SCIENTIFIC AMERICAN

EXPLODING WIRE

FIFTY CENTS

May 1962

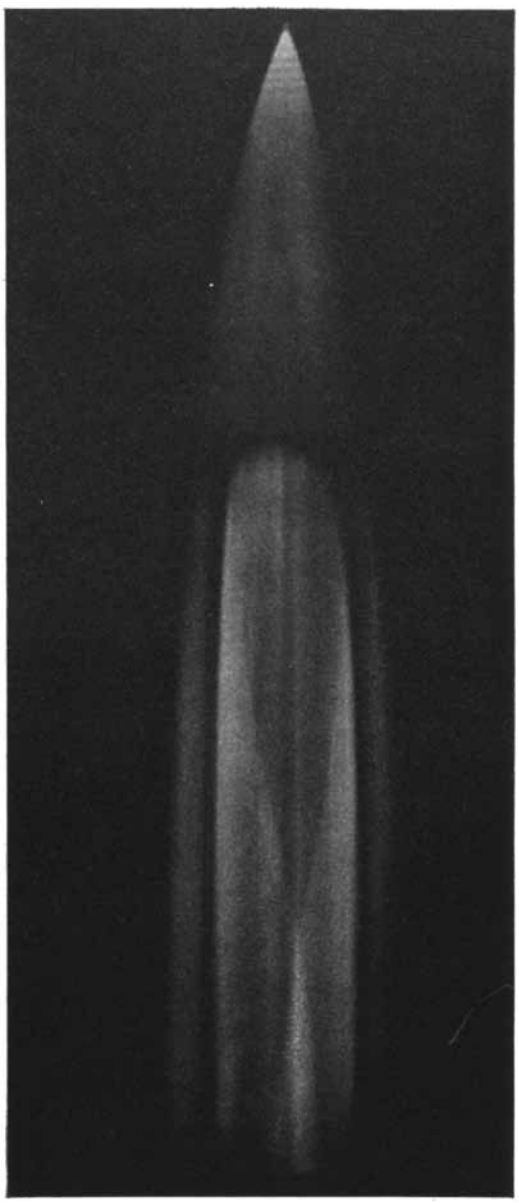
IBM® engineers set out several years ago to find a faster, simpler way of using electricity to put words on paper.

They began their search by forgetting the past fifty years of typewriter design.

The machine they developed is a new kind of typewriter, the IBM SELECTRIC. It has no type bars, no moving carriage. A metallic sphere no larger than a golf ball skims across the page, printing characters faster than the eye can see. To change type styles, you merely slip one typing element off, click another into its place. The IBM engineers even found a way to make the typewriter jam-proof through a unique stroke storage system that remembers one character while another is being printed.

Development of the SELECTRIC began with questions instead of preconceptions. Whether designing better typewriters or advanced computer systems, IBM applies this same approach to help businessmen and scientists solve information-handling problems.

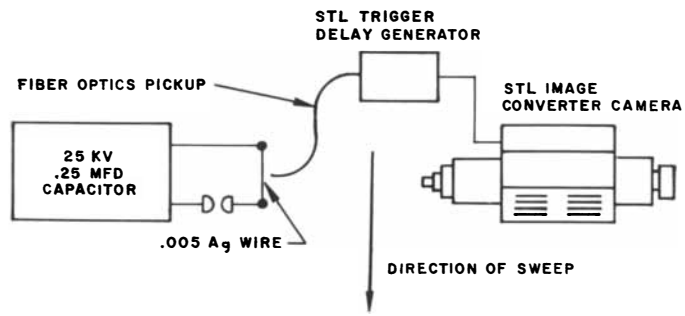
EXPLODING WIRE PHENOMENA SHOWN BY STL IMAGE CONVERTER CAMERA



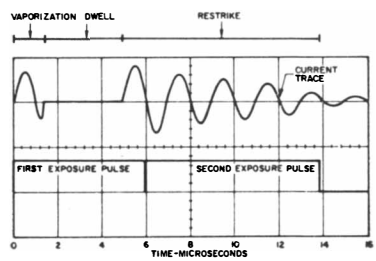
The complete history of the diverging and converging cylindrical shock waves is shown in this composite streak photograph of an exploding silver wire. This experiment was photographically recorded by the STL Image Converter Camera utilizing the Wide Range Streak Unit. Light amplification is required to properly record the shock fronts of the initial phase because of the low level of luminosity. Since the restrike phase is three orders of magnitude brighter than the initial phase, separate photographs were taken of each phase and correlated on a dual beam oscilloscope as shown on the accompanying diagram.

Analysis of this photograph shows that the dwell begins approximately 1.4 microseconds after the beginning of the luminosity. This point is indicated by the change of slope due to the velocity change when the shock wave is no longer driven by the electrical current.

The internal shock waves generated during the re-strike phase can be clearly seen in the lower part of this photograph. Recent exploding wire research has developed several theories to explain the behavior of these shock waves.



Copies of "Exploding Wire Driven Shock Waves," a paper presented at the 2nd Annual Exploding Wire Conference, are available upon request.



The STL Image Converter Camera provides scientists a highly flexible diagnostic tool wherever high speed luminous transients are being studied. The image converter tube, in conjunction with STL's new concepts for generating fast rising precision voltage pulses, provides the following specifications:

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STREAK OPERATION	—writing times from 50 nanoseconds to 10 microseconds.
LIGHT GAIN	—50 X
DOMESTIC PRICE	—$20,000 F.O.B. Los Angeles

A demonstration of the STL Image Converter Camera at your facility may be arranged by writing W. J. Schenck, P.O. Box 45738A, Westchester Station, Los Angeles 45, California.

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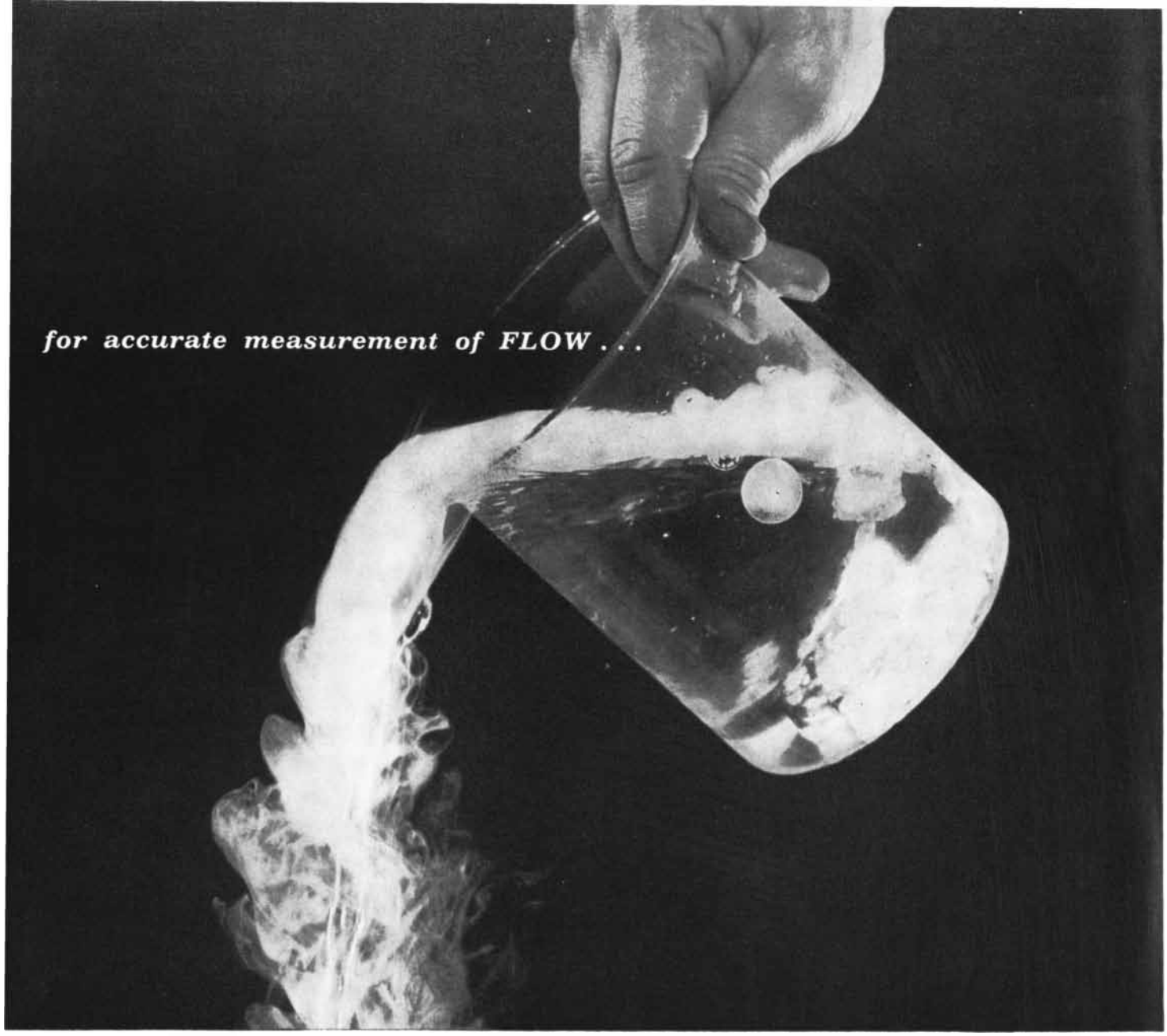

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INSTRUMENT DEPARTMENT

GENERAL ELECTRIC

Established 1845 **SCIENTIFIC AMERICAN** May 1962 Volume 206 Number 5

ARTICLES

DEPARTMENTS

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THE COVER

The photograph on the cover shows the explosion that accompanies a large burst of electrical energy in a copper wire (see "Exploding Wires," page 102). The camera that made the photograph contains a spinning mirror that spreads out on the film the image of a narrow section of the wire, making a record through time of the wire's expansion in space. The color fringes, produced by an interferometer in the camera, represent density changes in the material of the wire and in the argon gas around it. The gas is at a pressure of one atmosphere. Lower pressures radically change the patterns of the bright "tip" and of other features. The outer edges of the wedge are made by the primary, or "head," shock wave moving rapidly outward. The brownish area near the axis of the wire is the expanding wire material, within which a second shock wave can be seen propagating inward.

THE ILLUSTRATIONS

Cover photograph by Frederick D. Bennett, D. D. Shear and C. W. Cullum, Ballistic Research Laboratories, Aberdeen Proving Ground

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54–55	National Aeronautics and Space Administration (*left*), James Egleson (*right*)
56–57	James Egleson
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59–61	James Egleson
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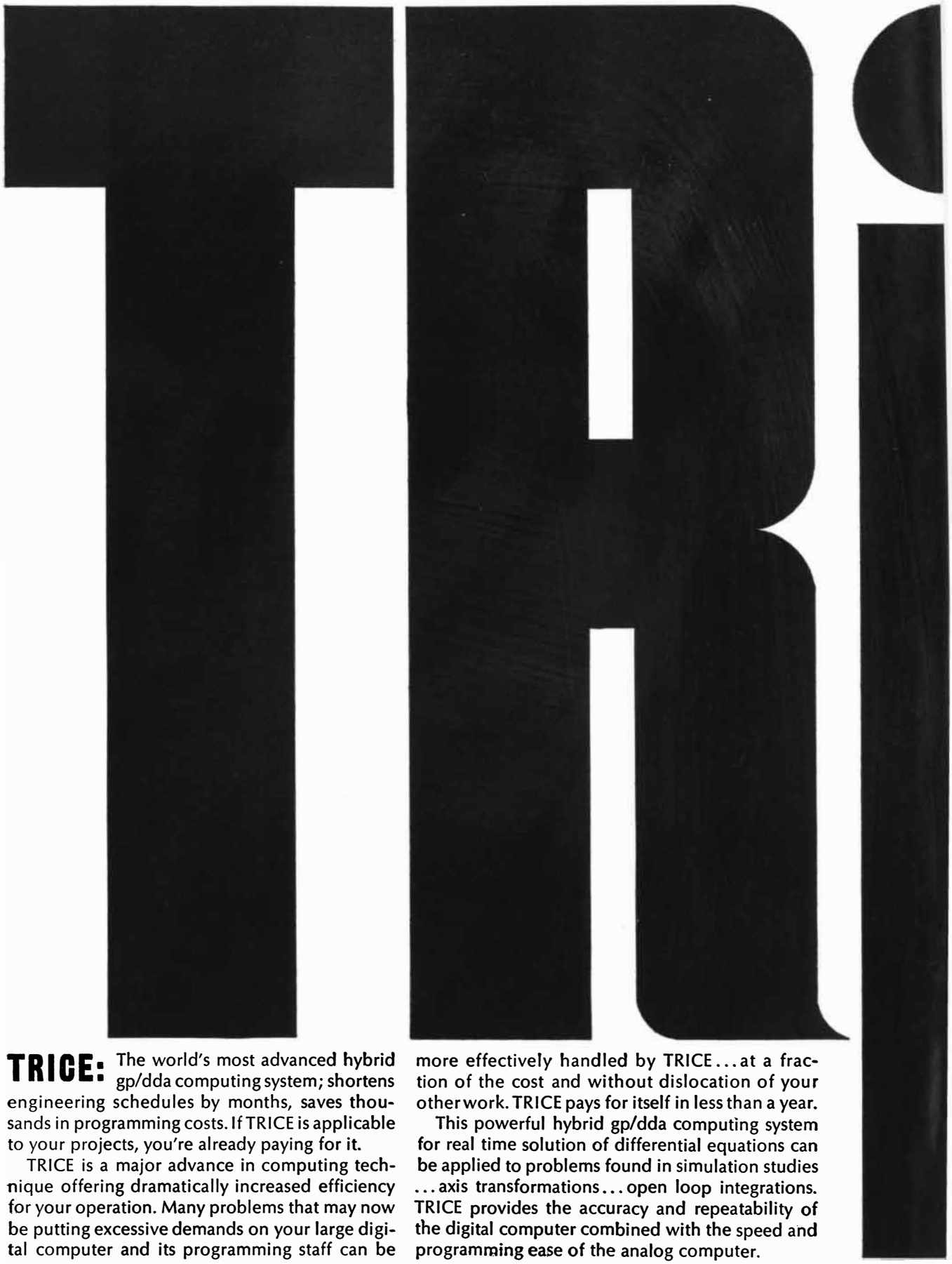
158	Rex Whistler from *¡OHO!*, published by The Bodley Head Ltd.
160	Private collection, New York
162–166	Thomas Prentiss
172–182	Roger Hayward

FIRST TITAN HARDBASE GOES OPERATIONAL. The nation's first Titan ICBM hardbase is now operational at Lowry Air Force Base, Colorado. It is rugged enough to survive and retaliate from a near hit by a nuclear bomb. It is the forerunner of many similar underground launch sites now being readied to serve with the Strategic Air Command as guardian of world peace.

Martin Company, the aerospace division of Martin Marietta, designed and built Titan for the U. S. Air Force and is the integrating contractor for Titan hardsites.



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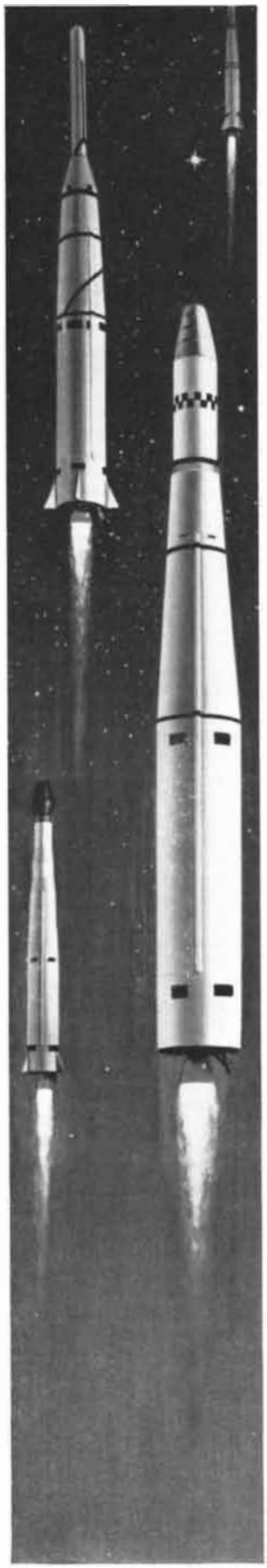


Thor sets 95% reliability record in 1961 space shots

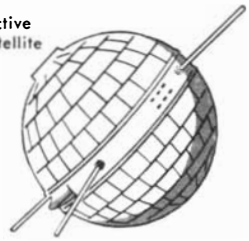
Douglas-built "Workhorse of the Space Age" launches more U.S. satellites than all other boosters combined!

To orbit any satellite, its launching vehicle must operate faultlessly. That's why Thor is such a favorite among space experts.

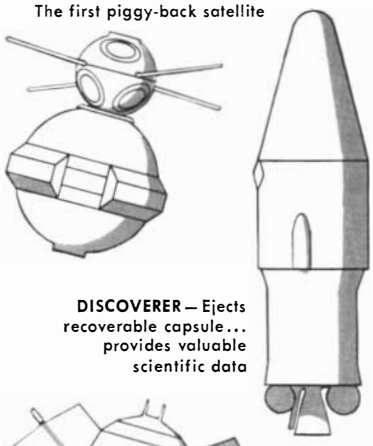
Thor has provided a perfect boost toward orbit for 3 Pioneers, 34 Discoverers, 2 Echos, 1 Courier, 3 Explorers, 6 Transits and 4 Tiros. Satellites launched by Thor have traveled well over 3½ billion miles.

Now an improved Thor is ticketed for even greater space-work. As an integral part of the NASA Thor-Delta program, also a Douglas project, the new Thor will launch a variety of man-moons...including solar observatories and active communications units. Among these will be the United States' first experimental active communications satellites, Relay, Syncom and Telstar.

Thor is an example of how Douglas carries a giant space systems program through design, manufacture and test and follows through to insure outstanding performance.

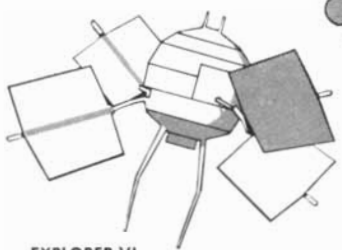


COURIER I-B — Active communications satellite



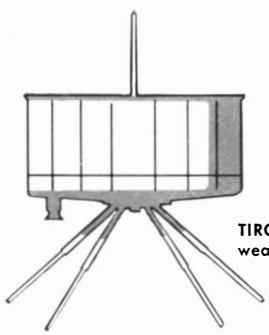
TRANSIT II-A AND GREB — The first piggy-back satellite

DISCOVERER — Ejects recoverable capsule... provides valuable scientific data

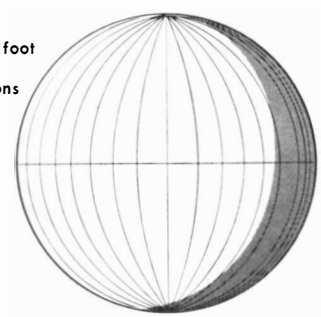


EXPLORER VI — Paddle-wheels utilize solar power

TRANSIT I-B — The first navigational satellite



TIROS I — Picture-taking weather satellite



ECHO I — 100 foot high passive communications satellite

Above are some of the satellites launched toward successful orbit by the Douglas Thor.

DOUGLAS

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New approaches to problems in technical measurement...

Minute electrical impulses previously unstudied or undependable as information because they were buried in high amplitude background noise take on new significance when they are put through the CAT computer. A four-input, digital computer of average transients, the CAT picks repetitive signals out of noise (even when ratios are as low as 1:100), stores them in its memory, averages them and displays the averaged signal for analysis — or sends them on to readout devices. This singular research instrument is the development of Mnemotron Corporation, a subsidiary of Technical Measurement Corporation.

The CAT computer shows promise in many applications in biological and physical research. For instance, it is used to measure and compare simultaneously evoked responses from different regions of the brain . . . to obtain time histograms of nerve action potentials . . . to single out faint communication signals for identification. The CAT can be used virtually anywhere that "signal-in-a-haystack" conditions exist.

As with the CAT, all Technical Measurement Corporation instruments represent progress in the realm of technical measurement. In nuclear research, for instance, the TMC family of pulse analyzers include the only 256-channel system with a choice of seven plug-in logic circuits; the most portable 400-channel pulse height analyzer available, and the world's first production 4096-channel time-of-flight analysis system. In telemetry, another TMC subsidiary, Telemetrics, Inc., provides reliable ground station equipment for military and space exploration installations.

If you are interested in the remarkably wide application possibilities of the CAT, write the Mnemotron Corporation, Pearl River, N.Y. If your problems are in the realm of nuclear research or telemetry, contact Technical Measurement Corporation, North Haven, Connecticut.

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1938

Entered electronics field with development of one of first radio control systems for drones.

1941

Developed "Gibson Girl" emergency radio transmitter, destined to save lives of many World War II pilots downed at sea.

1949

Introduced first high pressure hydraulic system for submarines.

1952

Introduced first integrated missile hydraulic system.

1955

Developed completely self-contained telemetry system for Atlas ICBM and associated nose cones.

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This year Bendix-Pacific celebrates its 25th anniversary...25 years of pace-setting achievements symbolized by those which are noted above. These and other Bendix-Pacific achievements have consistently demonstrated the "imagination plus" of Bendix-Pacific...the driving creative curiosity coupled with experience in depth which has made

ENGINEERING LEADERSHIP
FROM BENDIX-PACIFIC

1946

Participated in early "Bumblebee" missile program with development of subsonic and supersonic beam riders.

1947

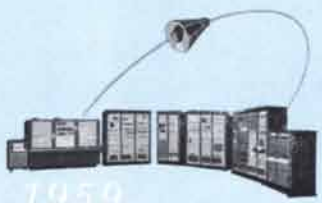
Entered sonar field with development of depth recording equipment for Navy.

1948

Participated in development of active radar homing guidance system for missiles.

1957

Developed first airborne scanning sonar.



1959

Selected as member of team to develop 18 worldwide ground instrumentation and tracking systems for Project Mercury.

1961

Occupied new Electronics Center, an advanced complex including largest indoor sonar test tank.

Bendix-Pacific a leader in the fields of Airborne Radar, Data Handling, Guidance, Hydraulics/Pneumatics/Electro-Mechanics, Military Navigation, Oceanics and Telemetry. For information on how Bendix-Pacific "imagination plus" can go to work for you in any of these fields, call or write Bendix-Pacific Division, North Hollywood, California.

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LETTERS

Sirs:

I greatly enjoyed Raymond Bloch's article "The Etruscans" [SCIENTIFIC AMERICAN, February]. The passages on their underground tombs reminded me of a recent visit to Pompeii.

When Pompeii was being excavated some years ago, a workman suggested that when a pick made a hollow noise, they should proceed cautiously, drill a small hole in the cavity and fill it with liquid cement. From this came (in some cases) almost perfect models of the human body in its position at the moment of death—complete even to the facial expression.

One of the sites I visited is known as The House of the Mysteries. In this house there is a subcellar of spacious proportions. When Vesuvius erupted, four men went down into the cellar. They were provident, wise citizens; they took with them jugs of water and (proving their wisdom) plenty of wine.

Everything worked splendidly in their shelter—except that they were killed very quickly by the noxious gases that accompanied the eruption. From the expression on the face of one of them, I should guess that all four were totally surprised. I give you this experience of mine for what it is worth.

BARKLIE MCKEE HENRY

Rome

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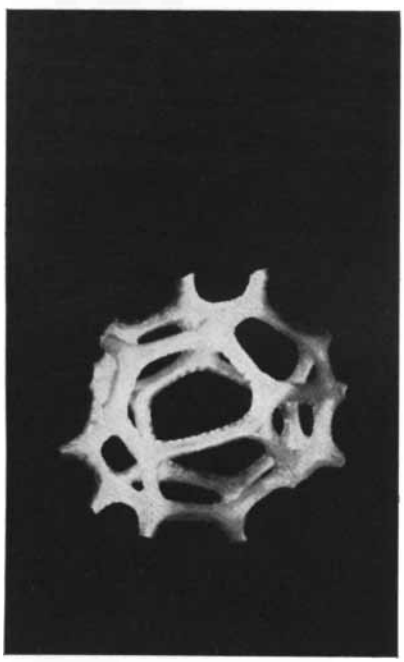
News from Allied Chemical:

A roundup of new developments which proves that, despite intervening "ages" of electronics, nucleonics and space, the Age of Plastics is still very much with us.



Urethane foam pore, magnified many times

What's with the urethanes today? Applications can now be numbered by the thousands. Some of the newer ones: lining for an astronaut's helmet, "shoes" for walking on water, marine finishes with double the life of spar varnish, sprays for reducing freeze-thaw cycles on concrete underpasses. In brief, urethanes are very much on the march, and Allied Chemical is a leading producer of basic urethane chemicals: Nacconate® Diisocyanates, Actol* Polyethers, and Genetron® Blowing Agents . . . and leader in the chemistry and commerce of urethane applications.

Polypropylene progress. Everybody's designing with polypropylene these days—and small wonder. Never before has a single thermoplastic combined so many valuable properties at reasonable cost. But, like all new plastic engineering materials, it presents new problems to designers and molders. To meet this need, Allied's Plastics Division has set up a type of technical service unmatched, we believe, by any other plastics supplier. Actually three services in one, it comprises an Applications Engineering Group, Field Technical Service Engineers, and Applications Research and Engineering. So if you or any of your friends are working with polypropylene, we suggest you remember the name Plaskon®. Plaskon polypropylene means top-quality product plus the help you need in working with a new engineering material.

Million-molecular-weight polyethylene. You may be able to tear a telephone book—but you can't tear a 1/16″ sheet of AC-X Polyethylene. This high-density polyethylene has a molecular weight of one to three million—is the strongest ever developed. AC-X exhibits exceptional toughness, high impact strength and abrasion resistance, as well as long-term resistance to fatigue. In the Bell stress test, compression-molded AC-X Polyethylene rates "no failures at any time." Perhaps *your* technical people should evaluate it. Samples and data sheets are readily available from our Plastics Division.

Boom without bust. Melamine plastic dinnerware is a booming business these days—due in large part to exciting new colors and patterns. Designs range from simple to intricate, from classic to contemporary. No "bust" is anticipated, for melamine plates and cups are virtually unbreakable. Allied doesn't make dinnerware; our job is supplying Plaskon Melamine.

Wrapping up a roundup. Our plastics roundup concludes with Aclar* and Capran*—not a vaudeville team, but two new packaging films for wrapping the hard-to-wrap. Both stem from our General Chemical Division. Aclar is a fluorohalocarbon—a clear, tough film with virtually zero moisture absorption. It protects products against oxidation and is unaffected by almost all chemicals, solvents, and oils. Capran is a polyamide (nylon) film, with strength approaching 10,000 psi. It defies heat, shrugs off cold, scoffs at fats and oils. Heat-sealable, Capran takes printing without pretreatment.

For literature on any of the above-mentioned items, just write on your company letterhead to Allied Chemical Corporation, Dept. SA-5, 61 Broadway, New York 6, New York.

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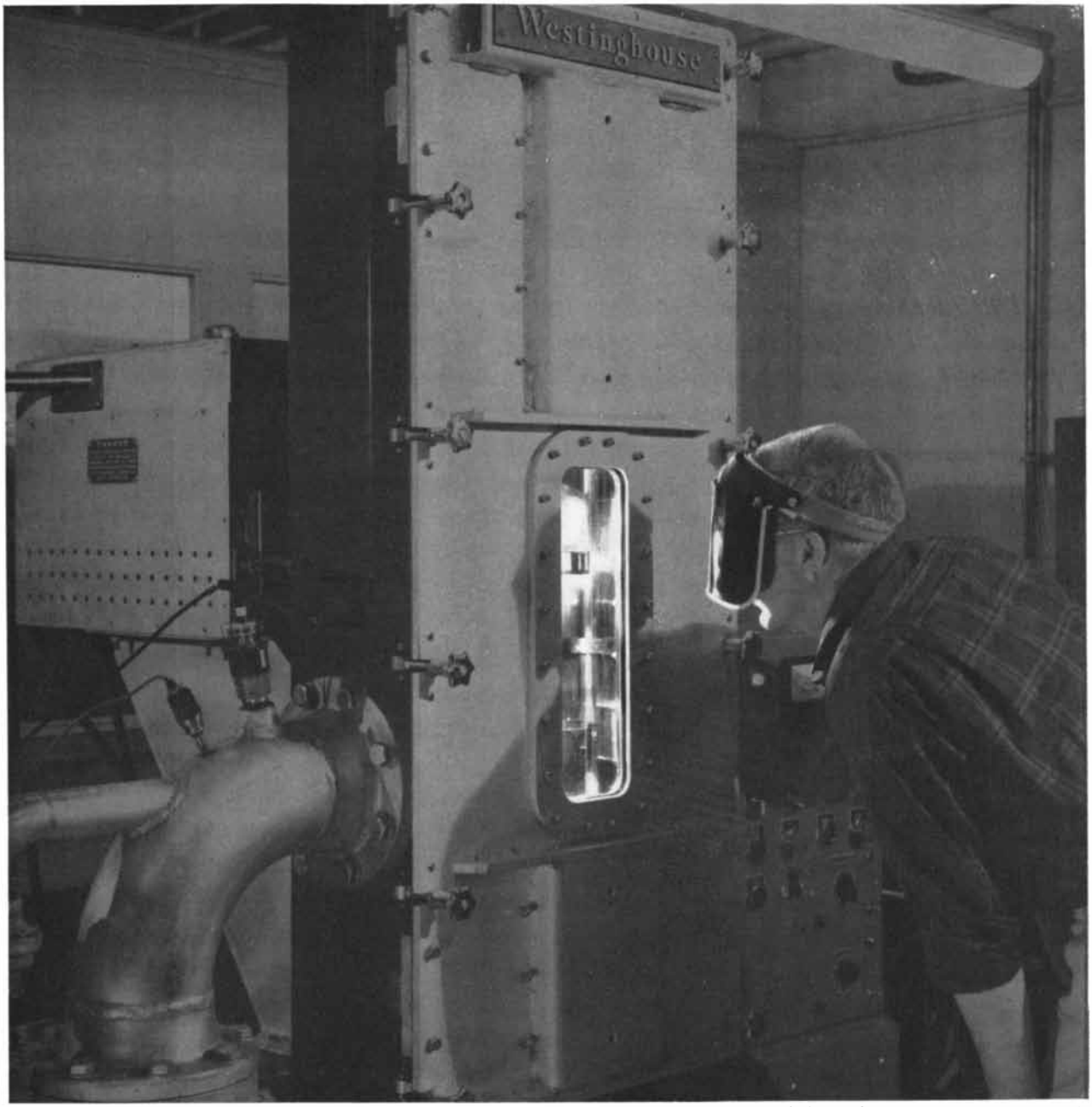

Zone refining ¼ inch tungsten rod at 3400°C.

New Floating Zone Scanner Refines Tungsten, Iron, Silicon

Ultra-pure metals and semiconductor materials are now zone refined in vacuums up to 10^{-6}mm of Hg. with a new Westinghouse scanning fixture. The unit employs induction heating techniques to heat the molten zone, and support it, when necessary, by levitation.

The scanner is designed to handle high-temperature metals with melting points up to 3500°C. It can be operated with gas atmosphere or vacuum. To insure satisfactory vacuum operation, magnetic drives are used to eliminate dynamic seals.

The apparatus is capable of processing rods up to 1½ inches in diameter, and 24 inches in length. For semiconductor work, 10Kw at 4Mc. is normally used. For other applications, the material to be processed and the rod size will dictate power level and optimum frequency. In all cases, the heating coil is positioned within the vacuum chamber.

This allows close coupling between the coil and the work to minimize zone length and obtain maximum levitation.

For further information on this advanced new zone refining equipment, contact Industrial Electronics Department, 2519 Wilkens Avenue, Baltimore 3, Md.

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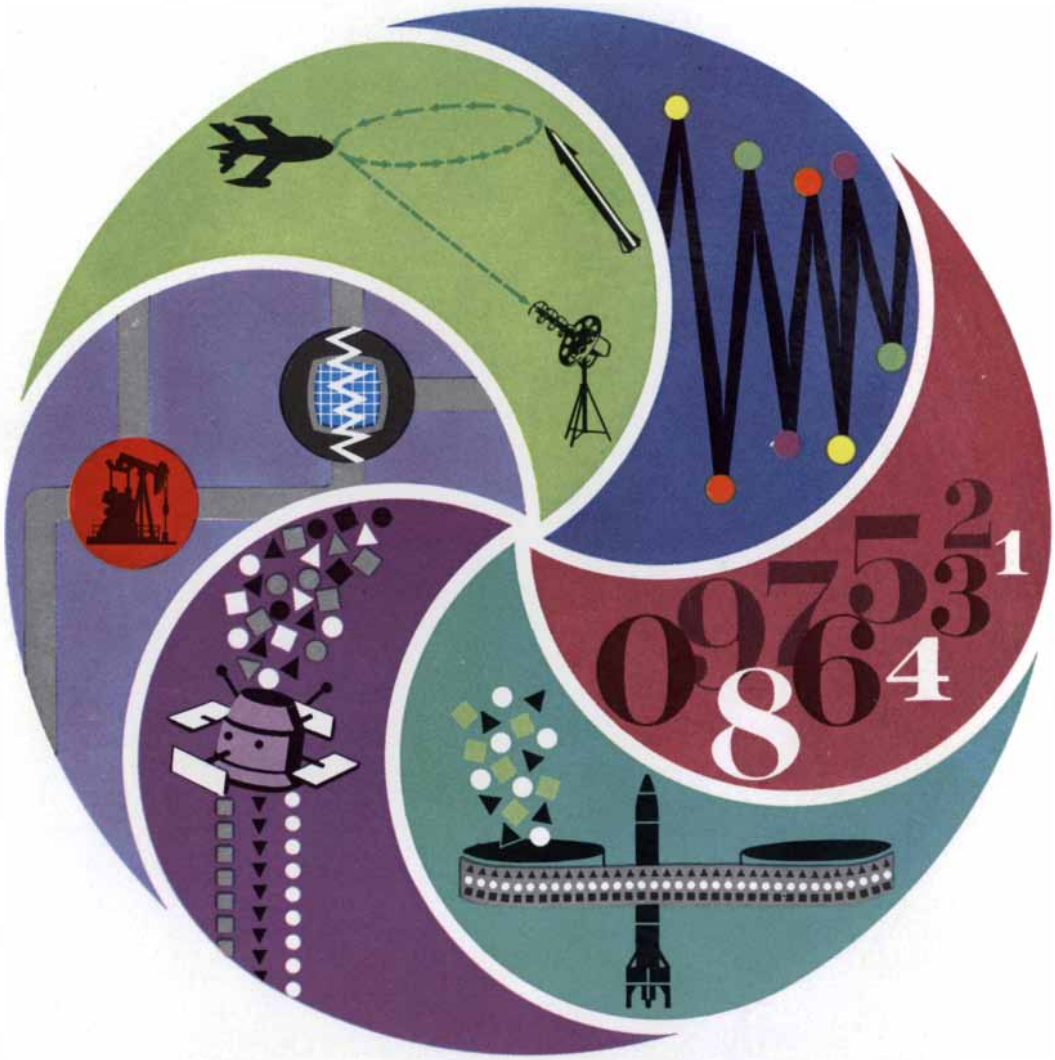

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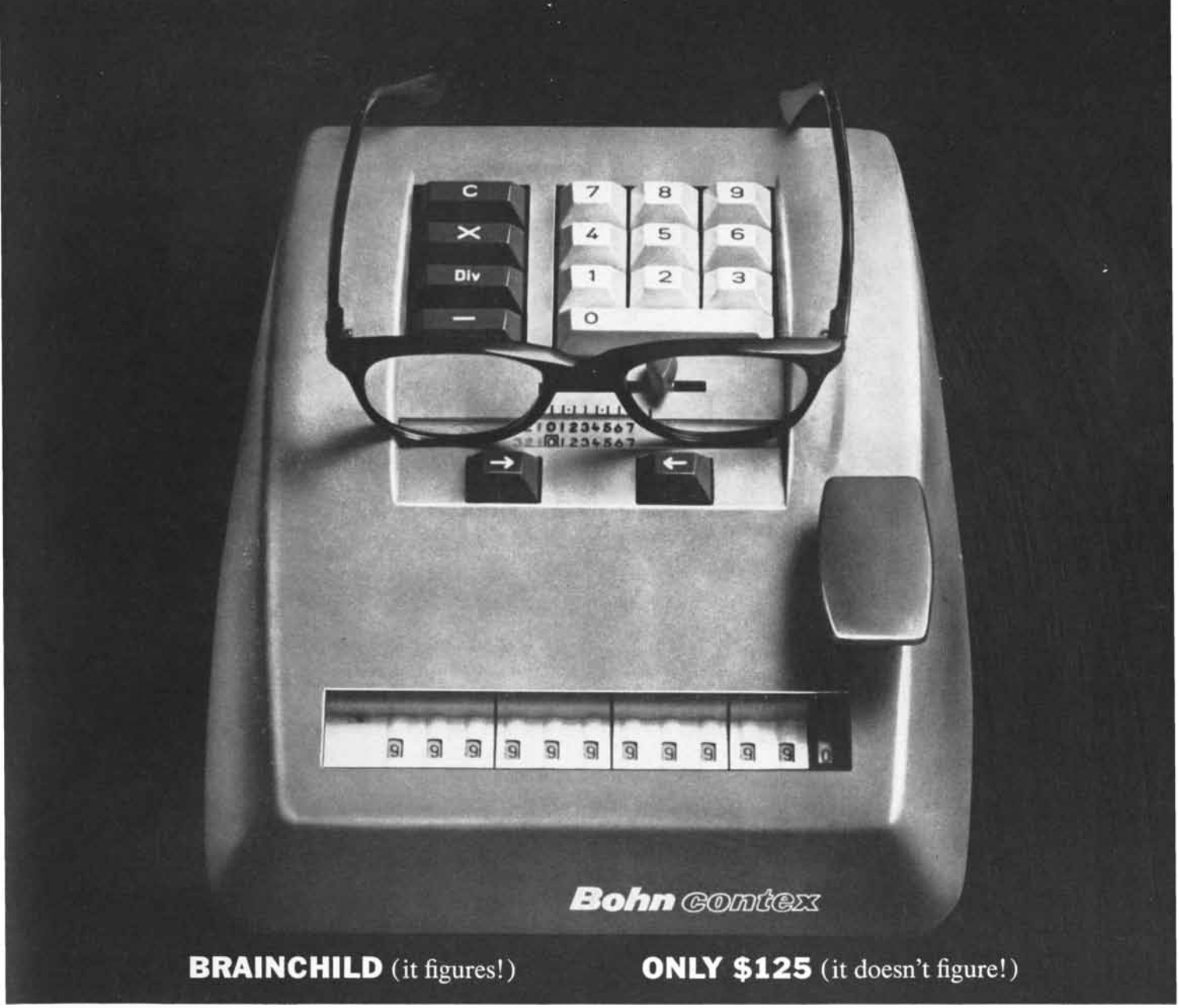

BRAINCHILD (it figures!) **ONLY $125** (it doesn't figure!)

This smart little machine weighs only six pounds, yet does just about everything the big, expensive machines do...and a couple of things they can't.

The big machines add, subtract, multiply, divide.

So does the Bohn Contex.

Here's what the expensive calculators *can't* do.

They can't double as high-speed 10-key adding-subtracting machines.

The Bohn Contex can.

They can't be operated by anyone after just a few minutes instruction.

The Bohn Contex can.

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Businessmen, salesmen, engineers, architects, students, housewives find the Bohn Contex the easiest, fastest way to figure bills, invoices, percentages, extensions, estimates, income tax.....All this for **$125***

For hour-after-hour use, the Bohn Contex *Electric*. Same size, same features, but greater speed and ease because the motor does the work.....Only **$235***

To a businessman who pays $500 to $1,000 for an office calculator, the price of our Brainchild seems too good to be true. Our suggestion: *borrow a Bohn Contex and see how it figures to save you money*. Any dealer listed below will lend you a hand (or electric) model. If the dealer in your city is not listed, or you're not in a borrowing mood, just mail the coupon.

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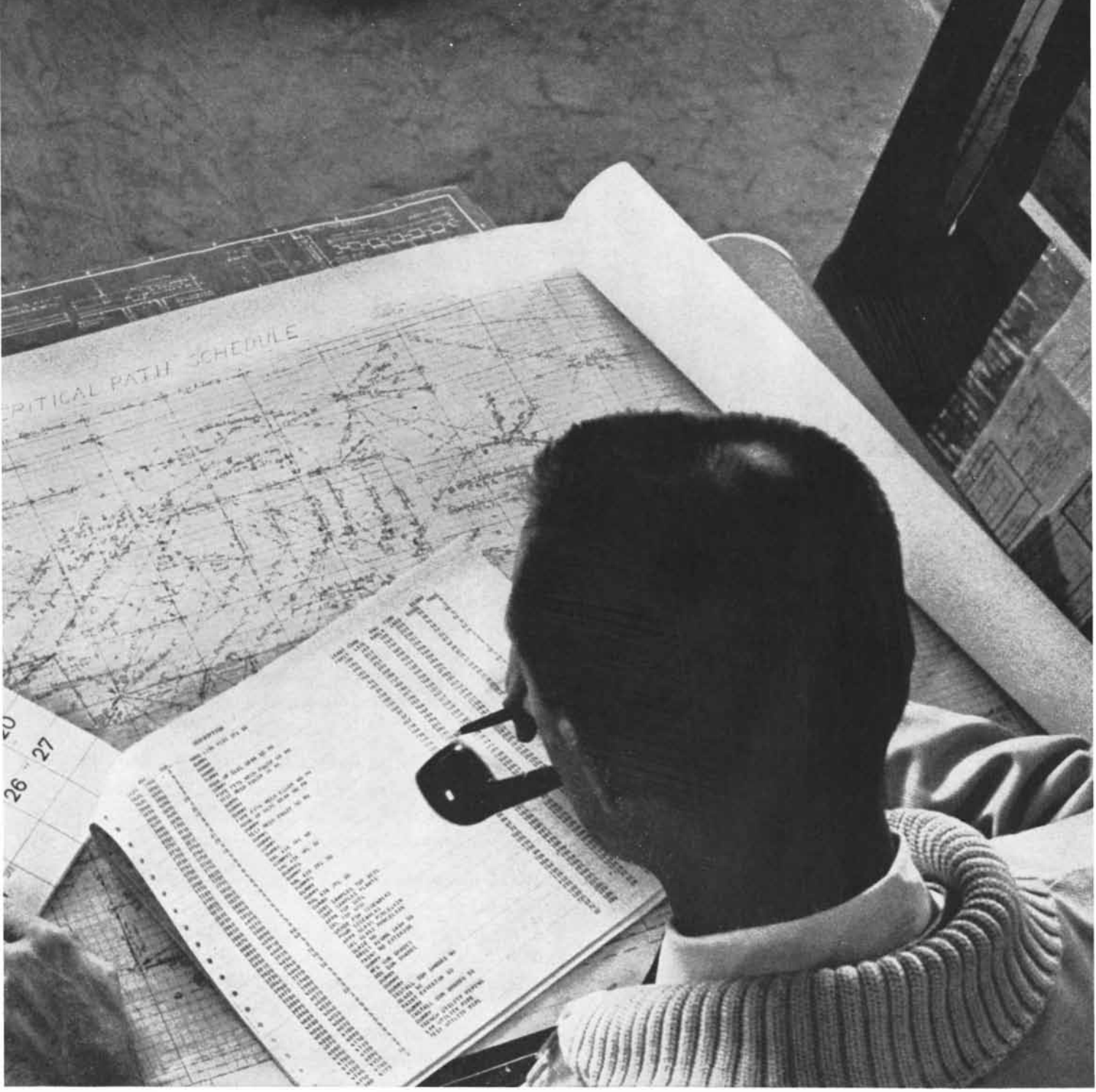
Atlanta, DeKalb Office Equip.; Tidwell Co. **Bakersfield,** Valley Office Supply **Baltimore,** Lucas Bros. **Billings,** Western Office Equip. **Boise,** Kalbus Office Supply **Boston,** Thorp & Martin **Bridgeport,** Frank McGuire **Buffalo,** Office Automation **Charleston, S.C.,** Fred Johnson Inc. **Chicago,** Horder's; Benbow **Cincinnati,** Pounsford's **Columbus,** Dorsey's General Office Equip. **Dallas,** S. L. Ewing **Denver,** Kistler's **Des Moines,** Berry-Myron **Detroit,** Macauley's **Eugene,** Clary Bus. Mach. **Fresno,** Stanton Office Mach. **Houston,** Maverick-Clarke **Indianapolis,** Rex. Bus. Mach. **Jacksonville,** Frank Coar Agency **Kansas City,** Kansas City Loose Leaf **Lancaster, Pa.,** Weaver Book Store **Lansing,** Hasselbring **Los Angeles,** Office Machines Inc.; Long Beach, California Calculator; Sherman Oaks, Valley Stationers **Louisville,** Fetter's **Memphis,** S. C. Toof **Miami,** Accurate Bus. Mach. **Milwaukee,** Clark Bus. Mach. **Minneapolis,** Farnham's **Newark,** New Jersey Office Supply **New Orleans,** Amann Bus. Mach. **New York,** Mineola, L. I., D. Waldner **Ogden,** Weber Office Supply **Palo Alto,** Delmer Israel **Pasadena,** Anderson Typewriter **Philadelphia,** Pomerantz **Phoenix,** Heinze, Bowen & Harrington **Pittsburgh,** Milton Wiener **Portland,** Oregon Typewriter **Raleigh,** Business Machines Inc. **Rochester,** Dunphrey Duplicating **Sacramento,** David's Office Equip. **St. Louis,** Von Soosten & Co. **Salem,** Needham's **Salinas,** Peninsula Typewriter **Salt Lake City,** Salt Lake Desk **San Bernardino,** Stockwell & Binney **San Diego,** Nelson Bus. Mach. **San Francisco,** Quality Office Mach. **San Jose,** Kennedy Bus. Mach. **Santa Barbara,** Lund Office Equip. **Savannah,** Chatham Typewriter **Seattle,** J. K. Gill & Lowman-Hanford **Springfield, Mo.,** Carroll Typewriter **Tucson,** Tucson Office Supply **Washington, D.C.,** Ginn's, Stockett-Fiske **Wichita,** Wilbur E. Walker **Wilmington,** Hilyard's **Winston-Salem,** Hinkle's **In Canada,** Scandinavian Bus. Mach., Montreal

"Don't worry about that late delivery

How does he know? When the supplier called him about the delay, he checked his critical path schedule and found that the delivery was for an activity not in the critical path . . . a delivery that could be delayed without affecting the project's completion date.

Building a bridge? Doing routine plant maintenance? Starting a research and development project? Planning a data processing installation? Critical path scheduling can help *you* do it better, faster, right from the planning phase; gives you continuous, timely reports that identify potential problem areas; lets you simulate effects of alternate decisions; lets you know whether you are meeting your deadlines.

Like to know more? Call your local IBM Representative.



.we'll still finish on time"

xamine all the activities in your ject. Prepare a logical network, n add time estimates, and punch information into cards.

■ Use one of the several programs IBM supplies at no additional cost. Programs are available for single or multiple time estimates.

■ Quickly, the computer checks all possible paths through your network, and prints out a detailed report that shows the critical path.

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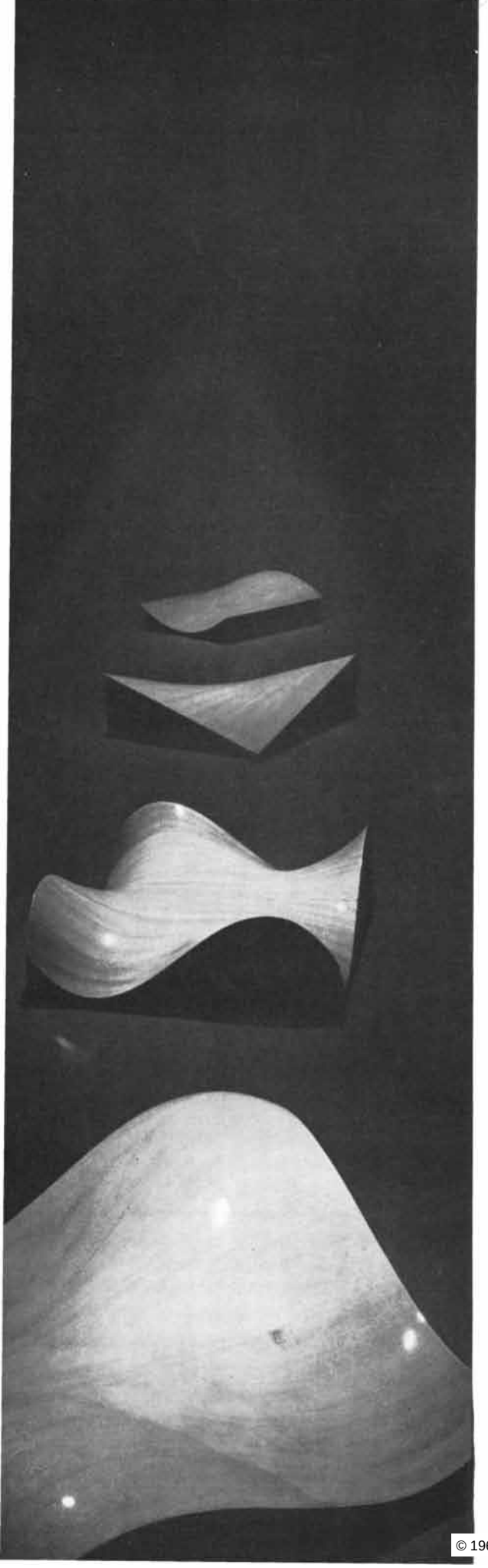

One of a series

Interpolation: the mathematical art of reading between the lines

It begins with the problem "Given certain isolated points: What is happening in between?" Men from Napier and Newton have then proceeded to discover formulas for the most probable in-between points.

Recently mathematicians at the GM Research Laboratories have been looking at new ways to interpolate in three-dimensional space. As a result they've come up with a fresh approach to the mathematical representation of surfaces. It is called *smooth surface interpolation.*

Their new interpolation formula is the sum of twelve terms. Each term corresponds to a way you can deform an elastic plate by bending or twisting its corners. (Four of the ways are shown in our illustration.)

To develop a surface, those isolated points in space are first fitted with a crisscross network of curves using a 3-D extension of shipbuilders' spline interpolation. Each rectangular element of the network can then be interpolated with the new formula so it will join smoothly and without a ripple to adjacent elements. Result: a completely smooth surface. A continuously differentiable surface.

A distinct contribution to mathematical theory, this work has suggested a host of related techniques *and* potential applications to our new advanced mathematics group. We think it typical of General Motors' constant effort to seek and find—A BETTER WAY.

General Motors Research Laboratories

Warren, Michigan

SULPHUR helps to create headline products

FAST ON TARGET

...through the aid of Polysulphide Fuels

From the earliest days of our missile program solid fuels have been very much in the picture—with the polysulphides playing a leading role all the way. Today's successful NIKE HERCULES Defense Missile and SERGEANT Attack Missile are excellent examples of the types using polysulphide solid propellants. Motors for these missiles are produced by Thiokol Chemical Corporation. The need for sulphur in these fuels is important—a need that cannot be satisfied as well by any other element or by any compound.

It was no casual compliment paid to Sulphur when industry labeled it 'One of the Four Pillars of Processing.' Sulphur plays a part—directly or indirectly—in so many new products that reach the headlines. The policy of TGS, as the leading producer of Sulphur, by both Frasch Mining and Gas Reduction, is to maintain ample stocks of both solid and molten sulphur to meet industry's requirements—and to set up and supply sectional distribution terminals for molten sulphur.

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MAY, 1912: "In the matter of safeguards against foundering at sea the *Titanic* was not so well provided as her famous prototype, the *Great Eastern*, of over 50 years ago. Indeed, we do not hesitate to say that, in the extent of her double-hull construction, in the most important question of the height of the top of the bulkheads above the water line, and in the provision of longitudinal subdivision, the great ship of the year 1858 was immeasurably superior to the boasted product of our ever boastful 20th century."

"Dr. Walter O. Snelling, consulting chemist of the Bureau of Mines and of the Panama Canal Commission, now doing laboratory work in Washington, has developed a liquid gas of which a little steel bottle will carry enough to light a house for a month. Snelling puts 2,000 feet of gas into a steel container four feet high and six inches in diameter. This follows from the fact that Snelling gas has a calorific power somewhat over four times that of ordinary coal gas. As commercially prepared, the gas consists chemically of about 50 per cent liquid ethane, 40 per cent liquid propane and 10 per cent liquid butane."

"Christian Laden, a Norwegian explorer, has returned to this country with what he believes to be the first evidence of the fate of Salomon August Andrée's balloon. At a point 200 miles north by west of the place at which it has been generally believed Andrée perished, Laden encountered a tribe of Eskimos, who related a story to the effect that several years ago a large bubble fell from the heavens, containing two creatures supposed to be 'devils' and who were able to hurl forth fire and thunder from strange implements that they carried. The members of the tribe attacked the two creatures and succeeded in killing one of them with arrows, whereupon the other made motions to them signifying that he and his companion were shooting at birds for food and had come in peace. When the Eskimos realized that they had attacked human beings who had no unfriendly motive, they fled in dismay, leaving the surviving white man alone. What became of him they do not know."

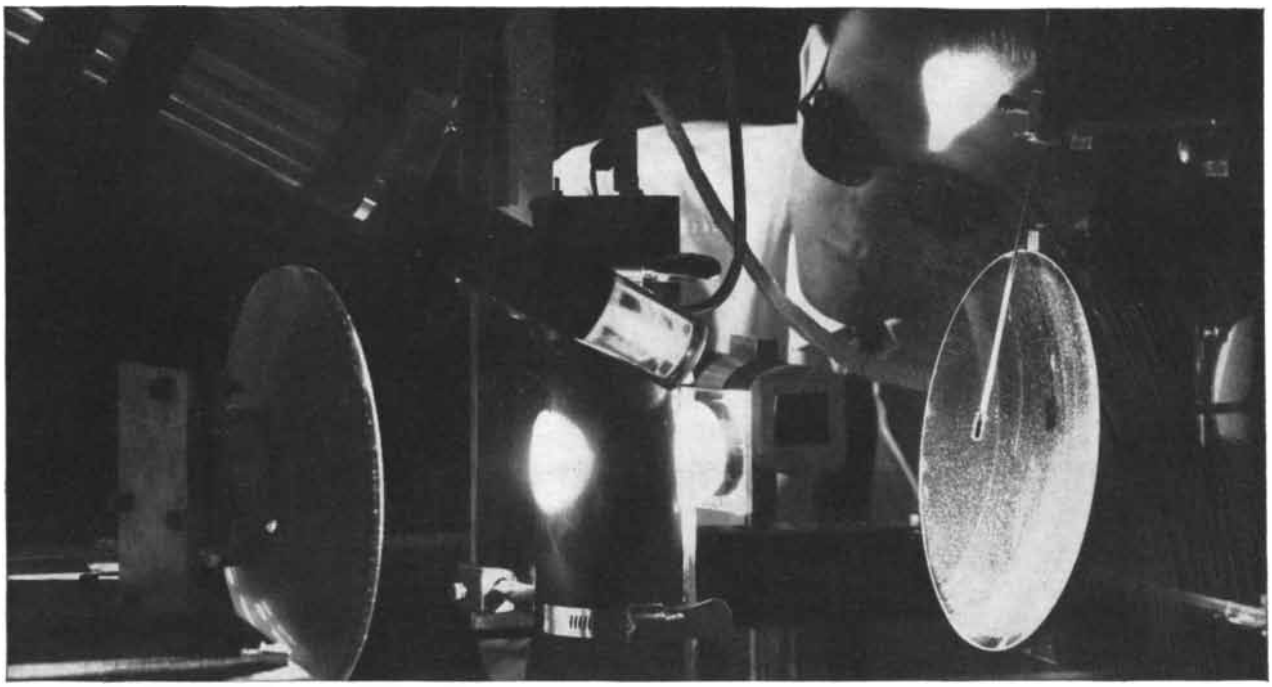
"The life of a tissue (as of heart or spleen or muscle) taken from the body and cultivated in vitro—that is, in a glass receptacle such as a bowled slide—is in general very short: in from three to 15 days its growth becomes less rapid and eventually ceases altogether; it then dies and its cells degenerate. Dr. Alexis Carrel has made many memorable experiments to the end of prolonging such tissue life; he now, in *The Journal of Experimental Medicine* for May, describes the work he has done to determine the conditions under which the active life of a tissue outside the organism could be indefinitely prolonged. By various remarkable techniques he has been able to maintain such tissue cultures in active life for beyond 60 days, in some cases at least 85 days."

Scientific American.

MAY, 1862: "The total number of human beings on earth is now computed in round numbers at 1,000,000,000. They speak 3,064 known tongues, and in which upward of 1,100 religions or creeds are preached. The average age of life is 33⅓ years. One-fourth of those born die before they reach the age of seven years, and half before the 17th year. Out of 100 persons only six reach the age of 60 years and upward."

"A subterranean railway is now in an advanced stage of construction, running about four and a half miles under the city of London. It commences at Victoria Street, whence it passes eastwardly, having a large number of intermediate stations. On the occasion of a recent trip made through a portion of its length, the air was found to be perfectly sweet and free from all unpleasantness."

"The report of the capture of New Orleans is fully confirmed. The Southern newspapers said at first that the boats of Commodore Farragut's fleet ran by the forts below the city without reducing them, but the Norfolk *Day Book* of May 3 had the following telegram from Augusta, Georgia:—"The Savannah *News* has a special dispatch from Mobile of May 1. It says that Forts Jackson and St. Philip had fallen and that Gen.



Exploring the possibilities in Coherent Light

At Bell Laboratories, Donald F. Nelson studies a beam of coherent red light produced by a continuously operating ruby optical maser. The heart of the device is a uniquely shaped ruby crystal immersed in liquid nitrogen in the tubular glass dewar extending from upper left to center. Light from the mercury arc lamp (lower center) is reflected by round mirror at left to mirror at right and then is focused on the ruby crystal to produce maser action. Coherent light emerging from end of dewar is picked up by a detector.

Is it feasible to take advantage of the enormous bandwidth available at optical frequencies? Could coherent light, for example, be sent through protecting pipes to provide high-capacity communication channels between cities?

To study such possibilities it is, first of all, necessary to have a source of continuous coherent radiation at optical frequencies. Such a source was first produced when Bell Laboratories scientists developed the gaseous optical maser.

Recently, our scientists demonstrated the generation of continuous coherent light by solid materials. Using a crystal of neodymium-doped calcium tungstate, a material developed at Bell Laboratories, continuous optical maser action was obtained in the near infrared. It has also been attained with visible light, using a new optical "pumping" arrangement to excite a ruby crystal. (See illustration above.)

Multichannel light highways for communications are still far from realization. But with continuous sources of coherent light available, it becomes possible to explore the problems of modulating, transmitting, detecting, amplifying and, in general, controlling light for possible communications applications.

BELL TELEPHONE LABORATORIES

World center of communications research and development

Duncan was in New Orleans on his parole. Also that the Federal flag was hoisted on the Custom House.' "

"M. Berthelot, of Paris, has succeeded in a most interesting chemical experiment, resulting in nothing less than the direct combination of hydrogen and carbon. Having for a long time been convinced that at an extremely elevated temperature they would combine with each other, he tried the experiment at all temperatures but at first without obtaining the desired result. Finally the extremely simple and happy idea occurred to him of making a current of hydrogen pass between the two carbon points of the electric light excited by Bunsen's battery of 60 elements, and then his efforts were crowned with success. At this extreme temperature the hydrogen combines with the carbon, and the product of the combination is carbide of hydrogen, discovered some years ago by M. Berthelot, to which he gave the name of acetilene."

"In the course of our investigations at the Patent Office we have come across a patent granted to Thomas Gregg on March 19, 1814—48 years ago—for an invention of a 'ballproof vessel, to be propelled by steam,' which, on examination, proves to be an almost exact model of the *Merrimac*. The sides were to be plated with iron, inclined at an angle of 18 degrees, and the drawings show a sharp iron prow, evidently to be used as a ram. This prototype of the latest triumph in naval architecture was patented only seven years after the introduction of steam navigation."

"The theory of spontaneous generation was long since proposed to account for the origin of beings whose germs were too minute or too obscure to attract attention. One after another the different organisms supposed to arise from spontaneous generation have been proved to originate from germs. At present the question of spontaneous generation concerns only the origin of entozoa and those minute organisms that can be studied with the aid of the microscope, as molds (minute fungi) and Infusoria, both animal and vegetable. The common theory that the spores or germs of these minute organisms are constantly floating in the atmosphere ready to start into activity whenever they meet with a suitable nidus has found an able advocate in M. Pasteur, of the École Normale Supérieure in Paris, who has published in the *Comptes Rendus* a series of valuable papers on this subject."

MEASURE. RECORD. ANALYZE.

(It sounds easy when you say it fast.)

It used to be that data acquisition was as simple as looking at a dial or a glass thermometer. No more. The entire data handling process itself has become more and more complicated and demanding. Because of this, it has become increasingly prudent to call for expert advice when you have a challenging problem—or even a routine one, for that matter—in the field of data handling. We believe the examples cited below bear out this practical wisdom.

• •

"LONG DISTANCE" DIAGNOSIS. In experimental tests in Birmingham, Alabama, electrocardiograms are being "dialed" by special telephone hook-up directly from patients in one hospital and automatically charted on a Honeywell Visicorder direct-writing oscillograph at another hospital across town for immediate interpretation and diagnosis. The success of these experiments, conducted by the Memorial Institute of Pathology, with the Birmingham Baptist Hospitals and engineers of Honeywell collaborating, demonstrate the feasibility of transmitting and recording, even thousands of miles distant, practically any type of physiological data which can be sensed electronically. Thus the knowledge and ability of medical specialists can be made available to physicians and their patients in any part of the country.

• •

GET DOWN TO THE ELEMENTS. This was the assignment recently handed to Honeywell engineers by a midwestern manufacturer of scientific instruments. That is: determine the various elements in a hydrocarbon mixture: carbon, hydrogen, oxygen, nitrogen, sulfur, and so on. For some time, gas chromatographs have been used to determine the percentage of components of a gaseous mixture—methane, butane, ethane, hexane, propane, and other hydrocarbon compounds. Starting with this instrument and its Honeywell strip chart recorder, adding a mass spectrometer, and feeding the signals into a multichannel Visicorder oscillograph, a time-correlated record of the various component elements of a gaseous mixture was readily obtained. Since few recorders can keep up with the speed of a mass spectrometer, an extremely wide range of galvanometric sensitivities had to be provided to measure the wave lengths of the various elements. In practice, the assembly works with speed and precision, doing instantaneously analytical work that previously took hours of laborious laboratory time.

• •

ELECTRONIC "SLIDE RULE" FOR STEEL MILLS. In the basic oxygen steelmaking process, a heat of steel is produced very quickly, and the charge for the next batch must be calculated as the current one is being poured. If the mix is off, the steel may not reach the proper temperature by the time the furnace is tapped, and the whole batch has to be reblown. If the narrowly limited tapping temperature range is exceeded, the steel has to be cooled down. In either case, it's costly, and seriously interferes with production schedules. The proper proportion of charge ingredients—raw steel, scrap, scavengers, etc.—can be figured out empirically on a slide rule, but even the best human calculations are too slow to keep up with the furnaces. Honeywell engineers designed for Jones & Laughlin Steel Corp. a special analog computer that determines instantly the proper charge formula for a specified end temperature.

• •

CLINICIAN TURNS REPORTER. In the treatment of Parkinson's disease and other musculomotor disorders, it would be most helpful if the therapist could accurately measure cogwheel rigidity (muscular resistance) before and after treatment. Working with Duke University Medical Center, Honeywell field engineers and university physicians devised a two-channel amplifier that measures the angle of the patient's arm and reports muscular resistances while the arm is being rotated through an arc. A two-pen Honeywell recorder forms an integral part of this system, and furnishes the hospital a permanent strip chart record for further study and evaluation.

• •

You will find that a combination of experience, equipment, and engineering competence offers a unique capacity for coping with the complete range of data handling problems—acquisition, reduction, computation and analysis, and presentation. If you would like to enlist Honeywell's cooperation in solving yours, call your nearby Honeywell field engineer or write Industrial Products Group, Minneapolis-Honeywell, 4412 Wayne Avenue, Philadelphia 44, Pa.

Honeywell

H Data Handling Systems

HONEYWELL INTERNATIONAL Sales and service offices in principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Where no metal but Platinum

Platinum safeguards test results at Esso Research and Engineering Center

At research installations across the nation, scientists frequently select Platinum for their equipment and apparatus to avoid the influence of corrosion products on reactions.

For example, at the Esso Research facilities in Linden, New Jersey, crude oil was to be processed in a pilot plant at 2400°F.

Critical: in the pilot process freedom from the influence of corrosion products was needed so that the data collected on every run would be reliable.

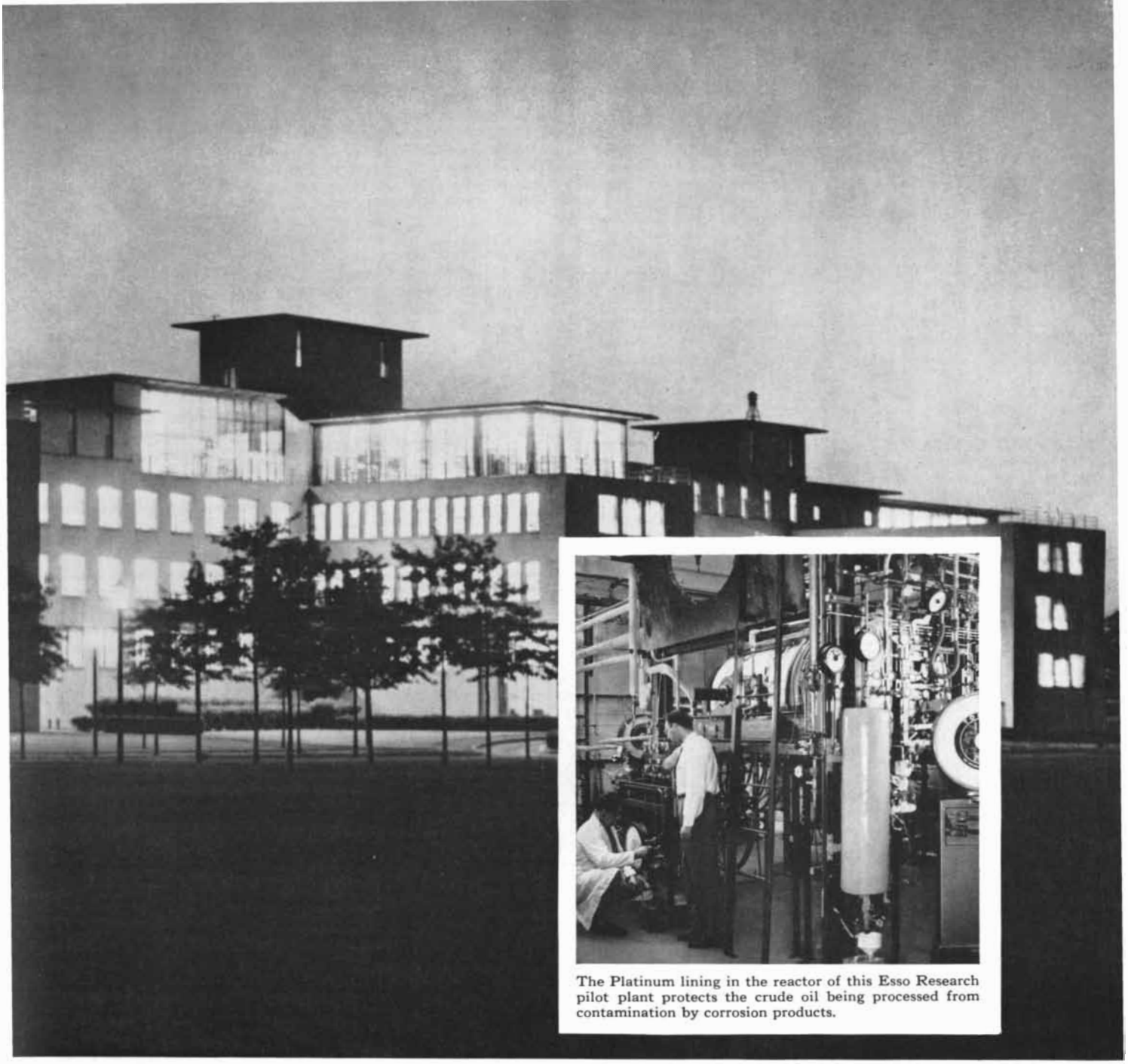
Esso Research lined the pilot plant reactor with Platinum because laboratory experience showed it to have excellent corrosion resistance under the extreme conditions.

Result: project successful.

Esso's experience is just one example of how many organizations — both research and production — are using Platinum. The fact that Platinum is virtually all recoverable after it has done its job is another sound economic reason for its wide usage.

It could pay you to use a Platinum Metal

Your problem might be readily and economically solved with Platinum Metals — where exceptional corrosion resistance is needed to protect the purity of products or chemicals under test or in processing... where high temperature corrosion and spark erosion are involved, such as in aircraft spark plugs... where reliable make-and-break electrical contact is indicated, such as in low-noise high-fidelity transmission... where wear-resisting, non-tarnishing surfaces are required, such as for printed electrical circuits... where peak catalytic efficiency is required, as in the refining of high octane gasoline... the Platinum Metals have proved to be the most economical for certain critical equipment.



The Platinum lining in the reactor of this Esso Research pilot plant protects the crude oil being processed from contamination by corrosion products.

will do the job as well...

Industry is going to higher temperatures and higher pressures. Perhaps your own progress has been blocked by the limitations of materials to withstand such severe conditions. The Platinum Metals have removed many barriers. Have you considered them for your problems?

Platinum, palladium, rhodium, ruthenium and iridium have unique potentials, well worth your attention. Specialists are prepared to work closely with you in evaluating these metals for new commercial and scientific uses.

As a first step, write us for additional data on the outstanding characteristics and successful applications of the six Platinum Metals and their alloys—indicating your field of interest or how we might be of assistance.

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Exceptional Chemical Inertness
High Temperature Stability
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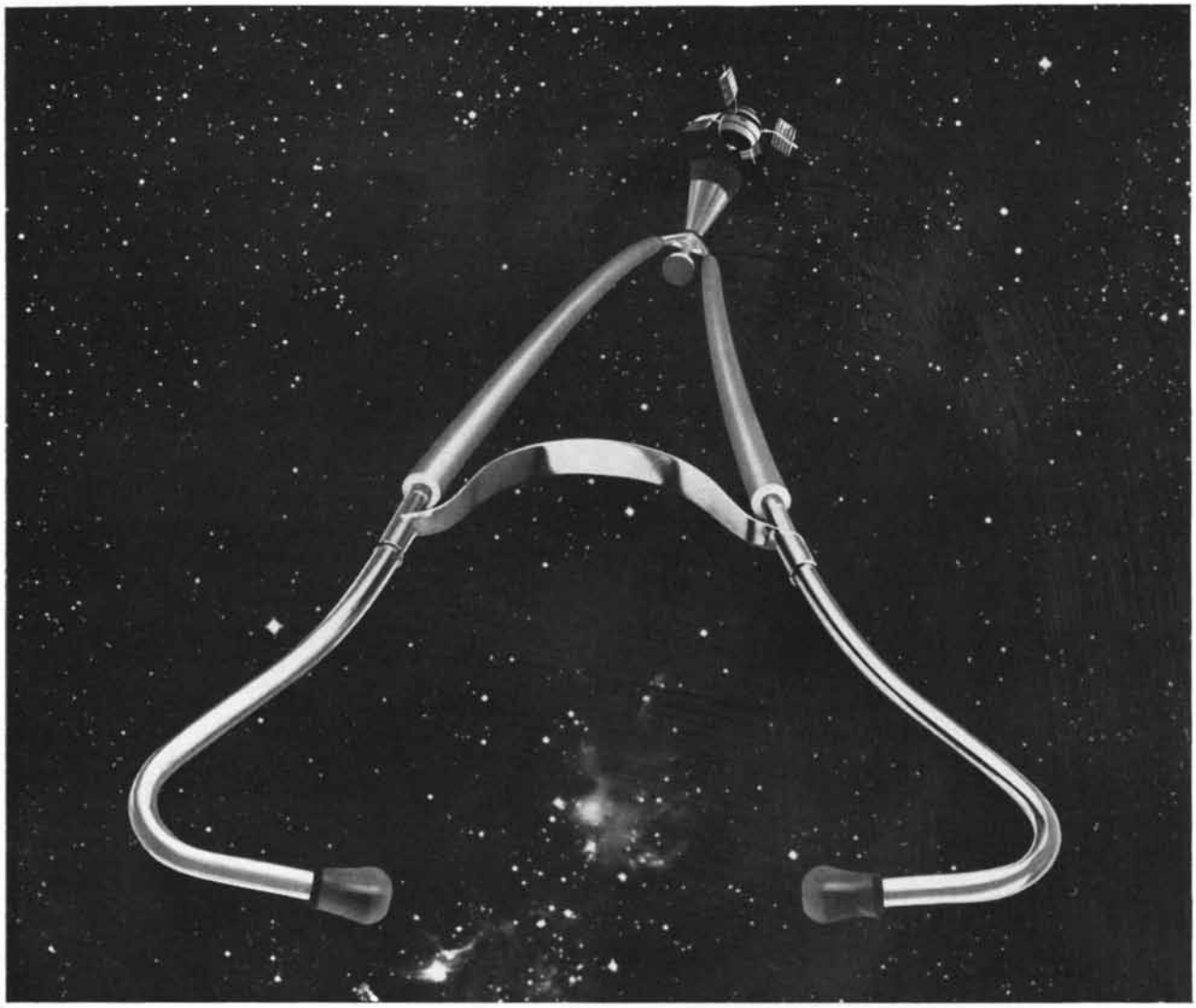

Siegler monitors the heartbeat of a satellite

Only a communications satellite system... carefully instrumented, accurately tracked and clearly heard... can meet the free nations' urgent requirement for communications-with-security.

From the first important space probe efforts, Siegler has participated in these programs... major contributions achieved by the company's wide capabilities in the electronic, electro-mechanical, and metallurgic fields.

An example: part of a vital worldwide communications system is the Siegler satellite tracking antenna system. Siegler-designed and produced—including complete fabrication of the antenna, all mechanical components and electronic instrumentation—and installed in record time.

In this tracking system, every critical part of the giant, 60-foot parabolic antenna is more precisely machined for its size than the parts of a fine watch. The result: not only the greatest tracking accuracy ever achieved in an antenna of this type, but also the extreme sensitivity required for clear reception of faint signals from far distances in outer space.

The vital area of space communications is only one phase of Siegler versatility. In today's major aerospace programs, Siegler supplies meteorological electronics including completely automatic weather stations; missile launch check-out systems; aero-space structures; solid-state space television and many other contributions to military and research projects.

Every Siegler contract includes the asset of divisional coordination, assuring outstanding dependable performance and unusually fast response.

SIEGLER

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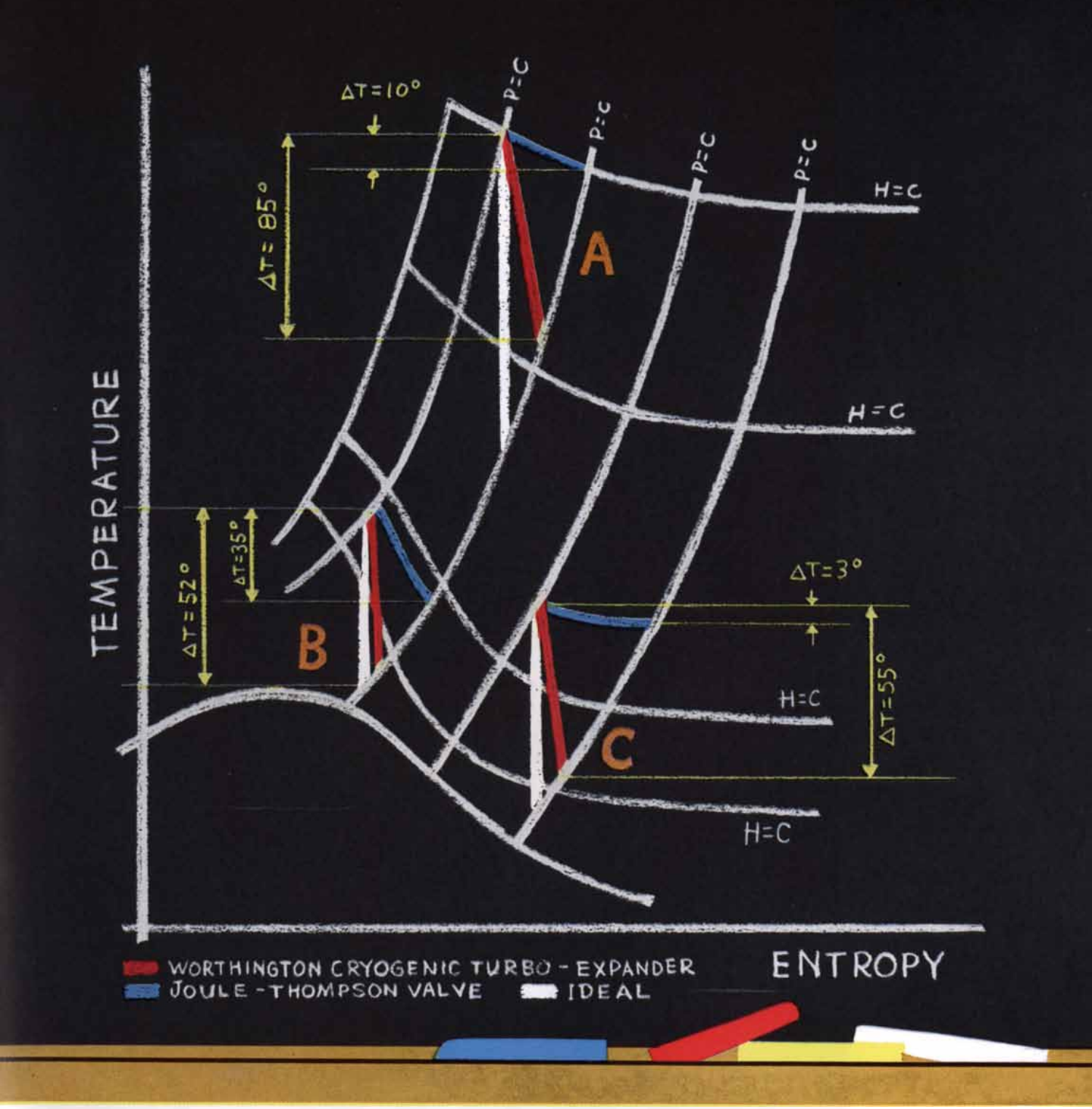


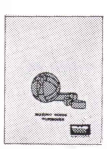
CRYOGENIC NEWS: FOR ENGINEERS WHO KNOW THEIR ABC'S

This is news for men who understand a turbo-expander's performance at points A, B and C on this chart. You readily understand the ideal area for applying machines such as Worthington's Cryogenic Turbo-expanders. And you certainly are involved in developing high-flow cryogenic cycles for industry.

Here is the news: we have produced the first successful "U.S.-built" Axial-flow Turbo-expander operating with liquid in the exhaust. It opens the path to a variety of machines which can operate in higher flow cryogenic cycles. Could you use such a machine in a new or improved cycle?

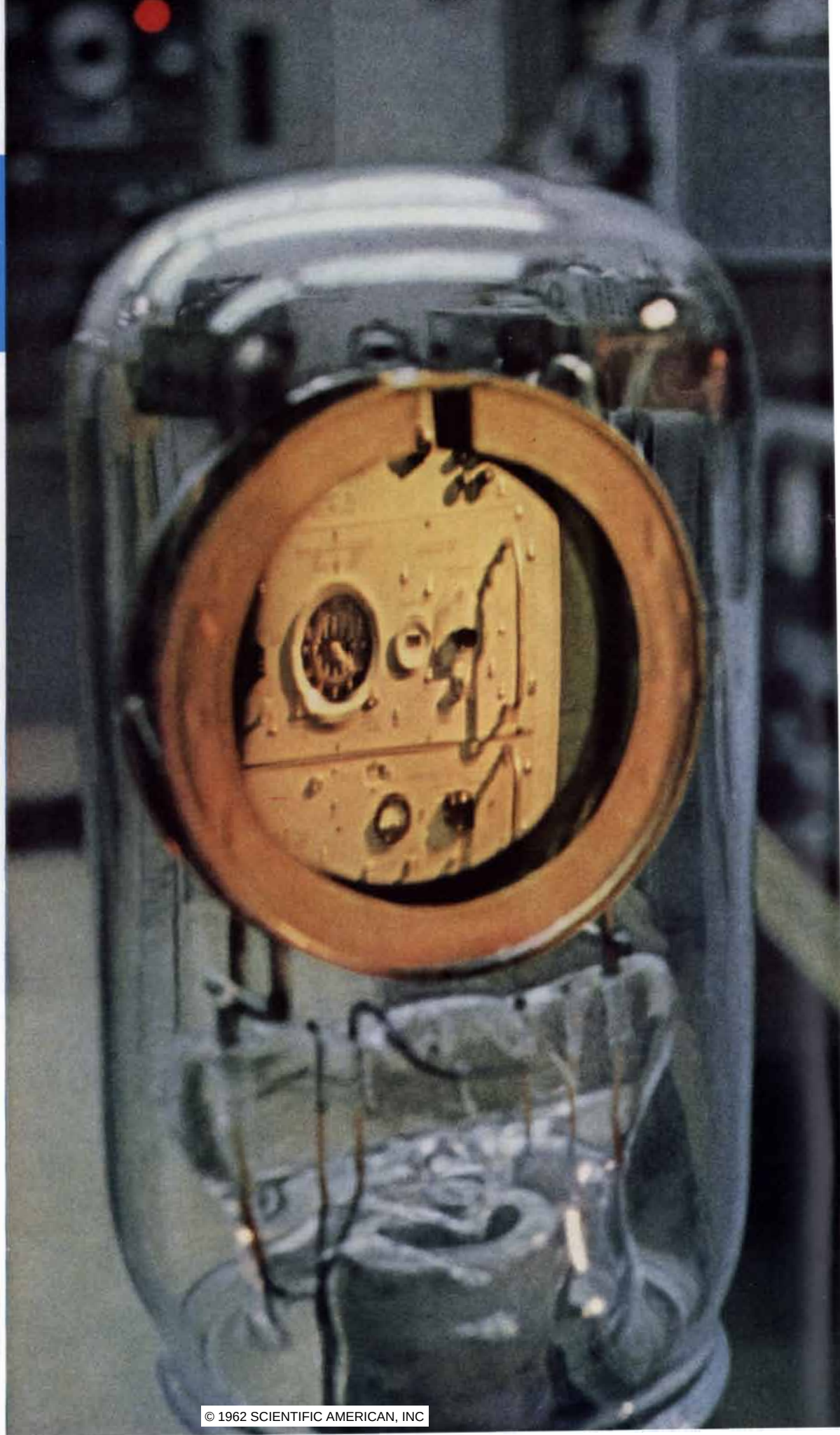
Remember, Worthington Radial Cryogenic Turbo-expanders are in full commercial production. Up-to-1000-hp machines are successfully operating. And the Turbo-expanders involved run at the highest efficiencies found in this class of equipment.

Today we have 15 years of successful Cryogenic Turbo-expander application—more than any other manufacturer. With this record, we can help you apply the most reliable and economical turbo-expanders in early stages of cryogenic cycle design. Typical cycles are for ethylene, air-separation, natural gas liquefaction and helium recovery. For these or similar processes, let us help you examine the cycle opportunities. Write for our Cryogenic Turbo-expander Bulletin, Worthington Corporation, Turbine Division, Wellsville, New York.



Special! To get more turbine value, ask for our new turbine buying guide. Your Worthington representative has it . . . ask him or write us today.

WORTHINGTON



A Hewlett-Packard precision frequency/time standard system is reflected in the deposited gold surface of a glass-encapsulated quartz crystal. Advanced technology produces crystals that assure high accuracy in the system.

PROGRESS *in measurement...*

...accuracy comparable to 8/10 inch in 25,000 miles, from frequency stability of 5 parts in 10^{10}/day

Successful programs of space navigation, missile control, and modern communication depend on highly accurate time and frequency measurements. Today, the quartz-controlled frequency/time standard is the most used basic reference for precise measurement.

Hewlett-Packard, to assure accurate and dependable performance of the standard systems it builds, designs and manufactures the quartz crystals which determine basic system accuracy.

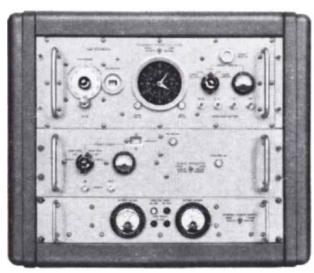
hp manufacturing specifications for quartz crystals are exact and unyielding. For example, crystal thickness governs frequency. Hewlett-Packard's tolerance for this dimension is 70 billionths of an inch.

If the angular orientation of the crystal's surface to its atomic structure is not exact, even small temperature changes can affect frequency. To minimize this effect, hp controls the generation of the surface in atomic space to a few seconds of angle.

Mechanical stress on the crystal affects its frequency. Hewlett-Packard prevents stress by suspending each crystal on a unique kinematic support—the nearest thing to floating in space.

To eliminate contaminants which can cause long-term frequency changes, the crystal is first placed in a dry nitrogen atmosphere filtered to 0.3 microns. Then contaminants are boiled away at 300° C, the crystal is gold plated by vacuum deposition and sealed in an evacuated glass envelope.

Finally, the crystal's characteristic curves are plotted and the optimum temperature for operating stability is determined. The crystal is then housed permanently in its oven, and the oven set to the optimum temperature. Under extreme environment this temperature varies less than ± 0.01°C.



The stability and reliability thus achieved have made Hewlett-Packard frequency/time standard systems widely used references in laboratories concerned with precise measurement. The typical hp system shown here includes (top to bottom) hp 113BR Frequency Divider and Clock, hp 103AR Quartz Oscillator and hp 725AR Standby Power Supply. Model 113BR provides time signals precise to 1 microsecond, and allows accurate system calibration with WWV standards broadcasts; price, $2,750. Model 103AR provides 1 MC and 100 KC sinusoidal outputs whose guaranteed long-term stabilities are $5/10^{10}$/day and whose short term stability is such that $1/10^{10}$ can be expected under laboratory conditions; price $2,500. Model 725AR powers the oscillator and clock and assures continued operation in the event of line power failure; price, $645.

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THE AUTHORS

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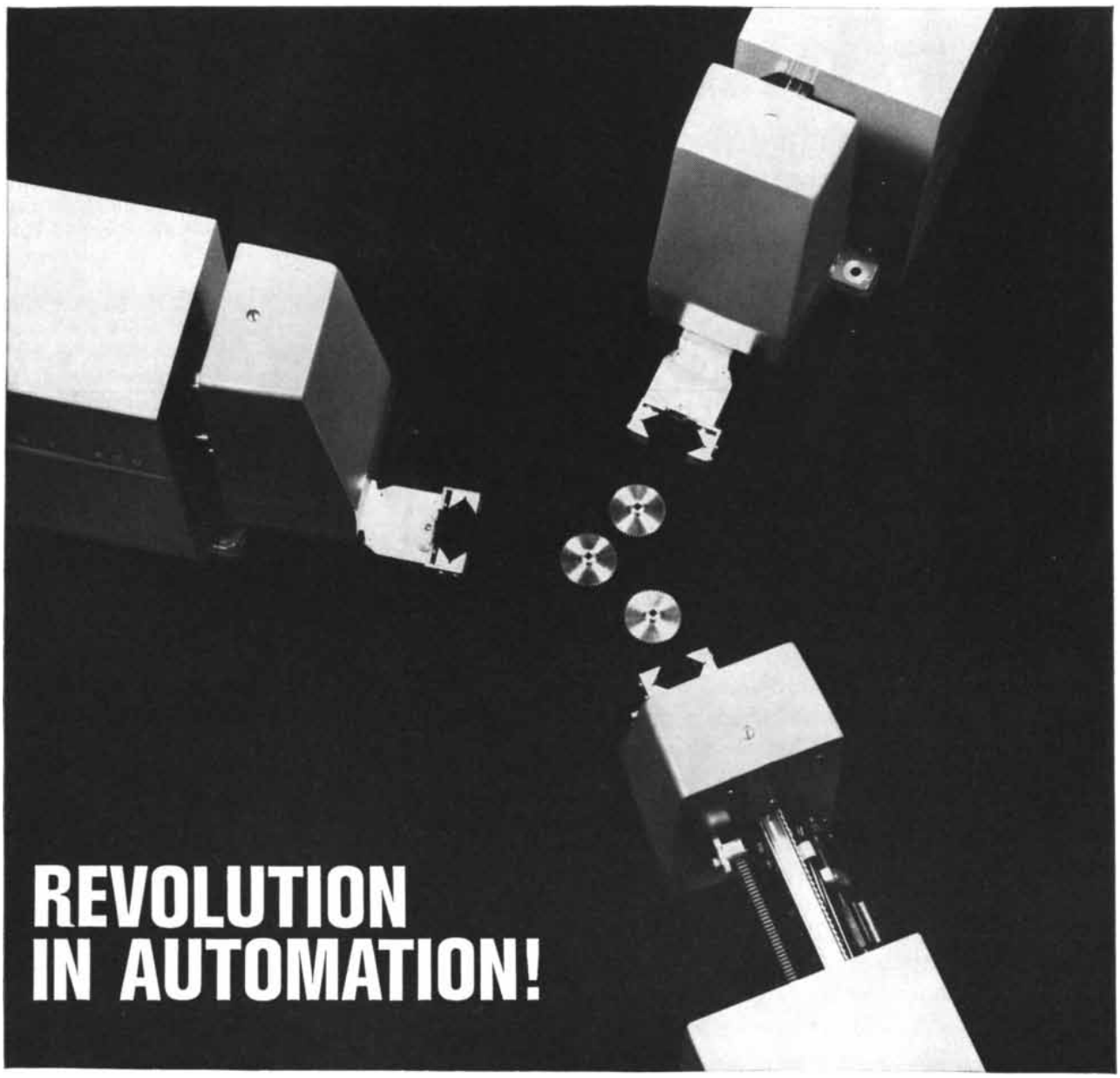
IVO KOHLER ("Experiments with Goggles") is professor of psychology and philosophy and director of the Institute for Experimental Psychology at the University of Innsbruck. Born in Austria, Kohler received his Ph.D. from the University of Innsbruck in 1941. At the end of World War II he became assistant to Theodor Erismann, then director of the Institute for Experimental Psychology. The results of their collaboration are discussed by Kohler in his article. Kohler succeeded to his present post in 1956, when Erismann retired.

CARLOS A. ALVARADO and L. J. BRUCE-CHWATT ("Malaria") serve with the World Health Organization, the former as director of the Division of Malaria Eradication, and the latter as chief of research and technical intelligence in the division. Alvarado, born in Argentina in 1904, obtained his M.D. at the University of Buenos Aires in 1929. He also holds diplomas in tropical medicine and hygiene and a degree from the Scuola Superiore di Malariologia in Rome. Alvarado, who spent 24 years in the national health service of Argentina, was responsible for the planning and organization of the malaria-eradication program in his native country. His report on the problem of malaria in the Americas prompted the Pan American Sanitary Conference in 1954 to urge the governments of the two continents to develop their projects for controlling malaria into projects for eradicating the disease. The following year Alvarado joined the Pan American Health Organization as chief of malaria eradication, and he was appointed to his present post with WHO in 1958. Bruce-Chwatt acquired his medical degrees in Poland and did postgraduate work in France, Britain and the U.S. An officer in the Polish army during World War II, he escaped from German-occupied Poland and eventually made his way to England, where he joined the British army. From the end of the war until he joined WHO in 1958, Bruce-Chwatt worked in Nigeria with the Colonial Medical Service and was in charge of the antimalaria program there.

FREDERICK D. BENNETT ("Exploding Wires") is a member of the staff of the Ballistic Research Laboratories at the Aberdeen Proving Ground in Maryland. Bennett received his A.B. at Oberlin College in 1937 and his M.S. and Ph.D. in physics at Pennsylvania State College in 1939 and 1941. After two years of teaching at the University of New Hampshire, Bennett worked from 1943 to 1946 as a physicist in the special projects laboratory at Wright Field, spent a year at the University of Illinois and took his present job in 1948. Bennett began studying exploding wires in 1956 as a light source for interferometers. This soon led to studies of the shock waves, fluid dynamics and plasma physics of such explosions.

MAURICE EWING and LEONARD ENGEL ("Seismic Shooting at Sea") are respectively director of the Lamont Geological Observatory of Columbia University and a science writer. A geophysicist, Ewing received three degrees from Rice Institute, including a Ph.D. in physics in 1931. He taught geology at Lehigh University from 1930 to 1943,



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joined the faculty of Columbia University the following year and in 1949 took his present position as director of the university's Lamont Geological Observatory. Engel attended Columbia University and the University of Chicago. He took part in two earlier cruises of the *Vema* in 1959 and 1960. His articles have appeared in some 40 publications, including *Harper's, The New York Times Magazine* and SCIENTIFIC AMERICAN.

ADRIAAN KORTLANDT ("Chimpanzees in the Wild") is senior lecturer in animal psychology and ethology at the University of Amsterdam. He studied at the universities of Utrecht and Amsterdam from 1936 to 1943, took part in the Dutch resistance during the war years and subsequently joined the Ministry of Reconstruction and Housing. Kortlandt began teaching part time at the University of Amsterdam in 1949 and in 1952 became a full-time staff member of the university's Zoological Laboratory. His article is based on field work Kortlandt did in 1960 in the Congo and West Africa. Last year the International Union of Biological Sciences adopted for consideration Kortlandt's proposal for the establishment of an international laboratory of primate biology on a group of islands in Kivu Lake in the Congo, which would combine the advantages of field conditions and the semicaptive conditions of an open zoo.

ISAAC HARARY ("Heart Cells in Vitro") is associate professor at the University of California Medical Center in Los Angeles. Harary acquired a B.A. from Brooklyn College in 1945 and a Ph.D. in biochemistry in 1952 from New York University. As a Fellow of the American Cancer Society, Harary did research at the University of Chicago from 1952 to 1955. He took his present job in 1958, having served as assistant director of the radioisotope research unit at the Veterans Administration Hospital in Long Beach, Calif., for three years.

ALBERT SZENT-GYÖRGYI, who in this issue reviews Edward Teller's *The Legacy of Hiroshima,* is director of research at the Institute for Muscle Research in Woods Hole, Mass. Before coming to the U.S. from his native Hungary in 1947, Szent-Györgyi was professor of medical chemistry at the University of Szeged from 1931 to 1945. His work there, particularly that on vitamin C and the catalysis of fumaric acid, won him the Nobel prize for physiology and medicine in 1937.

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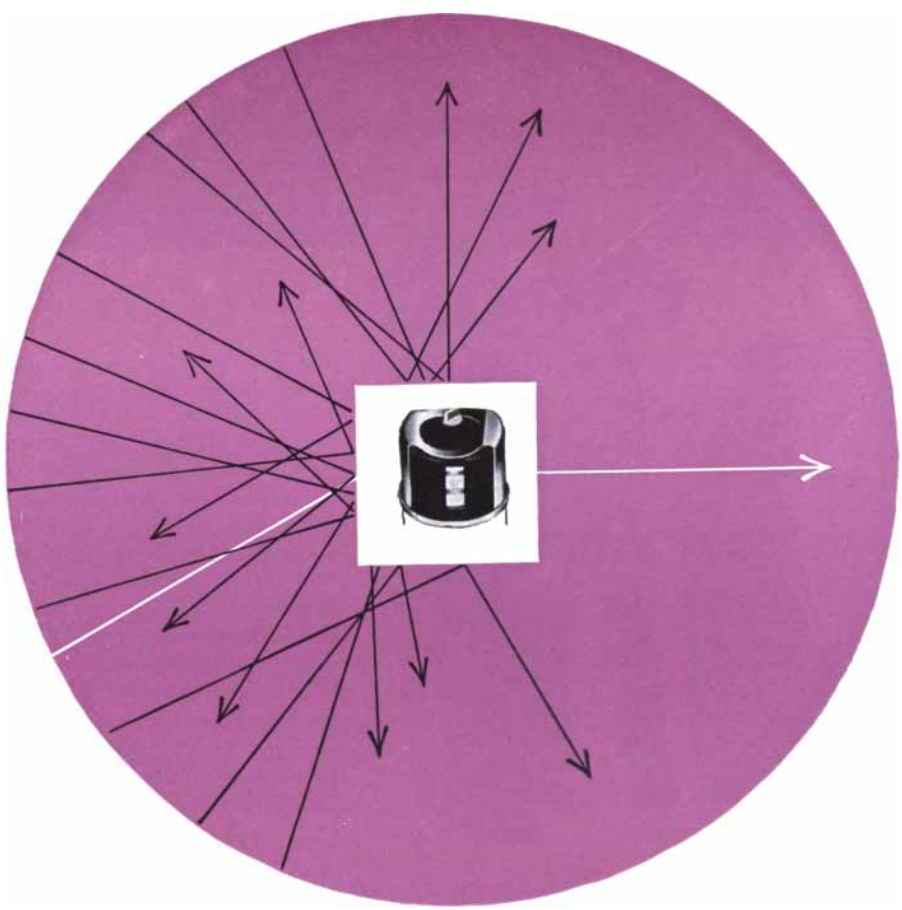

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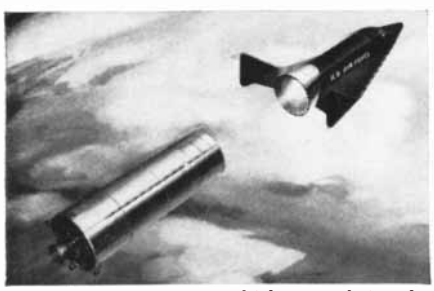

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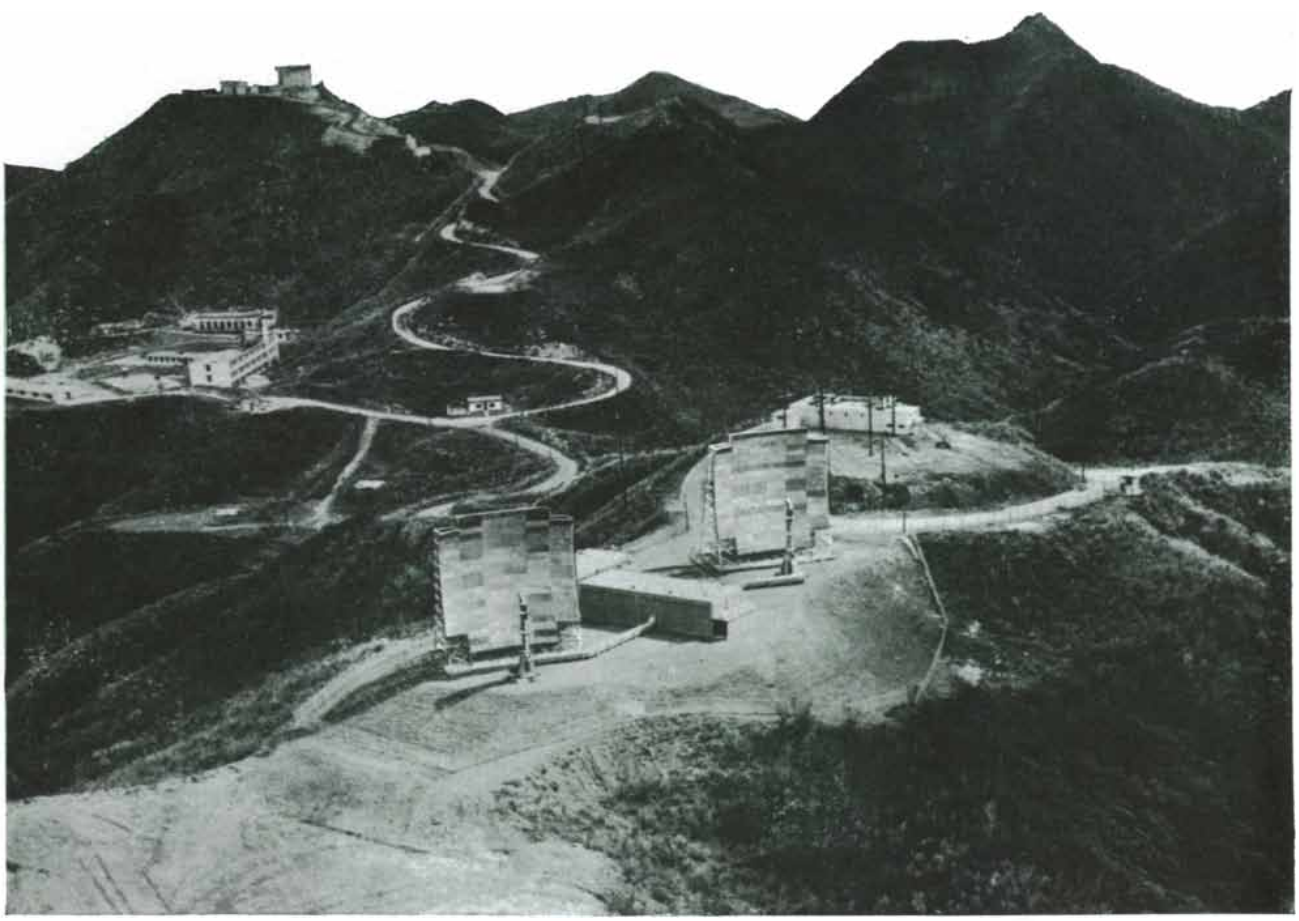

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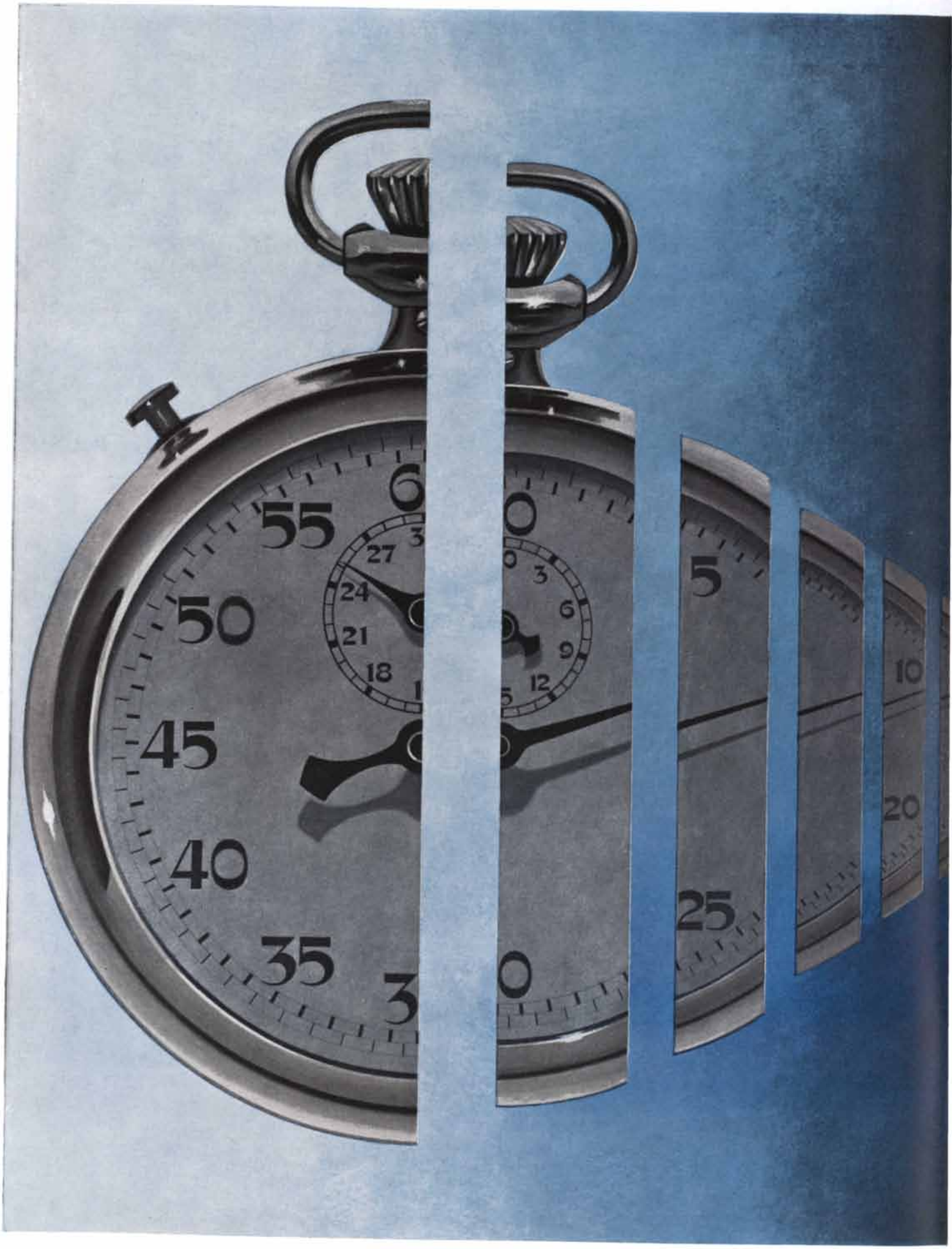

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The Shelter-centered Society

Eight social scientists reflect on the unprecedented effects of a large-scale peacetime civil defense program and present some urgent questions for the consideration of other citizens

by Arthur I. Waskow

Civil defense has been a topic of increasing public concern since July 25 of last year, when President Kennedy, in an address to the nation on the Berlin crisis, called for the preparation of shelters against the local fallout that results from a nuclear explosion on the ground. Most public discussion—for example, the hearings and debates on civil defense legislation in Congress—has focused on whether fallout shelters would be useful during and after a nuclear attack. There has been little examination of the possible effects that the creation and operation of a shelter-centered civil defense system might have on U.S. society during peacetime. It is apparent, however, that these effects must be reckoned with, whether or not the usefulness of the system is ever tested.

In January the Peace Research Institute, a nonprofit organization headed by James J. Wadsworth, former Permanent U.S. Representative to the United Nations, brought together a group of social scientists to consider this aspect of the proposed civil defense system. The conference is one of a number of projects recently undertaken by the Peace Research Institute to stimulate scientific research concerning ways to further the cause of peace, in the same fashion that research has been effectively used in recent years in support of the arms race.

The conferees [*see Editor's Note at bottom of opposite page*] prepared themselves by studying a number of background papers and documents; they were briefed, in the course of their deliberations, by officials of the National Security Council and the Office of Civil Defense and by experts from the Institute for Defense Analyses. In addition to their basic knowledge of social theory and of experimental findings in their fields of learning, the conferees brought to their study such special data as recent observations of overseas reactions to the U.S. civil defense program, scientific surveys of U.S. public opinion and locally observed reactions among students, patients and the general public.

On one conclusion the conferees felt they could confidently agree: The existence of a shelter-centered civil defense would be a wholly new departure in U.S. history. Because the prospect is without precedent they did not attempt to produce ironclad predictions of what would happen. They sought rather to define the problems that are likely to develop. As the product of their work together, the conferees issued not conclusions but a series of questions. They shared unanimously the sentiment that the questions are urgent and that action taken without careful consideration of these questions might lead to irreversible and disastrous consequences.

The civil defense program, the conferees agreed, portends an unprecedented departure in U.S. life because it implies major effects on our society as a whole. In official statements the program is described as "minimal insurance" against the "unlikely" event of a nuclear war. Because of its uniquely potent psychological and social appeal to survival instincts, however, it would be extremely difficult to limit the program to any predetermined minimum. A drive for continuous expansion of the program—a drive far more powerful than the usual pressures to expand, for example, Social Security—threatens to press constantly on the decision makers. Once having promised survival to some, they would soon have to meet all objections of inadequacy or noncoverage by broadening the program geographically and by improving its quality. To inspire any hope of effectiveness in war, civil defense must be able to call forth virtually universal teamwork. Since failure in any of a number of crucial tasks could gravely impair the operation of the system, the program must instill in all Americans a wholehearted willingness to carry out difficult orders on short notice. It would require the training of a large cadre of men and women to a fine pitch of elaborate knowledge and total dedication, and the training of the rest of the population for unquestioning obedience in a crisis.

All the evidence from the experience of the armed forces indicates that such "training" comes not from reading textbooks or instruction posters but from actually rehearsing crisis behavior. Civil defense would require whole detachments of civil defense workers to go into and stay in shelters, whole populations to

unlikely. They agreed that those people who were committed to supporting disarmament before the call for civil defense might take the call as a signal for desperately intensifying their previous efforts. For almost everyone else civil defense and disarmament are what is known in social psychology as "dissonant"; that is, civil defense fits into a view of the world in which negotiation has failed and war is looming, whereas disarmament fits into a view of the world in which negotiation seems possible and war seems avoidable. Confronted by the physical reality of shelters such popular support as there is for disarmament might weaken and wane. In other words, the shelters themselves might be symbolically even more threatening to hopes of disarmament than the call for civil defense.

Meanwhile there is some evidence to suggest that the civil defense program might have the unintended effect of restricting the area open to the U.S. Government for negotiation. Public opinion surveys, conducted by the Survey Research Center of the University of Michigan, have already shown that the President's call for civil defense, regardless of what he intended, was widely accepted as a warning of intense and immediate danger of war ("Why else should he want us to do this?"), a warning that negotiations with the U.S.S.R. were not working. Might not the popular anxiety aroused by this "signal" lead to popular belief that negotiations cannot succeed? Since a real civil defense program is not just paper but underground buildings and training programs that persist over long periods, might the hostility to negotiation also persist into periods when the Government would see a possibility of resolving previous crises? If so, the ability of the Government to negotiate might be severely impaired by anxiety among the people.

Urie Bronfenbrenner of Cornell University was able to report, on the basis of his recent trip to the U.S.S.R., that many Russians, plain citizens as well as officials, see in the U.S. civil defense program a threat of war. Thus, regardless of the carefully qualified remarks of the President in his call for civil defense, the call was seen in both the U.S. and the U.S.S.R. as a signal that war was near, that negotiations were failing, and in each country as evidence that the other was threatening aggression. The dangers of such an atmosphere are obvious.

The creation of civil defense will bring to life in every nook and cranny of the nation special institutions economically dependent on and deriving their power and prestige from a civil defense program: Government agencies, private builders and suppliers, a cadre of trained shelter managers, and so on. Even if not a single individual in these groups directly or deliberately attacked the notion of negotiating with an adversary, might not the mere existence of these groups immensely complicate the task of working out a plan for general disarmament that would not disrupt U.S. society?

Investigators in social psychology suggest that the existence of an omnipresent, persistent and highly visible symbol of one line of action might distract attention from other, parallel and alternative lines of action that lack such a symbol. Thus fallout shelters on a national scale might constantly call attention to nuclear war as the technique for conducting international conflict. Both proponents and opponents of civil defense might tend to concentrate on nuclear dangers and their mitigation instead of trying to discover alternatives to the use of nuclear weapons, such alternatives as "conventional war," political and economic pressure, tension-reducing initiatives or the invention of international institutions for conflict control.

The proposed civil defense program raises corresponding questions about this country's relations with its allies and neutral nations. Through civil defense the American people would in effect be searching for a way of survival for themselves and would tacitly be abandoning non-Americans to die if nuclear war should come. Among U.S. citizens the civil defense program might produce feelings of isolation from and lack of interest in the rest of the world. Among even the most friendly peoples the program might be taken to mean that the U.S. had withdrawn from its undertaking to promote the interests and the defense of its allies. From a recent visit to Japan, David Riesman of Harvard University was able to report that many people in that country feel considerable uneasiness over the U.S. shelter program and fear that it may indeed symbolize a turning inward of U.S. interests and policy. If this response should become more widespread, it might be seized on by some Americans as evidence of the unreliability of allies who could be so easily annoyed by American attempts at self-protection. Therefore the possibility exists that feelings of isolation in the U.S. could feed on feelings of isolation from the U.S., the two processes being constantly reinforced by progress in the civil defense program and culminating in substantial alienation of the U.S. from its friends and allies.

Just as civil defense might affect the course of American foreign policy, so it might change the ways in which the country's traditional democratic processes work at home. If mobilization of total support and participation should become a goal of the program, would not the civil defense organization be impelled to invade the privacy and liberty of individuals? There is the great danger that teachers, clergymen, editors, civil servants and other leaders of opinion would be required to become enforcers of official policy on civil defense—in the assumed best interests of those coerced. What if some teachers, clergymen, editors and civil servants should disagree with the policy? Would they be punished for encouraging "shelter dodgers" as they would be if they incited draft dodgers? Although no such official pressures have yet been exerted, it is disquieting to hear reliable reports from New York City that some high school students who refused to participate in shelter drills have been refused recommendations for admission to college.

It is possible that the "confusion" that has marked the civil defense effort so far is in reality a kind of unconscious civilian resistance to the half-understood possibilities of enforced conformity. Civilian doubts, hesitancies and ambivalences may be having a "last fling" in anxious anticipation of the absolute unanimity and centralization that might

SHELTER DRILL is conducted from time to time in the Norwalk, Conn., elementary

practice responding to emergency signals, whole cities to drill on a winter night. The demand for disciplined obedience to authority extended to the entire population would be entirely new in U.S. life. Indeed, in virtually no society is there any precedent for maintaining a large portion of a civilian population over a long time in trained readiness for a threatening event with a low probability of occurrence.

Proponents of civil defense have made a virtue of the need for such co-ordination of sentiment and action and have argued that by making the danger to survival obvious to all, the shelter program would enhance a national sense of community. But the conferees, on the basis of sociological evidence from the past, were unanimous in the doubt that feelings of community would be thereby reinforced. People working together to face danger perceived as equally threatening to all, in a civil defense program perceived as equally protective of all, might well have their community solidarity strengthened. But the danger of attack weighs differently on different Americans, the prospective usefulness of shelters is vastly different in different situations, and the work of building and operating shelters would actually be done by different agencies working along different lines at different levels of expense and with different chances of success or failure. In these conditions the evidence suggests that existing stresses and strains in the community would be amplified.

Already the civil defense effort has strained the web of community. Some people have concluded that shelters (private or public) would be useless to them unless they were prepared to limit the number of occupants to those whom the shelter could physiologically support. They have therefore announced their intention of excluding neighbors, or people from the next block, or strangers from the next county, or casual visitors to town, from the family or community shelter. Suburbia has been pitted against city, one state against another. These strains cannot be expected to disappear. It is indeed likely that they would worsen as cities realize how vulnerable they are to attack, as racial and ethnic groups compete for space in and access to community shelters, as farmers realize that refugees from the cities will deplete their food stocks.

From the point of view of the individual, the conferees agreed, the announcement of the civil defense program represented simultaneously a highly authoritative threat of personal death and social destruction and a promise that there is a way to meet this threat. Even a program announced as "minimal insurance" against an "unlikely war" signals to people that the danger is high ("Otherwise, why the program?") and that safety is possible ("Maybe not for other people, but for me").

It might seem that the threat is actually posed by the existence of nuclear weapons rather than by a shelter program. In people's minds, however, it is the civil defense program that spells out the danger. The call for civil defense is seen as a warning that war is highly possible and imminent; the physical trappings of civil defense make a visible and immediate impact on local and family affairs. In comparison the distant and half-realized military arsenal is a much less potent symbol of danger. At a still more distant remove is the outside military threat, which can be ignored, denied or suppressed in one's mind. Civil defense, however, is immediately visible, tangible and unavoidable.

The probable effect of this powerful threat and promise is to bring about three distinct reactions in the population. First, the threat generates anxiety in almost the entire population. Second, the promise of some protection provides a considerable amount of relief from the anxiety. It goes without saying, however, that the relief cannot fully or permanently offset the anxiety. The relief depends on sustained conviction that the shelter program is adequate, whereas the anxiety can disappear only if the threat disappears. Contradictory as they are, these two reactions are likely to be confounded by a third reaction. Among some people—an unknown proportion of the population—the civil defense program is bound to stir a dark attraction to the world of which civil defense is a warning: a world wiped clean of complications, ambiguities and dissension. The coexistence in the population of deep anxiety, precarious hope and an obsessive concern with violence and death would constitute a new situation for U.S. society.

This analysis of the impending impact of civil defense on American life suggests a number of urgent questions. First among them is the question of whether or not a commitment to the proposed program will tend to restrict the U.S. Government's freedom to negotiate with Communist governments. In the long run such a development would make it more likely that conflicts between the U.S.S.R. and the U.S. would lead to the use of force.

It is conceivable that public opinion might come under the sway of intense and uncontrolled hostility to the idea of negotiation with Communist states. Such hostility could result from the public's interpreting civil defense to mean that an enemy threatens imminent death to home, neighborhood and nation. Against this prospect it is sometimes argued that the shock and immediacy of a civil defense program might bring home to Americans the possibility and the peril of a nuclear war and thereby increase interest in and devotion to negotiations toward such goals as mutual disarmament. It was the unanimous judgment of the conferees, however, that a reaction in favor of disarmament is extremely

EDITOR'S NOTE

This article is a condensed version of the report of a conference on the potential implications of a national civil defense program, held by the Peace Research Institute in Washington, D.C., on January 13 and 14. Partial support for the conference was given by the National Institute of Mental Health and the American Psychological Association. The full report can be obtained from the Peace Research Institute.

The conferees were Raymond A. Bauer of the Harvard University Graduate School of Business Administration, Urie Bronfenbrenner of the Department of Psychology at Cornell University; Morton Deutsch of the Bell Telephone Laboratories; Herbert H. Hyman of the Department of Sociology at Columbia University; Erich Lindemann, professor of psychiatry at the Harvard Medical School and Psychiatrist-in-Chief of the Massachusetts General Hospital; David Riesman of the Department of Social Relations at Harvard University; Stephen B. Withey, director of Public Affairs Studies at the Survey Research Center of the University of Michigan; and Donald N. Michael, director of Planning and Programs for the Peace Research Institute, who was chairman of the conference. All the conferees are in essential agreement on the substance of the report.

be required if civil defense became a paramilitary organization of the entire population. Since the doubts and confusions themselves interfere with civil defense, they may themselves bring about more effort to eliminate the doubts and to control their expression more tightly. Thus the fears of centralized control could help to bring such control into force. To prevent this kind of repressive process from beginning or continuing—if it can be prevented at all—would take an understanding of the problem on the part of citizens and Government officials and a careful re-examination of the whole situation to locate the points at which the process could most effectively be halted.

These problems might be compounded if the peculiar imagery and symbolism involved in civil defense attracts particular personality types into leadership of civil defense organizations. Such special groups of people might be benign; for example, they might well include protective individuals, committed to saving, helping and nursing their fellow human beings in time of disaster. But the image of a world of death and destruction might act as a kind of "pornography of violence" to attract people to civil defense work who "want to get it over with"—who see nuclear war as a relief of intolerable tensions and as a way of "ending" international conflict—or who see themselves as survivors and rulers in a world where affluence and internal bickering had given way to pioneer exertions and tightly controlled order. In fact, civil defense publications in certain localities suggest that people with these kinds of personality structure have already begun to dominate some local civil defense organizations.

The combined promise of life and warning of death put forward by civil defense involves such strains in individual hopes and fears that any failure, mistake, corruption or delay in the program might have far more basic consequences than even total collapse of an ordinary political proposal. There is a disturbing prospect that widespread disillusionment with the political leader, the scientist and the expert and even democratic government itself could grow out of a civil defense program.

Since there is a considerable "cultural lag" in translating new knowledge of weapons effects into new civil defense procedures, in transmitting the new procedures to local civil defense officials, and in putting the new procedures to work, there might exist at any time a publicly known gap between the need and the program. Such a gap might well provoke anger and disenchantment in citizens who knew that it might mean their death. The anger and disenchantment might be deep enough and broad enough to exceed the normal amount of disapproval felt by free peoples toward democratic governments.

For example, a leading businessman could be asked by his local civil defense director to make expensive alterations in his building at the very moment when the same businessman hears from his Washington sources that these alterations are out of date and that specifications may soon be changed. Should he go ahead with the alterations or not? In either case, what would he and the local civil defense director think of the Federal Government? Since Federal officials will have recognized this difficulty, would they hesitate to keep the civil defense program up to date for fear of destroying morale? If they should decide to maintain an out-of-date program, what would happen to their own morale and self-respect?

Finally, it should be pointed out that in civil defense, as in every program in any society with any form of government, sooner or later there are sure to be mistakes, instances of corruption and so on. In most public programs people take such occasions in their stride (although in the U.S. they have sometimes led to dangerous contempt for politics and politicians). In a program that would be as deeply tied to national and personal life or death as civil defense, any fall from grace might provoke a much more serious revulsion against political leaders and possibly even against democratic politics. Similarly, the image of the scientist and the expert might suffer badly if the presumed experts disagree profoundly on what nuclear war could mean or urge a program of civil defense that is later shown to be ineffective. Since the scientist is perceived as the ranking "expert," disenchantment with him might generalize to disbelief in Government experts of all kinds. And cynicism

schools. These pupils are first-graders at the Tracey School. The children march out of their classrooms and line up along the walls of an interior corridor. They sit on the floor, head down and hands clasped behind neck for protection against a nuclear explosion.

among Government officials, if they privately see mistakes, failures, inadequacies and delays in so crucial a program, might still further sap belief in democracy and might make corruption or apathy more likely.

Of all the questions raised by civil defense, the conferees agreed, the most troublesome and dangerous is the question of how the commitment, once made, could ever be limited or reversed. A shelter-oriented civil defense system will of necessity create a large, highly organized institution with crucial connections in every area of American life. The civil defense hierarchy—Federal, state and local—will be carrying the heavy burden of training a large cadre of shelter managers and survival specialists. The trained cadres in turn will have the task of training large groups of people to follow orders in a hurry at a time of catastrophe and crisis, in spite of their anxieties, fears and lack of information. The civil defense organization will have to insist on the economic adjustments and controls necessary to implement and operate a shelter program without unsettling either long-range business investments or day-to-day business where shelters are being dug or buildings modified. If the civil defense organization should attempt to supply only shelter structures and other physical necessities, fearful of involvement in educational, psychological or economic problems, it is likely that local demands for drills, training and controls will quickly arise as the shelters themselves appear. The very existence of the civil defense system will make it a social force of great importance, powerful even if it abjures power.

As the shelter program grows, proponents and administrators of civil defense might become more preoccupied with imagined attack situations. They might feel that in the overwhelming emergency of attack it will be necessary to have fully co-ordinated action in order to use the shelters efficiently. Individuals who have not learned their places and tasks—who in panic block shelter entrances, who forget to take along essential personal medicines or who bring along too much luggage for the available space—will be endangering not only their own lives but also the lives of others. For this reason the civil defense organization will find itself more and more pressed to demand virtually universal acceptance of civil defense and preparation for it.

The social, psychological and political momentum generated by an operating civil defense system would therefore make it increasingly impossible for the nation to change its mind once the program was under way. The program would be much harder to reverse than most political decisions. One well-established social and psychological mechanism that might make civil defense irreversible is the common transformation of conflict and confusion into rigid and overwhelming commitment. The puzzlement and disagreement that will have preceded adoption of a civil defense program might bring about such a commitment to the program as it goes into effect. Having cast its doubts away and invested huge amounts of labor, capital, energy and imagination in civil defense, the nation might find it difficult to surrender the hope of survival through the new program. Once it acts for civil defense, the nation would find itself seeking constantly for new reasons to be so acting. This phenomenon—the bringing of ideas and wishes into line with action already being taken—is well known to behavioral scientists and politicians.

With the continued escalation of the destructiveness and accuracy of nuclear weapons and their delivery vehicles, it would be difficult to resist demands for constant expansion and intensification of civil defense. At any extreme—even underground cities—civil defense would be inadequate against many conceivable weapons (some already in existence) that could be brought against it. Thus at any existing level of civil defense various groups (for instance, the political opposition) might be able to demand a larger and more effective program. A system of escalating political blackmail could well develop. Such pressure would be difficult to resist if the Government had already implied that it could protect at least some people. With the pressure always in one direction, the civil defense program might be always expanding, never contracting.

The difficulty of reversing policy on civil defense can be made clearer by examination of the conditions in the past under which some major political decisions have actually been reversed by the U.S. political system. The abandonment of the National Industrial Recovery Act in the early days of the Roosevelt administration seems to have been one such reversal. But two crucial conditions accompanied that episode: it was legitimized by an institution specially assigned to make such reversals, the Supreme Court; and it was made palatable by the adoption of a series of alternative New Deal programs.

The fulfillment of these two conditions in the case of civil defense would be difficult. In matters of defense policy it is hard to see how any outside institutionalized body, such as the courts, could reverse the decisions made by the President and Congress. In fact, the decisions of the President in the field of defense have since 1940 been given such weight that it is difficult to tell whether a real option for reversal would exist even in the hands of Congress. As to alternatives, it has already been suggested that disarmament, for example, could probably not mobilize as much support within a shelter-centered society as it could before shelters were begun. Alternatives may therefore be hard to promote even should it seem wise at some later date to dismantle the civil defense program.

In thus detailing the questions raised by civil defense, the conferees did not suggest that a policy of no civil defense would be without problems. The anxiety aroused by the cold war and its crises, by nuclear weapons and the images of the destruction they would deliver already exists in the U.S. To do nothing would not reduce the anxiety, and to do nothing might well lead to problems other than those herein described as possible results of implementing civil defense.

Whether the appropriate action should be a search for alternatives to civil defense or a search for ways of so managing civil defense as to lessen or eliminate its difficulties is for the nation to decide. What is essential is that the problems that might very well grow out of civil defense be examined carefully and that policy be re-evaluated so that the nation need not be confronted by a world in which the possible difficulties have become real disasters.

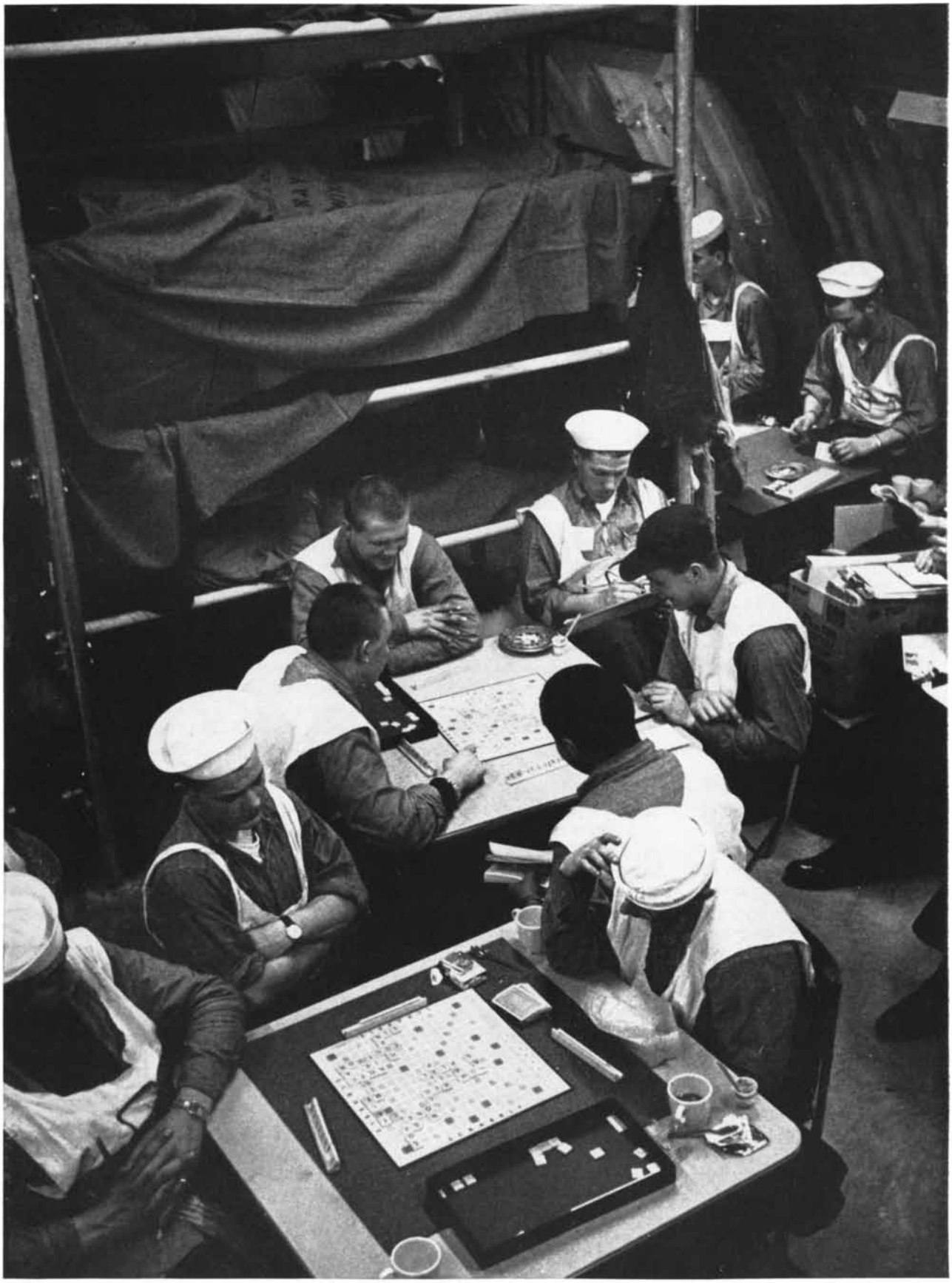
The conferees therefore put to the American people and its leadership these questions:

Are we prepared to accept the possibility that unhappy social and political consequences will occur if the proposed civil defense program is implemented?

If we reject the possibility that adverse consequences will develop, on what grounds do we do so and with what assurance that we are right?

If we are not prepared to accept unhappy consequences, are we prepared to recognize the difficulties consciously and apply the arduous study that would be necessary to discover if ways exist of avoiding those consequences?

If, after study, there seems to be no way of avoiding the unhappy results, do we have alternative policies in mind?



FALLOUT-SHELTER TEST run by the Navy last winter involved 100 men, who stayed in an underground steel and concrete shelter for two weeks. Ventilating fans supplied filtered air. The sailors ate emergency rations and spent the time sleeping, reading, playing cards and Scrabble. The test was designed to study the physical effects of long confinement underground in cramped quarters.

GAMMA RAY ASTRONOMY

An ingenious telescope in a satellite has provided the first view of the universe at the shortest wavelengths of the electromagnetic spectrum. This historic glimpse is supplied by just 22 gamma rays

by William L. Kraushaar and George W. Clark

The radiations that reach the earth from outer space include photons, electrons, protons and neutrinos—in short, all the stable elementary particles known to physics. To this list of four particles (seven if the antiparticles of the electron, proton and neutrino are included) one must add the bare nuclei of atoms heavier than hydrogen, which also originate in space and constantly bombard the earth's atmosphere. The broad task of astronomy is to exploit all these forms of incoming energy and matter to build up a comprehensive picture of the universe.

The photon, in the form of light and ultraviolet radiation, and more recently in the form of radio waves, has provided astronomers with almost everything they have learned so far. Within the past year or so the merest glimpse has been obtained of the universe as revealed by the very-high-energy photons called gamma rays. The glimpse has been provided by fewer than 100 energetic photons, recorded by a gamma ray "telescope" carried into orbit on April 27, 1961, by the artificial satellite *Explorer XI*. It is doubtful whether such a small number of particles has ever before been analyzed so intensively in an effort to extract information about the universe. The analysis is still continuing in our laboratory at the Massachusetts Institute of Technology, and the entire sample of events that we are prepared to discuss numbers only 22. Even this minuscule sample seems to be enough to rule out one version of a theoretical model of the universe.

Broadly speaking, the radiations that reach the earth from space are of two types: electrically charged and electrically neutral. The charged radiations, commonly lumped together and called cosmic rays, are mostly the nuclei of hydrogen (protons) and of other atoms, with a small admixture of electrons. Because of their charge cosmic rays do not travel in straight lines but follow helical paths that twist around the lines of magnetic force throughout the galaxy. It is therefore impossible to identify where in the galaxy, or where outside it, charged particles originate. The neutral particles (photons and neutrinos) are totally unaffected by magnetic forces; consequently it should be possible to establish their place of origin. For the photons of light a conventional telescope serves nicely. For photons of radio energy the problem is more difficult: the sky must be scanned point by point with a large directional antenna. In the picture of the sky that can be built up from radio observations objects that are bright to the eye or to a photographic plate are often virtually invisible. Many objects that are faint at the wavelengths of light, on the other hand, shine brilliantly at radio wavelengths, and the entire band of the Milky Way glows with a diffuse radio emission from the tenuous matter in interstellar space. What can one expect to "see" in a picture of the sky constructed from directional observations of photons having the wavelength of gamma rays? And what can one hope to learn?

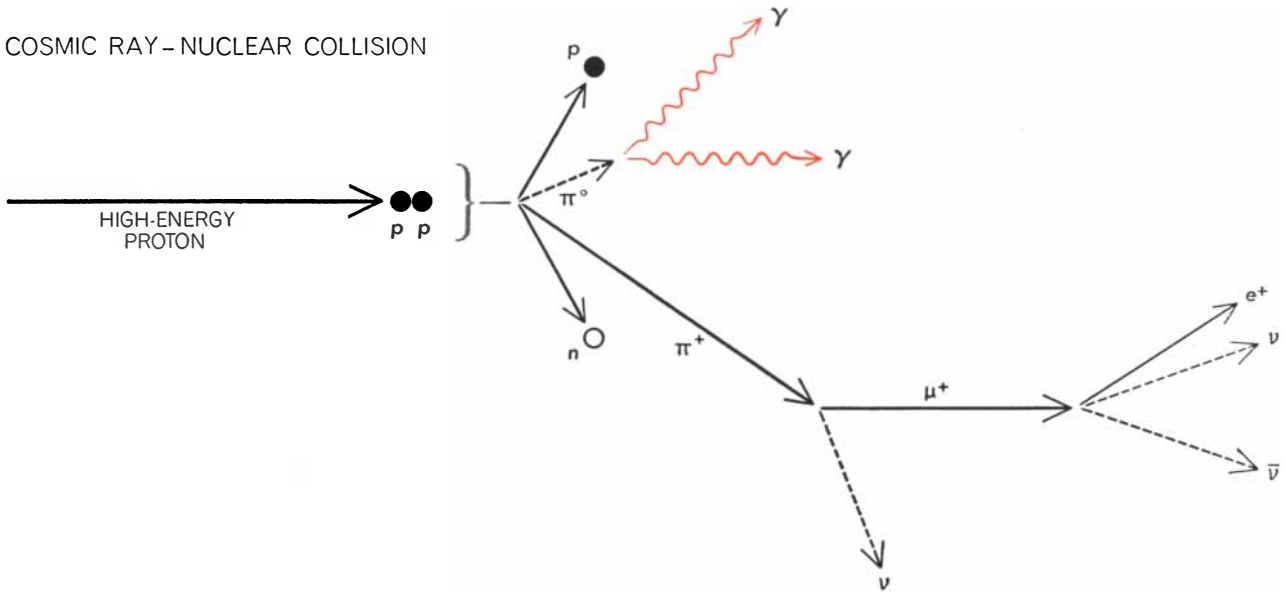
The gamma rays of greatest interest to us are those with energies above 50 million electron volts (Mev), and their special significance lies in the special conditions under which they are produced. They are created, for the most part, when high-energy particles collide with other particles. Probably the most important source of high-energy gamma rays is the process that occurs when a high-energy proton strikes either another proton or an atomic nucleus and produces, among other things, one or more neutral pi mesons, or pions. These are unstable particles that decay into a pair of gamma rays, each with a minimum energy of 72 Mev. Since the pion is usually moving at high velocity as a result of its violent birth, the gamma rays are projected forward in a V [*see top of illustration on opposite page*]. This collision process gives rise to gamma rays with a broad spectrum of energies, reflecting the energies of the incident protons.

If the incident proton has an energy greater than a few billion electron volts (Bev), it can create not only pions but also a nucleon-antinucleon pair, either a proton and an antiproton or a neutron and an antineutron. The particles in a pair produced by a particular collision usually fly off in different directions, but eventually in traveling through space the antinucleon will encounter another nucleon and the two will annihilate each other. The annihilation process creates several pions, including as a rule one or more neutral ones. The neutral pions quickly decay into gamma rays.

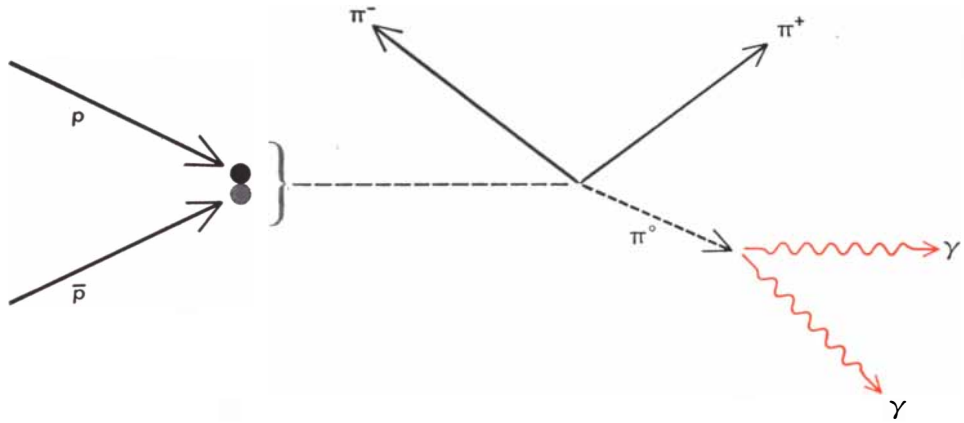
If antimatter exists in the universe apart from its production in high-energy collisions, it too can be expected to produce annihilation reactions and therefore gamma rays. The existence of large amounts of antimatter is predicted by one "steady state" model of the universe, in which it is assumed that matter and antimatter are being produced continuously in equal quantities.

Still another source of high-energy gamma rays is the deflection of high-speed electrons and positrons when they pass close to an atomic nucleus. An electron, being negatively charged, is deflected toward the positively charged nucleus; a positron is deflected away from it. In either case the change of direction causes the particle to emit a photon approximately in the direction of its line of flight before deflection. These photons are called *Bremsstrahlung*, which means "braking radiation." The

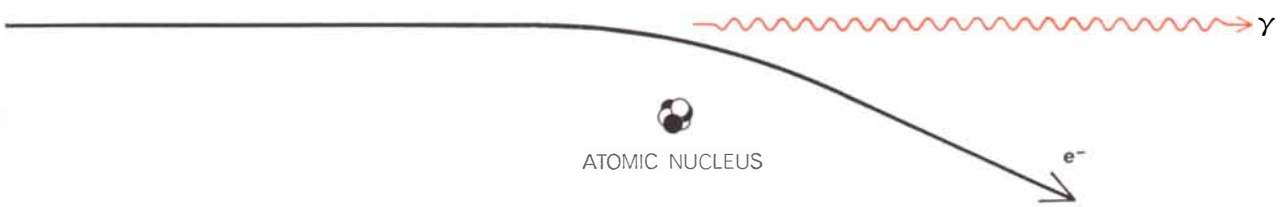
COSMIC RAY – NUCLEAR COLLISION



PROTON-ANTIPROTON ANNIHILATION

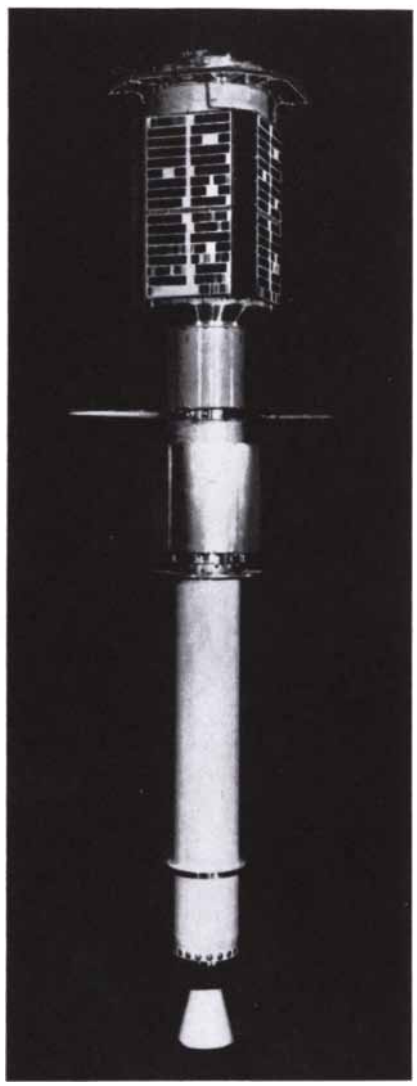


ELECTRON BREMSSTRAHLUNG



p	PROTON	π^-	NEGATIVE PION	$\bar{\nu}$	ANTINEUTRINO
$\bar{p}$	ANTIPROTON	π°	NEUTRAL PION	e^-	ELECTRON
n	NEUTRON	μ^+	POSITIVE MUON	e^+	POSITRON
π^+	POSITIVE PION	ν	NEUTRINO	γ	GAMMA RAY

HIGH-ENERGY GAMMA RAYS can be produced in space in several ways. The most common is probably the collision of a high-energy proton (one kind of cosmic ray) with the proton in an atom of interstellar hydrogen (*top*). Such collisions can yield an antiproton instead of the products shown. If it later meets a proton, the two may be annihilated (*middle*), and the products usually include high-energy gamma rays. A third source of rays is a close encounter between an electron and an atomic nucleus (*bottom*).



EXPLORER XI **carried into orbit the gamma ray telescope built by the authors and G. Garmire. The telescope is located at the top of the satellite behind the solar cells.**

energy of the resulting gamma ray varies with the energy of the electron and how close it passes to the nucleus; in some encounters almost the entire energy of the electron is transferred to the photon. Although *Bremsstrahlung* and nucleon-antinucleon annihilation are possible processes for cosmic gamma ray production, our estimates show that the process mentioned first—direct production of neutral pions in high-energy proton-proton collisions—is by far the most important.

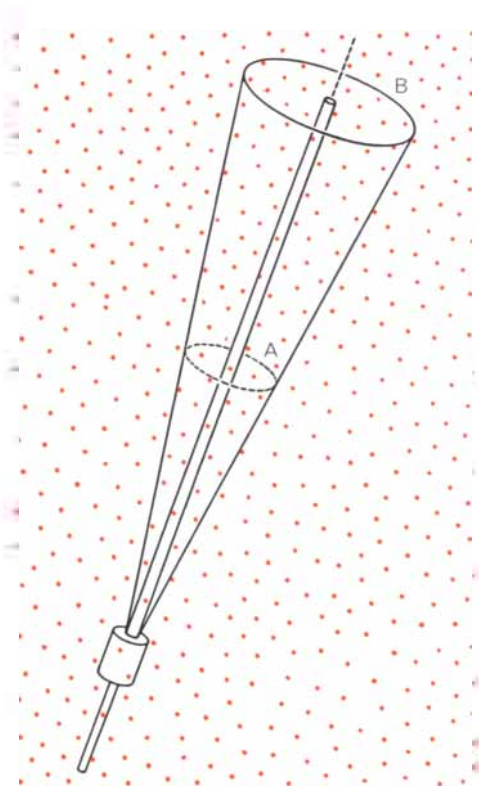
From astronomical and other observations it is possible to make reasonable predictions about the number and energy distribution of gamma rays that strike the earth's upper atmosphere, and these predictions serve to guide the experimental approach. It is known that cosmic rays bombard the atmosphere from every direction (after due allowance is made for those that originate in the sun). This, together with evidence from radio astronomy, suggests that cosmic rays populate the galaxy more or less uniformly. Consequently they should produce gamma rays everywhere at about the same rate. If this is not confirmed by actual observation, an explanation must be provided. For example, local concentrations of interstellar dust and gas would make cosmic ray collisions more probable and lead to "hot spots" in the gamma ray map of the sky.

When we and others estimated the flux of gamma rays reaching the earth from space, we found it discouragingly low. We calculated that an apparatus small enough to be placed in a balloon or a satellite would count about one gamma ray an hour. A balloon experiment seemed most unpromising because there would be no way to distinguish between gamma rays originating in the galaxy and those produced when cosmic rays strike atoms in the atmosphere above the balloon. The important quantity in these flux estimates is the total number of cosmic-ray-bombarded gas atoms in a column starting at the detector and extending out into space. In the vicinity of the solar system a column one square centimeter in cross section extending to the limits of the galaxy would contain about 10^{22} atoms of hydrogen. But at typical balloon altitudes the number of atmospheric atoms still above the detector would be at least 10^{24}. This meant that a balloon-borne instrument would "see" 100 or more atmospherically produced gamma rays for every galactic gamma ray and would be powerless to distinguish between them.

Nevertheless Thomas Cline, formerly of our laboratory, did undertake a balloon experiment in 1957. One of his objectives was to look for discrete high-intensity gamma ray sources comparable to the discrete sources of cosmic radio waves. If a gamma ray telescope were aimed at a high-intensity source, the source might produce a significant increase in the counting rate, over and above the high rate expected from the collision of cosmic rays with atoms of air. In 1960 Cline's telescope was flown at an altitude of 110,000 feet. In the small part of the sky his telescope scanned, no discrete gamma ray sources were detected, and the unfavorable flux calculations were confirmed.

In 1958 our laboratory was given the opportunity to design a gamma ray instrument to be placed aboard one of the Explorer satellites. The operation of the detector, designed by us in collaboration with G. Garmire, is best explained with the help of the diagram on page 58. Being electrically neutral, gamma rays cannot be detected directly. They can be detected indirectly, however, because an energetic gamma ray will readily produce an electron-positron pair if allowed to interact with the strong electric field of an atomic nucleus. The electrically charged electron and positron can then be detected by a number of methods. In our instrument an incoming gamma ray is quite likely to produce an electron-positron pair when it enters a scintillation detector consisting of a sandwich of cesium-iodide and sodium-iodide crystals. The creation of a pair is accompanied by a pulse of light that is detected by a photomultiplier tube.

One or both members of the pair, which are thrown forward in the direction of the parent gamma ray, continue through the instrument and enter a Čerenkov counter, which consists of a block of clear plastic. A charged particle will generate a cone of light—called Čerenkov radiation—if it travels in a transparent substance faster than light travels in that substance. In our instrument Čerenkov radiation in the plastic is detected by photomultiplier tubes. Co-



CONE OF VIEW of the gamma ray telescope forms an angle of 17 degrees with the central axis of the instrument. A gamma ray arising anywhere in this cone may reach the telescope, but the likelihood of its actually doing so falls off as the square of the dis-

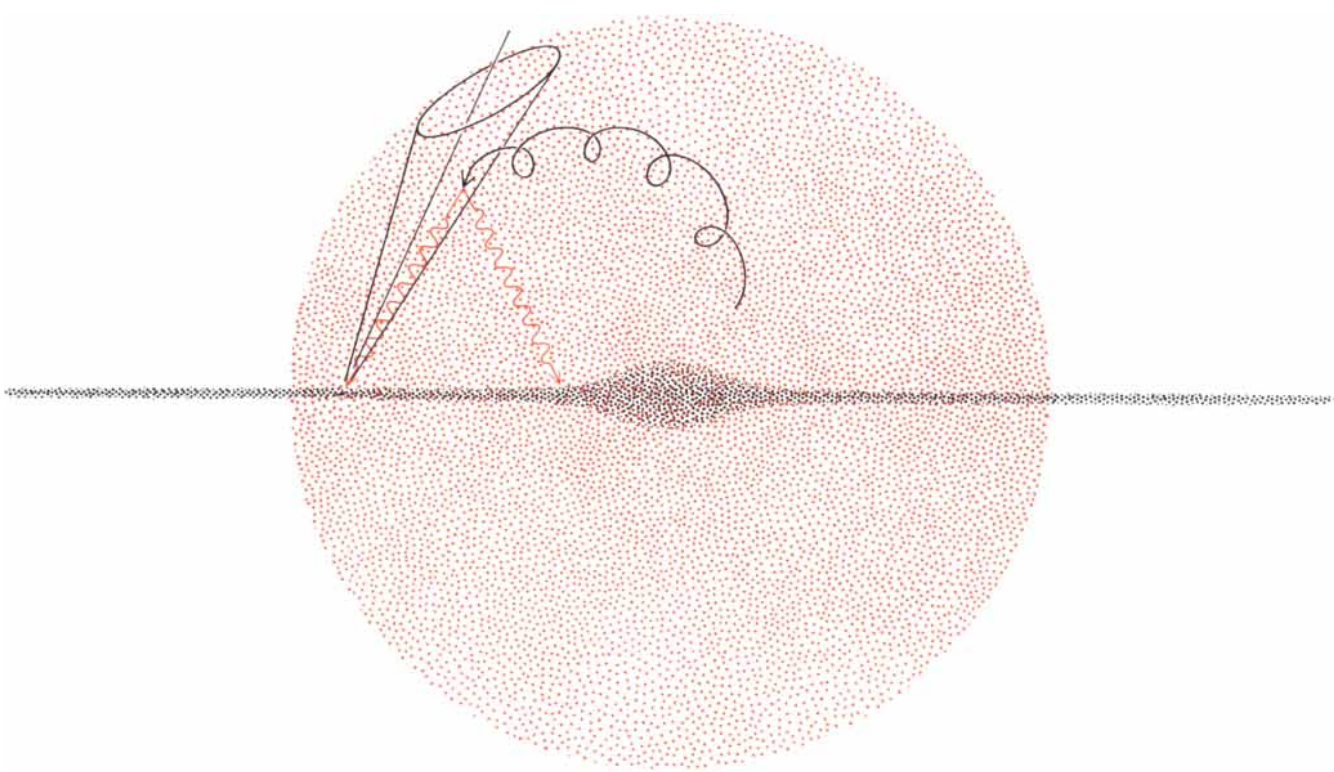
incidence circuits establish when a flash in the cesium-iodide–sodium-iodide scintillation detector has been followed almost immediately by a flash in the Čerenkov counter. There is a high probability that gamma rays entering the instrument within 17 degrees of its axis will produce such a dual flash. Gamma rays entering more obliquely will not.

This coincidence circuit is triggered about once a second by the relatively large flux of cosmic rays (chiefly protons) that continuously bombard the instrument. The two central detectors, therefore, are surrounded at the front and on the sides by a scintillating plastic that serves as a "veto" counter to distinguish the signals produced by cosmic rays from those produced by gamma rays. The veto counter readily responds to charged particles but not to gamma rays. There is only a small probability that a gamma ray will produce an electron-positron pair in its journey through the light elements (carbon, oxygen and hydrogen) of which the veto counter is made. (The probability of pair production is proportional to the square of the atomic number. For cesium, iodine and sodium these numbers are respectively 55, 53 and 11; for oxygen, carbon and hydrogen they are 8, 6 and 1.)

To sum up, the central counter and the Čerenkov counter make up a "telescope" in the sense that when a charged particle traverses the instrument from the forward direction, the two counters respond simultaneously. If the cause was an incident charged particle, the veto counter also responds and wipes out the record of the simultaneous event. But if the incident particle was a gamma ray, the veto counter does not respond, and a signal is telemetered to earth giving an indication of the energy lost by the electron-positron pair that activated the central scintillator.

For our telescope to provide even a rough survey of the gamma ray intensity of the sky, it would have to point in many different directions during its few months of operating life. Deliberate orientation of the instrument was out of the question for a satellite weighing only 82 pounds. That the scanning problem could be solved automatically was pointed out to us by James E. Kupperian, who co-ordinated the entire *Explorer XI* project, and Charles A. Lundquist, both of the National Aeronautics and Space Administration. The last stage of a Juno II rocket vehicle, which would carry our gamma ray telescope, goes into orbit spinning around its long axis at a rate of about 340 revolutions per minute. The spinning is intended to keep the satellite pointing at a fixed angle in space. If, however, the satellite has a long and thin body—more or less pencil-shaped like ours—this spinning motion itself is unstable. Experience with early Juno II vehicles had shown that after several days the satellite begins to wobble like a top that is slowing down. The wobble increases and soon the satellite is tumbling slowly in a flat plane around its transverse axis. Thereafter magnetic, gravitational and air-drag forces precess the tumble plane roughly 10 degrees a day and so provide in time a scan of the whole sky.

There was a worrisome period of about 15 days after the launching of *Explorer XI* on April 27, 1961, when the opening angle of the cone of motion remained quite small. By May 19, however, the motion was practically all tumble, and our gamma ray telescope, located from 300 to 1,100 miles above the earth, could begin its sky survey. For the next four months the satellite's 20-milliwatt transmitter operated beauti-



tance. The cone's cross-sectional area, however, increases as the square of the distance, so the contribution of gamma rays from a given plane (*B*) is the same as from a plane (*A*) half as remote (assuming equal production in both planes). As a result the gamma ray flux at the telescope is simply proportional to the number produced in a column of uniform cross section extending from the instrument to the boundary of any uniform region of space. The diagram at right indicates how a halo of low-density hydrogen (*colored dots*) envelops the inner portion of our galaxy, shown in cross section. The diameter of the galaxy is about 100,000 light-years. The cone of view of the gamma ray telescope is superimposed, together with a cosmic ray track (*black*) and two gamma rays.

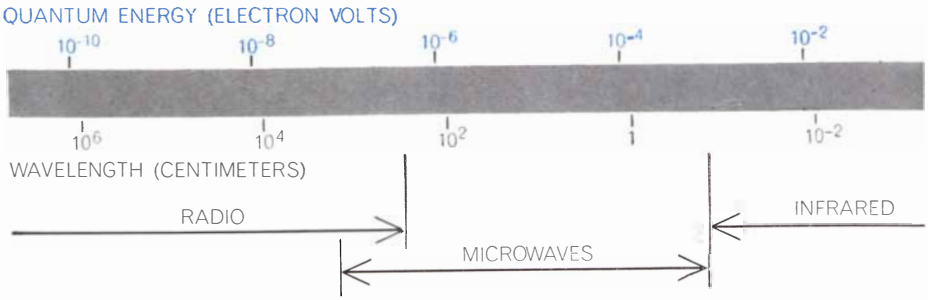
fully, providing nearly 20 miles of data on microfilm.

To establish the direction in which the telescope was pointing when a gamma ray event was recorded, we have used information of two kinds. First, the satellite carried light sensors that provided a signal when the satellite was pointed either at the sun or at the highly reflective surface of the earth. Second, the dozen receiving stations around the world that recorded information from the satellite also made a systematic record of the strength of the received signal. This intensity varied in a complicated fashion as the tumbling satellite passed over a station because its transmitting antenna did not radiate energy equally in all directions. A group at the George C. Marshall Space Flight Center at Huntsville, Ala., has successfully used the intensity variation in the received signal to deduce the satellite's orientation. The map on the opposite page shows how a line perpendicular to the satellite's plane of tumble moved across the sky over a six-month period.

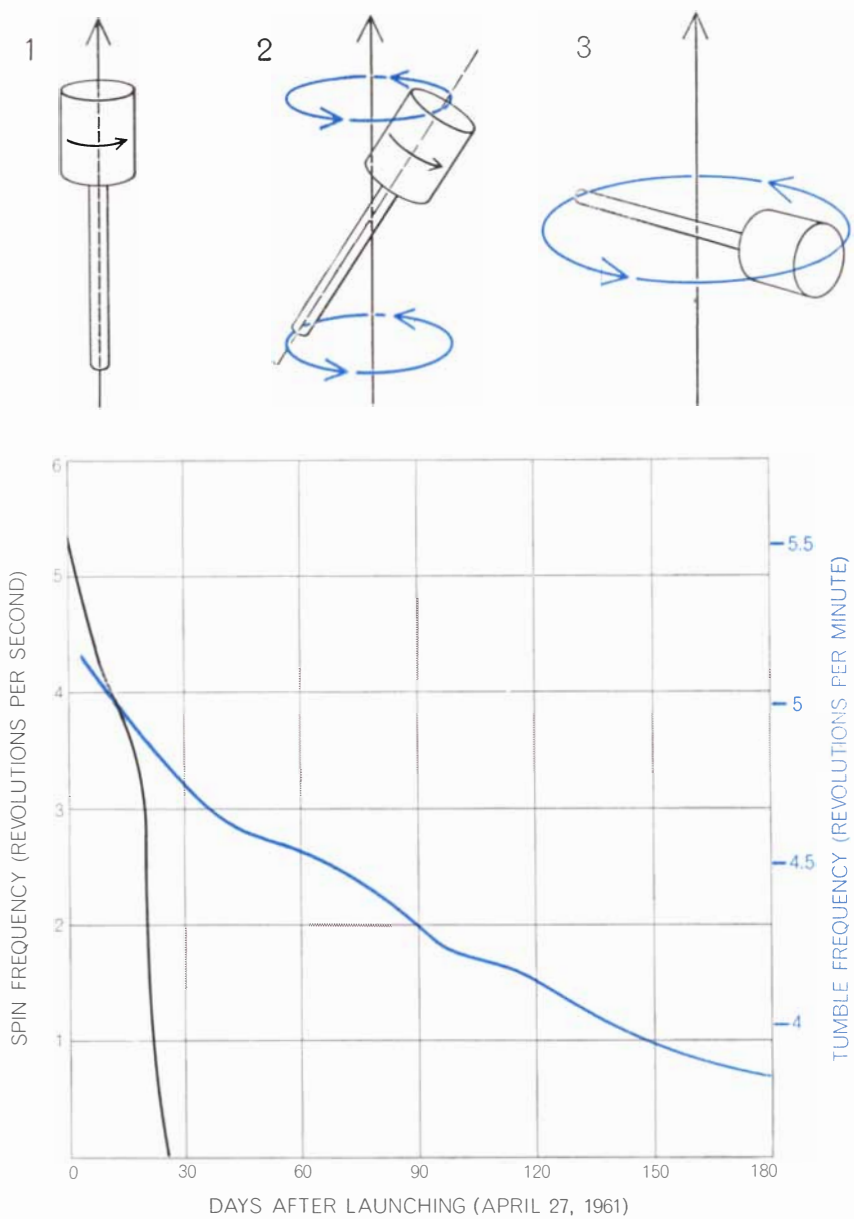
The microfilmed information from the satellite usually establishes the time of arrival of a gamma ray with an uncertainty of about .1 second. If we want to know to within five degrees or less where the telescope was pointing at that instant, we must first determine the plane of tumble with an accuracy of a few degrees and then establish the tumble frequency with an accuracy of about one part in a million. The accurate determination of the tumble plane and period, and the process of getting the data off the microfilm and into suitable form for presentation to an IBM 7090 computer, has taken somewhat longer than we had anticipated. So far we have fully analyzed only 23 days of data, or about a fifth of the total. Even this small amount has proved to be rewarding.

First of all, we are fairly certain that we have detected high-energy gamma rays from space. We say "fairly certain" and not "certain" because we have not been able to make all the cross checks and verifying tests that a physicist would make in his own laboratory on the ground. In more detail, here is what we have detected:

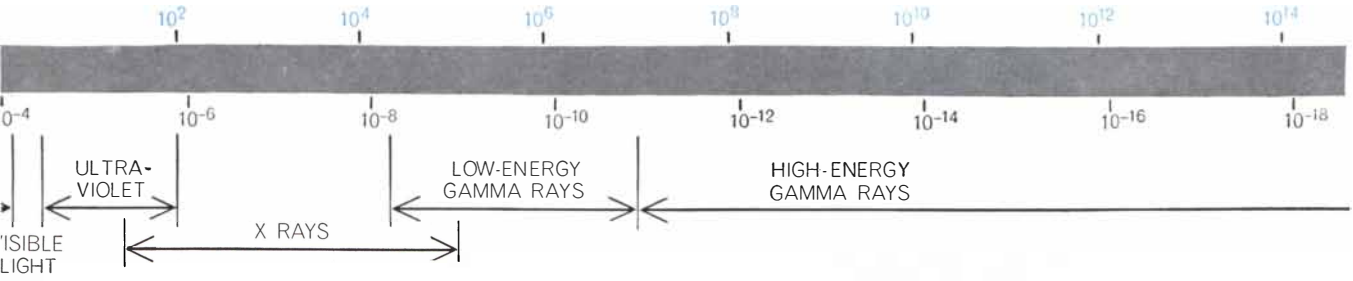
The 23 days of data include a total of nine hours during which the telescope was pointing into space and another 10 hours during which it was pointing at the earth. During the rest of the 23 days the satellite either was not over a receiving station, was temporarily inoperative while passing through the intense radi-



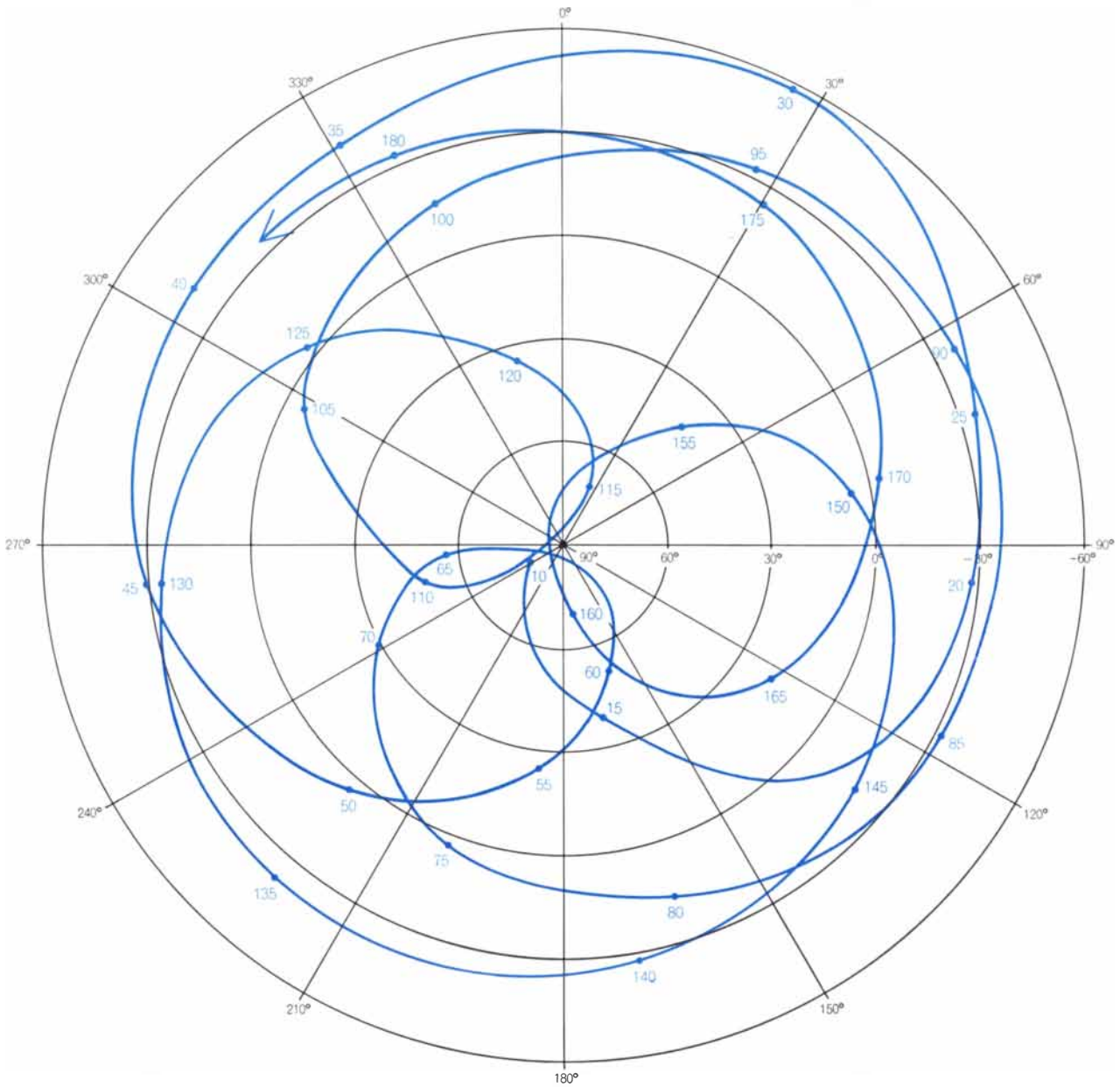
ELECTROMAGNETIC SPECTRUM is arbitrarily divided into regions that have somewhat confusing popular names. The entire spectrum is nothing more than a spectrum of photons



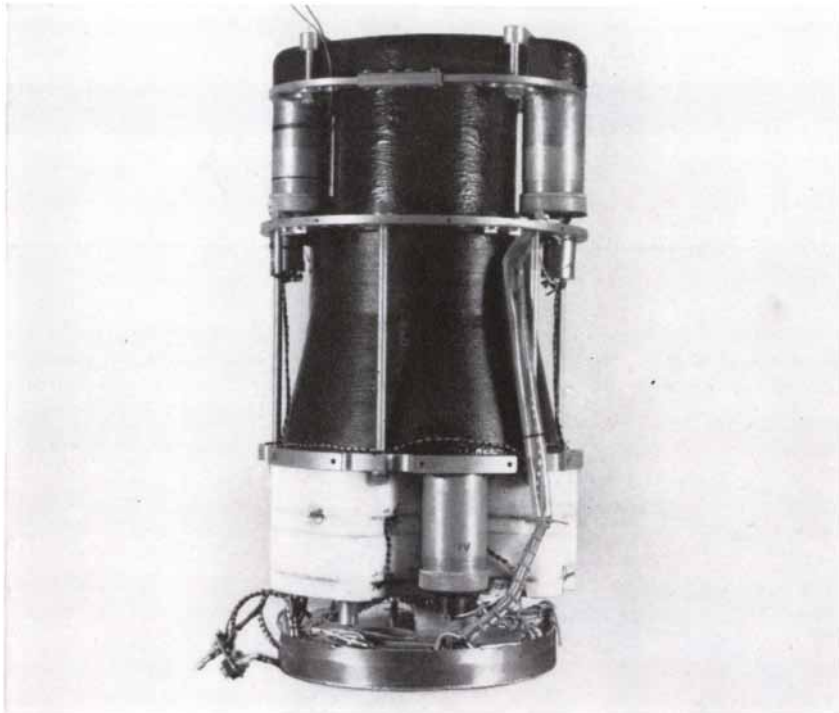
CHANGE FROM SPIN TO TUMBLE in the motion of *Explorer XI* was essential to making a gamma ray survey of the sky. As the satellite entered its orbit it was spinning on its long axis (*1 in diagram at left*) and thus was aimed at a fixed point in space as it circled the earth. Gradually the satellite began to wobble like a top slowing down (*2*); by the 30th day all



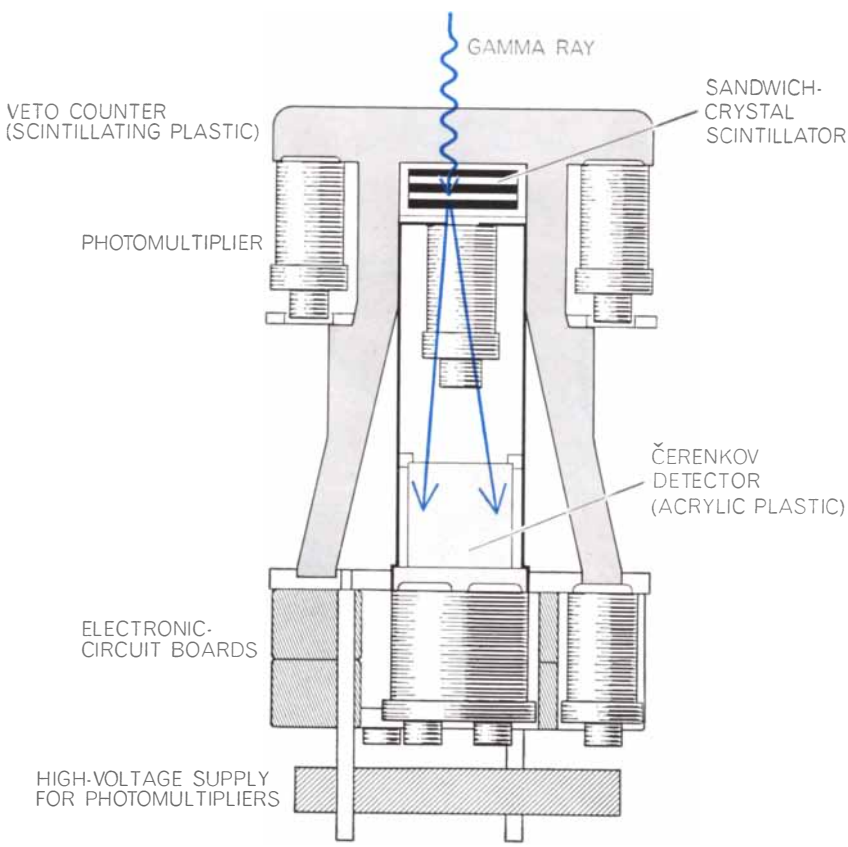
that carry different amounts of energy. Optical astronomy deals with photons of visible light and those of nearby energy. Radio astronomy deals with radio and microwaves. Gamma ray astronomy deals chiefly with photons lying above 50 million electron volts.



spin ceased and the satellite was tumbling in a flat plane (*3*). The tumble axis (*vertical arrow in 3*) assumed various orientations in space as it was precessed by various forces, chiefly magnetic. The map at right, prepared at Marshall Space Flight Center, shows how the axis of the tumble plane swept around the sky. The colored numbers indicate days after launching. To determine the direction of origin of each gamma ray recorded, the tumble axis and rate of tumbling have had to be established with great accuracy.



GAMMA RAY DETECTOR was designed and built in the Laboratory of Nuclear Science at the Massachusetts Institute of Technology. It weighs 30 pounds and is 20 inches high.

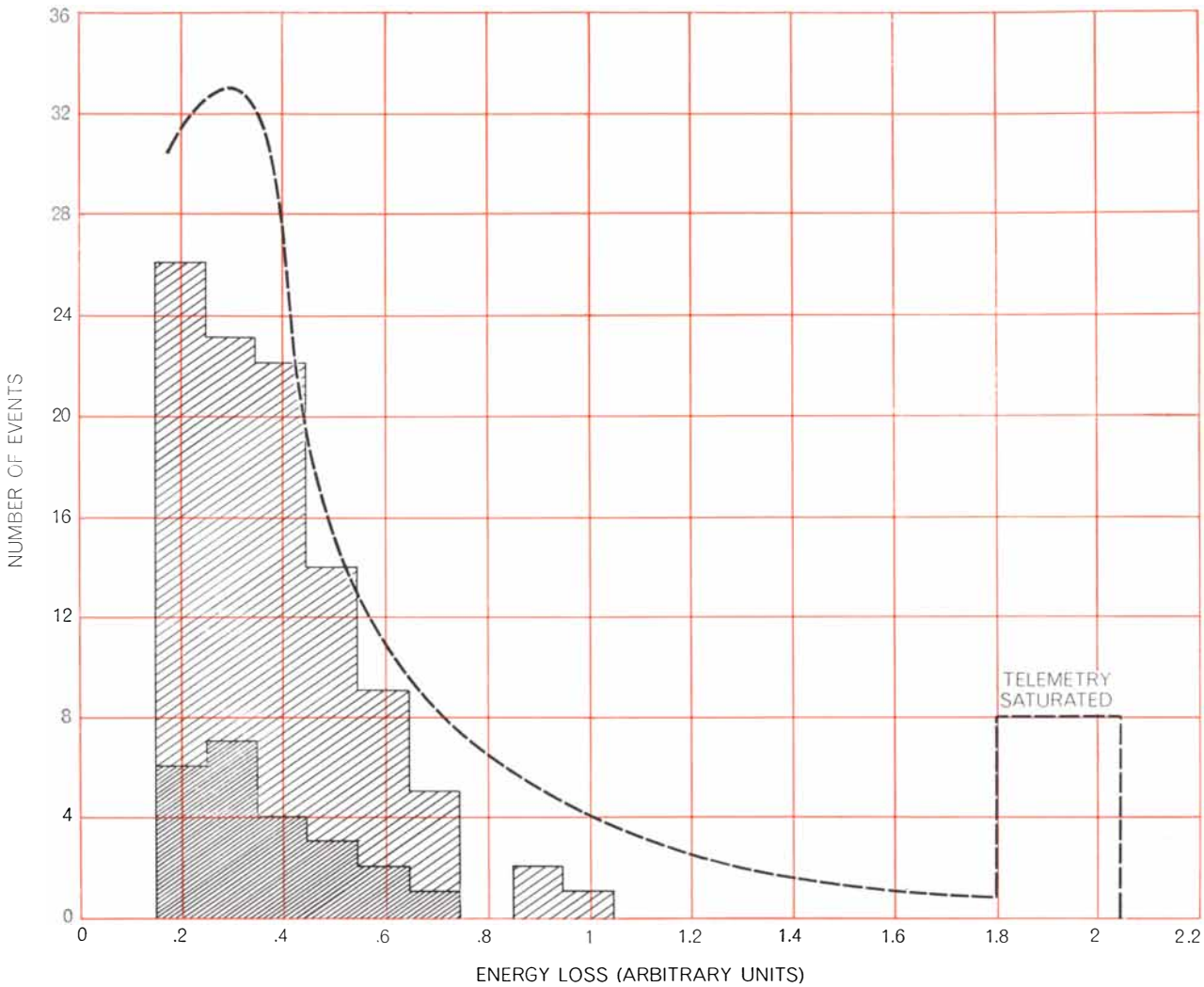


CROSS SECTION OF DETECTOR shows seven of the eight photomultiplier tubes crucial to its operation. A gamma ray that enters from the top passes through the "veto" counter, without giving off light, and is converted into an electron-positron pair (*straight colored arrows*) in the cesium-iodide–sodium-iodide crystal scintillator. In passing through the scintillator the pair produces a flash of light. If either member of the pair enters the Cerenkov counter, it causes another flash of light. Although such a sequence of flashes can also be created by incident charged particles, they trigger the veto counter as well and so can be rejected.

ation of the lower Van Allen belt, or had been commanded by radio to enter a calibration state. During the nine hours of looking at space the detectors recorded 22 events as being due to gamma rays and about 22,000 as being due to charged cosmic rays; during the 10 hours of looking at the earth the records show 105 gamma rays and about 3,000 charged particles. Of course no "cosmic" gamma rays or particles originate in the earth's atmosphere, but when cosmic rays collide with air atoms, some secondary gamma rays and charged particles fly backward, so to speak, from the earth. It was these that provided the 3,100-odd events counted when the satellite was looking down.

Since the proportion of charged particles to gamma ray events is very large, it is reasonable to worry that some, if not all, of the gamma ray events are spurious. If a charged particle slipped through the veto counter without activating it, the particle would be recorded as a gamma ray when it subsequently tripped the two central counters of the telescope. Fortunately there is evidence that this did not happen, or at least did not happen often. When the telescope looked into space, there was one gamma ray event for every 1,000 charged particles, whereas there was one gamma ray event for every 30 charged particles when the telescope faced earthward. If the veto counter was grossly inefficient, the proportions should be the same.

This does not rule out the possibility, however, that the veto counter might have had an inefficiency of one part in a 1,000, or enough to account for the 22 gamma ray events recorded from space. Again there is evidence that this is unlikely. For checking purposes the veto counter was turned off periodically. When this was done, the satellite telemetered to the ground the energy loss of every charged cosmic ray traversing the telescope. If the particle passes through the central scintillator without a nuclear collision, its energy loss is small. But if a collision occurs, several secondary high-energy particles are created and much more than the usual amount of energy is lost. With the veto counter off, 14 per cent of the charged particles released so much energy that they actually saturated the telemetry system. Accordingly if the gamma ray events detected with the veto counter operating were, in part, protons slipping through because of veto counter inefficiency, about 14 per cent of them should show large energy losses. Actually, however, among the 127 gamma ray events we have completely analyzed and the



GAMMA RAY EVENTS recorded by *Explorer XI* are of two types: "cosmic" gamma rays and "noncosmic" ones produced when cosmic rays strike the earth's atmosphere. Analysis of *Explorer XI* data so far shows 22 cosmic events (*dense shading*) and 105 noncosmic events (*open shading*). This chart shows, for each event, the energy loss in the sandwich-crystal detector. Evidence that gamma rays recorded were genuine is inferred from the energy-loss distribution of charged particles (*broken line*), which were tallied when the veto counter was deliberately turned off. About one in seven were so energetic that they saturated, or overloaded, the telemetry system. Since none of the gamma rays did so, it can be assumed that none was a charged particle that had slipped by the veto counter.

several hundred more we have inspected, none shows a large energy loss. That is why we feel "fairly certain" that *Explorer XI* has really detected gamma rays from space. Since it detected 22 in nine hours of total observation time, the rate works out to 2.4 per hour.

The results are far too meager to allow any general inferences about the distribution of cosmic rays and gas in our galaxy. But we can at least compare our results with the expected counting rate, based on prevailing estimates of the various astrophysical quantities involved.

The number of gamma rays emanating from a given region of space is proportional to the cosmic ray intensity multiplied by the number of gas atoms per unit volume. If one assumes that the cosmic ray intensity is everywhere the same, then, as we have seen previously, the gamma ray intensity in a given direction is proportional to the total number of gas atoms in a column of uniform cross section. The number in such a column is the density multiplied by the length of the column. This density varies, of course, in different regions of space. These regions include the solar system, the galactic disk, the galactic "halo," the space occupied by the local group of galaxies and the space between the galaxies.

One can compute the intensity of gamma rays that should arrive at the earth from these various regions by making certain assumptions about gas and cosmic ray densities. For the solar system out to the orbit of Pluto we can take the gas density to be about 30 hydrogen atoms per cubic centimeter, which is about the average value measured by *Explorer X*, and we can assume that the average cosmic ray flux is the same as it is near the earth. These assumptions predict a gamma ray counting rate for our satellite instrument of about one every 300,000 hours, an insignificant fraction of the rate actually observed.

This and other predictions are listed below. The first number after the region is the estimated number of hydrogen atoms per cubic centimeter; the second number is the predicted gamma ray counting rate per hour.

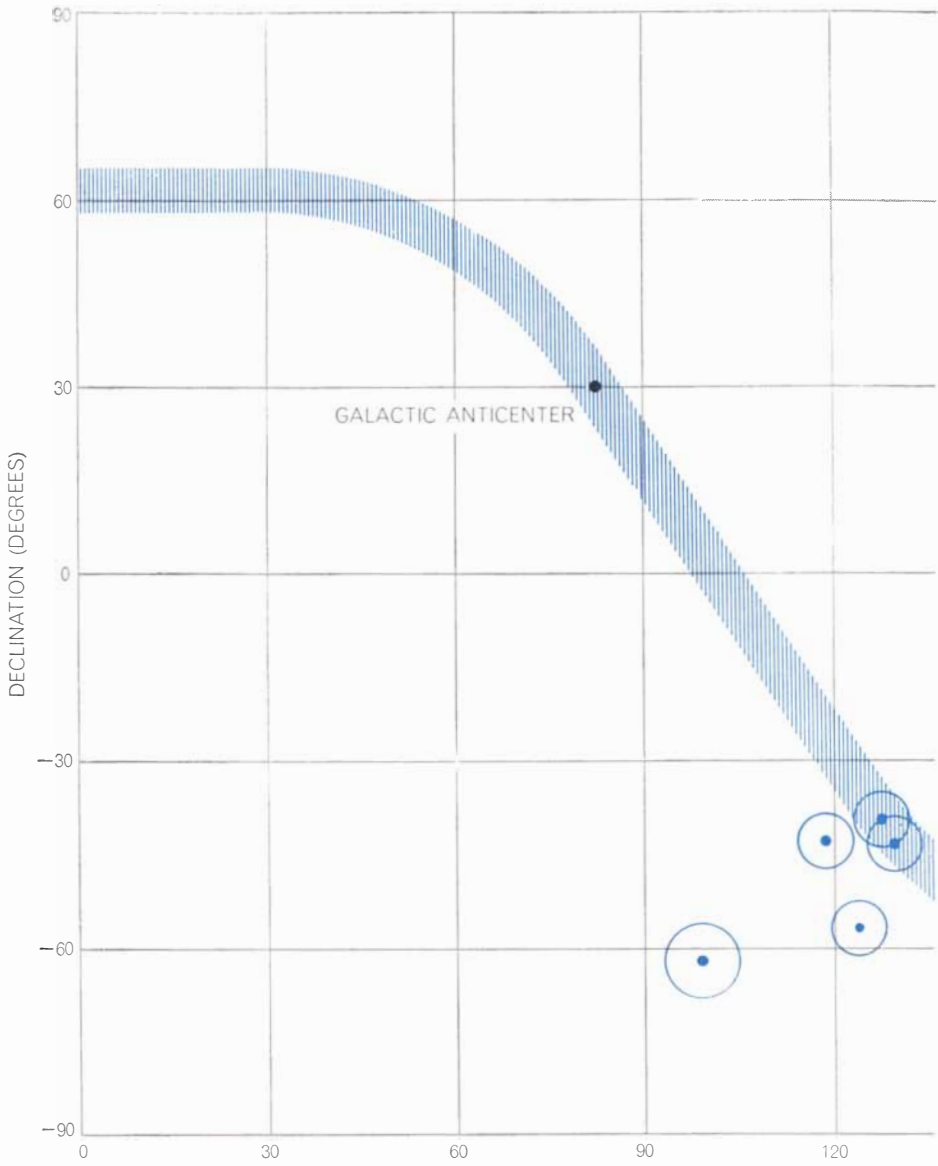
Solar system	30	.000003
Galactic disk	1	.3
Galactic halo	.01	.04
Intergalactic space	.000001	.7

The galactic disk is about 100,000 light-years in diameter and 1,000 light-

years thick. It contains about 100 billion stars and a volume of hydrogen gas approximately equal in mass to all the stars. If spread evenly throughout the disk, the gas would have a density of about one atom per cubic centimeter. Centered on the disk is the halo, a roughly spherical region that contains about the same total mass of gas as the disk but spread through a volume 100 times greater. The gamma rays from all this immense volume of space yield a predicted counting rate of only about one every three hours, or about a seventh the rate measured by our telescope.

If our count of 2.4 per hour is valid, it may indicate that most of the gamma rays entering our telescope came from intergalactic space. This region extends to a distance estimated at 13 billion light-years. The predicted count of .7 per hour from this vast region is quite uncertain and tentative. It assumes that intergalactic space is filled as densely with cosmic rays as galactic space is. This seems rather unlikely, for then the total energy in the universe in the form of cosmic radiation would be about 100 times greater than the energy in the form of light from stars. Stellar-fusion reactions are highly efficient at producing starlight, and no one can visualize how still greater amounts of energy could be fed into cosmic rays. The figure of an average of .000001 atom of hydrogen per cubic centimeter is also little more than a guess. If the actual value should be 10 times that figure, the predicted counting rate would be seven per hour instead of .7 per hour. All we can say is that our counting rate of 2.4 is consistent with the hypothesis that the cosmic ray flux is substantially the same everywhere.

If the gamma rays we have detected are coming from our galaxy, a plot should show more coming from the galactic plane and galactic center than elsewhere. The map on these two pages shows the direction of origin of the 22 gamma rays studied so far. The slight tendency for the gamma rays to cluster near the galactic plane is not significant, considering the small number of events, and the more pronounced concentration near the galactic center is barely significant. If the rest of our data confirms this tendency toward an asymmetrical distribution, we should be able to estimate rather well the fraction of gamma rays originating in the galaxy. If, on the other hand, our data should favor a symmetrical distribution, we will be perplexed. Symmetry would indicate that the galactic contribution is small compared with the intergalactic.

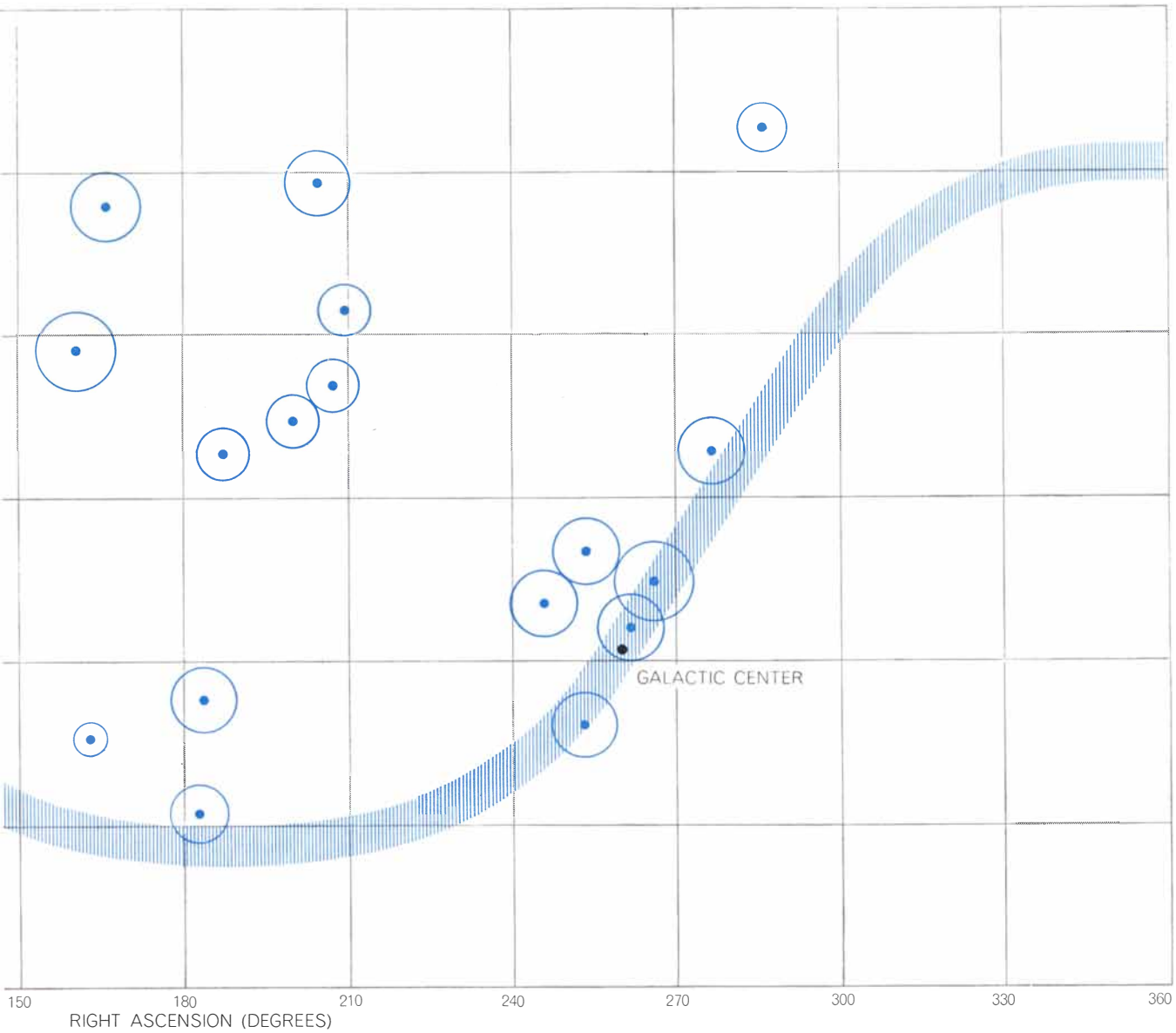


TWENTY-TWO GAMMA RAYS (*colored dots*) recorded by the telescope in *Explorer XI* came from many directions. If most gamma rays originate in the galaxy, they should tend to concentrate about the galactic plane (*shaded*) and particularly about the galactic center.

But whether our results point to a galactic or an extragalactic origin, they will be unable to tell us whether the gamma rays originated diffusely, over large regions of space, or whether they came from relatively small intense sources. The sky could conceivably be filled with many discrete sources so close together that our low-resolution detector would not be able to distinguish one from another.

For all its limitations, our experiment can be used with some confidence to test the version of the steady-state model of the universe to which we have referred. The general steady-state model is based on the hypothesis that the large-scale features of the universe have always been as they are now. To maintain the universe in this steady state, in the face of its apparent expansion, the model provides for the continuous creation of matter in the form of hydrogen atoms (protons and electrons). The required rate of creation is one hydrogen atom per century in a volume of space equal to that of a large office building.

In the version of this cosmological model that we wish to consider, it is assumed that antiprotons and positrons (antielectrons) are created in equal number with protons and electrons. Unless one postulates a special mechanism for keeping particles and antiparticles



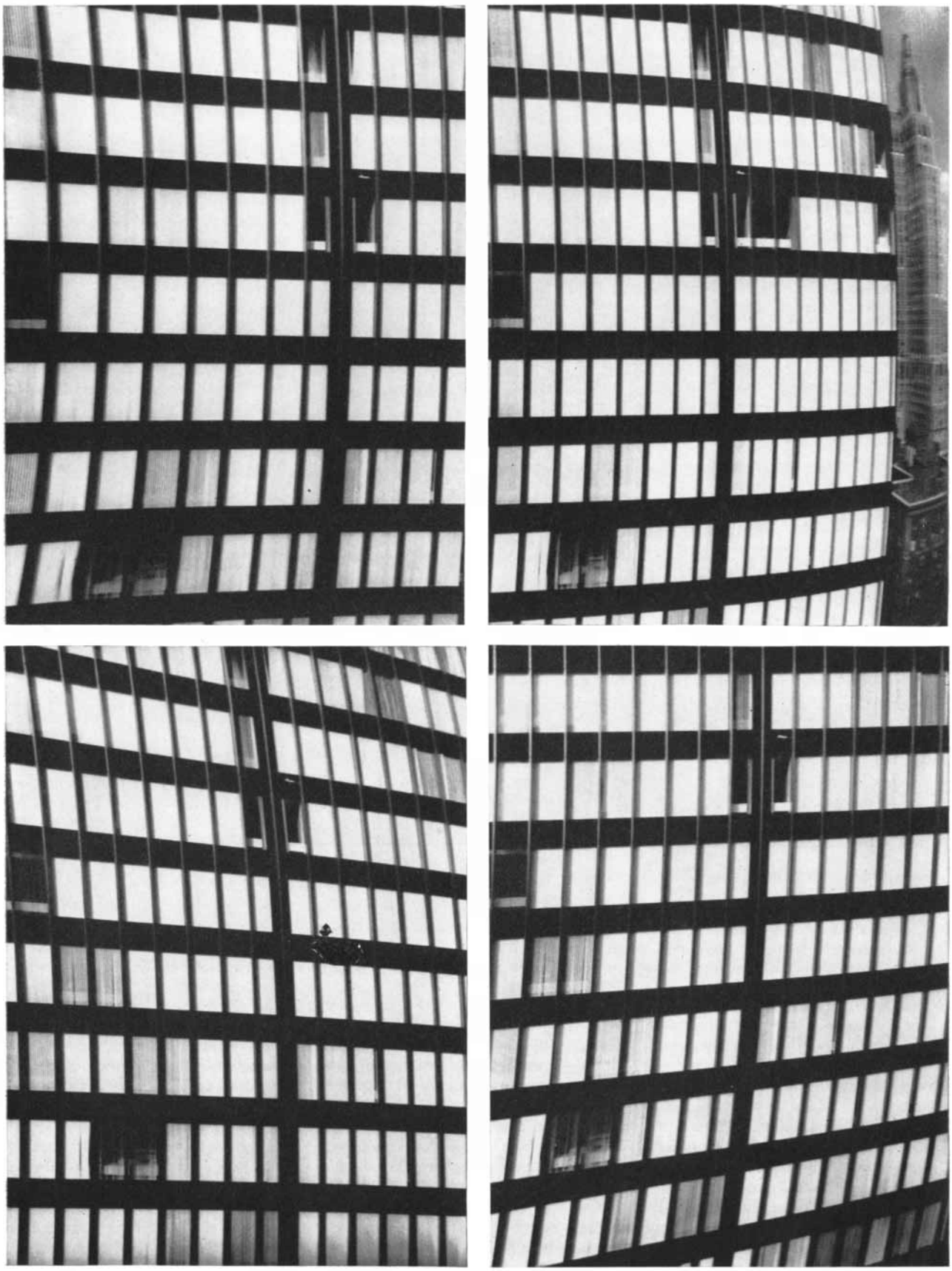
The areas of the circles around each gamma ray are proportional to the observational weight that should be attached to it. The weights differ because all portions of the sky were not scanned by the telescope for equal lengths of time. The region near right ascension 150 degrees, declination —50 degrees, was scanned the most. The region near the galactic anticenter was scanned the least.

apart indefinitely, any given antiproton set free in our galaxy would meet a proton in about 10 million years and the two would annihilate each other. Since gamma rays are one of the products of annihilation, they should influence the counting rate in our experiment. In fact, the antiprotons needed to maintain a balanced creation of particles and antiparticles in a steady-state universe would produce a gamma ray counting rate of more than 3,000 per hour. *Explorer XI* has clearly ruled out this possibility.

Before long other gamma ray sky surveys will be made from satellites. Moreover, at least three separate groups have designed ground-based equipment sensitive to gamma rays of very high energy, 10^{13} electron volts and higher. Strangely enough, such energetic gamma rays cannot travel so far in intergalactic space as those of lower energy. The reason is that gamma rays more energetic than 10^{12} electron volts are capable of producing electron-positron pairs not only by interacting with matter but also by direct interaction with the photons of starlight. The chance of such interaction is so great that few gamma rays of 10^{12} electron volts could ever finish a trip of a billion light-years.

Gamma rays of lower energy, on the other hand, should have no difficulty traveling the 13 billion light-years that separate the solar system from the "edge" of the universe. Thus satellite and ground-based observations may complement each other in determining the relative importance of extremely distant gamma ray sources.

It may be too extravagant to hope that gamma ray astronomy will ever prove to be as powerful and enlightening a tool as radio astronomy. The difficulties of improving the resolving power of gamma ray telescopes will be severe, particularly if only satellite-borne instruments prove to be feasible. But new techniques are bound to be developed, just as they have been in radio astronomy, as more workers become interested.



"RUBBER WORLD" is created by prism goggles. These photographs show what the eye would see through a prism with its base held to the right. If the head is turned to the right while glancing to the left, the image expands toward the left (*top left*). If head and eye movements are reversed, the image shrinks (*top right*). If the head is moved up and down, vertical and horizontal lines tilt so as to produce a "rocking chair" effect (*two bottom pictures*). For an undistorted view of this building see the opposite page.

Experiments with Goggles

In which special lenses are used to demonstrate the eye's remarkable ability to correct for distortions. Such studies help to explain how the visual system learns to produce an effective picture of the world

by Ivo Kohler

Of all the senses the one most intensively studied is undoubtedly vision. Much has been learned about the physical and physiological basis of visual perception, but understanding of the process remains primitive. Vision is perhaps the most complex of the senses; nonetheless it offers the investigator a tantalizing opportunity to learn how the brain processes sensory data and constructs an effective image of the outside world. Presumably this image is the result of an unconscious learning process; the image is "better" than it should be, considering the known defects in the visual system. For example, the lens of the eye is not corrected for spherical aberration; hence straight lines should look slightly curved. By the same token, lines of a certain curvature should appear straight. It is also well known that the eye is not corrected for color; as a result different wavelengths of light—originating at a common point—do not come to a common focus on the retina. One would expect this defect, called chromatic aberration, to have a noticeable effect on vision, but it does not, except under special conditions.

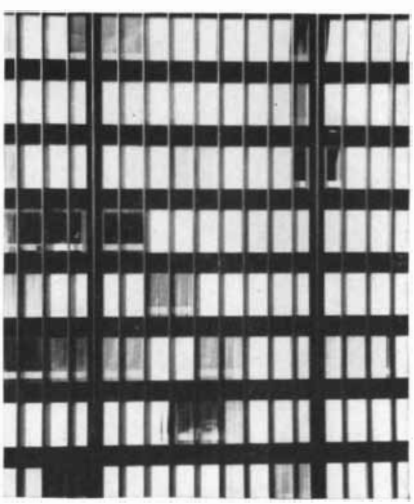
One way to explore the unconscious learning process that goes on in normal vision is to investigate how the visual system responds to images that are systematically distorted by specially constructed goggles. In this article I shall describe some of our studies, conducted at the University of Innsbruck in Austria, which show that the eye has a remarkable ability to discount or adapt to highly complex distortions involving both spatial geometry and color. But we have been surprised to discover that the eye does not adapt to certain other distortions that seem, superficially at least, less severe than those to which the eye does adapt. Some of these findings appear to be incompatible with traditional theories of vision in general and of color vision in particular.

In addition to contributing to the understanding of vision, experiments with goggles have immediate practical importance for ophthalmologists. If the ophthalmologist knows the extent to which the visual system can adapt to "wrongly" constructed experimental glasses, he will be less reluctant to prescribe strong glasses for his patients. The stronger a glass, meaning the higher its refractive power, the greater its capacity to distort images and produce a fringe of color around them. The ophthalmologist can tell a patient in need of strong glasses that the initially disagreeable distortions and rainbow fringes will disappear if he wears the glasses faithfully for several weeks. Or, to give another example, an operation to repair a detached retina sometimes leaves a fold in the retina that causes a bulge in the patient's visual world. On the basis of goggle experiments, the physician can assure the patient that the bulge will become less noticeable with time and will probably disappear altogether. The fold in the retina will remain, but the patient's vision will gradually adapt to discount its presence. What this implies, of course, is that an individual born with a fold or similar imperfection in his retina may never be aware of it.

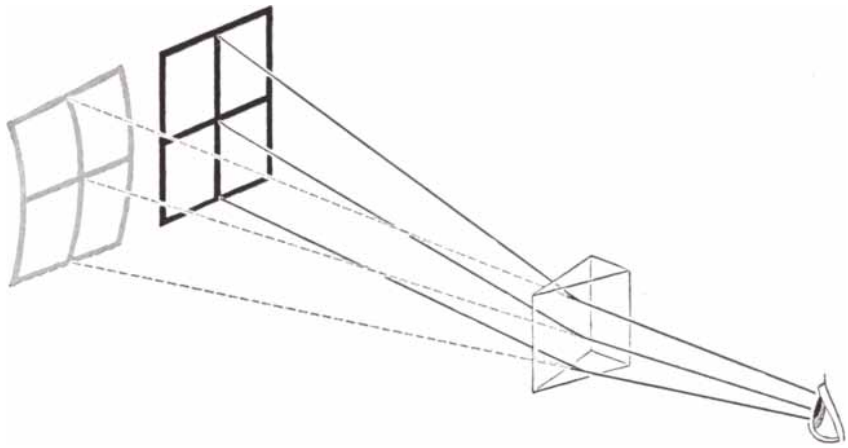
We conclude, therefore, that sense organs are not rigid machines but living and variable systems, the functioning of which is itself subject to variation. If a sensory system is exposed to a new and prolonged stimulus situation that departs from the one normally experienced, the system can be expected to undergo a fundamental change in its normal mode of operation.

The use of distorting goggles seems to be the simplest way of producing novel and prolonged visual-stimulus situations. The volunteer subject can be said to be wearing the laboratory on his nose; he cannot leave the laboratory unless he closes his eyes or removes the goggles. The entire visual system, including the manifold projection regions in the brain of which we still know so little, is subjected in a certain way to a completely novel and disturbing situation. Finally it "breaks down"; established habits are abandoned and the visual system begins to respond in a new manner.

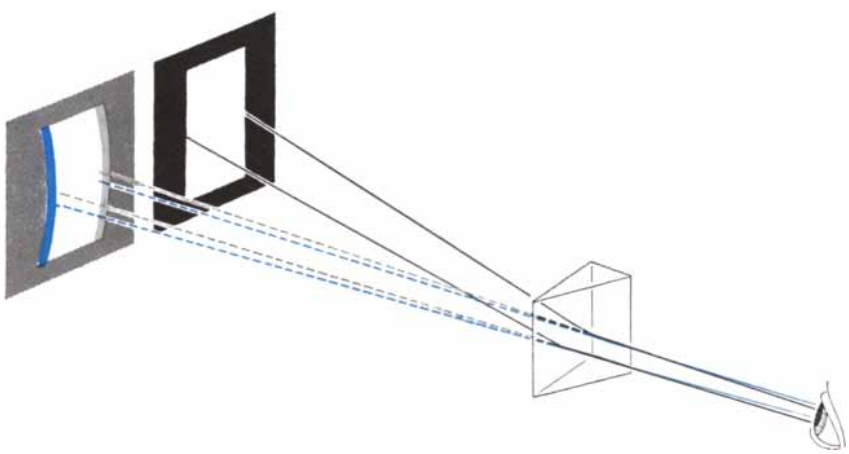
When we make the system break down and learn a new way of functioning, we do not believe we are forcing the system to function artificially or abnormally. We assume, rather, that a single mechanism is at work at all times. The mechanism that removes or minimizes an artificially created disturbance is the same one that brings about a normal



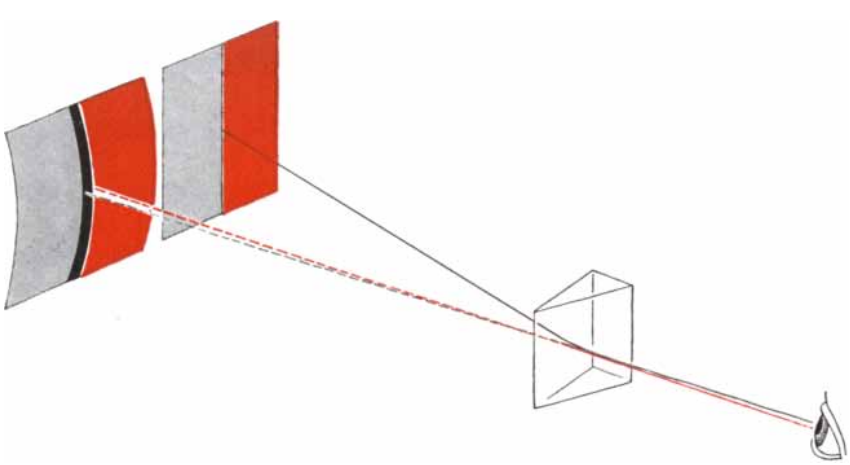
UNDISTORTED VIEW of the Union Carbide Building in New York can be compared with distorted images on opposite page.



CURVATURE OF LINES is observed when looking through a prism because light rays entering the prism obliquely are bent more than those entering at right angles. A prism that has its base to the right displaces images to the left and bends the top and bottom of vertical lines still farther to the left. As a result vertical lines seem to bow to the right.



FRINGE OF COLOR borders light-colored objects because a prism bends short wavelengths of light more than long wavelengths. If the prism base is to the right, blue rays, being bent the most, are seen as a blue fringe along the left-hand border. Similarly, a yellow-red fringe of color (*shown here in gray*) appears along the right-hand border of the object.



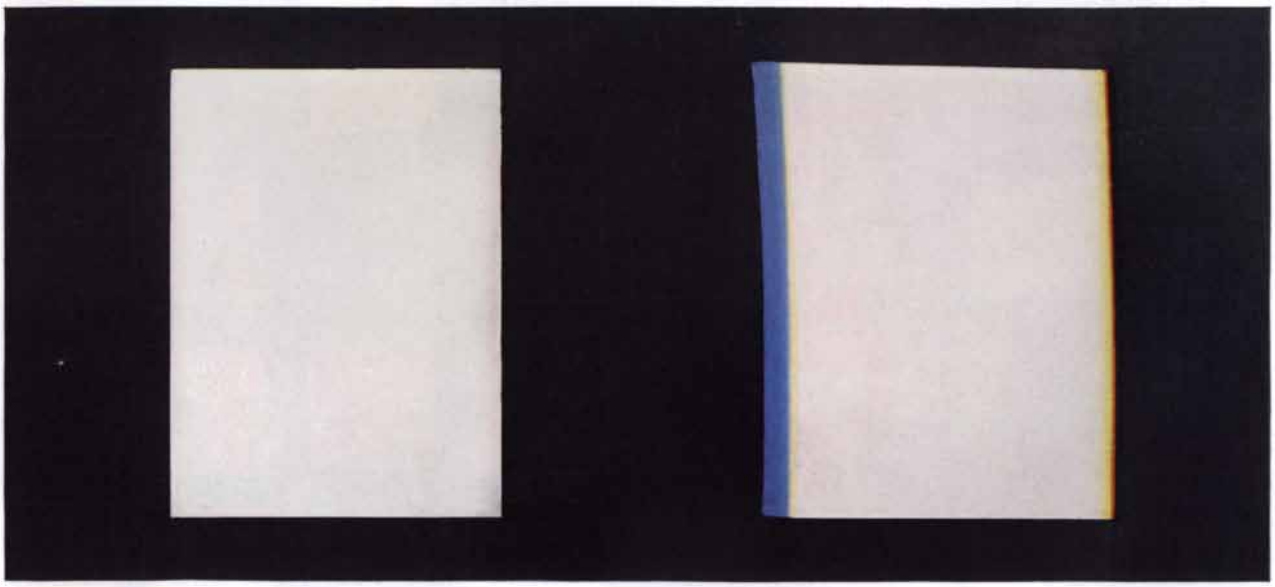
COLOR DISPLACEMENT is another consequence of the differential bending of light rays having different wavelengths. The diagram shows what happens if the green-red figure on the opposite page is viewed through a prism, base to right. The green area (*gray here*) is displaced to the left more than the red area, leaving an empty dark space between the two.

functioning of the sensory system under normal conditions. If this assumption is correct, the development of the normal visual system—in so far as its development depends on the environment—can be explored by the goggle method.

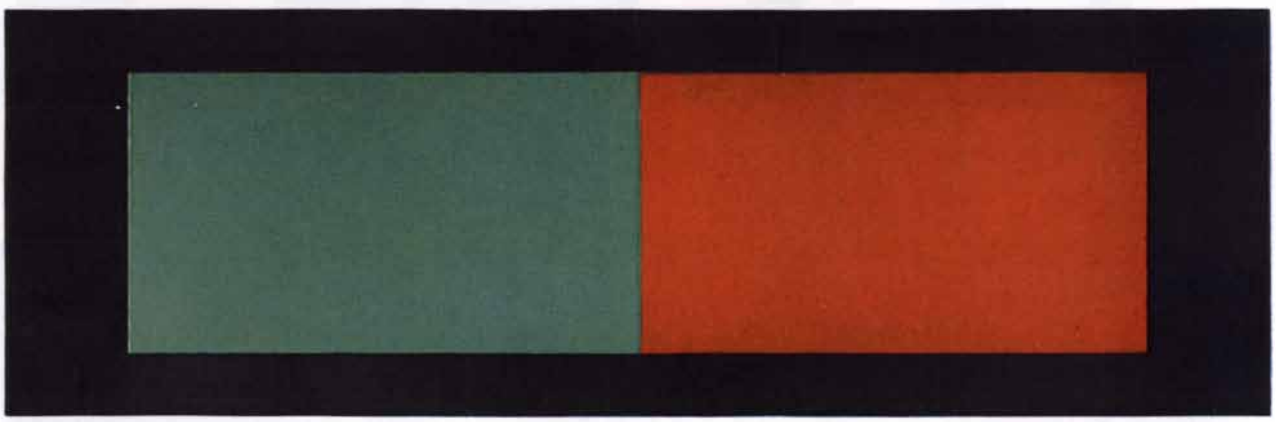
The application of distorting goggles to the study of visual adaptation dates back to the work of G. M. Stratton of the University of California, who used himself as a subject. Primarily because of the difficulty of finding subjects willing to wear goggles for days, weeks or even months, the method was little employed until about 1928. Then, independently and simultaneously, goggle experiments were undertaken by Theodor Erismann at the University of Innsbruck and by James J. Gibson at Smith College. Gibson's subjects wore goggles that placed a glass wedge, or prism, in front of each eye. Erismann experimented not only with prism goggles but also with more elaborate devices that transposed the visual field from right to left or from top to bottom. Another device allowed the subject to see only directly to the rear, as if he had eyes in the back of his head. After several weeks of wearing goggles that transposed right and left, one of Erismann's subjects became so at home in his reversed world that he was able to drive a motorcycle through Innsbruck while wearing the goggles.

Although Gibson's subjects wore goggles for only a few days at a time, they were the first to discover adaptation to the color fringes and line curvature that a prism produces. Depending on the extent to which the front and rear faces of a prism depart from the parallel, light rays passing through the glass are bent to a greater or lesser degree. This property is called the deviation of the prism. The deviation angle is approximately half the angle between the two faces. Deviations between five and 15 degrees are most useful for goggle experiments. Color fringes arise because light of short wavelength, such as blue light, is bent more than light of longer wavelength. As a result the line marking the edge of an object is spread out into a small spectrum, which becomes more noticeable the greater the contrast between the brightness of the object and that of its background [*see top illustration on opposite page*].

The curvature of lines is part of a more general prism effect that produces a variable change in the curvature, angle and distance of observed objects. The effect arises because the angle of deviation varies with the direction of the light reaching the front face of the prism.

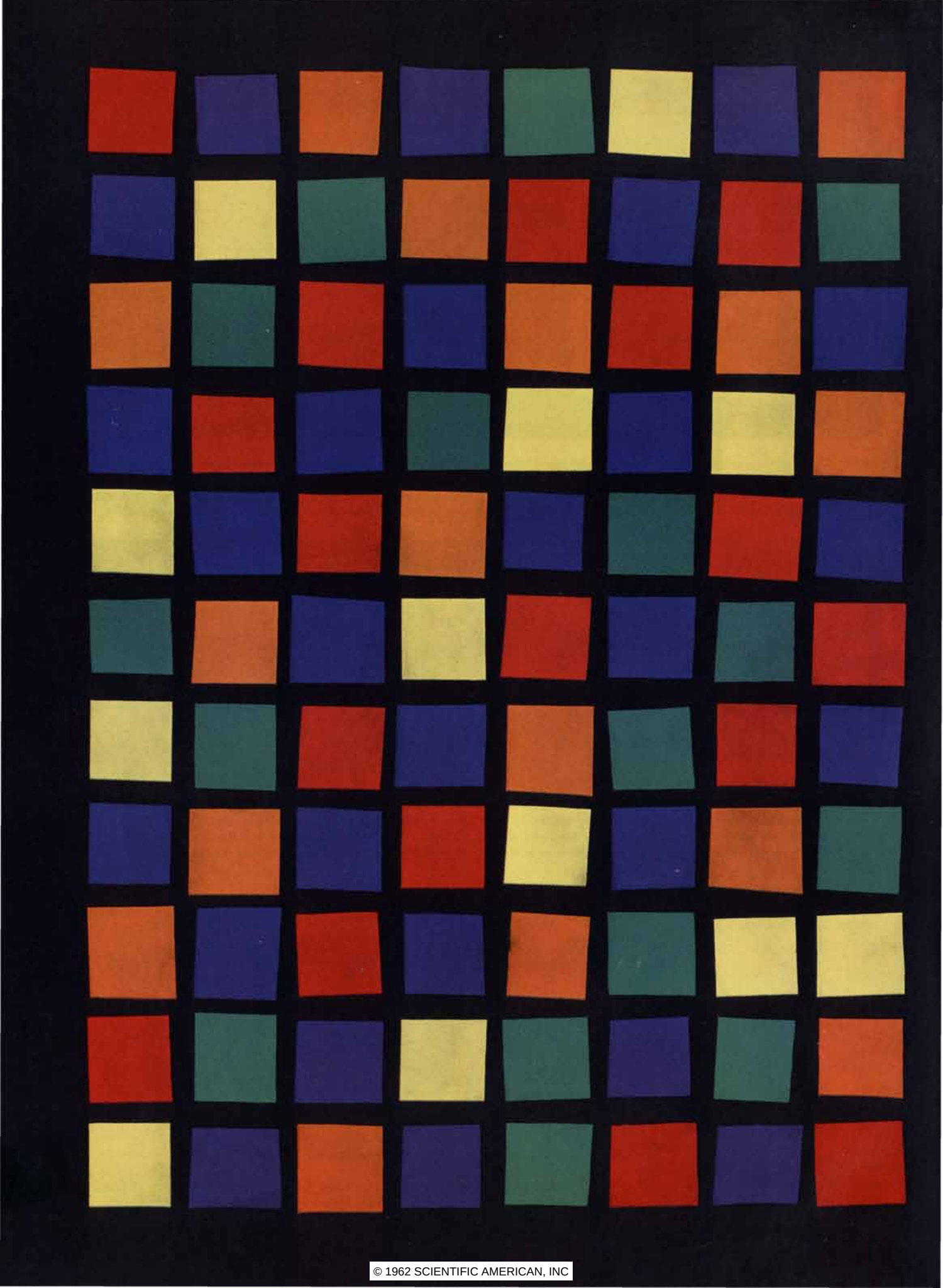


COLOR FRINGES appear (*right*) when a simple white-on-black figure is viewed through a prism having its base to the right. The prism also bends vertical lines. The undistorted figure is shown at the left. These prismatic distortions are explained in the upper two illustrations on the opposite page. After a subject has worn prism goggles for a few days the color fringes and line curvature largely disappear. When he removes the goggles, he sees fringes of a complementary color and lines having a reverse curvature.



TEST FIGURE shows how colors are differentially shifted by a prism. When viewed through a prism with base to the right, the greater shift of the green image leaves a thin black void at the color boundary (*see bottom illustration on opposite page*). When the prism is turned around, green overlaps red, producing a thin white border. An eye with prismatic defects will see similar effects.

COLORED GOGGLES devised by the author create a blue-tinted world when the wearer looks to the left and a yellow-tinted world when he looks to the right. If the goggles are worn for several weeks, the eye adapts and the color distortions tend to disappear. Somehow the visual system learns to introduce the proper correction according to whether the eyes are turned to the left or right.



Rays entering at an oblique angle are bent more than rays entering at a right angle. Consequently straight lines appear curved, right angles seem to be acute or obtuse and distances seem to be expanded or foreshortened [*see illustrations on page 62*].

To a subject wearing prism goggles these assorted distortions produce a visual world whose appearance changes drastically as he turns his head. One of our subjects reported that it is "as if the world were made of rubber." When the head is turned to right or left, objects become broader or narrower, producing a "concertina" effect. When the head is moved up or down, objects seem to slant first one way, then the other. We have called this the rocking-chair effect.

Although the distortions arising from prism movement are severe, they might present the eye with a straightforward adaptation problem if the prism were held in rigid alignment with the central axis of the eye. In this case the rays reaching any particular area of the retina would always be deflected by the same amount and would therefore maintain a fixed angular relationship to rays striking adjacent retinal areas. Such a rigid relationship between prism and eye could be achieved if the prism could be worn as a contact lens resting directly on the cornea.

In the Erismann and Gibson experiments, however, as well as in our more recent ones, there is a small distance between the eye and the prism. As a result the eye can, and frequently does, move with respect to the glasses. Two kinds of relative motion arise. In one case the eye can be fixed on a given object while the head and goggles move. In the second case the head and goggles remain fixed while the eye moves. If one analyzes the geometry of the rays striking the retina, one finds that the adaptation problem is much more severe than if the prism and the eye could be held in rigid relationship. Let us consider a single retinal area, for example the important small region called the fovea, near the center of the retina, where the eye has its maximum acuity. The images reaching the fovea will be distorted more when the eye is looking obliquely through the prism than they will be when it is looking straight ahead. In fact, the distortion changes with every change in the angle that the axis of the eye makes in relation to the prism.

In the accounts of his experiments Gibson neglected the free mobility of the eyes with respect to the glasses. Since his experiments were of short duration it is not clear how much adaptation took place among his subjects. He refers specifically only to adaptation to color fringes and to the curvature of lines. The latter is often called the Gibson effect.

In our much longer experiments, which extended the investigations begun by Erismann, a finely differentiated adaptation can be observed. Like Gibson's subjects, ours adapt rather quickly to color fringes and line curvature. We refer to these as constant distortions because they are essentially independent of head and eye movement. After wearing prism goggles for several weeks, however, our subjects also adapt to the more complex variable distortions, which are generated partly by movement of the head and goggles and partly by movement of the eyes behind the goggles.

I should like to stress the distinction between constant and variable distortions. Adaptation to the latter category apparently involves a process more complex than all previously known processes of visual adaptation. Let us suppose that the subject is provided with goggles that have prisms whose bases point to the right. When, at the start of the experiment, the subject turns his head to the left and glances to the right, he sees an image that contracts in its horizontal dimensions. Conversely, when he turns his head to the right and glances to the left, he sees an expanding image. After several weeks, however, an adaptation occurs that counteracts both of these forms of distortion. This process of double adaptation tends ultimately to eliminate the concertina effect. What seems so remarkable is that this takes place in spite of the fact that the fovea and other retinal areas have been exposed to a random mixture of these variable images. Somehow the visual system has learned a general rule: a contracted image must be expanded and an expanded image must be contracted, depending on the respective position of head and eyes.

If, after weeks or months, the subject is allowed to remove his goggles, the adaptation continues to operate when he views the normal world. The result is an apparent squeezing of images when he glances one way and an expansion when he glances the other. It is as if he were looking for the first time through prisms that have an orientation exactly opposite to those he has been wearing for so long. Moreover, all the other distortions, such as the rocking-chair effect, to which his eyes have slowly become adapted now appear in reverse when the goggles are removed. These aftereffects in their turn diminish in strength over a period of days, and the subject finally sees the stable world he used to know.

Both adaptation and aftereffects are vividly reported by our subjects. But in addition we have built devices that provide an objective measurement of the phenomena. These devices, for example, present the subject with a variety of horizontal and vertical lines that he can adjust in orientation and curvature until they look "right." Another device allows the subject to look through prisms and select the one with the strength appropriate to cancel the aftereffects induced by wearing prism goggles.

Let us now consider the adaptation to the color fringes a prism produces. If a prism with base to the right is placed before the eye and one looks at a white card on a black background, one sees a blue border along the left vertical edge of the card and a yellow-orange border along the right edge. The explanation is that the various colors of light reflected from the card and carrying its image no longer overlap precisely after passing through the prism. The result is a whole series of slightly offset colored images: yellow to left of red, green to left of yellow and blue to left of green. Across most of the area of the white card the multiplicity of colored images is not apparent because the various colors recombine to form white light. But at the left edge, where the card meets the black background, the blue image, which is shifted farthest to the left, can be seen as a blue border. Similarly, the red image appears along the right edge. (When the prism is weak, the right border looks yellow or orange rather than red because red and yellow lie so close together in the spectrum.

If one views the world through goggles with their prism bases fixed in the same direction, the rainbow fringes diminish rather quickly in intensity and

COLOR-STEREO EFFECT refers to a visual phenomenon in which colors appear to be located at different depths, according to wavelength. It is a special case of color displacement. The reader should be able to obtain the effect by looking at the opposite page with the outer half of each eye shielded with a card, as shown in the drawing on the next page. Blue and green squares should appear to float above those of other colors; red should seem farthest away.

within a few days virtually disappear. Here again, as a result of adaptation, a complementary aftereffect appears when the glasses are removed. The adaptation that has canceled the blue fringe on objects produces a yellowish fringe and vice versa. This complementary aftereffect, which we call the rainbow phantom, can appear after goggles have been worn for less than a day.

At first consideration the rainbow phantom may not seem surprising. Everyone is familiar with the complementary afterimage that can be induced by staring for about 20 seconds at a brightly colored pattern. Evidently the retinal elements that have been intensively exposed to a given color change in some manner, so that when they are subsequently stimulated by a neutral light, they produce a different signal from adjacent elements that are still fresh. In accordance with the work of the German psychologist Ewald Hering, we ascribe such phenomena to a process of self-regulation. The sensory response becomes shifted in such a way as to make a persisting color stimulus appear more and more neutral. As a result a second color stimulus that had previously seemed neutral now appears shifted along the spectrum; for example, toward the blue-green if the first stimulus was red.

The puzzling aspect of the rainbow phantom is that blue and yellow are themselves complementary colors. Moreover, the small foveal area, which provides most of the eye's sensitivity to color, is randomly exposed to both yellow and blue stimuli during prism-goggle experiments. Consequently the response of the fovea should become equally modified to both colors, and since each is the complement of the other their aftereffects should cancel.

Nevertheless, the rainbow adaptation and its aftereffect, the rainbow phantom, do take place. How can they be explained? As in the case of adaptation to variable distortions of geometry, we must evidently assume a similar kind of multiple (at least double) adaptation for color vision also. The two aspects are the distortion itself and the context or situation in which the distortion occurs. I have already indicated that adaptation to the concertina effect requires the visual system to learn that images contract when one looks in one direction and expand when one looks in the other. In the case of color fringing the distortion is related to a brightness gradient. The subject looking at the world through prisms that have their bases facing to the right unconsciously learns a new rule: The boundary between a dark field on the left and a light field on the right always has a fringe of blue; when the dark field lies to the right of the light field, the fringe is always yellow. We must assume that the total adaptation process requires simultaneous adjustment to these two conditions. The rainbow phantom, which appears when the goggles are removed, can then be explained as a direct consequence of the complex adaptation process.

Once we had arrived at this explanatory concept, we undertook a further exploration of "situational color adaptation." For this purpose we designed goggles in which each lens was made up of two differently colored half-segments. For example, each lens might be half blue and half yellow [*see bottom illustration on page 65*]. Wearing such goggles, a subject sees a blue-tinted world when he looks to the left and a yellow-tinted world when he looks to the right. If the two colors are complementary, the situation is somewhat analogous to the rainbow effect of prism goggles. The difference is that the colors are related not to a brightness gradient but to specific positions of the head and eyes; in other words, to a "kinesthetic" gradient.

The experimental results were in accord with those obtained with prism goggles. As before, we found that the visual system adapts to complementary color stimuli so long as the colors are invariably associated with a particular situation—in this case, particular head-and-eye positions. The illustrations on pages 70 and 71 show the results of measuring color adaptation on the first day and on the 60th day of an experiment with blue-yellow glasses. The measurements are obtained through the use of an illuminated window whose color can be varied by turning a dial. The subject first looks at the window through the yellow half of his glasses and turns the dial until the window appears white or neutral in color. To achieve this condition the window must actually be made somewhat blue. The amount of blue light required is automatically recorded. The subject then readjusts the color of the window while looking through the blue half of his glasses. Finally he views the window without glasses, with his eyes turned first to the right and then to the left.

When the subject eventually removes his two-color goggles after wearing them continuously for 60 days, there is no doubt that his visual world is tinged distinctly yellow when he looks in the direction that his goggles had been blue and blue in the direction that his goggles had been yellow. The movement of the eyes, either to right or left, seems to act as a signal for the foveal area to switch over in its color response, compensating for a yellow image in one case and a blue image in the other.

At this point in our investigations everything seemed reasonably clear, but suddenly a new and mystifying phenomenon appeared, the implications of which have not yet been fully explored. During our prism experiments we had also constructed glasses in which the prisms in front of each eye were mounted with their bases pointed in opposite directions. Similar glasses are regularly prescribed by ophthalmologists to correct strabismus, also known as squinting. People with strabismus are unable to focus both eyes on the same object because the eyes turn either inward or outward; crossed eyes are an example. Ophthalmologists are often reluctant to prescribe corrective prism glasses for strabismus because of their concern that the patient may be disturbed by the distortions and color fringes that such glasses produce.

It was partly this prejudice that prompted our experiments. Because our subjects did not have strabismus they

COLORS ACQUIRE DEPTH if viewed with the eyes partially covered by two cards (*left*), which exploit the chromatic aber-

found the wearing of "squint glasses" difficult until they learned to squint; that is, to turn their eyes either inward or outward, depending on the orientation of the prisms. We found, nevertheless, that adaptation is possible and that it occurs just as rapidly as it does with our usual prismatic goggles.

Our interest, however, was soon drawn to some special effects produced by squint glasses. Because the prism bases face in opposite directions, the glasses create novel stereoscopic effects in addition to those normally seen in binocular vision. The stereoscopic effects involve geometric figures and, more important, colors. If one looks at a vertical rod with prism glasses of the type described earlier, the rod will seem to bend either to the left or to the right, depending on which way the prism bases face. If the same rod is viewed with squint glasses equipped with prism bases facing outward, the rod will appear to be bent away from the observer. Similarly, plane surfaces will look concave.

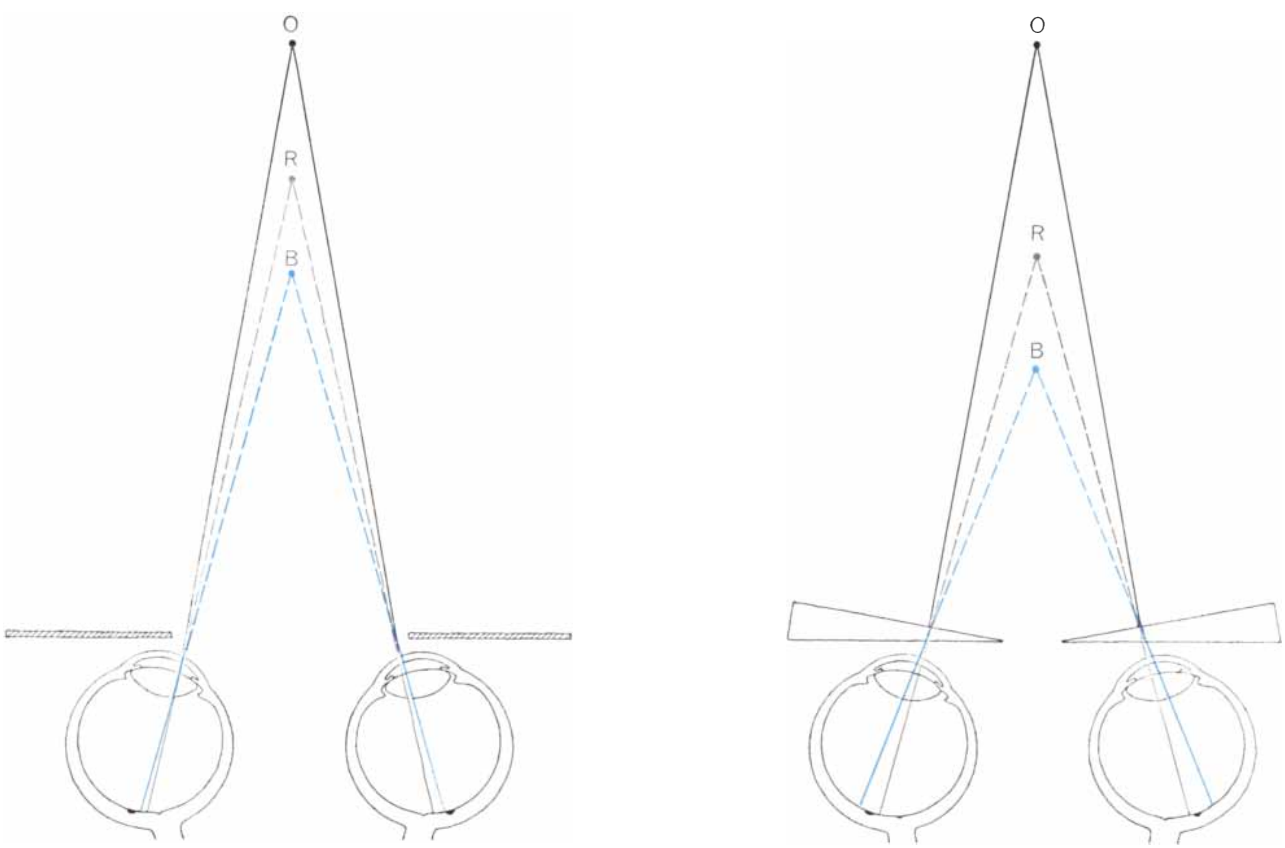
But it was the stereoscopic effects involving color that took us most by surprise. On September 10, 1952, the first day of an extended experiment with squint glasses, one of our subjects described his discovery as follows.

"In the course of a trip through town, I made the following peculiar observations: multicolored posters, traffic signs, people wearing multicolored clothes, and so on, did not appear as before to lie in one plane, but blue seemed to protrude far beyond the object plane, whereas red seemed to recede, depending on whether the background was bright or dark. A woman carrying a red bag slung over her back seemed to be transparent, and the bag to be inside her, somewhere near her stomach.... Most peculiar was a woman wearing a red blouse. She had no upper body, and the red blouse seemed to be following her about a pace behind, moving its empty sleeves in rhythm with the movement of her arms."

After explaining to ourselves this "color-stereo" effect, we were impatient to learn whether or not the subject's eyes would ultimately adapt and restore colored objects to their proper place. The explanation is not difficult. Each prism deflects colors differentially according to wavelength but in opposite directions since the prism bases are in opposition. When the bases face outward, the blues are deflected outward more than other colors and the eyes must actually converge more to bring blue images into focus than to focus red images, which are deflected less by the two prisms. As a result, blue images seem closer to the observer than red images, and images in other colors seem to lie somewhere between the two, according to wavelength [*see illustration below*].

Again we were surprised by the outcome of the experiment. We have discovered that there is not the slightest adaptation to the color-stereo effect. This was true even in our longest test, in which a subject wore squint glasses for 52 days.

The reader can see the color-stereo effect for himself by viewing the illustration on page 66. Although the effect is more vivid with two prisms, or even one, it can be observed by making use of the chromatic aberration present in the normal eye. The procedure was described almost a century ago by the German physicist Hermann von Helmholtz. One covers the outer half of each

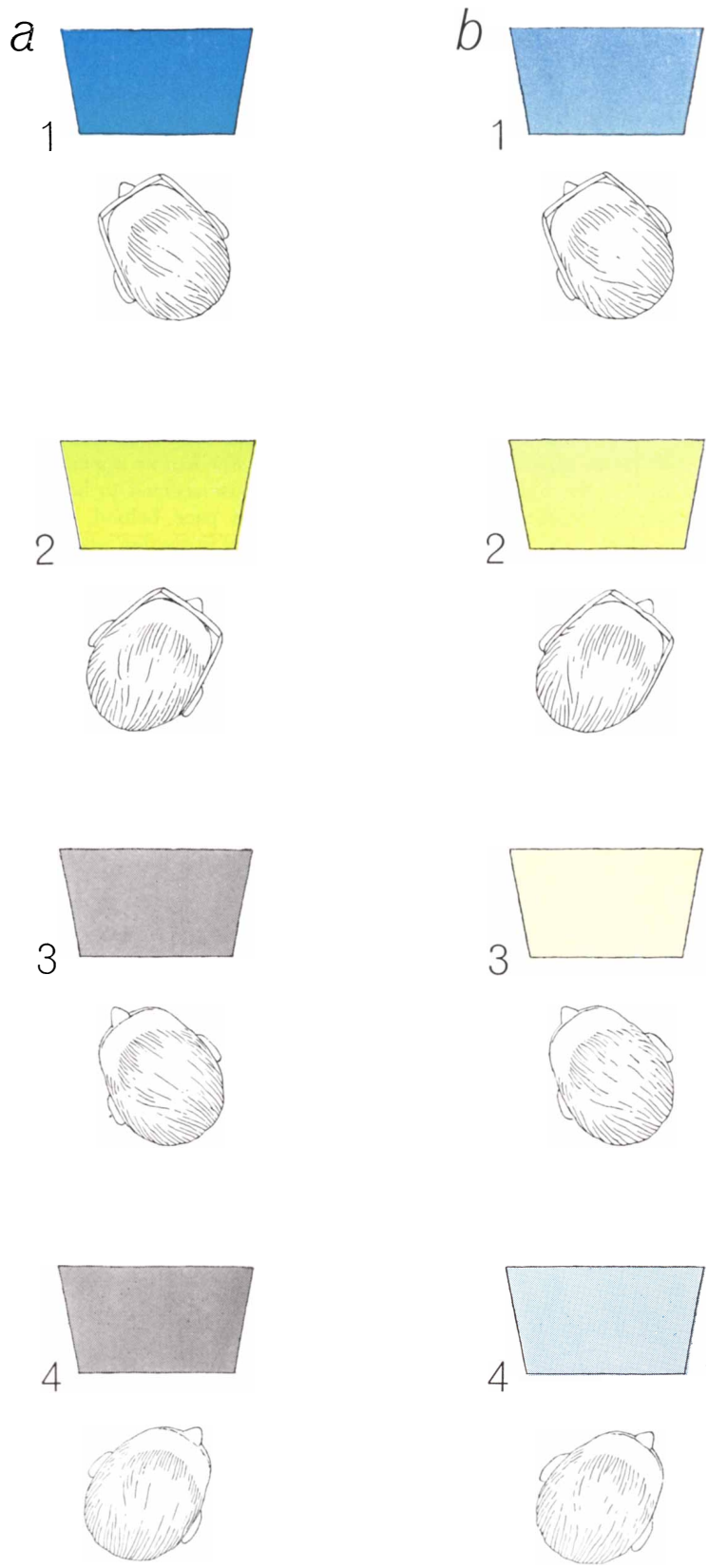


ration of the eye and simulate the effect of looking through prisms whose bases are opposed. The stereo effect works best when strong colors appear against a black background, as on page 66. If light originating at *O* is blue (*B*), it is bent more than red light (*R*) in passing through the shielded eye (*center*) or a prism (*right*). The displacement makes the colors appear to be at different depths.

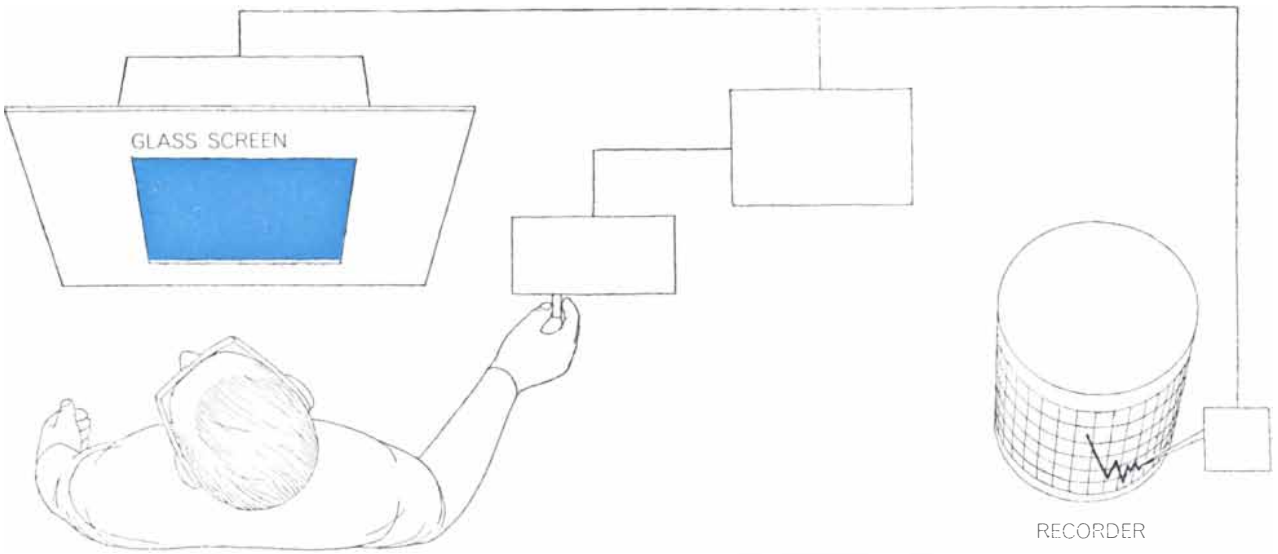
pupil, using two fingers or two pieces of paper. With the outer half of each lens covered, light passes only through the inner halves, which act as if they were prisms with bases facing outward. If the inner halves of the two lenses are covered, a reverse stereo effect takes place and red objects look closer than blue ones. (The reverse effect is difficult to obtain with prisms because it is hard to force the eyes to diverge enough when the bases of the prisms face inward.)

In a small percentage of people the prismatic defects of the eye are large enough so that they can obtain a color-stereo effect even without prisms or the use of Helmholtz' procedure. A sensitive check for such defects can be made with the help of the green-red figure in the middle of page 65. The figure is to be viewed with each eye separately. To a normal eye the green and red halves of the figure meet cleanly, without any noticeable peculiarity. A defective eye, however, will see either a thin black line or a thin white line where the two colors meet. A black line indicates that the green area is being displaced slightly farther to the left than the red, as it would be by a prism having its base to the right. A white line indicates that the green is being deflected to the right as by a prism with base to the left. When the green shifts to the right, it overlaps the red image, and the combination of green and red reflected light creates a white boundary. People with prismatic defects of the eye have a certain advantage over people with normal eyes, for they can differentiate colors not only by hue but also by the color-stereo effect.

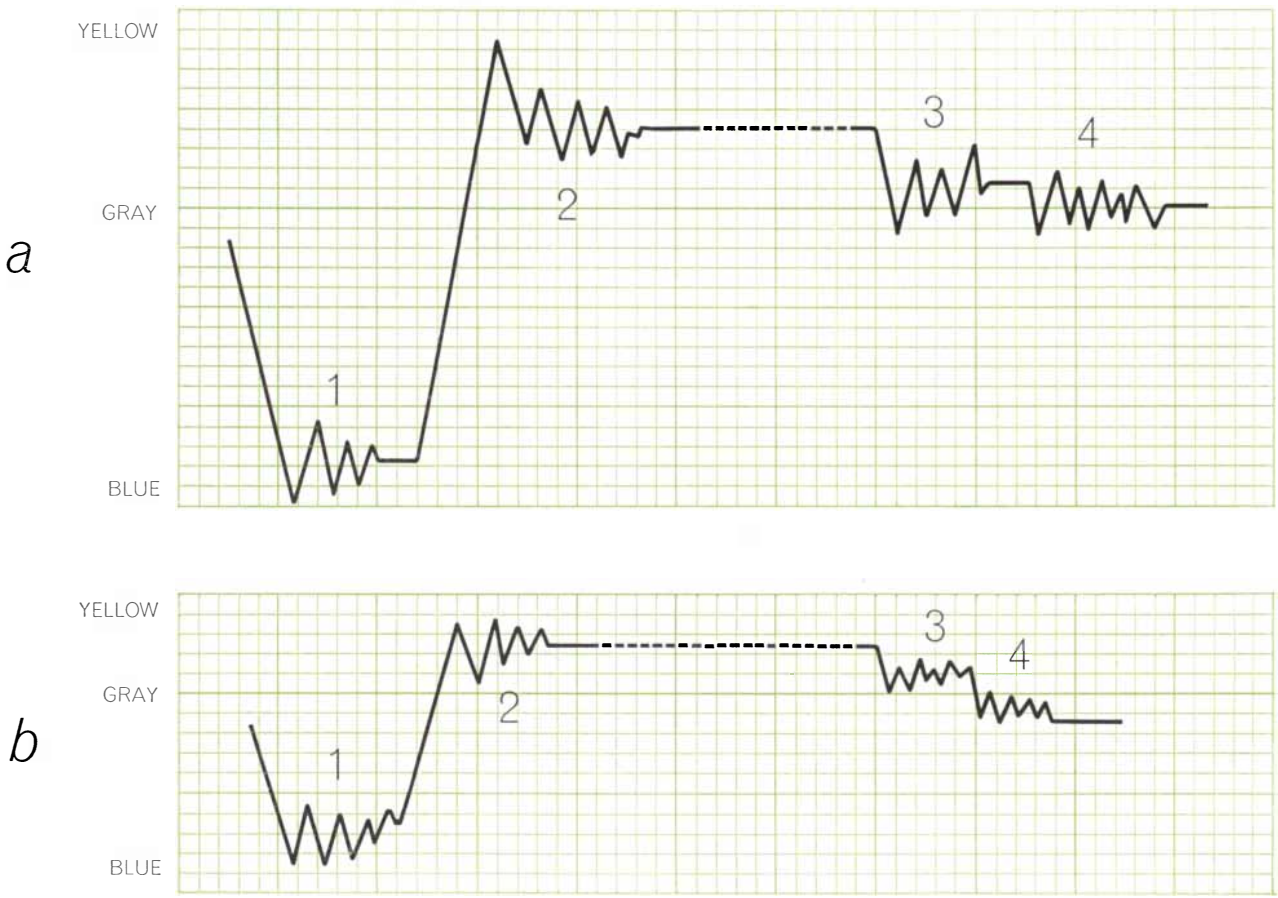
Although it may not be immediately obvious, the color-stereo effect does not depend on the ability of the eye to see color. Like a prism, the lens of the eye bends light according to wavelength regardless of the hue we have come to associate with any particular wavelength. For example, if one photographed the colored pattern on page 66 in black and white using a stereoscopic camera equipped with a suitably oriented prism in front of each lens, one would obtain two pictures that would look three-dimensional when viewed through a stereoscope. The colored squares of the pattern would appear in various shades of gray, lying at various depths according to the wavelength of the original colors. It follows from this that one could enable a color-blind person to discriminate colors by providing him with prism glasses. He could be taught, for example, that the green in a traffic light will look closer to him than



EXPERIMENTS WITH COLORED GOGGLES determine the adaptation to a split-color field, blue on the left, yellow on the right. On the first day of the experiment (*a*) the subject adjusts the color of a glass screen (*see top illustration on opposite page*) until it looks neutral through the yellow half of the goggles (*1*), the blue half (*2*) and with goggles removed (*3 and 4*). After goggles have been worn 60 days the results are different (*b*).



ADAPTATION-MEASURING DEVICE consists of a glass screen or panel whose color can be adjusted by the test subject. The setting of the color-selection dial is automatically transmitted to a pen recorder (*far right*). The subject is viewing the window through the yellow half of goggles that are half yellow and half blue, as shown at the bottom of page 65. His task is to make the window look neutral gray in color, which requires, in this case, that it be adjusted to look blue as seen by the normal eye.



RESULTS OF COLOR-ADAPTATION TEST are shown by chart records made on the first day (*a*) and 60th day (*b*) of the experiment with blue-yellow goggles. On the first day the window of the test apparatus must be made strongly blue (*1*) to compensate for the yellow tint of the goggles and yellow (*2*) to compensate for the blue tint. When the goggles are removed after several hours, the aftereffects are negligible (*3, 4*). By the 60th day, however, the eye has adapted significantly to the color distortions produced by the goggles (*b1, b2*), and when the goggles are removed, the complementary aftereffects are significant (*b3, b4*).

REAR-LOOKING "GOGGLES," actually a mirror device, were used in early experiments by Theodor Erismann at the University of Innsbruck. Here Erismann is testing the responses of a subject.

INVERTING GOGGLES, which transposed up and down, were also devised by Erismann. This subject is balancing on a springboard to help relate the upside-down world to his bodily sensations.

yellow and that yellow will look closer than red.

The color-stereo effect may also have general implications for biology. It has always seemed strange that in the eyes of most animals, including man, the fovea lies to one side of the optical axis of the lens system. This lack of alignment may combine with the eye's chromatic aberration to produce prismatic effects that are opposite for the left and right eyes, thereby producing a weak color-stereo effect. When we consider that these defects—off-center fovea and chromatic aberration—have persisted through millions of generations of animals without being "corrected" by evolution, we cannot refrain from speculating that the defects may have functional utility. Perhaps in the development of the vertebrate eye the color-stereo effect provided the first form of color discrimination, the colors being associated not with hue but with subtle differences in the depth of images. As a matter of fact, cats, mice and other animals, which are known to be color-blind, sometimes puzzle psychologists by their apparent ability to distinguish a few strong colors in visual tests. Although this color sensitivity is likely to be demonstrated by only a few animals in any experimental group, the ability cannot be ignored, and the explanation may well be that the unusual animals possess a heightened sensitivity to the color-stereo effect.

My colleague Anton Hajos can be credited with showing, by rigorous measurement, that not the slightest adaptation to the color-stereo effect occurs among subjects wearing squint glasses. He also conceived the idea of intensifying the stereo effect to see if it heightened the sensation of color. To test this idea we were fortunate to find in Innsbruck a man who had lost his color vision as the result of an accident. When he put on a pair of our squint glasses, he reported that he was instantly able to see all the colors he had not seen for years. When he removed the glasses, the colors disappeared again. We are carrying on a further investigation of this and related cases.

What shall we make of the finding that the eye adapts rather readily to various intense distortions of geometry and color but fails totally to adapt to the type of distortion embodied in the color-stereo effect? One possible explanation is that in all cases where adaptation occurs the eye is provided with certain systematic clues as to the nature of the distortion. Straight lines always curve in the same direction; blue or yellow color fringes occur in fixed relation to light-dark boundaries; blue and yellow glasses present the eye with color fields that remain consistently either on the right or on the left; even the rubber world is rubbery in a consistent way. The color-stereo effect, however, presents the visual mechanism with a random and nearly unpredictable assortment of displaced images. As the focus of the eye shifts from one point to another, it is just as likely to encounter one color as another, and, depending on wavelength, brightness and background, the stereoscopic position of the colored image is shifted forward or back. Although the eye might conceivably learn to correlate color and displacement and thereby use the former as a basis for correcting the latter, the task is evidently beyond the power of the eye's adaptation mechanism. There is, however, an alternative possibility: the color-stereo effect may represent a primitive way of identifying colors. The failure of the visual system to adapt to this effect, when presented in exaggerated form by squint glasses, may be evidence that spatial displacement of colors indeed played such an evolutionary role.

Kodak reports on:

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Great blocks of sensitivity

KODAK Nuclear Track Pellicles, Type NTB4, are hereby announced. This merchandise is manufactured for the simple purpose of understanding the fine structure of the universe. Prizes (or at least respectful attention at high-energy physics conferences) may be won for the ingenious use of this merchandise. Try particle accelerators, reactors, satellites, spacecraft, balloons, mountain peaks, rooftops, submarines, deep mines. We offer no new suggestions on use. We have done our part by devoting a great deal of the time and talent of what we hope are the world's best photographic emulsion technologists to the problem of substantially exceeding the highest previously available sensitivity and manufacturing the product to high standards of uniformity and within the continental limits of the United States. We have succeeded. To wit, minimum-ionization track is delineated by no fewer than 30 grains per 100 microns of track length. The silver-to-gelatin ratio is grotesquely high.

Pellicles are 3″ x 4″, 4″ x 4″, 4″ x 6″, or any other size rectangles of unmounted photographic emulsion around 600 microns thick. A nominal thickness is given on the label and held to ±5% over the pellicle, the box of pellicles, and the whole blooming batch of pellicles. They are shipped immediately after packaging. Customers stack them into great blocks of emulsion, sometimes as much as a cubic foot of solid, three-dimensional sensitivity. Somewhere inside may terminate the journey of a nucleus that has been moving fast in a relativistic straight line ever since Creation.

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Before embarking on all this, you will want to check out a few more details with Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.

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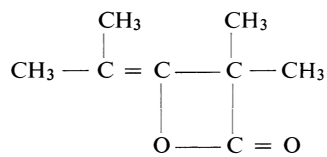
A typical EASTMAN Industrial Chemical at the commercially nascent stage is 2,2,4-Trimethyl-3-hydroxy-3-pentenoic Acid, β-Lactone, *to be known as TMBL and represented as*



This structural formula is expected to inspire a wise, commercially motivated reader to ask himself, "Wouldn't this make a lovely starting material for our (********)?" We would then inform him that in pilot-plant quantities it is priced at $3.50 per pound, that we can send him a technical data report which explores its properties and reactions in a preliminary way, that from the host of compounds derivable from our wealth of isobutyraldehyde and our devotion to ketene chemistry we selected this one for study largely for its fetching look. We can probably ship 5 gallons from stock; an order for a drum might have to wait as much as six weeks, depending on the work load in the pilot plant.

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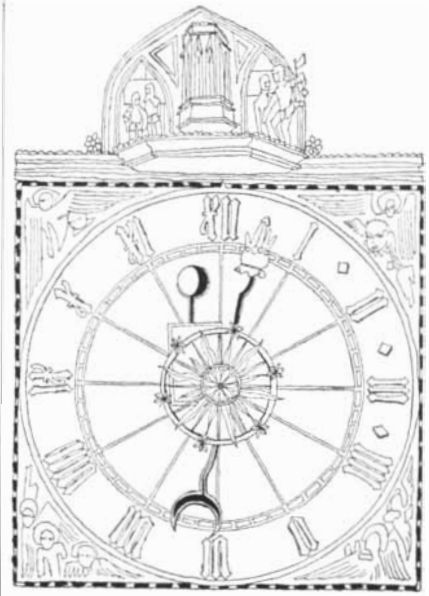
*O. Lehmann, *Flüssige Kristalle und ihr scheinbares Leben*, Voss, Leipzig (1921)

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science



SCIENCE AND

Co-operation in Space

The movement toward an international program in space research has given signs of gaining momentum. President Kennedy has followed up the general proposals for co-operation between the U.S. and the U.S.S.R. that were exchanged after the successful flight of the U.S. manned satellite. In March he submitted to Premier Khrushchev a list of joint projects in space medicine, weather and communication satellites, mapping the earth's magnetic field and tracking space vehicles by radio. Eventually, he suggested, the two countries might join in sending instruments and perhaps human explorers to the planets. Although not agreeing to any specific proposal, the U.S.S.R. sent rocket expert Anatoli A. Blagonravov to the U.S. for four days of "informal discussions" with Hugh L. Dryden, Deputy Director of the National Aeronautics and Space Administration.

The two representatives conferred during a meeting of the United Nations Committee on the Peaceful Uses of Outer Space, which had been largely inactive since its creation in 1959. Now the group is establishing a scientific and technical subcommittee and a legal subcommittee, which are to begin work in Geneva on May 28. Early this month scientists of the Committee on Space Research (COSPAR), an outgrowth of the International Geophysical Year, will meet in Washington.

Meanwhile the UN's "public registry" of space-flight information received its first data. The U.S. filed material—apogee and perigee, nodal period and equatorial inclination—on 72 objects "launched into sustained orbit or beyond," which it planned to bring up to date every two weeks, and also a special statement on the flight of John H. Glenn, Jr. The U.S.S.R. submitted data on 16 vehicles, including its two manned satellites.

New Particle

The next to the last entry on the predicted list of "strange" particles has been discovered. Announcements in *Physical Review Letters* by U.S. and European groups of physicists describe the independent identification of the particle known as the anti-xi minus. In both cases the particle was created, together with a xi-minus, by the collision of a high-speed antiproton with a proton. After about a ten-billionth of a second the anti-xi decayed into a pi meson and an antilambda particle. This last in turn disintegrated into an antiproton and a pi meson. The complex mode of decay gives the xi and anti-xi particles their other name: cascade particles. The only particle still missing is the uncharged anti-xi zero.

Both experiments were performed with a beam of fast antiprotons produced in the 30-billion-electron-volt accelerators at the Brookhaven National Laboratory and at the European Organization for Nuclear Research (CERN) in Geneva. Even these powerful machines were barely adequate to the task of producing the rare interactions in which the anti-xi is created; a U.S. team at Yale University examined 34,000 bubble-chamber pictures, each showing an average of 14 antiproton tracks, to find one anti-xi-minus "event." The CERN pictures were analyzed at the Centre d'Études Nucléaires in Saclay and at the École Polytechnique in Paris. The anti-xi was identified by the energy and momentum of the particles involved in both its creation and its decay.

The new particle adds confirmation to two principles already established in particle physics: (1) the rule that every particle has its corresponding antiparticle and (2) the classification scheme for strange particles devised independently several years ago by Murray Gell-Mann of the California Institute of Technology and K. Nishijima of Japan.

THE CITIZEN

At the time that Gell-Mann and Nishijima proposed their classification the strange particles were considered strange because, although they were created in extremely fast interactions, they decayed much slower. Now this very quality has made the strange particles into old friends that have been thoroughly studied by the tracks they leave in detection chambers. It was from a consideration of the experimental properties of the known particles that Gell-Mann and Nishijima were able to construct a sort of periodic table showing that other particles could be expected to exist. Meanwhile still more particles have turned up that do not live long enough to leave a visible track. In fact, as their name, "resonances," implies, they may be merely combinations of particles already known. In any case their theoretical significance is as yet unclear and therefore so is their relation, if any, to the now familiar strange particles.

Secret Satellites

Scientific advisers of the House Committee on Science and Astronautics appeared before that committee late in March to protest the secrecy under which the Department of Defense has been proceeding with plans to launch a geodetic satellite. The satellite, a joint venture of Army, Navy and Air Force, is to be equipped with a powerful flashing light. Fixes taken on the light will yield improved determinations of the shape of the earth and of distances between points on different continents. The flashing schedule has been classified on the ground that such fixes will also reduce error in establishing the relative locations of the launching site of an intercontinental missile and its target.

Members of the House Committee's scientific panel, a Congressional counterpart of the White House science advisory committee, pointed out that the continental maps are interlocked to within a range of error of 50 to 500 feet. Thus, in the opinion of George B. Kistiakowsky, chairman of the House panel and formerly science adviser to President Eisenhower, "the accuracy of target locations is already known with sufficient adequacy." Pointing down the length of the House Caucus Room, where the hearing was held, James A. Van Allen

of the State University of Iowa observed: "It really makes very little difference whether the center of impact of a thermonuclear weapon is in one corner of this room or another."

Failure to release the flashing schedule, according to Fred L. Whipple of the Smithsonian Astrophysical Observatory, will largely nullify the usefulness of the satellite, which calls for a maximum number of fixes from many points around the earth. The secrecy order, he said, is in violation of the U.S. pledge given to COSPAR (Committee on Space Research of the International Council of Scientific Unions) to launch an "open" geodetic satellite.

The geodetic satellite, it appears, is neither the first nor the most heavily classified U.S. satellite project. In a recent editorial *Flight International*, the journal of the British Royal Aero Club, charged that the U.S. has made six launchings since October under its secret Samos reconnaissance and Midas early-warning satellite programs. No basic orbital data, the magazine said, has been released on any of the six. At least one has nevertheless been observed from Britain.

Toward Man

From a hillside in Kenya has come a new exhibit in the gallery of human ancestry. The creature is represented by a fossilized bony palate with several teeth attached, plus a lower molar. Both teeth and palate place their owner somewhere between Proconsul, a primitive ape of 25 million years ago, and the earliest known tool-making man, who inhabited East Africa about two million years ago.

L. S. B. Leakey and his wife Mary, British prehistorians who have made several major discoveries in East Africa, found the remains in a slope above a river valley 40 miles from Lake Victoria. The site, a former British outpost called Fort Ternan, has long been known for its richness in fossils. In 1959 a farmer from the area sent the Leakeys a sack of bones collected on his farm. They were unusual enough to bring a visit from the prehistorians and, last fall, a digging crew from their permanent camp at Olduvai Gorge in Tanganyika. In addition to the primate fragments the excavators uncovered a wealth of fossils, including the first evidence of a small ancestor of the present-day giraffe.

The Fort Ternan primate, which has not yet been given a name, had low-crowned molars and canine teeth that projected only a fraction of an inch be-

This gray line

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low the incisors—both prominent characteristics of human teeth. A depression in its cheekbone below the eye resembles a feature associated with muscles for control of the lips in man, which are not found in apes. The fossil primate, Leakey said, is not a hominid but "would seem to be heading toward man." It was established as being 14 million years old by Garniss H. Curtis and Jack F. Evernden of the University of California, who carried out radioactive-dating tests on the rock in which the remains were found.

Messengers by the Milligram

The first evidence that mammalian cells depend on the same sort of "messengers" as bacterial cells do for the transmission of genetic information within the cell has been reported by an international team of workers at the Rockefeller Institute. Bacterial studies had previously shown that the synthesis of proteins in a cell such as the colon bacillus is directed by the chemical code embodied in a special form of ribonucleic acid called messenger RNA. This RNA in turn represents a direct transcription of a code contained in deoxyribonucleic acid (DNA), the fundamental repository of genetic information. The new mammalian work is reported in the *Proceedings of the National Academy of Sciences* by Alfred E. Mirsky and Vincent G. Allfrey of the Rockefeller Institute, in collaboration with two visiting investigators, Atuhiro Sibatani of Japan and S. R. de Kloet of the Netherlands.

The Rockefeller group isolated messenger RNA from the nuclei of cells obtained from the thymus gland of the calf. In contrast with the trace amounts of messenger RNA obtainable from bacterial cells, relatively large amounts—measured in tens of milligrams—can be extracted readily from the thymus cells. Experiments with radioactive tracers show that the messenger RNA fraction is the most active form of RNA yet found in the nucleus.

The way is now open to many important experiments. It has been shown, for example, that RNA and DNA chains that are complementary in composition will combine to form a "hybrid" helix, resembling the characteristic helix formed by complementary chains of DNA. This means that if one can isolate the messenger RNA that carries the manufacturing code for a single protein, say hemoglobin, one should be able to find, by a hybridization test, which of the various DNA molecules in the cell

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nucleus carries the gene for that protein.

An extension of this experiment could test the assumption, basic to genetic theory but never really proved, that every cell of an organism contains a full set of genes. If this is so, messenger RNA for hemoglobin (or any other protein) should hybridize with DNA obtained from any cell of the organism, including the many cells that do not synthesize hemoglobin.

Human Cold, Animal Cancer

A virus that causes upper respiratory infection in man can produce cancer in hamsters. So reported John J. Trentin, Yoshiro Yabe and Grant Taylor of the Baylor University College of Medicine at the meeting of the American Association for Cancer Research in Atlantic City, N.J., last month.

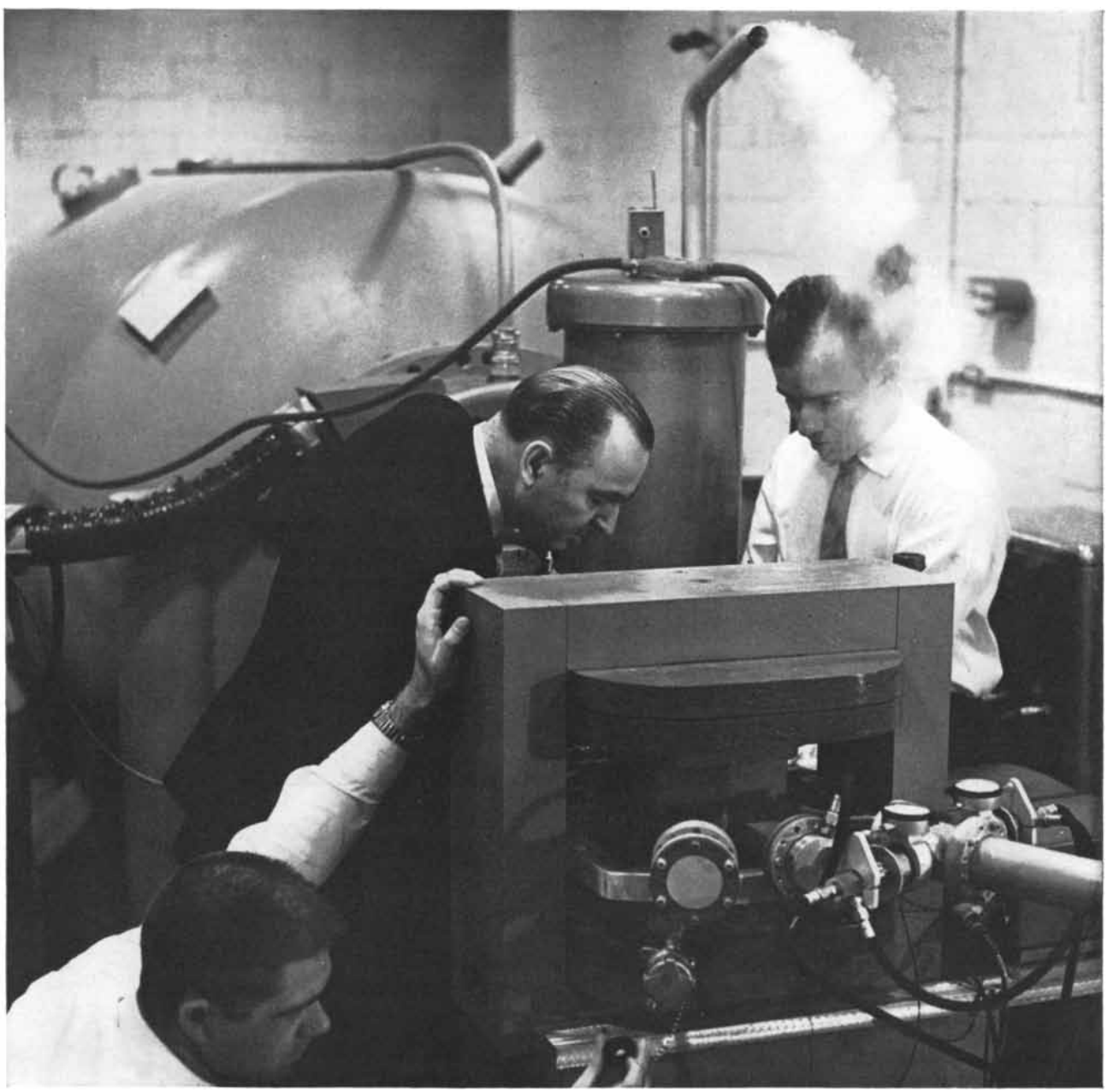
Like many other investigators, the Baylor workers have been trying, so far unsuccessfully, to isolate specific human tumor viruses from patients with cancer. A standard technique in this research is to inject extracts that may contain such viruses into animals susceptible to virus-induced tumors. The Baylor group decided to try injecting instead some known human virus. The idea was suggested by the fact that certain animal viruses have been found to cause both acute infections and, as a later effect, cancer. Moreover, these viruses cannot always be recovered from the tumors that they produce.

As an experimental animal Trentin and his colleagues chose the Syrian hamster, which is susceptible to cancer viruses from other species of animals. As experimental viruses they selected the group known as adenoviruses because of a general resemblance to some animal tumor viruses. Nine different types of adenovirus were inoculated into the lungs of newborn hamsters. Eight had no effect. However, the ninth, adenovirus Type 12, produced malignant thoracic tumors in 41 of 45 animals within three months.

Type 12 is one of the rarer of the 28 related viruses isolated to date from the adenoids, tonsils or throats of patients with upper respiratory infections or histories of recent infection. Much further research, Trentin emphasized, will be required to determine whether or not it plays any part in human cancer.

Energetic Electrons

The newest member of the family of giant particle accelerators, the Cambridge Electron Accelerator, has gone



into operation. A joint undertaking of Harvard University and the Massachusetts Institute of Technology, the new machine began generating a 2.2-billion-electron-volt (Bev) beam—the most energetic electron beam yet produced by man—early in March. Its designed output, a beam of electrons traveling at .999999996 the speed of light and with an energy of six Bev, should be attained this summer.

Like the 30-Bev proton accelerators at Brookhaven and CERN, the Cambridge machine is a synchrotron: it accelerates particles held in a circular orbit by a magnetic field. Particles moving on a curved path lose energy by electromagnetic radiation, and with electrons having an energy approaching 10 Bev this loss nullifies any increase in power. Electrons with an energy of more than 10 Bev can be generated only in huge linear accelerators, such as the two-mile-long, 20-to-45-Bev machine to be built at Stanford University (see "The Two-Mile Electron Accelerator," by Edward L. Ginzton and William Kirk, SCIENTIFIC AMERICAN, November, 1961).

Machines like the Cambridge accelerator nevertheless have a key part to play in critical areas of nuclear physics. Until now exotic fundamental particles have been created in the laboratory chiefly with high-energy protons. Such particles can also be produced with six-Bev electrons, and the processes involved should be easier to analyze because electron interactions involve only the well-known electromagnetic forces and not nuclear forces, which are not so clearly understood.

Electron accelerators similar to the Cambridge device are also being built at Hamburg in West Germany and at Yerevan in the U.S.S.R. The Cambridge accelerator, which occupies a site on the Harvard campus, has a track 236 feet in diameter. To keep bursts of electrons in the track for the 10,000 circuits required to attain an energy of six Bev, the machine employs the principle of "strong magnetic focusing" devised originally for use in large proton accelerators by a group headed by M. Stanley Livingston of M.I.T., who will direct the operations of the new Harvard-M.I.T. facility. The machine cost $12 million to build.

Semitic Minoans?

New evidence that the "lost" language of the Minoan kingdom in ancient Crete was Phoenician has been brought forward by the classical philologist Cy-

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rus H. Gordon, chairman of the Department of Mediterranean Studies at Brandeis University. Five years ago Gordon stirred up a controversy by identifying the language of Linear A—a script used in Minoan Crete before its conquest by the Greeks in the 15th century B.C.—as Akkadian, the Semitic tongue spoken in Babylonia. On the basis of new translations Gordon now declares that the language of Linear A was really Phoenician (like Akkadian a Semitic language) and that Phoenician was also the language of Eteocretan, a script employed in some communities of Crete 1,000 years later.

Ancient Cretan inscriptions and tablets contain three forms of writing—Linear A, Linear B (which uses many of the same symbols) and Eteocretan—all of which long resisted deciphering. In 1952 the puzzle of Linear B was solved by Michael Ventris, a young British architect and amateur cryptographer. Ventris showed that Linear B was Achaean Greek (the language spoken by Homer's heroes) written largely in Minoan symbols. When the Achaean Greeks conquered Crete, they took over not only many Cretan arts but also the Cretan script. In 1957 Gordon found that he could read as Semitic words many symbols in Linear A inscriptions that were obviously warehouse lists and the like. His conclusion that the Minoan language was probably Semitic was promptly challenged, however, since the isolated words he had translated might be nothing more than "loan words" borrowed by the Minoans for use in their own tongue.

Last year a new edition of the Minoan texts, prepared by W. C. Brice, was published in England. The volume included clear photographs and ink copies of 18 Linear A cult objects containing whole phrases and sentences. With their aid and with the aid of other clues, Gordon was able to establish the language of the inscriptions as being Phoenician. He next tackled the problem of Eteocretan, a Greek-letter form of Minoan inscribed on four stones dating to about the fifth century B.C. Assuming that Eteocretan was also Phoenician, Gordon was able to translate whole phrases.

Gordon terms his finding that Phoenician-speaking people were living in Crete in pre-Greek times "more important to historians than the Dead Sea Scrolls." He holds that Greek and Hebrew cultures can no longer be said to have developed independently; both sprang from a common Semitic heritage that spanned the entire eastern Mediterranean in Minoan times.

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MALARIA

It still disables more people than any other disease. Many nations in which it is a major problem now aim, with the aid of the World Health Organization, at its total eradication

by Carlos A. Alvarado and L. J. Bruce-Chwatt

Of all the ills that afflict mankind few have taken a higher toll than malaria. From earliest times it has laid a cruel burden on much of the earth's human population. Again and again it has erupted in epidemics as deadly as the plague of the Middle Ages. Today it still disables more people and exacts a higher material cost than any other disease.

Yet today the outlook is increasingly hopeful. Although many difficulties still lie ahead, the way to success has in principle been found. During the past 15 years modern methods have cut the number of cases of malaria from a worldwide total of 350 million to fewer than 100 million. Moreover, in several areas eradication has already been achieved. There now seems no reason to doubt that the same results could be attained in the remaining malarial regions of the globe. A continuing international campaign aims at nothing less than the complete eradication of malaria from the whole human population.

Of the antiquity of malaria there can be no doubt; that it antedates man himself is shown by the fact that the almost identical parasites that he shares with the anthropoid apes are survivals of a common heritage. As the earliest records from Assyria, Egypt and China attest, the disease was clearly recognized at the time of the most ancient civilizations. Hippocrates gave the first detailed clinical description of malaria, noting its cyclic character and its association with swamps. The Romans of a few hundred years later were well aware of this association and avoided marshy lands, particularly when they were building military camps and new settlements. During the whole of the Middle Ages and until the 19th century malaria was widespread throughout Europe, even in the northern latitudes. It is not known with any certainty whether malaria existed in pre-Columbian America. The Spanish conquerors of South America suffered from it, and it seems certain that the disease was widely spread by the slaves brought to America from Africa.

Malaria is essentially a chronic disease. It causes, apart from its classic fevers, high infant mortality, stillbirths and abortions; it produces anemia with enlargement of the spleen, and it predisposes those who suffer from it to other infections. In areas where agricultural production and levels of life are already low, its economic effects are obvious: food supplies are further reduced by the fact that large malarial areas are left untilled, and social and economic development are profoundly retarded.

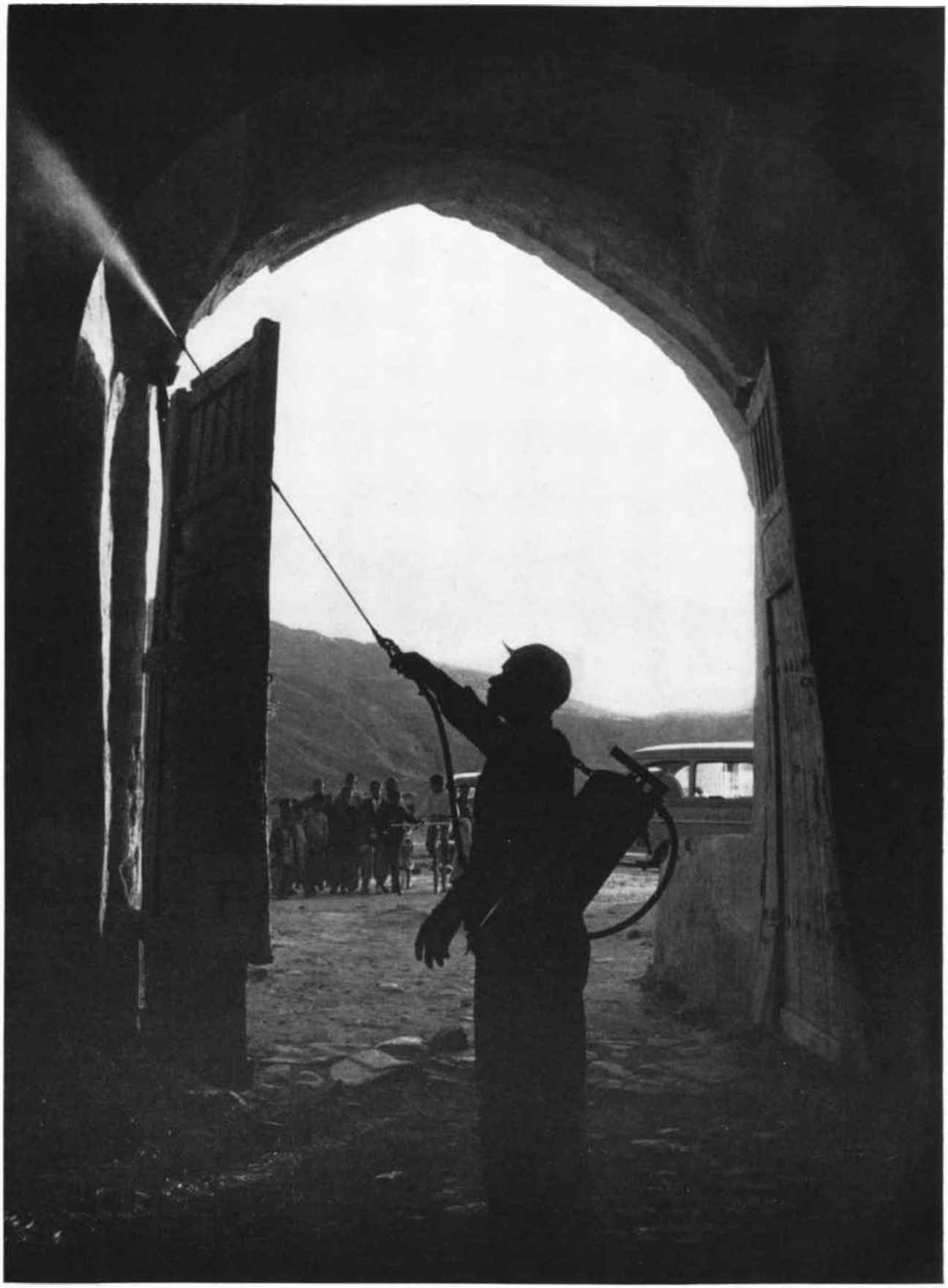
The greatest epidemic of malaria in modern times struck the U.S.S.R. in the year following World War I. More than five million cases were reported in 1923, with at least 60,000 deaths. In Brazil the introduction of a foreign species of mosquito from Africa in 1938 produced 100,000 cases and killed 14,000 people. As recently as 1958 an epidemic in Ethiopia claimed thousands of lives.

The Parasite

Two thousand years ago in Rome, Columella and Varro surmised that diseases were caused by "minute animals," but until the 19th century malaria was ascribed to the effects of unwholesome emanations from damp, low-lying lands; hence the name *mal'aria*. As often happens, physicians found a way to treat the disease long before they understood its cause. In 1632, after the conquest of Peru, the bark of the cinchona tree was brought back to Europe and proved to be the first efficacious remedy. Some 200 years later quinine was extracted from cinchona. The availability of the preventive drug made it possible for men to enter the most malarial areas in comparative safety. On the west coast of Africa, where malaria had claimed hundreds of the early missionaries, explorers and traders, William Balfour Baikie's expedition up the Niger in 1854, supplied with quinine, lost not a single man. Yet 49 years earlier Mungo Park, on his last (and fatal) journey to discover the mouth of the Niger, lost 40 of his 45 men in five months.

Finally, in 1880, the French army physician Charles Louis Alphonse Laveran identified pigmented bodies in the blood of malarial patients as the organism responsible for the disease. There followed several years of intensive studies, and some confusion, before the development of the parasite in the red blood cell was traced and the different species of plasmodium were classified. By then it was established that four species infect man. *Plasmodium vivax*, the most widely distributed, causes benign tertian malaria (fever recurs every third day). *P. falciparum*, the second most common type, is responsible for the most dangerous infection, malignant tertian malaria, which is often fatal if not treated; this organism thrives best in hot climates and is mostly confined to the tropics. *P. malariae* causes quartan malaria, a relatively uncommon form that persists because it can remain in the blood for years. *P. ovale*, the rarest type, is confined to the west coast of Africa, where it produces a mild infection.

Once the parasite had been found, it became possible to study its transmission. The idea that mosquitoes might carry the infection is mentioned in a



INTENSIVE SPRAYING of an entire malarial region for several years is the key to eradication. Here a sprayman is working in an old caravansary near Kamaradi, Iran. The World Health Organization helped Iran start its eradication campaign in 1957.

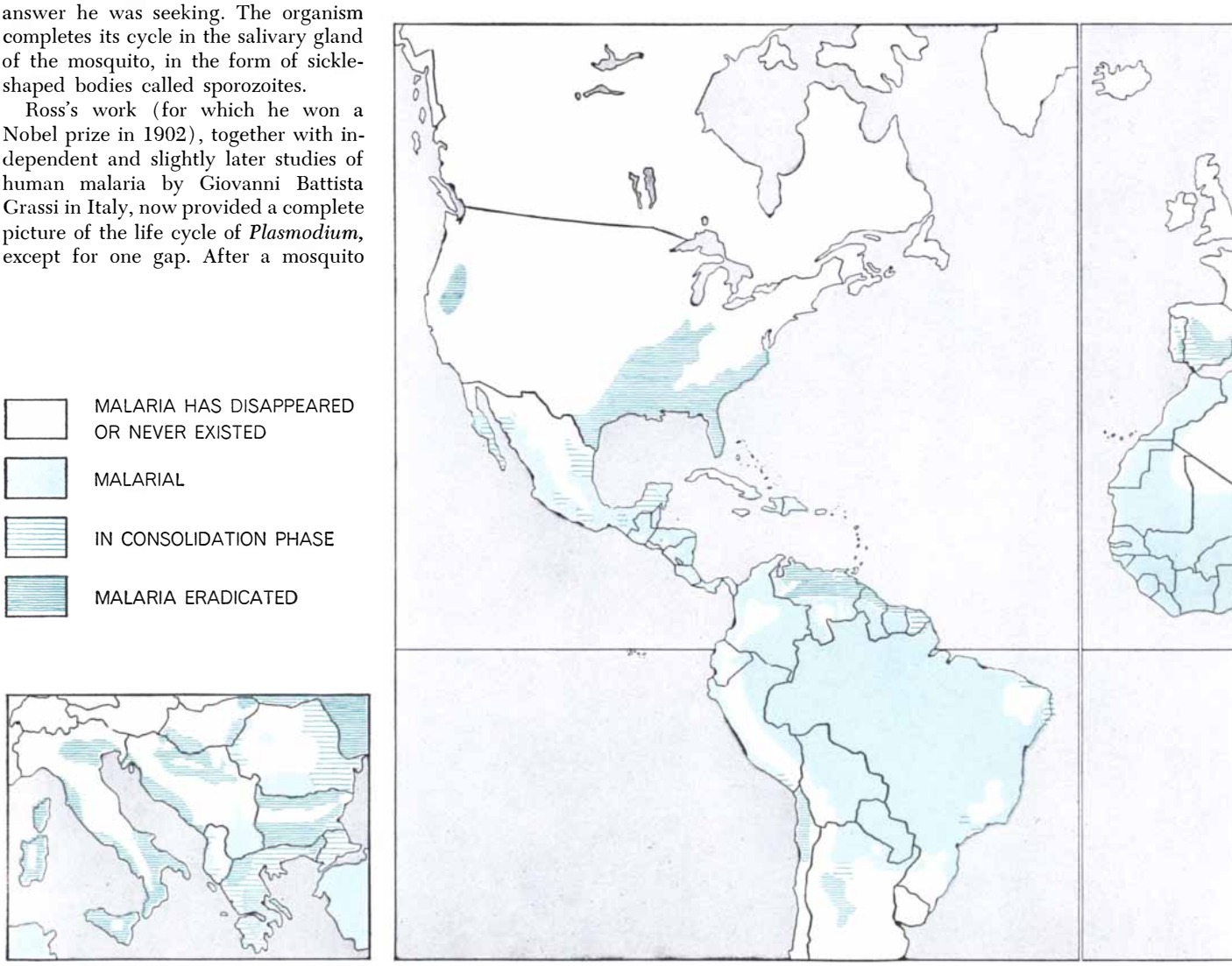
Sanskrit work of the sixth century B.C. There was no serious investigation of the matter, however, until the 1890's, after mosquitoes had been proved to transmit filariasis. Then Ronald Ross, a British army surgeon in India, undertook to find out whether they play a similar role in malaria. At first he tried infecting *Culex* and *Aëdes* mosquitoes by allowing them to feed on malaria patients, but he discovered that the parasite failed to develop in these insects. Only when he began to work with the *Anopheles* mosquito did he find a host in which the plasmodia could complete their life cycle.

Unable to continue working with human volunteers, Ross transferred his experiments to the malaria of birds. He fed mosquitoes on infected birds, then laboriously traced the parasite in its different phases of development through the organs of the insect. After hundreds of dissections he at last found the answer he was seeking. The organism completes its cycle in the salivary gland of the mosquito, in the form of sickle-shaped bodies called sporozoites.

Ross's work (for which he won a Nobel prize in 1902), together with independent and slightly later studies of human malaria by Giovanni Battista Grassi in Italy, now provided a complete picture of the life cycle of *Plasmodium,* except for one gap. After a mosquito bites a human being, several days pass before the parasite appears in the blood. Where it goes in the meantime was not discovered until 1948. In a brilliant series of experiments H. E. Shortt and P. C. C. Garnham of the London School of Hygiene and Tropical Medicine traced the missing plasmodia to the liver.

The marvelously complicated life cycle of the malaria parasite now stood fully revealed [*see illustration on pages 90 and 91*]. When sporozoites are injected by a mosquito into the bloodstream of a human being, they migrate to the liver. There they remain for six to 12 days, developing into large bodies with many nuclei, called primary tissue schizonts. At the end of the period the bodies divide into a large number of small merozoites, which enter the bloodstream and invade the red blood cells. In some species of parasite, merozoites also lodge in the liver, producing secondary tissue schizonts. These mature periodically, releasing their crop of merozoites and causing relapses, often many months after the primary attack. In the red blood cell the merozoites grow first to trophozoites and then into small, pigmented erythrocytic schizonts. In a few days the infected cell ruptures, the schizonts release a new supply of merozoites into the circulating blood, and the red blood cell cycle starts over again. Some of the parasites in the blood develop into sexual forms called gametocytes, which are taken up by a mosquito with its blood meal.

In the mosquito's stomach the male gametocyte expels hairlike flagella that enter the female gametocyte and fertilize it. The fertilized gametocyte elongates, pierces the wall of the stomach and becomes encysted on its outer sur-



STATUS OF MALARIA throughout the world at the end of 1960 is shown on these maps. Eradication campaigns are being planned or are under way in many of the areas that are still malarial. On a map of this scale it is not possible to indicate the situation on smaller

face. Within this oöcyst thousands of sporozoites develop, to be released into the body cavity of the insect when the cyst bursts. The sporozoites migrate to the salivary glands, ready to continue their life cycle when the mosquito bites another human being.

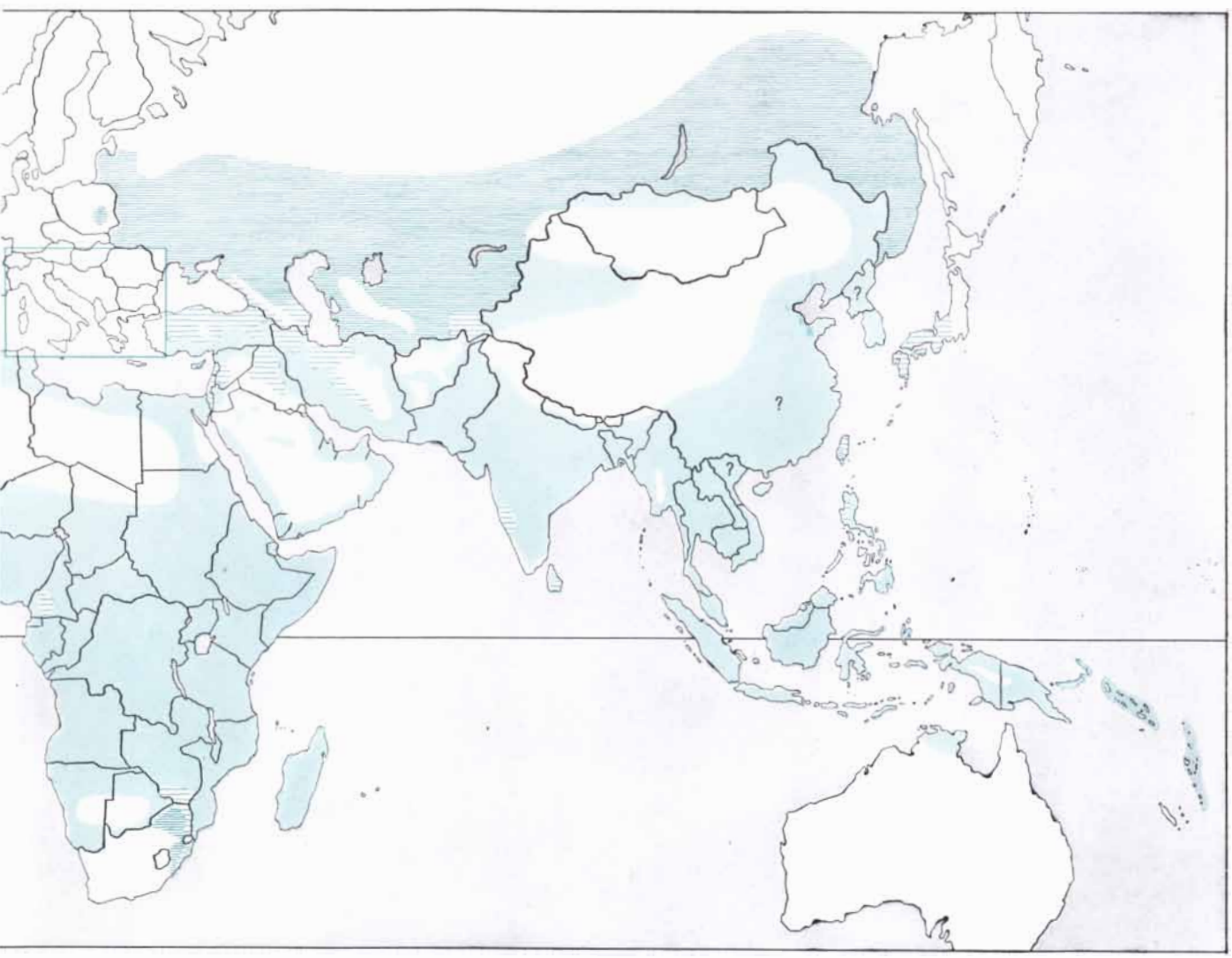
The Control of *Anopheles*

Of some 2,000 known species of mosquito in the world, some 400 belong to the genus *Anopheles*. Females of about 100 species of the genus can harbor the malaria parasites of primates, including man. Only about 60 species, however, are sufficiently closely associated with man to rank as important vectors, or carriers of disease. Generally a continent or group of countries has no more than 10 different species of *Anopheles* that act as vectors, and often no more than one or two species are the main transmitters of malaria.

Once the role of the mosquito was recognized, malaria control became a practical possibility. Since Roman times swamps had been drained as an antimalaria measure. Now drainage was supplemented by the destruction of mosquito larvae on the surface of the water by means of poisonous substances. Shortly after the turn of the century campaigns in the Panama Canal Zone as well as in Malaya and India demonstrated that drainage and larvicides can exclude malaria from limited, intensively treated areas.

To apply these methods on a large scale, however, was prohibitively expensive and in many cases impossible. Drainage works are costly to undertake and require constant maintenance. Larvicides must be applied indefinitely and frequently. Many malarial areas contain no swamps or open waters and do not lend themselves to easy draining. Mosquitoes breed in puddles, gutters, holes in trees, wells, pools in rocks and forests, leaf axils, drains, furrows, hoofprints and other places that will hold water—many extremely difficult to locate, let alone drain or treat.

In 1935 G. A. Park-Ross and Botha de Meillon reported from South Africa that better and cheaper results could be obtained by attacking the adult mosquito with pyrethrum sprays in houses. Not only is the number of mosquitoes greatly reduced but also many die before the parasite can complete its development or before they can pass on the infection. Three years later the insecticidal effects of DDT were discovered; these effects, together with the fact that DDT sprayed on walls and ceilings retains



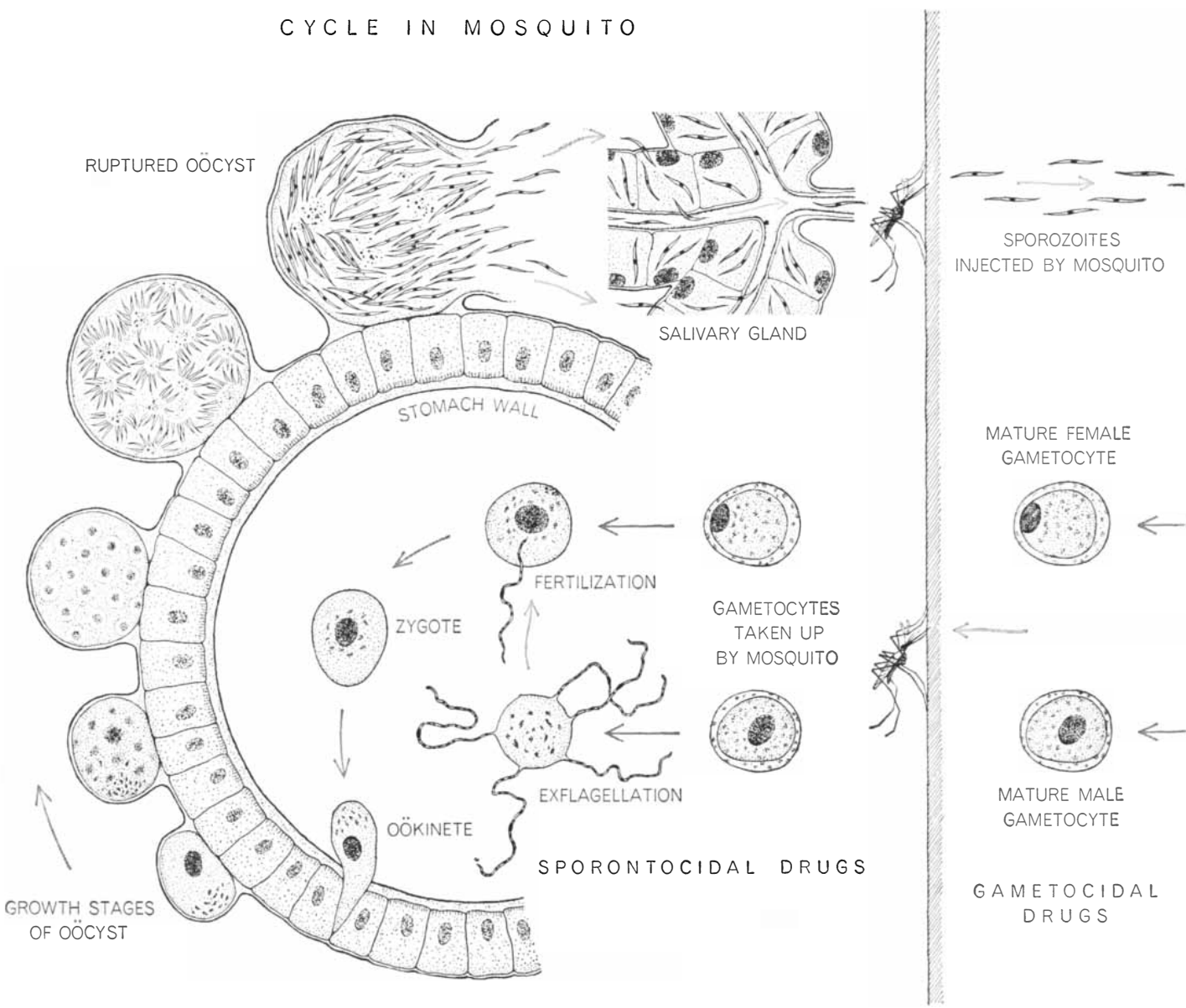
populous islands. Malaria has been eradicated on Puerto Rico and several other islands in the Caribbean; most of the remaining Caribbean islands have eradication programs. The status of malaria in mainland China, North Korea and North Vietnam is not known.

its potency for months, were to revolutionize antimalaria methods further. Female *Anopheles*, having fed on man, usually enter houses and settle there to rest and digest the blood meal that alone can ensure maturation of their eggs. On the treated surfaces they pick up a fatal dose of insecticide, from which they soon die. After the appearance of DDT other insecticides soon followed: benzene hexachloride, chlordane, dieldrin and malathion.

The Eradication of Malaria

It would be impossible to overestimate the importance of the change-over from the attempt to eliminate the larva to the attack on the adult mosquito. Houses, unlike potential breeding places, are easy to locate. Their area of wall surface can be closely estimated, and it is possible to forecast accurately requirements in materials, equipment, personnel and finance. Moreover, the residual effect of the insecticide reduces the number of applications to two or three a year. Thus for the first time the logistics of malaria control became relatively simple and campaigns became both operationally and economically possible.

After World War II many nations took up the new approach in earnest [see "The Eradication of Malaria," by Paul F. Russell; SCIENTIFIC AMERICAN, June, 1952]. The World Health Organization of the United Nations furnished leadership as well as technical and financial assistance. WHO inherited a long tradition of international co-operation in the fight against malaria, going back to the establishment of the Pan American Sanitary Bureau in 1902. In subsequent years the Rockefeller Foundation and the Malaria Commission of the League of Nations encouraged and helped the establishment of control schemes in many parts of the globe. The scope of their earlier



LIFE CYCLE OF *PLASMODIUM*, the malaria parasite, involves numerous changes of its form in both the mosquito and the human host. Various drugs can attack the parasite at different stages. Although most of the life cycle was known by the beginning of

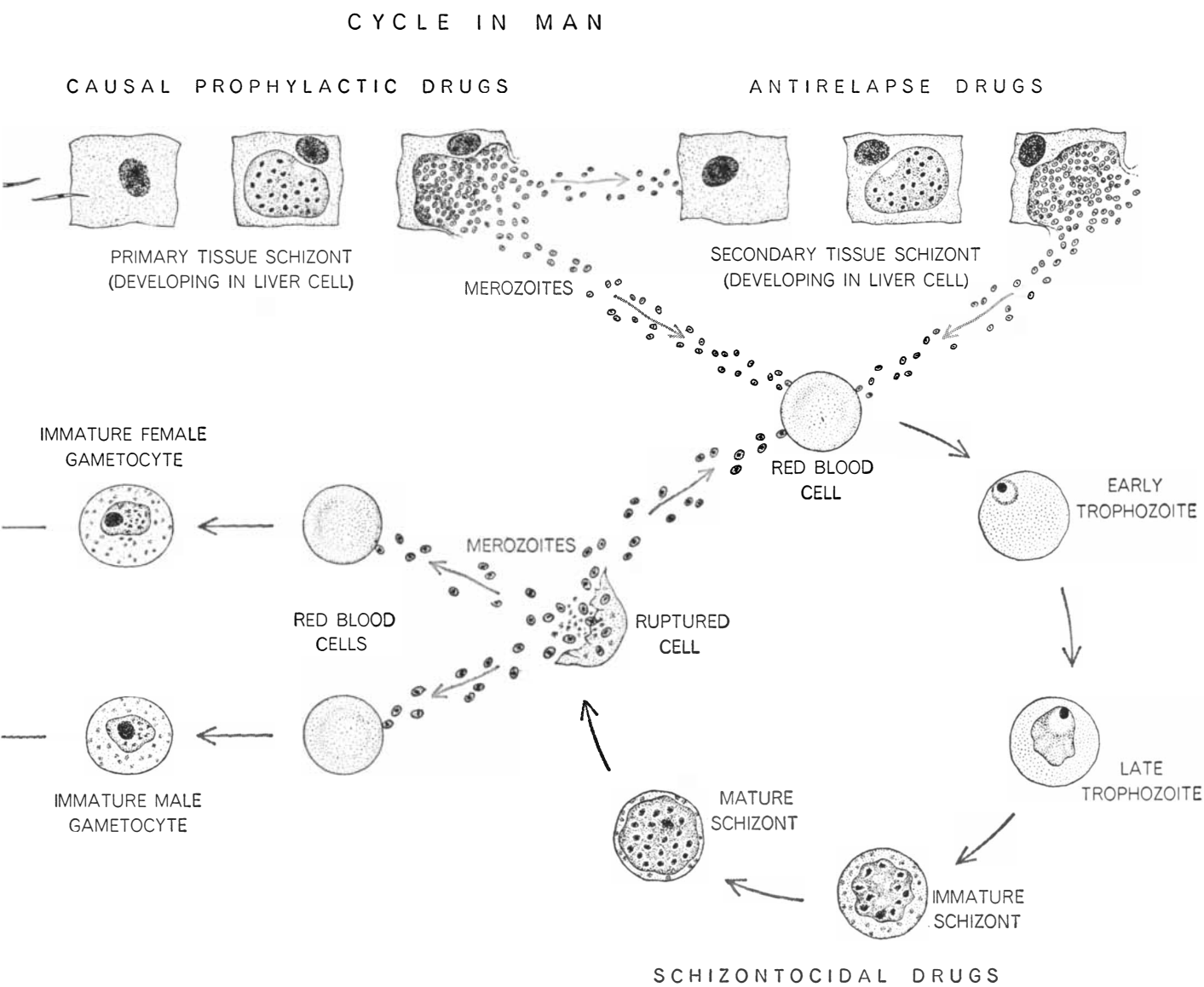
efforts was set, however, by the limitations of the drainage and larvicide techniques.

Once the potentialities of large-scale spraying were demonstrated, the program expanded rapidly. The number of national malaria-control projects increased from 13 in 1949 to 29 in 1953. During the same period the number of people protected rose from 872,000 to 6.5 million. By 1955 the control of malaria had been widely extended and the idea of eradication was beginning to be considered as a real possibility. This was supported by four major considerations:

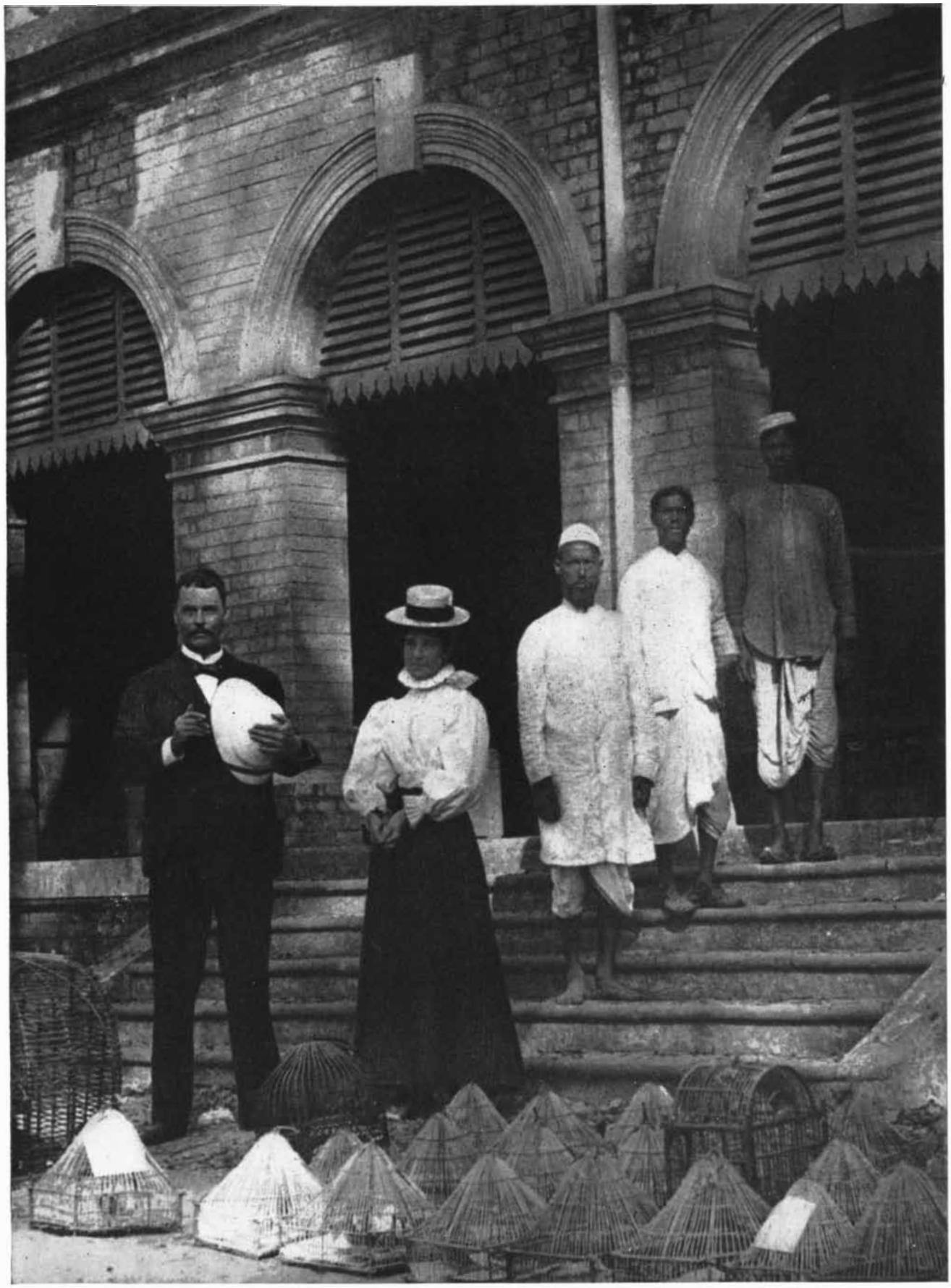
First, malaria control schemes as they then existed offered no hope of a final solution and postulated a permanent financial burden. Moreover, as soon as malaria ceased to be a problem of immediate urgency, interest flagged and it became more and more difficult to raise the funds necessary for the efficient maintenance of the control scheme. Eradication, although initially far more costly, held out hopes of a permanent solution and eventual release from heavy financial commitments.

Second, experience in Sardinia, Italy, Cyprus and British Guiana had shown that complete elimination of the *Anopheles* mosquito is not essential to eradicate malaria. One of the earliest and best-executed antimalaria programs proved this point on a large scale in Venezuela. Provided that the *Anopheles* population can be reduced below a certain critical level, transmission of the parasite is no longer maintained and the infection dies out.

Third, malaria infection in the two main forms found in man is not long lived, even in the absence of specific treatment. If, therefore, in a community, over a period of three years, all the old infections have been cured or have died out spontaneously, and if there is no importation of malaria from the out-



this century, it was not until 1948 that the primary tissue stage in the liver was discovered. The light, wavy arrows here represent actual movement of the parasite from one place to another; the heavier arrows denote changes in the many stages of development.



SIR RONALD ROSS, who proved that mosquitoes transmit malaria, is shown with his wife, assistants and bird cages in Calcutta in 1898. He obtained the final proof in his monumental studies by infecting the mosquitoes with avian, not human, parasites.

side, no further infection should arise.

Fourth, the alarming reports of mosquito resistance to insecticides called for rapid and decisive action. Only by an intensification of effort, by the inclusion of all possible malarial areas and by the radical interruption of transmission in the shortest possible time could man hope to win his fight with malaria.

This last point was of particular significance. In 1951 the first reports of resistance of *Anopheles* to DDT had come from Greece. Even more disturbing were the later reports of higher degrees of resistance to some of the newer insecticides. In 1956 only five species of *Anopheles* were involved, but by the end of 1960 resistance had appeared in populations of 29 species, 16 of them important malaria vectors. At the present time most of the cases of resistance are to dieldrin or related compounds, some to DDT, and in a few cases resistance to both groups was reported. If the opportunity to eliminate malaria were not seized in time, the resistance of the mosquitoes might eventually put it out of reach. This explains why so much basic and applied research on the problem of resistance is now in progress.

The Eradication Campaign

The goal of the global eradication of malaria was formally adopted at the Eighth World Health Assembly in 1955. A resolution put the program under the supervision of WHO and the Pan American Health Organization. It also set up a special account for funds to be donated by UN member nations to help defray the additional cost of eradication campaigns.

These campaigns differ from control projects in the thoroughness with which they are planned and carried out. The time factor is a very important one; once spraying has started no delays can be tolerated. Careful preparation and accurate planning must cover all possible contingencies that might hold up the scheme. Spraying with a residual insecticide must cover the area completely in order to interrupt transmission as rapidly as possible. Thereafter all remaining cases of malaria must be detected and treated to prevent the reestablishment of transmission.

The campaign proper is preceded by a pre-eradication survey to delimit the malarial area of the country, to obtain data on the prevalence of malaria and to assess the effects of the disease on the population. In addition, an entomological investigation provides information on the local vectors and on their susceptibility to insecticides. Type, dosage and frequency of application of the insecticide are also determined at this stage. Existing facilities are examined and estimates made for supplies and equipment, transport and budget. On this basic information a plan of operations is drawn up that must be agreed on and signed by the government of the country concerned before the first phase of the campaign can be undertaken.

This preparatory phase consists of a geographical reconnaissance; that is, the enumeration of houses, the establishment of administrative boundaries and the arranging of itineraries. It also covers the setting up of laboratories and entomological units, the recruitment and training of spraying teams, technicians and administrative personnel and the organization of transport and supplies. During this period also comes the build-up of public relations and the health education of the population. If necessary legislation must be sought to ensure right of entry for the spraying teams and the enforcement of compulsory notification of malaria cases in the later stages. The preparatory phase must cover at least one year in order to take into account changing seasonal conditions.

Following the preparatory phase comes the attack phase: intensive, total-coverage spraying. At the same time infection rates and entomological findings are constantly reviewed to assess progress. Careful watch is kept for signs of resistance in the mosquito population. After a period of three to four years spraying may be stopped if it has been shown that transmission has been definitely interrupted and infection rates have been reduced to well below one per 2,000 of population.

Next is the phase of consolidation. All remaining pockets of transmission must be eliminated by small-scale spraying, and all people still infected must be cured. The main activity now consists in the detection of cases. This means checking every person with fever symptoms, by house-to-house visits and by screening fever patients in hospitals and clinics. All suspected cases are reported, and blood samples are promptly sent to the laboratory. Every person with confirmed malaria must undergo treatment at once.

These activities continue for at least three years. If at the end of that time no new infections are turning up, the program passes into its final phase of maintenance. A special organization is no longer required. The procedure now falls within the normal routine of the local health services. Reporting of malaria remains compulsory and all cases are treated by the local doctor or nurse. As far as possible the origin of each infection must be traced so that potential sources of disease can be dealt with.

The foregoing outline hardly suggests the magnitude of the effort and the difficulties that lie in its way. In 1959, for example, more than 100 million houses were sprayed. The campaign required 130,000 sprayers and consumed 60,000 tons of insecticide. On the medical side no fewer than 45 million blood smears are now being examined annually by 3,000 microscopists working full time. In some countries transport alone constitutes a herculean task. Elsewhere the chief problem may be the structure of the houses (which sometimes consist of no more than a roof and four posts), the habit of replastering or repainting houses at frequent intervals, or the nomadic life of the population and the impermanence of dwellings and settlements. Another difficulty is that some species of *Anopheles* tend to bite out of doors and do not settle on walls afterward.

Moreover, the efficiency of the spraying campaign—that is, the speed with which it interrupts transmission of malaria—depends on the type of malaria encountered. In intensely malarial areas transmission is high, a large proportion of the population is infected, the mosquito vector has a relatively long life and the climate favors rapid development of the parasite and repeated infection in the course of the year. Here the density and longevity of the vector must be reduced to a very low level to interrupt transmission. This requires a correspondingly long and intense effort.

As has been mentioned, a spraying campaign must go hand in hand with a continuous and accurate measurement of the amount of infection in the region. In the early stages this incidence can be determined by two classical methods: palpation of the spleen to detect its enlargement and examination of blood smears in random samples of the population. When the infection rate drops below 3 per cent, however, these methods are no longer sensitive enough. Then the only way to assess the amount of malaria remaining is to find and check every case of fever. In areas of endemic malaria even this may not be good enough. People who suffer frequent infection throughout life may develop a degree of tolerance to the parasite and show few, if any, clinical symptoms of their infection. Such carriers are the source

of persistent infection in a community, and blood examination of the entire population is the only means of detecting them.

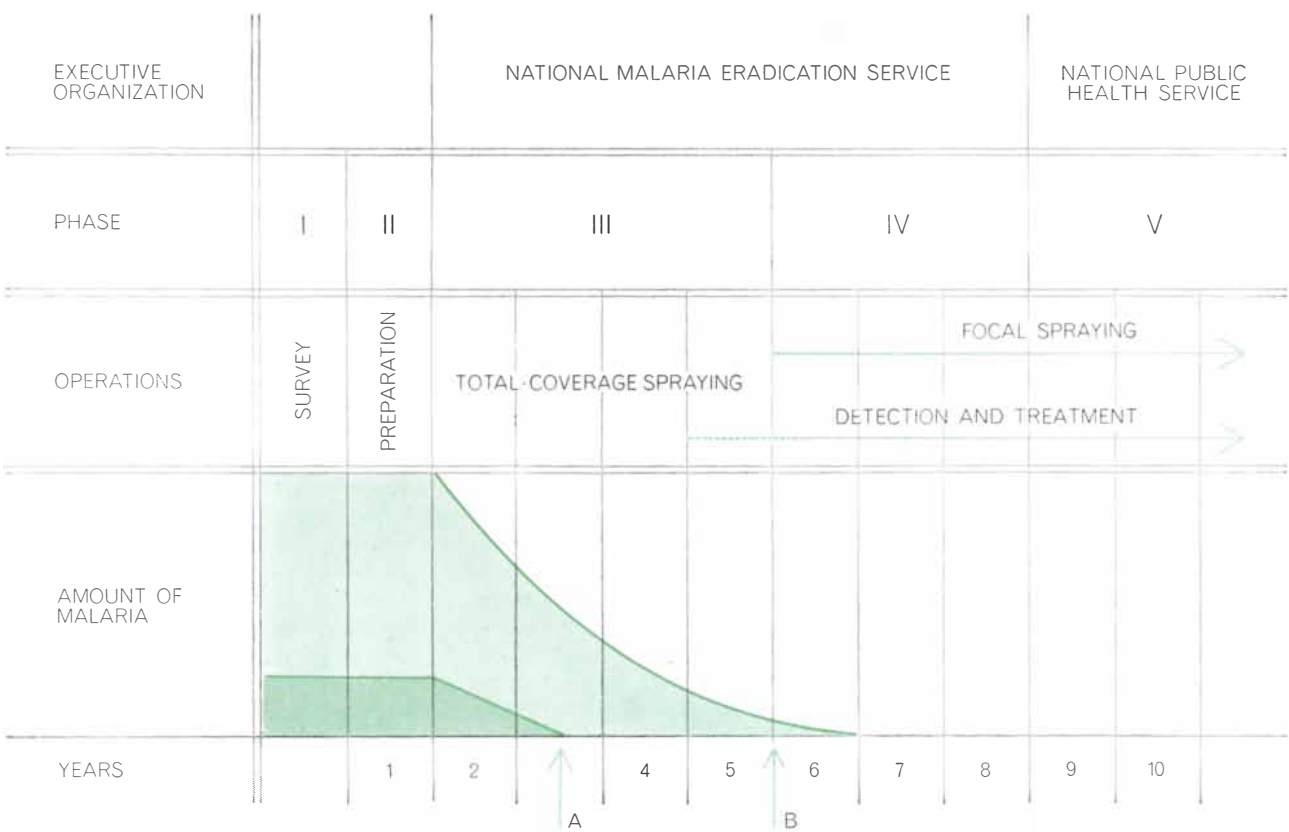
Antimalaria Drugs

Although total-coverage spraying is largely responsible for interrupting the transmission of malaria, the final clean-up can be accomplished only by using drugs to treat the remaining cases. The wide variety of synthetic antimalaria compounds now available is a legacy of World War II research, when the Japanese occupation of Indonesia cut off supplies of quinine. Some of the synthetic drugs—such as proguanil and pyrimethamine—are prophylactics; they prevent the establishment of the parasite in the liver, cutting the infection short before symptoms appear. Others —including quinine, mepacrine (atebrin), chloroquine and amodiaquin—attack the plasmodia in the red blood cells and are used for treatment. Pamaquine and the new primaquine also kill gametocytes, thereby interrupting transmission from man to mosquito. Antirelapse drugs—such as primaquine—act on secondary tissue schizonts in the liver cells.

Mass drug administration has often been advocated as a means of eradicating malaria. Unfortunately all these drugs are rapidly excreted by the body and when used for prevention of malaria must be administered frequently and regularly. In military units and similar organized groups such mass administration of drugs has been most successful. On a country-wide scale, however, this approach, which would mean frequent and regular dosing of every man, woman and child in a large population, poses insoluble problems of organization, distribution and, above all, persuasion. Underdeveloped countries with inadequate health services are particularly unsuited to such an attempt.

Interestingly enough, the ingenious large-scale use of drugs has been introduced in certain parts of Brazil. Because one of the chief vectors in the area is an outdoor biter, and because most of the local houses have no walls, the spraying campaign met with little success. Chemotherapy seemed to be the only answer, but the vast territory involved, the inaccessibility of many villages and the shy and even hostile attitude of the more remote people made the direct distribution of drugs impossible. Mario Pinotti, the Brazilian Minister of Health, decided to add chloroquine to salt, much as iodine has been added in regions of endemic goiter. A government monopoly guaranteed that the whole population would get the medicated salt. It was expected that if everyone in the area received enough chloroquine to suppress malaria, this method would be completely effective. Pinotti's method is now undergoing field trials in several countries.

Meanwhile the plasmodium, like the mosquito, is developing resistance to some drugs. In certain parts of the world malaria parasites do not respond normally to the prophylactic drugs proguanil and pyrimethamine; in Colombia resistance to chloroquine and amodiaquin has been reported. The search for new antimalaria compounds continues, with the hope not only of keeping ahead of the developing resistance but also of some day finding a drug that will be ef-



ERADICATION CAMPAIGN proceeds in well-defined phases taking about eight years. This chart shows a typical program: I, pre-eradication survey; II, preparatory phase; III, attack phase; IV, consolidation; V, maintenance. Lightly shaded area indicates decline in reservoir of old infections; deeper shading denotes rate of transmission or new infections. Arrow *A* marks interruption of transmission, *B* an infection rate of only one person in 2,000, at which point total-coverage spraying of the malarial region can end.

fective over a long period when given in a single dose.

In spite of all the practical problems, and of the growing resistance of mosquitoes and parasites, there is no doubt that well-planned eradication campaigns, unhindered by financial or administrative difficulties, can achieve complete success. Starting its campaign in 1952, the U.S.S.R. has eliminated malaria from the whole of its vast area. It was able to assign almost unlimited personnel to the task and to make use of its widespread network of public health units. Venezuela and Mexico have carried out their programs with outstanding drive and determination. In the latter country an imaginative educational effort enlisted the active support of all citizens, and the logistics of the program was planned and assisted by the Mexican army. At present India is conducting the biggest campaign, covering a population of 420 million. When it began in 1958, the Indian program ran into a number of difficulties, in large part because of its very size, but it is now progressing so satisfactorily that in the spring of 1962 areas inhabited by 140 million passed from the attack phase to the phase of consolidation. Mainland China, where mosquitoes are classed with flies, rats and sparrows as one of the four great plagues, is known to be attacking malaria, but it has released little information on methods or results. On Taiwan a well-planned and well-executed malaria eradication program has met with outstanding success.

Two years ago an interesting incidental finding was considered by some to be a new threat to the goal of eradication. Some workers in a laboratory carrying out research on lower monkeys contracted an infection of *Plasmodium cynomolgi bastianellii*, which had previously been thought to be a purely simian parasite. Studies in the U.S. confirmed the ability of the parasite to infect man and also showed that it can be transmitted from man to monkey to man by an *Anopheles* mosquito. This remarkable discovery posed the problem of the feasibility of malaria eradication in areas where infected monkeys are numerous and live in comparatively close association with man.

It does not seem that these fears were justified. What is actually known is that two strains of malaria parasite of lower monkeys from Malaya can survive and develop in man and in lower monkeys, and that two species of North American *Anopheles* can transmit the infection under experimental conditions. That such transmission can occur in nature

is far from certain. It is not known whether other species of *Anopheles* mosquitoes, in Malaya or elsewhere, feed on monkeys in the wild, nor whether the insects become infected, nor whether they enter human dwellings and feed on man often enough to maintain the chain of transmission. The possible significance of simian malaria as a reservoir of infection for man will be clear only when human malaria comes close to the vanishing point in Malaya, Borneo, Indonesia, the Philippines, Brazil and Taiwan, where the monkeys may be infected.

The WHO Effort

A few figures will give an idea of the present extent of the international eradication effort. In 1961 the population living in malarial or previously malarial regions throughout the world amounted to 1,420 million. Of these, 317 million now live in malaria-free areas and 710 million more in places where eradication programs are now under way. Preliminary planning has begun in countries having a population of 170 million. This leaves some 223 million as yet totally unprotected.

Not all the programs are equally successful. Some have been disappointing so far. Nevertheless, there is every reason for optimism. At the present rate of progress malaria should be eradicated from continental Europe by the end of 1962, and from the Americas, North Africa and a large part of Asia within the next 10 years. Progress in much of Africa is slower, however, and it would be difficult to make a forecast at this stage.

What is the cost of ridding the world of this burden? In 1959 WHO made a highly conjectural estimate of $1,691 million. For 1958 and 1959 an annual expenditure of $90 million can be definitely accounted for, and in 1960 $103 million. More than half of this amount came from the countries directly concerned. The rest was furnished by WHO, the United Nations International Children's Emergency Fund, the UN Technical Assistance Board, the Pan American Health Organization and U.S. bilateral funds. The sums mentioned do not include contributions from other sources, such as the Colombo Plan of the British Commonwealth, the French FIDES funds and other types of bilateral assistance.

Although the over-all contribution of the international agencies is much less than that of national governments, the international funds play an important catalyzing role. In many cases national funds would not have been forthcoming without the stimulus of international assistance. Until 1955 the financial requirements of the malaria campaign remained well within the regular budget of WHO. Thereafter they increased so rapidly that in 1955 the Malaria Eradication Special Account was created, the funds to be provided on a voluntary basis by member states of the UN. By the end of 1960 the total amount received or pledged amounted to $12,772,000, of which $11 million came from the U.S. Unfortunately many countries that had never known malaria, or that had been free from the disease for a long time, gave little or nothing, and the contributions fell far short of actual needs. The World Health Assembly in New Delhi in 1961 therefore decided to finance malaria eradication programs out of the regular budget of WHO. As economic conditions improve and production rises in underdeveloped countries, they will be able to bear more of the costs. However, since most eradication schemes require at least eight years to reach the maintenance phase and since many areas are only in the planning stage, financial relief will not come soon.

In addition to helping to finance eradication programs, the funds dis-

MALARIA CONVOY in Burma uses elephants. Tanks of spray guns can be seen on first two elephants. One of the most difficult aspects of an eradication campaign in countries without numerous roads is simply reaching the dwelling places in outlying areas.

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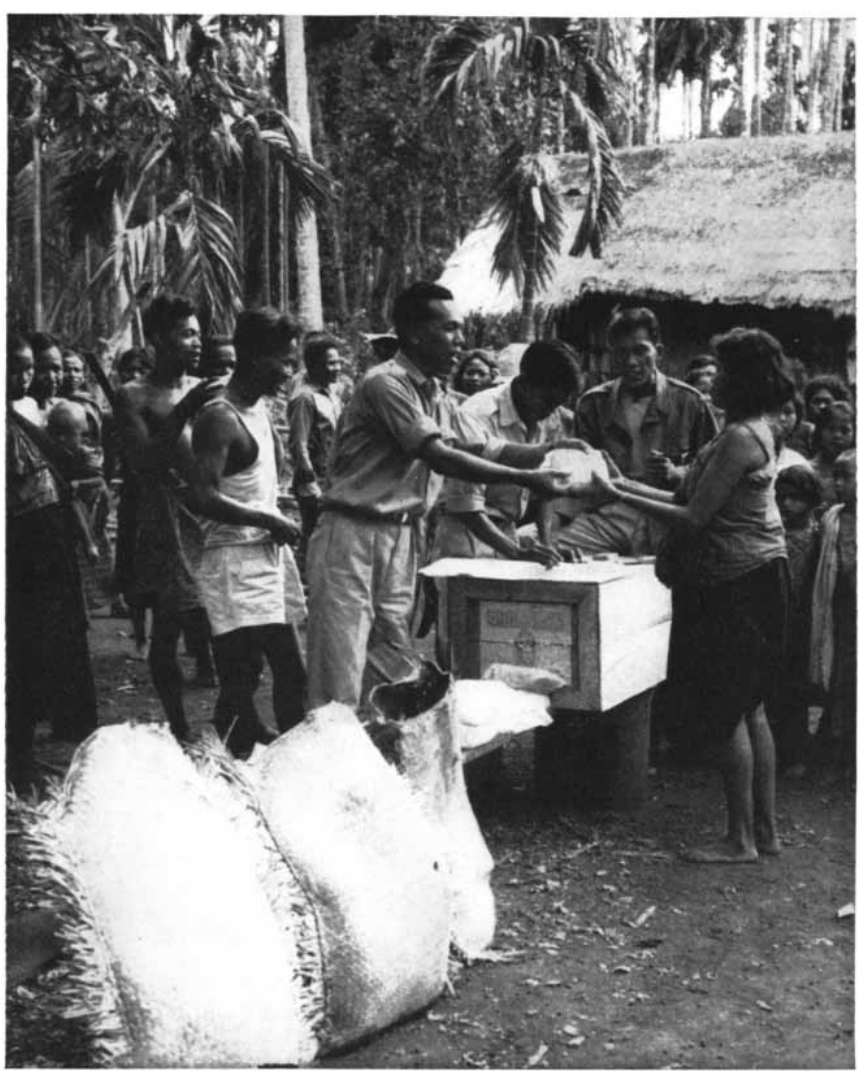
BLOOD SAMPLE is taken from African child in Cameroon. Microscopic examination of smear on slide will reveal any malaria parasites. Blood sampling is a key part of a campaign.



SALT CONTAINING CHLOROQUINE, an antimalaria drug, is distributed in Cambodia. The medicated salt helps eliminate malaria where spraying is not completely effective.

bursed by WHO support a massive program of research and training. Laboratories in many parts of the world are now carrying out a promising large-scale search for new insecticides. WHO has prepared and distributed special test kits for determining the susceptibility of different species of *Anopheles* to various insecticides. This information is useful not only in planning specific campaigns but also in fundamental studies of the biochemistry and genetics of resistance. Other entomological research is concerned with mosquito behavior, distribution, species differentiation and ecology; the chemistry of insecticides is also being studied. Parasitology, chemotherapy and epidemiology are the subjects of important research projects. To provide at least the cadres that can set up and operate eradication programs, WHO organizes courses for physicians, sanitarians, entomologists, laboratory technicians and administrative officers.

It is frequently said that antimalaria campaigns are adding to the world's woes by contributing to a population "explosion" in underdeveloped countries. There is no doubt that the malariologist's work invariably reduces death rates and increases longevity. To this he pleads guilty; but this indictment must be shared by the physicians who cure or prevent any disease, the engineers who build dams and pipe water supplies, the architects who convert slums into clean houses, and generally by all who in any way contribute to the improvement of health standards. But if some lives are saved and others prolonged, it is also true that regained health and energy are reflected in well-tended crops, more abundant harvests, reclamation of long neglected lands and regular attendance in workshop or factory.

This is not to deny that the rise in population has often outrun the rise in productivity and economic development. In countries where it has happened there is so much to do and there are so many problems to solve that progress cannot be uniform on all fronts. The best that the public health worker can do is to attempt to co-ordinate medical progress with progress in general and, where possible, to direct his efforts at those infections that play the most important part in the vicious circle of poverty, ignorance and disease. Healthy and educated populations are a prerequisite of rapid social and economic advance. In highly malarial countries no real progress in any field is possible until the burden of disease is lifted and men are free to give their full strength to the task of building a better life.

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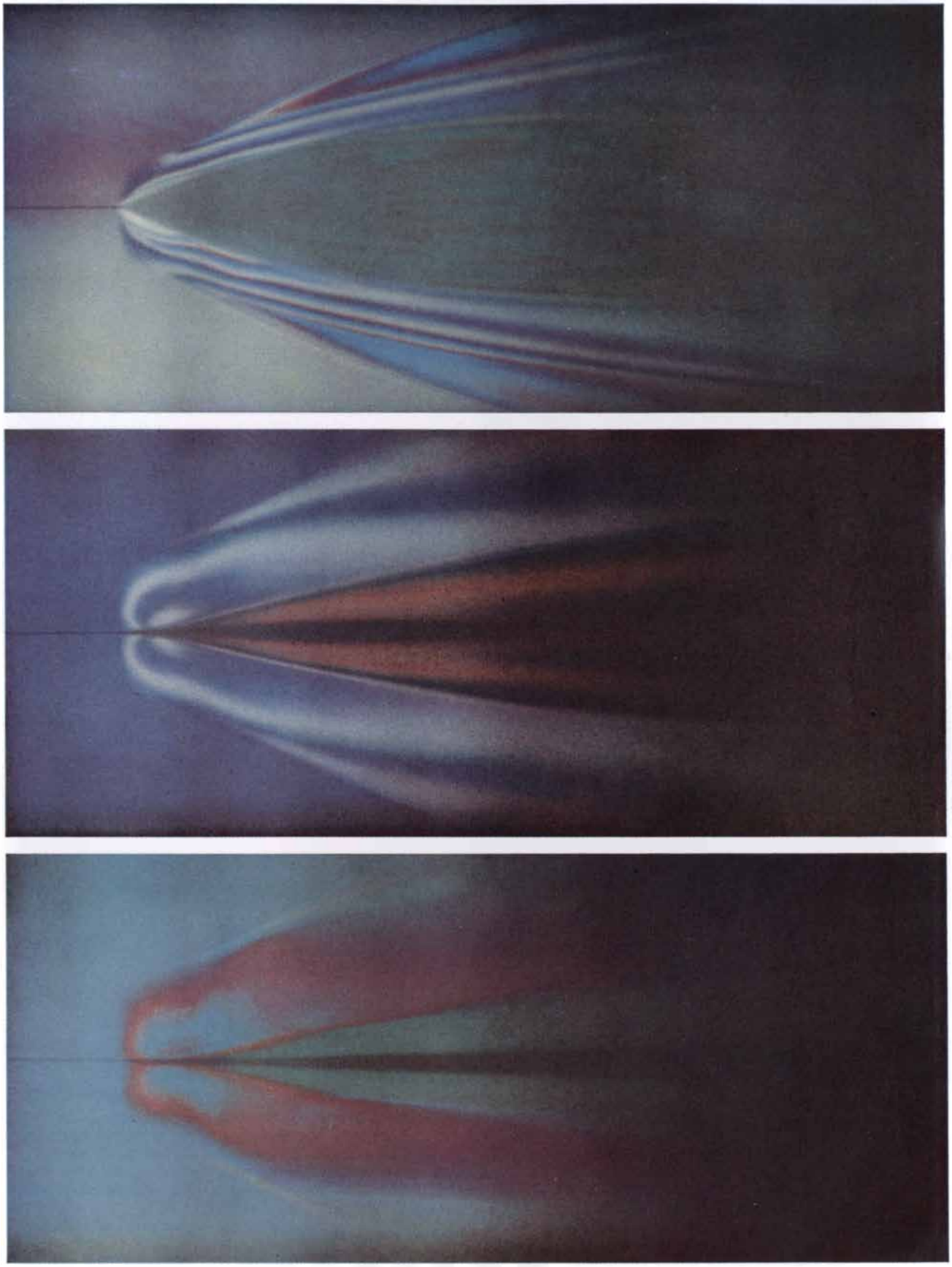


COMPLEXITY OF WIRE EXPLOSION is readily apparent in these photographs made in author's laboratory by the streak-interference technique. The three copper wires were exploded in argon at pressures of 1/4 (*top*), 1/16 (*middle*) and 1/32 atmosphere. As pressure drops, the "head" shock wave (*see diagram on opposite page*) grows weaker, wire starts to expand later and then expands less, and electric arc and ionized gas, or plasma, at "tip" occupy more space. Each picture covers about 20 millionths of a second.

Exploding Wires

Fine copper wires exploded in the laboratory by a large burst of electrical energy produce shock waves that are analogous to those created by meteorites and missiles in the atmosphere

by Frederick D. Bennett

Anyone who has changed a blown fuse and noticed the black spot on the little mica window has seen something of the effects of an exploding wire. Such explosions go back to the early days of the study of electricity. In 1774 the *Philosophical Transactions* of the Royal Society in London described an experiment in which several wires were exploded at once to prove that the current in every part of a closed circuit is the same. Although the demonstration was inexact, it carried conviction—energetic wire explosions give rise to a loud noise and a brilliant flash of light.

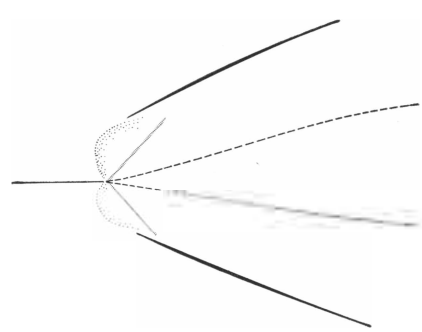
It is not difficult to make a thin wire explode: just connect it across a fair-sized condenser charged to a few thousand volts. In the days of Leyden jars and Wimshurst machines wires probably exploded frequently by accident. Observing the phenomenon in detail, however, has not been so simple, and understanding it is a job that has only begun. Physicists have analyzed the light flash with spectroscopes since the 1920's but until recently had found out comparatively little about the changes that occur in the wire itself. Surprisingly, the mechanism that causes the loud noise has only recently been examined in detail. (The somewhat similar case of the thunderclap that accompanies a lightning bolt is far from understood.)

Current interest in exploding wires has arisen because certain related phenomena have become important. The development during the past 20 years of high-speed photography with submicrosecond exposure times (a microsecond is one millionth of a second) and of methods for displaying equally brief electrical pulses has made it possible to measure the fluid motions and electrical changes encountered in wire explosions. In the same period problems connected with high-speed flight and with ionized gases, or plasmas, have revived interest in the study of fluid mechanics, a subject neglected by physicists since the time of Kelvin and Helmholtz. Analysis of the shock waves and other patterns of flow around exploding wires can provide valuable information about the analogous disturbances caused by meteorites, missiles and other high-velocity objects traveling through the atmosphere.

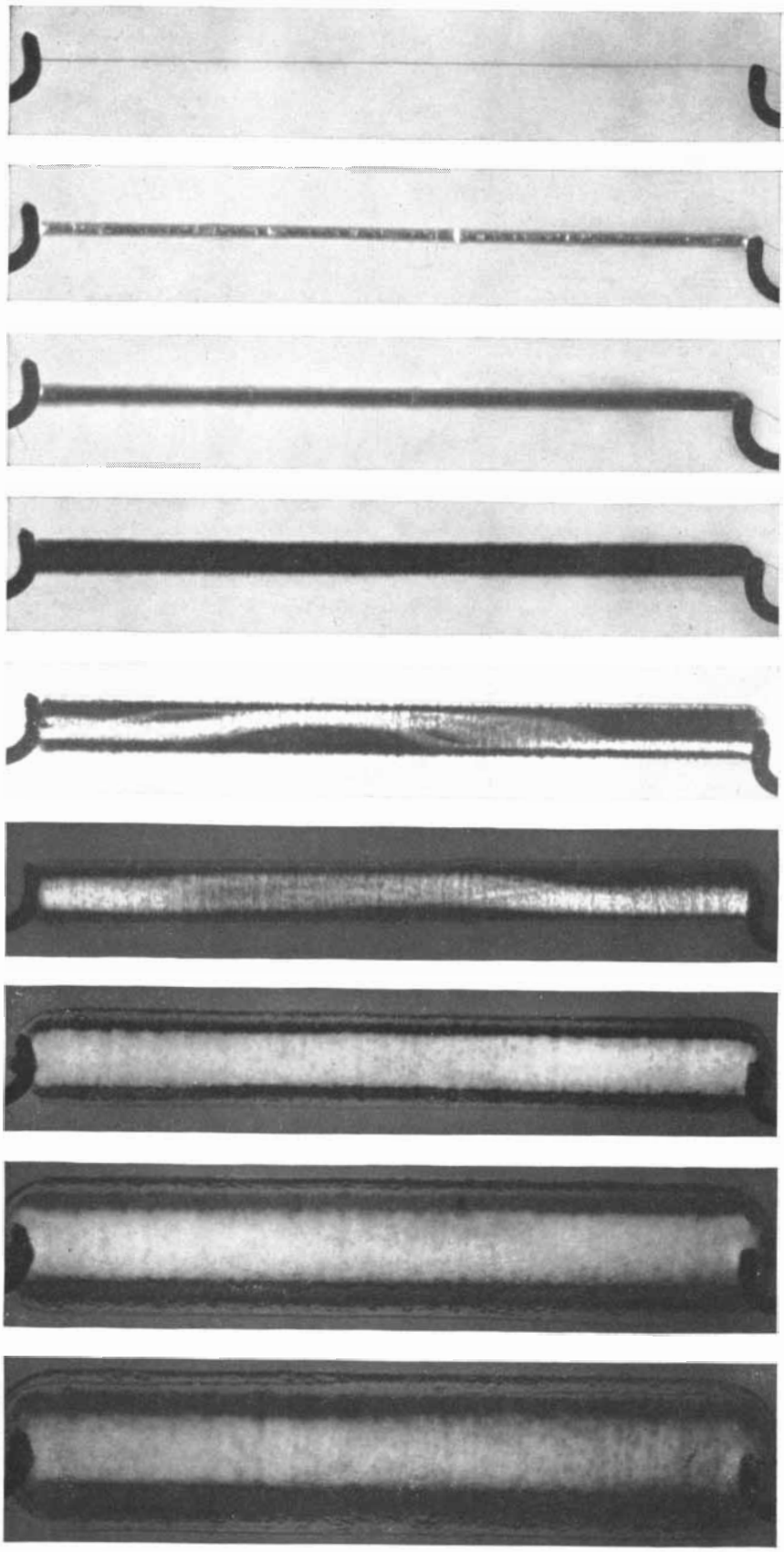
Practical problems in space technology and in the field of thermonuclear power have created a great interest in plasmas and their behavior in magnetic fields. Plasmas can be produced in wire explosions. Wires exploded in air or other reactive gas mixtures create free radicals and unusual short-lived molecules. Light from the explosion can be used to trigger photochemical reactions. In our work in the Ballistic Research Laboratories at the Aberdeen Proving Ground we have primarily been studying the shock waves produced by exploding wires. Recently we have also been investigating the associated plasmas.

Many variables affect the course of an explosion: the length, thickness and material of the wire; the density and chemical composition of the surrounding gas and, of course, the amount and rate of addition of electrical energy. In our laboratory we normally use a uniform copper wire about two centimeters long and a hundredth of a centimeter in diameter, exploding it in air or in the inert gas argon at pressures from one atmosphere (14.7 pounds per square inch) down to a few thousandths of an atmosphere. Our explosions are usually in the moderate energy range—an electrical pulse of several thousand amperes is delivered at rates no higher than 100 million watts. This is quite a bit of power in everyday terms, but some experiments involve thousands of times more. Inordinate amounts of electrical energy are never required, however, because the pulses are extremely short.

The instant the current comes on, the greatly overloaded wire begins to heat. After about half a microsecond it expands smoothly to several times its original diameter. The temperature of the metal is inferred to be far above its normal boiling point. As the copper atoms separate, the resistance of the wire rises and also the voltage across it. The high voltage has created many tiny arcs between parts of the scattering metal. After the wire has expanded to three or four times its original diameter it can no longer conduct and the current drops sharply. The surrounding magnetic lines of force, which were induced by the current, collapse and cause an additional voltage. Now the total voltage across the wire may considerably exceed the original voltage in the condenser. At this point an explosion takes one of two courses.



SHOCK STRUCTURE in the middle and bottom photographs on opposite page is complex. Stippled tip here marks the apparent outer boundary of the plasma. Gray lines just behind denote a weak shock wave in the plasma, whereas broken lines mark edges of expanding wire. The heavy black lines represent the primary, or "head," shock wave moving out through the ambient gas.



SEQUENCE OF EVENTS during explosions of wires is shown in photographs of different wires made at successively later times. First photograph was made 1/2 microsecond after electric current was turned on. Tiny arcs appear at one microsecond, followed by "dwell" (*third and fourth photographs*) lasting one microsecond. Internal arc strikes at two microseconds. Last photograph was made seven microseconds after current was turned on. This series was made by Werner Müller at the Laboratoire de Recherches Techniques in France.

When the voltage is high enough to strongly ionize the surrounding gas, the electric current is simply transferred into the gas as an intensely luminous arc that forms a hollow cylinder around the wire. The material of the wire continues to expand, and the arc around it grows larger and then decays in intensity. Meanwhile a disturbance separates from the outside edge of the expanding wire and races ahead into the gas. This is the primary, or "head," shock wave. If enough energy remains in the circuit, another arc finally forms inside the hollow cylinder of dispersed metal. In our laboratory we work mainly with this continuous-current type of explosion.

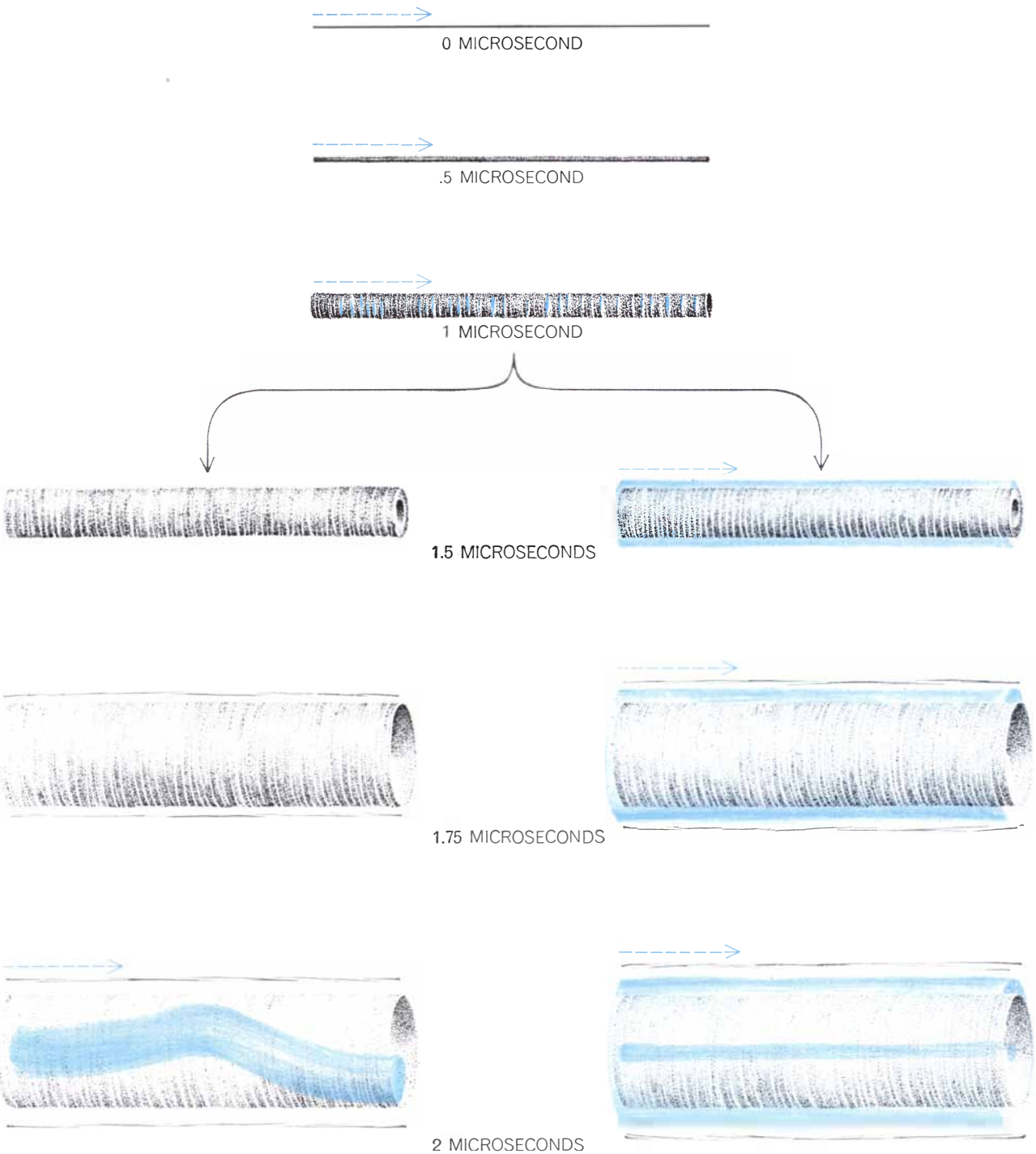
The other type of explosion occurs if the voltage is too low to break down the gas around the wire. When the wire becomes nonconducting, the explosion enters a "dwell" phase, in which the wire continues to expand but practically no current flows. The shock wave appears during this period. The dwell lasts a microsecond or so, then an arc strikes along the inside of the cylinder and the explosion becomes luminous. This arc may form a second shock wave. Meanwhile the wire material continues to expand until it finally loses its symmetry and disappears.

In either kind of explosion a good deal remains to be learned about the behavior of the metal. It is not clear whether the wire expands as a uniform, superheated vapor and condenses into molten droplets that then solidify, or whether it disperses as a vapor mixed with molten or solid particles. Some of the evidence indicates that pressures inside the exploding wire, when the current is near the maximum, are several thousand times greater than pressures in the outer parts of the expanding material. Such large differences suggest that the exploding matter is not in a uniform, finely divided state. Indeed, both X-ray and light photographs show striations across the wire, and the X-ray pictures reveal gaps along its length. The exploding wire seems to resemble a stack of rings, with periodic spaces, lying on its side. The equations of fluid dynamics predict a hollow cylindrical form for an exploding wire but offer no insight into the origin of the ring structure.

The foregoing description rests primarily on direct photographs of exploding wires, in particular the remarkable series made by Werner Müller at the Laboratoire de Recherches Techniques in France [*see illustrations at left*], and on X-ray pictures made by G. Thomer at the same institution. Such series are

usually compiled by exploding a number of identical wires under identical initial conditions and photographing them at successive times. A few sequences of pictures of single wires exploding have also been made.

In our laboratory we do not view the whole explosion at isolated instants but follow a small section of it continuously throughout its history. For this purpose we use a streak camera, invented in 1893 by C. V. Boys of England for studying sparks. The wire is placed behind a narrow slit and at right angles to it. In front of the slit is a rapidly rotating mirror [*see top illustration on next two pages*]. As the mirror spins it sweeps the image of the slit over a photographic plate, thereby spreading out the temporal sequence spatially. In the classic form of the camera, light is furnished by the explosion itself. In the modified camera that we have developed, the light comes from a pulsed arc lamp synchro-



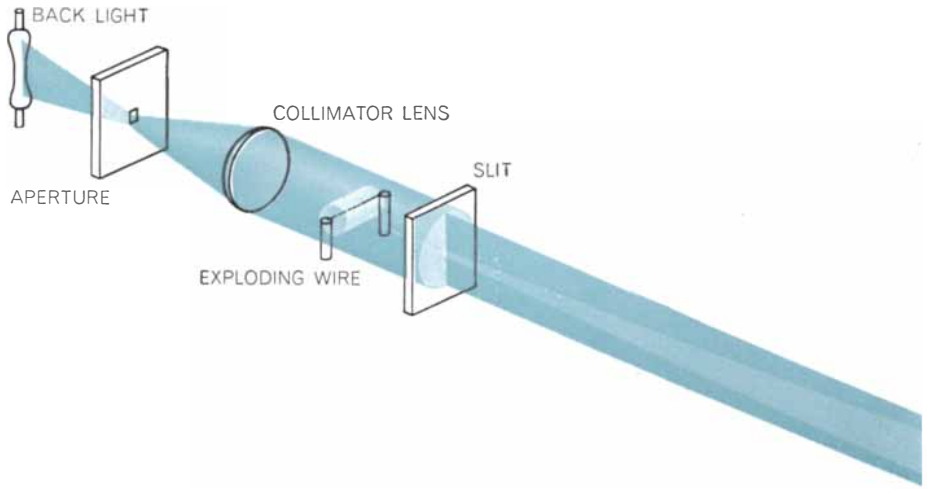
TWO MODES OF EXPLOSION are the dwell, in which the flow of electric current is interrupted, and the continuous-current explosion. Arrows indicate that current is flowing. Both types start in the same way. Lower voltages in the condenser favor dwell type (*left*). After dwell, an arc (*color*) strikes through expanding cylinder of metal. In continuous-current explosion (*right*) an arc forms around expanding metal at 1.5 microseconds; the internal arc appears later. In both types the shock wave appears at 1.75 microseconds.

nized with the explosion, or from a plane mirror or plaque of parallel reflecting wires placed behind the exploding wire. The resulting elongated picture of the expanding wire and shock waves looks strikingly like a photograph of a hypervelocity missile in flight. (Interestingly enough, the same equations apply to the shock trajectories in both.)

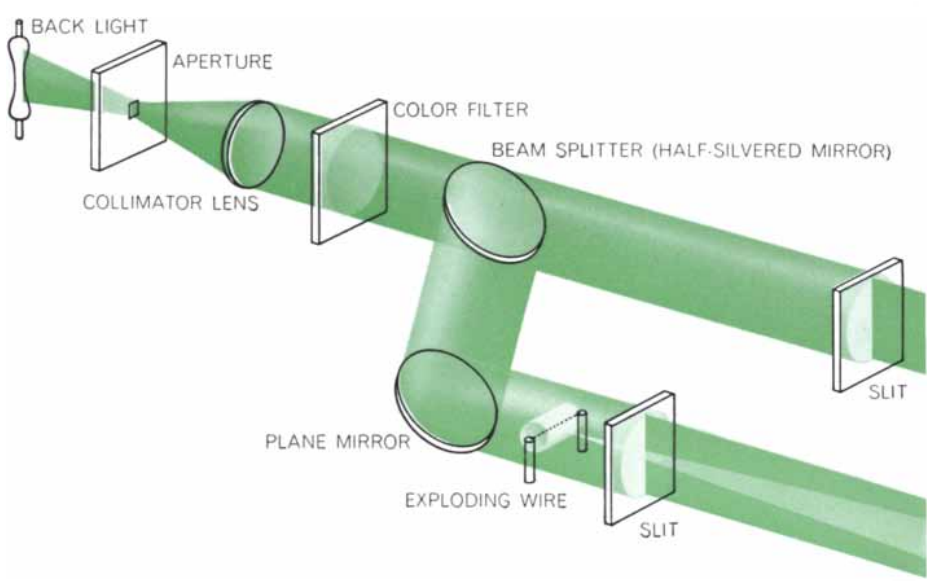
We began to use our modified streak camera in 1958. Until then the shock wave produced by an exploding wire had not been clearly observed and was believed to coincide with the boundary of the luminous region of the wire. Our first pictures showed that the shock wave leaves the luminous metallic region far behind. It propagates as if it were a blast wave produced by a cylindrical explosive charge. At the beginning of the explosion the wire material expands briefly at extremely high (theoretically infinite) speeds; some of the expansions have been clocked at Mach 20 (20 times the speed of sound). Then the explosion quickly slows down. A short distance behind the luminous "tip" that we see in the photographs—that is, a short time after the start of the event—the head shock wave leaves the glowing region, moving out at a speed of Mach 10. The subsequent curvature of the wave results from the fact that it slows down as it moves away from the wire [*see illustrations on page 108*].

The streak photographs also revealed an internal shock wave. This second wave is set up within the wire material. In the initial rapid expansion of the wire the wave is carried outward with the metal. But the shock itself is actually propagating inward, and as the expansion slows down, the shock wave begins to move inward. Eventually it reaches the axis of the wire and is reflected outward again. Other disturbances inside the explosion may also be shock waves, but as yet we cannot definitely say that they are. In any case the two major waves account satisfactorily for the sound energy that eventually produces the noise of the explosion.

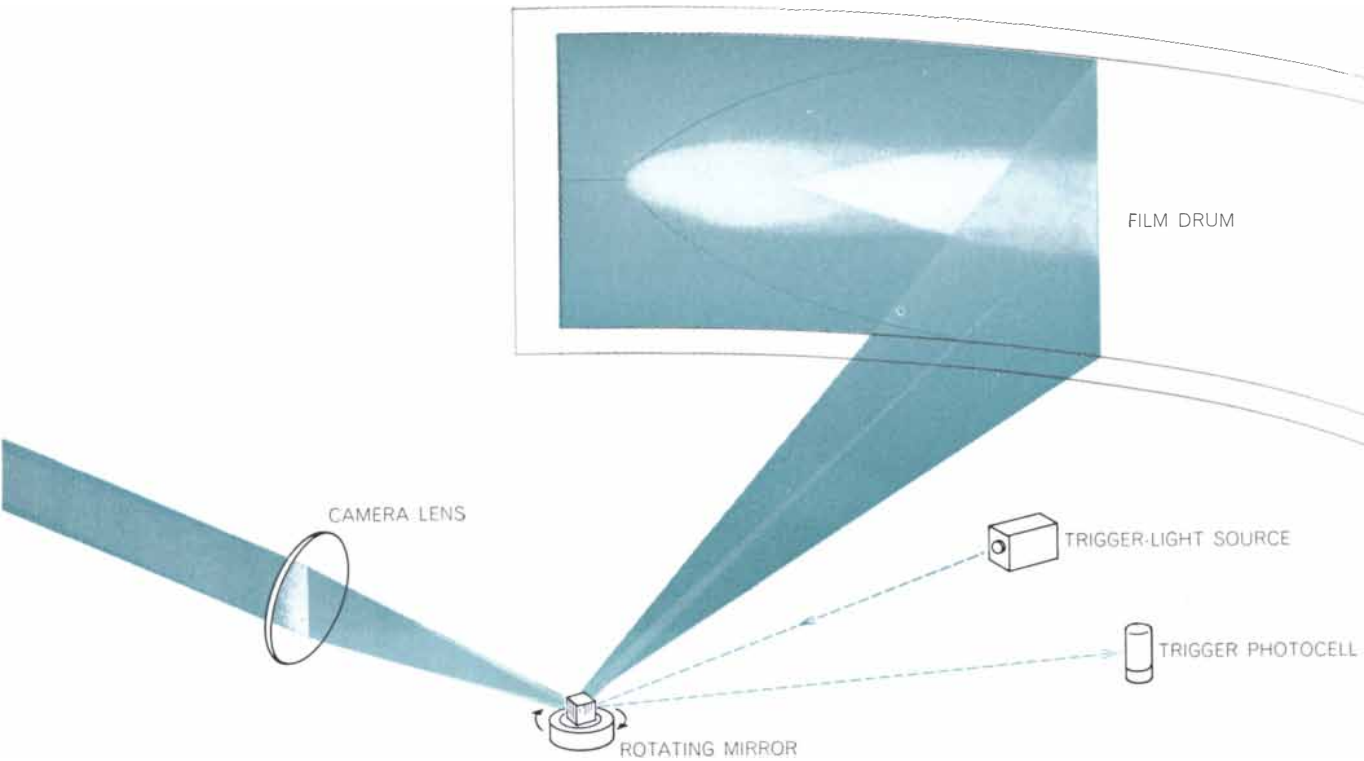
Although the pressure jumps of the shock waves proper show up well in the streak-camera photographs, the pictures provide little information about the conditions of flow behind the shocks. In other words, the camera shows mainly the outer surface of a complex, expanding structure. This is particularly frustrating to anyone interested in the analogy to supersonic flight. It is precisely this region behind the shock wave that he wants to know about. Fortunately the density variations in this region can be



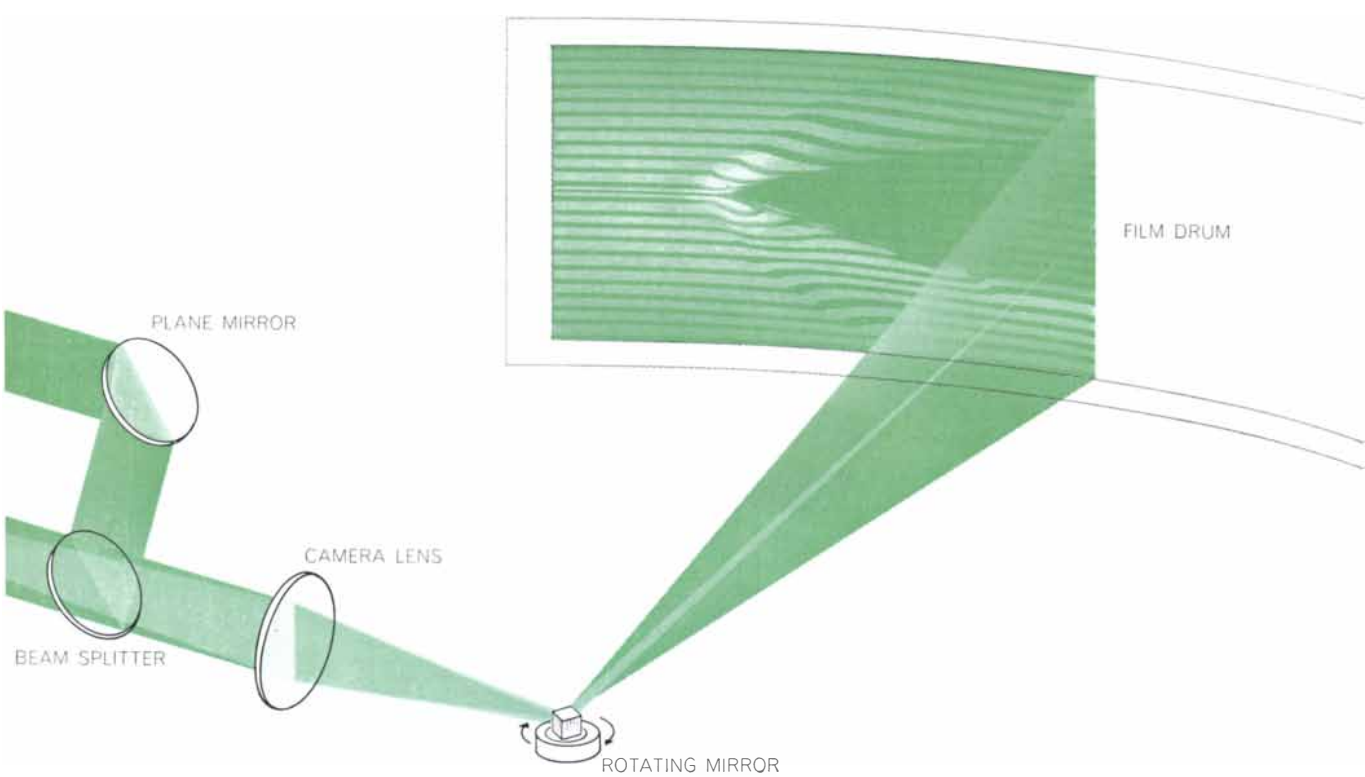
AUTHOR'S STREAK CAMERA in the modification using a pulsed arc lamp for back-lighting is shown in this highly schematic diagram. The collimator lens makes the light rays parallel. (A mirror or a plaque of shiny wires is sometimes used instead of the back light and collimator lens.) Wire shown here is in midst of an explosion. The slit passes a very narrow beam of light; only a tiny section of the wire is actually photographed. Camera lens



STREAK CAMERA COMBINED WITH INTERFEROMETER produces pictures that can be analyzed with great mathematical precision. The interferometer splits the beam of parallel light rays into two beams. When they recombine, bright areas, or fringes, appear where crests of light waves from one beam combine with crests from the other. Dark fringes



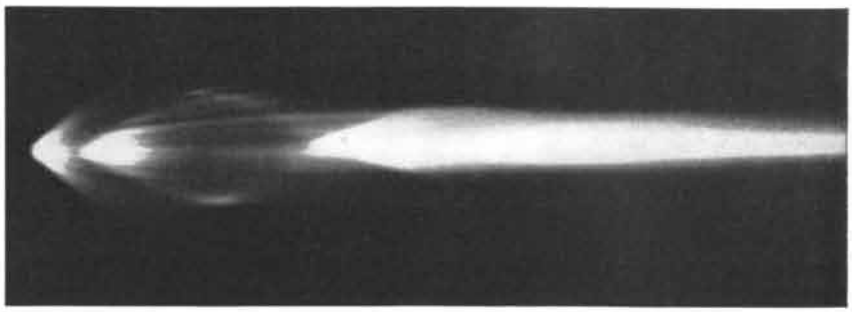
focuses the light so that it reflects from one side of the mirror, a small stainless-steel cube mounted on a cone. Compressed air blown upward against indentations in the cone spins the cube at extremely high speed. Its rotation sweeps the image of the section of wire onto the film, recording explosion through time. The size of the image is greatly exaggerated here. Another face of the mirror reflects light from the trigger-light source to the trigger photocell to set off the explosion and the back light when the mirror is in the right position to cast the image onto the film. (The triggering mechanism is omitted in the diagram below.)



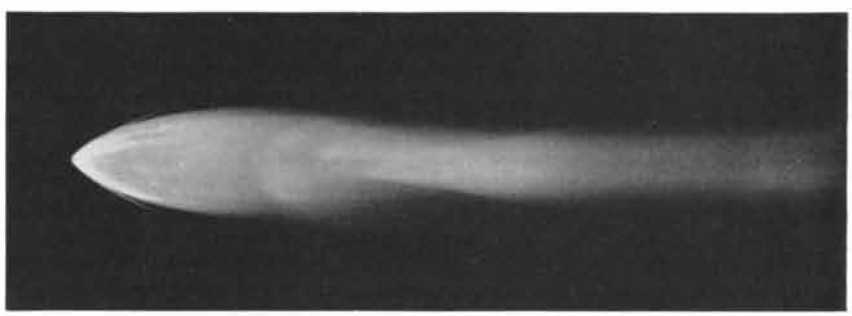
arise where crests of waves meet troughs and cancel. Changing the angles of the plane mirrors and beam splitters makes fringes wider or narrower. With color filter, as here, multifringe pictures are produced. White light gives fringes of the colors of the spectrum. Lighter shade in lower beam and beam coming from mirror represents image from one point on the exploding wire. All the photographs on the following pages were made by the author and his colleagues using one or the other of these two instruments.

determined with another instrument. Once the variations are known, other characteristics of gas motion can be computed.

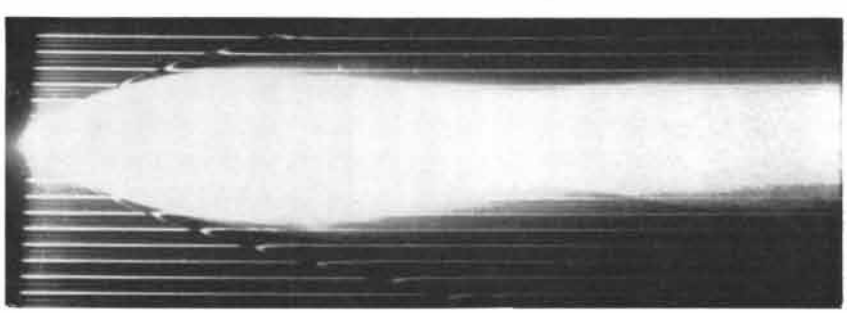
The instrument is a type of interferometer invented independently by two European physicists, Ludwig Mach and Ludwig Albert Zehnder, in 1892. It operates by splitting a beam of parallel light rays into two beams, directing them to a common meeting place along different paths and then recombining them to produce an interference pattern [*see bottom illustration on pages 106 and 107*].



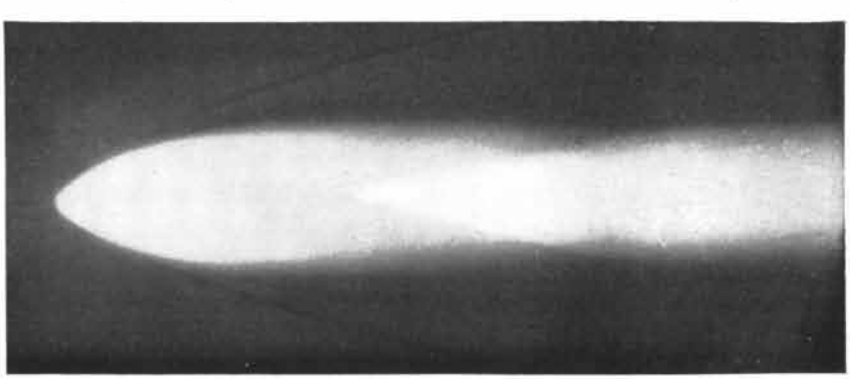
STREAK PICTURE lighted solely by wire itself shows peripheral arc (*tip*), which dies quickly, and internal arc, in which second shock converges, then expands (*bright wedge*).



MIRROR BEHIND WIRE reflects light of explosion, showing head shock as luminous whiskers. Bright internal wedge is second shock wave expanding after it has converged.



PLAQUE OF SHINY WIRES instead of mirror stands behind exploding wire. Refraction of their image caused by head shock wave shows the shock wave over a longer interval.



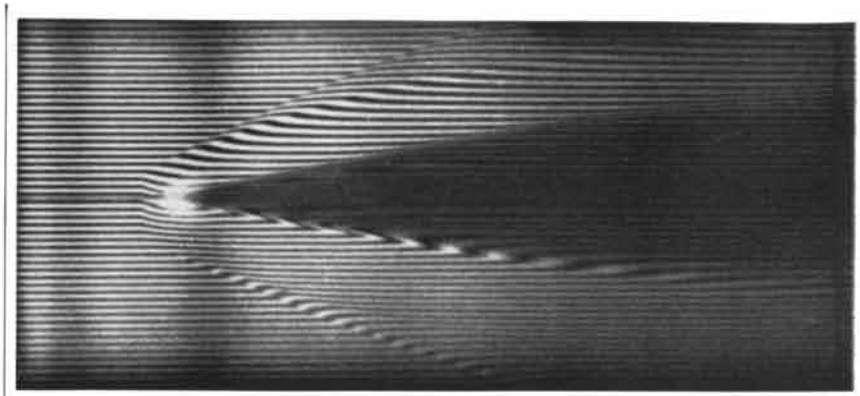
FLASH LAMP for back light shows head shock as a dark parabola. These streak-camera photographs were made in air at one atmosphere. Each covers about 15 microseconds.

If the lengths of the paths are the same, or if they differ by a whole number of wavelengths of the light, the waves in the two beams will be in phase when they recombine. They will reinforce each other to produce a bright field. If one path is a half-wavelength, or any odd number of half-wavelengths, longer than the other, the recombining beams will be out of phase: the crests of one will coincide with the troughs of the other. Accordingly they will cancel each other and produce a dark field. By adjusting the mirrors in the instrument, the length of one of the paths can be made to increase slightly across the width of the beam. In that case beams of monochromatic light (consisting of a single wavelength) will recombine to give an alternating series of light and dark bands, or fringes. If white light is used, different wavelengths reinforce at different points; the fringes are limited in number and take on various colors of the spectrum.

Now suppose that somewhere along one of the paths the air or other gas transmitting the light is made denser. The beam traversing that path will slow up and arrive at the meeting place a little later than if there were no increase in density. This changes its phase with respect to the other beam and therefore shifts the positions of the fringes by an amount related to the change in density.

Exploding a wire in one of the paths produces a complex density pattern that is mapped by the interference fringes. With the help of some complicated mathematics the displacements in monochromatic fringes can be translated into values of the density. Such calculation used to take weeks, but today a high-speed computer can finish it in a few hours. At present more time is spent performing the experiments, measuring the interferograms and studying the computed densities.

In its original form the Mach-Zehnder interferometer works only with density patterns that do not vary with time. By combining it with the streak camera we have overcome this limitation. In our arrangement the same flash lamp backlights the explosion and illuminates the interferometer. The exploding wire lies across one beam, parallel to the fringes. When the explosion starts, the rotating mirror sweeps the interference pattern onto the film and the shifting fringes write a detailed history of the density changes through time. The analytical methods devised for the study of steady supersonic flows caused by a projectile or a high-speed jet can be applied, prac-



MULTIFRINGE INTERFEROGRAM shows copper wire exploding in argon at 1/16 atmosphere. It was made in monochromatic green light. Brief dip in the fringes in luminous region at tip is caused by free electrons. Upward curve of the fringes marks head shock wave.

tically without change, to our streak interferograms.

With this new technique we at once discovered complications that we had not suspected before. At the same time some earlier puzzles were cleared up. One of these had arisen in our studies with the modified streak camera of explosions set off under reduced pressure. Starting at about 1/2 atmosphere, as the pressure was reduced, the head shock wave failed to propagate outward as rapidly as expected and its energy began to fall short of the amount thought to be available for producing the shock.

When we examined low-pressure explosions with the interferometer, we found the reason for the delayed appearance and the energy deficit. The clue was provided by photographs such as the one reproduced above. At the tip of the picture (that is, in the earliest part of the explosion) the fringes shift downward. The head shock wave is outlined by an *upward* shift of the fringes. The shock wave is a region of high density; light passing through it slows up and is retarded in phase. Since the upward shift represents a retardation, the downward shift must signify an advancement in phase. Such advancements are found only when light (or any electromagnetic wave) travels through a gas containing a large number of free electrons. Electrons are so light that they are set into vibration by the electrical oscillations in the light wave, and the resulting interaction between particles and electric fields advances the phase of the oscillations.

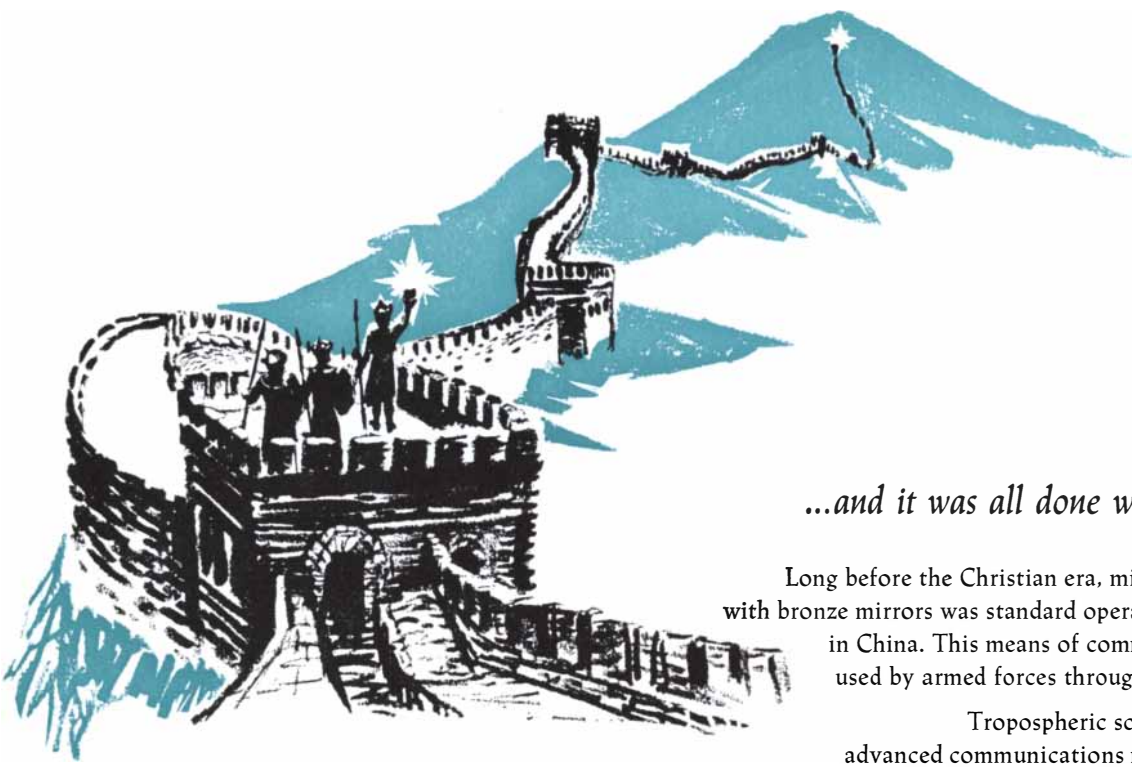
The source of free electrons in wire explosions is the peripheral arc. Before the explosion there are a few free electrons around the wire as a result of cosmic rays and rare high-energy collisions between the gas molecules. When the voltage approaches its peak, it produces a strong electric field that accelerates the electrons. If the voltage is high enough, each electron builds up enough speed to knock another out of one of the molecules it hits. These new electrons are accelerated in turn and the result is an avalanche of free electrons moving through an equal number of positive ions, which together constitute a plasma.

The lower the pressure of the gas, the farther the electrons travel in the electric field before hitting a molecule and the greater the speed and energy they acquire. Thus the build-up of charged particles occurs sooner at the lower pressures and the arc can form earlier during the voltage rise. When it forms, it diverts the current and energy away from the wire. At pressures below 1/2 atmosphere the arc drains energy away so soon that the wire material cannot expand fast enough and far enough to create a major shock. Instead the arc itself produces the shock by a mechanism involving expansion of the electron cloud. Finally, smaller impulses from the wire contribute to the shock structure.

From the observed displacement of interference fringes in the plasma it is possible to calculate the density of electrons and therefore the degree of ionization. We have found as many as a billion billion electrons per cubic centimeter, signifying that 65 per cent of the gas molecules are ionized. By plotting curves of constant electron density we get a good idea of the shape and extent of the plasma.

Like the streak photograph, the multifringe interferogram has its drawbacks. It lends itself to quantitative analysis but it obscures the symmetry of an explosion as well as many beautiful and subtle features of the event. We

A SIGNAL SUCCESS IN 200 B.C.



...and it was all done with mirrors!

Long before the Christian era, military signaling with bronze mirrors was standard operating procedure in China. This means of communication was used by armed forces through the centuries.

Tropospheric scatter—the most advanced communications method today—is not done with mirrors. But it *is* magical how this ultra high frequency radio technique hops mountains, oceans and other geographical barriers to carry its messages far beyond the horizon with unprecedented reliability.

The name Radio Engineering Laboratories, too, has been carried afar. REL is a pioneer in the design and construction of tropo scatter communications equipment. You'll find its name on the radio apparatus in use or on order by fifteen out of eighteen major tropo networks.

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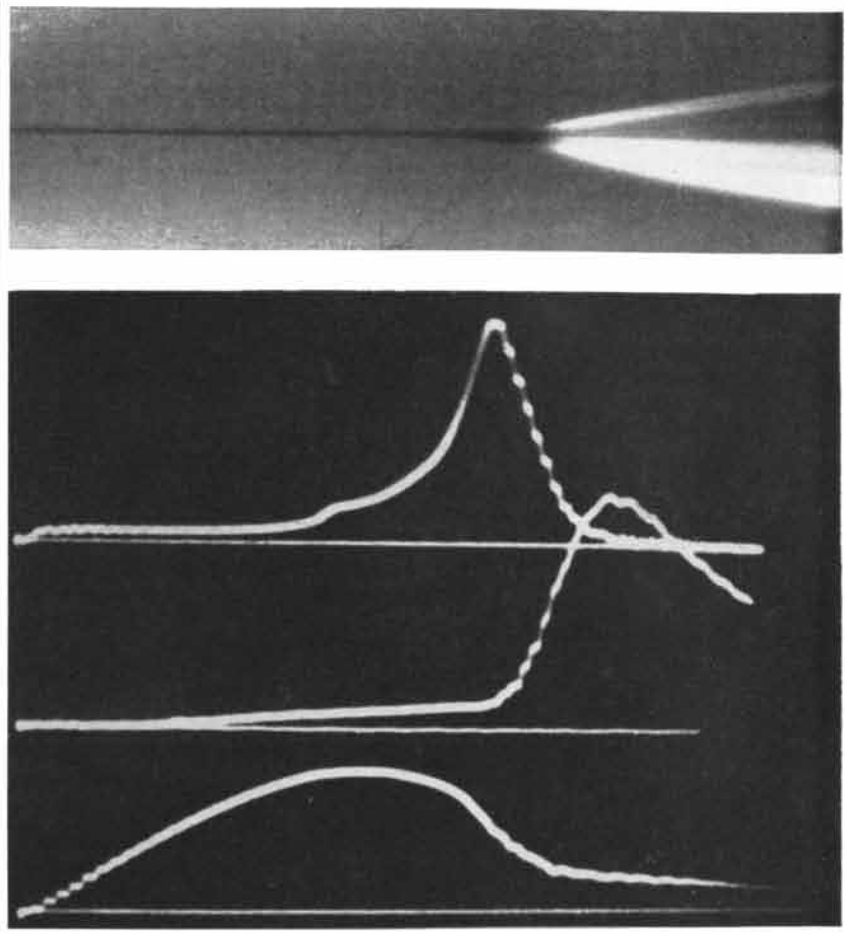


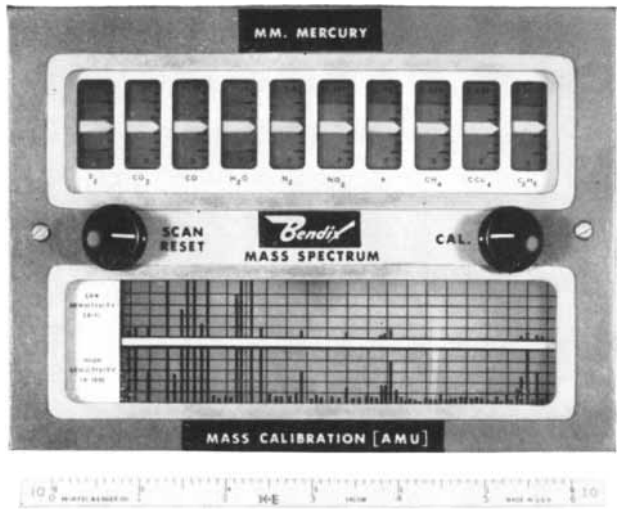
OSCILLOSCOPE TRACES correlated with streak-camera photograph of tip of exploding wire show that voltage (*top trace*) reaches peak before light output of explosion (*middle trace*). The amount of current in and around the wire (*bottom trace*) reaches peak, then starts to drop as voltage reaches a maximum. The mirror made a very fast sweep for picture at top, which covers 1.2 microseconds. It was made in air at pressure of one atmosphere.

overcome the limitation by using white light instead of monochromatic light and a single broad fringe instead of multiple fringes. (By adjusting the optical elements of the interferometer it is possible to spread out the fringes until any one of them is wide enough to cover the entire photographic field.) Extremely complex flow structures in both the gas and the copper wire show up plainly in single-fringe interferograms, especially when they are photographed in color [*see photograph on the cover of this issue and illustrations on page 102*]. We are only beginning to analyze the wealth of detail the pictures contain, but certain features stand out at once.

The head shock wave is more apparent than ever before, and it appears to be much more complex than we had thought. At lower pressures the plasma associated with the arc is sharply outlined. Within it one can see weak shock waves created by the expanding plasma and reflected outward by the wire material. From the behavior of these waves it is possible to compute that the temperature in the plasma is about 25,000 degrees Kelvin (degrees centigrade above absolute zero). Other calculations indicate that near the boundary of the arc the electrons are substantially more energetic than the other particles in the plasma. Their temperature is estimated to be two million degrees K.

The edges of the expanding wire are particularly well defined in the single-fringe pictures. Furthermore, we think we can see vapor boiled off the wire by the peripheral arc at the lower pressures. If so, we can hope to obtain direct information about the index of refraction of metal vapors. Preliminary study of the fringes within the expanding wire confirms the idea that it is a hollow cylinder.

Most of the nuances of single-fringe interferograms, however, remain to be explored. It will probably take several years to understand everything these pictures can tell us.



Mid-scale readings of the ten indicators show safe levels of ten gases measured simultaneously by a Bendix Mass Spectrometer. The mass spectrum displayed in the lower portion of the panel can be used to warn of unknown or unexpected constituents.

The Application of Mass Spectrometry to Space Environment Measurements

Problem: create an instrument which can continuously monitor the breathable atmosphere inside a spacecraft; one which can also analyze whatever atmosphere exists outside. Important: the instrument must be able to fit into the small amount of carefully rationed space available in the craft.

Without question, mass spectrometry (separation on a molecular weight basis) appears attractive. With this unparalleled analytical technique, we can easily detect and identify relatively large numbers of mixed gases. Unfortunately, standard laboratory mass spectrometers are of little use in space work because of their excessive weight and complexity.

But, the time-of-flight mass spectrometer—developed by the Bendix Instrumentation Group—has great inherent design potential for miniaturizaton, simplicity and ruggedness. More important, the principle offers the required accuracy and speed of analysis.

The original design weighed about 700 pounds. The present instrument weighs about ten pounds, and lighter models are on the way. Yet this extreme miniaturization was accomplished with no sacrifice of the unique performance characteristics.

Advanced sample handling techniques also had to be developed. Truly representative samples of gases must be brought quickly to the spectrometer, and the inherently small sample requirements must be preserved. Our new time-of-flight mass spectrometer requires less than 1% of the allowable leak rate for a three-man capsule!

The end result is a single, stable instrument which can detect and analyze complex respiratory gases, with continuous and simultaneous monitoring of ten or more important component gases. It can also quickly scan the remainder of the mass spectrum in search of unexpected gases, and gases not important enough to warrant an exclusive readout channel.

Other pressing instrumentation problems involve the measurement of meteorological parameters such as ozone, temperature, pressure, turbulence, dew point, albedo, and a number of others. For these, we're developing advanced techniques and sensors, many of which embody new design approaches to meet limitations imposed by the vehicle on size, weight, and power drain.

Bendix research embraces a complete range of disciplines including acoustics, nuclear, data processing, microwave, fluid power, lasers and masers, guidance, electronics, solid state physics, and mechanics. Motivation: to develop new techniques and hardware for producing complete, integrated, advanced systems for defense, industrial and commercial applications. Inquiries are invited. We also invite engineers and scientists to discuss career position opportunities with us. An equal opportunity employer. Write Director, Bendix Research Laboratories Division, Southfield, Michigan.

Research Laboratories Division

THE Bendix CORPORATION

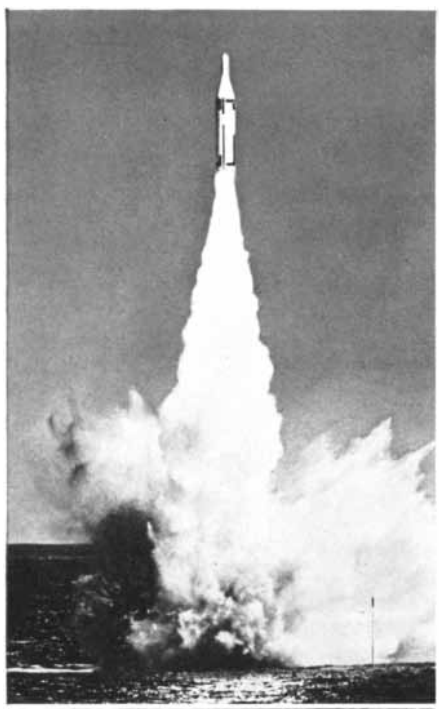
WHERE IDEAS UNLOCK THE FUTURE

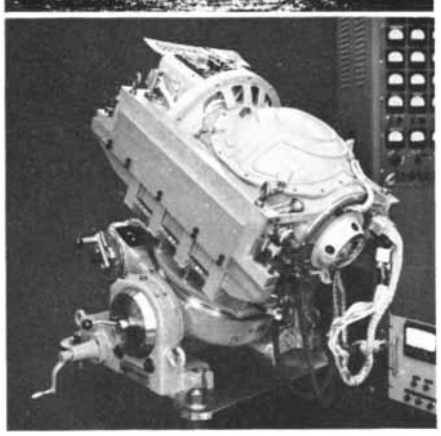
Turning theory into hardware

Technological breakthroughs are almost an everyday occurrence in electronics. Everywhere we see many new scientific discoveries being turned to the service of man.

Hughes is one of those companies whose obligation is not only to form these theories, but also to visualize how they might be applied. And then to make that application—both in man's defense and in the betterment of his life.

Today, Hughes technology is being applied in over 500 projects, programs and studies.



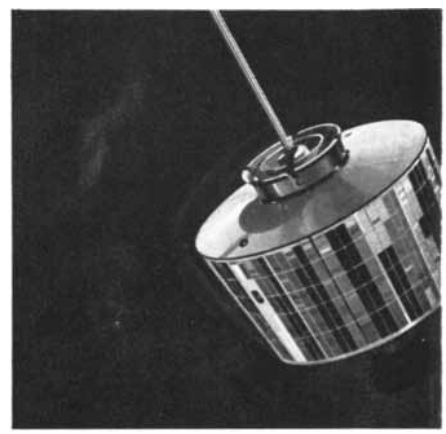


Polaris missile brain

Through the application of its advanced manufacturing technology, Hughes is now a a prime contractor in inertial guidance systems (illustrated above) for the U.S. Navy's Polaris missile. It is one of the world's mightiest, most reliable forces for freedom.

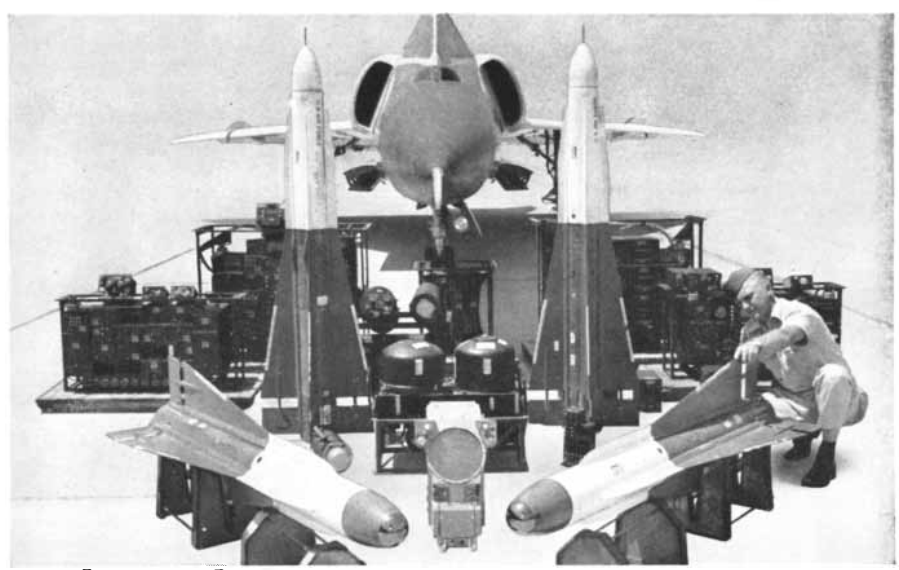
"No-rock" radar

Aware of the limitations of conventional radar which must "rock" to position its beams, Hughes pioneered a technology where the beams are positioned electronically. Based on land or aboard ships, this antenna gives 3-dimensional information—range, bearing and altitude—on hundreds of targets. Even more advanced Hughes antennas, which search hundreds of miles of sky, are now on operational duty.



Satellite "switchboard"

Soon, NASA is scheduled to launch the first communications satellite capable of being remotely spin stabilized and positioned in a 22,300 mile-high synchronous orbit. Just four similar Syncom satellites could relay the telephone, TV, telegraph and radio-photo messages of 130 nations. Hughes—developed and built for NASA, this Syncom system could add a new dimension to man's communication with his neighbors.



Modern Falconry

In the late 1940s, airborne electronics was in its infancy. Yet, in a few years, U.S. Air Force jets were equipped with Hughes advanced weapons control systems armed to fire Falcon missiles. Together (and vastly improved) they have become our most potent air defense weapon. Hughes—the leading builder—has delivered thousands of control systems and well over 30,000 infrared and radar-guided Falcons.

at Hughes

A few are shown to illustrate: Completely new technologies which are creating new devices . . . Major improvements in existing technologies . . . Advanced manufacturing technologies which produce more reliable hardware for duty in this world—and out of it.

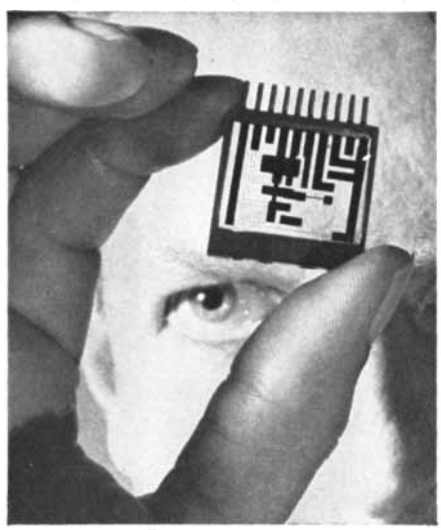
More than 5,000 Hughes engineers help create the theories. More than 20,000 other skilled Hughes people help translate their work into practical hardware. Together they are helping create a new world with electronics.

Boxed air defense systems go anywhere

Air-lifted by helicopter to inaccessible areas, Hughes new "packaged" air defense control systems can be ready for operation in minutes. The "helihuts" contain a highly miniaturized "operations central" plus communications networks for battlefield control of U.S. Army and Marine Nike and Hawk missile batteries.

Ion engines for deep-space probes

Hughes research into the theory of electrical propulsion has led to development of ion engines which are called the "ultimate" source of power for deep space trips. Built for NASA, Hughes cesium-powered ion engines have been "test-flown" in space-simulating vacuum chambers—and are scheduled for actual test in space within the year.



Microelectronics

Heat, vibration, overweight—these are the enemies of common electronic circuits. One example of Hughes micro-miniaturization technology puts a complete circuit on a thin film. Lighter, cooler and more reliable, it can withstand the most rugged usage in supersonic airborne systems.

Missile checker

Today's checkout systems must provide the "preventive medicine" that keeps our missiles in constant readiness.
Result of Hughes advanced computer technology, D-PAT (Drum—Programmed Automatic Tester) has a built-in "intelligence" of 1 million bits of information. This capability is now in the U.S. Air Force's VATE program to check and evaluate ICBM missiles—in less time, with greater accuracy, at less cost.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY

Seismic Shooting at Sea

By setting off explosions in the water and observing how sound waves from them are reflected and refracted, the oceanographer can determine the structure of the earth's crust three miles below the ocean's floor

by Maurice Ewing and Leonard Engel

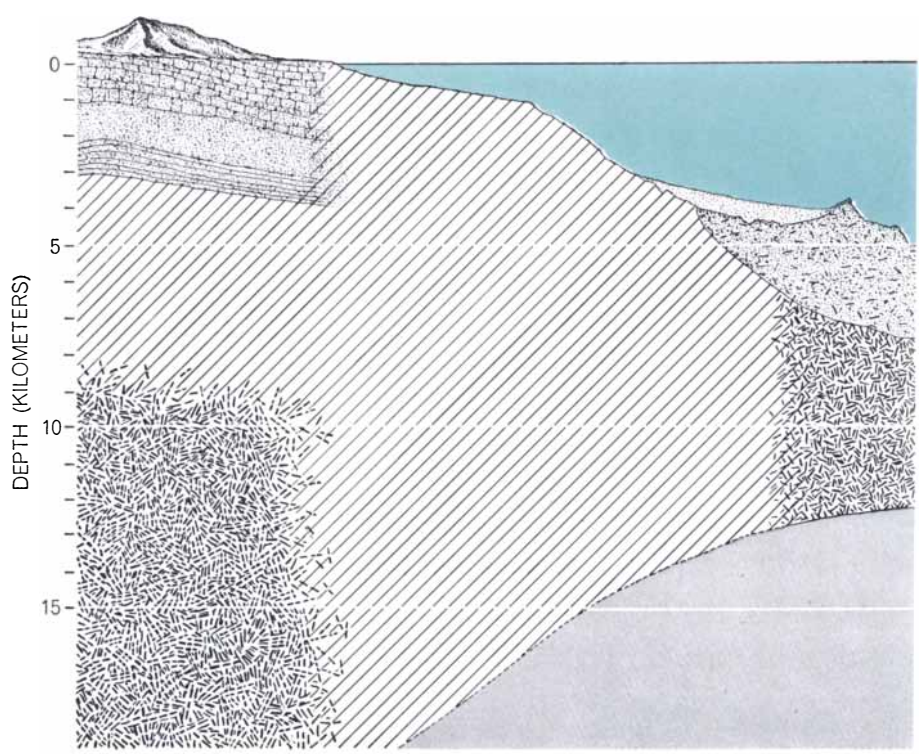
Some 70 per cent of the earth's surface is ocean bottom. On a topographic map of the world, until a few decades ago, this vast terrain was almost as empty and featureless as the ocean itself. Now it has begun to acquire a detailed landscape. What is more, the depth of the sediments that lie on it and the thickness of its rock strata have been measured. These soundings have shown that the suboceanic crust is much thinner than the crust of the continents and have raised broad questions about the structure and history of the crust as a whole. One layer of rock in the floor of the ocean—the "second layer" just beneath the sediments—may well be the original surface of the earth.

The new picture of the ocean floor has been brought into view largely by waves of sound. Because sound no less than light obeys the universal laws of wave motion, a single kind of measurement has sufficed to draw the picture. It is necessary only to observe the time it takes the sound waves to travel through the water, sediments and underlying rock. Application of the laws that govern the reflection, refraction and speed of the waves thereupon yields the depth of the layers below sea level and their thickness, plots their topography and even tells something about their physical properties.

For more than a century seismologists have studied the waves of motion set off in the earth by earthquakes in order to look into the earth's deep interior. The sound waves now employed by geophysicists to explore the earth at shallower depths differ from true seismic waves only in frequency and amplitude; the sound waves are usually generated by the detonation of explosives in the ground or under water.

The idea of creating small-scale artificial earthquakes for the purpose of investigating subsurface geology was first proposed in 1848 by Robert Mallet, an Irish engineer. Gunpowder, to be sure, could not match earthquakes in generating long-distance waves. But gunpowder could be fired at will and at an accurately recorded moment for precise measurement of the travel time of the resulting waves; to this day seismology is handicapped by the difficulty of determining the exact time of a distant earthquake. Mallet attempted to measure the velocity of explosion-generated waves in granite by firing a gunpowder charge in a bed of granite and observing through a telescope the ripples that appeared an instant later in a bowl of mercury on the granite some distance away. Curiously, little was done with Mallet's idea until the 1920's, when petroleum prospectors began to use "seismic shooting" in the search for oil, at first on land and then, a bit later, in the bays and lakes of Louisiana.

It was in the Texas oil fields that one of us [Ewing] had his first experience with this technique. In 1935 Ewing



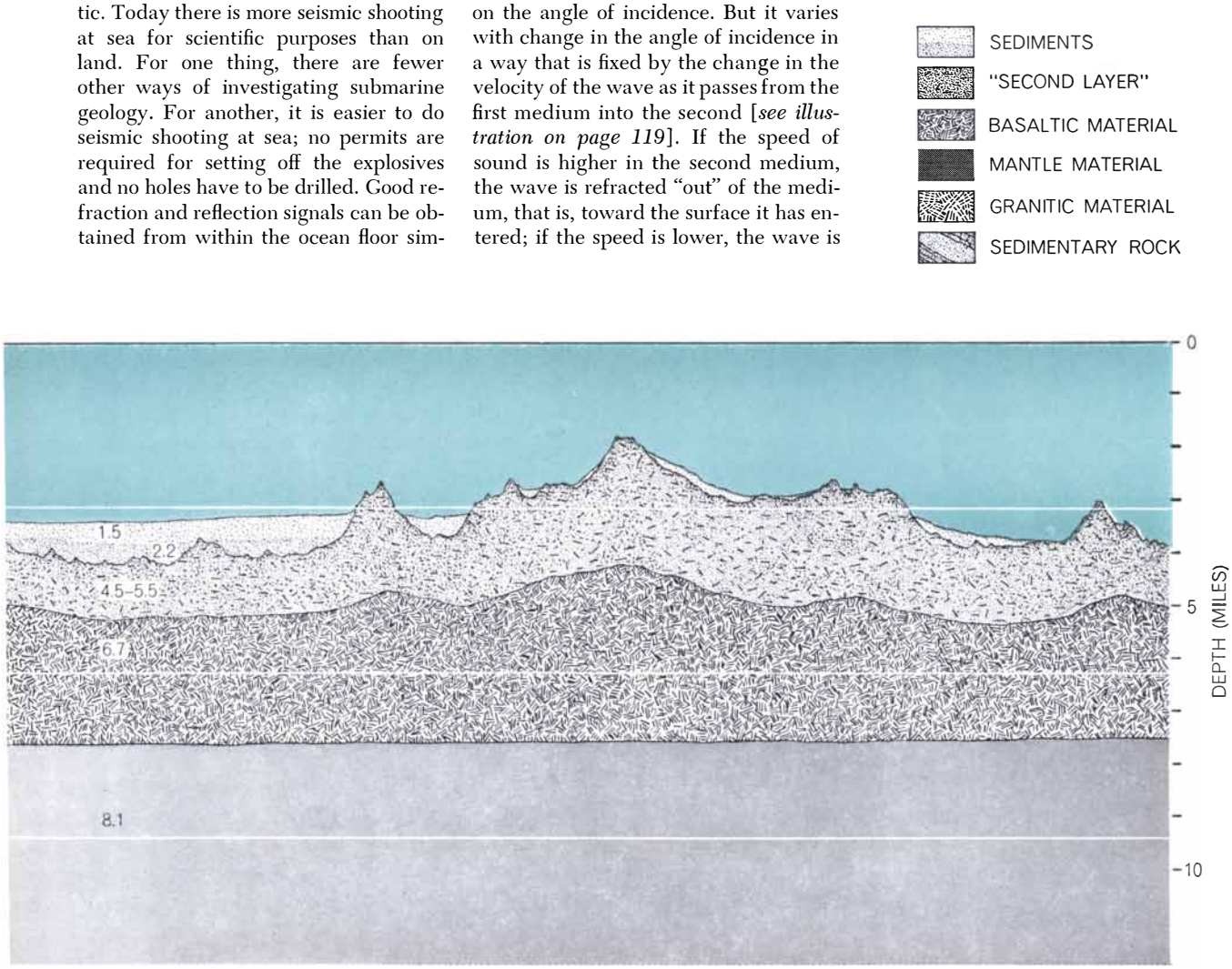
PRINCIPAL FEATURES of the suboceanic crust as determined by seismic shooting show it to be roughly five to six times thinner than the continental crust. Two layers of sediment overlie the "second layer." The latter was identified as a continuous undersea layer rather

(then an instructor of physics at Lehigh University) and his students Albert P. Crary and H. M. Rutherford conducted the first experiments with seismic refraction in the open sea. At the prompting of Richard M. Field of Princeton University and William Bowie of the U.S. Coast and Geodetic Survey, they set off and recorded a series of shots on a line across the Virginia coastal plain and 75 miles out to sea off Cape Henry. From this work came the first seismic record of the continental shelf.

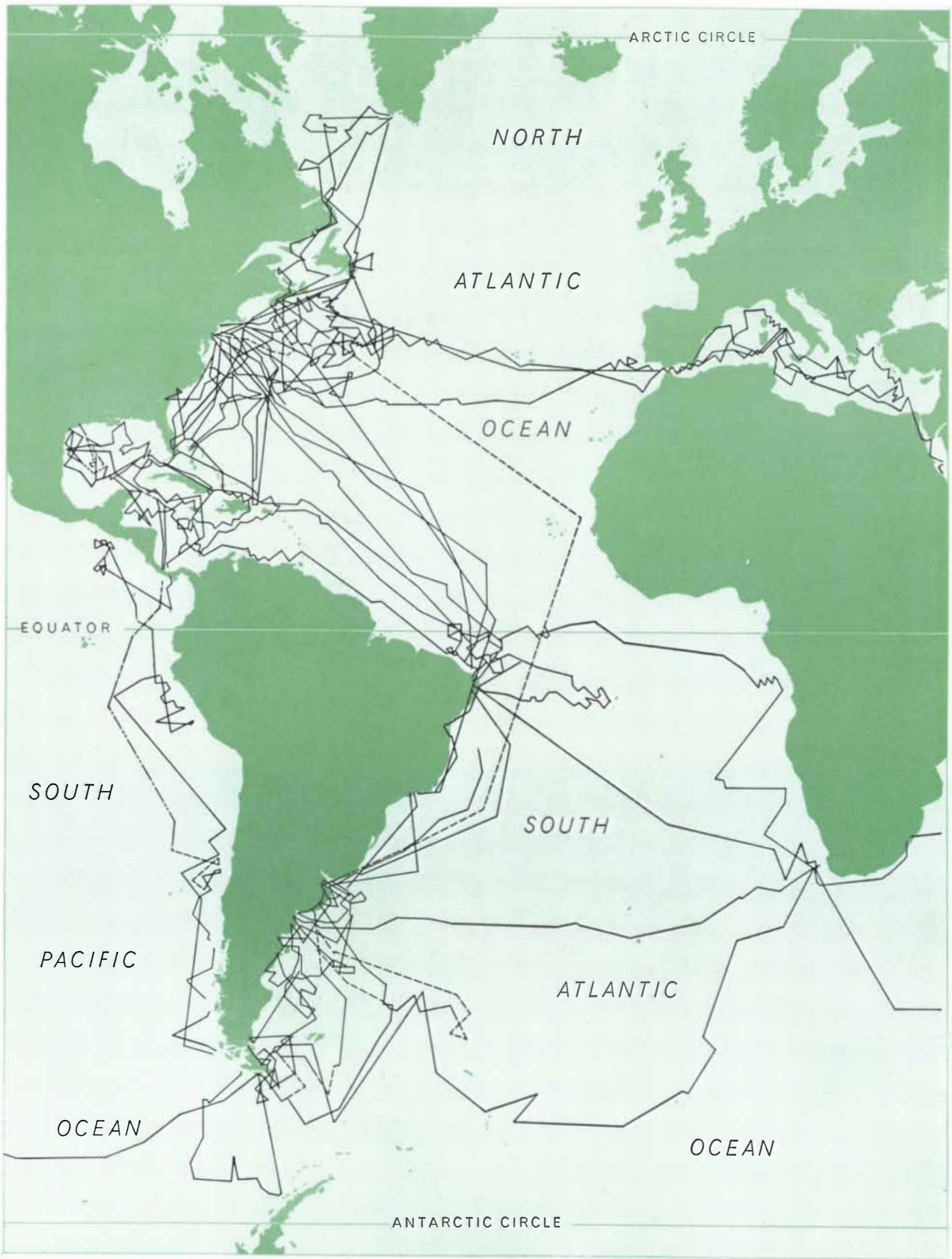
In the years since then seismic shooting has become a principal occupation of oceanographers. The research schooner *Vema* of the Lamont Geological Observatory of Columbia University, working in co-operation with other vessels, has gathered more than 200,000 miles of seismic profiles in all the oceans of the world, including the Arctic and Antarctic. Today there is more seismic shooting at sea for scientific purposes than on land. For one thing, there are fewer other ways of investigating submarine geology. For another, it is easier to do seismic shooting at sea; no permits are required for setting off the explosives and no holes have to be drilled. Good refraction and reflection signals can be obtained from within the ocean floor simply by dropping the charges over the side of the ship and allowing them to explode in the water. An experienced crew can obtain satisfactory records even in quite heavy weather; shooting must be discontinued only when work on deck becomes hazardous or when the shooting ship can no longer maintain enough speed to get away from its own charges.

When a sound wave travels from one conducting medium to another, for instance from the water of the ocean into the underlying sediments, the energy is in part reflected from the interface between the two mediums and in part refracted (that is, its line of travel is deflected) through the second medium. As in the more familiar case of light, the angle of reflection is equal to the angle of incidence. The angle of refraction, as observed in the apparent bending of a stick inserted in water, also depends on the angle of incidence. But it varies with change in the angle of incidence in a way that is fixed by the change in the velocity of the wave as it passes from the first medium into the second [*see illustration on page 119*]. If the speed of sound is higher in the second medium, the wave is refracted "out" of the medium, that is, toward the surface it has entered; if the speed is lower, the wave is refracted into the medium away from that surface. It should be observed here that the speed of sound (or light) in a particular material is as much a characteristic of the material as its density. The speed of sound, in fact, is a clue to density; although the two characteristics are not truly related, the speed of sound generally increases with density.

Seismic shooting at sea for the purpose of observing the refracted waves usually involves two ships working together, one to do the shooting and the other the "listening." One vessel proceeds along a predetermined course and drops explosives at selected intervals as it goes, starting as far away as 60 miles and continuing to fire as it comes up to the listening ship, passes it and proceeds



than an isolated phenomenon during the 1960–61 cruise of the *Vema*. The numbers at center show the velocity of sound in kilometers per second in the various layers; sound velocity in water is 1.5. The diagonal lines at left indicate a region of uncertain structure in the crust; the position of the Mohorovicic discontinuity between the mantle and the crust in this region is also uncertain.



RESEARCH CRUISES OF THE *VEMA*, the oceanographic research vessel of the Lamont Geological Observatory, have covered approximately 200,000 miles since they were begun in 1953. The broken line marks the route of the 17th cruise (1960 and 1961); during this cruise the seismic profiler discussed in the text was first used to record 30,000 miles of undersea reflection profiles.

as much as 60 miles farther. The charges range in size from small boosters, for close-in firing, to standard 300-pound Navy depth charges, from which sound waves carry over longer distances. The listening vessel meanwhile remains still, with hydrophones suspended in the water and with engines and other noise-making gear turned off to prevent interference.

The sound waves generated by the detonation of a charge—concentric spheres of pressure waves—travel outward radially in all directions from the site of the explosion. The section of the wave front that starts out in the horizontal plane reaches the hydrophones directly through the water, traveling at approximately 1.5 kilometers (one mile) per second, the speed of sound in water. The sections of the wave front that impinge on the ocean floor are in part reflected from and in part refracted through the sediments and underlying rock. They reach the hydrophones at different times, depending on their itinerary and the speed of sound in the mediums through which they travel.

To form a mental image of how the sound waves find such circuitous routes to the hydrophones one cannot do better than to call on the classical analysis of the transmission of sound waves first proposed by the Dutch natural philosopher Christian Huygens in 1690. According to Huygens each particle set in motion by an advancing wave front becomes itself the point of origin of a new wave. It communicates its motion not only to the next particle in line but also to all others that surround it, thereby generating its own spherical wavelet. The multitude of wavelets effectively cancel one another in all directions except in the direction of a straight line drawn from the source of the sound. In this direction they reinforce one another to produce a large wave—an "envelope" of wavelets—that travels outward unimpeded.

At the interface between two mediums with different characteristic speed of sound, the particles disturbed in the second medium by an impinging wave become the centers of wavelets that travel outward either faster or slower. The envelope formed by these wavelets is turned in a new direction as if it came from a different primary source. Thus a wave that enters a medium in which the speed of sound is higher is refracted out toward the surface it has entered. Correspondingly, on moving into a medium in which the speed of sound is lower it is refracted into the medium and away from the surface it has entered.

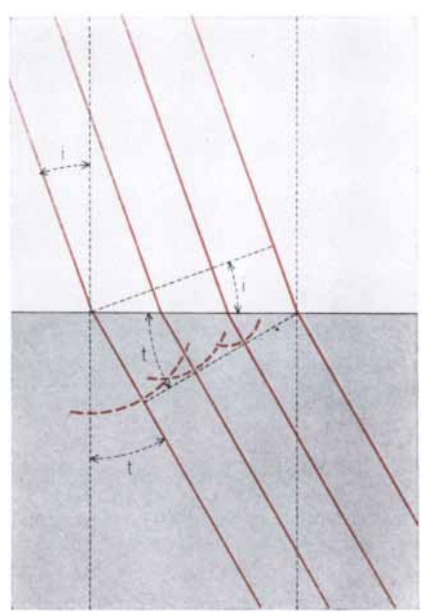
The speed of sound increases from layer to layer downward through the ocean floor. Waves moving downward are accordingly deflected toward the horizontal as they cross the interfaces between successive layers. This is because they are refracted toward the upper surface of each lower layer. At any one interface one wave will impinge on the lower layer at exactly the critical angle of incidence for the layer. The wave is refracted at an angle that sends it traveling horizontally along the interface in the upper surface of the lower layer. This wave is the first one to arrive at the hydrophones from that layer.

How do such waves escape from the layers of rock and sediment to make their way to the hydrophones? The answer is that the horizontally refracted wave advancing along an interface sets particles in motion all along the bottom of the layer above. Because the speed of sound is lower in this upper layer, the resulting wave fronts are refracted into the layer and hence upward. In fact, they are refracted upward at an angle that is the mirror reflection of the critical angle at which the sound entered the layer below. By cumulative refraction through the progressively slower layers above they are directed toward the surface along a path that forms a mirror image of the path along which the original wave train traveled down from the explosion [*see lower illustration on next page*].

Other waves travel along other paths through the water, sediment and rock. They can be reflected as well as refracted, ultimately tracing out more circuitous routes or more direct but slower routes that take them for longer stretches through the water.

A radio signal notifies the listening ship of the instant at which a charge is exploded. The lines to the hydrophones are thereupon slacked in order to minimize local noise. Two hydrophones are used as a protection against failures. They are tuned to pick up sound transmitted through the water in the one-to-four-kilocycle range (two to four octaves above middle C) and the sound that comes through the sea bottom in the range from three to 30 cycles per second (at the very lower limit of the audible range). At any given distance, energy from a shot may reach the listening ship through one or two layers only; depending on the path of the sound, as dictated by the critical angle of incidence, energy transmitted through other layers may be refracted right around the listening ship. To make sure that all layers are mapped, a series of shots must be fired at distances at least four or five times the depth of the deepest layers to be investigated.

The first waves to arrive from a shot fired at a great distance are those from the deepest and densest layer and hence the layer through which sound moves with the greatest velocity. Then comes the train of waves through the next layer above and then, in most oceanic areas, the train through the unconsolidated sediment on the ocean floor. Finally there comes the direct water wave, followed by one or more reflected waves that also make the journey entirely by water but that may bounce back and forth one or more times between the surface and the bottom of the sea. Needless to say, the sound is greatly at-

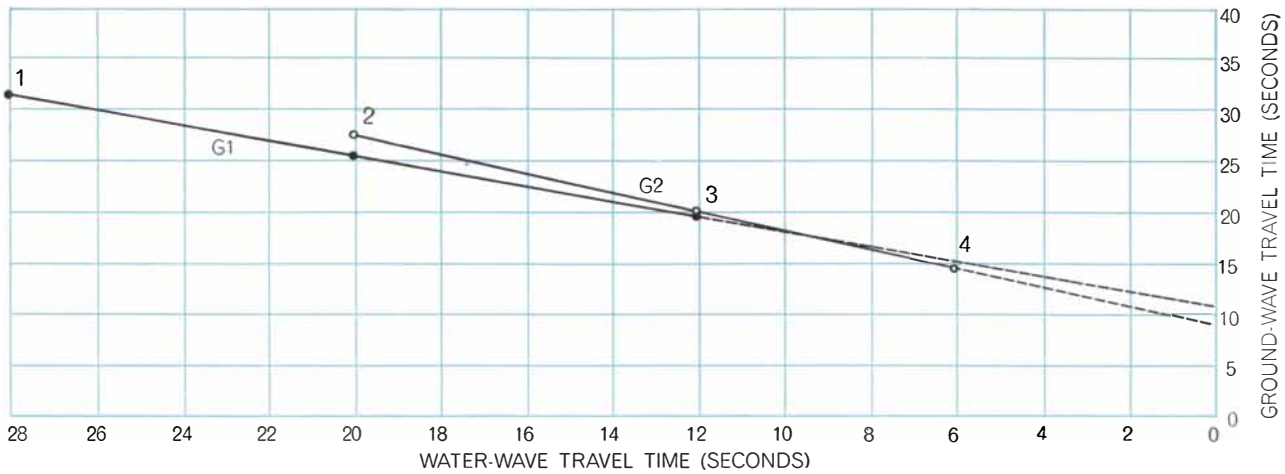


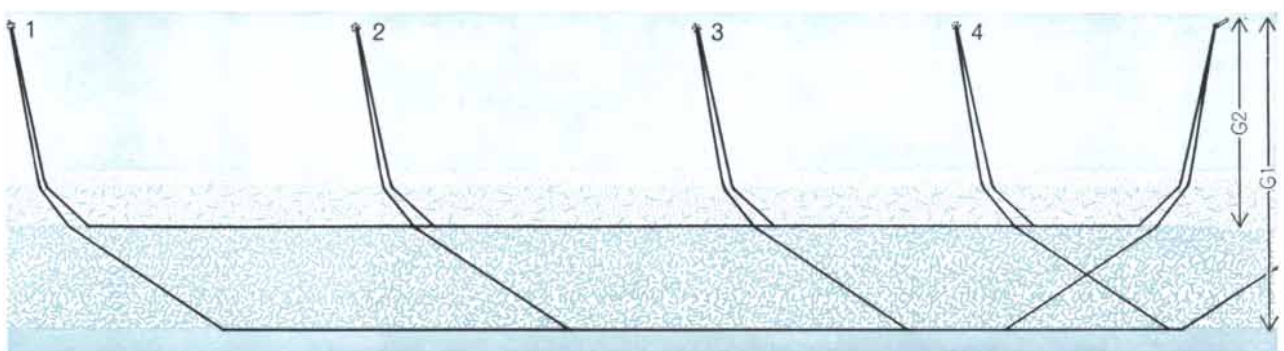
REFRACTION of sound passing from one medium to another can be compared to that of light. According to Huygens' principle, each point on an incident wave front (*upper diagonal broken line*) becomes a point source of wavelets (*colored broken lines*). Because sound travels faster in a denser medium, the first wavelet travels farther in a given time than the next one, and so on; the direction of the new wave front (*lower diagonal broken line*) is bent away from the vertical (light, traveling more slowly in a denser medium, is bent toward the vertical). Snell's law governs the degree of refraction: the ratio of the sine of the angle of incidence (*i*) to the sine of the angle of refraction (*t*) is a constant; the constant is also equal to the ratio of the speed of sound in the first medium to that in the second.

tenuated by the time it reaches the hydrophones—to less than one ten-millionth of its original energy.

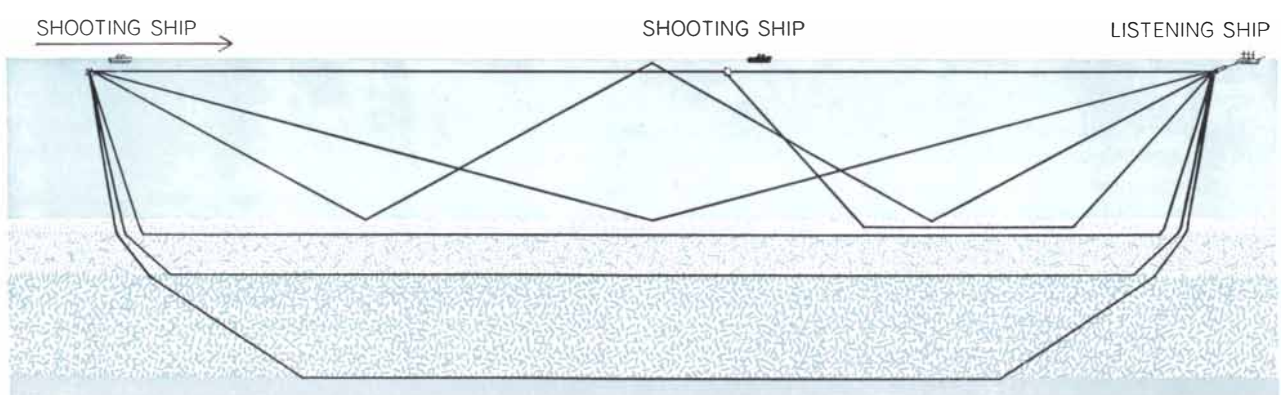
Each train of waves records itself as a series of oscillations of considerable duration. The sound of the original shot is smeared out in time because the waves take such different paths to the hydrophones. Investigators are currently trying to decode the information that may be contained in the amplitudes and frequencies recorded by the oscillographic camera. For the present, however, interest centers on the first squiggle written on the recording film by each train of waves. This records the "first arrival" of the refracted waves from a given layer and gives the travel time for sound through that layer.

The velocity of sound through the layer is found by plotting its travel time





TRAVEL-TIME GRAPH (*top*) plots distance (in travel time directly through the water; one second equals 1.5 kilometers) against the time required by two representative ground waves from four shots (*bottom*) to travel through the crust to the hydrophones of the listening ship. The shallower wave (*G2*) of the first shot is too weak to be distinguished; the deeper wave (*G1*) of fourth shot is refracted around hydrophones. Layer depths are calculated from extrapolation of data (*broken lines*) to vertical co-ordinate.



REFRACTION SHOOTING usually involves two ships, the "shooting ship" dropping explosives as it moves toward or away from the "listening ship." The hydrophones of the latter pick up refracted waves that travel along the interfaces between various layers as well as reflected waves, some of which bounce back and forth several times before they reach the hydrophones. Because the speed of sound is greater the denser the medium, the waves from the deeper layers arrive ahead of those from the shallower layers.

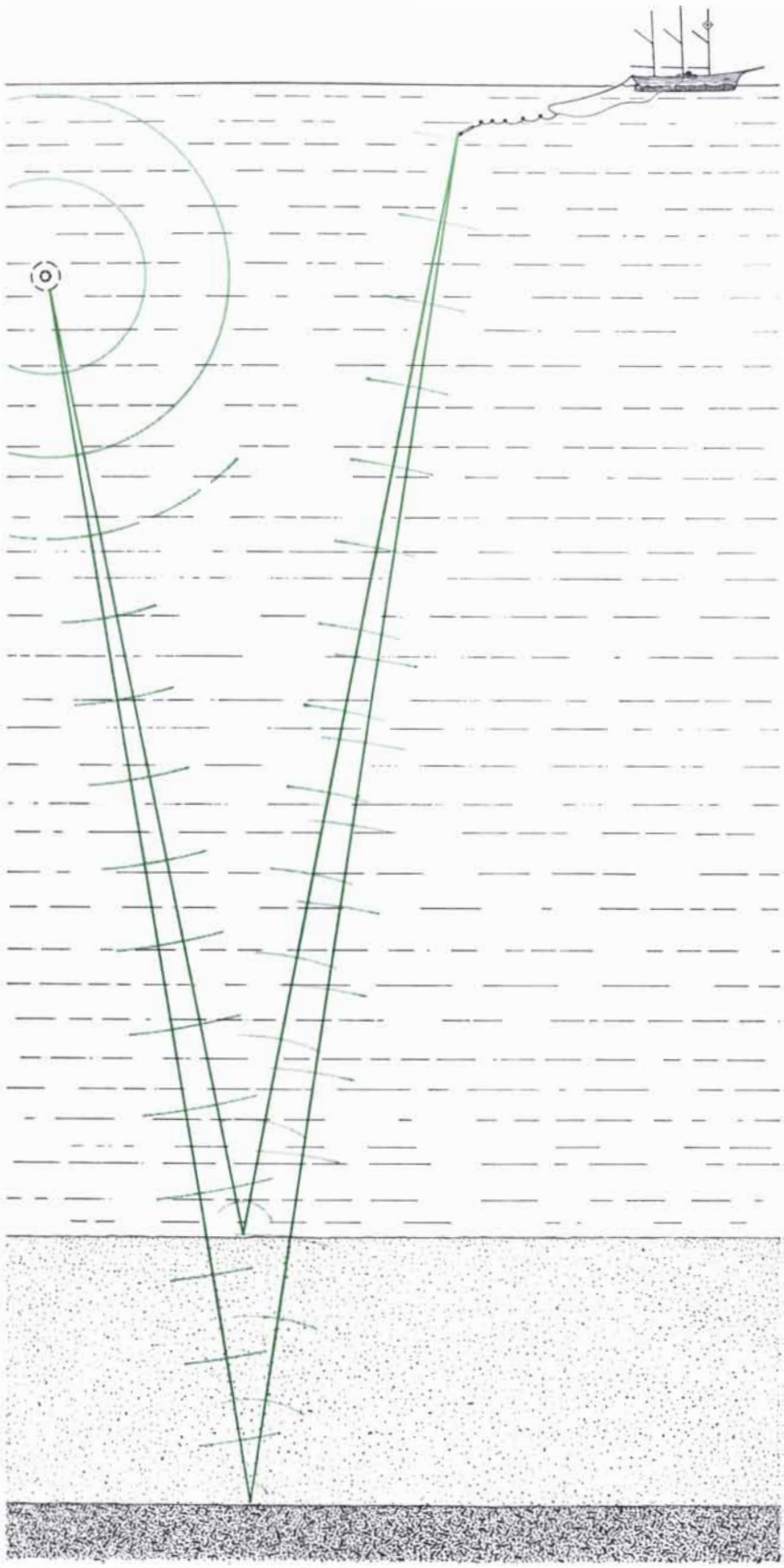
against the travel time of the direct water wave [*see upper illustration on opposite page*]. Since the velocity of sound in water is known, the velocity of sound through the sediment and rock layers is thereby determined. With some mathematics, the travel-time graph can also be made to yield the depth and thickness of the crustal layers. The record may sometimes be obscured by irregularities in the topography of the bottom. Major topographic features can be detected by shooting "reverse profiles," in the backward as well as the forward direction, along the line of shots. Details of structure, however, are missed in refraction shooting.

To develop such details, submarine geophysics is now equipped with a technique of reflection shooting that is essentially a high-powered expansion of the familiar technique of echo sounding, which measures the depth of the bouncing sound waves from the bottom. The echo sounder's electrically generated "ping" is too weak to penetrate much below the interface of water and sediments. Petroleum geologists have used explosive charges to generate echoes for mapping salt domes and other formations near the bottom in shallow waters. The echoes from deep suboceanic strata are too attenuated, however, to be detected by a hydrophone towed behind a moving ship.

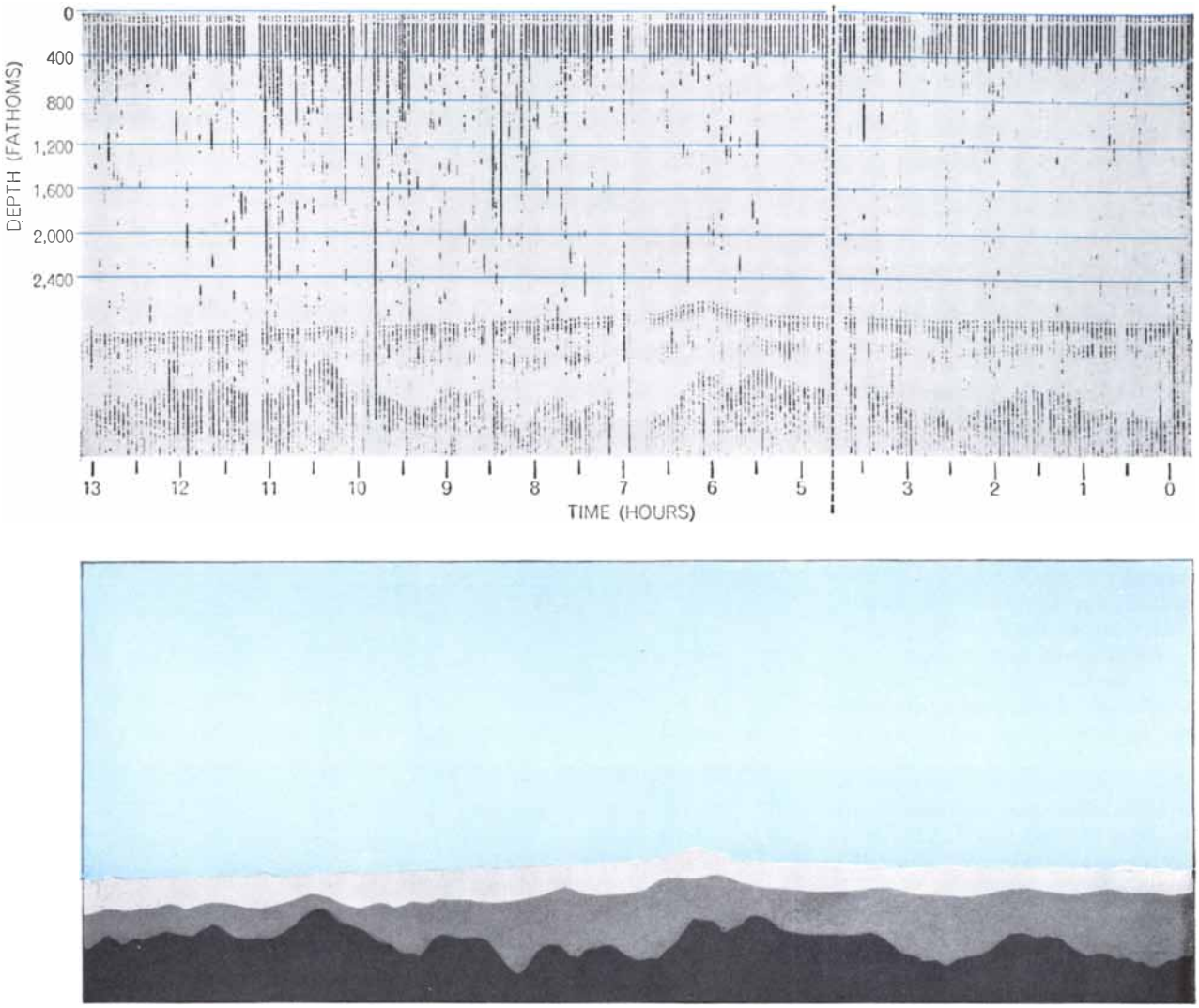
Last year a method of reflection shooting that surmounts this difficulty was developed by John Ewing and his associates at the Lamont Geological Observatory. By firing bigger charges and slackening the hydrophone cable with a winch, it is now possible to obtain detailed reflection records of the suboceanic crust down to 15,000 feet below the bottom. A new device, the seismic profiler, automatically records the echoes. Even more detailed records will soon be achieved with the help of mechanical sources that will generate more frequent pulses of sound and eliminate the hazard of handling explosives.

To convert the echo record to a profile of actual depths and thicknesses requires a determination of the sound velocities of the various layers. This determination in turn requires refraction shooting. But reflection shooting simplifies the task by locating areas for refraction shooting where the crustal topography is smooth. The combination of the techniques now promises to speed up the work of surveying the strata beneath the sea.

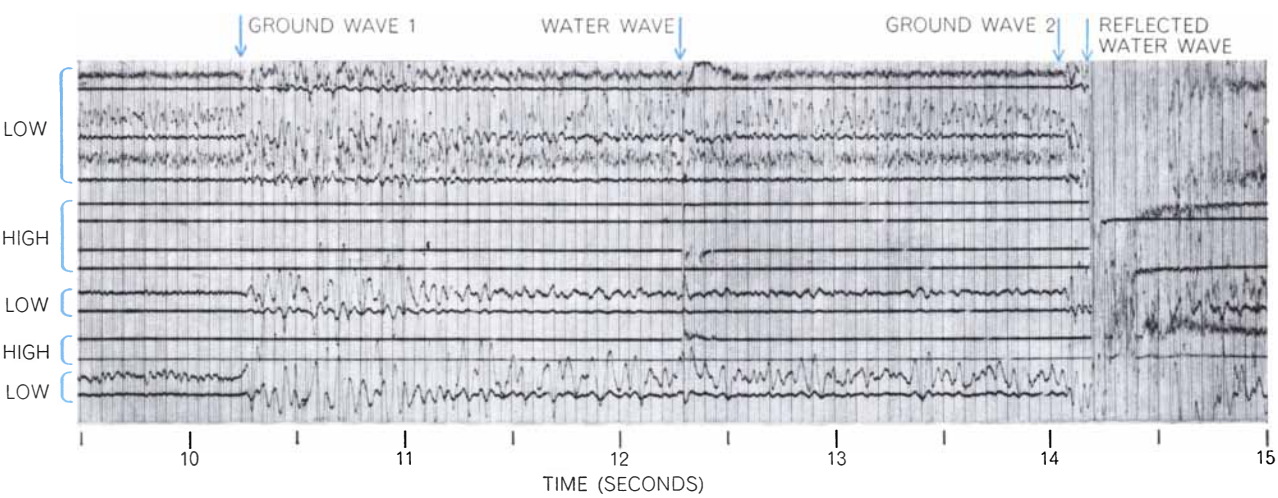
In a remarkably few years seismic shooting has taken the measure of the



REFLECTION SHOOTING provides crustal details that are not obtainable with the refraction method. Use of the seismic profiler to record the shot reflections (i.e., the echoes) yields an echogram cross section of the undersea crust (*see top illustration on next page*).



ECHOGRAM shown at top is the record made by the seismic profile recorder used in reflection shooting. The profiles at the bottom of the record are those of two layers of sediment and the "second layer" beneath them (*represented in illustration at bottom*). A corrected cross section can then be calculated from data provided by refraction shooting. The broken line marks a gap in the record.



HYDROPHONE RECORD of refraction shooting shows the successive arrivals (*indicated by colored arrows*) of four waves. The first ("*Ground Wave 1*") has traveled through the crust at a greater depth than has the third ("*Ground Wave 2*"). The second wave ("*Water Wave*") has traveled directly through the water. "High" and "Low" refer to the frequencies of the sound waves detected.

major features of the suboceanic crust. The uppermost layer of sediments has been shown to be 1,000 to 2,000 feet thick in the deep basins and up to 40,000 feet thick on the continental shelves. Composed of materials eroded from the land and of the remains of marine life, the sediments are characterized by a sound velocity of 1.5 to 2.2 kilometers per second. This is equal to or only slightly greater than the velocity of sound in water and shows that the layer of sediments is not consolidated into rock. Next below the sediments lies the "second layer," a layer of rock one to one and a half kilometers thick, characterized by a velocity of 4.5 kilometers per second. The second layer has been thought to be either volcanic in origin or to consist of sediments consolidated by heat and pressure into stone of moderate hardness. New findings suggest that it is neither but is probably composed of igneous rock that became differentiated from the underlying "basement" layer when it crystallized from the molten state. The basement layer, about 3.5 kilometers thick, is characterized by a velocity of 6.7 kilometers per second, which indicates that it is composed of hard, dense rock, probably basalt. Below this lowermost layer the Mohorovicic discontinuity, or Moho, defines the bottom of the oceanic crust. Here the velocity of sound jumps to 8.1 kilometers per second, indicating an abrupt change in the nature of matter.

Before World War II the Pacific Ocean was looked on by many earth scientists, because of its size and other features, as being the only "real" ocean—real in the sense of being an early feature of the earth's surface and differing fundamentally in geology from the continents. Other oceans were regarded as secondary, formed later and by processes different from those that laid down the Pacific floor. This was by no means a unanimous view, but the evidence to the contrary was inconclusive. The question was resolved in the first few years after the war by seismic-refraction surveys that produced the first measurement of the thickness of the sediment layers and the undersea crust in the Atlantic and Pacific. The vessels *Atlantis* and *Caryn* of the Woods Hole Oceanographic Institution obtained refraction profiles in the Atlantic all the way down to the Moho. Similar measurements were made in the Pacific by expeditions from the Scripps Institution of Oceanography. These showed that the undersea crust in both the Atlantic and the Pacific is only four to six kilometers

NINE-POUND FLOATED CHARGE is held by John E. Nafe (*left*), who will light the fuse and drop it overboard at a prearranged signal. In certain cases the gas bubble generated by an underwater shot gives rise to false reflection echoes; a charge kept afloat by a balloon, however, does not generate a gas bubble. At right Arthur E. Maxwell prepares another charge.

DEPTH CHARGE FUSE is lighted by Charles L. Drake as Maxwell stands by to help push the 300-pound charge through the rail of the *Vema*. These charges are used at relatively great distances from the listening ship; much smaller charges are used at closer distances.

thick, compared with the 25-to-40-kilometer thickness of the crust beneath the continents. An analysis of the pathways followed by surface waves from earthquakes confirmed these results, showing that the crust below all the ocean basins is thin and that, in this fundamental respect, one ocean basin is much like another and different from the land.

The division of the earth into distinct oceanic and continental provinces has since been sharpened in other ways. As shown in many refraction studies, the lightweight granitic rocks characteristic of the continental crust are missing below the sea. The predominant oceanic basement rock is heavier basalt. Moreover, it has been found that the continental margins act as a barrier to the passage of some types of earthquake-generated surface waves; such waves originating at sea often fail to reach the land and vice versa. Shear waves from earthquakes traveling through the upper part of the mantle beneath land show a velocity different from that of shear waves in the same region of the mantle under the sea.

Seismic shooting has also helped to illuminate the structure of the massive, 40,000-mile-long belt of undersea mountains called the Mid-Ocean Ridge. The ridge has gained wide attention not only because of its immense length but also because of the great rift running down its middle; the rift suggests that the earth's crust is pulling apart along the center line of the ridge [see "The Rift in the Ocean Floor," by Bruce C. Heezen, SCIENTIFIC AMERICAN, October, 1960]. Refraction profiles show that the ridge is the site of a great anomaly in the earth's crust. It is underlain by a belt of rock with a velocity of 7.5 kilometers a second, about midway between the 6.7-kilometer velocity of the basaltic rock of the ridge and the 8.1-kilometer velocity of the mantle. Nowhere else on earth is rock of this kind found in any quantity.

Last year, using the new method of deep-water reflection shooting, the *Vema* ran a survey to the Antarctic through the Atlantic and the eastern Pacific. One of the first results of this effort was the finding that the second layer, not always detectable by refraction shooting, lies everywhere beneath the sea. Moreover, the detailed profiles disclosed that the surface of the second layer is not smooth but quite rough.

The rugged topography of the second layer is hard to account for except in the supposition that it was crystallized directly from the molten state. If this

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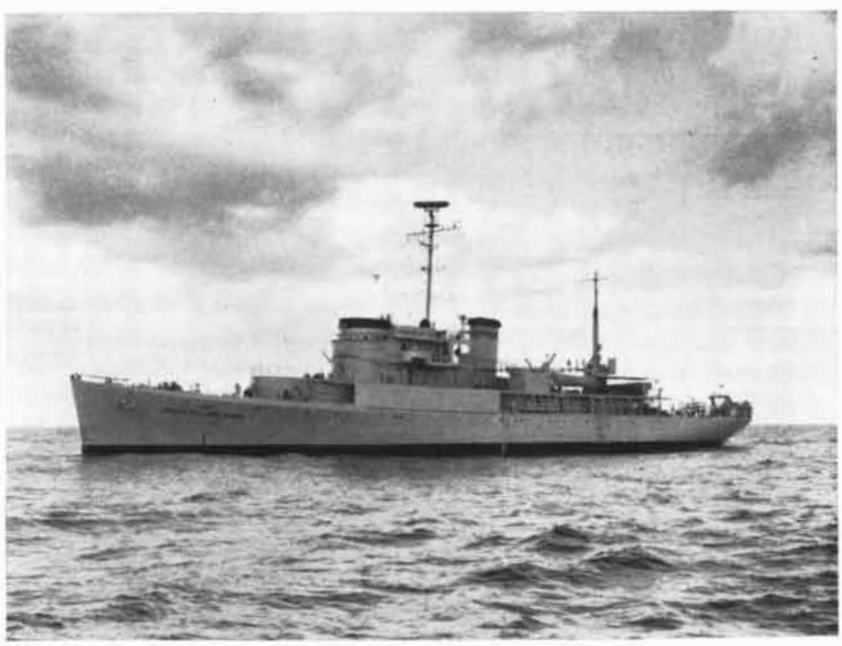
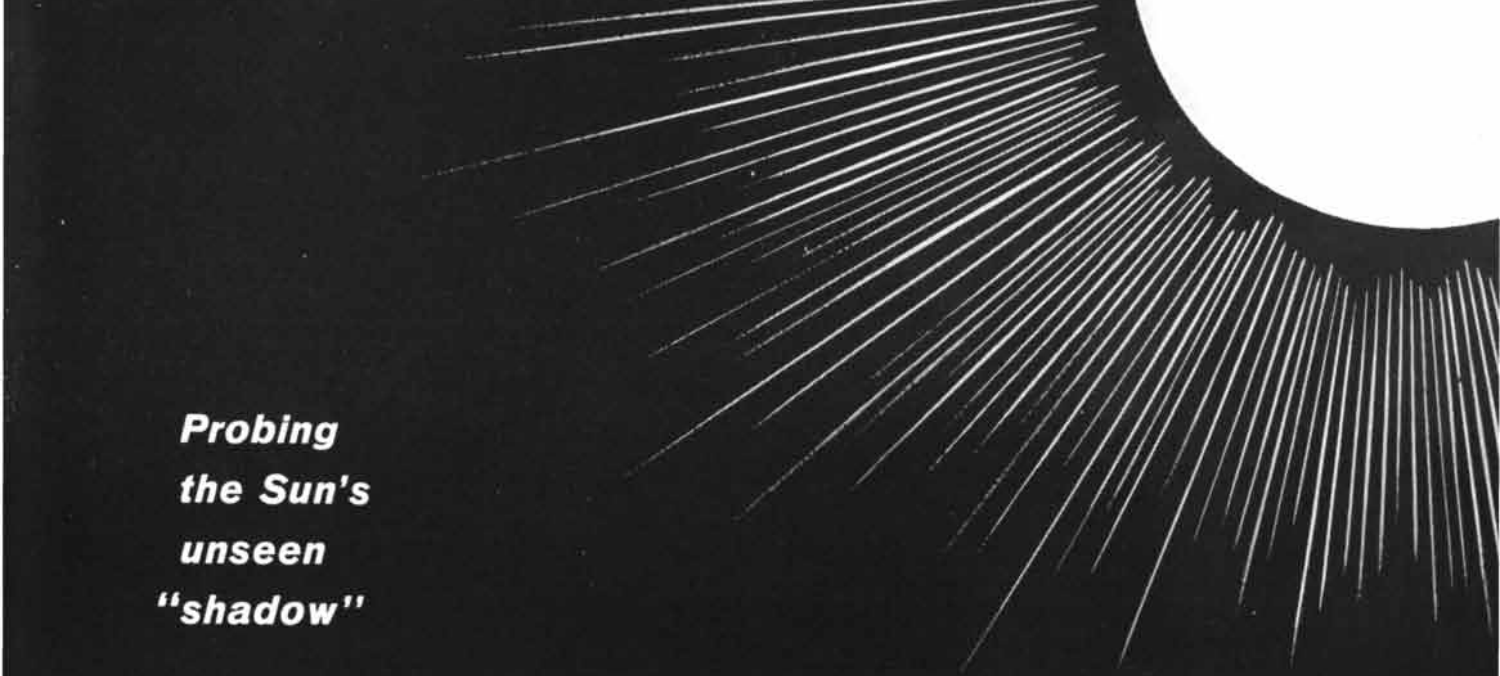
is the case, the layer must have been formed relatively early in the history of the sea—at any rate, before the accumulation of the ocean bottom's present burden of sediment. The reflection records revealed no evidence of any disturbance in the overlying sediments, as would have occurred if the second layer had been formed after the sediments had begun to pile up. If it is found that the oldest ocean sediments date back to the early days of the earth, the second layer may well represent the primordial surface of the earth.



TWO OCEANOGRAPHIC RESEARCH VESSELS employed in seismic shooting are the Lamont Geological Observatory's *Vema* (*top*) and the U.S. Navy's *Josiah Willard Gibbs* (*bottom*). The former vessel is at present in the South Atlantic Ocean on its 18th cruise.



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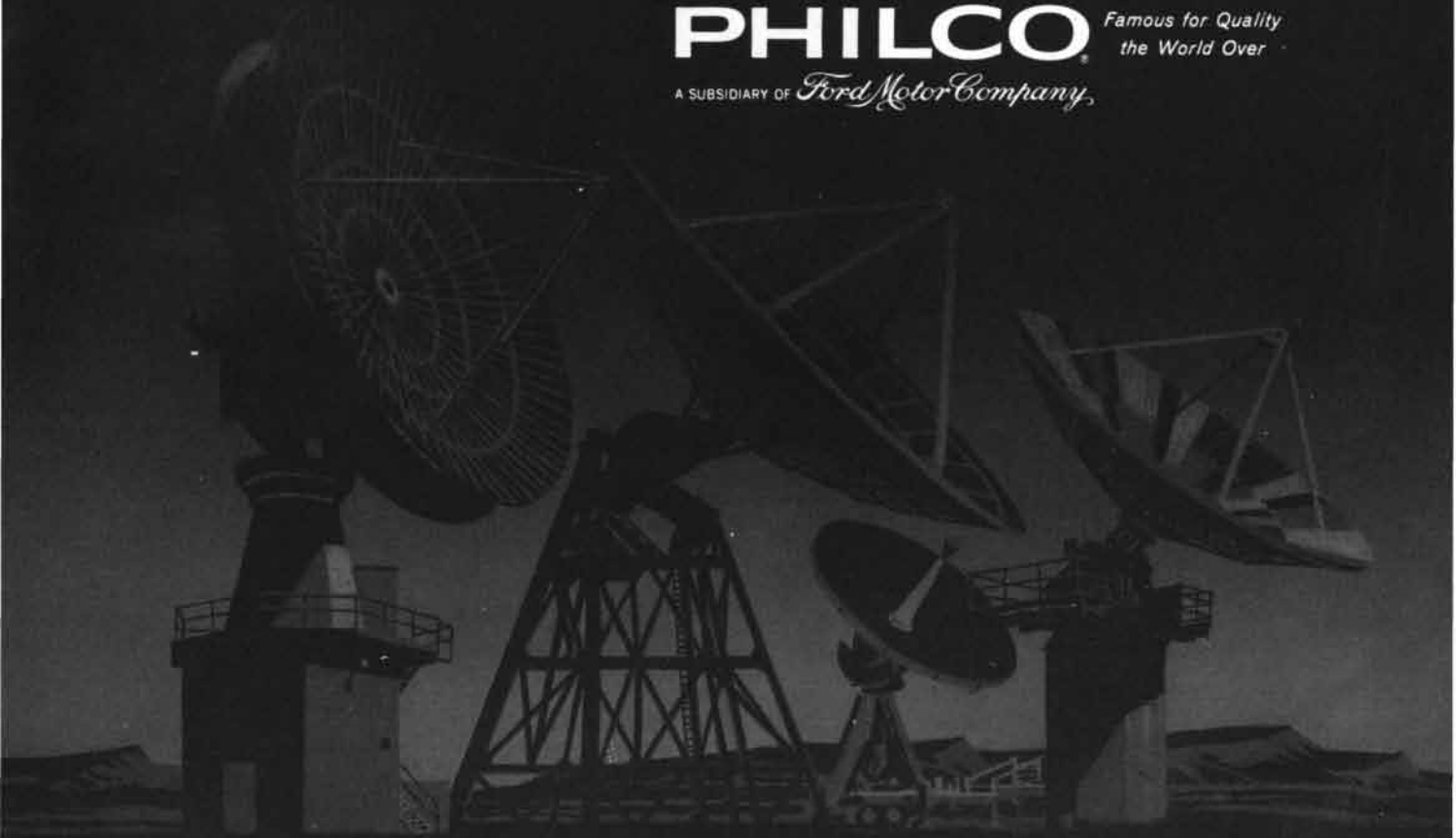

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CHIMPANZEES IN THE WILD

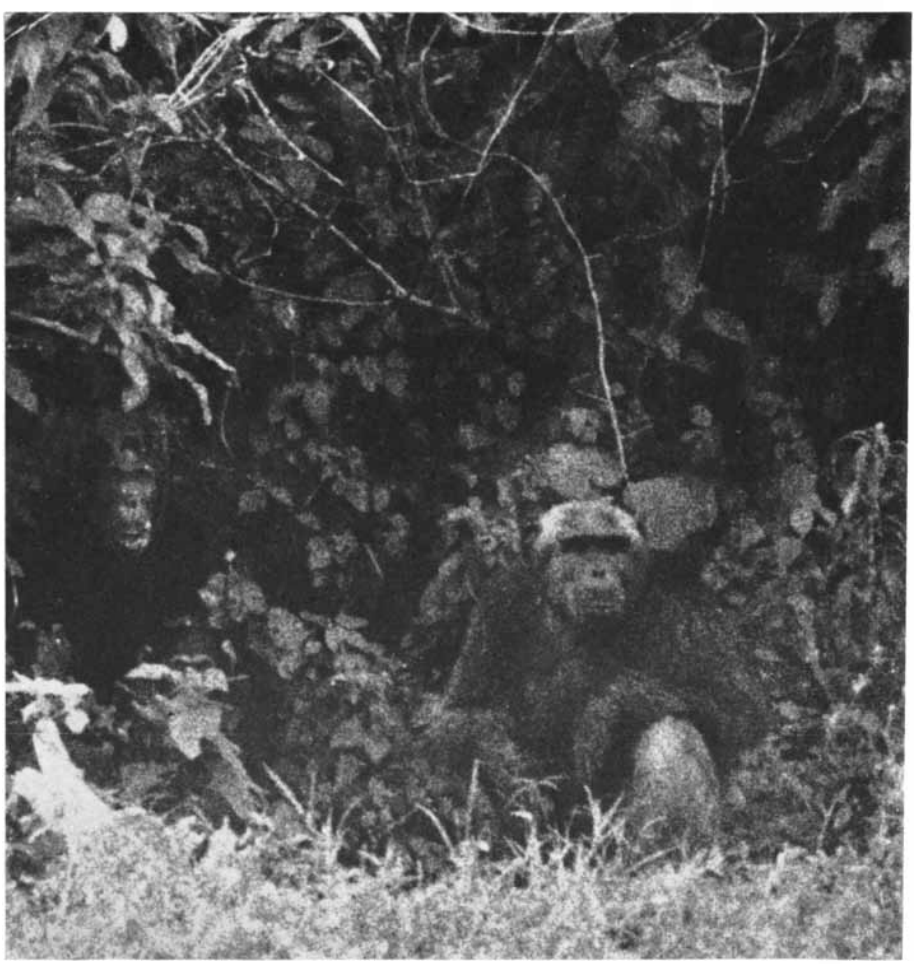
Although these intelligent apes are familiar in the laboratory and the zoo, they have seldom been observed in their native environment. A new study has revealed some unexpected features of their behavior

by Adriaan Kortlandt

If one wants to see chimpanzees living in the wild, most people think, one can simply go to Africa and look around in the forest. Nothing could be further from the truth. Very few people in Africa have ever laid eyes on these apes in their natural setting. Because of their great value as laboratory animals chimpanzees have been hunted to extinction in many areas, and elsewhere they have moved out of range of observation, deep into the tangle of leaves and lianas of the rain forest. Until recently no one had even photographed them undisturbed in their native state. Meanwhile experimenters continue to use chimpanzees as ersatz human beings without knowing how the animals behave except under the artificial conditions of the laboratory and the zoo.

In 1960 I went to Africa to try to find and observe wild chimpanzees. The expedition was sponsored by the Institute of National Parks of what was then the Belgian Congo, together with several Dutch scientific organizations and the Wilkie Foundation in the U.S. For some months I traveled the breadth of the continent searching for an open place that was regularly visited by chimpanzees and from which I could conduct my observations. Finally I found a perfect spot: a plantation at the edge of a forest in the eastern Congo. The plantation, given over to the cultivation of papaws and bananas, was an ideal feeding ground for the animals, and the Belgian owner did not begrudge them the relatively small amount of fruit they took. Within the boundaries of the plantation was a steep, heavily wooded hill where many of the chimpanzees frequently spent their nights. On the hill they were protected from preying leopards by the surrounding cultivated fields. They were also protected from their human neighbors—by superstition. The local people considered the hill to be sacred, guarded by spirits that would destroy anyone who killed an animal there or even felled a tree. Moreover, the chimpanzees themselves were endowed with magical powers: if a hunter threw a spear at one of them, the animal would supposedly catch it, hurl it back and kill the hunter.

After looking over the terrain I built several observation posts. At the foot of the main path down the sacred



WILD CHIMPANZEES were photographed by the author from observation posts on a plantation in the Congo. This group is composed of five adult males. Second ape from left is

hill stood a large tree, against the trunk of which I put a blind reached by a 20-foot ladder. A 25-foot tower on the crest of a small hillock provided an excellent view of the animals' central feeding area. For close observation I had two carefully camouflaged blinds alongside the chimpanzees' main route on the plantation grounds. I also wanted a panoramic view of the entire area. A great tree that stood between the forest and the sacred hill seemed the perfect place, but its lowest branch was almost 80 feet above the ground and its trunk was so smooth and hard that I could not negotiate it with my climbing irons. The problem was solved by a small band of Pygmies, who are the Alpinists of the African forest. One of them used a pair of lianas to make the first ascent. He looped a liana around the tree, climbed into the loop and threw a second one around the trunk higher up. Pulling himself up to the higher loop, he undid the lower one and again threw it upward. It was terrifying to watch him, but he calmly repeated the procedure 40 or 50 times before he gained the lowest branch. There he attached my rope ladder, and he and his companions and I proceeded to build an observation platform.

Installed in this aerie more than 80 feet high, I could keep almost all the open ground under observation. One morning I saw no fewer than 48 chimpanzees descend the sacred hill; however, this station had some drawbacks. On windy days the tree swayed so much that I could not use my field glasses. When a tropical thunderstorm came up unexpectedly, I could only pray that I would not be electrocuted. And once the chimpanzees had arrived I did not dare come down before nightfall lest I betray my presence and so permanently drive them away.

Since the apes spent much of their time in the forest and on their hill, I usually had to wait in one of my blinds for hours. The adult males were often the first to appear, their arrival always heralded by their cries, which grew in intensity as they approached. When they were quite close to the clearing, they would fall silent, and a broad black face would peep out cautiously through the leaves. Then one by one the males would emerge; usually each of them carefully looked and listened before he stepped out from behind the bushes and trees. Most of the time at least one of them walked upright for a while in order to get a better view of the open ground. Once they decided they were safe, the large males broke out in a wild and deafening display. They chased one another, shrieking and screaming. They stamped the ground with hands and feet and smacked tree trunks with one open hand. Sometimes they pulled down half-grown papaw trees. Occasionally one of them would grab a branch and brandish or throw it while running full tilt through the group.

In contrast the females, particularly the mothers, were almost always silent, wary and shy. Indeed, caution was the

"Granddad." He was 40 or more years old and the senior member of the troop the author studied. At far left an animal can be seen emerging from a tunnel the apes used to go from a virgin forest to the open grounds of the plantation, where papaws and bananas grew.

PYGMY climbed a 120-foot tree to build the author's observation tower. He made the climb by looping lianas progressively farther up around the trunk and stepping into each loop.

most conspicuous feature of maternal behavior. The mother's main task seemed to be to avoid exposing her offspring to any risk whatever. Children up to an age of what I gauged to be four years were usually carried, even for short distances. (Chimpanzee children are comparable in their development to human children half again as old.) When a mother climbed a papaw tree to pick fruit, her child clung to her back or belly, and when she and the child ate, they retired to the edge of the forest, ready to escape into it at any sign of danger. Even children up to the age of puberty (eight or nine years, according to experience with chimpanzees in captivity) were seldom let out of sight.

In spite of this close surveillance, the young chimpanzees led a wonderful life. They were quite pampered by human standards, and they were allowed to do virtually anything they pleased. Sometimes a mother would hand-feed a six- or seven-year-old as if it were an infant. Children could occasionally invite themselves to share a meal with a strange mother and child. They were allowed to touch even the smallest infants and gently investigate them. They could ride pickaback on certain of the males. Twice I saw a chimpanzee child run past an adult male and give him a hard smack on the rump without arousing any anger. Nor did the adults object if a child held onto its mother and a male when they were in the act of mating. But with all their freedom the children did not appear to be spoiled. They never whined or whimpered and they always obeyed their mothers at the first hint. Apparently awareness of the dangers of the jungle kept them in check; chimpanzee infants in zoos behave rather differently in this respect.

Just as the chimpanzees were tolerant of the young, they deferred to the old. The grand old man of the population I studied was, I should judge, over 40—considerably older than the oldest zoo chimpanzee I have ever seen. His silver-haired back was bent, his crown was gray and his face sagged. Granddad, as I called him, was evidently somewhat handicapped: he avoided climbing and seldom participated in any of the male intimidation displays. Among all other primates except man his infirmities would have had unfortunate consequences for him; in gorilla troops, for example, an aging male may be fought to death by a younger one. But Granddad was the tyrannical overlord of the band. All his whims and fancies were indulged, and even the biggest of the

senior males sought his company. Apparently he derived his authority from his experience and the knowledge it had given him of potential dangers; more often than any of the other males, he acted as a kind of security inspector, making sure that everything was safe.

Unlike zoo chimpanzees, which generally look increasingly dull and vacant with the years, the older wild chimpanzees seemed to me more lively, more interested in everything and more human. This is probably the reason it was so difficult, when I watched them from close by, to shake off the feeling that I was looking at some strange kind of human beings dressed in furs. The chimpanzees were unceasingly alert and curious. They seized every opportunity to bring variety into their lives, taking different paths down the hill on different occasions and continually changing their gait and their mode of locomotion. They were fascinated by everything new and unusual. They carefully examined all the objects I laid in their path and even collected some of them. Once I saw a chimpanzee gaze at a particularly beautiful sunset for a full 15 minutes, watching the changing colors until it became so dark that he had to retire to the forest without stopping to pick a papaw for his evening meal.

Another respect in which the animals resembled human beings was in their doubting and uncertain nature. They appeared to ponder such problems as whether to turn to the left or the right, or whether or not a papaw tasted good. Often, just like laboratory chimpanzees puzzling over a difficult problem in an intelligence test, the chimpanzees I observed scratched themselves elaborately while making these decisions. Although the blinds I used for close observation concealed me almost completely, the chimpanzees could see my eyes if they came close enough. I had some exciting moments when an adult male would come straight toward me, halt no more than 10 feet away and look straight into my eyes. But whenever this occurred, the animal neither attacked nor fled. He simply stood there for a while, staring thoughtfully into my eyes and scratching his arms and chest before he wandered off.

Except for the screaming of the males during their intimidation displays, the chimpanzees seldom made any noise. They generally communicated by gesture, or by changes in posture or facial expression. Children asked for food by holding out one hand. If a mother and child were seated side by side and the mother wanted to move on, she had only to look at her offspring for it to jump up on her back; if by chance the child was looking the other way, she merely tapped it lightly on the shoulder or arm. A child, surprised by seeing its mother climb to the top of an unusually tall tree or by a pigeon flashing suddenly overhead, did not utter a sound. Instead it jumped into the air, flinging its arms upward like a cheerleader. The children played tag and other games in silence. If two adult males came across anything suspicious, they merely looked inquiringly at each other. Screaming seemed to be reserved for intimidation displays or emergencies: a child screamed if it felt it was lost, and an adult screamed

TREETOP OBSERVATION POST was 80 feet up in the tree seen at left in this photograph. From it the author could keep a wide area under observation, including the hill and the forest where the chimpanzees lived and the plantation they visited for food.

if another adult chased it in earnest. On the other hand, when the animals sighted a human being, they first ran to cover; only then did they give an alarm signal.

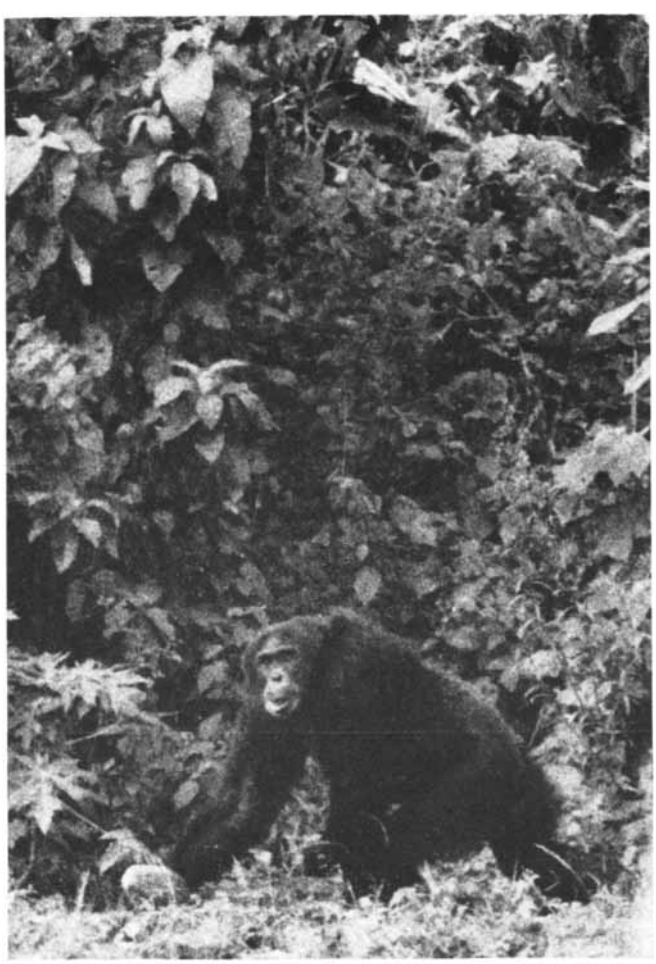
Zoo observations, incomplete field evidence and comparisons with other primates have led most writers to assume that in the wild chimpanzees live in small closed harem groups of five to 15 members. I saw nothing of the kind. When the apes were on the move, two kinds of aggregation could be clearly distinguished. One, the sexual group, consisted mainly of adult males and childless females, but often included a few mothers and children. The other, the nursery group, consisted of juveniles up to the age of puberty, their mothers and sometimes one or two adult males.

Participation in either kind of aggregation did not seem to be fixed or controlled in any way. Individuals were free to join or leave a group at will, and the groups themselves often merged or split up. The number of animals at a given location could vary from one to more than 30. Within a group there was no consistent marching order, nor did all the individuals do the same thing at the same time. Only twice, when individuals or groups met in passing, did I see any gesture that could have been construed as a greeting. At all other times each went its own way, like commuters at a railroad station. Nor did I see any signs of permanent or temporary sexual bonds or of sexual jealousy; none of the animals seemed disturbed at matings or homosexual pseudo matings in their midst.

In the sexual groups more than 20 animals generally traveled together, whereas in the nursery groups there were usually fewer than 15, of which more than half were children. Although the two kinds of group sometimes intermingled, they were more often apart than together. Moreover, they differed markedly in their behavior.

The sexual groups appeared to range over an area of several square miles. They visited the plantation once every two or three days—primarily, it seemed, to act out their intimidation display on the open ground. They were noisy and not particularly shy. As evidenced by the fact that they ate relatively few papaws, they did not depend on the plantation for their food. The nursery groups, whose members were extremely shy, covered a smaller area and moved quite slowly; I saw some mothers and children almost every day. From the number of papaws they ate I judged that for many of them the plantation was an important source of food.

To my knowledge there is no other primate—indeed, no other mammal—among which the chief social distinction is between childless and child-rearing adults rather than between males and females. This was the greatest surprise of my study. The pattern of chimpanzee social life may have grown out of the long and intensive care the animals give



STYLES OF CHIMPANZEE LOCOMOTION are recorded. Here an animal is walking on all four legs. He has a papaw in one hand.

THREE-LEGGED GAIT is common among chimpanzees. They often use it when they want to walk and eat simultaneously.

their young. Carrying a child around almost constantly for four or more years obviously tends to restrict the range of the mother's movements. In any case, this peculiar social pattern represents another response to the biological problem that man and many other animals have solved by monogamy and parental care by the father.

For many years the great apes were studied in the hope of tracing some aspects of man's evolution from them, since their behavior was considered to represent a more primitive stage than ours. Gradually, however, as it has been realized that man and ape represent diverging branches stemming from a remote intermediate ancestor, the emphasis has changed. The main problem of primate research today is to explain why the great apes did not become more nearly human than they are.

Experiments with captive animals have shown that the behavior patterns of chimpanzees are not almost wholly innate, as are those of monkeys. Instead, like human patterns, they are largely molded by maternal education, social tradition and other environmental factors. Keith J. and Cathy Hayes of the Yerkes Laboratories of Primate Biology in Orange Park, Fla., who raised a chimpanzee in their home and systematically applied a forced "humanizing" education to it, measured its IQ as 125 at the age of two years and eight months. Almost everyone has noted the striking resemblance of chimpanzee expressions and gestures to those of human beings. It is less well known that captive chimpanzees often spontaneously display a number of other human characteristics. They construct primitive shelters and improvise rudimentary tools and weapons. They sometimes forsake their natural vegetable diet, killing and eating small vertebrate animals. Recent discoveries indicate that the *Australopithecinae*, an extinct group of early hominids with brains little larger than those of the contemporary great apes, created an essentially human type of culture, including the making of tools. What stopped the chimpanzees?

One frequent answer is that they never came down out of the trees. My observations show this to be false. In the zoo chimpanzees give the impression of being essentially arboreal, but this is probably because their cages are too small. In the wild they behave like such basically terrestrial animals as baboons. The chimpanzees I watched had created an elaborate road system in the forest, opening into bowers that seemed to serve as clubrooms. On the plantation hill, where they were apparently safe from leopards, some of them even slept in nests on the ground. Moving around on the plantation and, as far as I could observe, in the forest, they walked on the ground from tree to tree, avoiding any climbing that was not absolutely necessary. When they did climb, they

TWO-AND-A-HALF-LEGGED GAIT is also common. Here one hand touches the ground but is not used as a firm support.

TWO-LEGGED GAIT enables the animal to carry several papaws. In open spaces chimpanzees in the wild quite often walk on two legs.

moved very cautiously, as if afraid they might fall. When a chimpanzee in a tree suspected the presence of a human being, it immediately fled back to the ground. Even the playful young seldom engaged in tree-climbing games. It should be said that Henry W. Nissen of the Yerkes Laboratories and Jane Morris-Goodall of the University of Cambridge have observed that chimpanzees do sometimes climb or swing from one tree to another in gallery forests, where the crowns of the trees are interwoven with each other. But in rain forests, where the tree crowns are of varying height, there is little opportunity for this behavior. Certainly chimpanzees are much more arboreal than man, but they are much less arboreal than has been thought until now. They are not even exclusively forest animals. In regions uninhabited by man and in areas where they are rigidly protected, they are often found in savannas where trees grow sparsely. In treeless sections they may walk long distances from one grove to another.

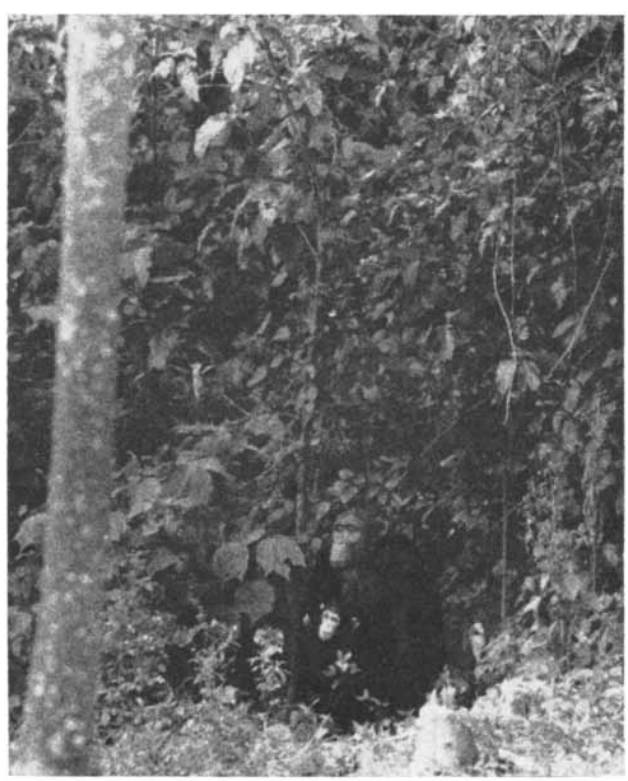
Moreover, in open areas chimpanzees spend a good part of the time on two legs, walking and running in a nearly erect and almost human posture. In the plantation where I made my study this mode of travel accounted on the average for 10 to 15 per cent of the distance covered by the apes when they were fully at ease. Apparently they walked bipedally in order to have their hands free—for example, to carry or eat fruit—or to gain a better view of their surroundings. Sometimes they simply seemed to enjoy a change from the four-legged and three-legged gaits demanded by the forest. To cross a brook that ran through the plantation all the animals, even mothers with children up to six years old on their backs—made a six-foot jump on two legs, and from a standing start on soft ground. From these and similar facts it seems probable that walking on two legs evolved primarily as a result of manual dexterity rather than, as has been commonly thought, the other way around. Furthermore, since walking on two legs is convenient on open ground but not in the forest, the chimpanzees' ability to change their way of walking and their fondness for doing it indicate that they, like the earliest hominids, were originally a species of mixed and diversified habitats.

Conceivably chimpanzees and early man may even have been serious competitors in the search for food, since both are able to climb trees with trunks too thick to be grasped by any of the contemporary lower primates. If this is true, it is probable that the apes were worsted by the human invention of the spear. In a fair fight an unarmed man would have no chance at all against an adult male chimpanzee; even if the man had a knife I would not bet on him. But with a spear a man could wound or kill a chimpanzee from a distance.

Chimpanzees use weapons too. I have mentioned the brandishing and throwing of clubs during intimidation displays, but this is apparently a kind of saber rattling rather than real fighting. I never saw one animal actually hit another with a club, nor did I see any wounds or scars. As a matter of fact, in most cases the intimidation display did not seem to be aimed at any individual; my impression is that it served mainly as an outlet that enabled the adult males to live together in peace.

In my opinion chimpanzees do use weapons against leopards. Although I did not find any evidence for this in my field studies, I have observed it in apes in captivity. At the Pasteur Institute in Guinea I put a tame leopard on the wall of a large compound in which an adult male chimpanzee, three mothers and five

MOTHER carries her child on her back. Young are carried until they are four years old or more. This child is three or four.



CHIMPANZEE CHILD sits in its mother's lap as she takes a nap. In the wild the young are very dependent on their mothers.

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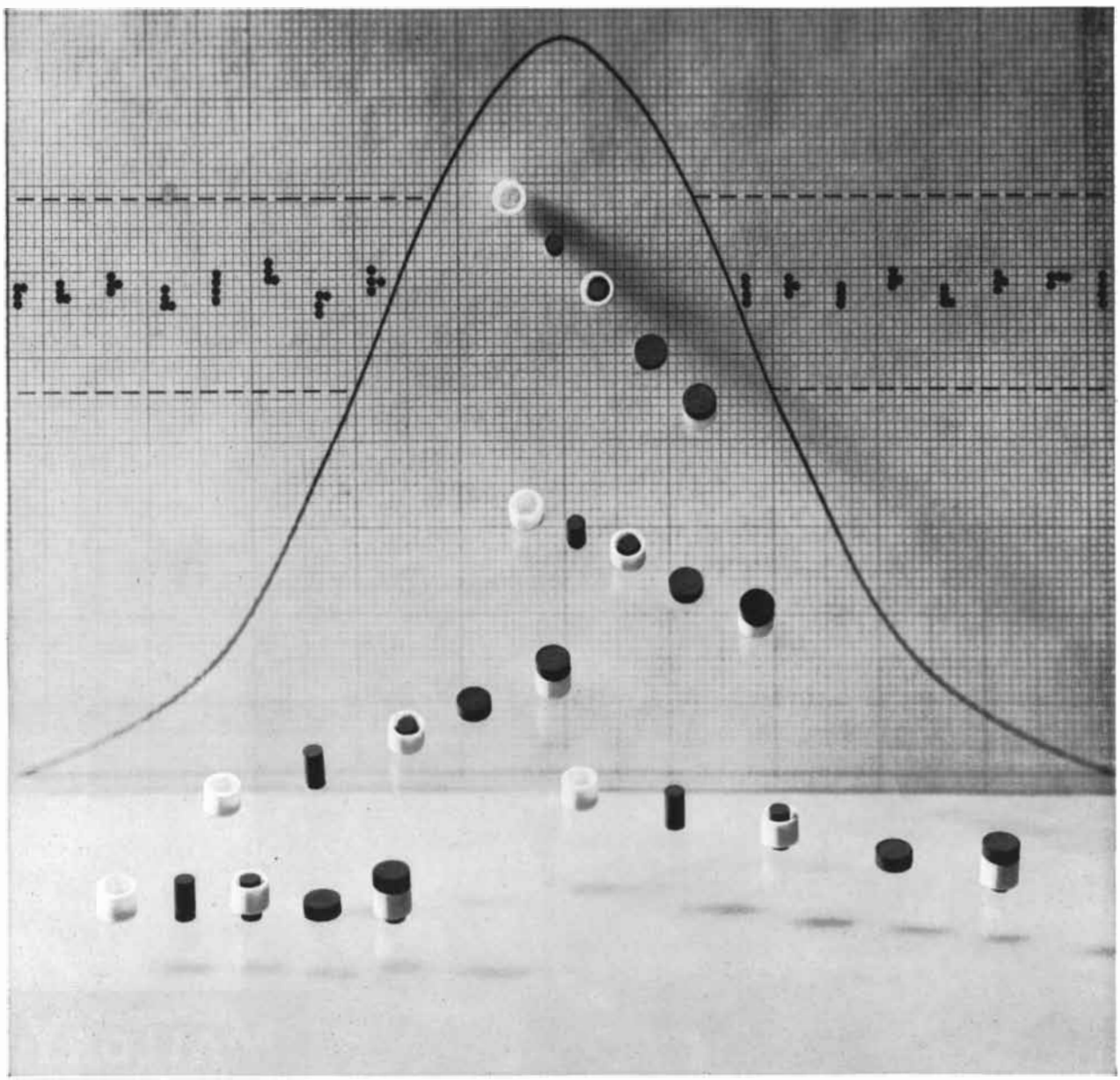

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OVULATING FEMALE is photographed. Chimpanzee mothers nurse their children for about three years and do not ovulate during this period. Puberty begins at about nine years.

juveniles were living under semiwild conditions. As soon as they caught sight of the cat, the adults ran toward it, screaming loudly and rising to their hind legs. Soon thereafter they grabbed the sticks I had previously scattered in their enclosure and threatened the leopard with them. Two of the apes, after finding the largest of the sticks, charged furiously at their enemy. The leopard was, however, just beyond their reach. Since these apes were near maturity when they were captured, they undoubtedly had had experience with leopards in the wild. In

GRANDDAD often acted as a "security inspector," making sure everything was safe. Here he emerges onto open ground. The photograph, like all the others, was made by the author.

another experiment I brought a caged tiger near a half-grown male chimpanzee that had been born in the zoo and had never before seen a large beast of prey. Within a few seconds the chimpanzee picked up some wooden cubes I had put in his cage and began to bombard the tiger with them.

This and other evidence from zoos indicates that the use of weapons is partly instinctive in the semiterrestrial great apes—gorillas as well as chimpanzees. Full development of this behavior among great apes in zoos occurs, however, only when the animals are kept in large open enclosures resembling the savanna rather than the forest. And when they do use weapons in genuinely fierce fighting, both species assume a two-legged posture. It therefore seems reasonable to assume that the technique of erect armed combat emerged among the common ancestors of man and apes many millions of years ago, and that it is not an early hominid invention of the past million years. This supports the idea that it was primarily the invention of the spear that humanized the hominids and dehumanized the anthropoids by driving them from the savanna. Whereas the forest offers the best protection against spears, it is a most unfavorable environment for the evolution of the human way of life.

The effect of the forest on chimpanzees manifests itself in several ways. It helps account for their loose and primitive social organization. The savanna-dwelling baboons have a definitely organized society [see "The Social Life of Baboons," by S. L. Washburn and Irven DeVore; SCIENTIFIC AMERICAN, June, 1961]. Forest living must have discouraged the evolution of a spoken language. Neurologically and anatomically the chimpanzee would in principle be capable of speech. But the forest is a dangerous place; behind any tree or bush may lurk a leopard, a snake or a human hunter. Silence is essential, particularly for mothers and children. Moreover, in a social system in which each individual gathers his own food, there is really very little to say.

Finally, the forest and its dangers have acted to slow the rate of behavioral development in young chimpanzees and thus, in an evolutionary sense, to suppress the more human potentialities of the species. Unless my age estimates were thrown off by field conditions, the behavior of the young chimpanzees I saw was markedly retarded in comparison with that of animals raised in captivity. The mothers' constant anxiety and close surveillance keeps the young dependent and must therefore act as a strong pressure against psychological development.

CHIMPANZEE WITH A CLUB was photographed in captivity. He was running to attack a leopard just beyond his reach. Apparently chimpanzees use clubs instinctively.

Even in the wild the rate of development accelerates if maternal control is relaxed. Miss Morris-Goodall, who observed chimpanzees in Tanganyika, has told me that the mothers there seemed considerably less anxious and that the young were correspondingly more advanced than those I watched. In my group there was one mother who seemed to be much older than the rest. Perhaps because long experience had taught her that the plantation was safe, she gave her two children much freer rein. She carried her three-year-old only if she was in a hurry or alarmed, and she usually left it at the edge of the forest when she came to the plantation to pick papaws. Both her children seemed more self-reliant than the other juveniles of corresponding ages.

Only up to a point, however. All the chimpanzees I observed were cautious, hesitant creatures. This is one of the major impressions one carries away from studying chimpanzees at close range in the wild. Behind their lively, searching eyes one senses a doubting, contemplative personality, always trying to make sense out of a puzzling world. It is as if the certainty of instinct has been replaced in chimpanzees by the uncertainty of intellect—but without the determination and decisiveness that characterize man.

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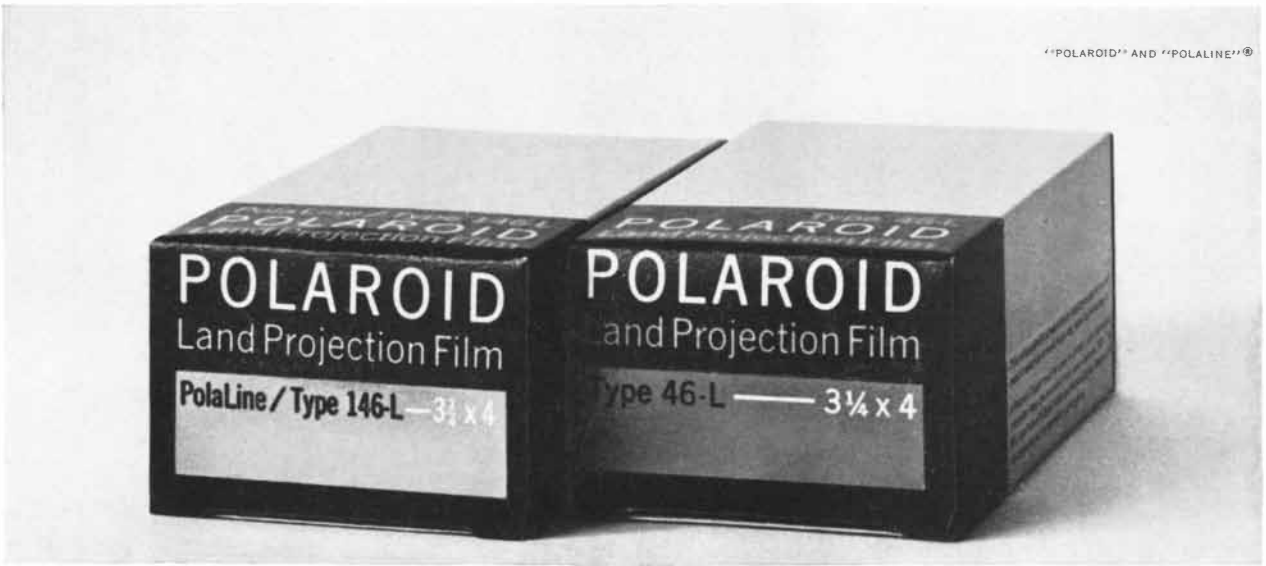
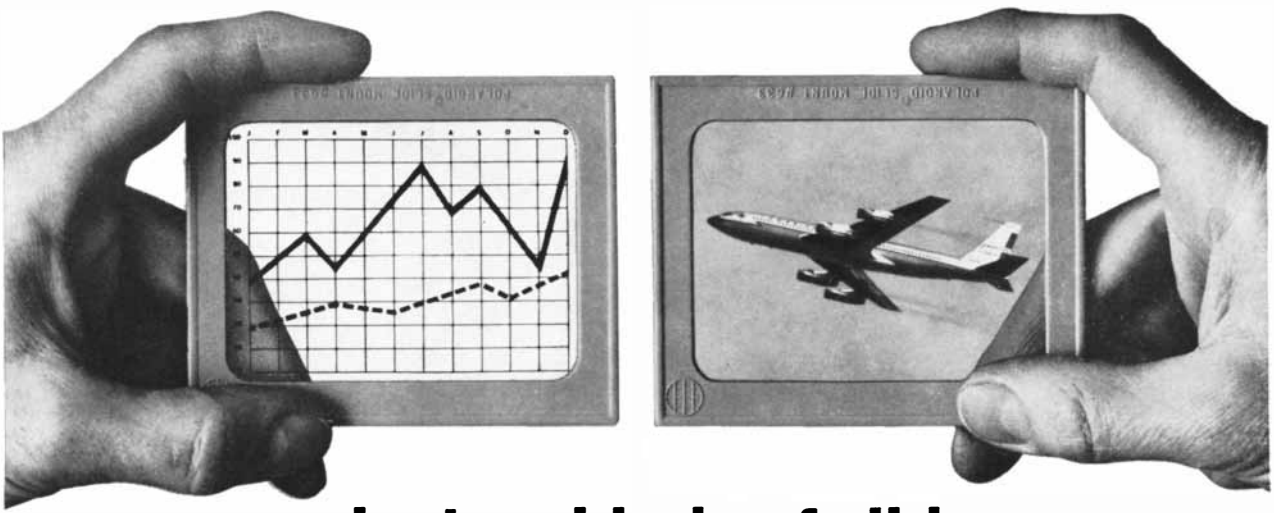


Two kinds of film



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Doesn't this make other kinds of slide making kind of old-fashioned?

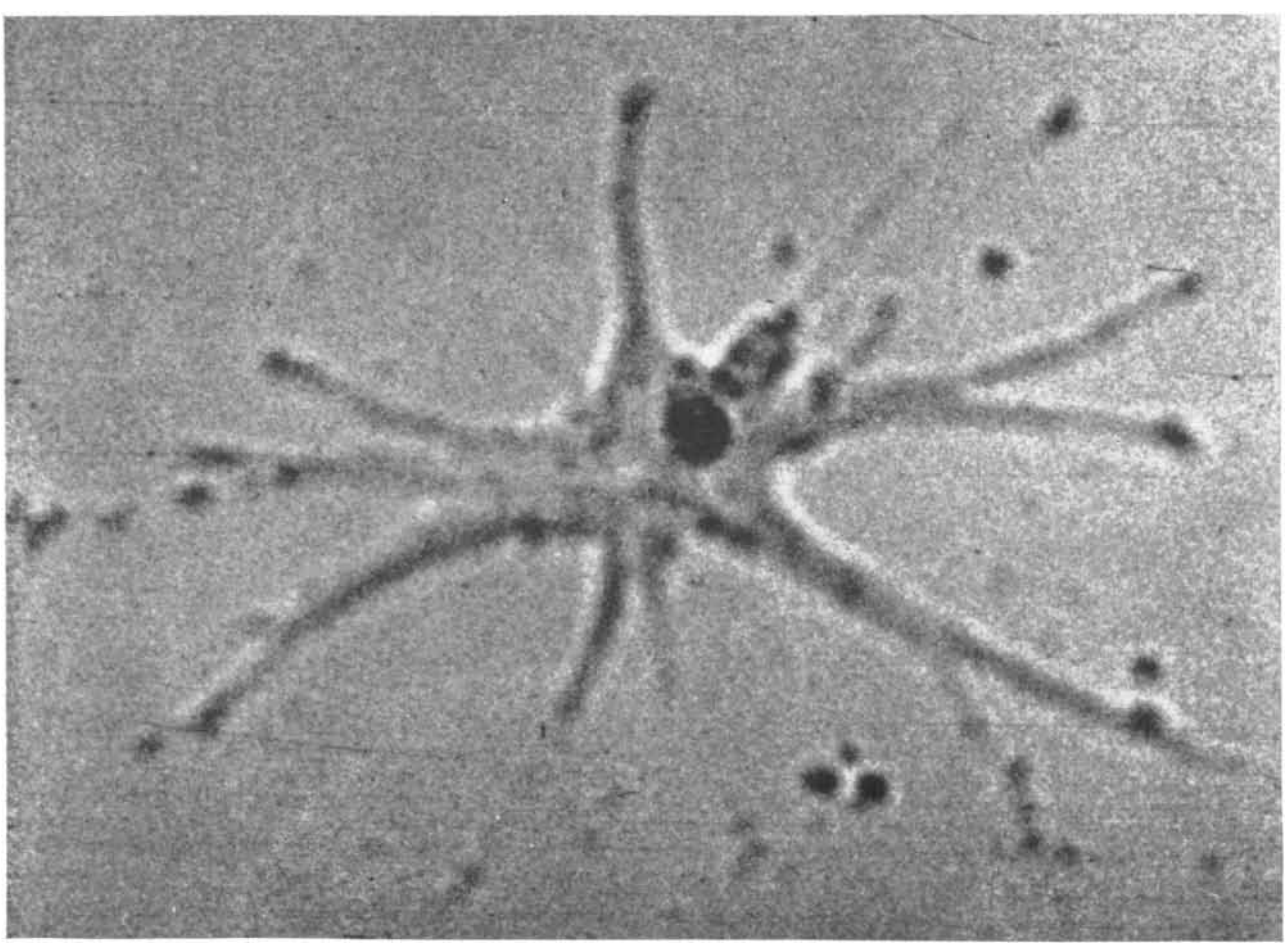
Heart Cells in Vitro

When mammalian heart tissue is dissociated and cultured, individual cells beat and organize themselves into fibers. Heart-cell cultures offer a new way of studying the heart and the differentiation of cells

by Isaac Harary

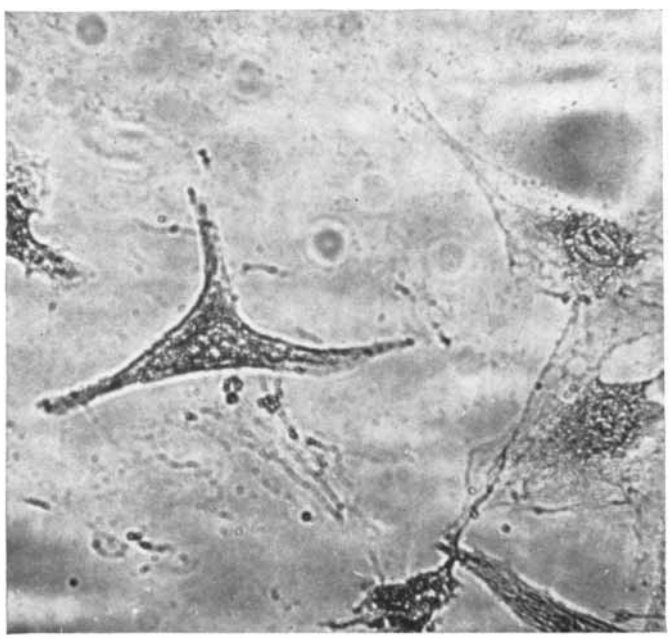
The beating heart is the very symbol of life. Long before men had an inkling of the purpose of the rhythmic pulsation they sensed its vital role. Today cardiac function has been analyzed—mechanically, electrically, biochemically—as thoroughly as any bodily process. Yet at bottom it remains a mystery. What makes the heart beat? What gives it its rhythm, and how is the rhythm communicated throughout the whole heart muscle? Is the special nature of the heart inherent in its component cells, or does it arise from their interaction? To attack such problems my colleagues and I at the University of California Medical Center in Los Angeles have been developing a new way of studying the heart. We take living cardiac tissue apart and observe the behavior of its individual cells.

Although it is only about 10 years since experimenters learned how to isolate and grow single mammalian cells,



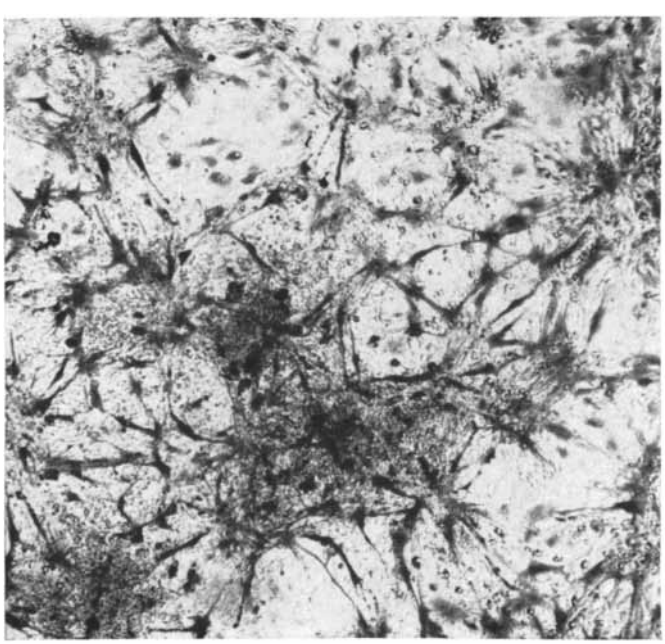
BEATING HEART CELL is enlarged 2,500 diameters in this frame from a motion-picture film made by the author. The culture had incubated for several weeks. The cell has put out a number of long, filamentous processes that have become attached to the laboratory dish. The beating of such a cell is seen in the film as a periodic heaving or twitching in the central portion of the cell.

the technique is now well established [see "Single Human Cells in Vitro," by Theodore T. Puck; SCIENTIFIC AMERICAN, August, 1957]. In our application of the method we start by treating minced heart tissue from young rats with trypsin. This enzyme breaks down the protein that cements the cells together, apparently without harming the cells themselves. Collecting the separated cells in a centrifuge, we suspend them in a medium containing blood serum and other necessary nutrients. At first the solution contains a variety of spherical, floating cells from blood and connective tissue as well as from heart tissue. But in about four hours the heart cells begin to settle to the bottom of the culture dish. After two or three days of incubation at 37 degrees centigrade (98.6 degrees Fahrenheit) almost all of them have fastened themselves to the glass surface. Now the medium can be changed to get rid of floating cells and debris. Under the microscope the heart cells are seen to have changed their shape drastically. They are stretched and flattened and are attached to the glass by long filaments [*see illustration on preceding page*].

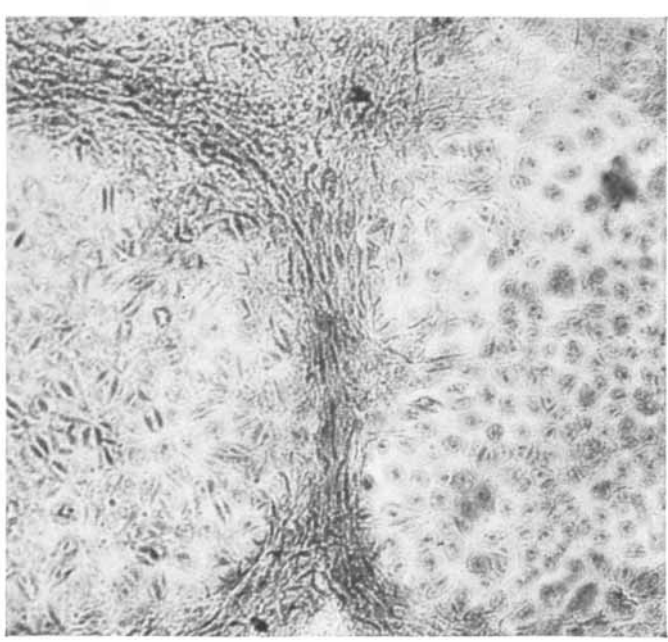


SINGLE HEART CELLS assume irregular shapes as they attach themselves to a glass dish after having been cultured for one day. The cells are stained with haematoxylin and eosin and enlarged 1,500 diameters.

INDIVIDUAL CELLS (stained and enlarged as in the preceding photograph) have put out filaments but are not yet in contact. The few "leading" cells are beating independently.



SYNCHRONOUS NET becomes more crowded. Centers of beating become established, around which the elongated cells are oriented in "rosettes." The stain is methylene blue; the magnification, 185 diameters.

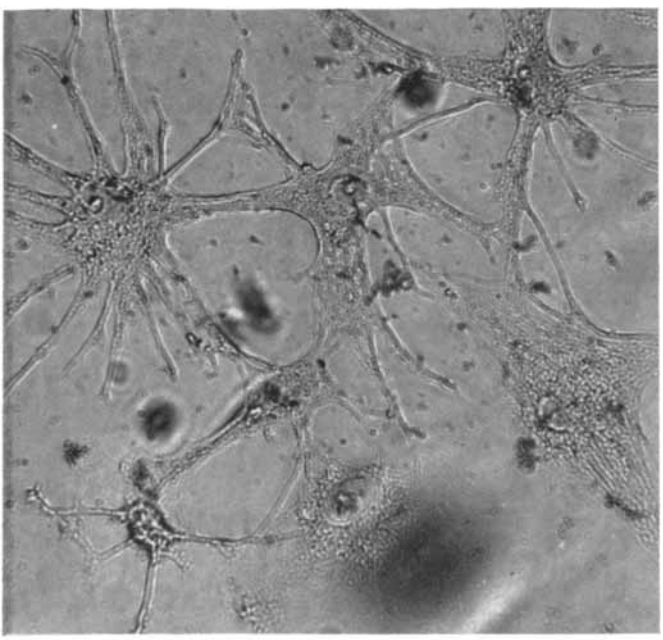


CENTERS OF BEATING are close together, and those on a line coalesce to form a long, beating ridge across a membrane of beating cells. Unstained cells are enlarged 370 diameters.

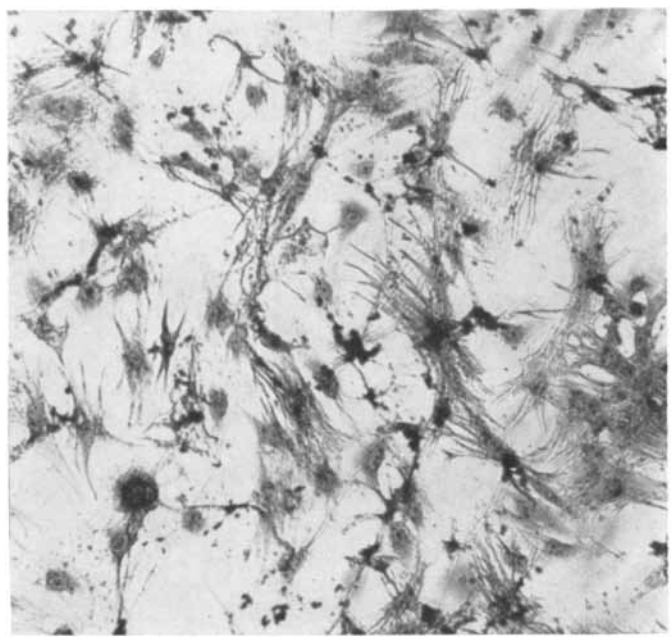
The first time we looked at one of these preparations we got quite a surprise—a few of the cells were beating! About one in every 100 of them was rhythmically contracting, each at its own rate, varying from 10 to 150 times a minute. Earlier investigators had discovered that isolated embryonic chick heart cells beat independently, but ours was the first such observation on the fully developed postnatal mammalian heart.

The observation demonstrated at once that the beating of the whole heart originates with the single cell; that is, the heartbeat does not require a community of cells or nerve connections. Both of these may be involved in regulating the action of the heart, but there is no doubt that periodic contraction is an inherent function of the single cell.

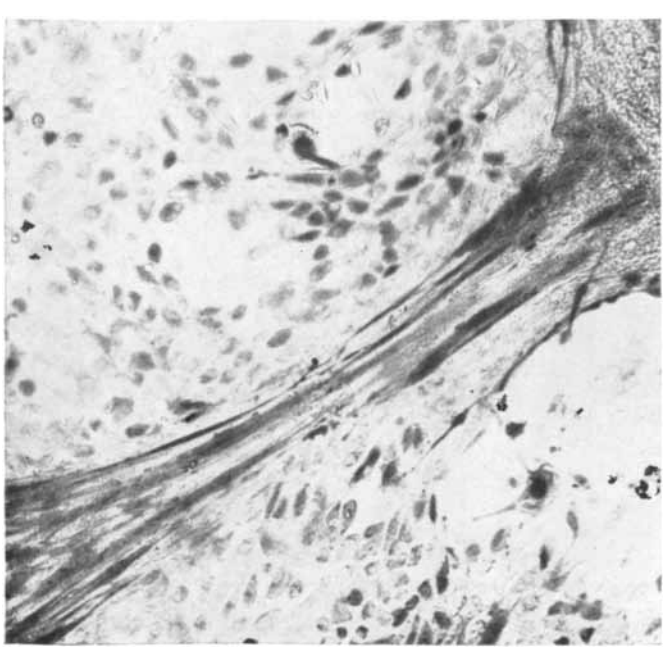
Until recently most authorities denied the existence of single cells in the heart. When they examined cardiac tissue in the light microscope, they saw what appeared to be bundles of interconnected, multinucleated fibers undivided by cell membranes. They therefore assumed that the heart consists essentially of one large cell with many nuclei, and that this structure had evolved to meet



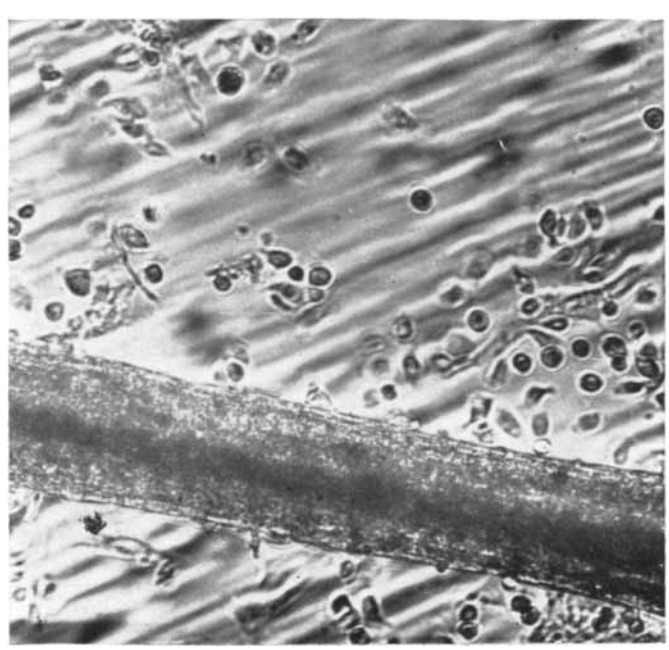
CELLS MAKE CONTACT through their filaments and more cells beat as synchronous nets develop. This four-day-old preparation is stained and enlarged as in the earlier pictures.



DENSITY OF NETS increases as the cells grow and multiply. When all the cells are in contact, they form a single net and all beat together. These cells, stained with methylene blue, are enlarged 370 diameters.



BEATING RIDGE develops into a fiber. This is apparent if a ridge is stained with methylene blue: the cells in the ridge are seen to be oriented along its axis. Enlargement: 370 diameters.

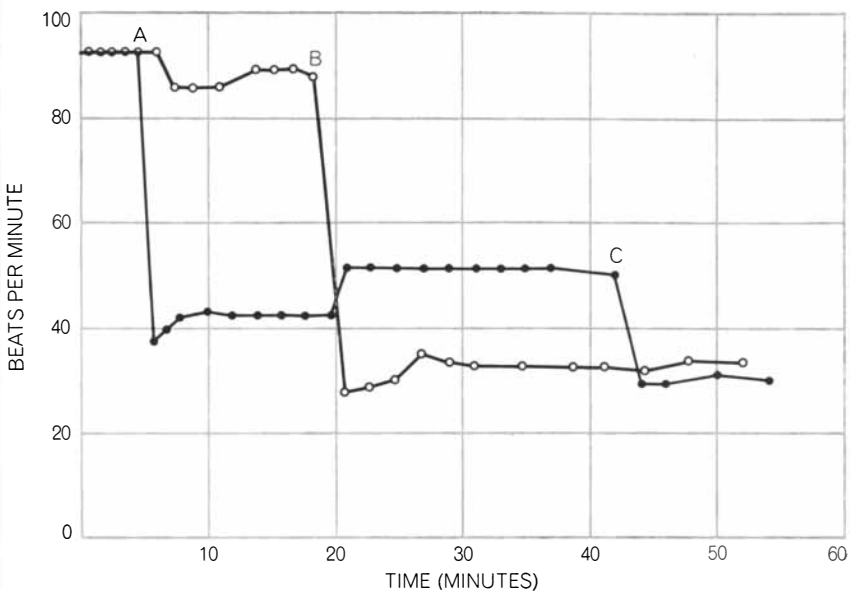


FINAL STAGE is a developed heart-cell fiber. This one is unstained and has been enlarged 185 diameters. The photomicrographs on these two pages were made by the author with the assistance of Pete Kalian.

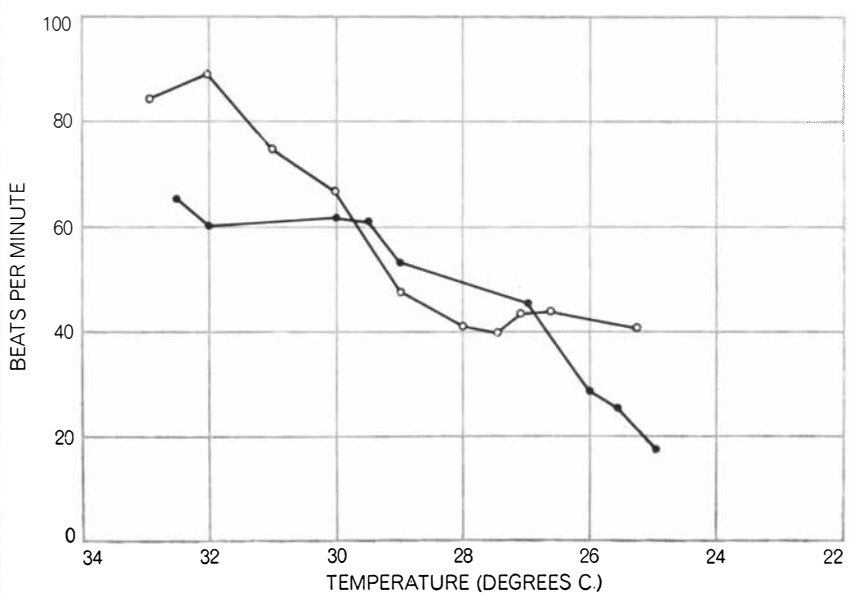
the requirements of co-ordinated action throughout the organ. Electron micrographs, however, show that membranes do in fact envelop the nuclei in heart fibers. Now our experiments confirm the idea that the heart is composed, at least potentially, of separate functioning cells.

In the first of these experiments we simply let our preparation incubate for several weeks and watched its development. As the cells ingest nutrients, they grow and multiply. Their filaments get longer and begin to make contact. The more cells there are joined together in this way, the more cells there are that beat. Eventually all the cells come in contact and then they all beat, but not independently. Once they are completely interconnected they beat at the same rate and in unison.

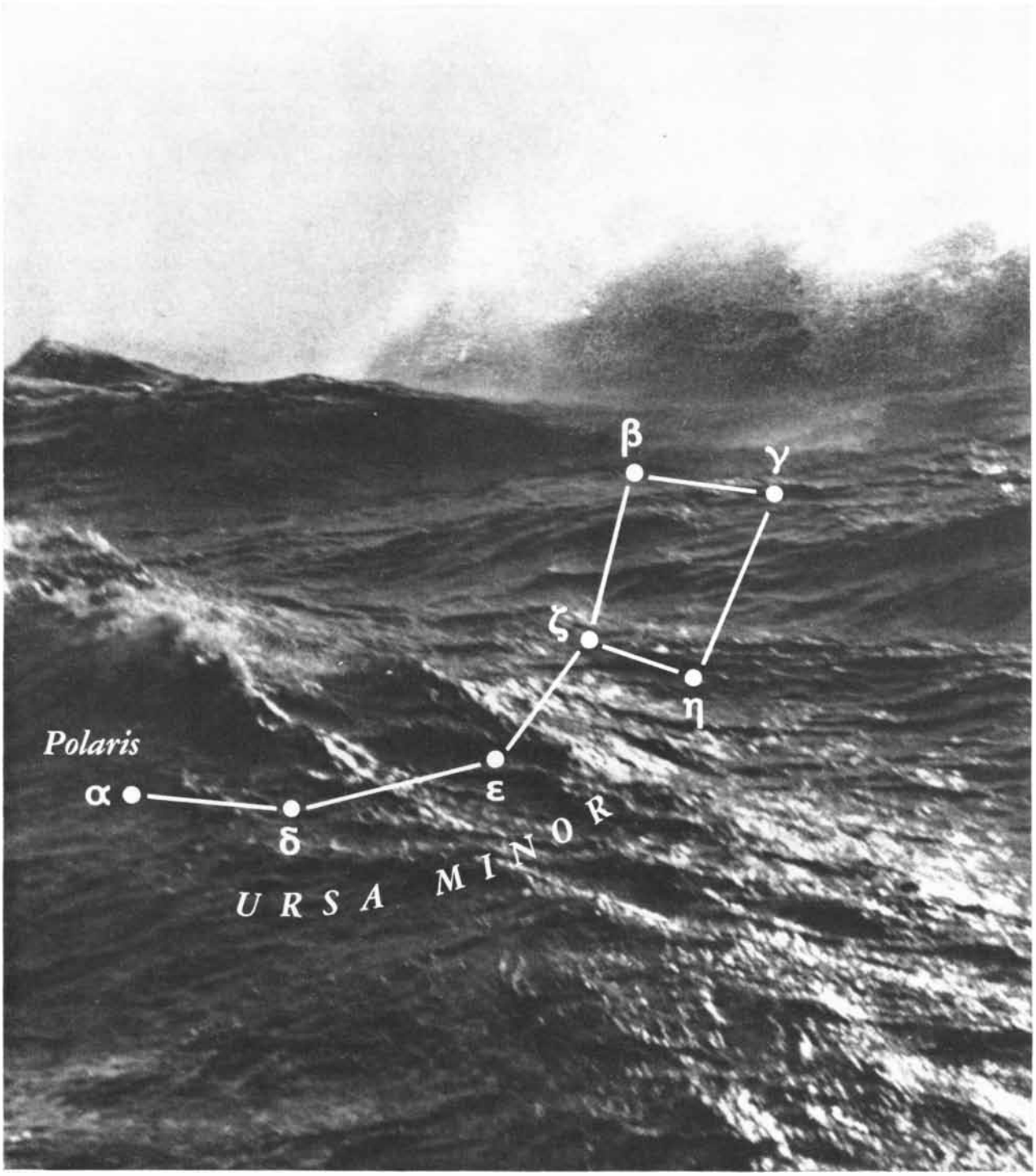
As the cells continue to multiply, the dish becomes more crowded and a new phase begins. A number of distinct centers arise in the net, with elongated cells arranged radially around them. The



IMPORTANCE OF CONTACT between cells was shown by an experiment that began with a single net beating 92 times per minute. When the net was cut (*A*), two synchronous nets were formed. One (*open circles*) stayed at about 90; the other (*black dots*) fell to 40. When acetylcholine was added to one side (*B*), that side was inhibited throughout. The other side was not affected until the drug was brought into contact with it by mixing the medium (*C*).



EFFECT OF TEMPERATURE on beating rate is shown by these curves for two different experiments. A temperature drop of 10 degrees centigrade cuts the rate two to three times.



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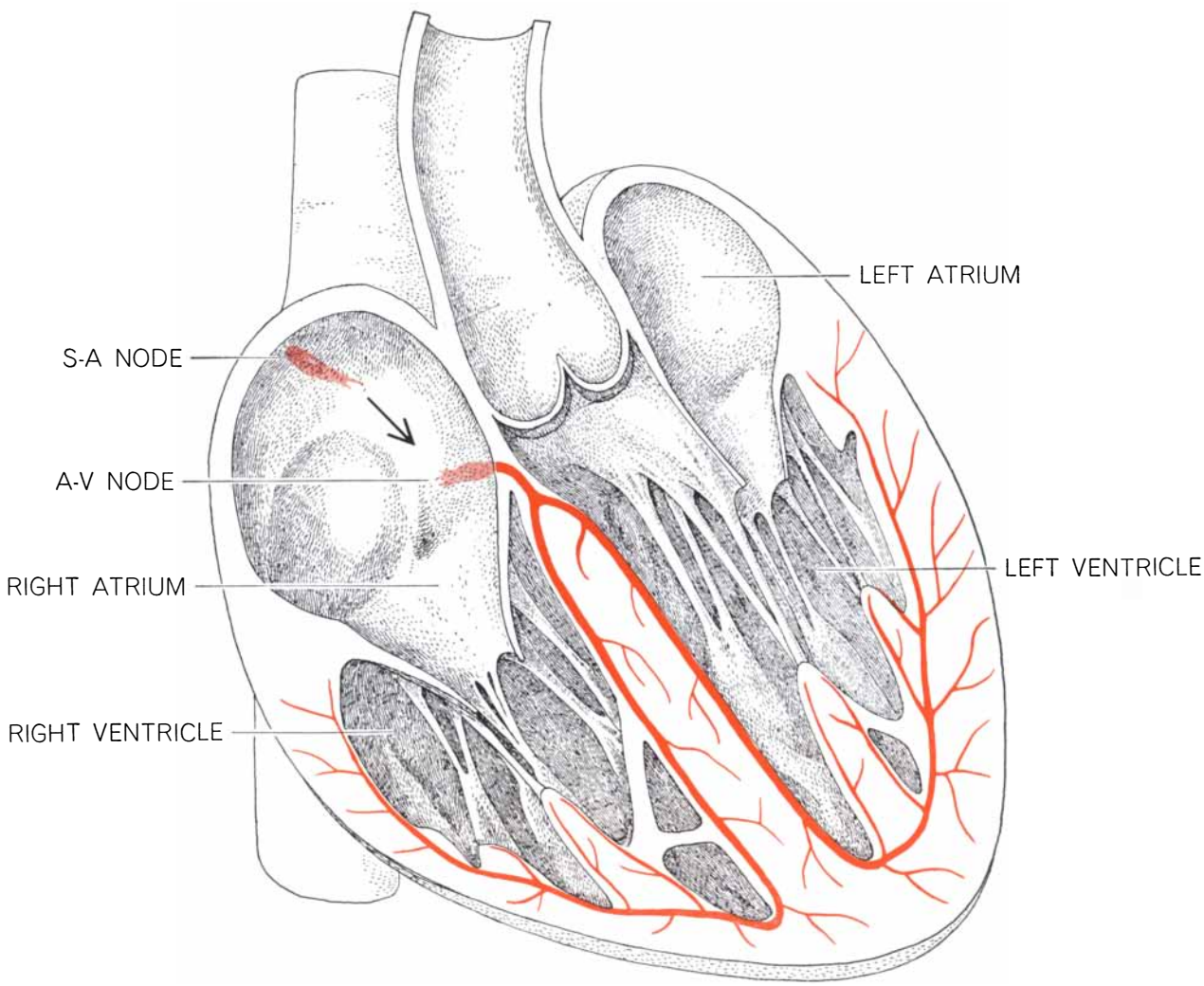
dish appears to be covered with rosettes, all beating in unison. In the next stage the cells coalesce into a membranous layer that beats in a single, heaving sheet. The rosettes line up to form long, beating ridges. Often the ridges thicken and partially separate from the membranous sheet, forming fiber-like structures that continue to beat [*see illustrations on pages 142 and 143*].

These observations suggest that the organization of the adult heart results in part from the activity of the cells themselves. A. A. Moscona of the University of Chicago has obtained similar results with tissue from other organs. He mixed together embryonic liver cells and kidney cells in a single culture and found that the two types eventually separated, each group organizing itself in a pattern resembling its parent tissue.

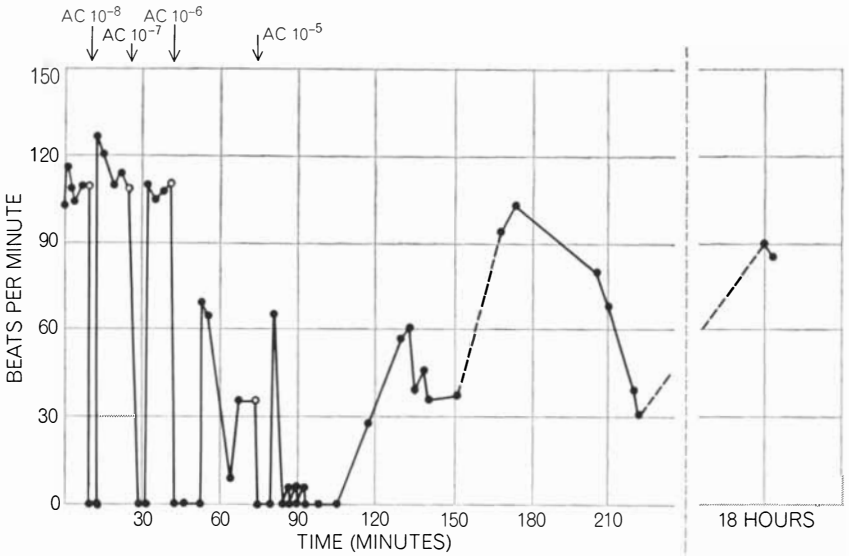
The way in which heart cells come together is also strongly reminiscent of the development of a slime mold, the peculiar organism that spends part of its life as a suspension of single cells and part as a multicellular organism. At the end of their free-living stage the cells of a slime mold stream together and eventually differentiate into the adult organism. During its aggregating phase the slime mold closely resembles our aggregating heart cells.

After watching the beating process spread through a culture as the cells made contact, we tried putting them close together at the outset. Instead of the dilute suspension of our first experiments we prepared a culture containing nine times as many cells per unit volume. Within a day or two all the cells had made contact and were beating in unison. In a suspension of intermediate concentration about 80 per cent of the cells began to beat over the same period. These cells had formed into a number of separate groups, each beating as a unit but out of step with the others.

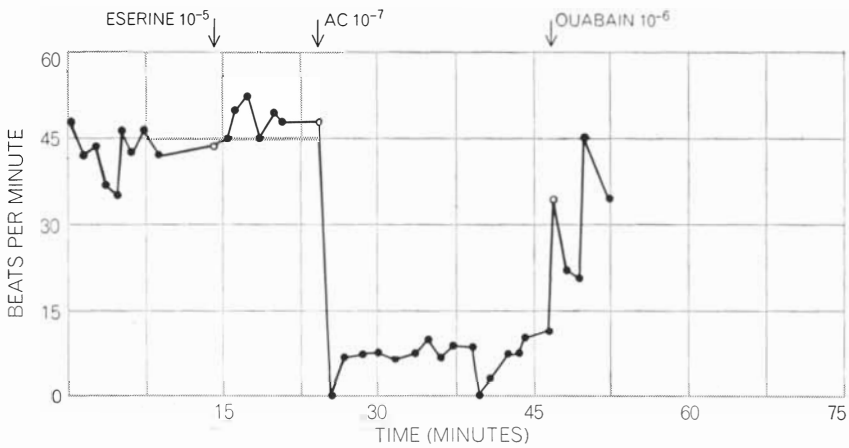
It looked as though beating is communicated by direct contact between cells. There was, however, the possibility that a chemical "messenger" was transmitted through the medium. To settle the question we cut a net of synchronously beating cells into two separate parts. The two halves immediately began to beat at different rates even though both were bathed in the same medium. In another experiment we applied acetylcholine, a drug that slows heart action, to a small area of an intact net. It inhibited the beating of all the cells in the net. Applied to one half of a divided net, however, acetylcholine inhibited only the cells in that half; the other half was not affected until we



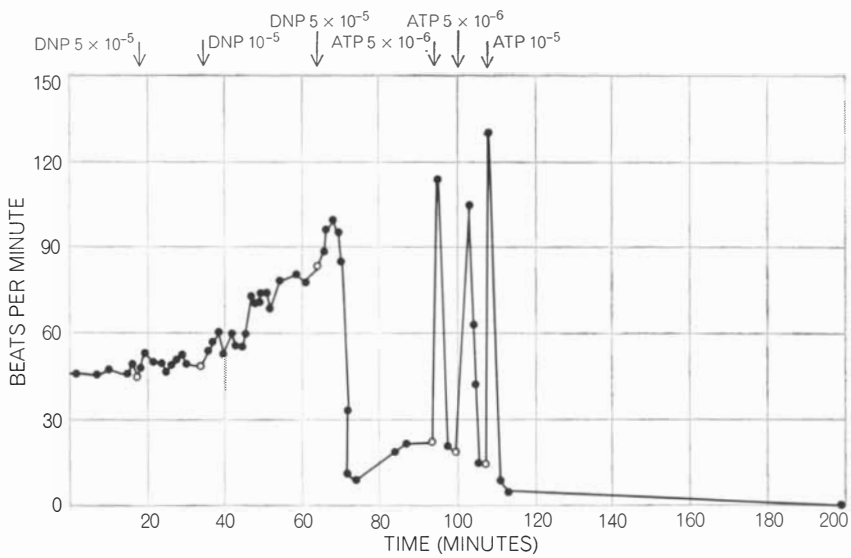
HEARTBEAT IS CONTROLLED primarily by specialized tissue (*color*) within the heart. The beating impulse is generated in the sinoatrial (*S-A*) node and travels over the surface of the atria to initiate their contraction. It also travels (*arrow*) to the atrioventricular (*A-V*) node. From there, after a short delay, it is conducted by the branching Purkinje fibers throughout the two ventricles. It appears that the spontaneously beating leading cells noted in the author's cultures arise from the nodal and Purkinje tissues.



ACETYLCHOLINE inhibits the beating of a single cell. The drug (*AC*) was added as indicated by the arrows and in the cumulative concentrations shown (in gram molecules per liter). The effect is transient because the drug is destroyed by the enzyme cholinesterase.



CHOLINESTERASE can be inhibited by the drug eserine. A cell pretreated with eserine is therefore inhibited by acetylcholine until the effect is reversed by another drug, ouabain.



ADENOSINE TRIPHOSPHATE (*ATP*) is apparently necessary for beating. ATP formation is inhibited by dinitrophenol (*DNP*). Application of DNP in sufficient concentration slows a heart cell's beat. The beating can be restored temporarily by the addition of ATP.

stirred the medium to bring the drug into contact with the cells across the dividing line [*see upper illustration on page 144*].

Our results indicated that there are two types of isolated heart cell: a few that beat spontaneously, which we call leading cells, and a majority, called following cells, that beat only on contact with one of the leaders. Treating a culture with methylene blue clearly distinguishes two types of cell. There are long, irregular cells that take the stain well and are deep blue; they may be the leading cells. And there are smaller, rounded ones—perhaps the following cells—that are stained very little.

In the intact heart two basic types of cells have also been recognized. One is the myocardial cell, the muscle cell that makes up the bulk of the heart. The other is found in specialized tissues that generate and distribute impulses to maintain the rhythmic heartbeat. Each contraction apparently originates with an impulse in the sinoatrial node, a knot of tissue in the right atrium, or auricle [*see illustration on page 146*]. From this "pacemaker" the impulse spreads over the two atria and reaches the atrioventricular node, whence it travels through a network of cells called Purkinje fibers to the rest of the heart. It seems probable that the leading cells in our cultures arise from the nodal and Purkinje tissues and the following cells from the ordinary heart muscle. Preliminary experiments supported this view: when we prepared a culture from the portion of the right atrium containing the sinoatrial node, we got a higher proportion of spontaneously beating cells.

We next wanted to find out what sets the rate of beating in a synchronous net. Is it determined by the slowest or fastest leading cell in the group, or is it some sort of average? A series of time-lapse photomicrographs, tracing the beating rates of individual cells as they joined together in a net, would answer the question at once. We have just begun to set up the necessary equipment.

Meanwhile we have obtained some information by a less direct method. This method depends on a fact discovered earlier: the tempo of pulsating heart cells increases with temperature. Using an apparatus that could establish a temperature gradient across a culture dish, we measured the beating rates in a net maintained first at 25 degrees C. (77 degrees F.) and then at 35 degrees C. (95 degrees F.). Then we heated one side of the dish and cooled the other, so that the

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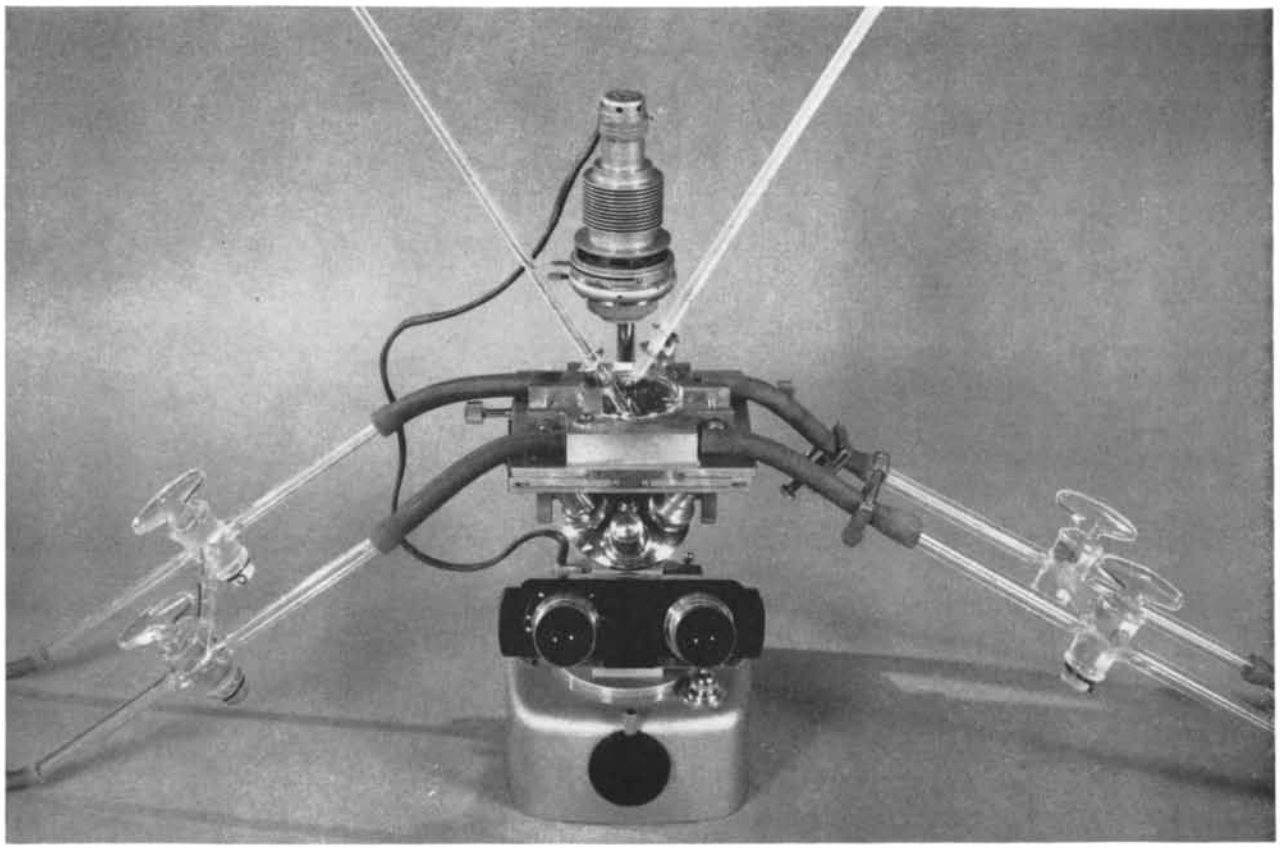

TEMPERATURE GRADIENT is established across a cell culture with this apparatus. Hot water can be run through one side of the aluminum holder and cold water through the other. The effect on the beating rate can be observed through the inverted microscope.

temperature ranged from 25 to 35 degrees across the net. The whole net beat as fast, or nearly as fast, as when it was all at the higher temperature. But when the net, still in the gradient, was separated into two halves, the heated half maintained the initial fast rate, whereas the rate of the cooled half dropped. In other words, the cells of the cool half stayed at the fast rate as long as they were attached to the heated cells. When the cooled cells were separated, however, they slowed down to the rate determined by the lower temperature. From this procedure and some additional manipulations we concluded that the over-all rate is determined by the fastest cell (or perhaps group of cells) in the net.

Experiments on the intact heart confirm these conclusions. The destruction of the pacemaker decreases the rate of beating as the atrioventricular node, which has a lower rate, takes over. Evidently the controlling cells at any time are those with the highest rate of beating. It has also been observed that when a developing chick heart is cut in two, the parts beat at different rates; when they are joined, the faster rate prevails.

In short, the over-all rate, in vitro and in vivo, is determined by the fastest cells solely because they are the fastest. And although all the cells in a net beat at a common rate, they potentially retain their individual differences.

If heart cells are cultured in very dilute concentrations, they do not form rosettes or fibers but continue to beat as single cells for as long as 40 days. For the first few days each beating cell behaves in many respects like the intact heart. But the beating cell is much more sensitive than the beating heart, and it provides a small-scale "model" of the heart that lends itself to many experiments. Drugs that slow the heartbeat can be applied to the single cell and their effects can be measured with great accuracy. Acetylcholine, for example, completely halts beating for a few minutes, the period varying with the concentration of the drug. Activity resumes when the acetylcholine has been destroyed by the cell enzyme cholinesterase [*see top illustration on page 148*]. If the cell is pretreated with eserine, a compound that inhibits cholinesterase, the effect of acetylcholine persists. The action of eserine is in turn reversed by ouabain, a drug of the digitalis family [*see middle illustration on page 148*].

Heart cells are also extremely sensitive to compounds that block certain steps in metabolism. One such substance, dinitrophenol (DNP), interferes with synthesis of adenosine triphosphate (ATP), the compound that is thought to provide energy for muscle contraction. We found that DNP at very low concentrations inhibits the beating of the single cell. The inhibition can be temporarily reversed by the addition of ATP [*see bottom illustration on page 148*]. It seems reasonable to conclude that ATP is necessary for beating. Other possible energy-supplying reactions can be studied with appropriate inhibitors. Such studies may eventually make clear the metabolic patterns underlying heart activity.

The gross nutritional requirements of single cells are less when they are merely beating than when they are also growing. A physiologically balanced salt solution containing a glycoprotein fraction of the blood serum, carbon dioxide and an energy source such as glucose or lactate will maintain beating. Whole serum, amino acids and vitamins

must be added to promote growth. If the cells are concentrated enough to grow into fiber-like masses, their requirements decrease: they are able to beat without an external source of carbon dioxide or glycoprotein. Harry Eagle of the Albert Einstein College of Medicine has discovered a similar effect in other mammalian cells. Dilute cultures require a supply of several amino acids that more concentrated cultures can do without. Whatever else these findings demonstrate, they prove unequivocally that the nutritional requirements of single cells cannot be predicted from knowledge of the whole tissue.

Of course the question of the relationship of single cells to the parent tissue underlies the whole approach I have been describing. There can be no doubt that taking a cell away from its neighbors in the organ and the organism and putting it in an alien environment must have a major effect on it. The cell maintains its function for a time because it retains structures and enzymes that were synthesized in the intact condition. It carries its history with it, so to speak. Thus we find that cultured heart cells at first exhibit striations typical of intact heart cells. They synthesize the characteristic enzymes. They even tend to organize themselves into patterns somewhat like those of heart tissue. And they beat. But in a matter of days or weeks they change. They lose their striations and no longer produce their specialized enzymes. Single cells in dilute concentrations beat no longer than about six weeks; crowded cells in synchronous nets degenerate after only two weeks.

All this suggests either a return to a more primitive, embryonic state—a "dedifferentiation"—or a directed response to the cells' new environment. In either case the cell culture offers a powerful means of attacking one of the most important problems in biology: how different types of cell in a developing organism utilize their presumably identical hereditary information in different ways. We have found that some enzyme changes in isolated heart cells occur as soon as the cells are cultured, whereas others come about later, when the cells lose their ability to beat. The mechanism of these responses to the changing environment may provide clues to how the cell manipulates its inventory of enzymes to relate to its specific function. And if we can learn how to prevent dedifferentiation, we should have some quite direct information on the factors that determine the characteristics of cells.

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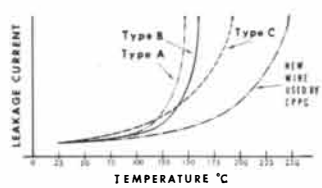

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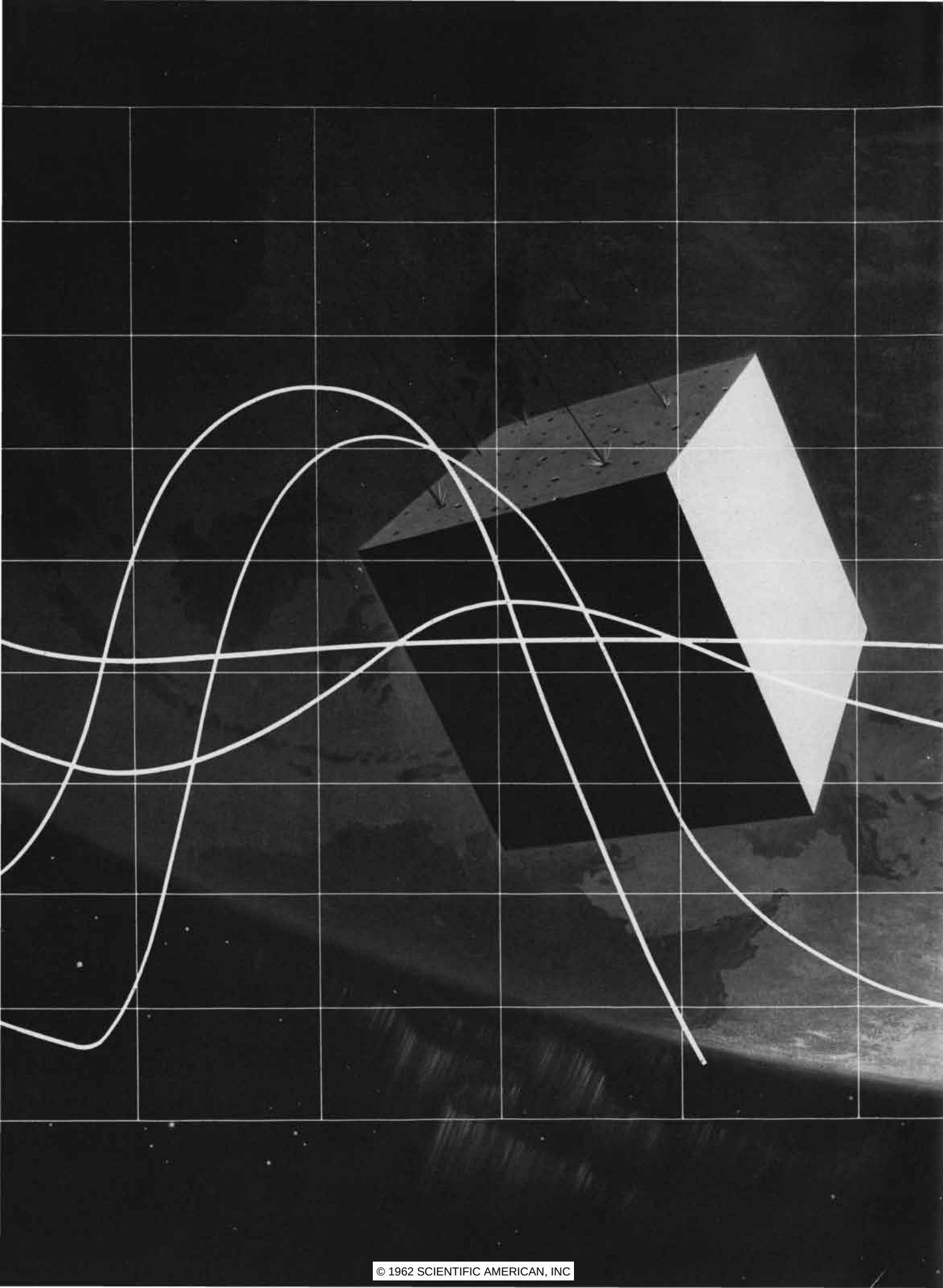

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MATHEMATICAL GAMES

Symmetry and asymmetry and the strange world of upside-down art

by Martin Gardner

A geometric figure is said to be symmetrical if it remains unchanged after a "symmetry operation" has been performed on it. The larger the number of such operations, the richer the symmetry. For example, the capital letter A is unchanged when reflected in a mirror placed vertically beside it. It is said to have vertical symmetry. The capital B lacks this symmetry but has horizontal symmetry: it is unchanged in a mirror held horizontally above or below it. S is neither horizontally nor vertically symmetrical but remains the same if rotated 180 degrees (two-fold symmetry). All three of these symmetries are possessed by H, I, O and X. X is richer in symmetry than H or I because, if its arms cross at right angles, it is also unchanged by quarter-turns (four-fold symmetry). O, in circular form, is the richest letter of all. It is unchanged by any type of rotation or reflection.

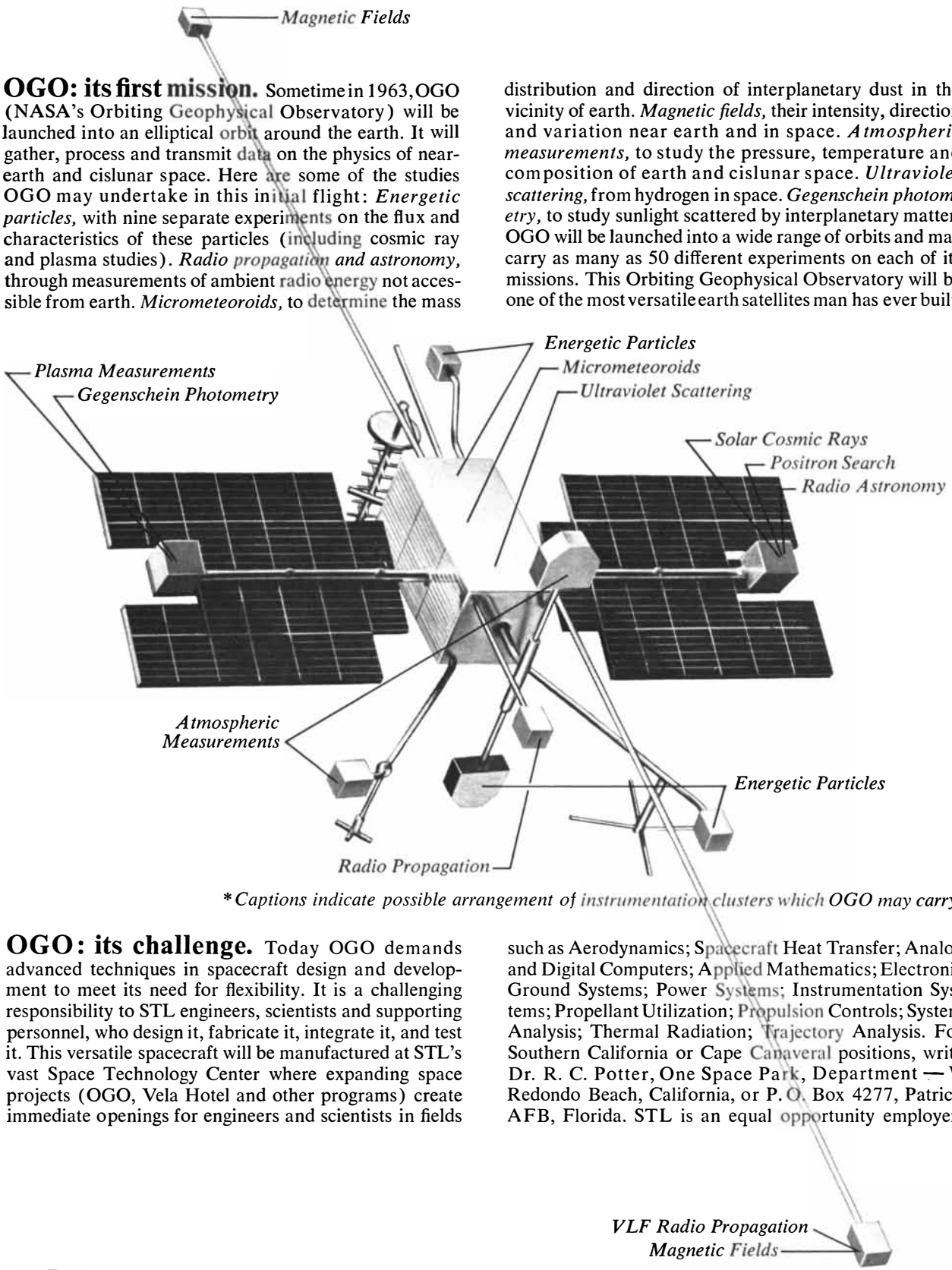
Because the earth is a sphere toward the center of which all objects are drawn by gravity, living forms have found it efficient to evolve shapes that possess strong vertical symmetry combined with an obvious lack of horizontal or rotational symmetry. In making objects for his use man has followed a similar pattern. Look around and you will be struck by the number of things you see that are essentially unchanged in a vertical mirror: chairs, tables, lamps, dishes, automobiles, airplanes, office buildings —the list is endless. It is this prevalence of vertical symmetry that makes it so difficult to tell when a photograph has been reversed, unless the scene is familiar or contains such obvious clues as reversed printing or cars driving on the wrong side of the road. On the other hand, an upside-down photograph of almost anything is instantly recognizable as inverted.

The same is true of works of graphic art. They lose little, if anything, by reflection, but unless they are completely nonrepresentational no careless museum director is likely to hang one upside down. Of course, abstract paintings are often inverted by accident. *The New York Times Magazine* (October 5, 1958) inadvertently both reversed and inverted a picture of an abstraction by Pieter Mondriaan, but only readers who knew the painting could possibly have noticed it.

So accustomed are we to vertical symmetry, so unaccustomed to seeing things upside down, that it is extremely difficult to imagine what most scenes, pictures or objects would look like inverted. Landscape artists have been known to check the colors of a scene by the undignified technique of bending over and viewing the landscape through their legs. Its upside-down contours are so unfamiliar that colors can be seen uncontaminated, so to speak, by association with familiar shapes. Many philosophers and writers have found symbolic meaning in this vision of a topsy-turvy landscape; it was one of the favorite themes of G. K. Chesterton. His best mystery stories (in my opinion) concern the poet-artist Gabriel Gale, who periodically stands on his hands so that he can "see the landscape as it really is: with the stars like flowers, and the clouds like hills, and all men hanging on the mercy of God."

The mind's inability to imagine things upside down is essential to the surprise produced by those ingenious pictures that turn into something entirely different when rotated 180 degrees. Nineteenth-century political cartoonists were fond of this device. When a reader inverted a drawing of a famous public figure, he would see a pig or jackass or something equally insulting. The device is less popular today, although *Life* for September 18, 1950, reproduced a remarkable Italian poster on which the face of Garibaldi became the face of Stalin when viewed upside down. Children's magazines sometimes reproduce such upside-down pictures, and now and then they are used as advertising

OGO: its first mission. Sometime in 1963, OGO (NASA's Orbiting Geophysical Observatory) will be launched into an elliptical orbit around the earth. It will gather, process and transmit data on the physics of near-earth and cislunar space. Here are some of the studies OGO may undertake in this initial flight: *Energetic particles,* with nine separate experiments on the flux and characteristics of these particles (including cosmic ray and plasma studies). *Radio propagation and astronomy,* through measurements of ambient radio energy not accessible from earth. *Micrometeoroids,* to determine the mass distribution and direction of interplanetary dust in the vicinity of earth. *Magnetic fields,* their intensity, direction and variation near earth and in space. *Atmospheric measurements,* to study the pressure, temperature and composition of earth and cislunar space. *Ultraviolet scattering,* from hydrogen in space. *Gegenschein photometry,* to study sunlight scattered by interplanetary matter. OGO will be launched into a wide range of orbits and may carry as many as 50 different experiments on each of its missions. This Orbiting Geophysical Observatory will be one of the most versatile earth satellites man has ever built.



**Captions indicate possible arrangement of instrumentation clusters which OGO may carry.*

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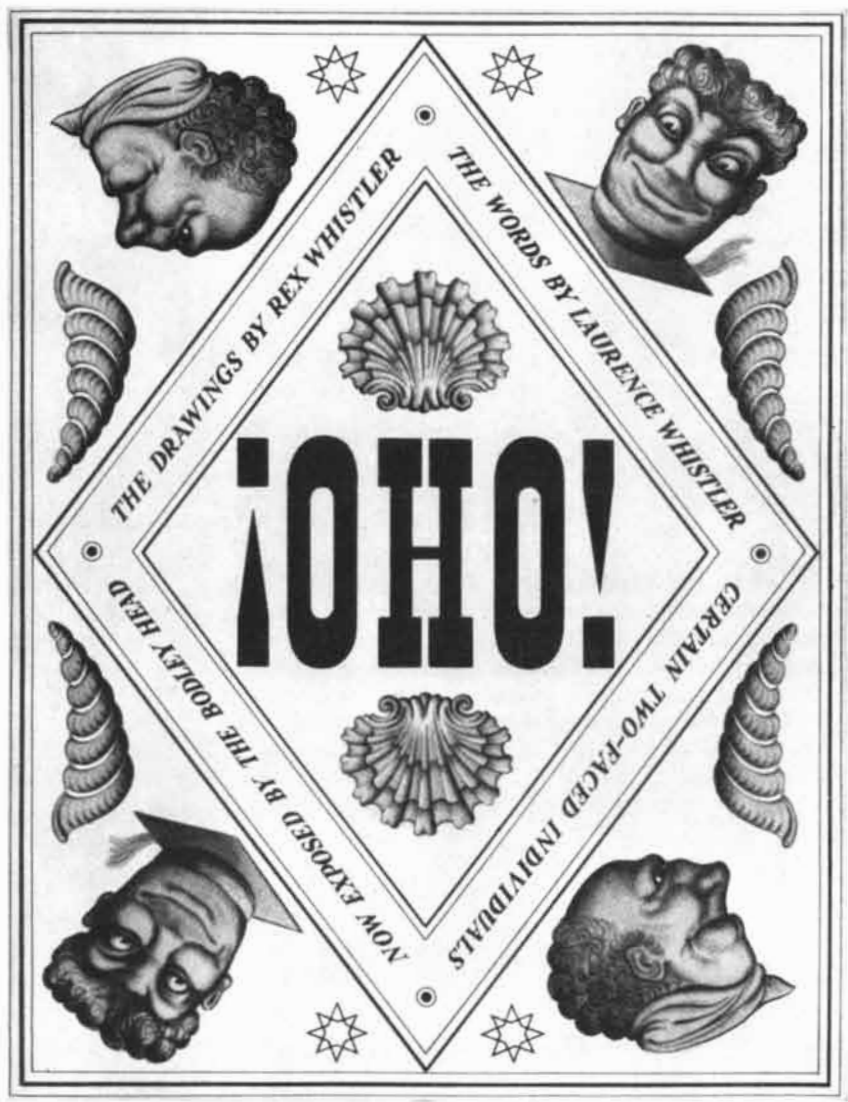
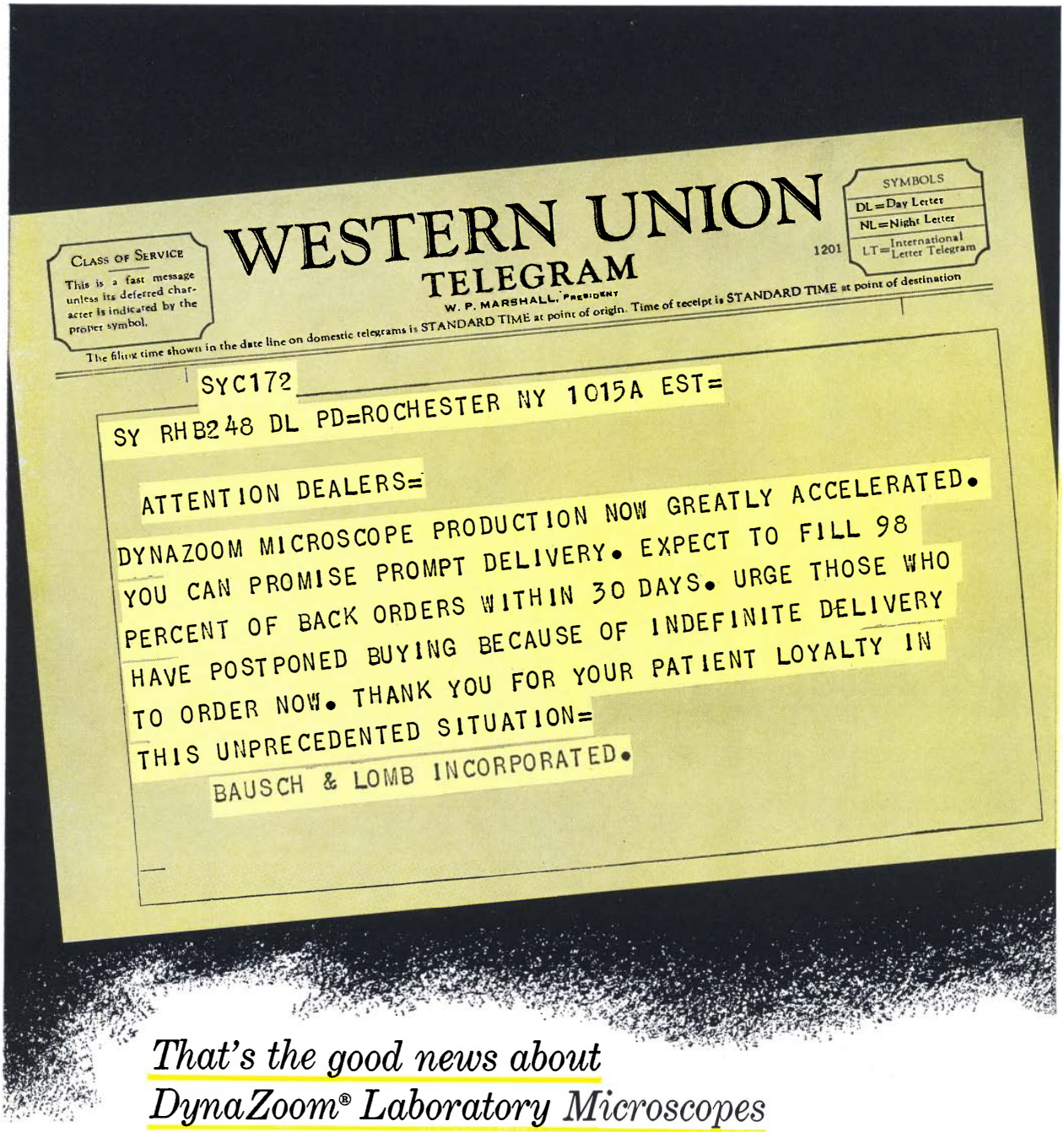
gimmicks. The back cover of *Life* for November 23, 1953, depicted an Indian brave inspecting a stalk of corn. Thousands of readers probably failed to notice that when this picture was inverted it became the face of a man, his mouth watering at the sight of an open can of corn.

I know of only three books that are collections of such drawings. In 1902 Peter Newell, then one of the country's most popular illustrators of children's books, published *Topsys & Turvys*, a collection of 26 color plates of scenes that undergo amusing transformations when inverted. In 1946 a London publisher issued a collection of 15 astonishing upside-down faces drawn by Rex Whistler, an English muralist who died in 1944. The book has the richly symmetrical title of *¡OHO!* (Its title page is reproduced below.)

The technique of upside-down drawing was carried to unbelievable heights in 1903 and 1904 by a cartoonist named Gustave Verbeek. Each week he drew a six-panel color comic for the Sunday "funny paper" of the *New York Herald*. One took the panels in order, reading the captions beneath each picture; then one turned the page upside down and continued the story, reading a new set of captions and taking the same six panels in reverse order! Verbeek managed to achieve continuity by means of two chief characters called Little Lady Lovekins and Old Man Muffaroo. Each became the other when inverted. How Verbeek managed to work all this out week after week without going mad



Invertible faces on the title page of Whistler's invertible book



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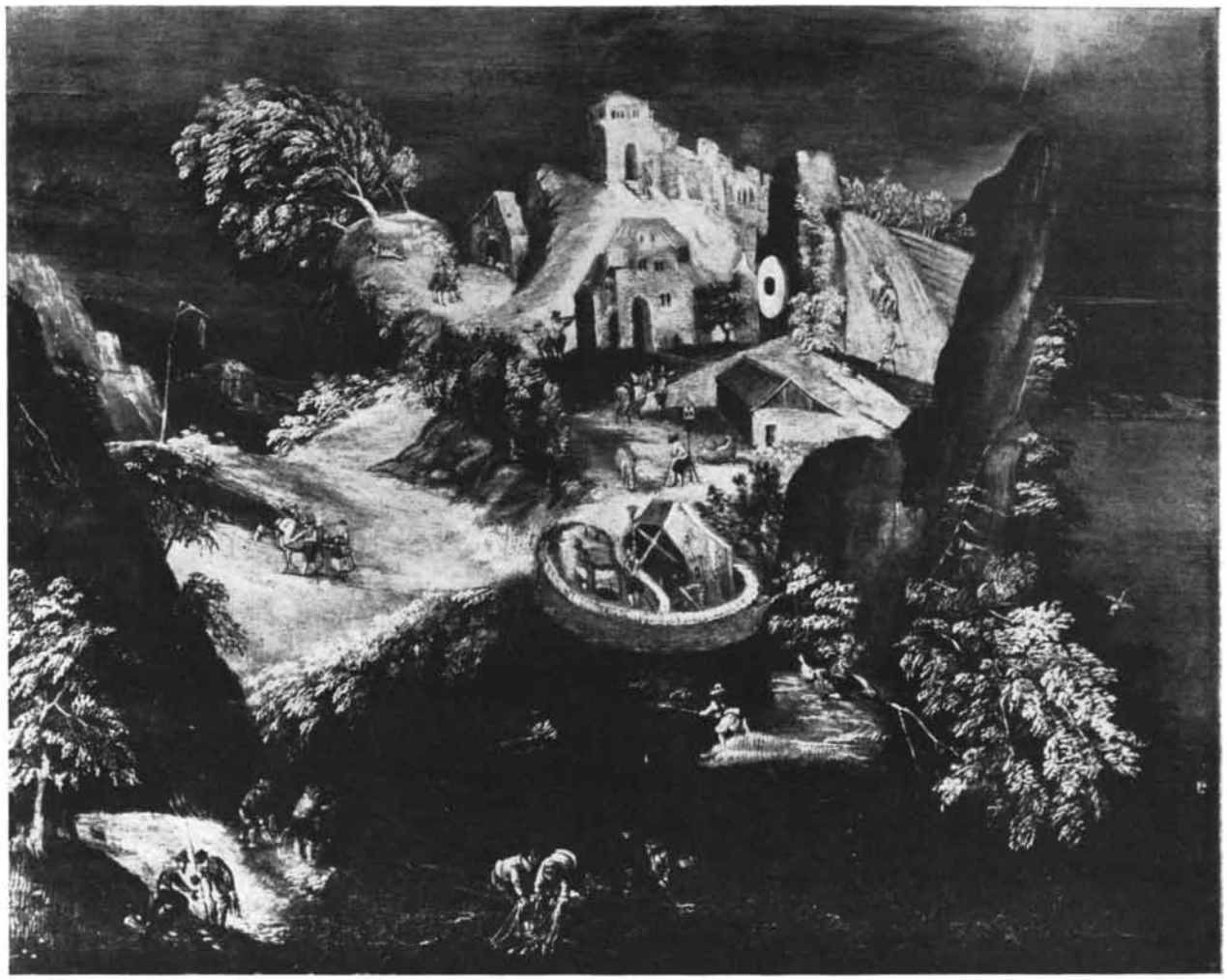

Matthäus Merian's "Landscape-Head." A quarter-turn counterclockwise reveals a profile

passeth all understanding. A collection of 25 of his comics was published by G. W. Dillingham in 1905 under the title of *The Upside-Downs of Little Lady Lovekins and Old Man Muffaroo.* The book is extremely rare.

The 90-degree rotation is less frequently used in art play, perhaps because it is easier for the mind to anticipate results. If done artfully, however, it can be effective. An example, reproduced above, is a landscape by the 17th-century Swiss painter Matthäus Merian that becomes a man's profile when the picture is given a quarter-turn counterclockwise. The rabbit-duck figure on page 162 is the best-known example of a quarter-turn picture. Psychologists have long used it for various sorts of testing. A few years ago Harvard philosopher Morton White reproduced a rabbit-duck drawing in a magazine article to symbolize the fact that two historians can survey the same set of historical facts but see them in two essentially different ways.

Our lifelong conditioning in the way we see things is responsible for a variety of startling upside-down optical illusions. All astronomers know the necessity of viewing photographs of the moon's surface so that sunlight appears to illuminate the craters from above rather than below. We are so unaccustomed to seeing things illuminated from below that when such a photograph of the moon is inverted, the craters instantly appear to be circular mesas rising above the surface. One of the most amusing illusions of this same general type is shown on page 164. The missing slice of pie is found by turning the picture upside down. Here again the explanation surely lies in the fact that we almost always see plates and pies from above and almost never from below.

Upside-down faces could not be designed, of course, if it were not for the fact that our eyes are not too far from midway between the top of the head and the chin. School children often amuse themselves by turning a history book upside down and penciling a nose and mouth on the forehead of some famous person.

When this is done on an actual face, using eyebrow pencil and lipstick, the effect becomes even more grotesque. It was a popular party pastime of the late 19th century. The following account is from an old book entitled *What Shall We Do Tonight?*

"The severed head always causes a sensation and should not be suddenly exposed to the nervous. . . . A large table, covered with a cloth sufficiently long to reach to the floor all around and completely hide all beneath, is placed in the center of the room. . . . A boy with soft silky hair, rather long, being selected to represent the *head,* must lie upon his back under the table entirely concealed,

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excepting that portion of his face above the bridge of his nose. The rest is under the tablecloth.

"His hair must now be carefully combed down, to represent whiskers, and a face must be painted... upon the cheeks and forehead; the false eyebrows, nose and mouth, with mustache, must be strongly marked with black water color, or India ink, and the real eyebrows covered with a little powder or flour. The face should also be powdered to a deathlike pallor. . . .

"The horror of this illusion may be intensified by having a subdued light in the room in which the exhibition has been arranged. This conceals in a great degree any slight defects in the 'making-up' of the head. . . ."

Needless to add, the horror is heightened when the "head" suddenly opens its eyes, blinks, stares from side to side, wrinkles its cheeks (forehead).

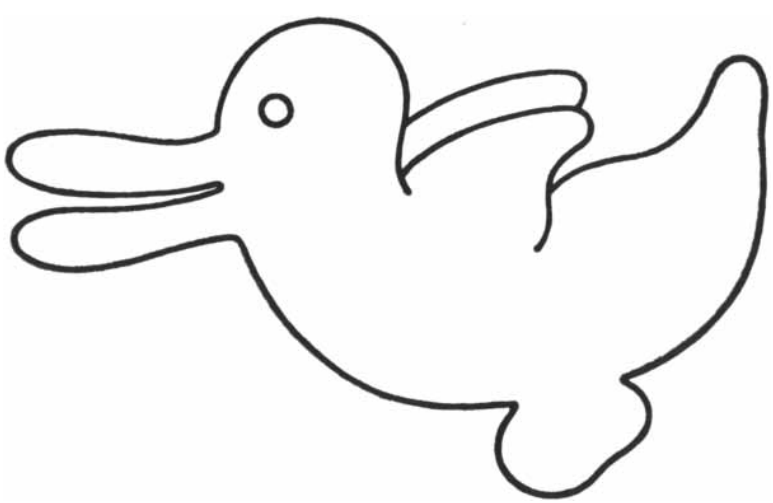
The physicist Robert W. Wood (author of *How to Tell the Birds from the Flowers*) invented a funny variation of the severed head. The face is viewed upside down as before, but now it is the forehead, eyes and nose that are covered, leaving only the mouth and chin exposed. Eyes and nose are drawn on the chin to produce a weird little pinheaded creature with a huge, flexible mouth. The stunt is a favorite of Paul Winchell, the television ventriloquist. He wears a small dummy's body on his head to make a figure that he calls Ozwald, while television camera techniques invert the screen to bring Ozwald right side up. Last year an Ozwald kit was marketed for children, complete with the dummy's body and a special mirror with which to view one's own face upside down.

It is possible to print or even write in longhand certain words in such a way that they possess two-fold symmetry. The Zoological Society of San Diego, for instance, publishes a magazine called *ZOONOOZ,* the name of which is the same upside down. The longest sentence of this type that I have come across is said to be a sign above a swimming pool, designed to read the same when viewed by athletes practicing handstands on the diving board: NOW NO SWIMS ON MON.

It is easy to form numbers that are the same upside down. As many noticed early last year, 1961 is such a number. It was the first year with two-fold symmetry since 1881, the last until 6009, and the 23rd since the year 1. Altogether there are 38 such years between A.D. 1 and 10000 (according to a calculation made by John Pomeroy), with the longest interval between 1961 and 6009. J. F. Bowers, writing in the *Mathematical Gazette* for December, 1961, explains his clever method of calculating that by A.D. 1000000 exactly 198 invertible years will have passed. The January 1961 issue of *Mad* featured an upside-down cover with the year's numerals in the center and a line predicting that the year would be a mad one.

Some numbers, for example 7734 (when the 4 is written so that it is open at the top), become words when inverted; others can be written to become words when reflected. With these quaint possibilities in mind, the reader may enjoy tackling the following easy problems:

1. Oliver Lee, aged 44, who lives at 312 Main Street, asked the city to give



A quarter-turn clockwise makes the duck into a rabbit

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his car a license plate bearing the number 337-31770. Why?

2. Prove the sum in the illustration on page 166 to be correct.

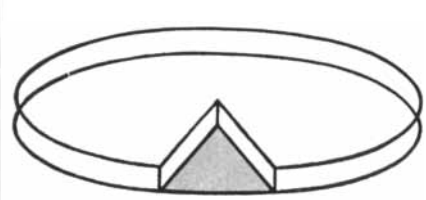
3. Circle six figures in the group below that will add up to exactly 21.

1	1	1
3	3	3
5	5	5
9	9	9

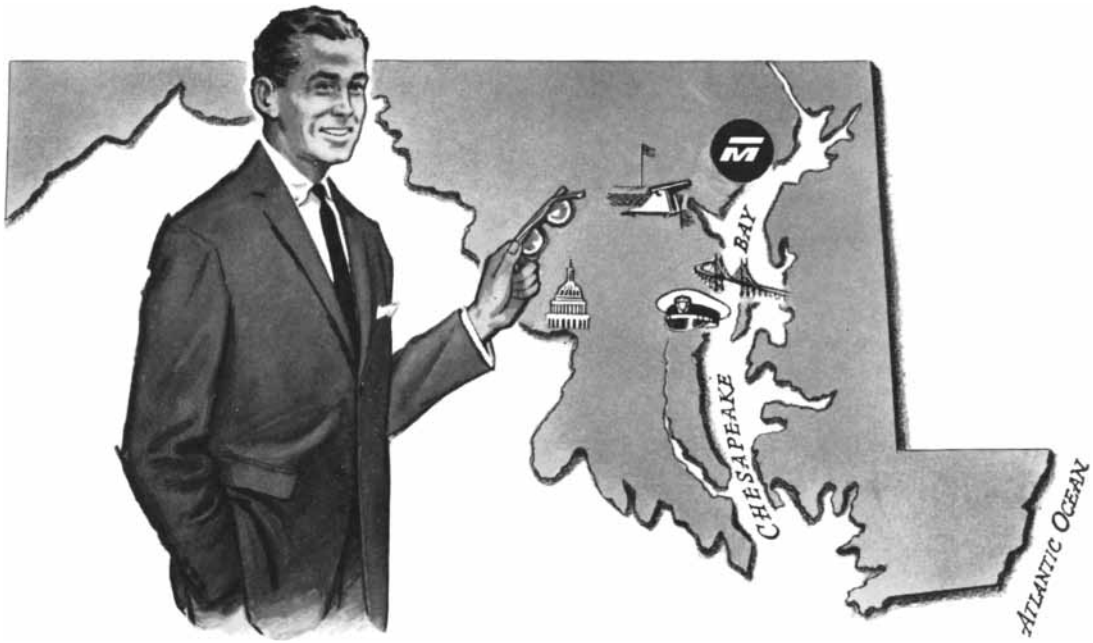
4. A basket contains more than half a dozen eggs. Each egg is either white or brown. Let x be the number of white eggs, y the number of brown. The sum of x and y, turned upside down, is the product of x and y. How many eggs are in the basket?

Readers were asked last month to devise a method by which the meaning of our word "clockwise" could be communicated by radio waves to humanoids on Planet X. It is assumed that Planet X is somewhere in our galaxy but covered by dense clouds that prevent its inhabitants from seeing the stars. It is also assumed that by ingenious codes scientists on earth and on Planet X have learned to talk fluently with each other. The problem is how to communicate the meaning of "left" and "right."

The startling answer is that until December, 1956, there was *no* way to communicate an unambiguous definition of "left" and "right." According to what physicists call the "law of parity," all asymmetrical physical processes are reversible; that is, they can take place in either of their two mirror-image forms. Certain crystals, such as quartz and cinnabar, have the property of twisting a plane of polarized light in one direction only, but such crystals exist in both left and right forms. The same is true of the asymmetrical stereoisomers, which also twist planes of polarized light. Organic compounds found in living forms may possess one type of handedness only, but this is an accident of the earth's evolution. There is no more reason for such compounds on another planet having the same handedness as those on earth as there would be reason to expect



Where is the missing slice?



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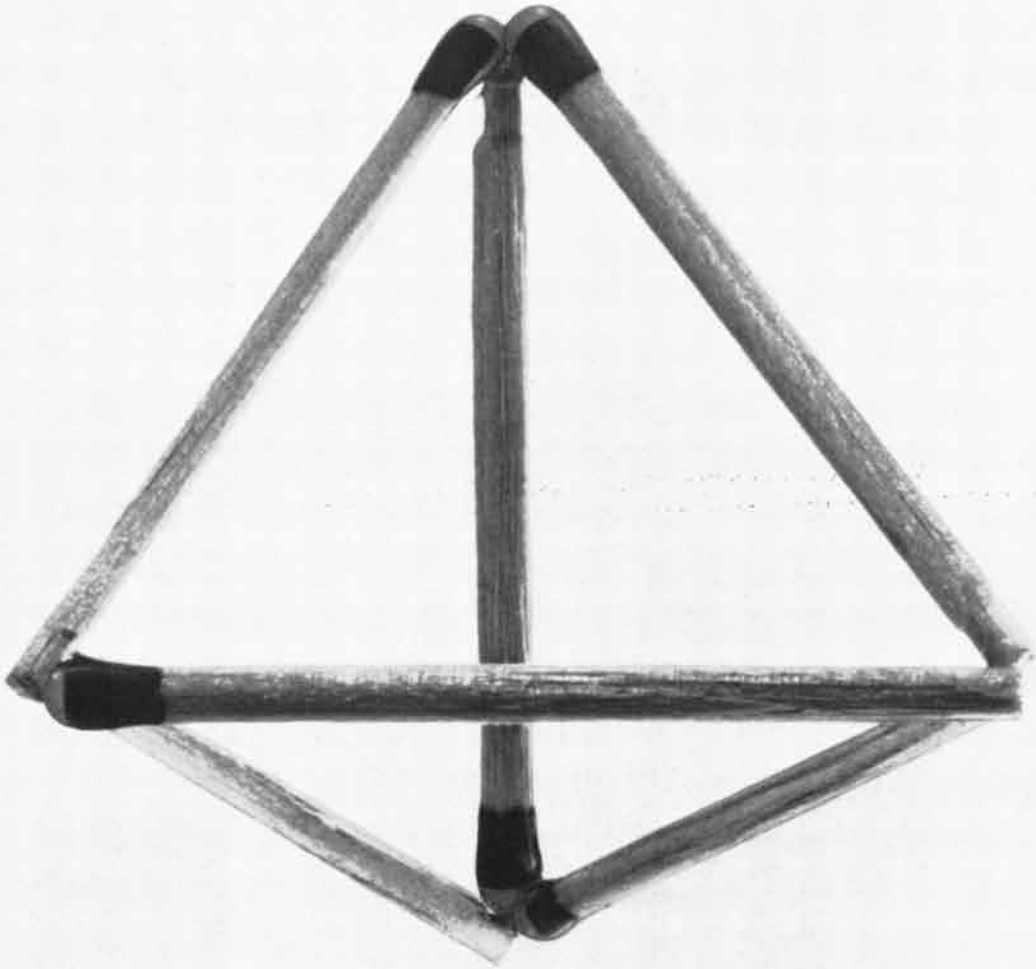
Is the sum correct?

the humanoids on Planet X to have hearts on their left sides.

Electrical and magnetic experiments are of no help. It is true that they show asymmetries (e.g., the "right-hand rule" for orienting a magnetic field surrounding a current), but it is only convention that decides which pole of a magnet is called "north." If we could communicate to Planet X what we mean by a "North Pole," the problem could be solved; unfortunately there is no way to do this without first having a common understanding of left and right. We could easily transmit pictures to Planet X by means of pulsed codes, but without agreement on left and right we could never be sure that their equipment was not reproducing the pictures in a form that was the reverse of ours.

It was in December, 1956, that the first experiment violating the law of parity was performed [see "The Overthrow of Parity," by Philip Morrison; SCIENTIFIC AMERICAN, April, 1957]. Certain "weak interactions" of particle physics were found to show a preference for one type of handedness regardless of the North Pole–South Pole convention. Sending the details of such an experiment is the only way known at present by which we could communicate to Planet X an unambiguous operational definition of left and right, clockwise and counterclockwise, the North and the South Magnetic Pole, or any other distinction involving handedness.

It should be added that if Planet X were in another galaxy, the problem would remain unsolved. The other galaxy might be made of antimatter (matter made of particles with reversed electrical charges). In such a galaxy the handedness of the weak interactions would probably be reversed. If we did not know the type of matter in the other galaxy (and light from it provides no clue), parity-violating experiments would be valueless in communicating the meaning of left and right.



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For some uses, a ten-contact connector the size of an Idaho potato will do just fine. In others, ten connections must be squeezed into a space no bigger than a jelly bean. Still other applications have unique requirements that relate to environment or mating force—even the technical skill of the operator.

WHY WE DO IT

We make a lot of different rack and panel connectors because it takes a lot to satisfy the wide range of applications.

For example: the Amphenol Blue Ribbon® rack and panel connector is widely used in "blind" mating applications. Part of Blue Ribbons' popularity is due to the fact that they mate with a smooth and gradual wedge-like force. Because they mate so smoothly, the "feeling" of correct alignment is unmistakable.

Another advantage of the Blue Ribbon design is the wiping action that occurs as connectors mate. Each time Blue Ribbons are mated, contact surfaces are wiped clean. Combine wiping action with high mated contact pressure, and the result is an extremely low-resistance connection.

THINKING SMALL?

As fine a connector as we know the Blue Ribbon is — it's just not right for the real tiny stuff. Thus, as miniaturized electronic equipment became popular, Amphenol engineers developed the Micro Ribbon®—a rack and panel connector utilizing the ribbon contact principle, but in as little as one-half the space. Further development produced a circular Blue Ribbon connector which crammed 50 contacts into a diameter just under 3 inches.

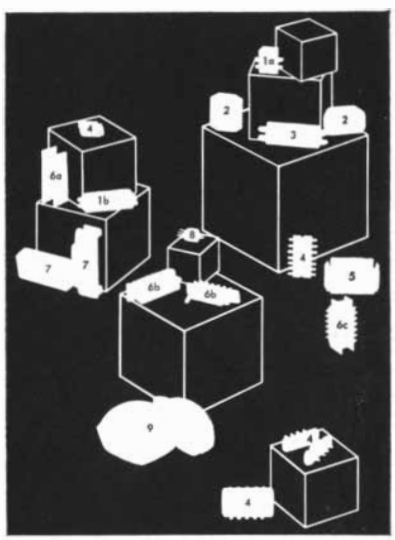
Also, there's the question of terminating rack and panel connectors. Often, confined quarters or complex wired harnesses can tax the dexterity of even the most skilled worker.

To solve this problem, Amphenol engineers developed rack and panel connectors with Poke-Home® contacts. Poke-Home contacts make it possible to terminate conductors independent of the connector. Contacts are crimped, soldered, or even welded to conductors, then inserted into the connector. Besides simplifying assembly, Poke-Home contacts can be easily removed *after* assembly should circuit changes or repairs later become necessary. Needless to say, Amphenol rack and panel connectors with Poke-Home contacts (Min-Rac 17®, 93 and 94 Series, for example) are popular items with engineers who are forced to think small, spacewise.

BEATING THE ELEMENTS

There's a need for environmentally resistant rack and panel connectors, too. High performance aircraft, missiles and space craft led to the development of Amphenol 126 and 217 Series environmentally sealed rack and panel connectors. (The 217 offers the added feature of Poke-Home contacts.) Other Amphenol rack and panel connectors can accommodate coaxial connectors; many can be supplied with hermetically sealed contacts. There are rack-to-cable connectors available in every series. There are super-economy types and super-reliable types.

So, when you have a rack and panel connector problem, contact an Amphenol Sales Engineer (or an authorized Amphenol Industrial Distributor). With the broadest line of rack and panels in the industry—if he can't solve it, no one can. If you prefer, write directly to Dick Hall, Vice President, Marketing, Amphenol Connector Division, 1830 South 54th Avenue, Chicago 50, Illinois.



Amphenol connectors shown on the opposite page are: **1**—Min-Rac 17 with (a) crimp-type contacts and (b) solder-type contacts **2**—94 Series **3**—Micro-Ribbon **4**—126 Series Rectangular **5**—93 Series **6**—Blue Ribbon with (a) barrier polarization, (b) pin polarization and (c) keyed shell and barrier polarization **7**—126 Series "CNI" **8**—126 Series Hexagonal **9**—Circular Blue Ribbon

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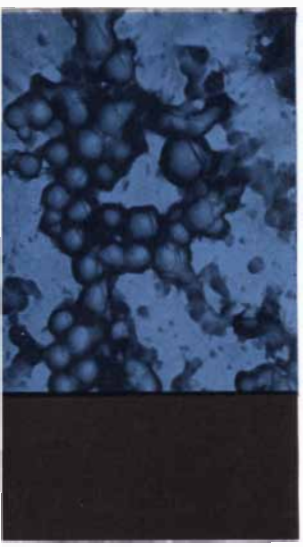
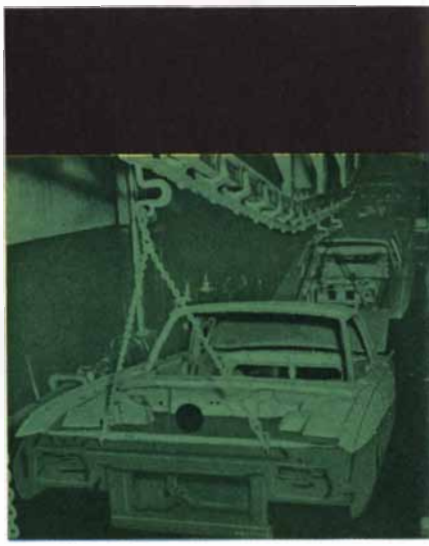


1 Particle size of high solids latex resin emulsion in the Glidden water-reducible primer is kept below 0.3 micron. This assures maximum dispersion of weather-protective resins, producing low-viscosity primers suitable for dipping, flow-coating, and spraying.

2 To make sure that Glidden-developed water-reducible primers would withstand corrosive road chemicals, test panels were exposed for 500 hours to severe 5% solutions in the Glidden lab salt-spray cabinets.

3 To satisfy exacting coating standards, Glidden produces its own resins in latest-type universal reactors. Here, technician checks sample of resin for water-reducible primer... one of more than 100 tests made between initial production and final tank-wagon shipment.



4 Glidden field technicians assist the automobile finishing-line people in adjusting speed of dip-tank travel, and bake-oven temperature to produce ideal preprimer and primer coats.

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THE AMATEUR SCIENTIST

How to study the diffusion of liquids and build a sensitive exposure meter

Conducted by C. L. Stong

When you drop a piece of hard red candy into a glass of water nothing much seems to happen for a minute or two. Then, as the sugar dissolves, pinkish color diffuses into the neighboring water. The process appears to be gentle and, as an experiment, rather dull. But close examination discloses a more interesting situation. At room temperature water is in a state of intense agitation. Its molecules, darting at random, continuously batter the lump of candy from every possible direction. Occasional impacts dislodge bits of sugar and coloring matter from the lump and send them skittering first one way and then another into the maelstrom of colliding molecules. In obedience to the laws of chance the dislodged particles wander farther and farther from the lump. Within a matter of hours color will have spread throughout the lower part of the glass. Although the dissolving molecules are heavier than those of water, the force of the impacts easily overcomes the force of gravity and the color moves upward. Within a week or so the water at the bottom of the glass will have turned a deep red that fades uniformly to a light pink at the top. Given enough time the color—and the sugar—will diffuse evenly throughout the water, but this would require months or even years.

Most liquids similarly diffuse into each other at a snail's pace when measured by the minute hand of a clock. Yet the rate is high enough to account for much of the vital mixing that goes on in the universe, including the transport of fluids across the microscopic distances that are encountered inside the tissues of plants and animals. The rate at which diffusion proceeds is determined by such factors as the absolute temperature of the diffusing fluids, their viscosity and the relative size of their constituent molecules.

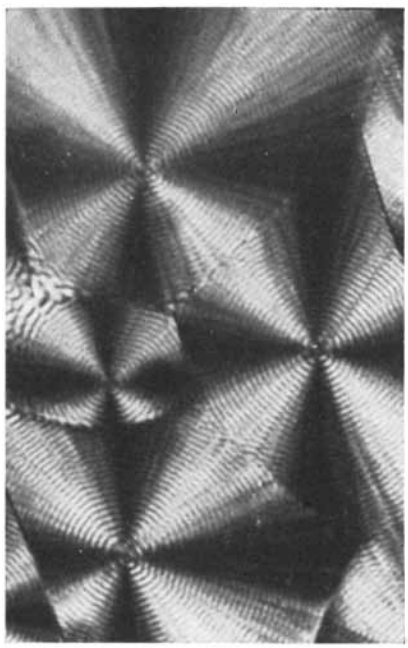
In 1905 Albert Einstein wrote an equation that relates the size of molecules to the rate at which they diffuse. Few amateurs have used the theory for exploring molecular migrations, because the classical apparatus for investigating the diffusion of liquids, the Tiselius cell, includes such hard-to-make parts as a rectangular glass vessel with parallel and optically flat sides, an interferometer, and an optical train of lenses and filters under the control of precision micrometers. Moreover, the Tiselius cell is tedious to use: the observations may extend over several hours or days, depending on the size of the diffusing molecules.

Last year an elegant solution to the problem of measuring diffusion rates was devised in the form of a simple and inexpensive apparatus by Yasunori Nishijima of the University of Kyoto in Japan and Gerald Oster of the Polytechnic Institute of Brooklyn. Their device consists of a microscope of the kind that sells for about $15, a pair of silvered microscope slides, a source of green light and a microscope camera attachment that can be built at home. The apparatus is as powerful as it is simple. Within five minutes one can determine the rate at which diffusion proceeds, the distance that a molecule migrates during a specified interval and the approximate radius of the molecule. Or, if the radius is known, one can confirm such values as Avogadro's number and the viscosity of the diffusing fluids.

Nishijima and Oster explain that the speed and economy of their technique derive from the fact that it is the average of the square of the distance over which a particle randomly wanders during diffusion that is proportional to the time of its travel. In other words, a particle that spends three minutes diffusing a distance of one millimeter requires nine minutes to wander two millimeters away. Expressed in still another way, the time varies inversely with the square of the distance traveled. Accordingly when one uses a microscope to measure the distance that a particle diffuses, the time required for observation is divided by the square of the microscope's magnifying power. For example, a microscope that magnifies the apparent size of the diffusing fluids by a factor of 50 reduces the time scale of observation by a factor of 2,500. This means that hours spent in observing diffusion processes with a Tiselius cell become seconds with Nishijima and Oster's microdiffusion apparatus. In addition to collapsing the time scale the microdiffusion apparatus requires very small amounts of specimen materials. Moreover, one can measure diffusion processes that proceed over microscopic distances to which the Tiselius cell is insensitive, such as those associated with living cells and the growth of synthetic fibers.

As with the Tiselius cell, the microdiffusion apparatus senses the movement of migrating particles by their effect on the optical properties of the solution into which they diffuse. The speed with which light travels through water is reduced by the addition of most solutes. This can be demonstrated by holding a glass of water up to a light and pouring a thick sugar solution into the water. A pattern of turbulence will be seen resembling the "heat waves" that rise above a hot radiator. The same effect on a smaller scale can be observed by placing a drop of clear water on the slide of a microscope, lighting the stage with a lens focused on a pinhole of light and adding a second drop of heavy sugar solution so that the two make contact.

A far more striking effect is observed when the drops are placed on a microscope slide that has been partially silvered and are covered by a similarly silvered slide that rests on a cover glass at one end. Because the slides are separated at one end the space between them has the form of a thin wedge. If the wedge, when dry, is lighted from the bottom, colored fringes will appear across the upper slide that resemble Newton's rings, the concentric circles of rainbow colors that can be seen if one sets a watch glass on a piece of plate glass. Optically the two effects are iden-



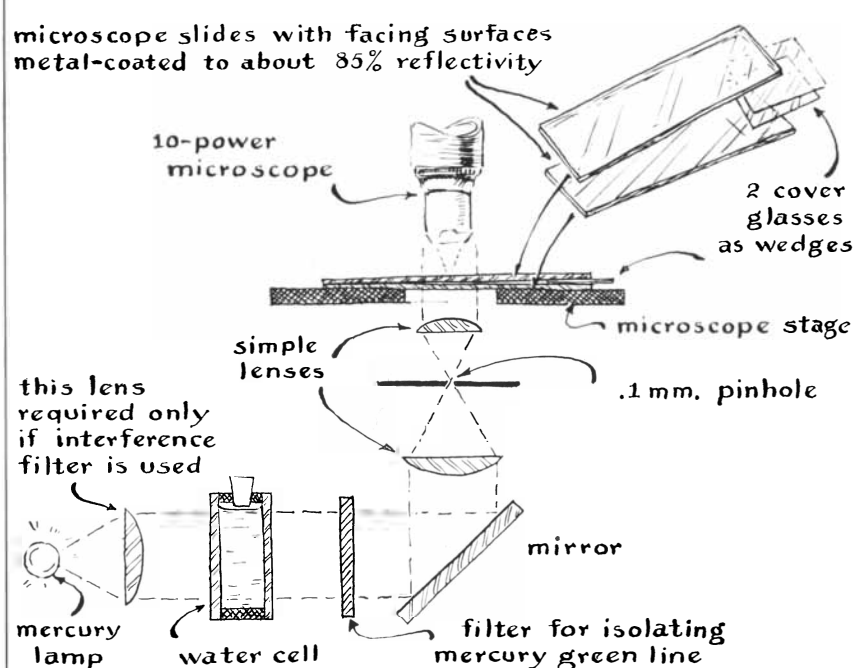
tical. Light waves transmitted by the bottom microscope slide are partially reflected by the silvering on the upper slide. Depending on the thickness of the wedge and the wavelength of the light, the light waves tend either to reinforce or to cancel each other. But the thickness of the wedge changes uniformly throughout its length. As a result octaves of color, created by the interference, appear as transverse fringes.

If the wedge contains a medium other than air—a medium that retards the speed of light more than air does—the fringes will crowd closer together as though the wedge had been opened somewhat. A wedge of water, for example, shows more fringes than one of air, and one of sirup shows still more. In short, an interferometric wedge can detect differences in the refractive properties of fluids. Nishijima and Oster took advantage of this effect not only to measure the differing refractive properties of two fluids but also to observe changes in refraction when one fluid diffuses into another. By observing changes in refraction they could investigate the process of diffusion.

Rainbow-colored fringes are not easy to distinguish because the colors of one fringe merge with those of neighboring fringes. If the interferometric wedge is illuminated by light of a single color, however, the fringes appear as alternately dark and light bands of the selected color, particularly if the light proceeds from a narrow source such as a pinhole.

A pair of silvered microscope slides lighted by the green rays of a mercury lamp constitute the essential element of Nishijima and Oster's apparatus. Their lamp is a General Electric Type H-100-A38-4, which operates from a Type 9T64Y3518 ballast. The lamp and ballast are priced at $12.75 and $16.50 respectively. The lamp is mounted at the focus of a lens about two inches in diameter that has a focal length of about two inches. The bundle of parallel rays that proceeds from the lens first passes through a water-filled box with glass sides, which absorbs heat radiation, and then through a filter that absorbs all colors except the desired green. (The filter is a Corning Type 4-64 two inches square; its cost is $4.10.) The filtered light falls on the flat side of the microscope mirror and is directed upward to a condensing lens that brings the rays to focus on a pinhole about .1 millimeter in diameter. This lens should have a diameter of about an inch and a focal length of a little less than an inch. The light is then made parallel again by a small lens, with a diameter of perhaps half an inch and a focal length of about half an inch, above the pinhole. Simple lenses can be used throughout. Color-corrected lenses, although satisfactory, are not needed because the light is monochromatic. The beam from the small lens above the pinhole proceeds through the interferometric wedge and into the objective lens of the microscope.

Brackets for supporting the lenses, the



Schematic arrangement of microdiffusion apparatus

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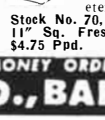

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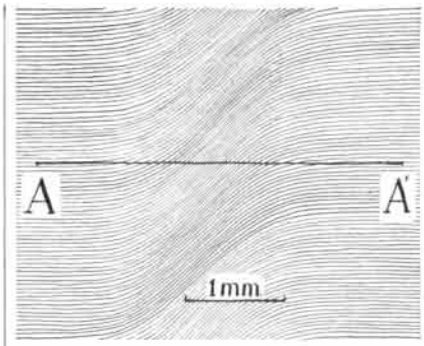

Diffusion interference fringes

water cell and the filter can be improvised from scrap sheet metal and attached to a firm wooden base, on which the microscope also rests. Ideally the microscope slides should be silvered so that about 85 per cent of the light is reflected and 15 per cent transmitted, but coatings that reflect as little as 50 per cent or even less will work. Microscope slides specially silvered for use in making interferometric wedges can be bought from Henry Prescott of Northfield, Mass., for $3 a pair. The complete optical train is shown in the illustration on page 172.

The technique of using the apparatus is best demonstrated by a specific example. Assume that the experimenter wants to know the rate at which granulated sugar diffuses into tap water and to measure the radius of the sugar molecule. A 10 per cent (by weight) sirup is made up and a silvered slide is placed on the stage of the microscope with the metalized side facing upward. A single drop of sirup is then placed in the center of the slide and a drop of tap water is added about an eighth of an inch away. A stack of two cover slips is then placed on one end of the slide, and the second slide, with its metalized side down, is placed gently on top to make the wedge. The time to the nearest second and the temperature of the room are recorded at the instant the drops come together.

After the mercury lamp has warmed up and reached normal operating intensity, select for observation a portion of the field where the sharp boundary between the liquids is at right angles to the fringes. Replace the eyepiece with a film holder and bring the image of the fringes to focus in the plane of the film. If a special microscope camera is not at hand, it is not at all difficult to improvise one [see "The Amateur Scientist"; SCIENTIFIC AMERICAN, February, 1961]. Make an exposure after about three minutes, noting the time to the nearest second. The resulting photograph should

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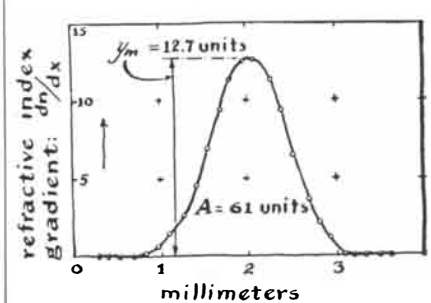
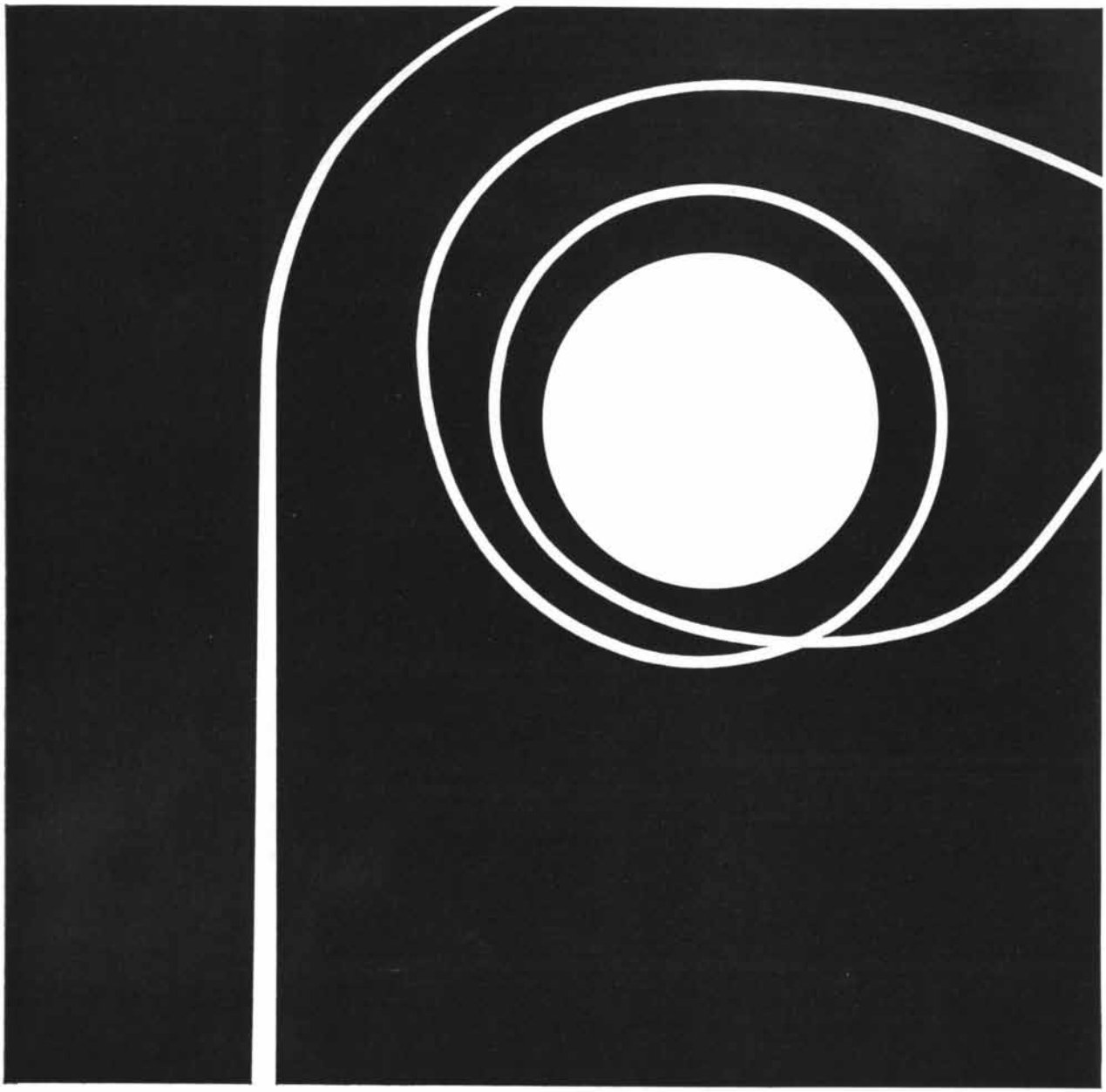
resemble the illustration on page 174.

The fringes that correspond to the bulk of the two liquids appear as straight lines at the sides of the photograph. The refractive index across the boundary of the drops varies continuously and causes the fringes to curve at the center of the photograph. Each fringe, whether it is straight or curved, represents a contour line of constant optical distance. A line, *AA'*, drawn parallel to the straight portions of the fringes in the region of constant refraction represents a line of constant geometrical thickness across the wedge. The change of the optical path along this line depends solely on the change of refractive index along the line. Hence the closer the fringes that cross the reference line, the greater the variation of refractive index along the line. The variation can be evaluated by dividing the reference line into any convenient number of equal parts and counting the fringes that cross each part. The resulting values are plotted vertically against the divisions of the reference line and joined by a smooth curve, as shown in the graph reproduced below. The value of the magnification is established by substituting a metric scale for the silvered slides on the microscope stage and drawing a line on the photograph that is equal in length to the distance between a pair of magnified millimeter graduations.

A numerical term, the constant of diffusion, is then derived from the graph. First, the area enclosed beneath the bell-shaped curve is measured. A planimeter can be used, or the measurement can be approximated closely by placing a sheet of translucent graph paper ruled with rectangular co-ordinates over the graph and counting the squares and fractions of squares that are included within the curve. The maximum height is determined by counting the column of squares that runs up through the top of the curve. In the case of the curve shown below, which corresponds to the fringes illustrated on page 174, assume that the height measures 12.7 squares



Graph of diffusion refraction pattern



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and the area amounts to 61 squares. Assume also that the diffusing drops were in contact 180 seconds when the exposure was made and that the temperature of the room was 25 degrees centigrade.

These four figures representing the height and area of the curve, the time and the temperature are substituted in the top equation on this page, which relates the several factors that determine the diffusion constant. The square of 61 (or 3,721) divided by $4 \times 3.14 \times 180 \times 12.7 \times 12.7$ (or 364,644) yields the quotient: 1.09×10^{-2}. Next, a scale-correction factor must be applied to transform the arbitrary dimensions of the graph paper into units of the centimeter-gram-second system. Comparative measurement discloses that 4.5 squares of the graph paper equal the length of the magnified scale representing one millimeter on the silvered slides. The metric height of the curve is therefore equal to 12.7 divided by 4.5 or 2.83 millimeters (.283 centimeters). This dimension is squared in the equation, so the quotient, 1.09×10^{-2}, must be multiplied by the square of the scale-correction factor expressed in centimeters: $1.09 \times 10^{-2} \times (1/45)^2 = 5.4 \times 10^{-6}$, the value of the diffusion constant in square centimeters per second for a 10 per cent solution of sucrose diffusing into tap water.

The equation for computing the radius of spherical molecules [*bottom equation on this page*] is just as simple to evaluate. First, the absolute temperature is found by adding the temperature of the room in degrees centigrade to 273. The result, in the example under discussion, is 298 degrees Kelvin. The absolute temperature must then be multiplied by Boltzmann's constant (the gas constant, 8.3×10^7, divided by Avogadro's number, 6.03×10^{23}): 1.38×10^{-16}. The equation also includes a term for the viscosity of water, a property that varies with temperature. Reference texts list the viscosity of water at 25 degrees C. as 8.9×10^{-3} poise. Performing the arithmetic, $1.38 \times 10^{-16} \times 298$ divided by $6 \times 3.14 \times 8.9 \times 10^{-3} \times 5.4 \times 10^{-6}$ gives the quotient: 4.5×10^{-8} centimeters, or 4.5 angstrom units—a reasonable value for the average radius of the sugar molecule.

It is also possible to compute the range through which diffusing molecules migrate by applying Einstein's theory of Brownian movement. The theory states that the root mean square displacement equals the square root of twice the product of the diffusion constant multiplied by the elapsed time to the observation. At the end of the first second sugar molecules will have migrated into the water a distance equal to the square root of $2 \times 5.4 \times 10^{-6}$, or 3.2×10^{-3} centimeters. After 180 seconds the increased distance will equal the square root of $2 \times 5.4 \times 10^{-6} \times 180$, or 4.4×10^{-2} centimeters.

$$D = \frac{A^2}{4\pi t (y_m)^2}$$

where:

D is the diffusion constant

A is the area under the gradient curve

y_m is the maximum height of the curve

t is the interval in seconds between boundary formation and the moment of observation

Equation for diffusion constant

Every now and again in the course of making an experiment the need arises for exposing photographic negatives under lighting conditions that are beyond the range of inexpensive exposure meters. The problem is usually solved by the time-honored technique of cut and try. This solution served R. B. Stambaugh of Chillicothe, Ohio, well enough for several years, but after making an inventory of his scrapped negatives last summer he decided to try for a less costly method of determining exposures. The result is the transistorized exposure meter illustrated on page 180.

"Today's high-speed photographic films and large-aperture lenses," he writes, "have made it possible to take pictures at 'available light' levels much too low for the average inexpensive light meter to handle. Sensitive exposure meters of wide range and high accuracy are commercially available—if one is willing to pay as much for them as for the camera—but they are hard to use and invite all sorts of error.

"After mulling over the problem of

$$a = \frac{kT}{6\pi\eta D}$$

where:

a is the radius of a spherical molecule

η is the viscosity of the medium

T is the absolute temperature

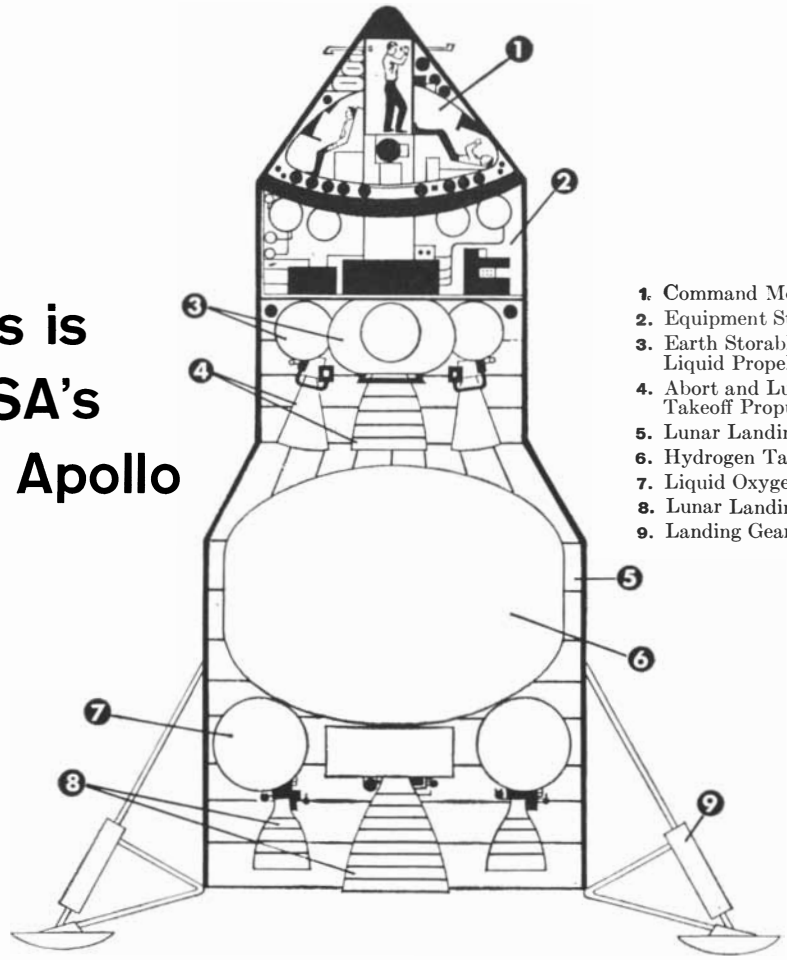
k is Boltzmann's constant, which is $\frac{R}{N}$

R is the gas constant

N is Avogadro's number

Equation for radius of molecules

This is NASA's Project Apollo



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4. Abort and Lunar Takeoff Propulsion
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6. Hydrogen Tank
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8. Lunar Landing Propulsion
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The project will proceed in three stages. Before the culminating voyages to the moon, three-man Apollo spacecraft will first orbit the earth for as long as two weeks. Next, spacecraft will head out toward the moon, circle it and return to earth.

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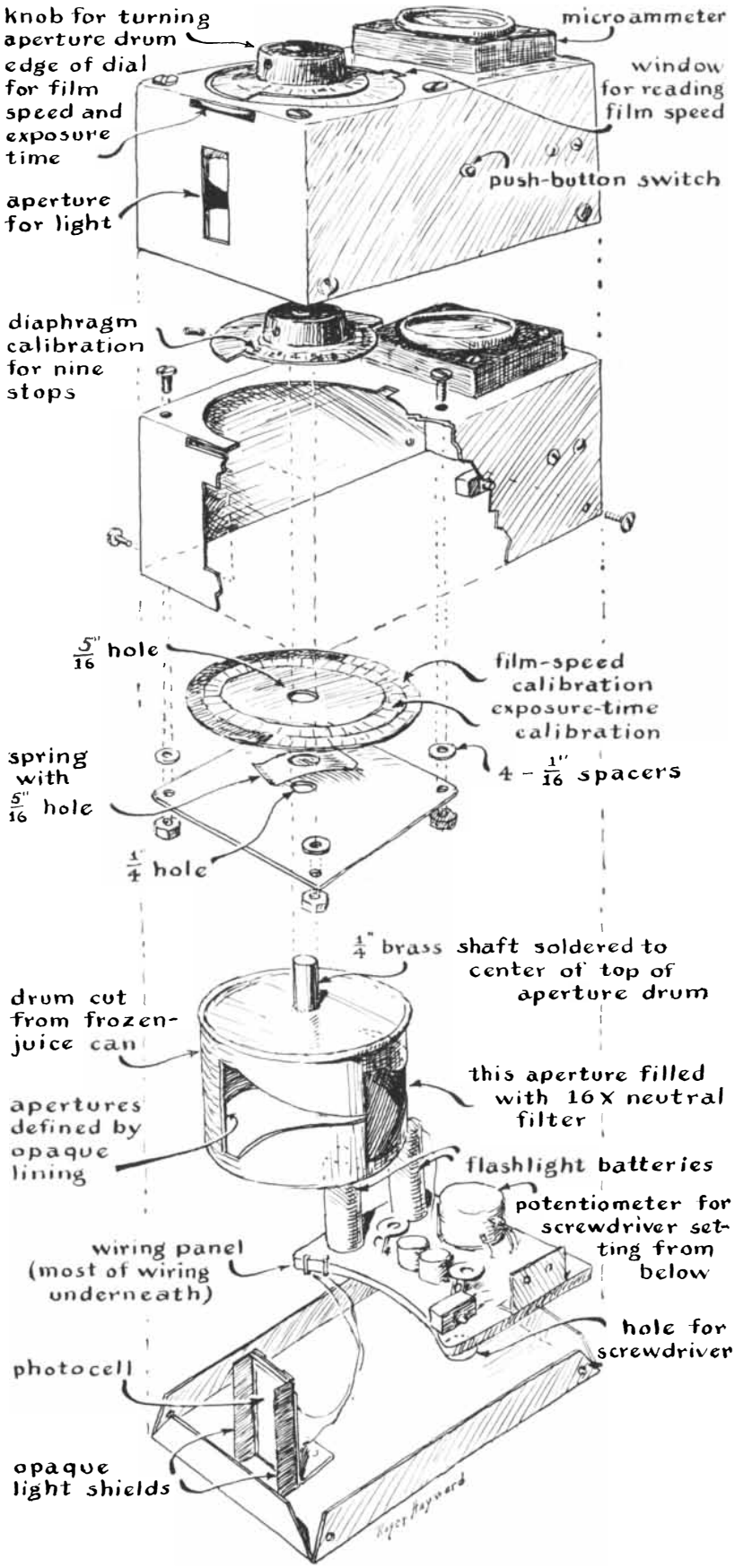


Details of transistorized exposure meter

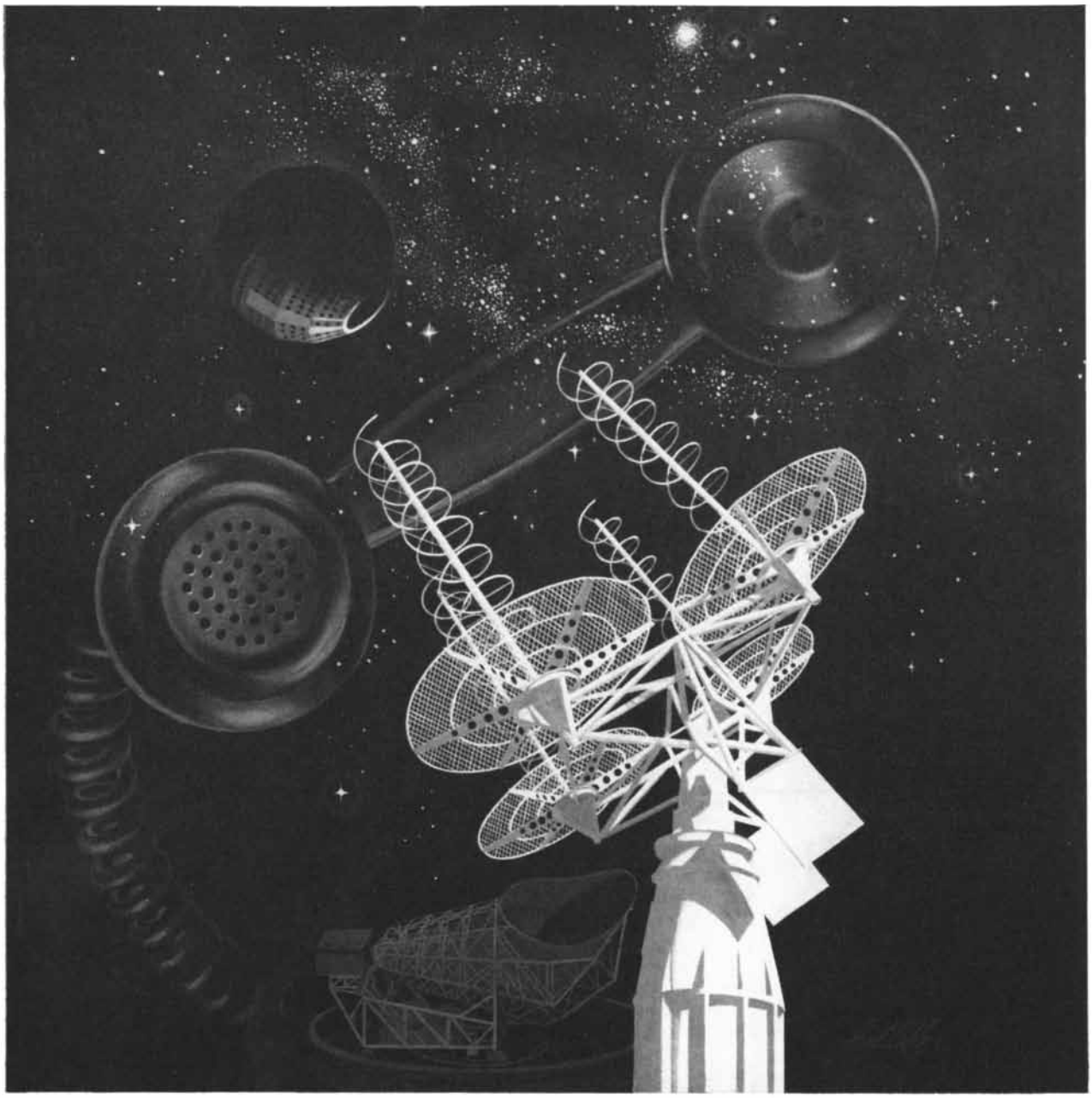
meter design for some months I eventually hit on an apparatus for measuring light that has proved to be reliable, adaptable to extreme ranges of measurement and inexpensive to build. The device consists essentially of a photosensitive cell, enclosed in a drum that has a slot of variable width to admit light, and a meter for indicating amplified cell current. Turning the drum shifts the position of the variable slot and admits more or less light to the cell. The drum is adjusted until the meter indicates a predetermined value of current. At this adjustment the cell always 'sees' the same amount of light and the meter always indicates the same value of current, regardless of the intensity of the external light.

"Adequate sensitivity is provided by a two-transistor amplifier arranged in a balanced bridge circuit, as shown in the accompanying diagram [*top of page 182*]. The bridge circuit reduces the effects of temperature and changes in voltage as the batteries age. The null balance principle of always reading a predetermined value of current eliminates the effect of nonlinearity in the response of the photocell to light and nonuniform amplification by the transistors.

"The entire assembly, including the miniaturized amplifier, drum and photocell, is housed in a box of sheet aluminum that is four inches long, three inches wide and two inches high.

"The slot in the drum is made by cutting a mask from a strip of opaque cardboard that fits smoothly around the juice-can drum. Ten areas are marked off on the strip. The width of each rectangular area is determined from the size of the aperture drum and the markings of the *f*-number dial. In my instrument, the dial covers nine *f* numbers in a 180-degree turn, or 20 degrees per *f* number. Twenty degrees corresponds to .37 inch on my drum, which is 2⅜ inches in diameter. One cannot easily hand-cut a slot much narrower than about 1/16 inch with the required precision. So I joined two tapered slots end to end and covered the second one with a 16X filter made from exposed film. This stunt enabled me to increase the width of the last five rectangles 16-fold. It is not necessary to cut the slots as a series of sharp steps; one needs only to draw a curve that connects the midpoints of the rectangles as shown in the accompanying illustration [*bottom of page 182*].

"The filter of desired density was made by taking 16 'pictures' of a blank wall while gradually increasing the exposure. A hole with an area one-sixteenth as large as the sensitive area of my sele-



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Example: Bell System's TELSTAR

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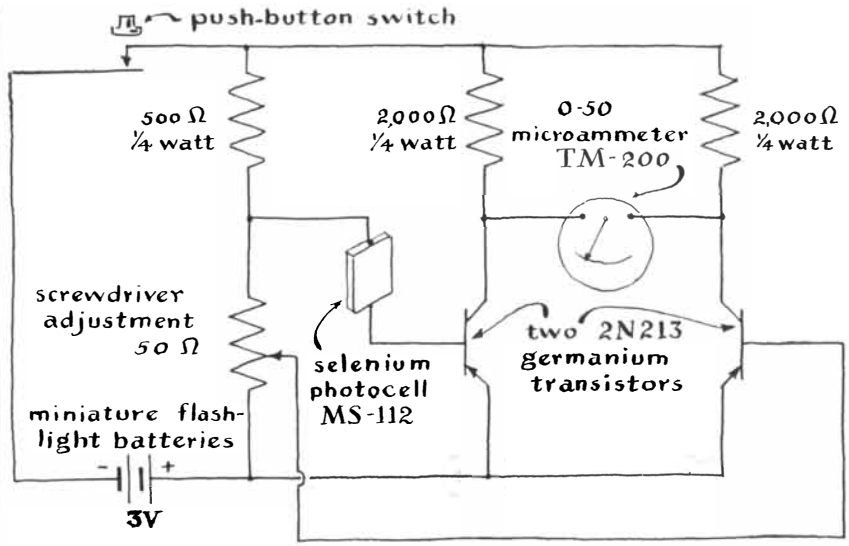


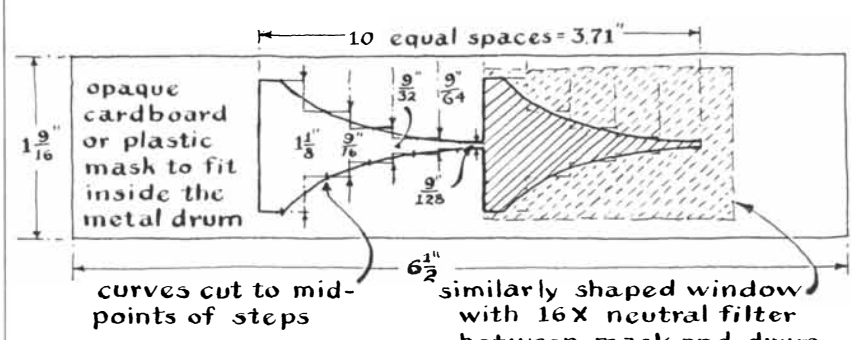
Circuit diagram of exposure meter

nium cell was then cut in a piece of opaque paper and used to mask the cell. The masked cell, connected to a microammeter, was exposed to the lamp of my enlarger at a distance such that the pointer of the meter was deflected to half-scale. The paper mask was then replaced by the film. The film was shifted until an area was found that deflected the meter to half-scale. This area was selected as the 16X filter.

"After assembly the meter was calibrated against a good commercial exposure meter by turning the knob until the microammeter read half-scale (25 microamperes) while both instruments were pointed toward a flat-lighted piece of white cardboard. The correct shutter speed, *f* number and film speed indicated by the commercial meter were transferred to the homemade meter by loosening the setscrew of the dial and, without disturbing the position of the aperture drum, rotating the dial until the *f*-number scale was opposite the proper shutter speed. When the setscrew in the knob was tightened, the meter was calibrated for every light level within its range of sensitivity.

"The dark zero balance normally will stay in adjustment unless there is an appreciable change in temperature, such as going from indoors to outdoors in winter. Zero balance is checked simply by pressing the 'on' button while holding one hand over the front opening. Balance is established by adjusting the potentiometer with a screwdriver until the meter reads zero when the cell is in darkness.

"It is apparent that the sensitivity of the meter can be increased by substituting a more sensitive photocell for the one used in this design, by increasing the amplification or by changing both the cell and the amplification. I am now testing a circuit that uses a cadmium sulfide cell, for example, which appears to be many times more sensitive than either the selenium or silicon type. The design invites other modifications, particularly with respect to miniaturization."



Variable-width slots for exposure meter

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In hilly Tacoma, shoppers now can go from one street level of stores to another without taking a step. Pedestrian traffic has increased 40%. Big increase in business, too! Chicago baseball fans stand still to reach grandstand seats. Outdoors and indoors, modern sidewalks, ramps and stairs-without-steps are flat-surfaced and safe . . . lower in cost, and with fewer moving parts than today's escalators.

A most important part is Morse HY-VO®, a Chain Drive developed by the Morse Chain Company, a subsidiary of Borg-Warner. HY-VO, a trouble-free component, transmits smooth, even power to the belt . . . eliminates noise, pulsation and vibration. Such wonders as these sidewalks, with Borg-Warner components, are another example of better products through creative research and engineering.

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BOOKS

Concerning Edward Teller's account of the nuclear age

by Albert Szent-Györgyi

THE LEGACY OF HIROSHIMA, by Edward Teller with Allen Brown. Doubleday & Company, Inc. ($4.95).

Edward Teller is an outstanding scientist who has made many valuable contributions to physics. I would accept his opinions about this science with the utmost confidence. During World War II he turned to weaponry and nuclear technology, and he has become, with his remarkable versatility, a leading authority in this field. I would accept his opinions about these applications of science with the same confidence. The main theme of the present book, however, is from neither of these two fields. The book is essentially a vehicle for Teller's political ideas in their relation to armaments.

Science and technology produce new tools and release new forces, but the question of what use these tools and forces are put to—construction or destruction—has little to do with science or technology proper, and so Teller's ideas and opinions in this field are as good (or as bad) as yours or mine.

One of the most puzzling characteristics of the human mind is its ability to produce coherent thoughts in one field and to be irrational in another, once biased by sentiment, ambition or interest. Louis Pasteur, for instance, who was one of the clearest scientific thinkers the human species has produced, said himself that in matters of religious thought he was on a level with the peasant women of Brittany. I have often had to smile at the childish nonsense about communism uttered by some leading English physicists, who were sentimentally biased in favor of this doctrine, about the application of which I have had a firsthand knowledge.

Teller's political opinions seem to be biased by his hatred for the Russians and his love for his children, the H-bombs, whose father he is said to be. He would like to see more bombs and better bombs, bigger and deeper shelters. He would like to see our children brought up underground and in underground schools. What gives undue weight to his opinions is that he has become the "voice" of the military-industrial complex, with its enormous vested interest in political tension and distrust, its political influence and virtually inexhaustible means. President Eisenhower sounded a warning in his "farewell address" about this complex, which amplifies the voice of Teller and magnifies his figure, while the public takes the political opinions of Teller with the confidence and homage due only to Teller the scientist or military technologist and not Teller the politician and strategist. All this makes Teller's book recommended reading for those who would like to see a world of hatred and distrust, with more bombs, bigger and better bombs, deeper shelters, with mankind marching under the deepening shadow of mushroom clouds. Those who would like to see the U.S. find its idealistic self again and assume the moral leadership of our fragmented world, and who would like to see mankind marching toward a brighter future, will put this book aside with a saddened heart.

The book is well written and easy to read. The authors try to discuss all the problems of relations between the U.S. and the U.S.S.R., and to give all the answers. They forget only one possibility: an honorable peace.

The first chapters of the book deal with the story of atomic energy and armaments and make interesting reading, flavored by anecdotes and firsthand personal experience. Nonetheless, the reader is left, so to speak, empty-handed, not being told what the problems really were. Here the authors were evidently limited by secrecy. Some of the later chapters, such as the one on education, deserve full attention, although I prefer that education be discussed for its own sake, without an edge turned against the Russians.

In at least one way the authors are guilty of an unscientific attitude. They deal with all their problems from the standpoint of current technology. They seem to forget that the present is only a point on a rapidly rising curve. This curve expresses itself, for instance, in the steady growth of the destructive power of nuclear bombs, which has increased 2,500-fold since Hiroshima, a rate of growth that shows no sign of slowing down. The authors also make the improbable assumption that in a world conflict there will be a winner and a loser. To support their argument they give a distorted picture of the biological effects of ionizing radiation, and they deal with world conflict as though it were a storm that quickly blows over, leaving social structures unchanged and the atmosphere cleared, with every problem solved.

So far as I am aware, Teller's political opinions do not represent those of the great majority of scientists. Science is the fruit of the work of a group of people, who form a unified intellectual community that knows no boundaries in time or space and knows no limitation by color, creed, race or passport. The basic moral rule of this community is uncompromising intellectual honesty, good will and mutual respect. Most scientists would like to see this spirit extended to political relations and wish for a wider human understanding that would mark the way toward higher levels of human existence. Some of us even believe that the formidable forces released by science can be handled without catastrophe only by the same mentality that created them. Teller sees the final solution in the establishment of a world government after a full democratic or communist victory. He seems unable to visualize a family of man with its temporary chasms bridged, and so he takes us back to the mentality of the religious wars, the problems of which must have seemed, in their time, as insoluble as ours.

Short Reviews

CONCEPTS OF MASS IN CLASSICAL AND MODERN PHYSICS, by Max Jammer. Harvard University Press ($6). A beau-

tifully wrought exposition of the historical development of the concept of mass. Of first importance in all branches of physics and an essential tool of scientific thought, this concept has in its long, troubled and exciting career undergone astonishing transformations. The origins of the word itself are uncertain. The Latin *massa*, from which the modern word "mass" is derived, meant a lump of dough or paste (the notion of inert lumpishness still accords with our unsophisticated intuition of mass); but as forerunners of the Latin word one must consider either the Greek *maza* (barley cake or bread) or the Hebrew *mazza* (unleavened bread). Philosophers, scientists, even theologians began early to draft the word for their own service; in this connection it is interesting to learn that the first explicit definition of the *concept* of mass, in the sense of *quantitas materiae*, originated "from a logical analysis concerning the Eucharistic transubstantiation of the Holy Bread." Jammer carries his story through many strange turns and twists, from ancient thought and the Neoplatonic concept of inertia to modern speculations on mass-energy equivalence and the concept of mass in quantum mechanics and field theory. One observes the constant sharpening and refinement of the concept: in medieval thought it was *quantitas materiae;* under Kepler's hand it became inertial mass; under Newton's, mass was turned into the carrier of *vis inertiae*, and "quantity of material" was proportional to it. Leonhard Euler put the finishing mathematical touches to this line of development. In the 19th century mathematicians and physicists had a go at further reappraisals in an attempt to remove conceptual difficulties that remained in spite of the fact that Newtonian dynamics had succeeded in "alienating" the concepts of mass (as well as force) from their metaphysical relation. Ernst Mach, James Clerk Maxwell and Max Abraham were among the proponents of vigorous new ideas; the gravitational and electromagnetic concepts of mass were a product of these labors. A little later Einstein's general theory of relativity played a major role in robbing mass of the eternal, solid, changeless conceptual features that had so long been attributed to it. "Mass" in relativity is merely the result of certain operations, the definitions or specifications of which are intimately connected with spatiotemporal considerations.

So far has abstraction traveled; so ethereal and insubstantial has the lump become. In modern physics and modern philosophy, thanks to field theories, mat-

ter is a ghost, which in some guises is "substantial," in others a blithe spirit; matter "does not do what it does because it is what it is, but it is what it is because it does what it does." Still, with all the refinements and the precision, all the whittling away and the concerted effort of physicists and philosophers, mathematicians and logicians, the intricate concept remains elusive, has not yet been fully clarified. It is no less a source of headaches to the teacher of elementary physics than to the theoretician agonizing over field theory. Jammer has written a fine biography of an idea, which sheds light not only on the idea itself but also on the whole process of intellectual growth. For this task, as already shown in his monographs on force and space, he is uniquely qualified: he combines the skills of a physicist with philological and historical training, philosophical perspective and a talent for lucid prose.

THE PAPERS OF THOMAS JEFFERSON: VOL. XVI, edited by Julian P. Boyd. Princeton University Press ($12.50). The 16th volume in this splendid series covers the period from November, 1789, to July, 1790. Jefferson has returned from France with his daughters and is confronted with the necessity of putting his personal affairs in order, especially the settlement of his private debts, and of deciding whether to accept Washington's bid to become Secretary of State. This he finally does, reluctantly, but having taken the office he throws himself into the work with his customary vigor and brilliance. The letters and papers of this period reflect Jefferson's crowded life, his intense interest in everything around him. He takes leave of friends in France; delivers a graceful address to his Albemarle neighbors; dispatches meticulous directions to his assistant in Paris on the packing and shipping of his possessions to Virginia, on procuring such items as wallpaper, renewing his subscription to the *Journal de physique*, buying stocks of Parmesan cheese, almonds and anchovies, getting hair "mattrasses" made, buying books, paying off his servants; concerns himself with every detail of how medals voted by Congress to American patriots should be executed and distributed; recommends the beginning of a coinage system; sends plants from Virginia to Madame de Tessé and receives rice seed brought back by Lieutenant Bligh of the *Bounty;* advises Washington on foreign affairs; passes on the Yazoo grants; takes the time—although how he found it is almost incredible—to write long, delight-

ful, gossipy reports to Virginia friends about the latest births, deaths, scandals, adulteries and related matters of New York high society; and, while suffering the agonies of a violent headache of six weeks' duration, draws up his famous paper on weights and measures. As always, he is incapable of being dull or unoriginal: everything bears his unmistakable mark—the trivia and the state papers, the chitchat and the political philosophy. The editors of this work are as tireless as Jefferson himself. Their commentary and notes, some of which are many pages long, are models of devotion, unflagging energy and accuracy.

JANE'S ALL THE WORLD'S AIRCRAFT, 1961–62, compiled and edited by John W. R. Taylor. McGraw-Hill Book Company, Inc. ($35). So far as one can now read the handwriting on the wall it appears that the airplane of the future will be a craft that will make no use of the air and will not be a plane. Meanwhile, however, the species is still active, proliferating, going faster and higher and receiving the earnest attention and a large part of the treasuries of the great nations of the world. *Jane's,* as usual, gives a full and accurate report of all this expensive stir. The 1960–61 edition was the largest ever; this one has 52 fewer pages but contains more information because the text has been set in seven-point type instead of the seven-and-eight-point mixture used in the past. Of the 959 half-tone illustrations, 531 are new. In addition to a comprehensive survey of piloted airplanes and other orthodox craft, *Jane's* has a wide assortment of information on such items as drones; side-wall-cushion vehicles; Goodyear's cozy Inflatoplane (which, packaged, can be shoved into a telephone booth); the Bartelsen Aeromobile (which seems to combine the worst features of an automobile and an airplane); the Bell Air Scooter (which has bicycle-type handlebars, is turned by shifting one's weight and is said, regrettably, to be operable by almost anyone after a few minutes' instruction); the NRA Air Carrier (a high-speed cargo and general utility air-cushion vehicle of the side-wall type that can do 50 miles per hour); the Denny S.O. 793 Hovership; the Little Joe booster; the Ranger lunar rough-landing space craft (guaranteed, if nothing else, to make rough landings); the Douglas MB-1 Genie nuclear-war-head unguided missile; the Wag Tail ballistic air-to-surface missile; the McDonnell GAM-72A Quail decoy missile; and a variety of other goodies. Colonel Glenn and his marvel-

ous little crib took off too late on their great adventure to make this edition.

DINOSAURS: THEIR DISCOVERY AND THEIR WORLD, by Edwin H. Colbert. E. P. Dutton & Co., Inc. ($7.50). A readable and comprehensive account by a foremost authority on these extraordinary reptiles that for more than 100 million years were lords of the earth. Ranging in size from creatures no larger than a chicken to majestic specimens 70 feet long and 40 feet high, dinosaurs populated a broad belt of the earth during the Mesozoic era from about 50 degrees north latitude to 30 degrees south. Colbert's book describes the different orders, suborders and families; the meat eaters and plant eaters; the bipeds and quadrupeds; the small-skulled and the large-skulled; the clumsy and heavy-boned and the graceful and light-boned. He tells about the discovery of dinosaur fossils and how these were painstakingly reconstructed to provide a clear picture of what the animals looked like. No less remarkable are the finds of dinosaur eggs, and of dinosaur footprints, some of which reveal to us incidents that took place 75 to 100 million years ago, when, for example, a carnivore stalked a herbivore, caught up with him and dined on him. In a concluding chapter Colbert reviews various conjectures as to the reason for the sudden (in the geological sense) and dramatic disappearance of the dinosaur. Many factors, it seems likely, conspired to extinguish the dinosaur population. Slow growth, longevity, small brains and especially the peaceableness of most dinosaur species were probably responsible for their long tenancy on earth. The meek, one may infer, do better than the proud. Copiously illustrated.

TURKEY: ANCIENT MINIATURES, by M. S. Ipsiroglu, S. Eyuboglu and Richard Ettinghausen. New York Graphic Society Publishers, Ltd. ($18). Another volume in the "UNESCO World Art Series." The miniatures that are reproduced are not only of the highest artistic interest but are also valuable to the sociologist and historian of the past because of Turkish artists' preoccupation with reality, thus affording colorful and detailed information about Turkish life during the Ottoman period.

PRINCIPIA MATHEMATICA TO *56, by Alfred North Whitehead and Bertrand Russell. Cambridge University Press ($1.95). This paperback covers part of the text of Vol. I of the great *Principia* and contains material of inter-

est to students beginning work in logic and the philosophy of mathematics. It includes the preliminary sections, which give the philosophy underlying the work, the whole of Part I, in which the logical properties of propositions, propositional functions, classes and relations are established, and discussions of the theory of deduction and truth functions. It is a service to higher education to offer this inexpensive selection.

BASIC LAWS OF MATTER, by H. S. W. Massey and Arthur R. Quinton. Herald Books ($3.75). This book, which explains the structure of matter, is an uncommonly skillful achievement. It succeeds in doing what most other primers merely promise to do. The student, teacher or ordinary reader without scientific background of any kind is led step by step, by means of a brief text and simple, effective diagrams, to an understanding of such terms as atom, proton, electron, neutron, solid, liquid, gas, radioactivity, nuclear fission, binding energy, isotope, molecule, half life, plasma and so on. Each concept gets a diagram and, on the opposite page, the concept and diagram are explained. As an introduction to the basic laws of matter this approach could not be bettered.

STRUCTURE OF THE MOON'S SURFACE, by Gilbert Fielder. Pergamon Press ($7.50). A well-written, most interesting survey for the professional scientist and the amateur astronomer of contemporary knowledge about the moon. The book discusses the moon's librations, how the heights of points on the moon's surface are determined, the figure of the moon, the luminous intensity and luminescence of the lunar rocks, the color of moonlight and the composition of the moon's surface, the moon's temperature, its atmosphere, changes that occur on the surface, crater distribution and related matters. Good illustrations.

CHINA'S EARLY INDUSTRIALIZATION, by Albert Feuerwerker. Harvard University Press ($6.50). A scholarly study, the first volume of the Harvard "East Asian" series, of the social and institutional context, the men and politics, and the economic problems and achievements of China's early industrialization. The main attention is to the Kuan-tu Shang-pan system, a "compromise between the urgent need for modernization . . . and the conservation of the traditional society," which permitted the establishment in the last decades of the 19th century of pioneering firms in such fields as cotton spin-

ning and weaving, maritime transport, telegraphic communications, coal and iron mining and steel.

CURRENT ISSUES IN THE PHILOSOPHY OF SCIENCE, edited by Herbert Feigl and Grover Maxwell. Holt, Rinehart and Winston, Inc. ($6). The proceedings of the history and philosophy section of the American Association for the Advancement of Science held in December, 1959. The volume comprises six symposia in which 24 philosophers and scientists participated, dealing with such topics as the logic of discovery, the genesis of the theory of relativity, the foundations of geometry, the theory of probability, fundamental constants in physics, quantum mechanics and the role of simplicity in explanation.

INTRODUCTION TO ANATOMY, 1532, by David Edwardes. Stanford University Press ($2.75). A facsimile reproduction of the first book on anatomy written in England (1532), with an English translation from the Latin and an introductory essay on anatomical studies in Tudor England by C. D. O'Malley and K. F. Russell. This book is of small intrinsic scientific interest except as a milestone of the beginnings of anatomy in England. Edwardes is also remembered as being responsible for the first recorded dissection of a human body in England.

GREAT CHEMISTS, edited by Eduard Farber. John Wiley & Sons, Inc.—Interscience Division ($29.50). A collection of more than 100 biographies of leaders in the development of chemistry in the last 3,000 years. The book begins with a general article on Babylonian chemists and carries through to an account of the life and work of Wallace Hume Carothers; no living chemists are included. The articles are taken from a variety of sources, some modern—such as the Obituary Notices of the Royal Society—and some written as far back as the early 19th century. Each biography is illustrated by a portrait. A useful compilation.

ELIZABETHAN LIFE IN TOWN AND COUNTRY, by M. St. Clare Byrne; LIFE AND THOUGHT IN THE GREEK AND ROMAN WORLD, by M. J. Cary and T. J. Haarhoff; ENGLISH WAYFARING LIFE IN THE MIDDLE AGES, by J. J. Jusserand. Barnes and Noble, Inc. ($2.25 each). These three volumes in the "University Paperbacks" series are inexpensive, illustrated reissues of standard historical studies, many times reprinted, accept-

able to both the student and the ordinary reader. Jusserand's book, in particular, is a joy, an exemplar of scholarship.

Notes

HYDRODYNAMIC AND HYDROMAGNETIC STABILITY, by S. Chandrasekhar. Oxford University Press ($16.80). An account of the theory of hydrodynamics and hydromagnetic stability developed as a branch of physics in which experiments play an essential part. The author is the noted University of Chicago astrophysicist.

THE HUMAN SPECIES, by Anthony Barnett. Penguin Books Inc. ($1.85). An inexpensive reprint of a biology of man. All phases of the subject are treated in a survey that is both sound and socially enlightened: heredity and reproduction, human diversity, man and society, food and soil, nutrition, population, life and death. There are also a number of illustrations.

SCIENCE AND TECHNOLOGY, by Andrew G. van Melsen. Duquesne University Press ($6.95). A Dutch philosopher examines the nature of physical science and technology and their influence, good and bad, beneficent and destructive, on contemporary culture.

ARGON, HELIUM AND THE RARE GASES: VOL. II, edited by Gerhard A. Cook. John Wiley & Sons, Inc.—Interscience Division ($17.50). The second volume of this treatise deals with production, analytical determination and uses of the elements of the helium group.

THE TREASURY OF THE AUTOMOBILE, by Ralph Stein. Golden Press, Inc. ($14.95). A delectable, envy-stirring picture book of great automobiles from the 18th-century fire and steam carriages to the Bugattis, Aston Martins, Duesenbergs, Ferraris, Rolls-Royces and other sublime chariots of modern times. Color plates, photographs and lithographs.

ALBERT EINSTEIN, by Leopold Infeld. Charles Scribner's Sons ($1.25). A paper-backed edition of an essay on Einstein's work and its influence on our world.

AXIOMATICS OF CLASSICAL STATISTICAL MECHANICS, by Rudolf Kurth. Pergamon Press ($7.50). An attempt to construct classical statistical mechanics as a deductive system, founded only on the equations of motion and a few well-

known postulates that formally describe the concept of probability.

SEA BIRDS, by Charles Vaucher. Oliver & Boyd, Ltd. ($23). A natural history, illustrated with 255 excellent photographs (15 in color), of the sea birds found in well-known sanctuaries on the coasts of Britain and Scandinavia. Among the birds treated are the fulmar, cormorant, shag, gannet, shelduck, arctic skua, gull, kittiwake, tern, puffin, razorbill and oyster catcher.

HOBBES, by Sir Leslie Stephen. The University of Michigan Press ($1.75). Inexpensive reprint of Stephen's brilliant essay on the life and thought of the famous 17th-century political philosopher.

ARCHAEOLOGY FROM THE EARTH, by Sir Mortimer Wheeler (95 cents); PREHISTORIC INDIA, by Stuart Piggott ($1.45). Penguin Books Inc. The stone, metal, clay and other materials that time has buried, and that persistent, inquisitive and ingenious searchers have dug up and pieced together into a story of the prehistoric past, are the central characters of these superior reviews of archaeology. Paperbacks.

THE METAL PLUTONIUM, edited by A. S. Coffinberry and W. N. Miner. The University of Chicago Press ($9.50). An assemblage of papers by pioneers in the work on this man-made element, dealing with the history of its development, plutonium metallurgy and plutonium in nuclear reactors. Illustrations.

ON HUMAN COMMUNICATION, by Colin Cherry. Science Editions, Inc. ($1.95). A soft-cover reissue of an able review, survey and criticism of a broad subject that includes such topics as the nature of communication, languages, signs and codes, analysis of signals, mathematical and statistical theories of communication and the logic of communication (syntax, semantics and pragmatics).

ATOMIC PHYSICS AND HUMAN KNOWLEDGE, by Niels Bohr. Science Editions, Inc. ($1.45). A soft-cover reprint of a collection of Bohr's essays on various subjects: light and life, biology and atomic physics, discussions with Einstein on epistemological problems in atomic physics, unity of knowledge and so on.

GEOLOGY OF THE ARCTIC, edited by Gilbert O. Raasch. University of Toronto Press ($22.50). The proceedings of the First International Symposium on Arctic

Geology held in Calgary, Alberta, in 1960. Among the topics discussed were the regional geology of the Soviet Arctic, Spitsbergen, Greenland, Canada, Alaska and the Arctic Ocean Basin; glaciology, permafrost, climatology, geomorphology and exploration.

MORAL EDUCATION, by Émile Durkheim. The Free Press of Glencoe ($6). The first English translation of Durkheim's study in the theory and application of sociology to education, originally published in French 35 years ago.

THE THOUGHT AND CHARACTER OF WILLIAM JAMES, by Ralph Barton Perry. Atlantic–Little, Brown ($15). A reissue in unaltered form of the definitive biography of the great psychologist. Long out of print, except in an abridged edition, and hard to find, this gracefully written, enriching work will have many grateful readers.

THE MANY-BODY PROBLEM, by David Pines; NUCLEAR MAGNETIC RELAXATION, by N. Bloembergen; QUANTUM THEORY OF MANY-PARTICLE SYSTEMS, by L. Van Hove, N. M. Hugenholtz and L. P. Howland; THEORY OF FUNDAMENTAL PROCESSES, by R. P. Feynman; QUANTUM ELECTRODYNAMICS, by R. P. Feynman ($3.95 each). W. A. Benjamin, Inc. These paperbacks appear in a lecture-notes and reprint series, "Frontiers in Physics," which is intended to make available to a wider audience of physicists lectures and graduate theses that summarize the present status of, or report advances in, various rapidly developing fields of physics.

MICHIGAN WILDFLOWERS, by Helen V. Smith. University Publishers, Inc. ($5). This book describes and illustrates (17 color plates) almost every wild flower found in Michigan, diverse in climate and rich in wild lands—swamps, prairies, beaches, dunes, woods and meadows.

FREUD: THE MIND OF THE MORALIST, by Philip Rieff. Anchor Books ($1.45). A soft-cover reissue of Rieff's learned, sympathetic and imaginative study, reviewed at length in these pages when it first appeared in 1959.

THE HISTORY OF IMPRESSIONISM, by John Rewald. The Museum of Modern Art ($20). A revised and enlarged edition of a brilliant survey of the development of the impressionist movement in painting. More than 600 plates, including 86 in full color.

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BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful.

THE SHELTER-CENTERED SOCIETY

THE LIMITS OF DEFENSE. Arthur I. Waskow. Doubleday & Company, Inc., 1962.

GAMMA RAY ASTRONOMY

COSMIC RADIO WAVES. I. S. Shklovsky. Harvard University Press, 1960.

ON GAMMA-RAY ASTRONOMY. P. Morrison in *Nuovo Cimento*, Vol. 7, No. 6, pages 858–865; March 16, 1955.

HIGH-ENERGY COSMIC RAYS. Bruno Rossi in *Scientific American*, Vol. 201, No. 5, pages 134–149; November, 1959.

RADIO GALAXIES. D. S. Heeschen in *Scientific American*, Vol. 206, No. 3, pages 41–49; March, 1962.

SEARCH FOR PRIMARY COSMIC GAMMA RAYS WITH THE SATELLITE EXPLORER XI. W. L. Kraushaar and G. W. Clark in *Physical Review Letters*, Vol. 8, No. 3, pages 106–109; February 1, 1962.

EXPERIMENTS WITH GOGGLES

ADAPTATION, AFTER-EFFECT AND CONTRAST IN THE PERCEPTION OF CURVED LINES. James J. Gibson in *Journal of Experimental Psychology*, Vol. 16, No. 1, pages 1–31; February, 1933.

SOME PRELIMINARY EXPERIMENTS ON VISION WITHOUT INVERSION OF THE RETINAL IMAGE. George M. Stratton in *The Psychological Review*, Vol. 3, No. 6, pages 611–617; November, 1896.

VISION WITHOUT INVERSION OF THE RETINAL IMAGE. George M. Stratton in *The Psychological Review*, Vol. 4, No. 4, pages 341–360; July, 1897.

VISION WITHOUT INVERSION OF THE RETINAL IMAGE (CONCLUDED). George M. Stratton in *The Psychological Review*, Vol. 4, No. 5, pages 463–481; September, 1897.

MALARIA

CHEMOTHERAPY OF MALARIA. Sir Gordon Covell, G. Robert Coatney, John W. Field and Jaswant Singh. WHO Monograph Series, No. 27, 1955.

EXPERT COMMITTEE ON MALARIA, SIXTH REPORT. WHO Technical Report Series, No. 123, 1957.

EXPERT COMMITTEE ON MALARIA, SEVENTH REPORT. WHO Technical Report Series, No. 162, 1959.

EXPERT COMMITTEE ON MALARIA, EIGHTH REPORT. WHO Technical Report Series, No. 205, 1961.

INSECTICIDE RESISTANCE IN ARTHROPODS. A. W. A. Brown. WHO Monograph Series, No. 38, 1958.

MAN'S MASTERY OF MALARIA. Paul F. Russell. Oxford University Press, 1955.

EXPLODING WIRES

EXPLODING WIRES. Edited by William G. Chace and Howard K. Moore. Plenum Press, Inc., 1959.

FUNDAMENTALS OF GAS DYNAMICS. *High Speed Aerodynamics and Jet Propulsion*, Vol. 3. Princeton University Press, 1954. See sections C, D and E, pages 350–525.

PHYSICAL MEASUREMENTS IN GAS DYNAMICS AND COMBUSTION. *High Speed Aerodynamics and Jet Propulsion*, Vol. 9. Princeton University Press, 1954. See Part 1, pages 3–108.

THE PLASMA STATE. E. J. Hellund. Reinhold Publishing Corp., 1961.

SEISMIC SHOOTING AT SEA

GEOPHYSICAL INVESTIGATIONS IN THE EMERGED AND SUBMERGED ATLANTIC COASTAL PLAIN. Part 3: "Barnegat Bay, New Jersey, Section." Maurice Ewing, George P. Woollard and A. C. Vine in *Bulletin of the Geological Society of America*, Vol. 50, No. 2, pages 257–296; February, 1939.

Part 7: "Continental Shelf, Continental Slope, and Continental Rise South of Nova Scotia." C. B. Officer and M. Ewing in *Bulletin of the Geological Society of America*, Vol. 65, No. 8, pages 653–670; August, 1954.

Part 10: "Continental Slope and Continental Rise South of the Grand Banks." Charles R. Bentley and J. Lamar Worzel in *Bulletin of the Geological Society of America*, Vol. 67, No. 1, pages 1–18; January, 1956.

INTRODUCTION TO GEOPHYSICAL PROSPECTING. Milton B. Dobrin. McGraw-Hill Book Company, Inc., 1960.

CHIMPANZEES IN THE WILD

THE APE IN OUR HOUSE. Cathy Hayes. Harper & Brothers, 1951.

ANNOUNCING AN ISSUE OF **SCIENTIFIC AMERICAN** DEVOTED TO THE TOPIC OF

THE ANTARCTIC

TO BE PUBLISHED IN SEPTEMBER, 1962

CHIMPANZEES. Robert M. Yerkes. Yale University Press, 1943.

THE NON-HUMAN PRIMATES AND HUMAN EVOLUTION. *Human Biology*, Vol. 26, No. 3; September, 1954.

THE SOCIAL LIFE OF BABOONS. S. L. Washburn and Irven DeVore in *Scientific American*, Vol. 204, No. 6, pages 62–71; June, 1961.

HEART CELLS IN VITRO

CELL, ORGANISM AND MILIEU. Edited by Dorothea Rudnick. The Ronald Press Co., 1959.

CELL AND TISSUE CULTURE. John Paul. E. & S. Livingstone, 1960.

DEVELOPING CELL SYSTEMS AND THEIR CONTROL. Edited by Dorothea Rudnick. The Ronald Press Co., 1960.

DIFFERENTIATION OF VERTEBRATE CELLS. Clifford Grobstein in *The Cell*, Vol. 1, edited by Jean Brachet and Alfred E. Mirsky, pages 437–496. Academic Press Inc., 1959.

THE MOLECULAR BASIS OF CONTRACTION IN CROSS-STRIATED MUSCLES. H. E. Huxley and J. Hanson in *The Structure and Function of Muscle*, Vol. 1, edited by G. H. Bourne, pages 183–227. Academic Press Inc., 1960.

SELECTED TOPICS ON THE PHYSIOLOGY OF THE HEART. W. F. H. M. Mommaerts, B. C. Abbott and W. J. Whalen in *The Structure and Function of Muscle*, Vol. 2, edited by G. H. Bourne, pages 517–556. Academic Press Inc., 1960.

SKELETAL MUSCLE TISSUE IN CULTURE. Margaret R. Murray in *The Structure and Function of Muscle*, Vol. 1, edited by G. H. Bourne, pages 111–136. Academic Press Inc., 1960.

MATHEMATICAL GAMES

ODDITIES AND CURIOSITIES OF WORDS AND LITERATURE. Charles Carroll Bombaugh. Edited by Martin Gardner. Dover Publications, Inc., 1961. See pages 345–346.

ON SYMMETRY. Ernst Mach in *Popular Scientific Lectures*, pages 89–106. Open Court Publishing Company, 1943.

THE AMATEUR SCIENTIST

DIFFUSION UNDER THE MICROSCOPE. Yasunori Nishijima and Gerald Oster in *Journal of Chemical Education*, Vol. 38, No. 3, pages 114–117; March, 1961.

AN INTRODUCTION TO INTERFEROMETRY. S. Tolansky. Longmans, Green & Co., Inc., 1955.

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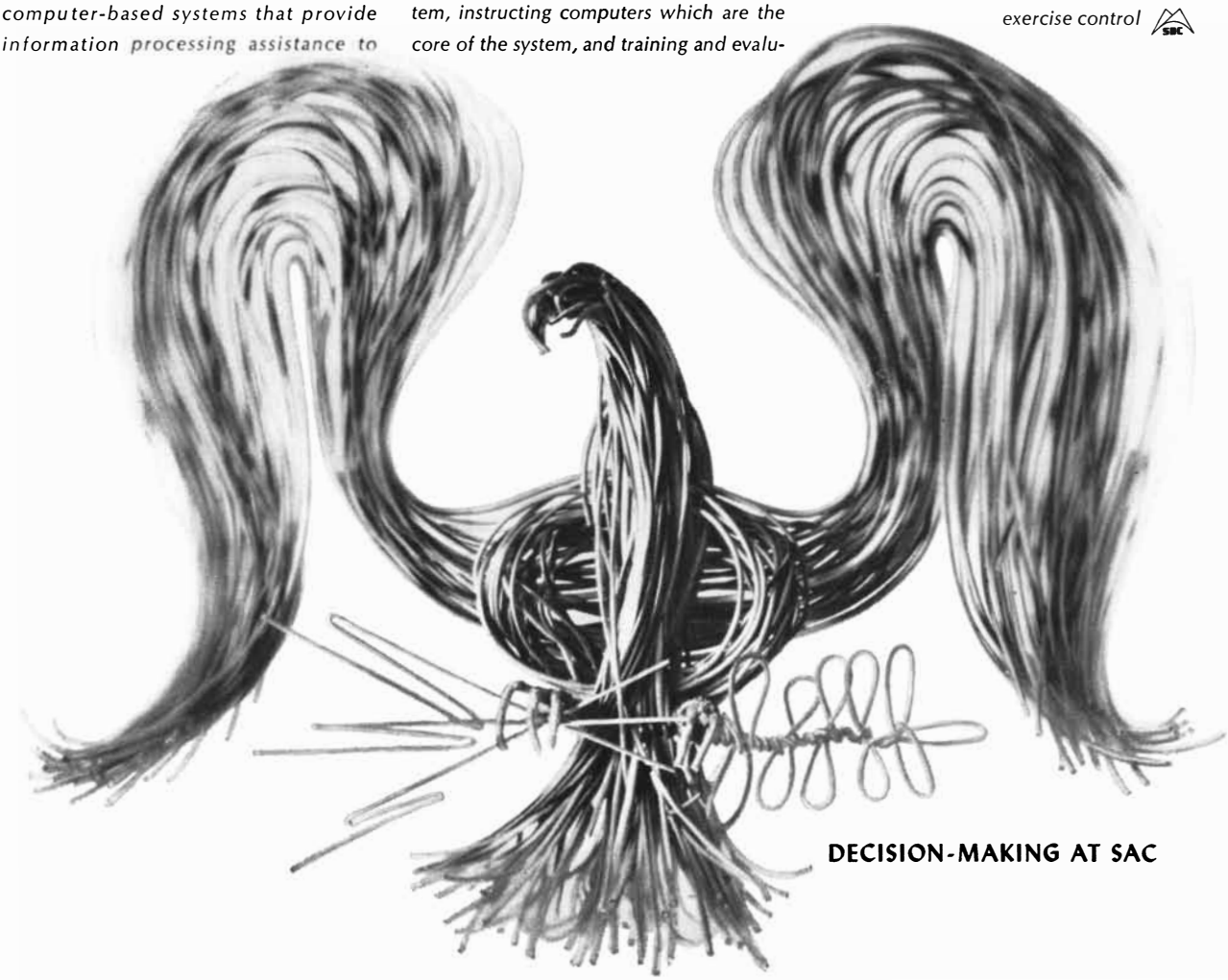

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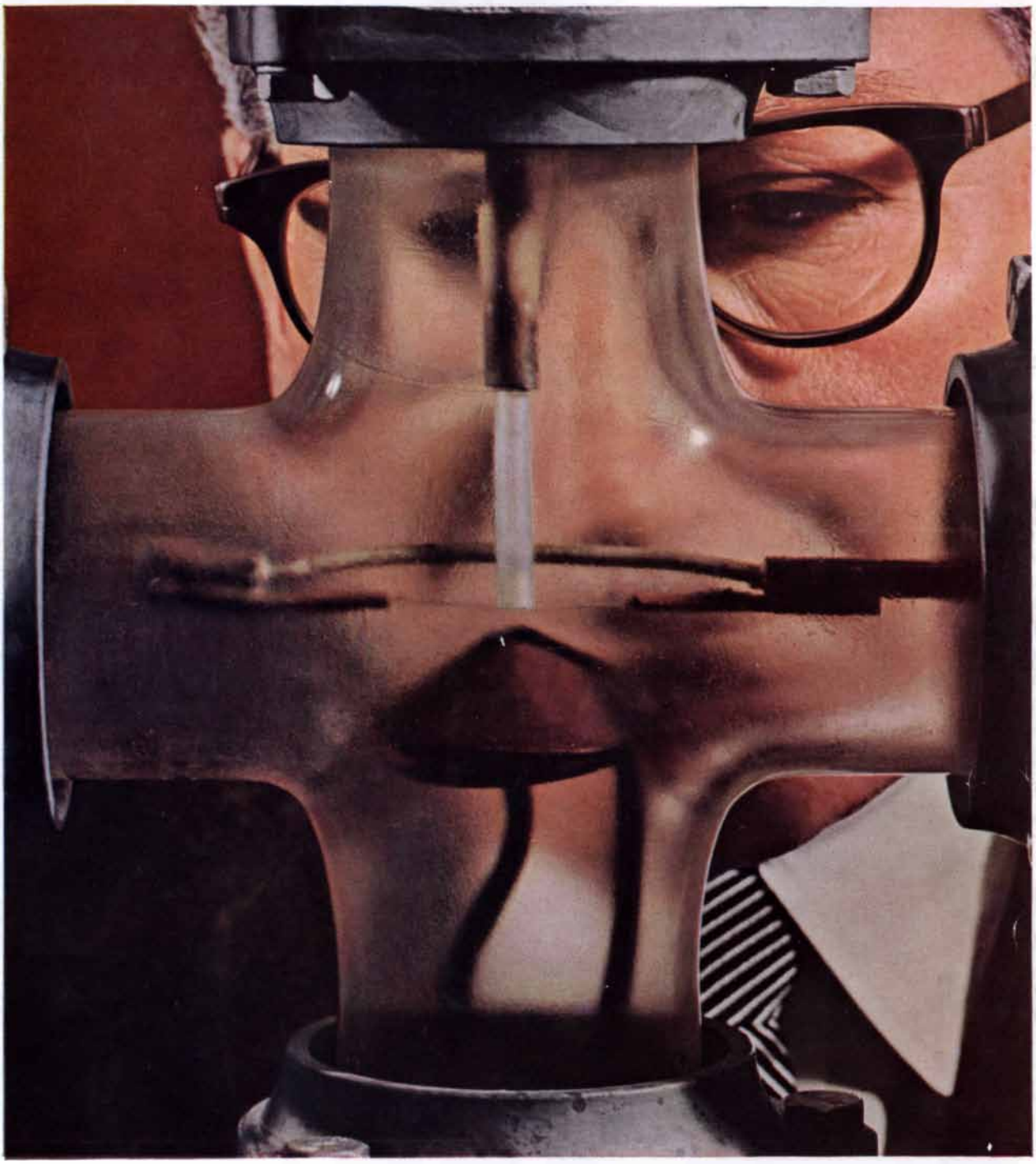

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