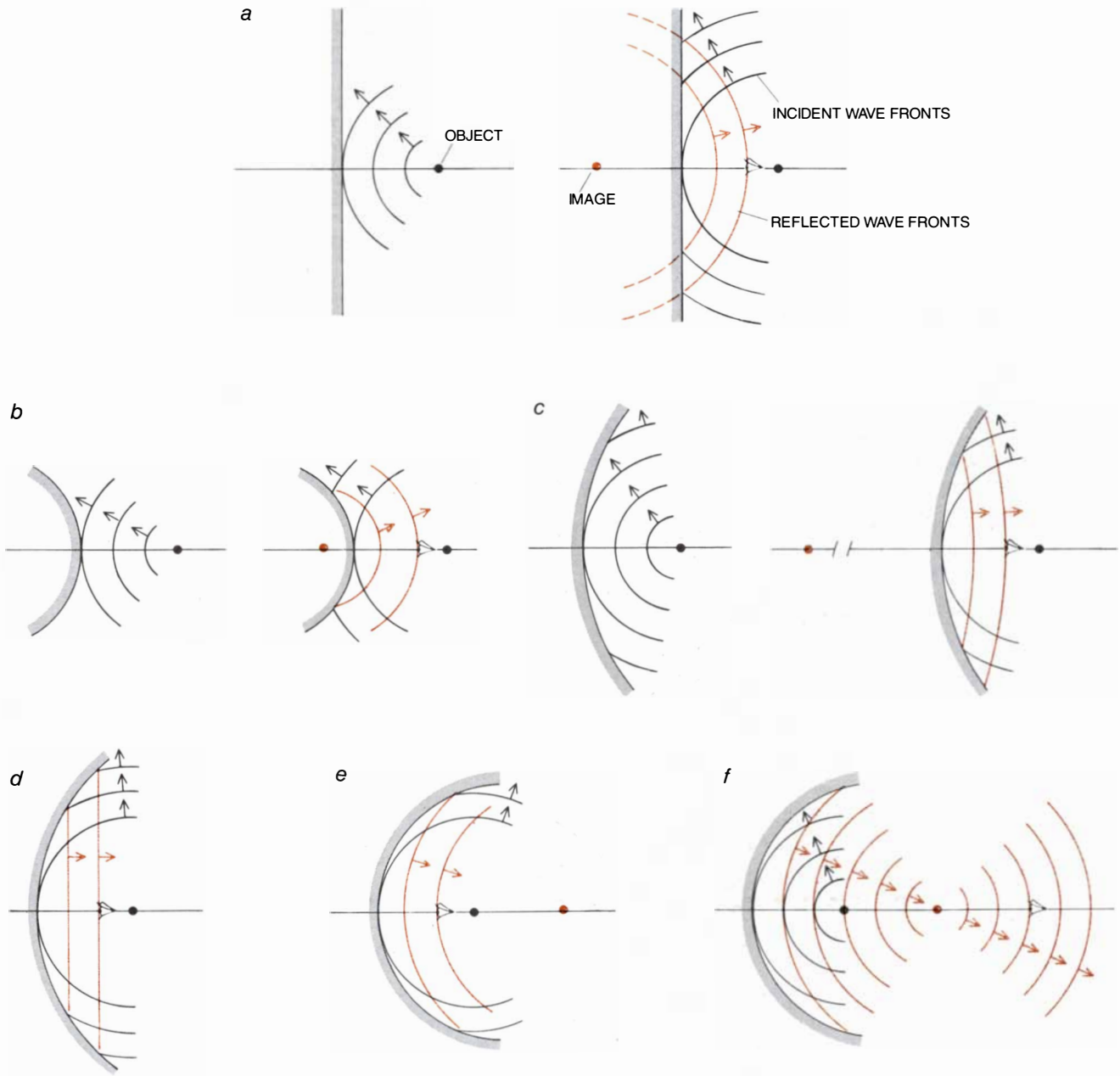
When the curvature along both principal axes of a nonsymmetrical mirror is known, it is possible to predict the general appearance of the images. Consider the mirror that is shaped like a convex cylinder. This basic curved mirror acts approximately like a convex mirror along directions parallel to the convex curvature and like a plane mirror along directions parallel to the plane curva-



CLOCK FACE with a transparent backing serves to define lateral directions in the plane tangent to a mirror at its center of curvature. For example, 2:00 identifies the lateral direction from the center of the clock to the numeral 2 and 10:30 identifies the direction from the center to the point midway between the numerals 10 and 11. An observer holding such a clock up to a mirror is able to see the real numerals (reversed and running counterclockwise) as well as their mirror images. When such a clock is held parallel to the surface of a plane mirror and the real and image clocks are compared "face to face" (*a*), it becomes evident that the plane mirror does not invert orientation along any lateral direction: the 2 in the image appears at 2:00, the 10 at 10:00 and so on. Neither 12:00 (up) nor 6:00 (down) nor 9:00 (right) nor 3:00 (left) is an inverting direction. Although the plane mirror introduces no lateral inversions, the handedness of the image is reversed. Moreover, a plane mirror, like any other mirror, does invert orientation along the forward-backward axis, so that an observer looks into the mirror to see objects in front of it. If the clock face is held perpendicular to the surface of the mirror, either right and left (*b*) or up and down (*c*) are inverted. A convex mirror (*d*) does not invert orientation along any lateral direction either, and so it too creates an upright, reversed image. For a concave mirror, if both the observer and the object are sufficiently close to the surface (*e*), orientation is not inverted along any lateral direction, so that once again an upright, reversed image is formed. If the observer and the object are sufficiently far from the concave mirror, however, orientation is inverted along all lateral directions. An inverted and reversed image is formed.

ture, creating images that are reduced in size along the first axis but neither reduced nor magnified along the second. By applying the rules of plane geometry it is possible to predict from the convex- and plane-mirror images a fairly accurate representation of the single image that would appear in a convex cylinder.

Similar predictions can be made for the images reflected in a concave cylinder, a basic mirror that acts approximately like a concave mirror along one principal curvature and like a plane mirror along the other. When either the observer or the object is sufficiently close to the surface of a concave cylinder (close enough so that in the same situation a simple concave mirror would create an upright, reversed and magnified image), the image reflected by the concave cylinder is upright, reversed and



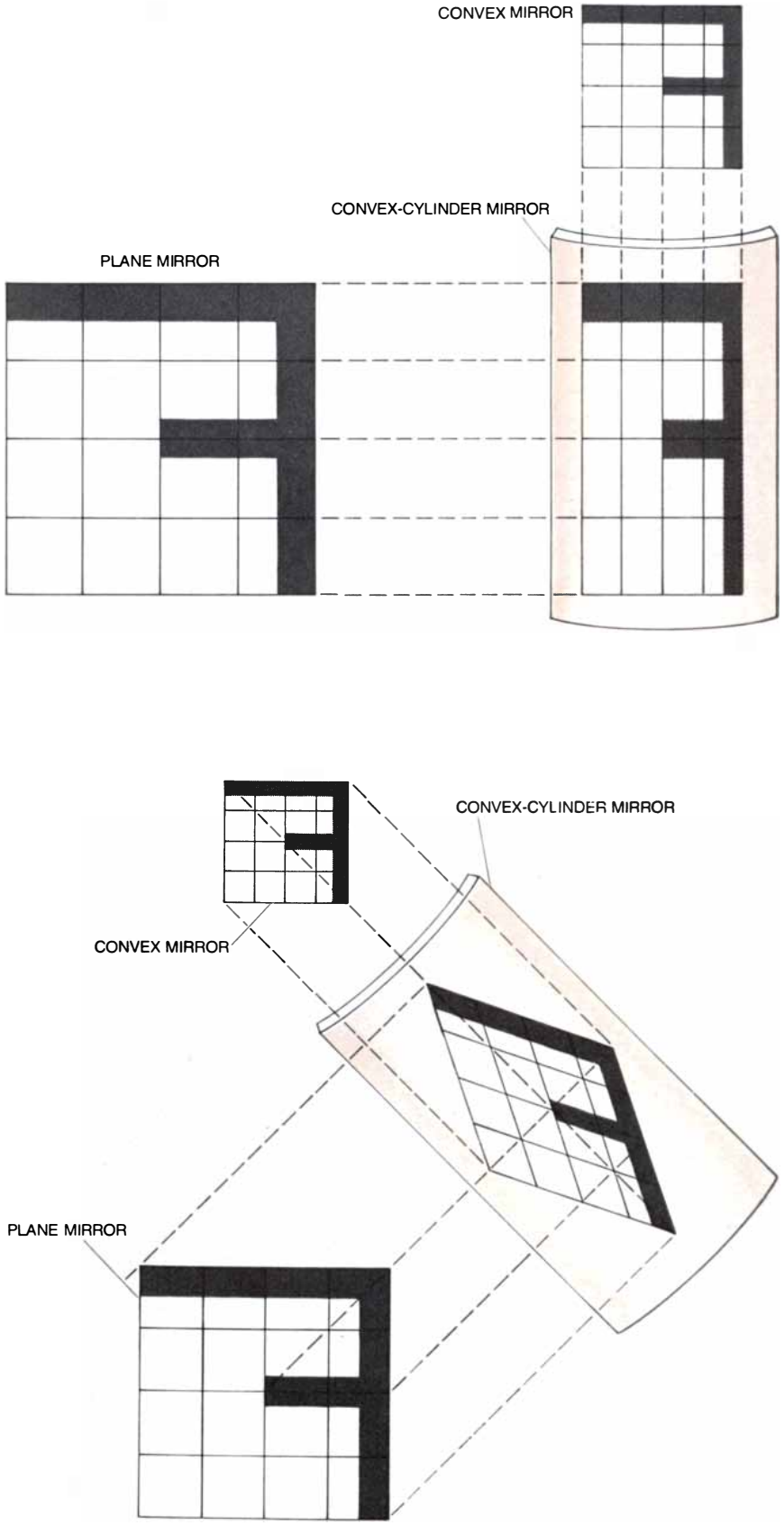
SIZE, ORIENTATION AND HANDEDNESS of a mirror image are determined by the way in which wave fronts of light are transformed by reflection. The wave fronts emanating from the object (*gray*) are spherical and diverging. The reflected wave fronts (*color*) can be diverging or converging. For a plane mirror (*a*) the reflected wave fronts appear to diverge from a point as far behind the surface of the mirror as the object (*black dot*) is in front of it. Hence the observer views an upright, reversed image (*colored dot*) that is neither larger nor smaller than the real object. The situation is similar for a convex mirror (*b*), although the reflected wave fronts appear to diverge from a point that is not as far behind the surface and the image is therefore smaller. For a concave mirror a number of cases must be considered. When the object is between the mirror and the focal point (where incident rays parallel to the mirror axis are focused), the reflected wave fronts appear to diverge from a point farther behind the mirror than the point where a plane-mirror image would be formed (*c*). As a result an upright, reversed image that is larger than its plane-mirror counterpart is created. When the object is at the focal point (*d*), the reflected wave fronts are flat and the observer must focus them, creating an upright image that is magnified compared with a plane-mirror image. When the object is beyond the focal point, the reflected wave fronts converge in front of the mirror. An observer between the mirror and the focal point must focus the wave fronts before they have converged, creating an upright, reversed and magnified image (*e*). An observer who is beyond the focal point intercepts the wave fronts after they have converged, and the image is reversed and inverted (*f*). The exact position of the observer determines whether the image is magnified, reduced or the same size as a plane-mirror image.

magnified along the concave axis. When the observer and the object are sufficiently far from the mirror (far enough so that a simple concave mirror would reflect an inverted, reversed image), the result is quite different.

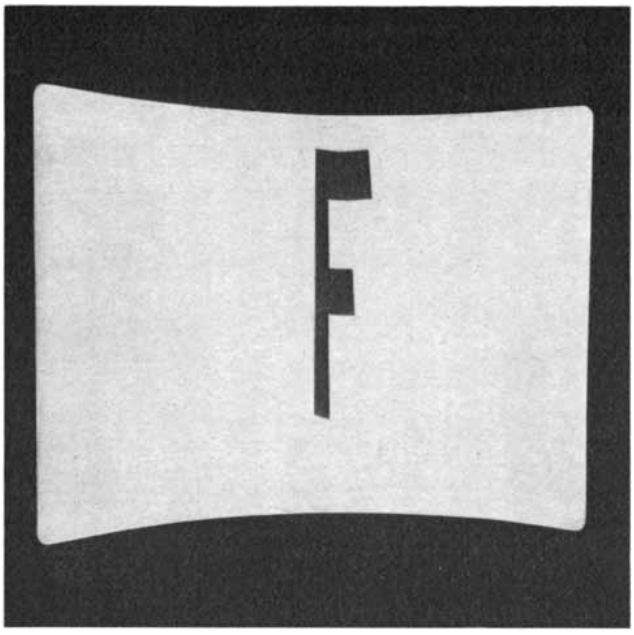
Wave fronts reflected from the surface of the concave cylinder, instead of being inverted in all lateral directions as they are after reflection from a concave mirror, are inverted laterally only along the concave curvature. Because the resulting image has a total of two inversions (one lateral and one front-to-back) it is not reversed, so that a left hand is reflected as a left hand. Depending on the positions of the object and the observer, the image can be magnified, reduced or the same size along directions parallel to the concave curvature. Moreover, the lateral orientation of the concave curvature determines the lateral orientation of the mirror image; hence by rotating the axis of the mirror it is possible to give the image any orientation. When the axis of concave curvature is positioned horizontally, the nonreversed image appears upside down.

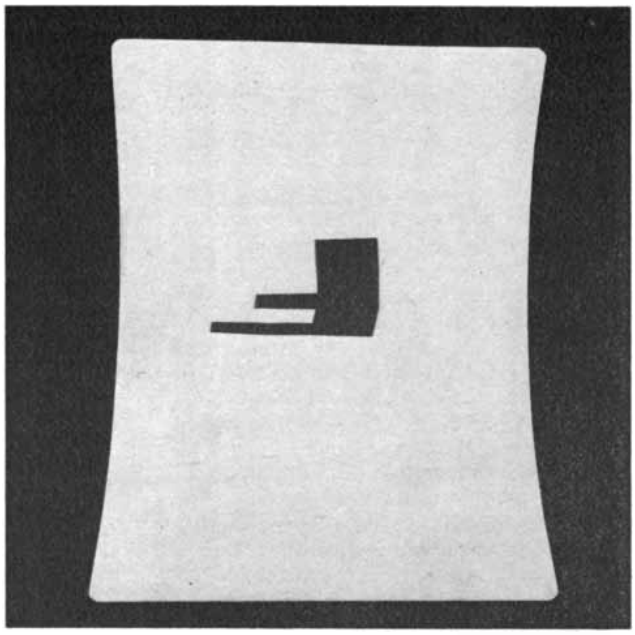
The wave fronts emanating from a point on an object are spherical until they reach the mirror surface of a concave cylinder. After reflection from the surface they become increasingly asymmetrical until they finally come to a focus. Since the converging wave fronts are lacking in symmetry, however, they cross over not through a single point but through a line parallel to the concave cylinder's planar curvature. An observer farther away from the mirror than this focal line is able to see a nonreversed mirror image by focusing the asymmetrical, inverted wave fronts, but the resulting image is generally blurred and distorted. The blurriness diminishes as the observer moves away from the mirror because as the wave fronts move past the focal line they approach a planar (and thus symmetrical) shape. It is not only the concave cylinder that has this property. Any curved mirror that lacks rotational symmetry can focus incoming light from a point source to a locus of points rather than to a single point. Hence the images reflected in mirrors such as the convex cylinder are also affected by this blurring, which is related to astigmatism in the eye.

To clarify these matters I find it helpful to distinguish between two types of mirror image. What I call a primary image is created by a mirror alone and "hangs" in space, appearing at the mirror's focal point or (in the case of asymmetrical mirrors) at the locus of focal points. What I call a secondary image is created by the mirror in conjunction with an observer and can be said to be positioned in the eye of the observer (on the surface of the retina or on a photographic plate). The concept of primary



CONVEX CYLINDER acts somewhat like a plane mirror along one lateral axis and like a convex mirror along the other lateral axis. By projecting from the corresponding plane- and convex-mirror images, it is possible to predict the appearance of the asymmetrically transformed image reflected in the convex cylinder. The image is upright, reversed and reduced in size along the axis of convex curvature. The same kind of geometric construction can be employed to analyze the image formed when the convex cylinder is tipped to the right or the left.

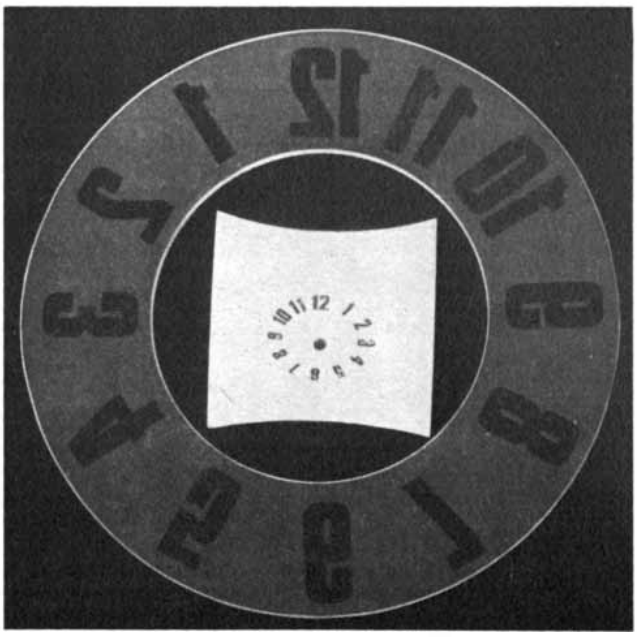


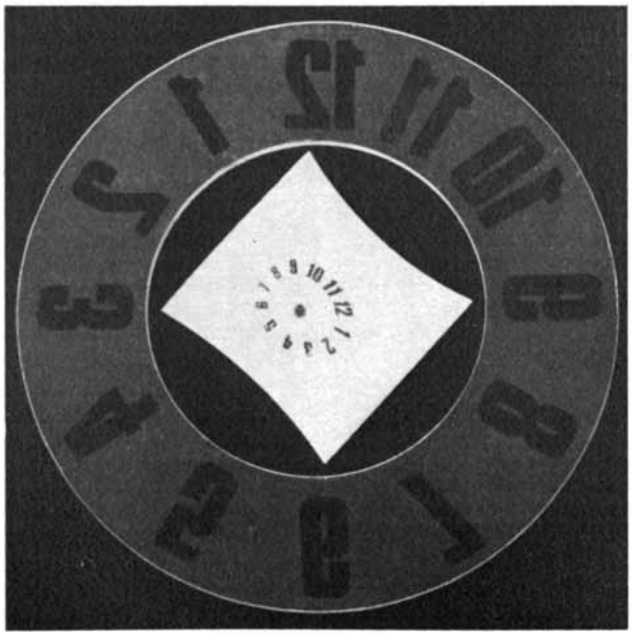


CONCAVE CYLINDER acts like a concave mirror along one axis and like a plane mirror along the other, so that when the observer and the object are sufficiently distant, orientation is inverted along just one axis and a nonreversed image is formed. When the axis of concave curvature is horizontal, as is shown at the left, right and left become inverting directions, so that the nonreversed image is upright. When the axis of concave curvature is vertical, as is shown at the right, up and down become inverting directions, and so the nonreversed image is upside down. The positions of the object and the observer determine whether the image appears magnified or reduced.

and secondary images serves to explain how a mirror shaped like a concave cylinder can combine the properties of a plane mirror, which reflects virtual images, and a concave mirror, which (for sufficiently distant observers and objects) reflects real images. How can an image act as if it were in two places at once? This puzzle of depth perception, known as the parallax paradox, is resolved by the idea that the image is neither in front of the mirror nor behind it but is in the eye of the beholder.

It is important to understand that the nonreversed images generated by a concave cylinder are the result of a single reflection of light. A pair of plane mirrors joined at right angles can also create nonreversed images, but they arise from two separate reflections and thus from two separate inversions of light.





SADDLE MIRROR acts like a convex mirror along one axis and like a concave mirror along the other. When the observer and the object are sufficiently distant, the saddle surface inverts orientation along directions that pass through the center of a hill but not along directions that pass through the center of a valley. The orientation of the image is determined by the orientation of the lateral axes. When the axis of concave curvature is horizontal (*left*), the mirror inverts 9:00 and 3:00 but not 6:00 and 12:00, and so an upright, nonreversed image is formed. When the mirror is turned 45 degrees clockwise (*right*), the mirror inverts the directions 1:30 and 7:30 but not 4:30 and 10:30. As a result the image clock is rotated 90 degrees clockwise (or twice the rotation of the mirror) and appears to be on its side.

Indeed, when an object is held up to such a configuration of mirrors, three images are observed: an upright, reversed image appears in each of the plane mirrors and a nonreversed image resulting from a double reflection appears at the boundary between the two.

The concave cylinder is not the only basic curved mirror in which nonreversed images result from a single reflection of light. Consider the saddle-shaped mirror, which acts approximately like a convex mirror along one of its principal axes of curvature and like a concave mirror along the other. For an observer or an object sufficiently close to the surface, the saddle mirror, much like the concave cylinder, generates upright, reversed images that are reduced along the axis of convex curvature and magnified along the axis of concave curvature. The images created for distant observers and objects differ according to the orientation of the mirror.

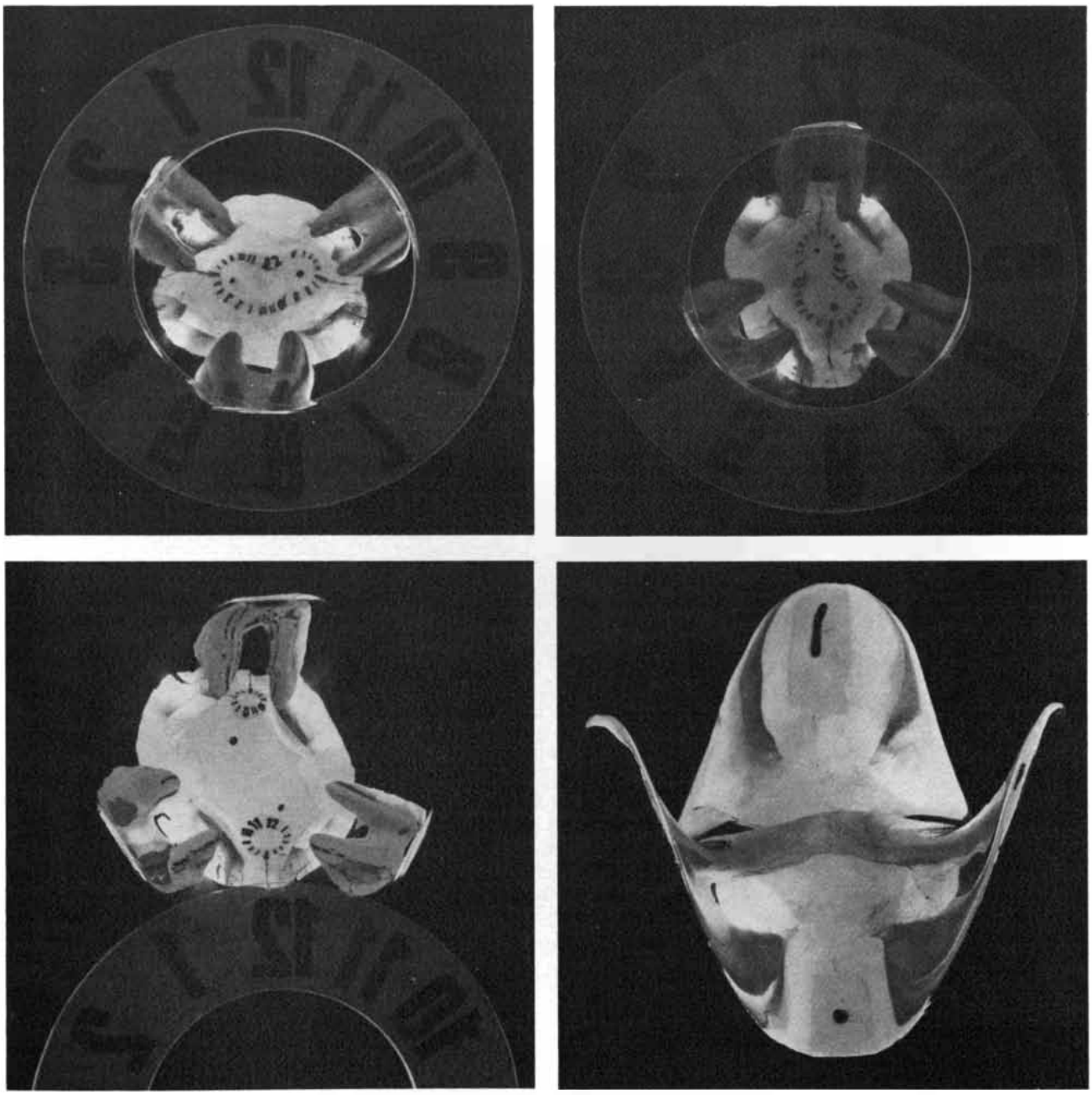
The surface of a saddle mirror can be divided into two hills and two valleys, arranged so that the centers of the hills lie on the axis of concave curvature and the centers of the valleys lie on the axis of convex curvature. Hence each lateral direction that passes through the center of a hill is inverting, whereas each lateral direction that passes through the center of a valley is noninverting. If the saddle mirror is held so that its hills lie on a horizontal line, 9:00 and 3:00 become inverting directions, whereas 12:00 and 6:00 become noninverting ones. Since 12:00 and 6:00 are not inverted, the image of an object is upright; since orientation is inverted along only one lateral direction, the image is nonreversed. In addition, compared with a plane-mirror image, the nonreversed image is usually reduced in all lateral directions. (It is possible, however, for the image to appear magnified along the direction of concave curvature.)

Rotating the saddle mirror clockwise 45 degrees brings the centers of the hills to 4:30 and 10:30, so that these directions become inverting, whereas 1:30 and 7:30 become noninverting. In this case 12 appears at 3:00 and 3 at 12:00, 6 appears at 9:00 and 9 at 6:00. The image is still nonreversed, but it has been rotated 90 degrees so that it appears to be lying on its side. When the mirror is rotated another 45 degrees, so that the centers of the hills lie on a vertical line and the centers of the valleys on a horizontal one, 12:00 and 6:00 are inverted but not 9:00 and 3:00. In other words, the nonreversed image is upside down. In general if a saddle mirror is rotated by any given amount, the image of a fixed object is rotated in the same direction by approximately twice that amount.

The properties of the saddle mirror can be made clearer by imagining how such a mirror would reflect a transpar-

ent clock face equipped with an hour hand. As the real hand makes one 12-hour journey around the face, the image hand also makes one complete rotation about the nonreversed image face, but (from the point of view of the observer) it moves in the opposite direction. If the mirror itself turns in the counterclockwise direction so that it completes one rotation every 24 hours, however, the motion of the image hand due to the rotation of the mirror and the motion of the image hand due to the rotation of the object hand cancel each other. Indeed, the image of the moving hour hand appears to be stationary, whereas the image of the stationary clock face completes one counterclockwise rotation every 12 hours.

By joining together mirrors of the six basic types it is possible to create an endless variety of compound mirrors with curious light-reflecting properties. For example, I have designed and patented a series of mirrors, beginning with a saddle mirror, that can generate a nonreversed image or several such images of a single object. Although the images are smaller than the corresponding plane-mirror images, they exhibit strik-



MULTILOBE MIRROR, such as the three-lobe version shown, is a compound mirror generated by rotating a saddle, or two-lobe, surface about a plane surface. Like the saddle, the multilobe mirror generates nonreversed images and inverts orientation along directions that pass through the center of a hill but not along directions that pass through the center of a valley. When the mirror is positioned as is shown at the upper left, 2:00, 6:00 and 10:00 are inverting directions, and so an 8 appears at 2:00, a 12 at 6:00 and a 4 at 10:00. On the other hand, 12:00, 4:00 and 8:00 are noninverting directions, so that another 12 appears at 12:00, another 8 at 8:00 and another 4 at 4:00. Two nonreversed images of each numeral are generated. The result is a nonreversed 24-hour clock face. When the three-lobe mirror is rotated 60 degrees clockwise, as is shown at the upper right, 12:00, 4:00 and 8:00 become inverting directions and 2:00, 6:00 and 10:00 become noninverting ones. The 24-hour image clock face is then rotated 90 degrees clockwise. When the object clock is moved away from the mirror axis, the reflected 24-hour clock face divides into two nonreversed 12-hour clocks, as is shown at the lower left.

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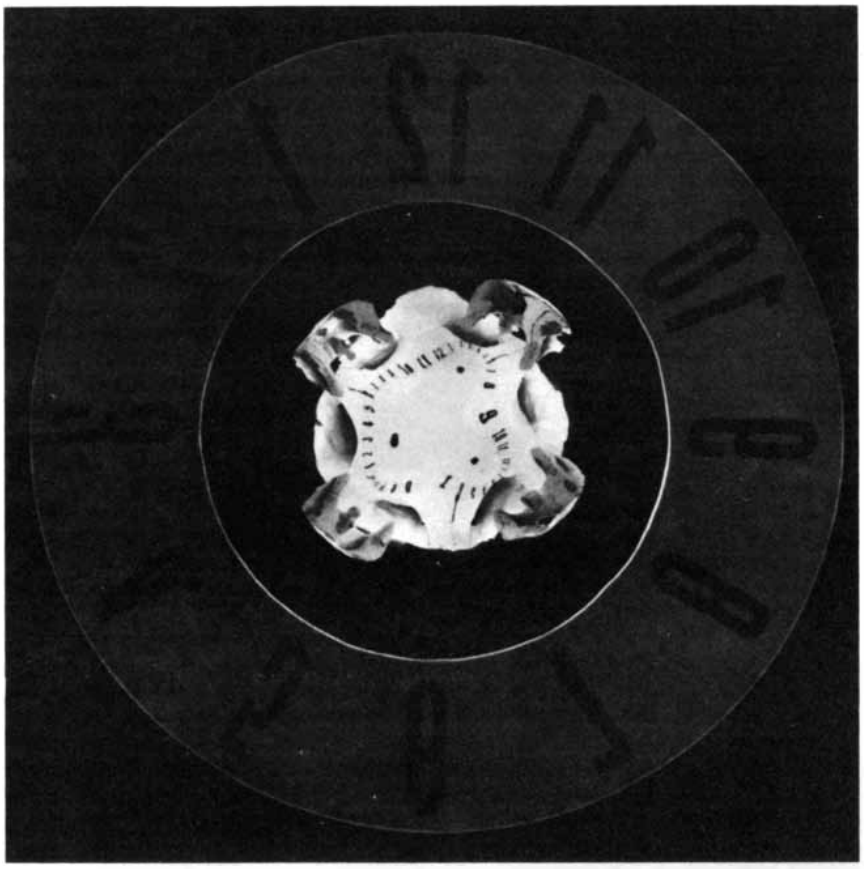

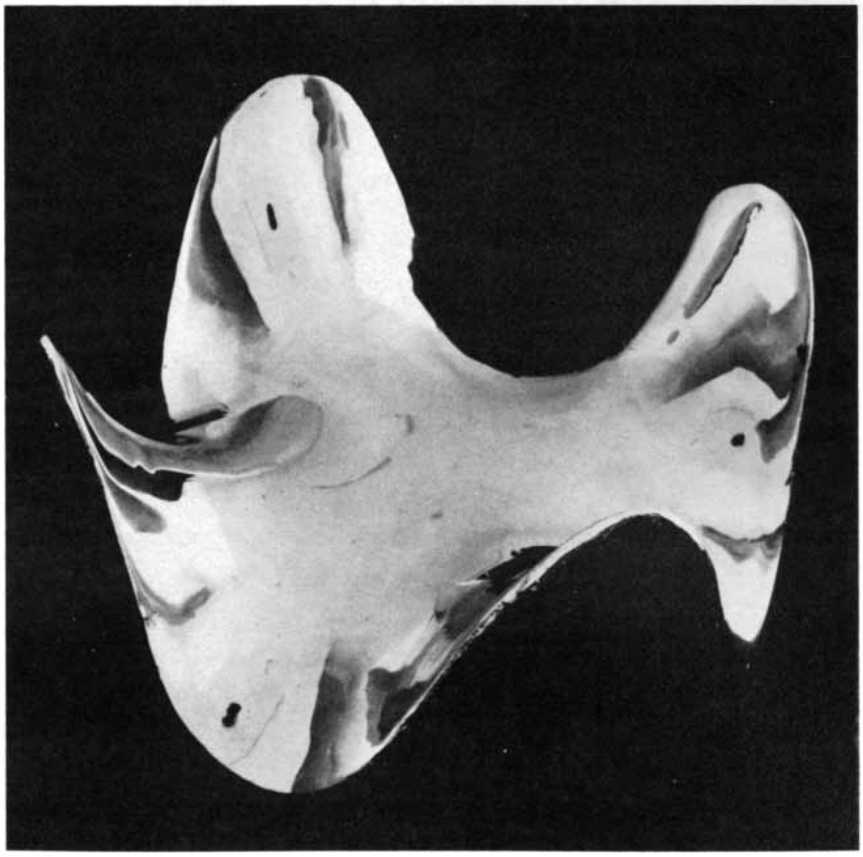

FOUR-LOBE MIRROR, shown in top and oblique views, generates three nonreversed images of an object. Here the mirror is positioned so that it inverts 1:30, 4:30, 7:30 and 10:30 but not 3:00, 6:00, 9:00 and 12:00. The result is a nonreversed image of a 36-hour clock face.

ing clarity. These compound mirrors are derived from the basic saddle mirror by rotating (in a complex manner) a saddle mirror about a planar region, possibly one as small as a single point. In this way a saddle surface with any number of lobes, or hills, can be generated, and so I call these reflecting surfaces multilobe mirrors.

As I have already demonstrated for the saddle mirror, or two-lobe mirror, on a multilobe mirror lateral directions from a center of curvature that pass through the center of a hill are inverting, whereas those that pass through the center of a valley are noninverting. When a three-lobe mirror is placed with its hills at 2:00, 6:00 and 10:00, it inverts those directions but not 12:00, 4:00 and 8:00, which are the directions taken by the valleys. Because of the inversions an 8 appears at 2:00, a 12 appears at 6:00 and a 4 appears at 10:00. Because of the noninverting reflections, however, another 12 appears at 12:00, another 4 at 4:00 and another 8 at 8:00. Indeed, provided the surface is continuous and smooth, two images appear for each of the 12 numerals on the object clock face. Because each of the two sets of image numerals appears in clockwise order, the image of the 12-hour clock face is a 24-hour clock face.

If the three-lobe mirror is rotated 60 degrees, it inverts 12:00, 4:00 and 8:00 but not 2:00, 6:00 and 10:00. In this case the image is still that of a 24-hour clock, but it has one 12 at 3:00 and another at 9:00, one 10 at 4:00 and another at 10:00, and so on. In general if the three-lobe mirror is rotated by a given amount, the mirror image of a fixed object is rotated in the same direction by one-and-a-half times that amount.

An hour hand on a transparent clock face reveals a more striking manifestation of the same phenomenon. As the hour hand rotates about the transparent 12-hour clock face two image hour hands are visible on the nonreversed 24-hour image clock face. Each hand rotates 180 degrees in 12 hours. At the end of 12 hours, then, the two image hands have exchanged positions, and only after the real hour hand has completed two 12-hour rotations has each of the image hands returned to its original position. It is also interesting to note that when a transparent clock face is moved to one side of the three-lobe mirror, so that the center of the face no longer lies on the mirror axis, the nonreversed 24-hour image clock face divides into two nonreversed 12-hour clock faces.

A saddle-shaped mirror with n lobes (where n is equal to or greater than 2) can create $n - 1$ nonreversed images of a single object. Thus the four-lobe mirror can generate three nonreversed images, reflecting a 12-hour clock face as a 36-hour clock face. In addition, when a mirror with n lobes is rotated by a

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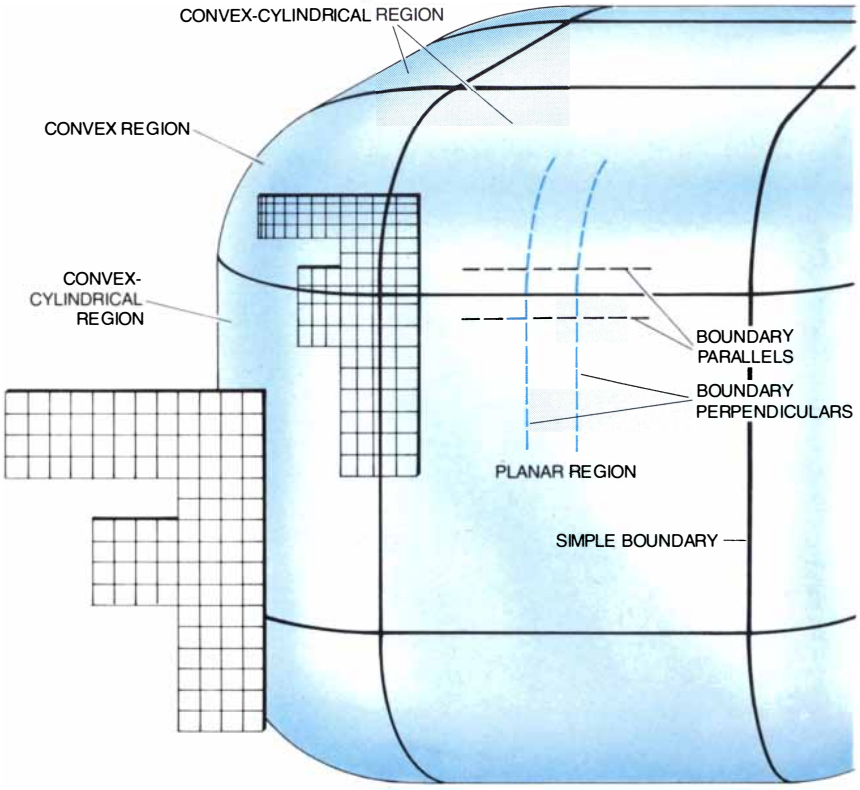
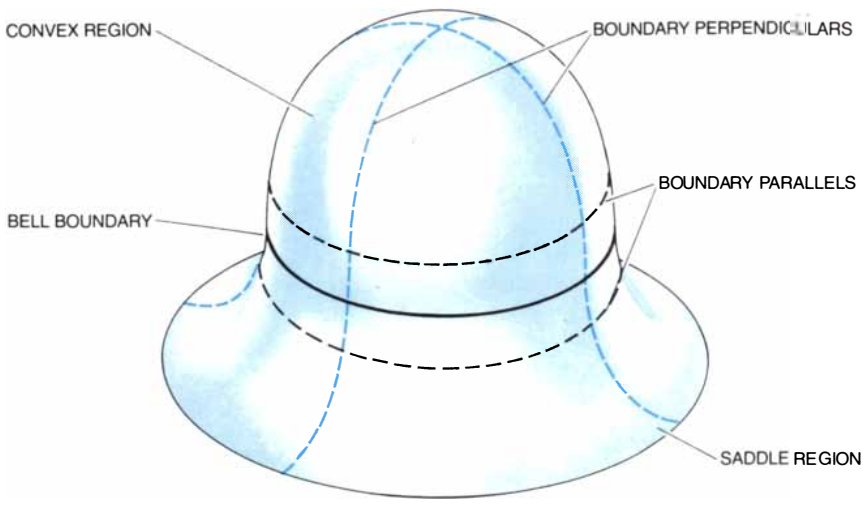


BASIC REGIONS IN A COMPOUND MIRROR are joined along smooth boundaries (*solid black lines*) that can be classified according to their effect on two sets of curves on the surface of the mirror. The curves are the boundary parallels (*broken black lines*) and the boundary perpendiculars (*broken colored lines*) that lie in the regions on each side of the boundary. The box-like mirror with rounded edges shown here is made up of three kinds of region: planar, convex and convex cylindrical. In all cases, as one moves from one side of a boundary to the other, the inverting properties of both the boundary parallels and the boundary perpendiculars are unchanged. For example, at the top of the front face, where a plane region joins a convex cylindrical region, the boundary parallels are planar and hence are noninverting on both sides of the boundary; the boundary perpendiculars change from planar to convex, but both of those curvatures are noninverting. A boundary that does not change the inverting properties of either its parallels or its perpendiculars is called a simple boundary, and a compound mirror that includes only simple boundaries reflects a single, connected image of a fixed object. The size of the parts of the image, however, may vary according to the regions in which they are reflected.



BELL BOUNDARY (*solid black*) changes the inverting properties of boundary perpendiculars (*broken color*) but not of boundary parallels (*broken black*). A boundary of this kind joins a convex region to a saddle region in a bell mirror. Since the inverting properties of the boundary perpendiculars are changed, a pair of images is created for each pair of regions.

given amount, the image of a fixed object is rotated in the same direction by $n/(n-1)$ times that amount. Conversely, if an object reflected in a stationary n-lobe mirror is rotated by a given amount, its image is rotated in the opposite direction by $1/(n-1)$ times that amount.

Saddle-shaped mirrors are only one of the many kinds of compound mirrors that can be made to form more than one image of a single object. Indeed, with the endless possibilities for connecting basic mirrors, the compound mirrors that reflect multiple images would seem to defy classification. The situation is not as hopeless as it appears, however. The key to the solution is to consider not only the basic regions that make up a compound mirror but also the boundaries that separate one region from another. (It is assumed that the "join" between two basic regions of a compound mirror is smooth, with no discontinuities.) The boundaries of a compound mirror fall into three main categories, and if the category of a particular boundary can be identified, the appearance of mirror images on each side of it can be predicted.

The best way to describe a boundary on a compound mirror is by considering its relation to two sets of curves that lie on the mirror surface: the curves that run parallel to the boundary and those that run perpendicularly across it. Like any curve on the surface of a mirror, a boundary parallel or a boundary perpendicular can be described as noninverting (if its curvature is either convex or planar) or inverting (if its curvature is concave). A boundary between two basic regions, then, can be categorized according to the way the inverting properties of its parallels and perpendiculars change as one travels from one side of the boundary to the other.

For example, I call a boundary simple if, as one goes from one side to the other, neither the parallels nor the perpendiculars are transformed from inverting curves to noninverting ones (or vice versa). Compound mirrors whose regions are all joined by simple boundaries generate a single, connected image of an object. Parts of the image in various regions of the mirror may differ in size depending on the curvature of those regions but the parts are attached to one another just as they are attached in the real object.

A boundary where the perpendiculars change from inverting to noninverting but the parallels do not change character is what I call a bell boundary. As one might expect, a mirror shaped like a bell, which consists of a convex region joined to a saddle region, is an example of a compound mirror with a boundary of this kind. Because the inverting properties of the perpendiculars change at

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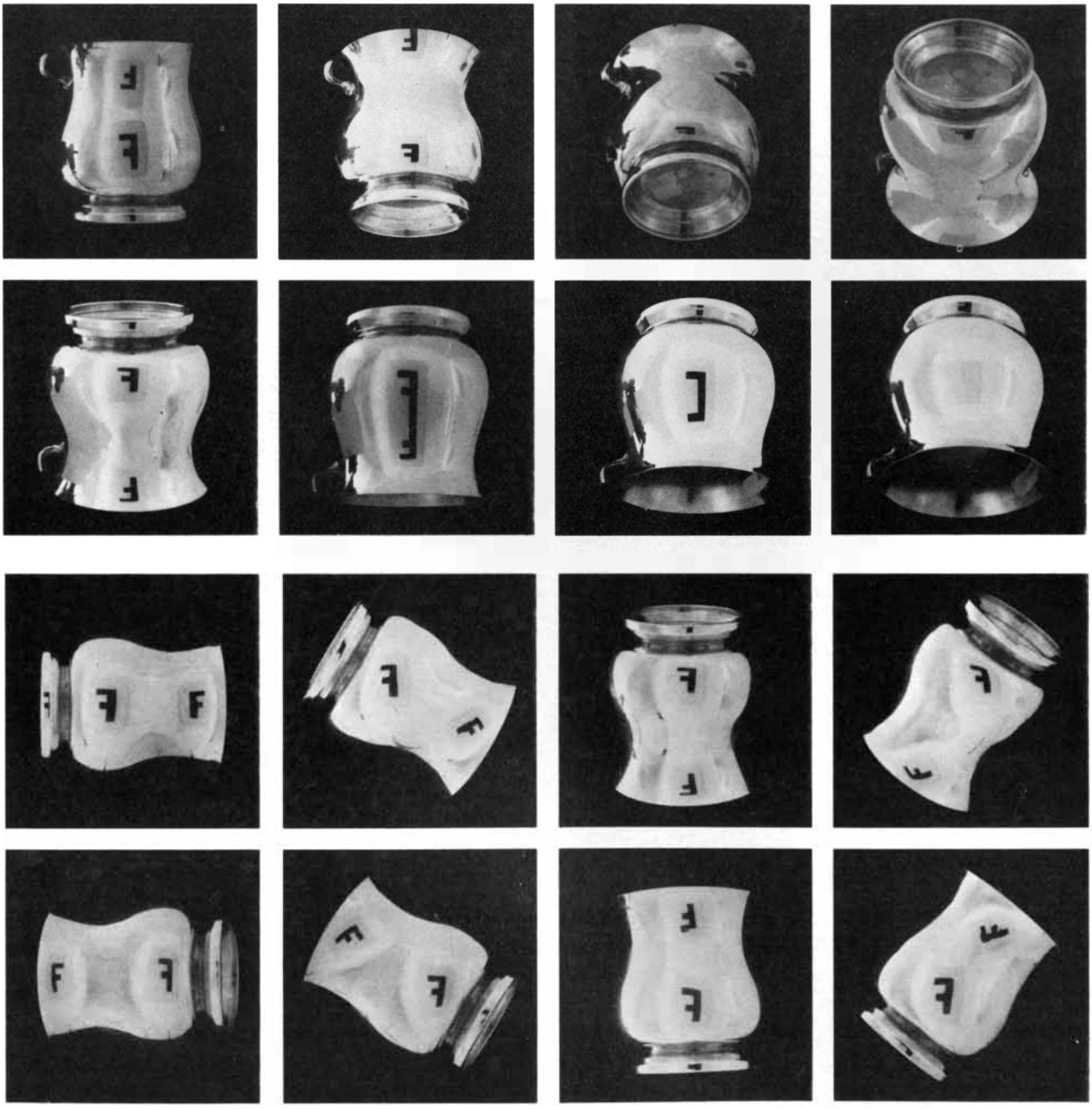
the boundary, a pair of images is created for each pair of regions. The images are enantiomorphic (they have opposite handedness), and they are arrayed symmetrically on opposite sides of the bell boundary.

When a bell mirror (or any compound mirror that creates pairs of enantiomorphic images) is turned about a lateral axis parallel to the bell boundary, the images may annihilate each other by merging and disappearing. Turning the mirror in the opposite direction will then "create" the pair of images apparently out of nothing. When a bell mirror is rotated about the forward-backward axis, however, the enantiomorphic images react quite differently. On the one hand, since reversed images are not affected by changes in mirror orientation, the reversed image reflected in the convex region retains the same orientation through a complete rotation of the mirror. On the other hand, since the orientation of nonreversed images depends on mirror orientation, the nonreversed image that appears in the saddle region completes two full rotations for each rotation of the mirror. In this way the nonreversed and reversed images always present corresponding sides to the bell boundary as well as to each other.

An array of four or more regions all joined by bell boundaries forms what I call a matrix mirror. The simplest mirror of this kind is the two-by-two matrix consisting of two saddle regions joined at a point and separated by a convex



ENANTIOMORPHIC IMAGES (having opposite handedness) appear symmetrically on opposite sides of a bell boundary. The bell mirror reflects an upright, reversed image in its convex region and an inverted, nonreversed one in its saddle region. The upper sequence of photographs shows the effect on the image when the mirror is turned about a lateral axis: the two images are first annihilated, merging and disappearing from the surface, and then re-created. The lower sequence shows the effects of turning the mirror clockwise: the reversed image remains upright, whereas the nonreversed one makes two full rotations in the course of a single rotation of the mirror.

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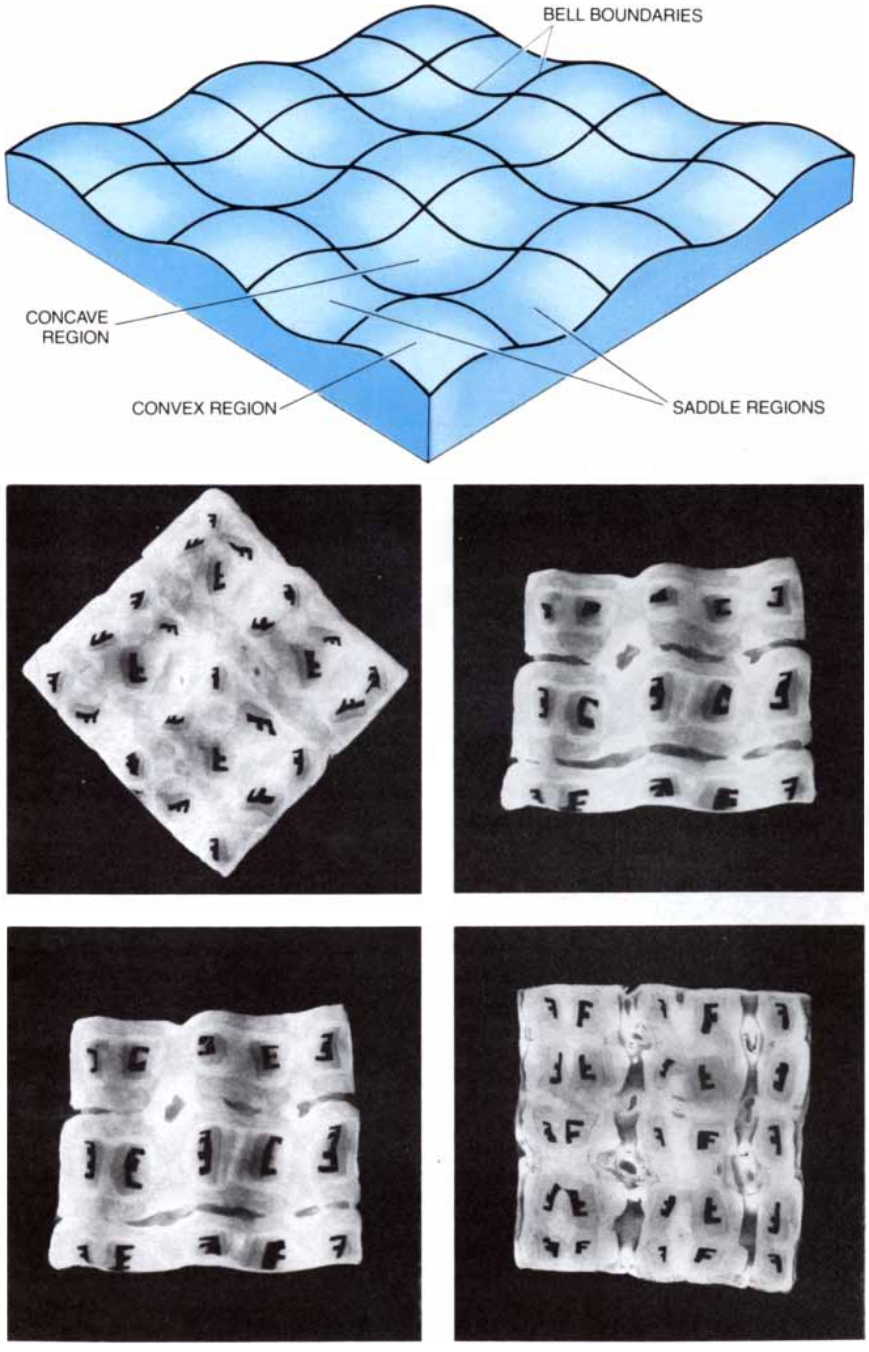
region on one side and a concave region on the other. By continuing this pattern it is possible to construct a matrix mirror with any number of rows and columns. For example, a five-by-five matrix can be put together that reflects as many as 25 images of an object. The four bell boundaries that separate the regions in the two-by-two matrix mirror come together at a single point, and it appears it is only at such a point that a convex region and a concave one can meet. This would explain why no boundaries seem to change the inverting properties of both boundary parallels and boundary perpendiculars.

Like bell mirrors, matrix mirrors can be made to form enantiomorphic pairs of images. When a matrix mirror is tilted obliquely, it can be made to generate double pairs, which can also be simultaneously annihilated or created. On no compound mirror, however, is it possible for more than four images of a single object to meet at the same point.

The saddle and planar regions of multilobe mirrors are also joined by bell boundaries that give rise to some interesting images. For example, although a three-lobe mirror normally reflects two nonreversed images of an object, if an observer holding the mirror with one hill at 12:00 begins to rotate the top of the mirror toward him, the two nonreversed images move toward the mirror's planar region. When the two images are close enough to the planar region, one of them divides into three new images, two of them nonreversed and one reversed. If the mirror is then turned again, the reversed image may annihilate any one of the three nonreversed images, leaving again only two nonreversed images.



MATRIX MIRROR consists of four or more basic regions joined by bell boundaries. In this example, convex, concave and saddle-shaped regions are brought together in a repeated two-by-two pattern. Because there are bell boundaries on at least two sides of each basic region, it is possible to generate as many as four images in each two-by-two cell of the matrix. By tilting the mirror obliquely double pairs of enantiomorphic images can be annihilated and created.

The third kind of boundary on compound mirrors is one that changes the inverting properties of the boundary parallels but not of the perpendiculars. I call this kind of boundary a torus boundary because it separates the convex outer region and the saddle-shaped inner region that make up a torus-shaped mirror. There are actually two torus boundaries on a torus mirror, one boundary joining the convex and saddle regions around the bottom of the torus and the other joining the two regions around the top. For the purposes of this discussion, however, it will suffice to consider the torus from the top view only, so that the two basic regions form a pair of concentric rings, with the saddle region on the inside, the convex region on the outside and a single torus boundary separating the two.

Viewed axially, this section of a torus mirror presents two images of a single object: a reversed image on the outer convex region and a nonreversed image on the inner saddle region. Although these images have opposite handedness, they differ from the enantiomorphic pairs reflected in bell or matrix mirrors in that they are not placed symmetrically with respect to the boundary between them. Instead the two torus images appear 180 degrees apart on their respective rings. For example, when the object is a clock face, the torus mirror generates two concentric images, one reversed and running counterclockwise in the convex region and one nonreversed but also running counterclockwise in the saddle region. Hence if the 12 on the outer image appears at 12:00, the 12 on the inner image appears at 6:00. In effect the nonreversed image of the clock is turned inside out; the nonreversed numerals run counterclockwise and their tops point inward. The connection between the reversed and the nonreversed images on a torus mirror is unusual. For example, the reversed 12 appears close to the nonreversed 6.

If objects are moved over the torus mirror, their images undergo peculiar

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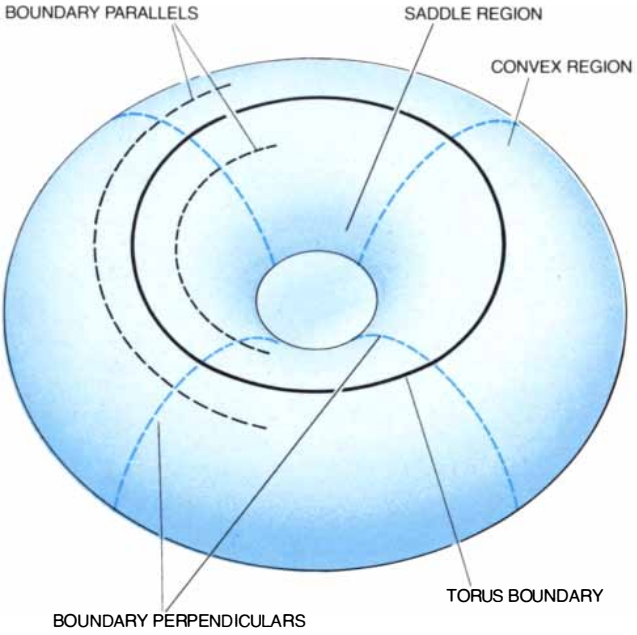

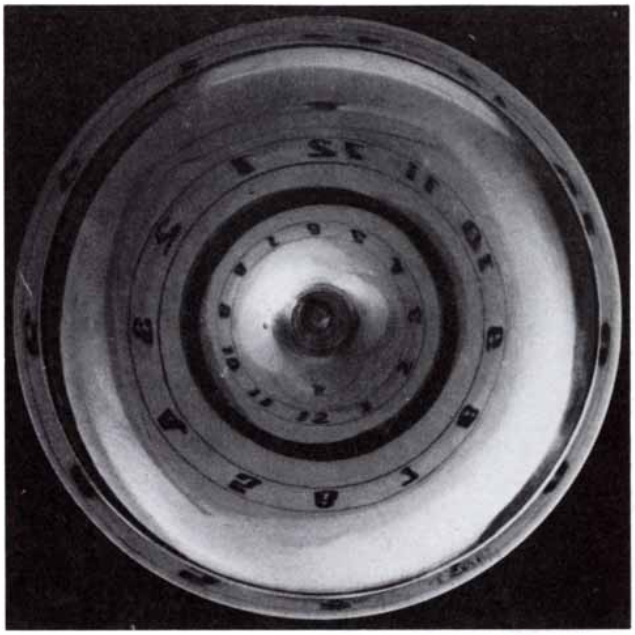

TORUS BOUNDARY (*solid black*) changes the inverting properties of boundary parallels (*broken black*) but not those of boundary perpendiculars (*broken color*). On the torus-shaped mirror shown in the diagram at the left, the torus boundary separates the outer convex region of the mirror from the inner saddle-shaped region. These regions create pairs of images that have opposite handedness and are positioned 180 degrees apart. In the photograph at the right a clock face is reflected as two concentric image faces, one reversed and running counterclockwise and the other nonreversed and also running counterclockwise. The inner clock appears to be turned inside out.

motions near the torus boundary. Instead of annihilating each other, like enantiomorphic images on a bell mirror or a matrix mirror, the images flow together to form an extremely distorted image at the torus boundary. The reversed and nonreversed images of a single object combine to form a ring-shaped image; the ring is composed of parts of four images (two reversed and two nonreversed). The new images flow out of the original nonreversed image much as they do in multilobe mirrors.

The peculiarities of the torus mirror bring me to the point with which I shall end this examination of curved-mirror images. From the preceding discussion of compound mirrors it should be clear that reversed and nonreversed images differ in more than handedness. For example, all nonreversed images can rotate with respect to fixed objects, whereas their reversed counterparts are constrained to remain either upright or inverted. Moreover, although on bell and matrix mirrors reversed and nonreversed images are always affected equally by pair and double-pair creations and annihilations, on multilobe and torus mirrors a nonreversed image may divide into three new images (two nonreversed and one reversed), whereas its reversed mate remains intact.

Although images can be created and destroyed, reversed and nonreversed images always appear and disappear in equal numbers, even in the multilobe and torus mirrors. For a given compound mirror the number of reversed images minus the number of nonreversed images is a constant "magic number," no matter how many images exist altogether. For example, the five-by-five matrix mirror can give rise to 13 reversed images and 12 nonreversed images; its magic number is $13 - 12$, or 1. If the mirror is tipped so that four rows of five images each annihilate one another, five single images remain; three are reversed and two are nonreversed, so that the magic number still equals 1.

IMAGE REACTIONS on a toroidal mirror are demonstrated by the changing forms of a reflected hand. When the hand is moved over the mirror, the nonreversed image in the saddle-shaped region undergoes a complex exchange with the reversed image in the convex region. The exchange of one image for the other on the toroidal mirror is quite unlike the creation and annihilation of paired images on a bell-shaped mirror: on the torus the reversed and nonreversed images of a single object are not adjacent but are 180 degrees from each other.

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Frost on a windowpane photographed by Gera Dillon

THE AMATEUR SCIENTIST

The physics of the patterns of frost on a window, plus an easy-to-read sundial

by Jearl Walker

One of the delights of winter for me is the frost that decorates my windows. The crystals appear in a variety of shapes and designs. Some are long and rodlike; others mimic flowers. Each crystal has developed in the supercooled water condensed from the air near the window. Some unseen nucleating agent, such as a dust particle, initiated the process, starting with a single crystal and then spreading to cover an entire windowpane.

Which of the several possible shapes appears depends primarily on the temperature in the vicinity of the crystal, but the relation is not fully understood. Even a difference in temperature of a few degrees can be critical in determining the shape. Since several different forms can be seen growing on the same window, usually at different heights, the temperature must vary by at least a few degrees over the window. The frost photograph on the opposite page was sent to me by Gera Dillon, a professional photographer in Morin Heights, Quebec, who delights in the frost on his windows.

The basic ice-crystal structure is hexagonal. The plane of the hexagon is called the basal plane and the axis perpendicular to it the *c* axis. Three axes labeled the *a* axes pass through the sides of the hexagon. The ice on a window is birefringent when it is viewed along any direction that is not parallel to the *c* axis. The term refers to the fact that two different values for the index of refraction can affect light as it passes through the ice.

I explained the general properties of birefringent materials in this department for December, 1977. To summarize briefly, a birefringent material has a "fast" axis and a "slow" one. The index of refraction depends on how the light is polarized when it passes through the material. The index is higher if the light is polarized parallel to the slow axis and lower if it is polarized parallel to the fast axis.

Suppose linearly polarized light (light polarized along a single axis perpendicular to the ray) is directed through the birefringent material with its axis of polarization at an angle to both the slow and the fast axes of the material. The polarization can be separated mathematically into two components, one parallel to the slow axis and one to the fast. These two waves were in phase when they entered the material, but because of the different indexes of refraction they probably emerge with a different phase relation.

The result is that the emerging light probably has a polarization different from that of the incident light. The new polarization might still be linear but with the axis of polarization oriented differently. The emerging light could also be circularly or elliptically polarized, which means that the axis of polarization rotates about the light ray as the light passes.

If the emerging light encounters a polarizing filter, it may or may not pass through the filter, depending on the relative orientation of the polarization axis of the light and the polarization axis of the filter. Birefringent materials are often analyzed by being placed between two polarizing filters. Light passing through the first filter becomes linearly polarized. It then passes through the birefringent material and probably is changed in polarization. When it encounters the second filter, it is transmitted or absorbed according to the relative polarization of the light and the filter.

The change in the polarization of the light by the birefringent material depends on the indexes of refraction for the slow and fast axes, the thickness of the material and the wavelength of the light. If white light is sent through the two filters and the birefringent material, some wavelengths will emerge from the material polarized in such a way that they can pass through the second filter and be seen. Other wavelengths will not pass through. Although white light is directed into the first filter, only certain colors emerge from the second. If either of the filters or the birefringent material is rotated, the colors that emerge from the second filter shift.

Frost on a window can be analyzed in much the same way because ice is slightly birefringent. In order to see the colors put a polarizing sheet on each side of the frost-covered window. All the crystals with the proper thickness and orientation will contribute colors. The crystals with *c* axes parallel to the line of sight will not contribute, however, because such an orientation eliminates birefringence.

The colors from the frost can be seen without polarizing filters if some of the frost has melted into a pool at the base of the window. The light scattered from the sky can be strongly polarized by mechanisms I described here in January, 1978. If the window is illuminated with such light, the first filter is not needed. If the light passes through the frost and then reflects from the pool of water, the reflection can act as the second filter, because a reflection can polarize light. When you look into the pool, you see colored versions of the colorless frost patterns on the window above the pool.

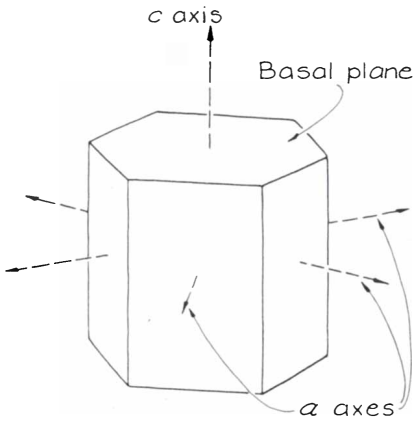
C. K. Sloan of Arapahoe, N.C., has designed an unusual type of sundial. Unlike many other types, his "analemmic sundial" is corrected for the effects of the declination of the sun and the latitude and longitude of the sundial. It can be read either in universal time or in the local apparent time ordinarily indicated by a sundial.

Sloan's sundial is a simple one: a vertical post casts a shadow onto a grid he has devised. In some versions of the sundial the grid is several inches across; in larger versions it measures as much as 75 by 150 feet. In any version the grid is beautiful, reminding me of ancient representations of the passage of the sun through the sky.

Many ordinary sundials employ a gnomon, or shadow-casting object, pointing obliquely at the celestial pole, the zenith of the sky over the geographical pole. The shadow is cast on a grid of lines extending from the base of the gnomon. When the sun is at its highest point of the day, the shadow falls directly below the gnomon on the noon mark, one of the radial lines extending from the base.

Although this garden variety of sundial is attractive, telling time with it calls for conversion tables and a little work. The dial is geared to the passage of the sun, not to a clockwork. The time read directly on a sundial is the local apparent time. When the sun is at its highest point, the local apparent time is noon. When the sun passes through an arc of 7.5 degrees in the sky, a half hour has elapsed.

The system is straightforward, but it presents at least two problems. One of them is that the local apparent time depends directly on the longitude of the sundial; sundials at different longitudes will differ in time. The other is that the length of an hour of local apparent time



The structure of an ice crystal

changes in the course of the year because of the shape of the earth's orbit around the sun. As a result the apparent speed of the sun across the sky differs with the passage of the months. Each hour of the local apparent time remains proportional to the sun's movement through an arc of 15 degrees, and so the length of an hour changes.

Another system of time, local mean time, is similar to local apparent time except that it is geared to the passage of an imaginary sun moving uniformly across the sky throughout the year. The uniform motion means that the length of an hour does not change with the passage of the months. The difference between the two systems of time is called the equation of time. Tables of the difference can be found in reference books devoted to the accurate timing of the stars and the planets.

During two periods of the year the sundial is said to be slow because its time lags behind the local mean time. During the other two periods of the year the sundial is fast. To convert the time given by a sundial in the slow period into the local mean time add the equation of time for that particular day to the local apparent time given by the sundial. In the fast periods the equation of time is subtracted from the local apparent time. This procedure requires, of course, ready access to a table of the equation of time. Moreover, the observer is still confronted with the problem that the local mean time is only local.

The time on a clock is usually "standard" or "daylight-saving" time. As is well known, the world is divided into time zones where regardless of the actual longitude of the clocks each clock keeps the local mean time for a certain meridian running through the zone. This special meridian is called the standard meridian for its time zone. The advantage of the system is that the time is the same for all clocks in a particular zone.

Converting the time read directly on a sundial (the local apparent time) into the time read on a clock (the standard time) calls for two operations. First the sundial's time must be converted into local mean time by using a table listing values for the equation of time. Then the local mean time for the sundial's location must be converted into the standard time for its time zone.

This second conversion amounts to determining the difference in longitude between the sundial and the standard meridian for the zone. If the sundial is west of the standard meridian, its local mean time will be late. The clock indicates noon when the imaginary sun passes over the standard meridian. Only later will the imaginary sun pass over the sundial. Hence the sundial's local mean time lags behind that of the clock. If the sundial is east of the standard meridian, its local mean time is ahead of the clock's. The greater the difference in longitude between the standard meridian and the sundial, the greater the discrepancy (four minutes of time for each degree of difference in longitude).

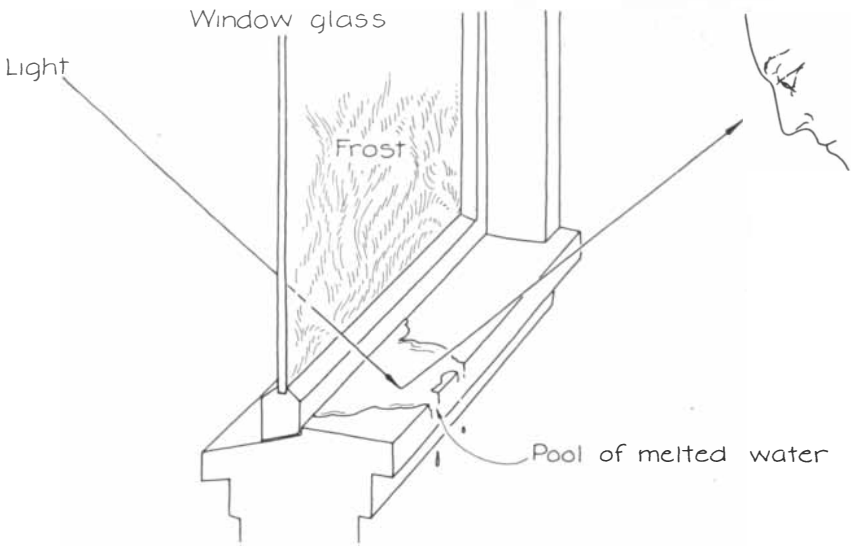
Attempting to read clock time from a common sundial can therefore be a tedious procedure. Sloan's design enables the observer to read the clock time directly from the sundial with no need for tables or further calculations. All the corrections are built into the design. Instead of having an oblique gnomon and following the rotation of the shadow around its base, Sloan has a vertical gnomon and follows the tip of the shadow. In the course of the day the tip of the shadow moves across the grid laid out around the post. Corrections for both the equation of time and the distance of the sundial from the standard meridian in its time zone are incorporated into the design of the grid.

The path of the tip of a vertical gnomon's shadow on a horizontal surface normally does not go directly from west to east as the sun passes through the sky. To determine the path Sloan erected a vertical gnomon and marked two key points near it. Due south of the gnomon, at a distance found by multiplying the height of the gnomon by the cotangent of the sundial's latitude, he marked what he called the ecliptic point. It is from this point that the radial lines, one line for each half hour of the day, were to be extended.

Sloan next determined another point (marked *N* in the top illustration on the opposite page) that was due north of the gnomon and at a distance consisting of the gnomon's height multiplied by the tangent of the latitude. Through this point he drew a straight line, called the equinoctial line, that ran east and west. The line is special because on the two days of equinox (March 21 and September 23) the tip of the shadow from the post travels along it. At noon on those days, when the sun is directly overhead, the shadow's tip falls at *N*.

In 30 minutes the earth turns 7.5 degrees, and the tip of the shadow moves along the equinoctial line by a distance equal to the tangent of 7.5 degrees multiplied by the secant of the sundial's latitude and by the height of the gnomon. Sloan marked off units of this distance on the line for half-hour intervals up to five hours before and after the noon point. He next drew radial lines extending from the ecliptic point (the point south of the post) to the half-hour marks. I shall call these lines the half-hour radial lines. Sloan could then read the time from his sundial for two days of the year: the two days of the equinox. On those special days the tip of the shadow first touched the west end of the equinoctial line and then traveled along the line, passing over the half-hour marks until it reached the noon point. Thereafter it continued along the line to the east.

I had originally thought the shadow would move in the same way on the rest



How to see color in a frost pattern

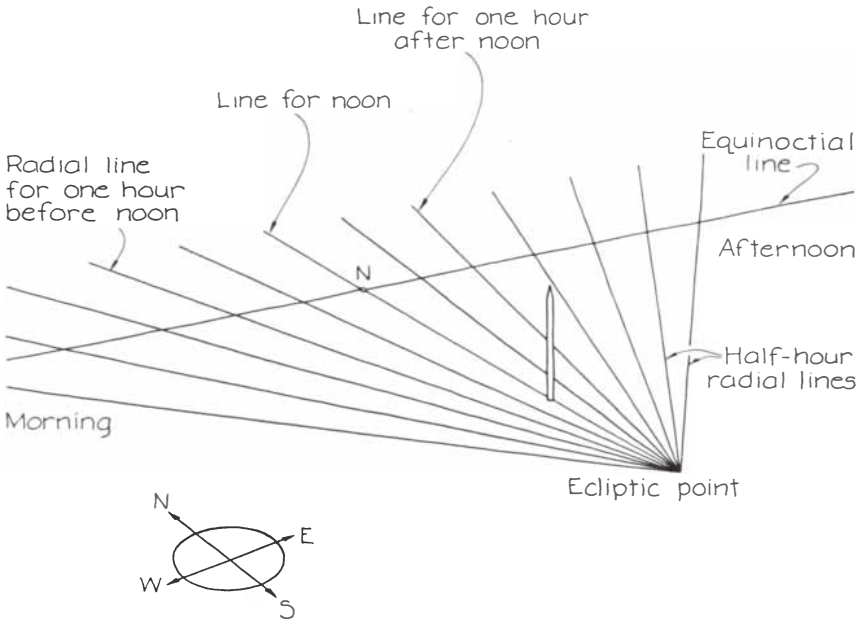
of the days in a year, but it does not. At other times the tip of the shadow falls north or south of the equinoctial line, depending on the season. More precisely, its distance from the line depends on the maximum height of the sun during the day. That height, which is commonly called the sun's declination, is taken to be zero on the equinoxes. In the fall and winter the declination is a negative number because the maximum height of the sun in the sky is relatively low. In the spring and summer the declination is positive because the maximum height is relatively high.

At each equinox the tip of the shadow falls at *N* on the equinoctial line when the sun reaches its highest point in the sky. In the fall and winter, since the declination is less than zero, the sun passes through its noon point lower in the sky and the shadow's tip falls north of the equinoctial line. In the spring and summer the shadow falls south of the equinoctial line and closer to the gnomon.

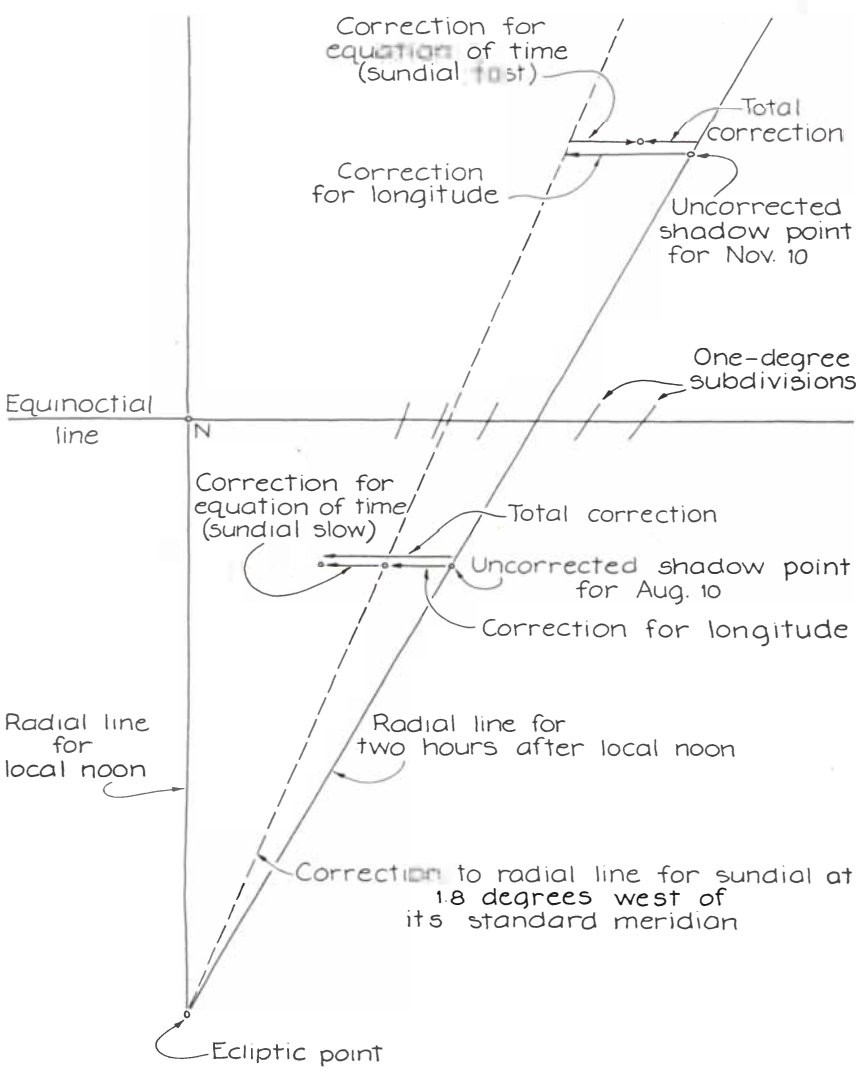
The calculations for the noon positions of the shadow's tip are easy. The distance from the gnomon is found by multiplying the height of the gnomon by the tangent of an angle equal to the algebraic subtraction of the declination of the sun from the latitude. In the spring and summer a positive value for the declination is substituted in the expression and then subtracted from the latitude. In the fall and winter a negative value is substituted, which means that the absolute value of the declination is actually added to the latitude because of a cancellation of negative signs.

The noon points for the shadow are easily determined in this way, but the half-hour points for the rest of the day are not. On an equinox the half-hour points fall on the equinoctial line, which is straight. On any other day of the year the shadow follows a curved path. In the fall and winter it begins the day toward the northwest, moves along a curved line toward the southeast until it reaches the noon point for that day and then continues toward the northeast along a curved line symmetrical with its morning path. The curved path in the spring and summer begins toward the southwest, moves to the northeast to reach the noon point and then curves to the southeast.

Sloan derived equations with which he could calculate the position of the shadow's tip for any time of the day and for any day of the year. With the results he could mark a grid around the post to indicate the local apparent time. I wrote a computer program to do the calculations for a sundial in the Northern Hemisphere. It is easily modified for one in the Southern Hemisphere. The program, which is shown in the illustration on page 238, is written in the computer language called Level II Basic for a Radio Shack TRS-80 home computer. (If you want a copy of the original equa-



A basic grid for a sundial



Corrections of shadow-point locations

tions, send a stamped, self-addressed envelope to me at the Physics Department, Cleveland State University, Cleveland, Ohio 44115. A table of the results of the computation for your latitude can be obtained from Sloan at Route 2, Box 236, Arapahoe, N.C. 28510. In addition he would like to hear how your sundial works out.)

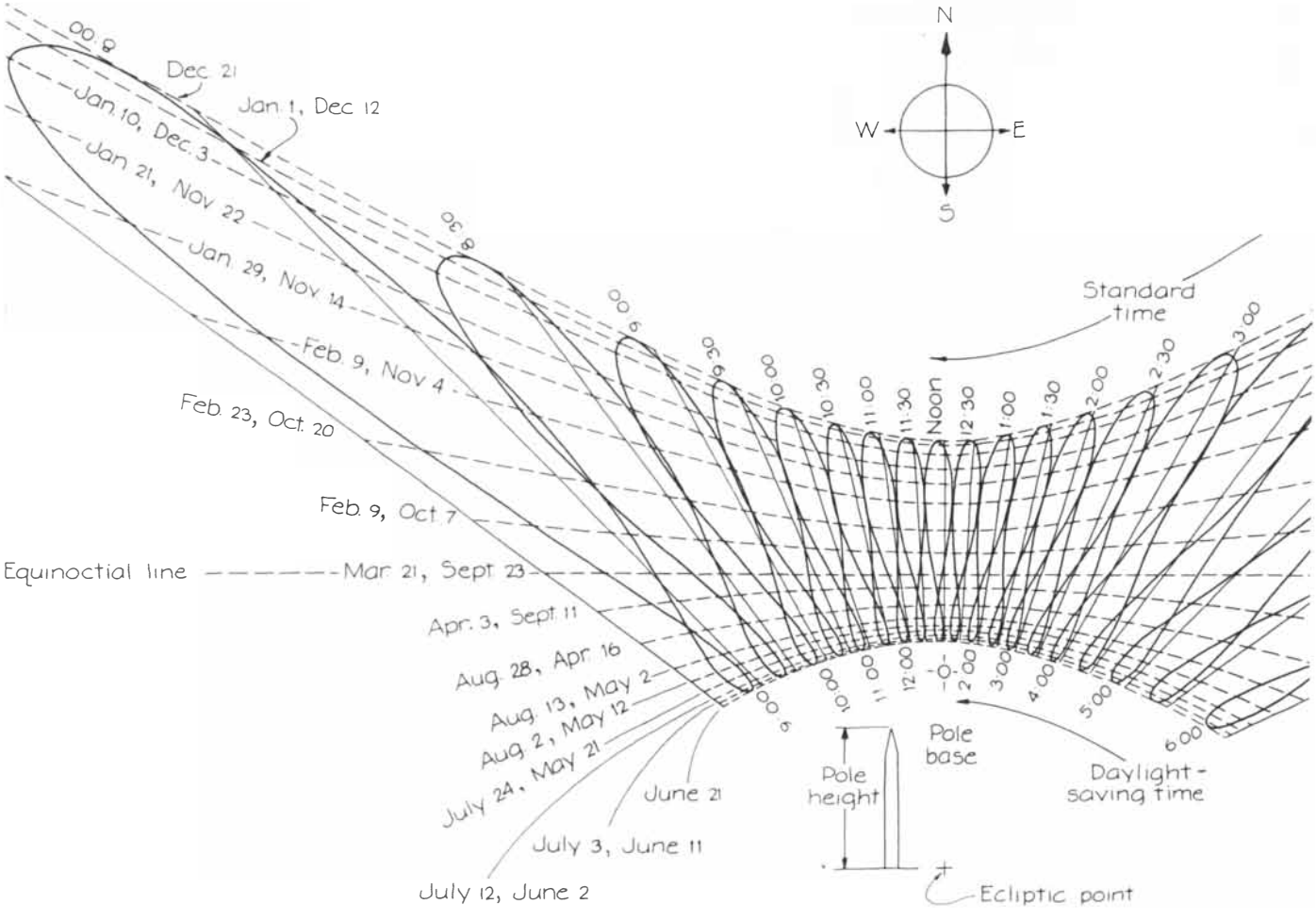
The program calculates the locations of the shadow points along the half-hour radial lines that extend from the ecliptic point. Line 10 contains the latitude of the sundial, which I took as 35 degrees north, and the height of the gnomon, which I took as one meter. (The quantity "RPD" converts degrees into radians, which is the unit required by the trigonometric functions farther along in the program.) When line 20 is reached, the computer asks me to enter a date and the sun's declination (in degrees) for that date. Lines 80 through 120 calculate the locations of the shadow points for 10 times before noon and for noon itself. Since the results will be the same for the equivalent times after noon, the locations are actually computed for 21 times of the day. (Some of the results will seem erroneous if you forget that in winter the sun rises late and sets early.)

Line 130 displays on the computer screen the time (in hours with respect to noon) and the distance (in meters) for the shadow-point locations. For convenience in plotting the results the distance is given with respect not to the ecliptic point but to the equinoctial line. For example, suppose that at a time of two hours before noon, that is, for a local apparent time of 10:00 A.M., the distance printed on the screen is .2 meter. I would mark the result on the radial line corresponding to 10:00 local apparent time. The point would be at a distance of .2 meter from the equinoctial line on the north side. A similar point would be marked on the radial line corresponding to two hours after noon, since the morning and afternoon patterns are symmetrical. If the distance indicated by the computer is negative, the point is to be marked on the south side of the equinoctial line.

I run the program to cover 34 days spaced approximately evenly through the year. Included are the days of the equinox (when the declination is zero) and the winter and summer solstices (when the declination is extreme). Following Sloan's instructions, I choose the days to achieve a total of 17 different declinations. Thus each date has a partner on which the sun has the same declination. For example, November 14 and January 29 both have associated declinations of approximately −18 degrees.

Plotting these results for the locations of the shadow points would in itself prove little. For any particular time of the day, say 2:00 P.M. local apparent time, I would plot the distances on the corresponding radial line extending from the ecliptic point. The position of the shadow point for June 21 would be closer to the ecliptic point than that for December 21. The other points would be plotted somewhere between these two extremes. Still, they would all be on the same half-hour radial line from the ecliptic. The resulting pattern would be similar to that of a common sundial.

The power of Sloan's sundial is evident when these shadow-point locations are corrected in two ways. First, for the conversion to local mean time they are corrected by the equation of time. Then for the conversion to standard time they are corrected for the difference in longitude between the sundial and the local standard meridian. Both corrections amount to a rotation of the shadow points around the ecliptic point.

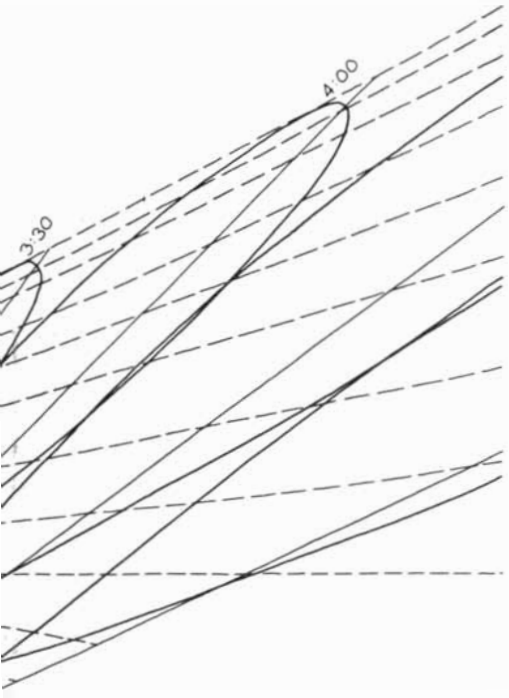


C. K. Sloan's pattern for an "analemmic sundial"

The program computes the total rotation to make the two corrections.

The second correction is a simple one. If the sundial is to the west of the standard meridian, its local mean time is behind the local mean time on the meridian; if it is to the east, its local mean time is ahead. The adjustment for the longitude is made in line 10 of the program, where "DL," the difference in longitude, is entered. I have imagined a sundial 1.8 degrees west of the standard meridian. For a sundial situated elsewhere the number must be changed. If the sundial is west of the standard meridian, the longitude difference is entered as a positive number. If it is to the east, the difference is a negative number.

The correction for longitude is easy because it is the same correction for all the shadow points on the grid. In my example for a sundial 1.8 degrees west of its standard meridian all the shadow points on the grid would be rotated about the ecliptic point by an angle of 1.8 degrees to the west. The appearance of the grid would be unaltered, since all the shadow points for any particular time would still lie in a straight line extending through the ecliptic. The only difference after this correction is that



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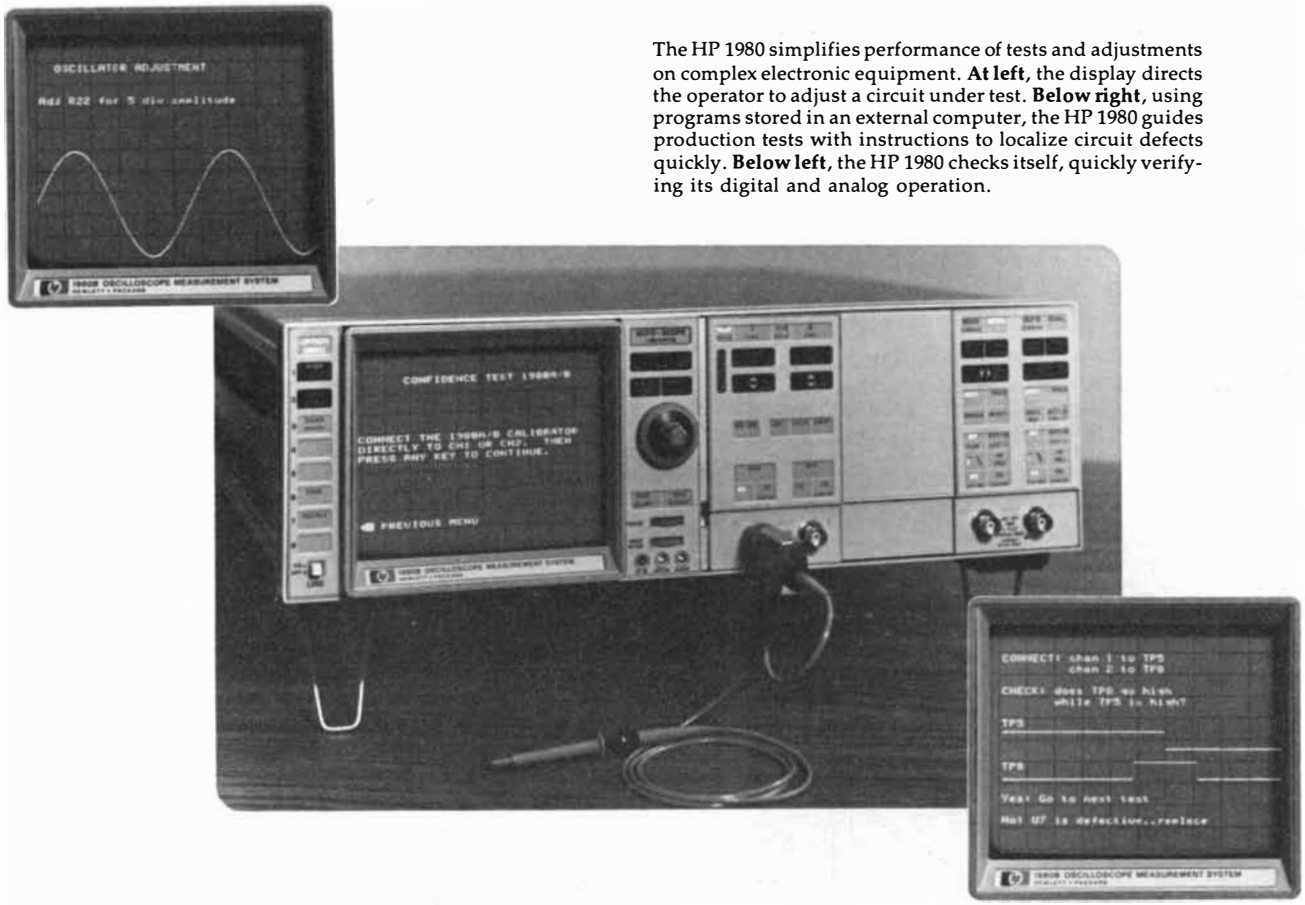

The HP 1980 simplifies performance of tests and adjustments on complex electronic equipment. **At left**, the display directs the operator to adjust a circuit under test. **Below right**, using programs stored in an external computer, the HP 1980 guides production tests with instructions to localize circuit defects quickly. **Below left**, the HP 1980 checks itself, quickly verifying its digital and analog operation.

The most obvious difference between the HP 1980 and conventional scopes is the front panel. The Hewlett-Packard system does away with the bewildering maze of knobs and switches scope users have had to master, and replaces them with a clean, logical array of color-coded keys and a single rotary control.

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- The simplified panel cuts setup time by as much as a factor of five. Front panel setups can be saved in the system's nonvolatile memory (they can't be lost even if the system is turned off), then recalled and implemented with only two keystrokes.

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If you are developing or manufacturing products that use electronics technology, you owe it to yourself to find out more about the HP Oscilloscope Measurement System. Price of the HP 1980 is $8500*.

enhance your skills?

For example: At Hoechst-Roussel, an HP 3000 computer system has helped cut the time it takes to complete a New Drug Application.

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Faced with this massive amount of data to enter, validate, and reduce, Hoechst-Roussel's Group Director of Research Systems, Dr. Krishan Arora, found most data handling solutions unsatisfactory. "We needed a local computer with power and flexibility, one that could provide efficient data entry as well as on-line data base processing and inquiry," says Dr. Arora.

The search finally led to an HP 3000 Series III computer system. In conjunction with a large, mainframe computer, the HP 3000 gives the Medical Research Department a powerful, easy-to-use tool for entering, editing, correcting, and reviewing the data that will later be analyzed on the mainframe.

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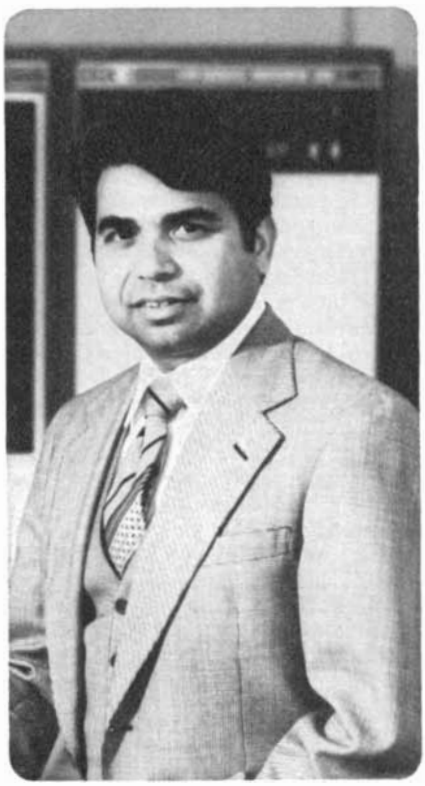

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the line is no longer one of the half-hour radial lines.

The entire pattern changes its appearance when the other correction is made, the one converting the sundial's local apparent time into its local mean time by means of the equation of time. Line 30 converts the equation of time into an angle: .25 degree for each minute of time. This angle and the longitude difference are displayed at the top of the computer screen. They are then combined and the total correction angle is shown. If the total is positive, the shadow points are to be rotated toward the west about the ecliptic. If the total is negative, the rotation is to be to the east.

Once the shadow points have been shifted according to the total correction angle the appearance of the pattern changes because the correction is different for each day of the year. (The daily difference comes from the equation of time, not from the longitude difference, which remains the same throughout the year.) Hence the shadow point for a particular time on a given day will shift in one direction from the half-hour line whereas the point for the same time on a different day will shift by a different amount or even in the other direction.

The result is both unexpected and pretty. If you draw a line through all the shadow points for any particular time of day, you see a distorted figure eight, an analemma. With this line you can tell the standard time on Sloan's sundial. Consider the analemma overlapping the noon line, which extends northward from the ecliptic. When the shadow tip passes the noon line, the local apparent time is noon. When the tip passes over the segment of the analemma corresponding to that day's date, the standard time (the time on a clock) is noon.

Each radial line from the ecliptic has an analemma. (If you make a small sundial grid, the pattern may be cluttered. Then you should draw an analemma around the radial lines corresponding to a full hour.) The local apparent time is read when the shadow passes a particular radial line, such as the one corresponding to 2:00 P.M. local time. When the shadow passes over the segment of the associated analemma corresponding to that day's date, the standard time is 2:00.

To make your own analemmic sundial first change the values for the latitude and for the difference in longitude that are listed in line 10 of my computer program. (Use positive for west and negative for east and enter both in units of degrees.) Also replace the value for *H* to correspond to the length of your gnomon (leave the value in units of meters). Then run the program. As the computer requests, enter a date and the solar declination (in degrees) for that date. Also enter the equation of time (in minutes) for that date and whether the sundial is fast or slow compared with the local mean time. Tables of average values for the declination and equation of time can be found in the delightful book on sundials by Albert E. Waugh cited in the bibliography on page 246. More precise values can be obtained from the *American Ephemeris and Nautical Almanac.*

The program displays on the screen the difference in longitude (in degrees), the equation of time (converted into degrees) and the total angle by which the shadow points are to be shifted for that date. Then it displays the date and two columns of figures: one column has the time (in hours with respect to noon) and the other has the corresponding location of the shadow point on the north side (positive result) or the south side (negative result) of the equinoctial line.

To plot the grid lay out the ecliptic point and the equinoctial line. Mark the half-hour points along the equinoctial line and draw radial lines through them from the ecliptic point. The basic sundial grid of half-hour radial lines is then finished. Next Sloan's modifications are to be made.

The distance between the radial lines represents half an hour, or 7.5 degrees of (apparent) rotation of the sun about the earth. Along the equinoctial line between the radial lines mark off units of one degree. Each unit will have a length equal to the tangent of one degree multiplied by the secant of the sundial's latitude and by the height of the post. These additional marks will help you to make the corrections of the shadow-point locations.

```
10 CLS : RPD = .01745 : L= 35.0 * RPD : DL = 1.8 : H = 1.0
20 INPUT "DECLINATION (DEG) ="; DECL : INPUT "DATE ="; A$
30 INPUT "EQUATION OF TIME (MIN) ="; ET : ET = ET * 0.25
40 INPUT "IS DIAL FAST OR SLOW"; B$ : D = DECL * RPD
50 IF B$ = "FAST" THEN ET = -ET
60 PRINT "DL ="; DL, "EQ TIME ="; ET, "TOTAL ANGLE ="; DL + ET
70 PRINT " ": PRINT "TIME (HRS)", "DIST (METERS)", A$
80 X = TAN (L) : F = 1/ COS (L) : G = X + 1/X : W = 1/ SIN (L)
90 FOR K = 0 TO 10 : C = K * 7.5 * RPD : B = TAN (C)
100 E = SQR ( (B * F) ↑ 2 + G ↑ 2) / G : J = 1/ (E * X)
110 A = ATN ( (G * E - J) / SQR (W ↑ 2 - J ↑ 2) )
120 Z = TAN (A - D) / TAN (A) : DIST = H * (Z - 1) * (G * E - J)
130 PRINT T, DIST : T = T + .5 : NEXT K : END
```

A computer program to calculate shadow-tip positions for a sundial in the Northern Hemisphere

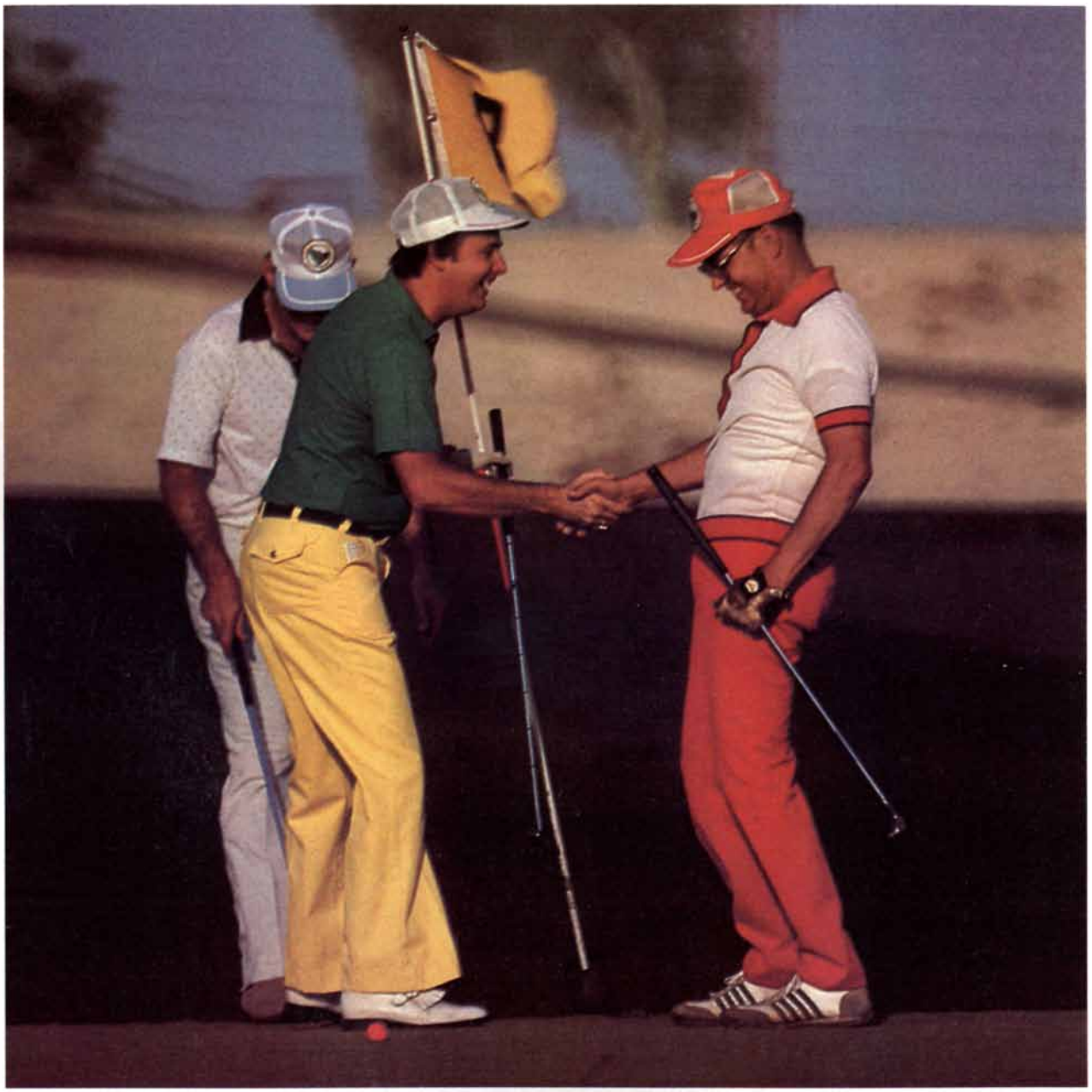
Run the program to cover 34 days of the year. Each run will yield a set of shadow points to plot on the grid, one point for each of the half-hour radial lines. Suppose that for the radial line corresponding to two hours after noon the distance is .2 meter on the north side of the equinoctial line and the total angle is two degrees to the west. The shadow point should be plotted on a line through the ecliptic point that is rotated two degrees to the west from the 2:00 radial line. Use the one-degree marks on the equinoctial line to find the correct place. On the rotated line (which is not drawn) the shadow point is .2 meter on the north side of the equinoctial line. Label the point with the date. All the shadow points plotted for that date will be shifted from the main radial lines by the same angle, so that the plotting goes quite fast.

After you have plotted the points for the 34 days draw an analemma for each of the half-hour radial lines. The grid for Sloan's analemmic sundial is then complete. The local apparent time is read from the half-hour radial lines, as would be done with a standard sundial. The standard time is read from the analemma that overlaps each radial line. If daylight-saving time is in effect, change the standard time by an hour.

The computations could be done with a pocket calculator, but they would take much more time. Readers skilled in a language for a home computer will be able to improve on my program. If analemmic sundials are to be designed for many locations, the values for declination and equation of time should be stored in the computer to eliminate the need for responding with the data when the computer needs it.

The appearance of the pattern varies with latitude in an interesting way. For places progressively closer to the Equator the half-hour radial lines become shorter because the sun is typically higher in the sky. The analemma overlapping each of the lines becomes a more perfect figure eight perpendicular to the equinoctial line. For the North Pole the pattern would be very different. (The pattern would of course be useful only for the spring and summer months, since the sun is not visible for the rest of the year.) The pattern is circular, with the noon radial line on one side and the corresponding line for midnight on the other side. The analemma consists of single loops instead of two.

Sundials similar to Sloan's were probably built long ago by the patient plotting of shadows rather than by calculations. I think it would be fun to mimic the ancients by building a huge sundial, rivaling in size the standing stones in Britain and France. Presumably the grid could be made accurate enough to incorporate the yearly changes in the declination of the sun and in the equation of time.



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5. Jim Burchett, center, birdied the 16th to beat Mike Ehlers and "Sib" Sibley.

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ARTICLES

MATHEMATICAL GAMES

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BIBLIOGRAPHY

Readers interested in further explanation of the subjects covered by the articles in this issue may find the following lists of publications helpful.

MATHEMATICAL GAMES

LET US NOW PRAISE PRIME NUMBERS. Helen Spalding in *An Anthology of Modern Verse 1940–1960,* edited by Elizabeth Jennings. Methuen & Co Ltd, 1961.

SEARCHING FOR THE 27TH MERSENNE PRIME. David Slowinski in *Journal of Recreational Mathematics,* Vol. 11, No. 4, pages 458–461; 1978–79.

A SEARCH FOR LARGE TWIN PRIME PAIRS. R. E. Crandall and M. A. Penk in *Mathematics of Computation,* Vol. 33, No. 145, pages 383–388; January, 1979.

INTERMEDIATE-RANGE NUCLEAR WEAPONS

THE 1977 ALASTAIR BUCHAN LECTURE. Helmut Schmidt in *Survival,* Vol. 20, No. 1, pages 2–10; January/February, 1978.

SALT AND THE NATO ALLIES. A Staff Report to the Subcommittee on European Affairs on Foreign Relations, United States Senate. U.S. Government Printing Office, 1979.

GALILEO'S SIGHTING OF NEPTUNE

THE GREAT UNEXPLAINED RESIDUAL IN THE ORBIT OF NEPTUNE. Dennis Rawlins in *The Astronomical Journal,* Vol. 75, No. 7, pages 856–857; September, 1970.

THE DISCOVERY OF NEPTUNE. Morton Grosser. Dover Publications, Inc., 1979.

MUTUAL OCCULTATIONS OF PLANETS: 1557 TO 2230. Steven C. Albers in *Sky and Telescope,* Vol. 57, No. 3, pages 220–222; March, 1979.

GALILEO AND SATELLITE PREDICTION. Stillman Drake in *Journal for the History of Astronomy,* Vol. 10, No. 28, Part 2, pages 75–95; June, 1979.

GALILEO'S OBSERVATIONS OF NEPTUNE. Charles T. Kowal and Stillman Drake in *Nature,* Vol. 287, No. 5780, pages 311–313; September 25, 1980.

THE COSMIC ASYMMETRY BETWEEN MATTER AND ANTIMATTER

OBSERVATIONAL TESTS OF ANTIMATTER COSMOLOGIES. Gary Steigman in *Annual Review of Astronomy and Astrophysics,* Vol. 14, pages 339–372; 1976.

THE FIRST THREE MINUTES: A MODERN VIEW OF THE ORIGIN OF THE UNIVERSE. Steven Weinberg. Basic Books, 1977.

MATTER-ANTIMATTER ACCOUNTING, THERMODYNAMICS, AND BLACK-HOLE RADIATION. D. Toussaint, S. B. Treiman, Frank Wilczek and A. Zee in *Physical Review D,* Vol. 19, No. 4, pages 1036–1045; February 15, 1979.

PLASMIDS

ON THE REGULATION OF DNA REPLICATION IN BACTERIA. François Jacob, Sydney Brenner and François Cuzin in *Cold Spring Harbor Symposia on Quantitative Biology,* Vol. 28, pages 329–348; 1963.

EXTRACHROMOSOMAL INHERITANCE IN BACTERIA. R. P. Novick in *Bacteriological Review,* Vol. 33, pages 210–263; 1969.

REPLICATION OF A BACTERIAL EPISOME UNDER RELAXED CONTROL. R. Rownd in *Journal of Molecular Biology,* Vol. 44, No. 3, pages 387–402; September 28, 1969.

INFECTIOUS MULTIPLE DRUG RESISTANCE. Stanley Falkow. Academic Press, 1975.

ON PLASMID INCOMPATIBILITY. Richard P. Novick and F. C. Hoppensteadt in *Plasmid,* Vol. 1, No. 4, pages 421–434; September, 1978.

CONTROL OF PLASMID R1 REPLICATION: FUNCTIONS INVOLVED IN REPLICATION, COPY NUMBER CONTROL, INCOMPATIBILITY, AND SWITCH-OFF OF REPLICATION. Søren Molin and Kurt Nordström in *Journal of Bacteriology,* Vol. 141, No. 1, pages 111–120; January, 1980.

EARLY MAN IN SOVIET CENTRAL ASIA

GUIDEBOOK/INTERNATIONAL SYMPOSIUM ON THE NEOGENE-QUATERNARY BOUNDARY. Edited by A. E. Dodonov, Y. R. Melamed and K. V. Nikiforoba. Nauka, 1977.

KARATAU I—DREVNEYSHIY PALEOLITICHESKIY PAMYATNIK V LESSAKH SREDNEY AZII (KARATAU I—THE OLDEST PALEOLITHIC SITE IN THE LOESSES OF CENTRAL ASIA). A. A. Lazarenko and V. A. Ranov in *Byulleten' Kommissii po Izucheniyu Chetvertichnogo Perioda,* No. 47, pages 45–47; 1977.

NAKHODKI PALEOLITA V DREVNIKH POGREBENNYKH POCHVAKH YUZHNOGO TADZHIKISTANA I IKH GEOLOGICHESKAYA POZITISIYA (PALEOLITHIC FINDS IN ANCIENT BURIED SOILS OF SOUTHERN TADZIKHISTAN AND THEIR GEOLOGICAL POSITION). A. E. Dodonov, V. A. Ranov and A. V. Pen'kov in *Byulleten' Kommissii po Izucheniyu Chetvertichnogo Perioda,* No. 48, pages 86–102; 1978.

TOWARD A NEW OUTLINE OF THE SOVIET CENTRAL ASIAN PALEOLITHIC. V. A. Ranov and R. S. Davis in *Current Anthropology,* Vol. 20, No. 2, pages 249–270; June, 1979.

ADDICTIVE BEHAVIOR

A MEDICAL TREATMENT FOR DIACETYLMORPHINE (HEROIN) ADDICTION. Vincent P. Dole and Marie E. Nyswander in *Journal of the American Medical Association,* Vol. 193, No. 8, pages 646–650; August 23, 1965.

METHADONE PLASMA LEVEL: SUSTAINED BY A RESERVOIR OF DRUG IN TISSUE. Vincent P. Dole and Mary Jeanne Kreek in *Proceedings of the National Academy of Sciences of the United States of America,* Vol. 70, No. 1, page 10; January, 1973.

DRUG INTERACTIONS WITH METHADONE. Mary Jeanne Kreek, Chai Leng Gutjhar, Jane W. Garfield, David V. Bowen and Frank H. Field in *Annals of the New York Academy of Sciences,* Vol. 261, pages 350–371; December 10, 1976.

METHADONE TREATMENT IN NARCOTIC ADDICTION: PROGRAM MANAGEMENT, FINDINGS, AND PROSPECTS FOR THE FUTURE. Robert G. Newman in collaboration with Margot S. Cates. Academic Press, 1977.

THE ESCAPE SYSTEM OF THE COCKROACH

RESPONSES OF GIANT INTERNEURONS OF THE COCKROACH *PERIPLANETA AMERICANA* TO WIND PUFFS OF DIFFERENT DIRECTIONS AND VELOCITIES. J. Westin, J. Langberg and J. Camhi in *Journal of Comparative Physiology,* Vol. 121, pages 307–324; 1977.

THE ESCAPE BEHAVIOR OF THE COCKROACH *PERIPLANETA AMERICANA,* II: DETECTION OF NATURAL PREDATORS BY AIR DISPLACEMENT. J. Camhi, W. Tom and S. Volman in *Journal of Comparative Physiology,* Vol. 128, pages 203–212; 1978.

MIRROR IMAGES

THE AMBIDEXTROUS UNIVERSE: LEFT, RIGHT, AND THE FALL OF PARITY. Martin Gardner. New American Library, 1969.

THE LEFT HAND OF THE ELECTRON. Isaac Asimov. Doubleday & Co., Inc., 1972.

GEOMETRY. Harold R. Jacobs. W. H. Freeman and Company, 1974.

THE AMATEUR SCIENTIST

AN EFFECT OF POLARIZED SKY LIGHT. S. G. Cornford in *Weather,* Vol. 23, No. 1, page 39; January, 1968.

SUNDIALS: THEIR THEORY AND CONSTRUCTION. Albert E. Waugh. Dover Publications, Inc., 1973.

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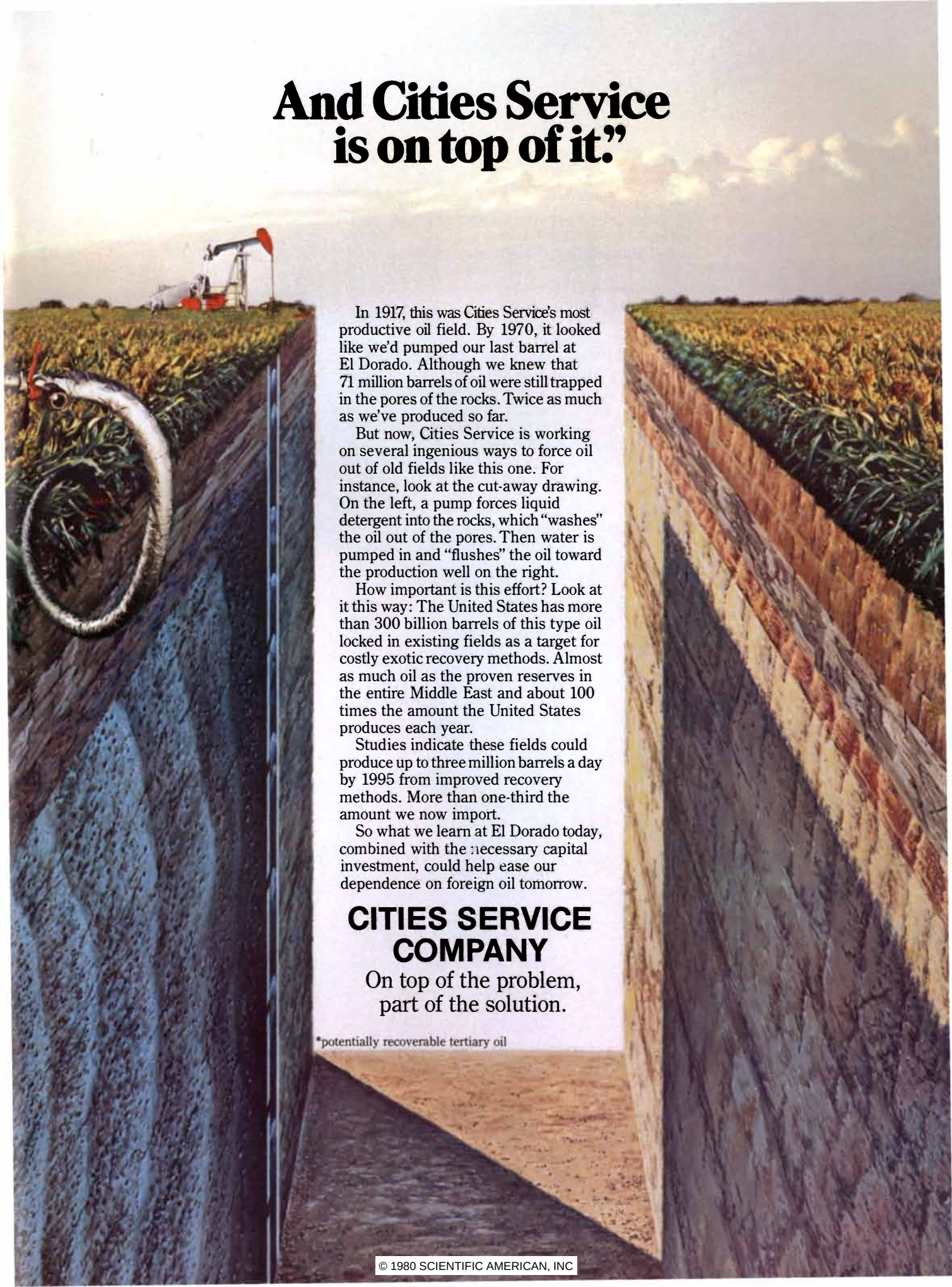

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