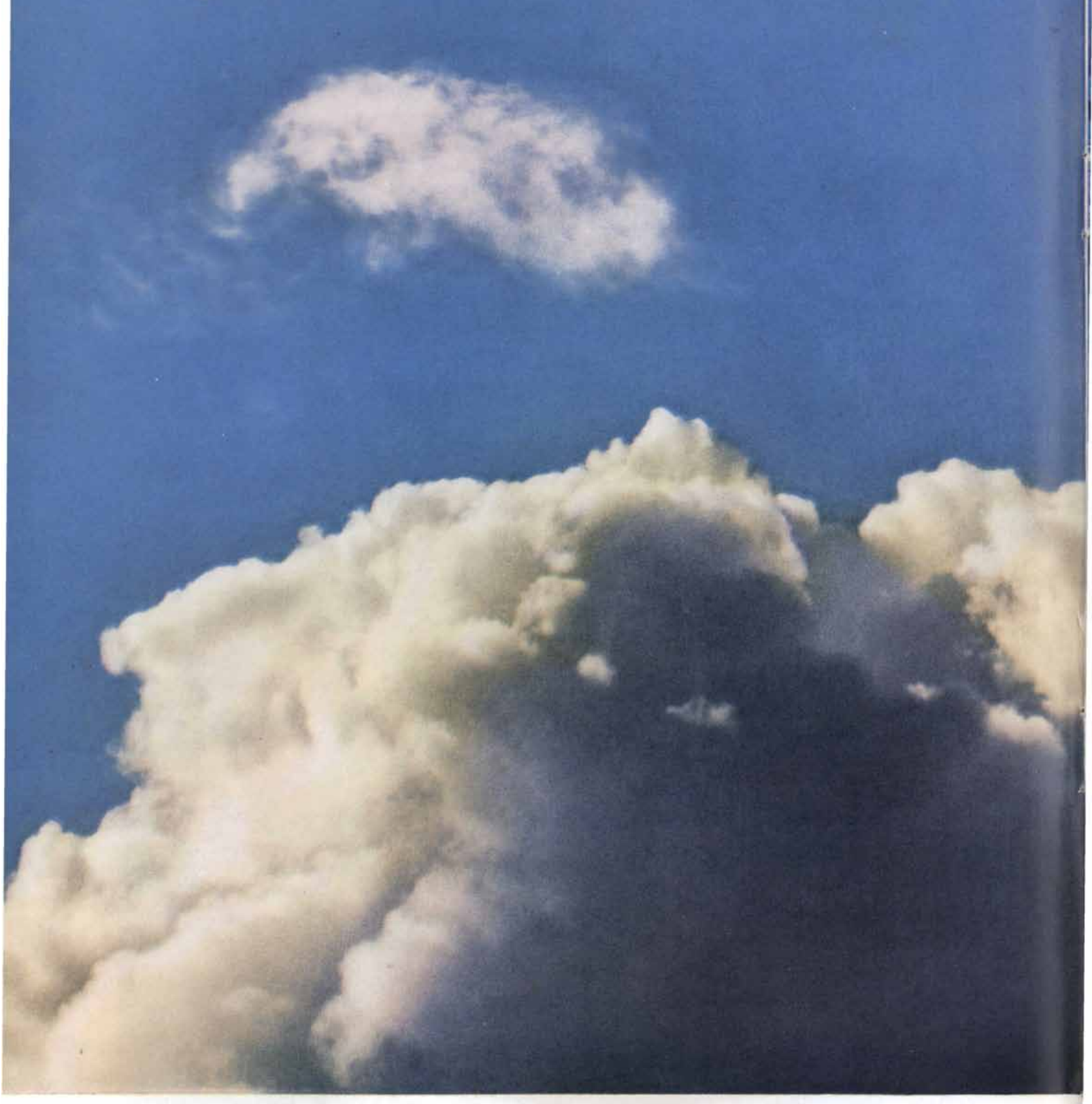
SCIENTIFIC AMERICAN

INHIBITED VIRUSES

FIFTY CENTS

May 1961



TO THE MAN ON CLOUD 13

When you're aloft on Cloud 13 there can't be any shadows in the blue skies. You are sure your inspiration will be a winner back there on earth.

Then come the uncertainties of how to make your idea become a reality.

Whenever there is a metal problem, look to Inco for its solution.

Inco is continuously making discoveries about the nature and behavior of metals. They may already have an answer that will make your idea workable.

This will enable your head to remain on Cloud 13, while your feet can be on solid ground.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 WALL STREET, NEW YORK 5, N. Y.

INCO RESEARCH

Prizes wrested from the Fluorine "Dragon"

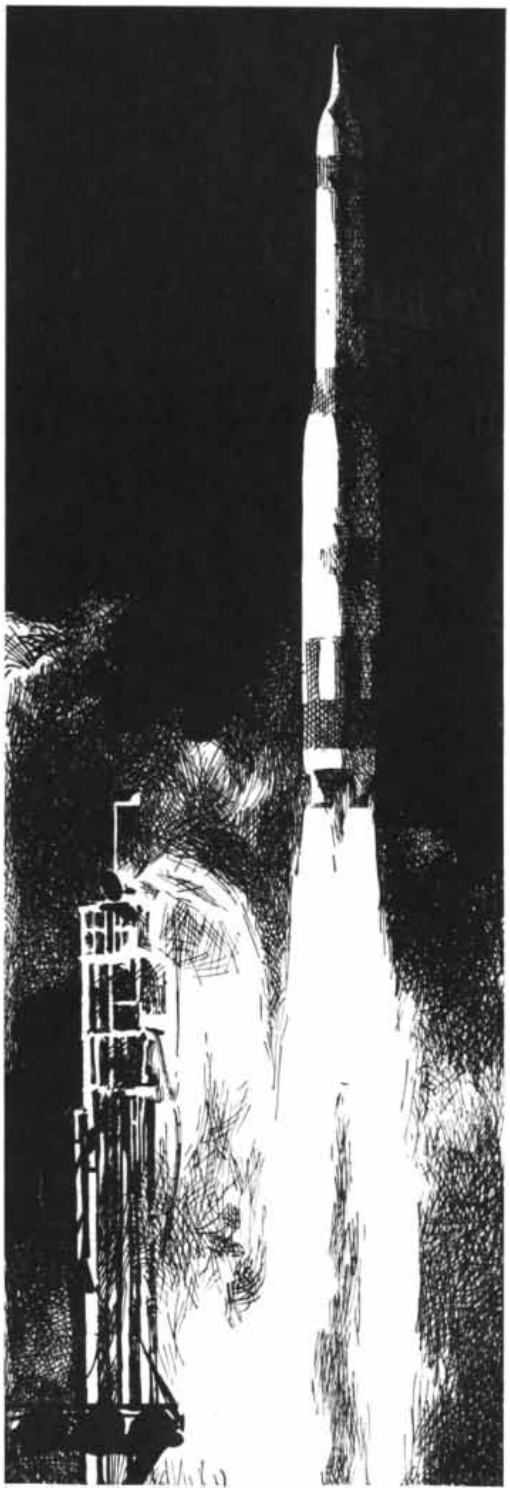
". . . but the prize was guarded by a dragon fiercer than the sleepless, fire-breathing monster Jason faced to win the Golden Fleece."

The quotation is from our new brochure, *Fluorine*. Chemists will understand the metaphor. They're quite accustomed to hearing fluorine called hard names. It's the most reactive element in the periodic table—often termed "the chemical outlaw."

The brochure traces the development of fluorine from its isolation in 1886 to the present. It points out "prizes" wrested from the volatile dragon: the latest advances in aerosols, nuclear power, insulation, medicine, rocketry. And it includes contributions from our General Chemical Division, pioneer in fluorine chemistry for over 60 years and now America's largest supplier of fluorine chemicals, with a list of more than 100 such products.

"Dragon" in a vacuum bottle. Until recently, extensive use of fluorine was handicapped by handling and shipping problems. Only small amounts could be transported—and in gaseous form at that. Several years ago, our General Chemical research people learned how to ship fluorine as a *liquid* in *bulk*. They devised a triple-tank truck, much like a giant vacuum bottle, with liquid fluorine in the innermost tank. Next, liquid nitrogen to cool fluorine below its boiling point of –306°F. Finally, a vacuum-insulated jacket. Now 5,000 pounds can be shipped by truck. And the door was opened to large-scale use.

Fluorine and atomic energy. In the nuclear energy field, a development by our research people permits the company to make exceptionally high-purity uranium hexafluoride, basic atomic raw material, by a unique and simpler process than that used by government-owned plants. Our plant, located at Metropolis, Ill., is the first privately owned facility to produce this basic atomic raw material for the Atomic Energy Commission. Last year, Allied delivered its 10-millionth pound of UF_6 to the A.E.C.



Rocket engines get a new "boost." Chances are, the first man on the moon may get there "via fluorine." The enormous energy liberated by the reaction of liquid fluorine and liquid hydrogen yields higher specific impulse (the key to rocket performance) than any stable chemical combination yet known. The first full-scale firings of a complete turbo-pump-fed rocket engine using these elements as propellants have already taken place.

New packaging film makes debut. It's ACLAR®, our new fluorohalocarbon film . . . characterized by fantastically low moisture vapor transmission, transparency, impact strength. To get the moisture barrier benefits of ACLAR type 33 film, a saran film would have to be over 100 times as thick, a polyethylene film over 400 times as thick, and a polyester film over 700 times as thick. Indicated uses: packaging electronic and other delicate mechanical equipment components, drugs, and chemicals. Its application in *your* field of interest might be of value to *your* product, too. Why not explore the possibilities of ACLAR?

Write today for our new brochure, *Fluorine*. Your name and title on your company letterhead will bring you a copy promptly. The address: Allied Chemical Corp., Dept. 51-S, 61 Broadway, New York 6, New York. Or phone HAnover 2-7300.

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The LGP-30 Electronic Computer is designed to stop the juggling of figures —and start the creating of profits.

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This means that the Royal Precision LGP-30 is ready to go to work to help your company create new products—and fresh profits—the very same day it is delivered. Can you wonder that there are more LGP-30's installed and working right this minute than any other electronic computing system in its class?

For more information: write Floyd Ritchie, Royal McBee Corporation, Port Chester, New York.

ROYAL McBEE | GENERAL PRECISION

ELECTRONIC DATA PROCESSING SYSTEMS

Established 1845 **SCIENTIFIC AMERICAN** May 1961 Volume 204 Number 5

ARTICLES

DEPARTMENTS

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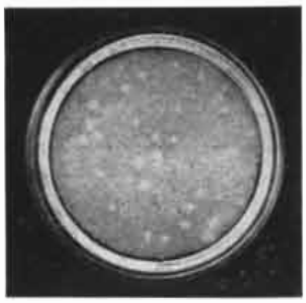

THE COVER

The photograph on the cover shows one method of assaying the activity of interferon, a protein cell product that inhibits virus growth (*see "Interferon," by Alick Isaacs; page 51*). The Petri dish contains a culture of chick embryo cells that has been infected at 60 randomly located spots with the virus of Eastern equine encephalomyelitis. Added to the culture is a sample of chick interferon in a 1-to-32 dilution. The small round clear patches show where the virus has multiplied and destroyed cells. Since there are only about 30 of these patches it can be inferred that the interferon has inhibited virus growth in about half of the infected spots. This provides a way of standardizing the potency of interferon samples. The photograph was made in the laboratory of Robert Wagner at Johns Hopkins University.

THE ILLUSTRATIONS

Cover photograph by William Vandivert

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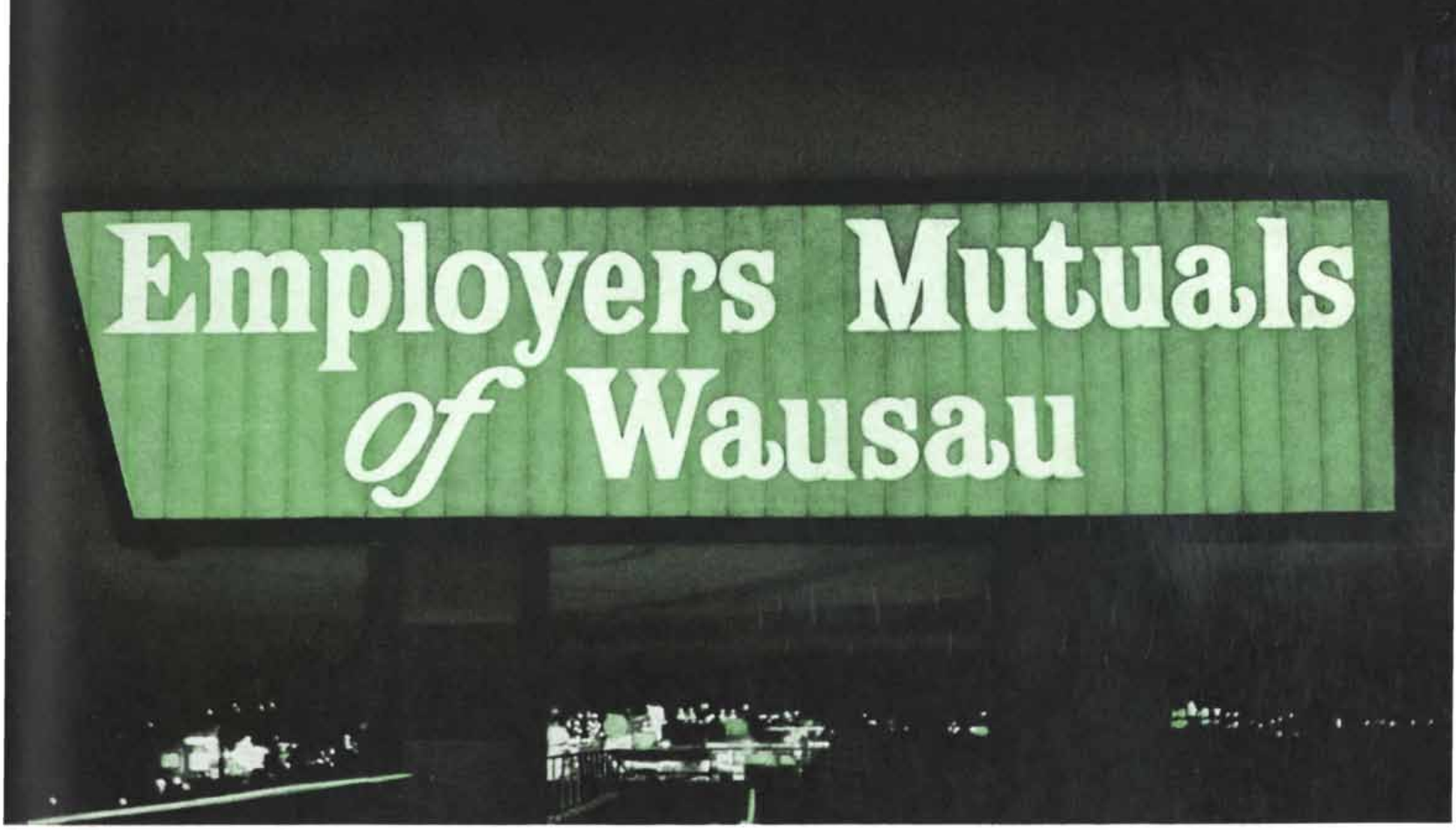

Sign manufactured by Everbrite Electric Signs, Inc., Milwaukee 12, Wis., for Employers Mutuals of Wausau offices in Milwaukee. Background and letters made from sheet extruded by Plaskolite, Inc., Columbus 15, Ohio, from a special weather-resistant formulation of Tenite Butyrate plastic.

Eye-catching, colorful–and tough ...outdoor signs of **BUTYRATE**

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Many thousands of industrial and consumer products are now made in whole or part of Tenite Butyrate. Learn more about its helpful properties, economical forming methods and diverse applications before your next material selection decision. Write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

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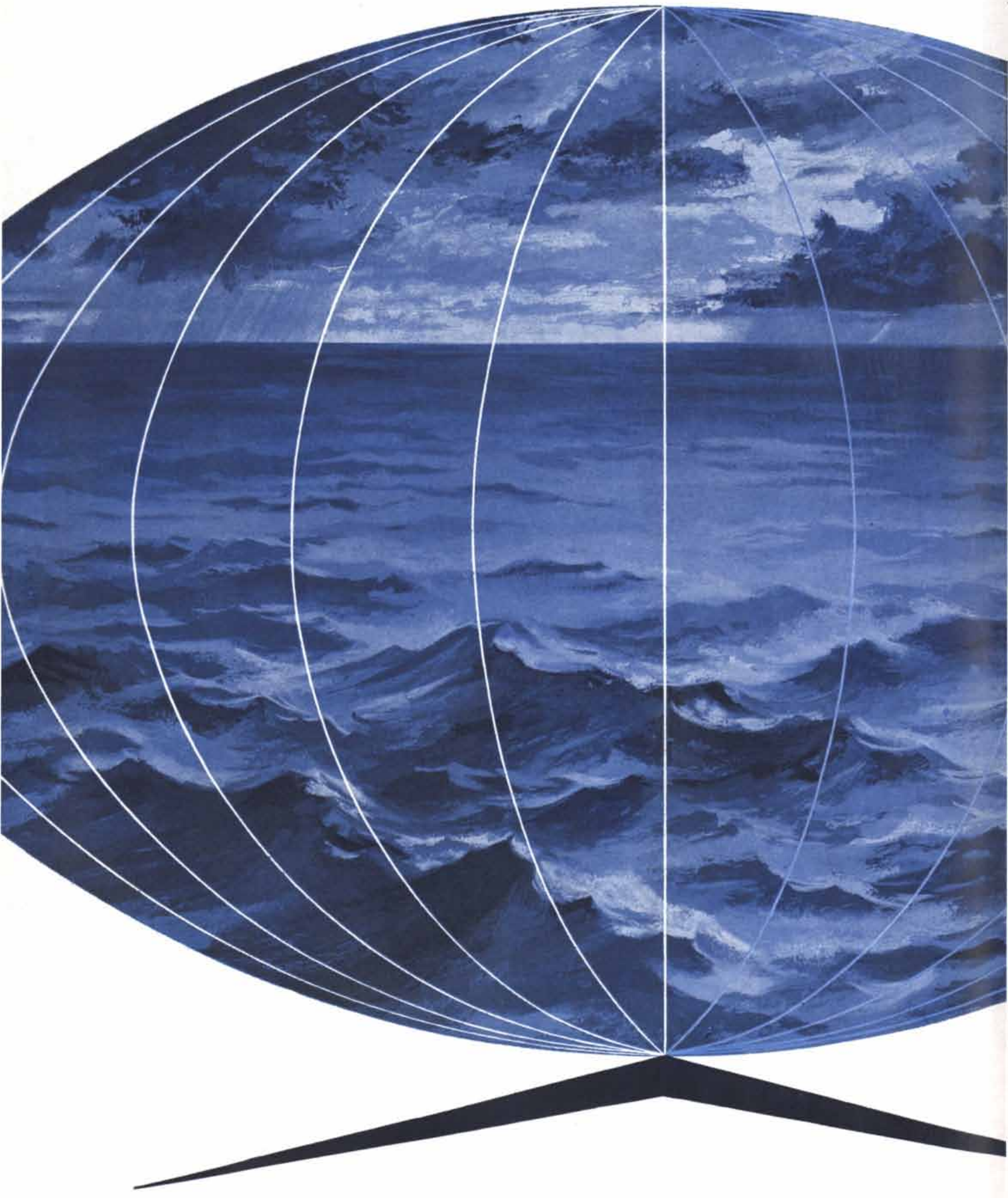
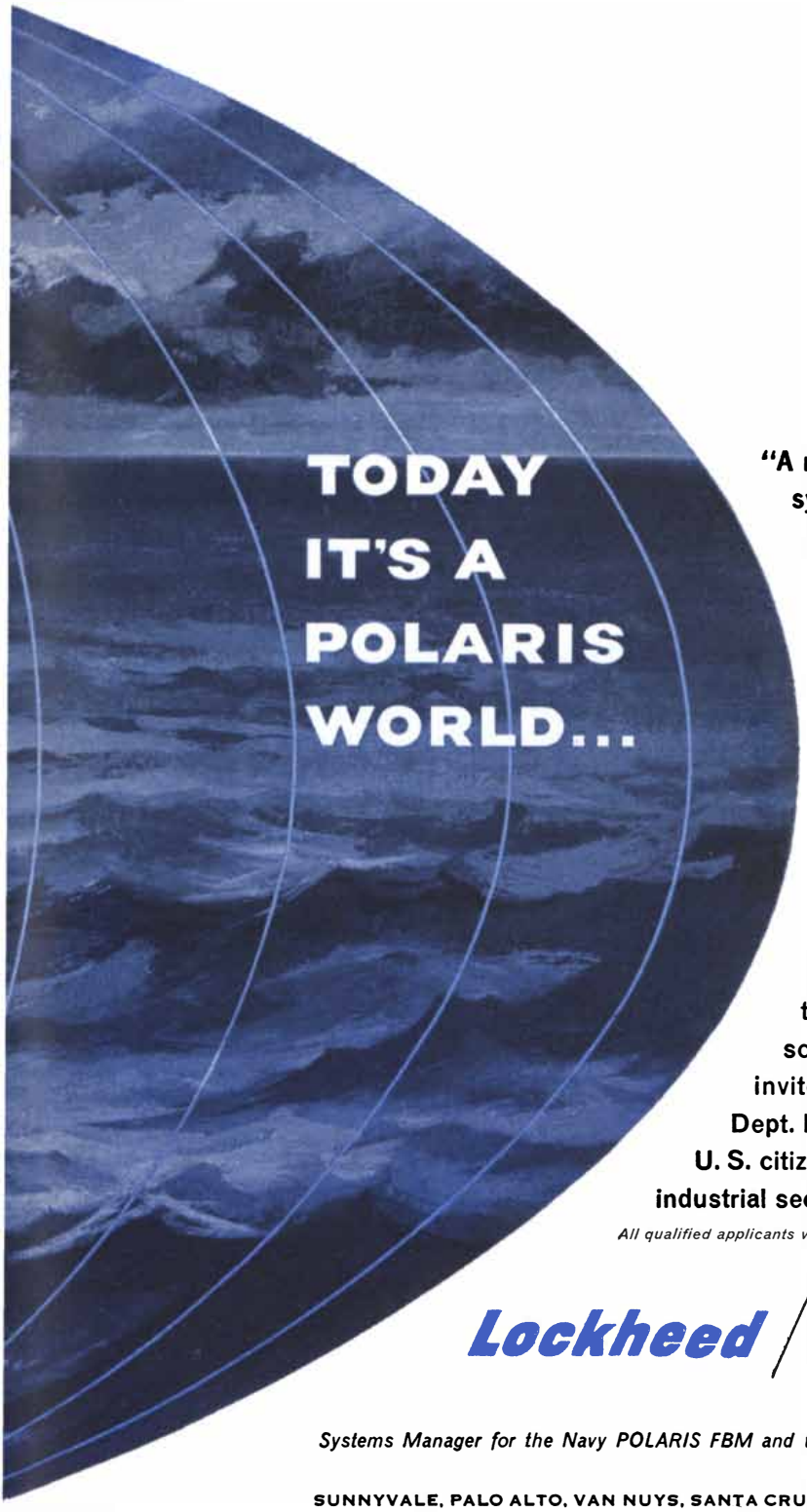




"A revolutionary and practically invulnerable ballistic missile system." President Eisenhower thus characterized the POLARIS Fleet Ballistic Missile—capable of being launched from hidden nuclear submarines anywhere in the oceans of the world.

As System Manager of this fantastic program, Lockheed Missiles and Space Division coordinated its overall design, research, development, testing, assembly, and evolved the missile frame and reentry body. Outstanding competence and teamwork brought the POLARIS to operational status years ahead of schedule. Such accomplishments exhibit a bold, imaginative approach to new and unusual concepts.

Similar challenging opportunities are continually developing at Lockheed. Other programs reach far into the future . . . a rewarding future which engineers and scientists of creative talent and inquiring mind are invited to share. Write Research and Development Staff, Dept. M-16D, 962 West El Camino Real, Sunnyvale, California. U. S. citizenship or existing Department of Defense industrial security clearance required.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Lockheed / **MISSILES AND SPACE DIVISION**

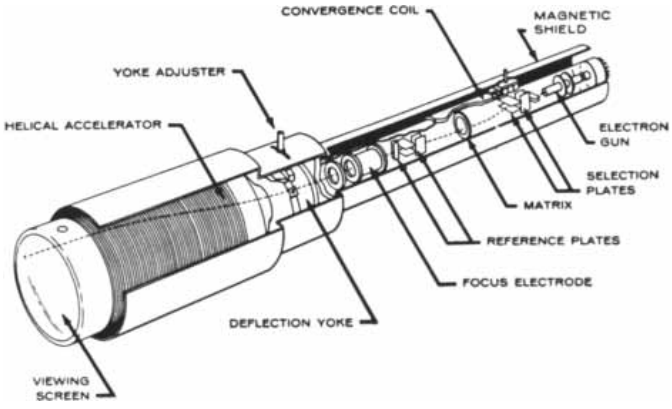
Systems Manager for the Navy POLARIS FBM and the Air Force AGENA Satellite in the DISCOVERER and MIDAS Programs

SUNNYVALE, PALO ALTO, VAN NUYS, SANTA CRUZ, SANTA MARIA, CALIFORNIA • CAPE CANAVERAL, FLORIDA • HAWAII

How the CHARACTRON® Shaped-Beam Tube achieves writing speeds of 20,000 high-resolution characters a second

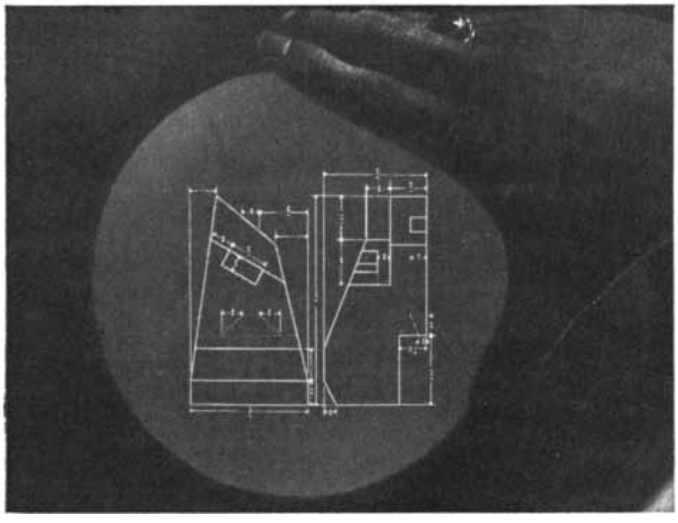
Ten years ago a small group of engineers mated the cathode-ray tube and the Magic Lantern to create a new device with almost unlimited possibilities for precision high-speed display. Systematic improvement and refinement over the past decade have created a new industry around items which were once laboratory curiosities. Today's CHARACTRON Shaped-Beam Tube, in a variety of types and sizes, is incorporated into high-speed microfilm recorders, electrostatic printers for computer data readout, and many visual situation display systems.

Among several inherent advantages of the CHARACTRON Shaped-Beam Tube is the instantaneous generation of the most complex alphanumeric characters and symbols. Character formation and generation time is not related to character complexity, as is the case with other methods. High resolution and very high speed are achieved by the beam forming and deflection methods. Characters from .75 inches to .02 inches with brightness and clarity are obtained at rates up to 20,000 characters per second.



The fundamentals of operation are basically simple. As in more conventional cathode-ray tubes, a beam of electrons is generated in an electron gun, accelerated, and introduced into a field between co-planar electrostatic plates. A special element, called the "matrix," is located at a precise distance beyond the deflection plates. The matrix is a thin beryllium-copper disc centered on the electron gun axis at right angles to the beam. Commonly, sixty-four minute characters in an 8 x 8 array are precision etched through the matrix disc. This permits selection of any character with a six-bit binary code. (Up to 256 characters have been provided for special applications.)

Applying a voltage to the deflection plates positions the electron beam at any given place on the matrix. The beam then passes through the character-shaped stencil and is returned either magnetically or by means of an electrostatic lens to the tube axis. Post-matrix reference plates and/or magnetic deflection are then employed to position the shaped beam at any desired position on the tube face.



CHARACTRON Shaped-Beam Tubes range in size from 1" x 3" rectangulars through 5", 7", 12", 19", to 21" in standard round types, with non-standard sizes available on a custom basis. Production types for slow-speed, high-speed, small-character, large-character, and variable-size character are provided off-the-shelf, depending on application and requirements. In addition to character display modes of operation, the tubes' special capabilities include line and Lissajous-figure drawing, graphical plotting, and even mechanical drawing with variable line weight for dimension and extension lines.

The cost per character of the CHARACTRON Shaped-Beam Tube in a computer readout system is less than any other comparable display device. You are invited to write for complete technical information to General Dynamics/ Electronics, Information Technology Division, Dept. B-28, Post Office Box 2449, San Diego 12, California.

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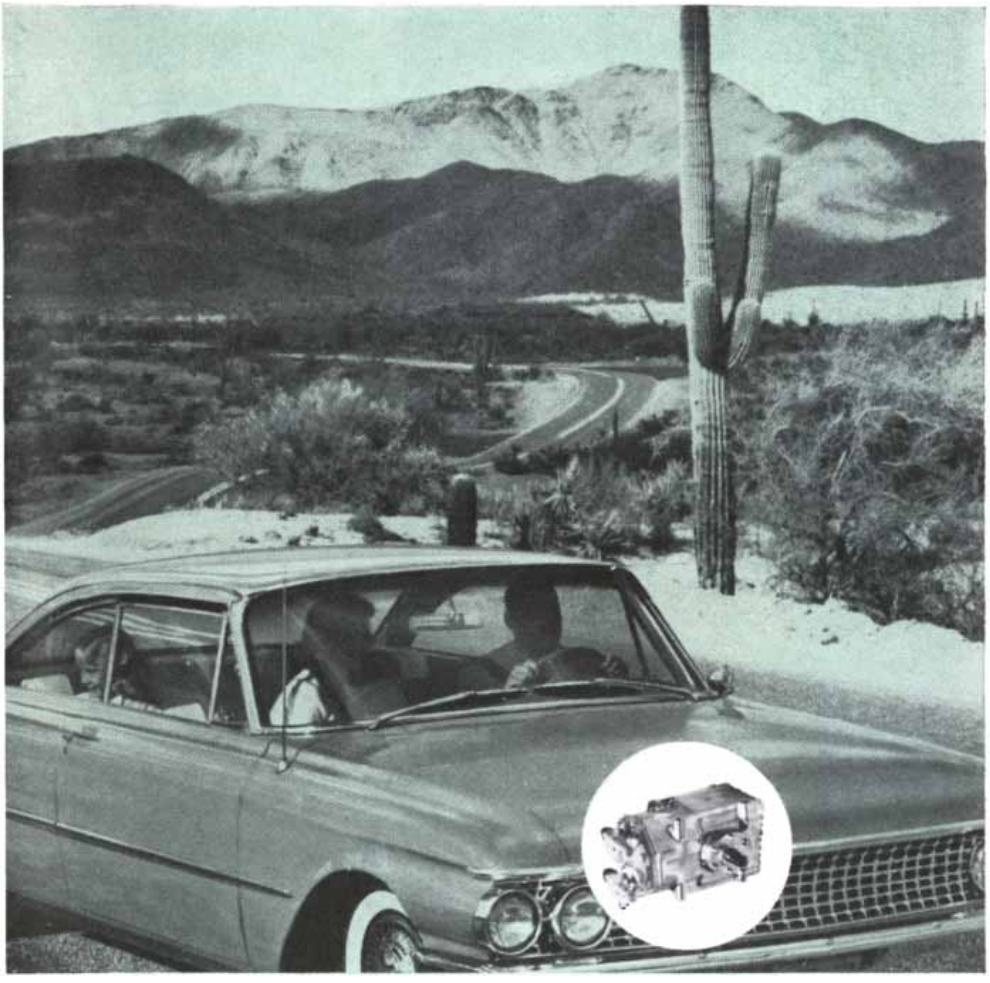
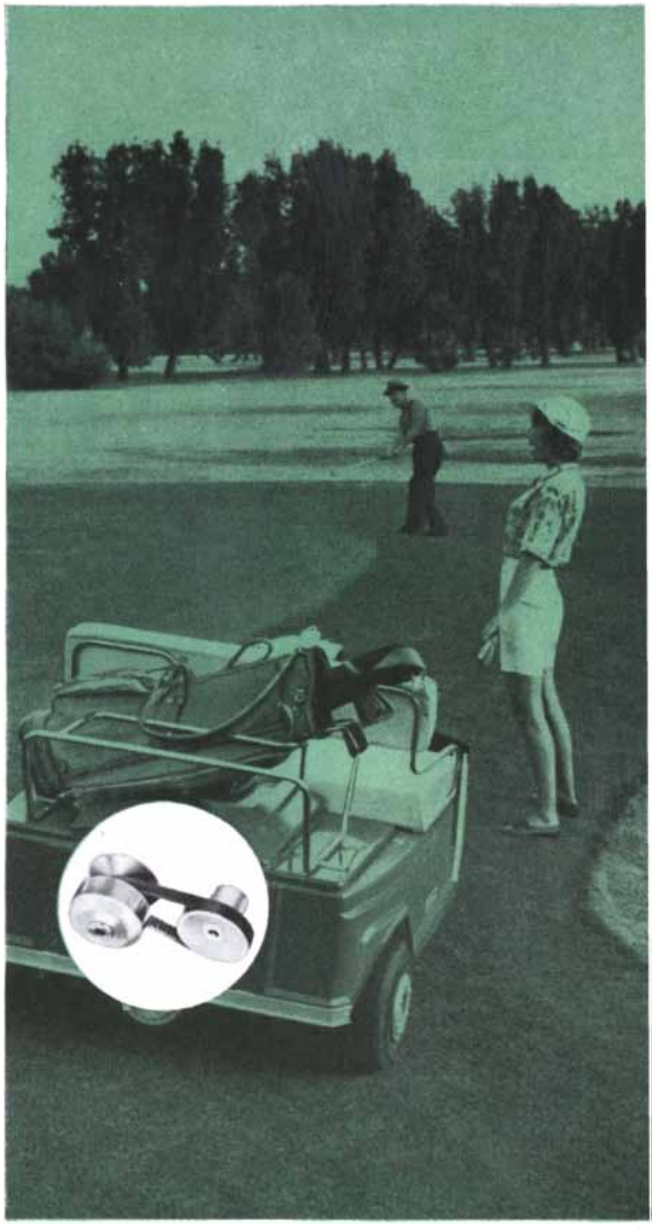
THE 7 HATS OF BORG-WARNER ... (top) national defense; oil, steel and chemicals; (middle row) agriculture; industrial machinery; aviation; (bottom) automotive industry; home equipment.



THE PART AT THE HEART of many an automotive air conditioner: an advanced new compressor by B-W's York Division. Specified by leading auto-makers because, through aluminum, it weighs in at a light 16¾ pounds. Effect on engine balance is next to nil. Also their choice because it mounts vertically or horizontally, on left or right side of engine ... takes up a minimum of precious under-the-hood space. Specified, too, for increased capacity and high-speed operation ... for its incredible efficiency in delivering cool, dehumidified, pollen-free air to a carload of travelers.



POWER LINK ON GOLF LINKS: Morse Power-Flow transmission for small engine that moves twosome from tee to tee on wheels. Uphill to green? This new unit, actually a torque converter that "senses" load requirements, adjusts automatically to go up and over without shifting gears or touching clutch. Without loss of engine speed, either. Ideal, too, for use in lawn mowers, motor scooters, industrial trucks. Product of Morse Chain Company, a B-W subsidiary.

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Control Computer System ideally fitted to industrial needs, with reliability concepts that upgrade the entire controlled system.

RCA 130

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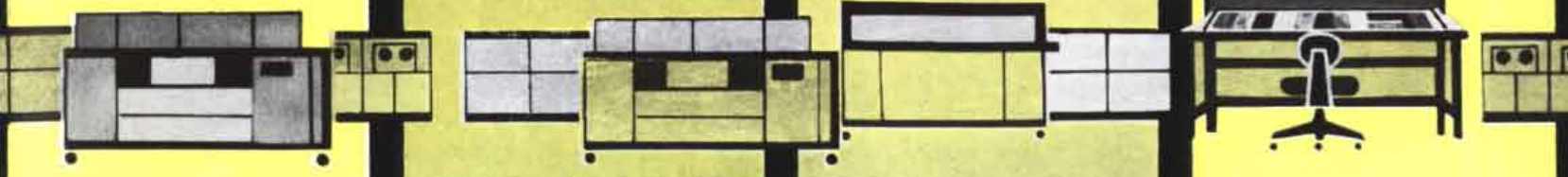
RCA 150

Industrial Data Analysis and Recording System . . . for high-speed scanning, data reduction and logging of control system operation.



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At American-Marietta's *Sierra Metals Corporation*, research scientists are pioneering in the development of advanced alloys capable of withstanding extremely high temperatures and radioactive bombardment. One new Sierra Alloy is now being tested by the Atomic Energy Commission as a basic material for the first nuclear powered reactor in the missile field.

Powdered aluminum is an essential for solid rocket fuels used to power such new missiles as the Minuteman, Hercules, Pershing and Nike-Zeus. American-Marietta's *Metals Disintegrating Company*, the nation's oldest producer of finely divided metals, is now a key supplier of powdered aluminum for solid rocket fuels.

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LETTERS

Sirs:

The recent work on the mechanism of pain summarized by Ronald Melzack ["The Perception of Pain"; SCIENTIFIC AMERICAN, February] provides a partial explanation for the apparently well-authenticated instances in which early Christians showed no sign of pain under torture. Gibbon, for example, describes the death of one Christian thus:

"He was burnt, or rather roasted, by a slow fire; and his executioners, zealous to revenge the personal insult which had been offered to the emperors, exhausted every refinement of cruelty, without being able to subdue his patience, or to alter the steady and insulting smile which, in his dying agonies, he still preserved on his countenance."

Like the wounded soldiers mentioned in Melzack's article, the martyr might feel "relief, thankfulness... even euphoria" rather than feeling himself to be the victim of a "depressing, calamitous event." To a devout Christian, martyrdom was one of the most fortunate things that could possibly happen, guaranteeing its fortunate recipient a place on the right hand of God. Presumably many Christians were not devout enough really to accept personal death by torture as good fortune, but some of them were, and for these the miracle is explained.

GORDON TULLOCK

Department of International Studies
University of South Carolina
Columbia, S.C.

Sirs:

It is apparently instinctive to assume that a highly reflecting surface, such as white paint or snow, is wavelength-independent. Such an assumption is made by James Marston Fitch and Daniel P. Branch in their article "Primitive Architecture and Climate" [SCIENTIFIC AMERICAN; December, 1960]. They draw an analogy between the radiative-heat reflection properties of the ice film on the interior walls of the Eskimo igloo and aluminum foil used for insulation in modern construction. The reflectivity of ice formed on the surface of the snow blocks is quite unlike that of aluminum and does not contribute to the radiative insulation of the igloo.

Both ice and snow behave optically as black surfaces and hence do not reflect at wavelengths longer than two microns. The spectral distribution of radiant heat from human skin at temperatures of approximately 300 degrees Kelvin corresponds to that of an ideal radiator, whose maximum emission occurs at 10 microns. Similarly, the radiation emitted by an oil lamp or a candle is almost entirely confined to the carbon dioxide and water-vapor bands that lie in the infrared region of the spectrum. The amount of energy issuing from such flames in the form of light is a very small fraction of the total, certainly less than 1 per cent. While the ice-film lining of the igloo does reflect appreciable amounts of energy in the visible spectrum, it is of no value whatever as a radiant heat reflector. Both the radiant energy from the flame of the lamp and that from the bodies of the occupants will be completely absorbed by the ice film. Only those materials possessing free electrons, such as metals, will reflect infrared energy.

In the latter part of the article the authors note that "walls are painted or stuccoed white to reflect a maximum amount of radiant heat." If by radiant heat they refer to solar radiation, then the white walls do reflect, but if it refers to the same kind of radiation as that in the igloo, then these walls are as ineffective as the ice.

C. P. BUTLER

U. S. Naval Radiological Defense Laboratory
San Francisco, Calif.

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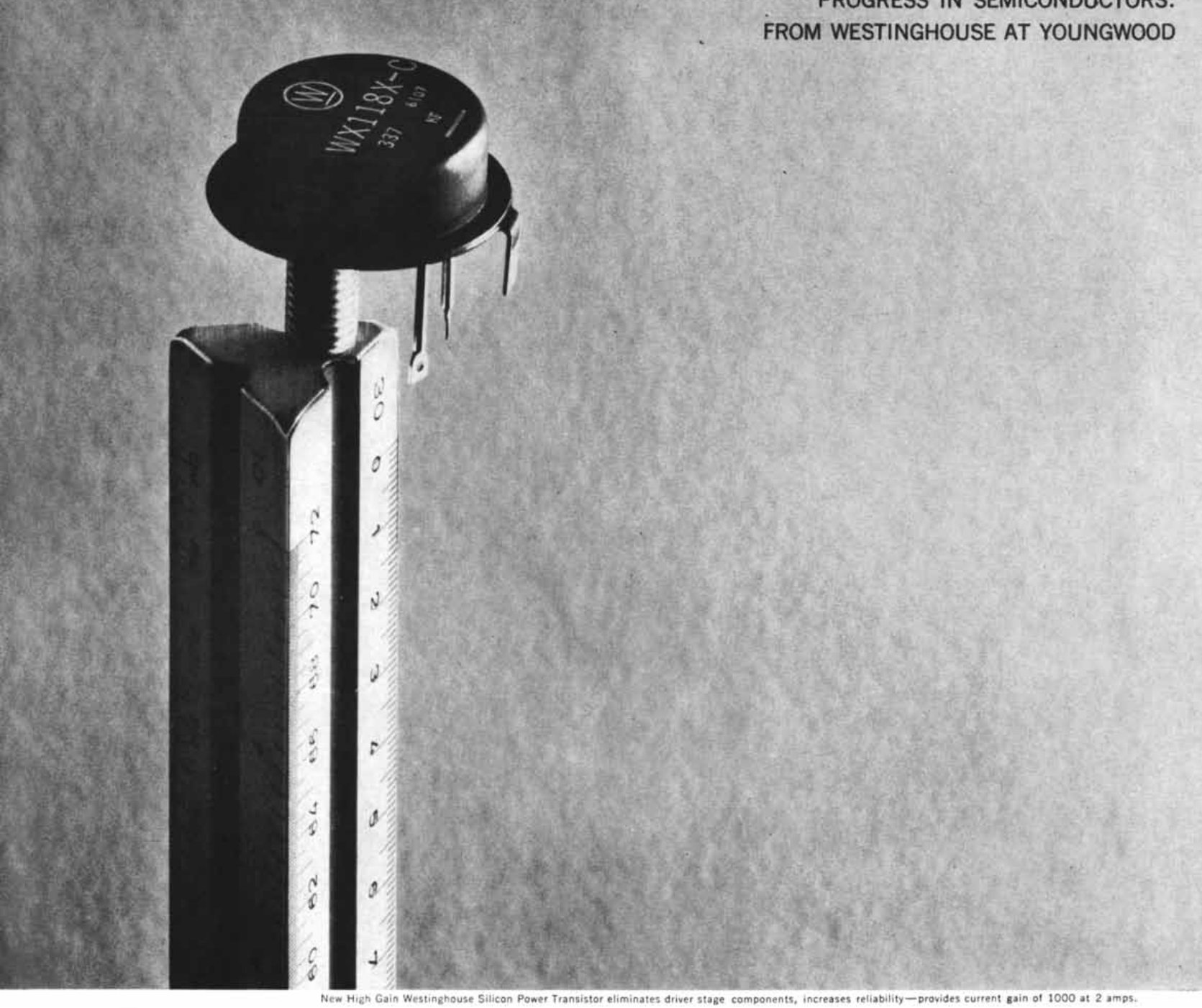
PROGRESS IN SEMICONDUCTORS:
FROM WESTINGHOUSE AT YOUNGWOOD



New High Gain Westinghouse Silicon Power Transistor eliminates driver stage components, increases reliability—provides current gain of 1000 at 2 amps.

What is the new measure of semiconductor reliability?

Semiconductors have built-in reliability. They're compact and solid—they have no moving parts. Yet, because their performance depends on such minute tolerances and critical molecular structures, reliability can never be taken for granted.

One way to safeguard reliability is to exert close control over basic materials and manufacturing methods. Westinghouse has developed many superior quality control techniques. Another important step is to conduct periodic life and environmental tests—including temperature, cycling, shock, vibration, operating life, storage life and others. Westinghouse continuously samples product lines to maintain design quality.

But in the final analysis, reliability means performance in service. Although factory tests cannot exactly duplicate field operating conditions, Westinghouse has developed new test procedures which simulate "worst-worst" field operating conditions. These tests provide the new measure of semiconductor reliability.

Most important of these new procedures is power testing. Each power semiconductor is 100% power tested over its full operating range—to achieve the most severe combination of voltage and current that might be encountered under field conditions. Power testing assures designers of conservative, realistic ratings that can be relied upon in actual service operation.

Westinghouse Semiconductor devices also owe their long life and in-use reliability to such exclusive design features as "Rock Top" Glazed Ceramic construction, all-welded cases, hermetically sealed lead-ins and hard-soldered construction. The combination of power testing and application-oriented design has led to unprecedented reliability in service.

If you would like details on the reliability program of Westinghouse Semiconductor devices, please write for booklet, "New Dimensions in Semiconductor Reliability." **Westinghouse Electric Corporation, Semiconductor Dept., Youngwood, Penna.** SC-1029

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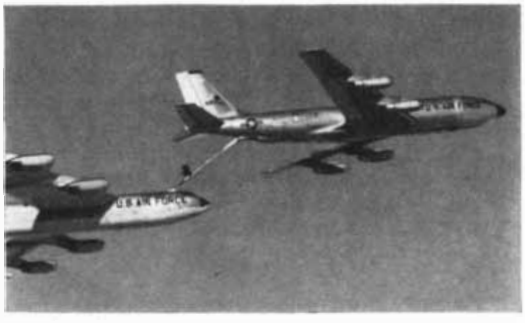
Historic first firing of Minuteman, the U. S. Air Force's first solid-fuel intercontinental ballistic missile. Completely successful, this flight marked the first time in history that so many missile components were tested on initial flight: three rocket stages, full guidance system and nose cone. Compact, quick-firing Minuteman missiles, scheduled for operational status by mid-1962, will be stored ready for instant action in underground silos and on special trains. Boeing is responsible for Minuteman assembly and test, design and development of launch control and ground support systems.

Capability has many faces at Boeing



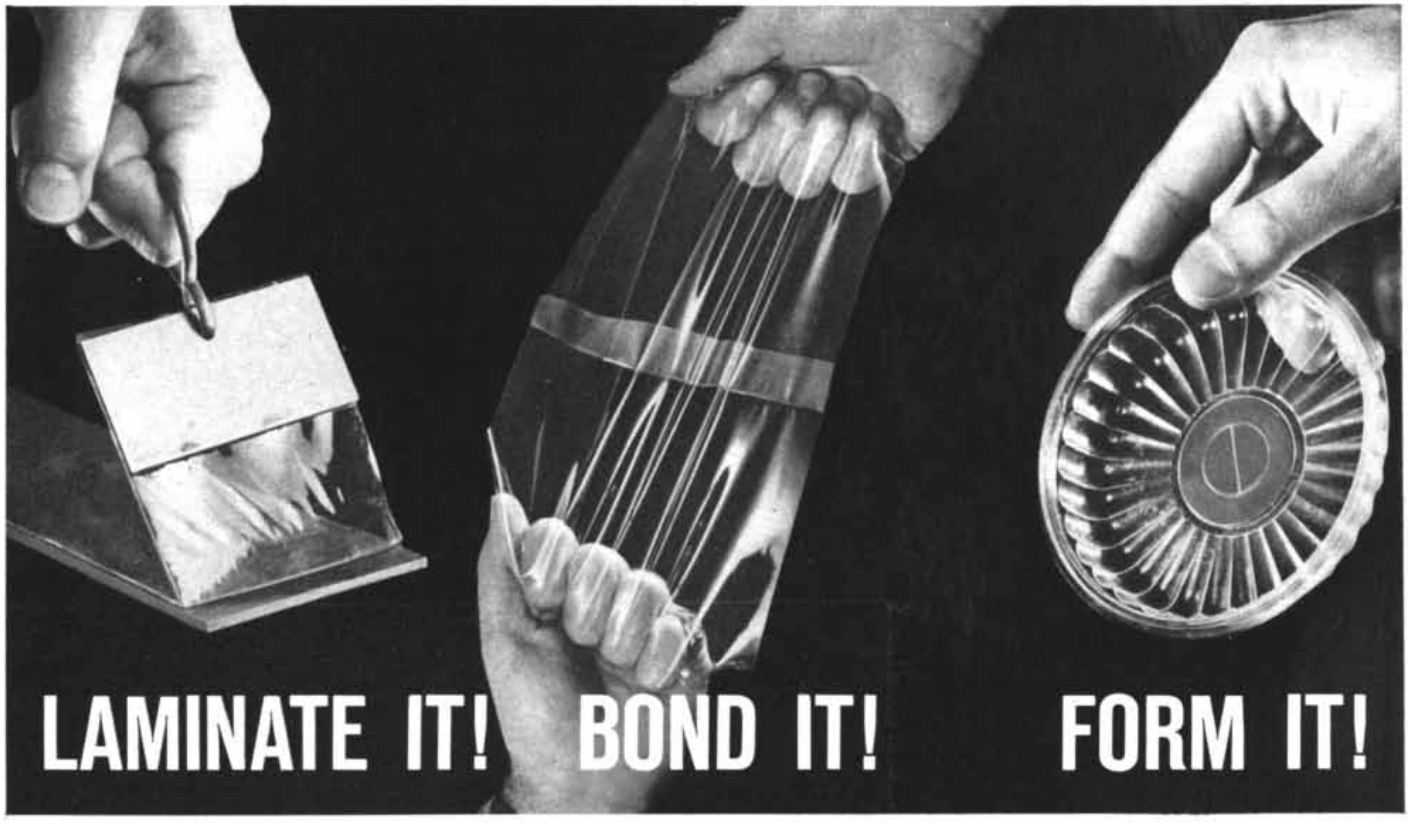
SKY TANKER. Boeing KC-135 jet tanker refuels bombers and fighters to provide greatly extended range. This versatile Boeing jet is also a military transport. The United States Air Force recently ordered 30 C-135s, cargo-jet version of KC-135.

TESTING. TESTING. Boeing electronic system tests effectiveness of radar and countermeasures systems. Boeing is widely active in electronics—in research, design, manufacture and test, and in the assembly of systems for Air Force's BOMARC and Minuteman missiles, and Dyna-Soar space-glider.

BOEING

NEW FROM DU PONT...
a thermoplastic "Teflon" film that's easy to fabricate

TEFLON® FEP FILM



New "TEFLON"* FEP-fluorocarbon film has nearly *all* the unique advantages of "TEFLON" TFE with one big plus. It's a true thermoplastic that can be easily formed and sealed. One type of this new film can be applied *with* adhesives, another can be laminated and heat-bonded *without* them.

Here are just some of the advantages of "TEFLON" you get in this new film • Unique antistick and low-friction properties • Chemically inert to practically all known chemicals • Electricals are high (up to 4,000 volts/mil dielectric strength) and *stay* high • Performance stays virtually constant from –250°C. to over 200°C.

"TEFLON" FEP film opens the door to whole new areas of design and product improvement. Mail coupon and start investigating "TEFLON" FEP film for yourself. (Briefly describe the end use you have in mind.)

**Du Pont trademark*

DU PONT
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BETTER THINGS FOR BETTER LIVING
...THROUGH CHEMISTRY

E. I. du Pont de Nemours & Co. (Inc.)
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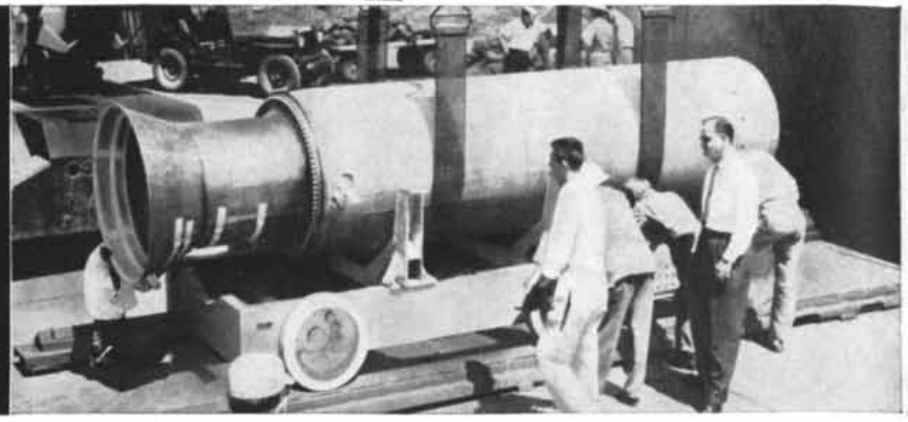
Wilmington 98, Delaware

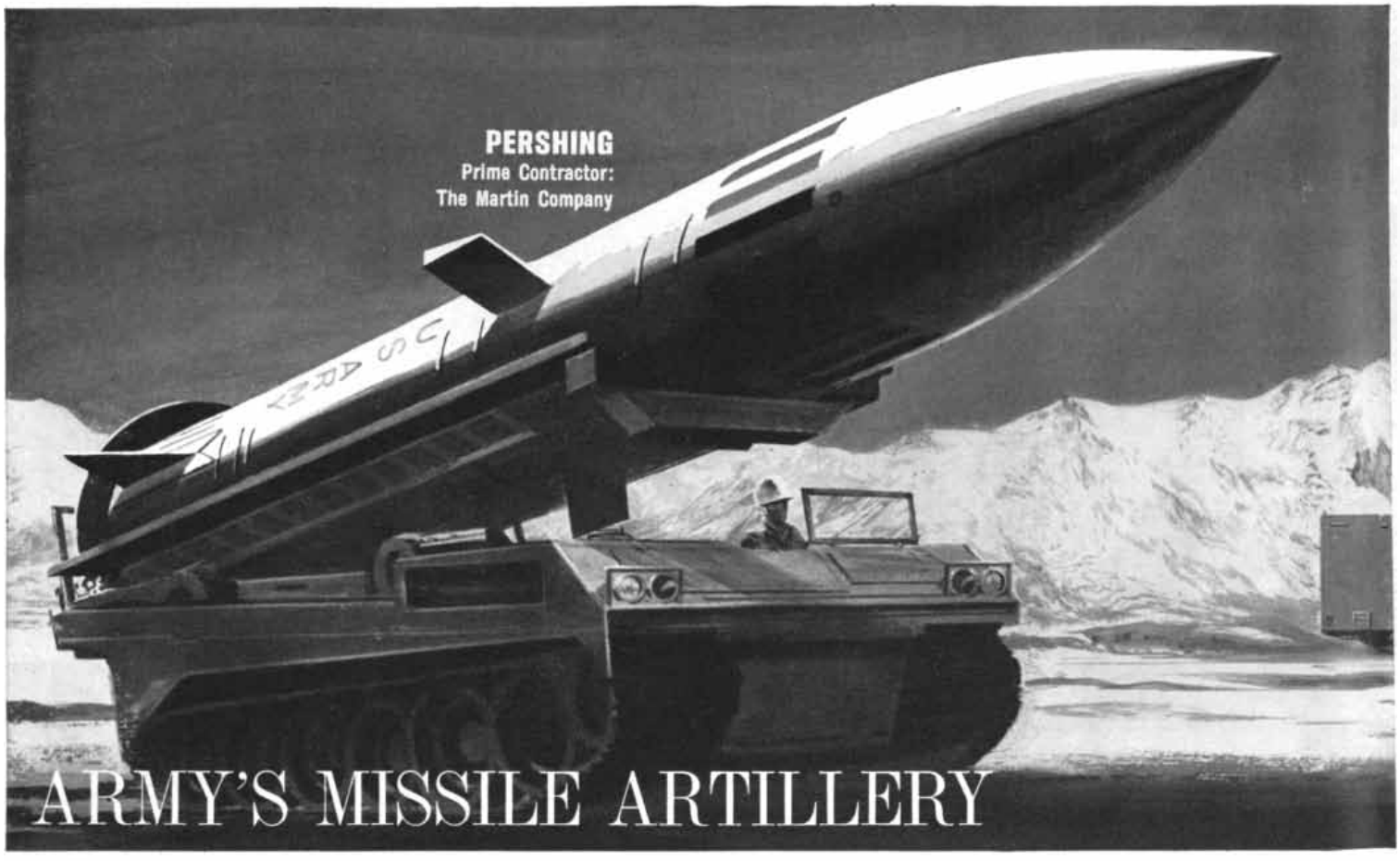
Name_____
Company Name_____
Address_____
_____
Job Function_____
Proposed End Use_____

Find out about *cementable* "Teflon" FEP film at the Design Engineering Show, Booth #860

RELIABILITY in depth, from



REDSTONE *Working as part of Army's Ordnance team, Thiokol's Redstone Division conducts research into propellant formulation and solid propellant motor development. Experiences—gained in the labs, through developing prototype engines, and at firing bays continuous since 1949—have resulted in many significant breakthroughs . . . providing a steady increase in size, thrust and performance of solid rocket motors.*

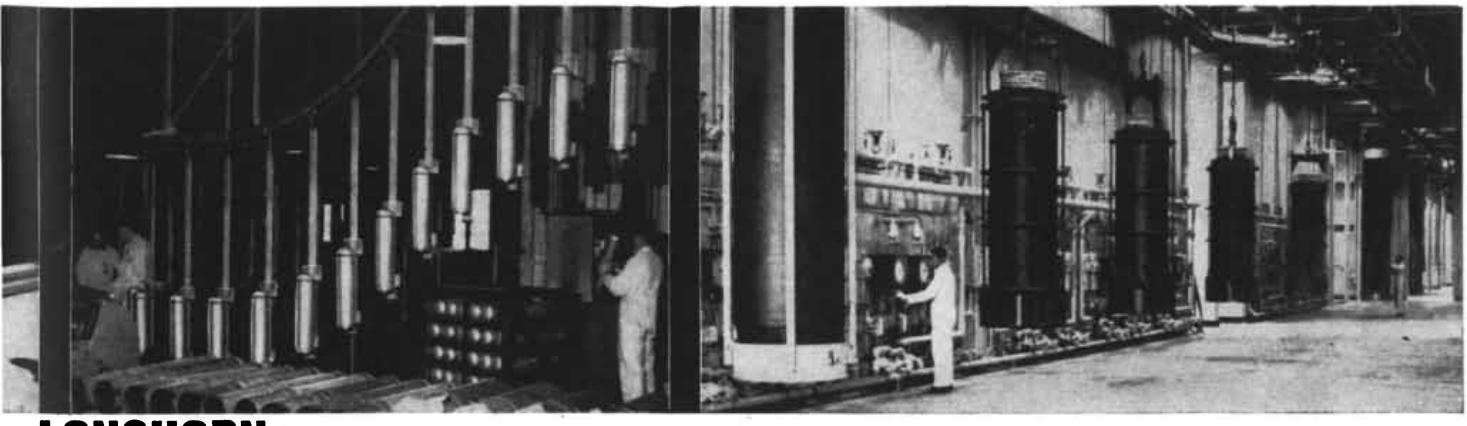


ARMY'S MISSILE ARTILLERY

ARMY

In close cooperation with the Army and prime contractors . . . Thiokol designs, develops and produces propulsion systems in wide variety to meet the most stringent military requirements. The associations are distinguished by a series of major breakthroughs in propulsion engineering—beginning with small rocket motors for tactical field use and carrying through to massive powerplants for anti-missile and satellite application. All have checked out in static firings and

research through production



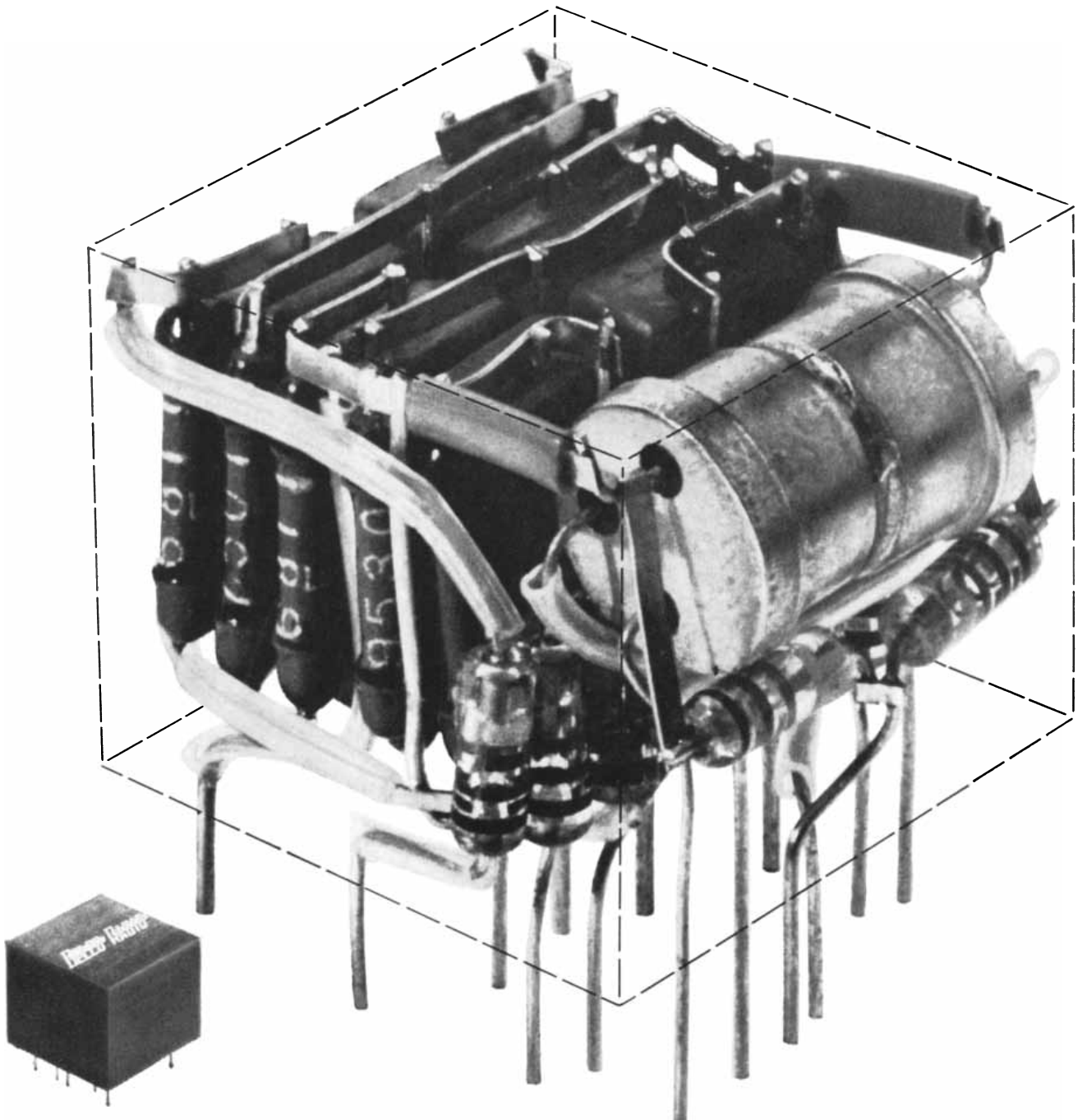
LONGHORN *Motors for the Lacrosse and for the developmental Sergeant and Pershing missiles, and for other major systems—all boasting remarkably high reliability scores—move into smooth mass production at Longhorn. Incorporating most advanced methods of manufacture and quality control, Longhorn's total productive capability has yet to be challenged. Other Thiokol Divisions provide additional scientific and production capabilities.*

flight tests with virtually 100% reliability. All have contributed mightily to advancing the total state of the art. Additional capabilities for Army's advanced thinking are provided by other Thiokol Divisions. Utah, for large engine production—RMD, for sophisticated liquid systems — and Elkton, for diversified special motors.

Through fluid programming of assignments, and strategic enlargement of facilities for research, development and production, Thiokol maintains a live capability to meet any current and future propulsion challenge — military or space.

THIOKOL

THIOKOL CHEMICAL CORPORATION, Bristol, Pennsylvania
Rocket Operations Center: Ogden, Utah



MINIATURE BUILDING BLOCK MODULES

5 times actual size to better show the 28 standard-sized components

Delco Radio's high density packaging of reliable standard components utilizes the unique three-dimensional welded wiring technique. These miniature modules are available off the shelf in 16 basic types. Or with them, Delco Radio can quickly build for you a compact, reliable digital computer for airborne guidance and control or any other military application. Vacuum encapsulated with epoxy resin, the modules perform all the standard logic functions. They meet or exceed all MIL-E-5272D (ASG) environmental requirements, and operate over a temperature range of −55°C to +71°C. Too, these same reliable digital circuits are available packaged on plug-in circuit cards. And we can also supply circuits to meet your specific needs. For complete details, just write our Sales Department. *Physicists and electronics engineers: Join Delco Radio's search for new and better products through Solid State Physics.*

PIONEERING ELECTRONIC PRODUCTS THROUGH SOLID STATE PHYSICS

DELCO RADIO
DEPENDABILITY
RELIABILITY

Division of General Motors • Kokomo, Indiana

EARTH'S EYE TO THE SKY

VA-842.
1.25 MW peak.
75 KW average.

Men have searched the sky for knowledge since history began. Each generation sees farther, learns more. But the human eye is reaching its limit—and there is still much more to know.

Radar astronomy can help. In Puerto Rico, the world's largest radar will send beams from an unusually powerful transmitter into a 1,000-foot wire mesh reflector, to bounce back out into space. The returning signals will extend man's "vision" by millions of miles.

Two Varian VA-842 klystrons will power the transmitter for this advanced USAF project. With each 2,000-microsecond pulse, these super-power tubes deliver 2.5 million watts at 430 megacycles. Write Tube Division for technical information.

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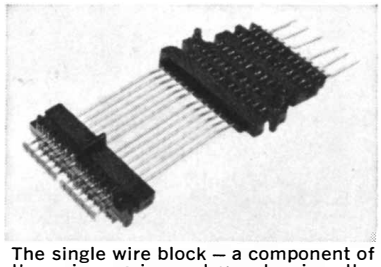
VARIAN A.G. (SWITZERLAND)

Hardly larger than cigarette packages, wire spring relays form the heart of switching apparatus for more than 200-million telephone calls a day. The pencil indicates the top row of tiny palladium-capped contacts which are vital to the relay's switching functions.

Probing for palladium via thermoelectricity

Wire spring relays are vital to the Bell Telephone System's reliable, high-speed switching equipment. Western Electric will manufacture more than 13 million relays in 1961. Palladium-capped contacts on these relays are necessary for their optimum performance—therefore, positive verification of the palladium is essential.

Verification by existing means has proved to be extremely difficult, however, because of the caps' size (only 1.01 x 0.73 x 0.042 inches) and the fact that the palladium and the cupro-nickel base blocks to which the caps are welded are similar in color, making visual checking highly unsatisfactory. Also, the characteristics of the metals involved make ordinary electrical and magnetic methods impractical.



The single wire block — a component of the wire spring relay — showing the cupro-nickel contact points, some of which must be capped with palladium.

Contact verification machine, developed and built by Western Electric, being programmed to check wire blocks for dielectric breakdown, physical configuration, and palladium contacts.

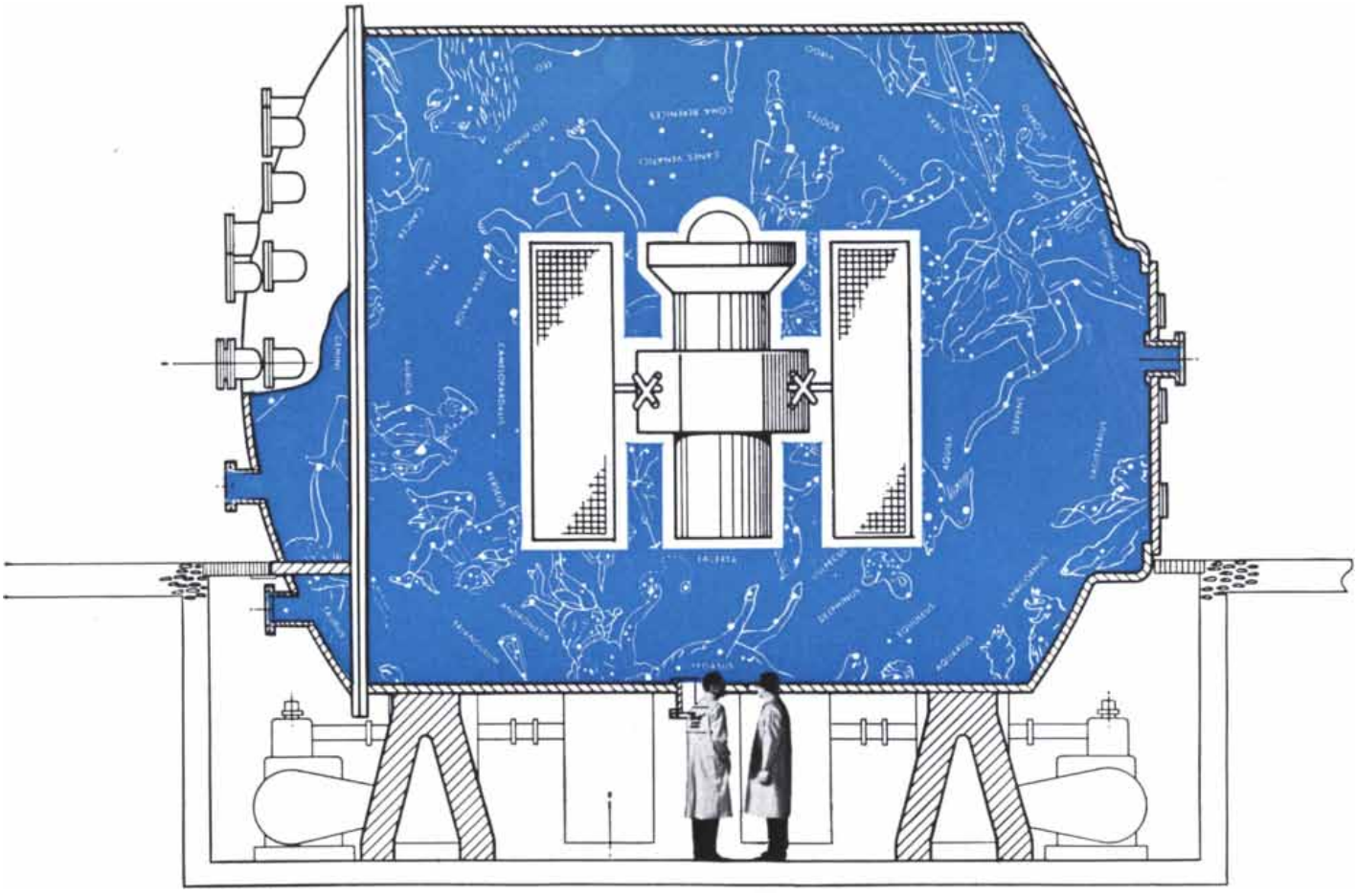
To overcome this problem, Western Electric engineers have developed and built an ingenious machine which utilizes the Seebeck thermoelectric effect, by which an electrical circuit made up of two different metals generates an electric current when the junction between the two metals is heated. In this case, nickel and palladium were the metals involved, but another feature of the Seebeck effect is that a circuit composed of nickel and cupro-nickel generates a current *which flows in the opposite direction.*

The engineers made use of this feature by using nickel probes — preheated to 300 degrees Fahrenheit — in the new machine. The probes touch all contacts on the relay's single wire block assembly, and the *direction* of the current produced indicates whether the probe has contacted palladium or the cupro-nickel base metal. Amplifier circuits enable the "indicator" currents to operate automatic controls and automatically reject defective assemblies.

Being able to intentionally leave caps off certain pre-selected contacts is also a prime advantage of this new verification process, since hundreds of thousands of relays use less than the maximum number of contacts. Savings in material costs, which are made possible by omitting precious palladium from unused contacts, are significant. But the most important advantage of the process is the proven ability to produce a product with verified quality — the kind of quality required by the Bell System's twenty-three local telephone companies to give highly dependable telephone service.

Western Electric

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM



SATELLITE IN DRESS REHEARSAL. This 20 x 27 foot, high-vacuum chamber now under construction is the newest addition to our series of chambers for complete space system development, assembly, and test at a single location. Full-size spacecraft will operate in this chamber as in orbit. Satellites will be subjected to both simulated solar glare and the chill of space darkness. They will also experience launch and boost conditions, and structural and thermal loads. Career opportunities are open to better engineers and scientists to staff this expanding space laboratory.

BENDIX SYSTEMS DIVISION
ANN ARBOR, MICHIGAN

THE Bendix CORPORATION

NO. 34 IN A SERIES

OUT OF THE LABORATORY

Manned space missions of extended flight duration must have a large, continuous, long lasting and reliable source of electrical power. Only a nuclear reactor heat source is compatible with these requirements to provide power for propulsion and to operate all equipment aboard the spacecraft. Advanced nuclear energy conversion systems are now being developed by Garrett's AiResearch divisions to meet these new power requirements . . . another vital contribution by Garrett to man's conquest of space.

• *Outstanding opportunities for qualified engineers*

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

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OTHER DIVISIONS AND SUBSIDIARIES: AIRSUPPLY-AERO ENGINEERING • AIRESEARCH AVIATION SERVICE • GARRETT SUPPLY • AIR CRUISERS AIRESEARCH INDUSTRIAL • GARRETT MANUFACTURING LIMITED • MARWEDEL • GARRETT INTERNATIONAL S.A. • GARRETT (JAPAN) LIMITED

New Money Makers for Industry:

KIN TEL CLOSED CIRCUIT TV SYSTEMS

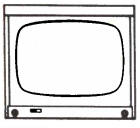
what they are, and what they can can do for you...

What is a KIN TEL Closed Circuit TV system?

The basic KIN TEL closed circuit TV system consists of a camera, camera control unit, and monitor, each connected by cable. The camera can be located at great distance from the monitor, and any number of monitors may be used to display the same picture.

Cameras are small enough to hold in your hand; rugged enough to operate in virtually any environment; versatile enough to cover (via remote control) almost any area; and sensitive enough to provide excellent pictures of subjects illuminated by a single candle.

The camera control provides automatic operation. The system is continuously self-adjusting for wide variations in light levels (several thousand to one), and features automatic high definition of bright objects. The only control you have to touch is the on-off switch.

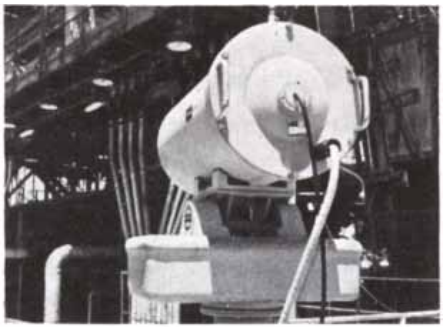


The monitor displays a crisp, clear picture...full 650-line resolution, twice that of the best home TV reception.

How are such systems used?

Today, KIN TEL TV systems are performing a number of jobs for *hundreds* of firms, safely, inexpensively, tirelessly.

They are being used to watch operations or events that are tedious, difficult, dangerous, or even impossible for men to watch.



For example: Convair (above), Douglas, Lockheed and Northrop watch rocket tests with KIN TEL systems. U.S. Steel uses one to see inside open hearth furnaces. Westinghouse watches nuclear power reactor tests with one.

They are being used for surveillance.

For example: The San Francisco Naval Shipyard uses one to guard against pilferage.

They are being used for traffic control.

For example: The Alameda Naval Air Station uses a KIN TEL TV system to observe aircraft landings on the portion of the runway that is not visible from the control tower.

They are being used to transmit visual information quickly and accurately; for remote observation of charts, meters, graphs, schedules, blueprints, photographs, images from microscopes, fingerprints, signatures...the list is almost endless.

For example: E. F. Hutton uses a KIN TEL system to transmit stock market quotations to the offices of the firm's executives. The Los Angeles Department of Water and Power uses one for remote viewing of water-level meters. The University of California teaches physics with one.

They are being used for monitoring any operation that normally requires standby personnel.

For example: American Potash and Chemical (above) monitors conveyor line and warehousing operations with a KIN TEL TV system.

Why do these firms choose a KIN TEL system?

For a variety of reasons.

First, *reliability.* KIN TEL TV is designed for continuous duty operation in severe environments. Day in and day out, it keeps working. It's the first choice for ICBM and other missile programs that really depend on TV, that can't chance failure, that can't afford to compromise with reliability.

Second, *picture quality.* KIN TEL TV presents clear, sharp pictures. Full 650-line resolution provides maximum data...essential for *quantitative* observation of complex operations or transmission of printed material.

Third, *automatic operation.* KIN TEL TV is the only closed circuit system that provides entirely automatic, through-the-lens compensation for light-level changes of several thousand to one.

Fourth, the KIN TEL closed circuit TV system is extremely *sensitive.* The light required to read this page is enough for sharp clear pictures, and usable pictures can be provided with less than one-foot candle illumination.

Fifth, KIN TEL TV systems are *easy to install* and *simple to operate.* With no changes in lens iris to make, with no difficult, interacting electrical adjustments required, the only thing the operator has to know is the location of the on-off switch.

Sixth, a *complete* line of shelf-item system components and a variety of cameras and monitors make virtually any application feasible...permit observation of nearly every kind of operation, under all kinds of conditions.

For example, with system components, you can remotely position the camera, remotely select one of several lenses, remotely "zoom" in or out for closeup or wide-angle viewing, operate the camera in extremes of temperature or in explosive or dusty atmospheres, view microscope images. Whatever your viewing problem, KIN TEL probably has a *stock* solution.

Seventh, you don't have to waste your time and money on application engineering. At no obligation to you, KIN TEL's nationwide factory-trained field engineers – thoroughly experienced in optics, environmental requirements, lighting, cabling, human engineering factors, and other installation considerations–can determine whether or not closed circuit TV can be put to profitable use in your intended application.

What can a KIN TEL system do for your business?

It can do what it is doing right now for hundreds of other firms. It can save you time and money...increase efficiency...better your service to clients and customers. To find out how, write direct for catalog 6-205 and the name of your nearest KIN TEL engineering representative.

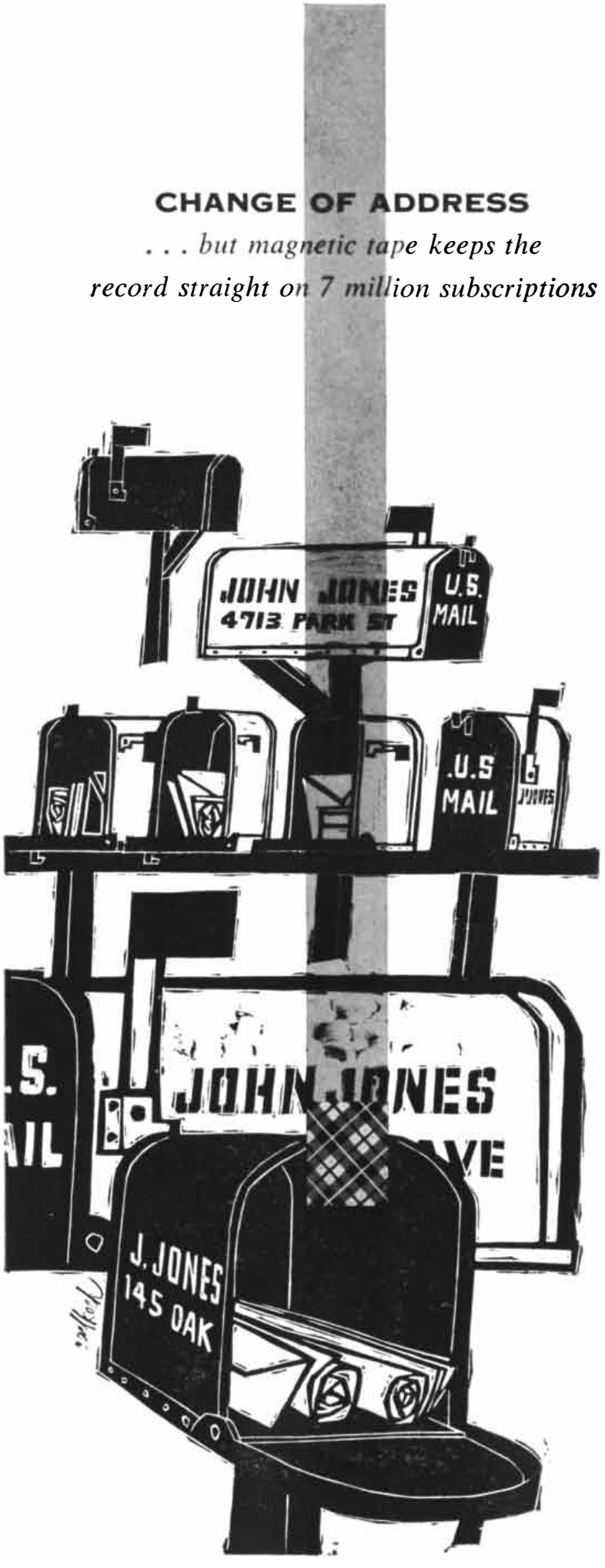
KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

5725 Kearny Villa Road, P. O. Box 623, San Diego 12, California, BRowning 7-6700

KIN TEL–pioneer and leader in closed circuit television.

CHANGE OF ADDRESS

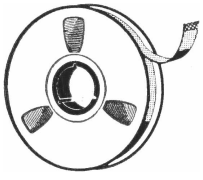
. . . but magnetic tape keeps the record straight on 7 million subscriptions



MR. JONES MAY MOVE THIS MONTH—but if he notifies Esquire, his magazine will follow him to his new home. His new address will be registered almost at once by an amazing electronic system now in use by the Esquire, Inc. subscription fulfillment center.

One of the nation's largest installations for alphabetic list maintenance, the Esquire system employs SCOTCH® BRAND Magnetic Tape. The tape not only helps maintain the lists, but controls the addressing of some seven million magazines which Esquire, Inc. mails for its own publications and others.

Subscriber information on punched data cards is converted to tape and updated weekly. When circulation time rolls around, the tapes are fed into a Remington Rand Univac* File Computer which transfers information on expiring subscriptions to other magnetic tapes for promotional addressings. Main tape remains intact and is fed into a serial printer. The tape-controller printer runs off addresses on a mailing strip at the rate of 35,000 per hour, bettering previous rates by nearly 28,000.



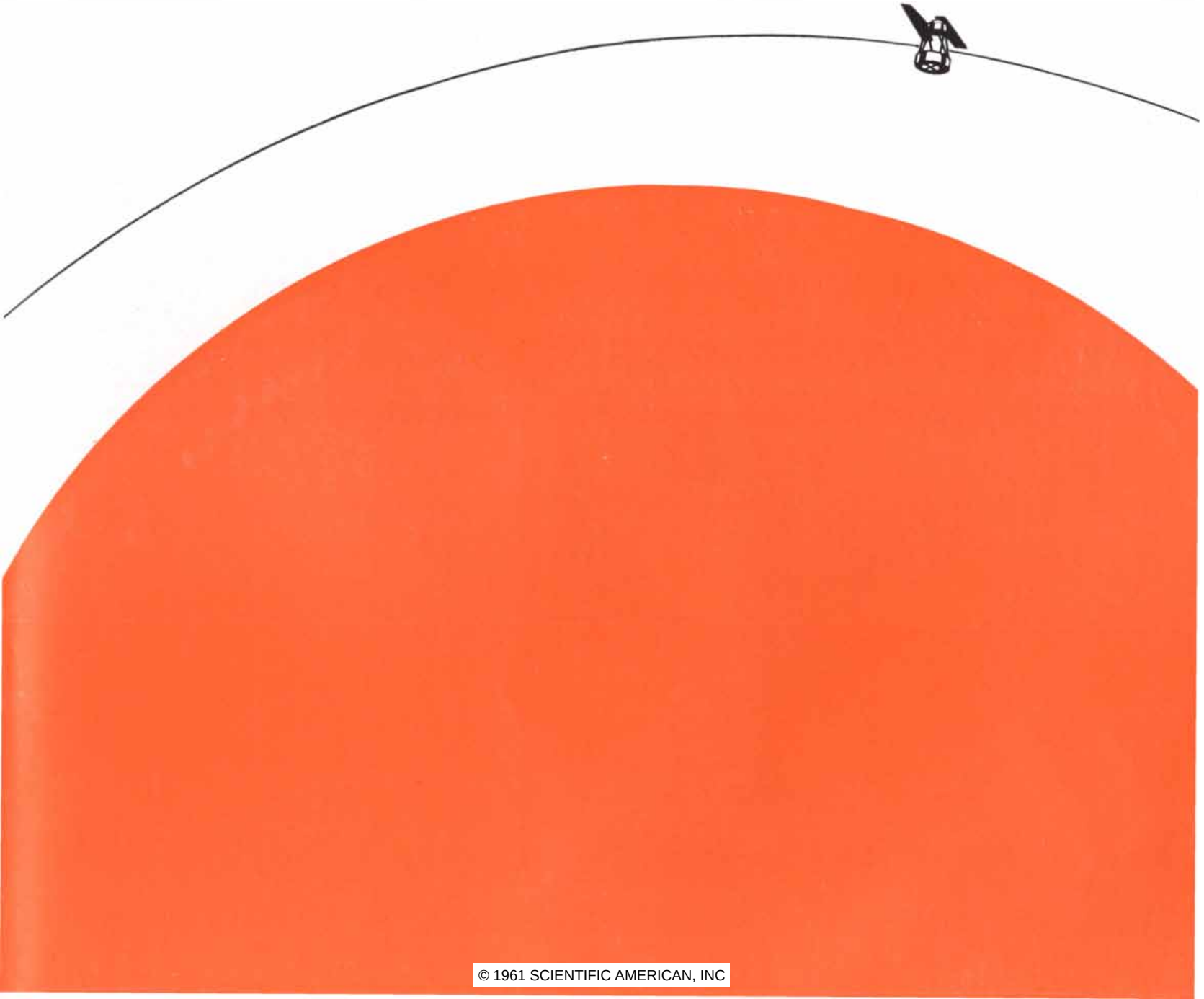
The speed and accuracy of the entire process is improved, while the space required for storage is reduced. After careful consideration, Esquire, Inc. selected "SCOTCH" BRAND Heavy Duty Instrumentation Tape No. 498 because it proved to have the endurance to withstand frequent runs through the system at very high speeds, according to Joseph Arnstein, Esquire's vice president for circulation.

This is just one of the many ways "SCOTCH" BRAND Magnetic Instrumentation Tape now serves the future. It controls industrial automation and helps scientists explore earth, sea, and space. The first practical magnetic tape devised, "SCOTCH" BRAND remains the leader as new, more sensitive tapes are developed for science, business, and industry. For details on tape constructions to serve your needs, write Magnetic Products Division, Dept. MBO-51, 3M Co., 900 Bush Ave., St. Paul 6, Minnesota.

MISSILE AND SPACE VEHICLE DEPARTMENT, PHILADELPHIA, PA.

NIMBUS will be America's next-generation weather satellite in space. Continually viewing the globe with TV cameras and other sensors, Nimbus will help man forecast the weather and learn more about its causes. General Electric's Missile and Space Vehicle Department is constructing the space craft and providing systems integration for the system designed by the National Aeronautics and Space Administration.

GENERAL ELECTRIC



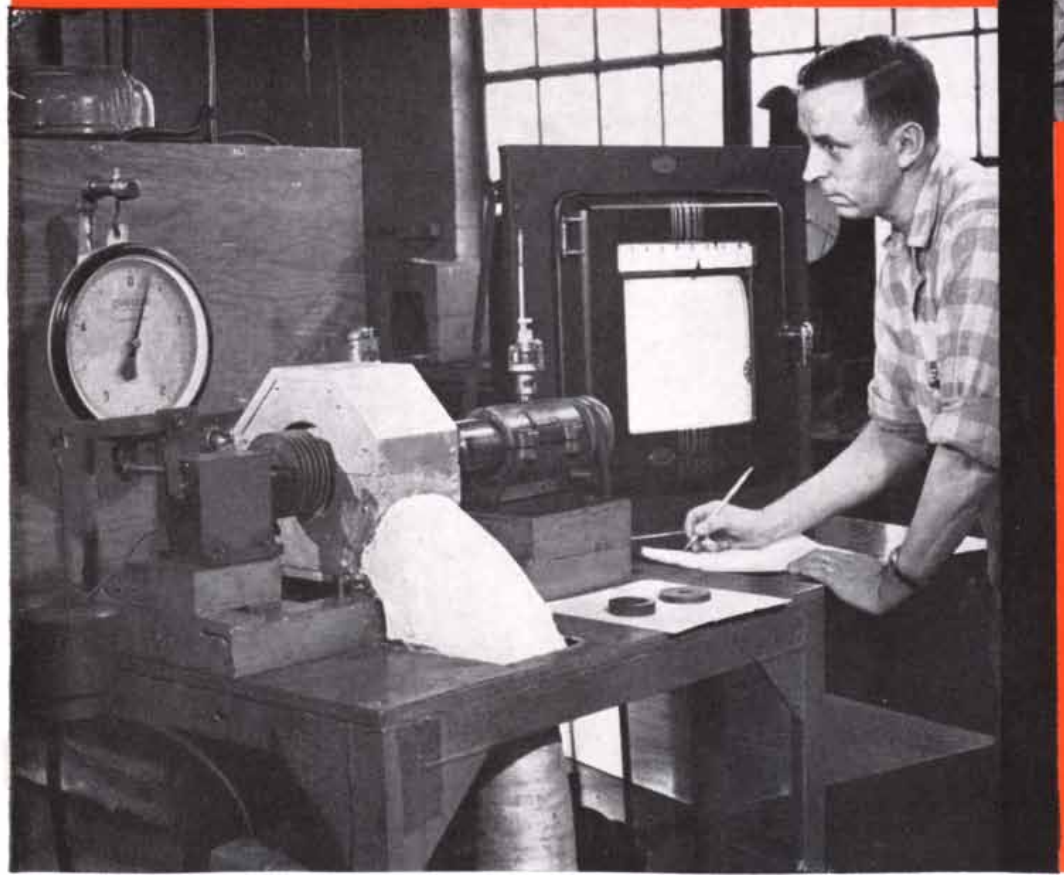
GRAPHITAR®

(CARBON-GRAPHITE)

FOR DEPENDABILITY

GRAPHITAR'S own character makes it dependable. A non-metallic engineering material, formed from carbon and graphite powders and a special binder, compacted under high pressures and furnaced at temperatures up to 4,500°F., GRAPHITAR possesses inherent characteristics that give finished parts exceptional dependability. GRAPHITAR'S natural heat resistance, for example, gives bearings, seals, vanes and rings exceptional dependability whenever dependability is one of the prime requisites.

There are other characteristics every bit as important to GRAPHITAR'S dependability. They include chemical and magnetic inertness, mechanical strength and adaptability to self-lubrication. Besides these natural characteristics, GRAPHITAR engineers can control porosity, strength and hardness to match GRAPHITAR'S physical properties to each individual application. It's little wonder that GRAPHITAR has become one of the design engineer's most versatile and useful materials.



In this laboratory test stand, oxidation-resistant GRAPHITAR parts are being checked under simulated operating conditions. Similar tests have proven that, when GRAPHITAR parts are exposed in oxidizing atmospheres at 1,200°F., they show only a weight loss of less than six percent after 200 hours.

In the Engineering Department of The United States Graphite Company, micro-photo studies are indispensable in the study of internal part structure. The Metallograph is just one of dozens of modern technological aids employed in both the quality control of production GRAPHITAR parts and in the research and development of new products. GRAPHITAR parts are engineered for dependability.

GRAPHITAR air/oil seals employed in today's high-speed turbojet engines have established an enviable record for operating dependability. Installed on the main shaft of the turbine, GRAPHITAR seals successfully withstand tremendous shaft speeds and generated heat.

GRAPHITAR bearings in the power reactor pumps of American nuclear submarines have compiled an outstanding record for dependability.

Unusually shaped parts of GRAPHITAR can be molded easily with today's modern techniques. Ears, face slots and outside diameter notches of friction disc above, left, were molded in one operation without need for secondary machining and finishing.

Do you have an application in which GRAPHITAR'S dependability can help solve a tough problem, reduce your costs and improve the operational life of your products? Our engineering staff can help you find out. Our field men can also give specialized, on-the-job consultation. Send for your free copy of Engineering Bulletin #20. Included is helpful information about the properties, characteristics and applications of GRAPHITAR.

THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 6, MICHIGAN

GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDER METALLURGY • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

R-294-2

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MAY, 1911: "The first annual banquet of the Aeronautical Society occurred at the Hotel Astor, New York City, on the evening of April 27. Brigadier General James Allen, chief of the Signal Corps, told of what the War Department is trying to accomplish with its $125,000 appropriation. He said the Signal Corps wants aeroplanes capable of carrying a load of 400 pounds in excess of the aviator, fuel, etc., and of flying as far and as fast as possible when fully loaded. That the War Department will pay good prices for machines that fulfill the requirements is shown by the purchase last week of new Wright and Curtiss biplanes at $5,000 and $6,000 respectively. General Allen hoped that the amateur aviators of the country could be called on in time of need, and he made it plain that the Government expects to help them in practical experimentation whenever possible. The arrival of the Hon. William Howard Taft was the cause of great cheering. The President spoke reminiscently of the progress of invention as noted by him years ago when he was a lawyer and a judge and came into intimate contact with inventors and their work. In closing he said that he was ready to go up whenever an aeroplane was produced that would lift his avoirdupois."

"In 'Radioactivity as a Kinetic Theory of a Fourth State of Matter,' a discourse delivered at the Royal Institution by Professor William H. Bragg, F.R.S., we find the following: 'The motions that the kinetic theory of gases considers are those of the molecules of which gases consist; in the case of radioactivity, the things that move are quite different. In general, the radiant particles move hundreds of thousands of times as fast as the gas molecules do, and it is, no doubt, because of this fact, as well as their usually extreme minuteness, that their power of penetrating matter is so great. The newer movement exists superimposed upon the other. There is a grosser movement of gas molecules that has long been studied, and in the same place and at the same time there is a far subtler and far more lively movement that is practically independent of the other. Your vice-president, Sir William Crookes, was the first to find any trace of it. The behavior of the kathode rays in the vacuum tubes that he had made showed him that he was dealing with things in no ordinary condition. Whatever was in motion was neither gas nor solid nor liquid as ordinarily known, and he supposed it must be possible for matter to exist in a fourth state. We have gone far since Sir William's first experiments. The X-ray tube and radium have widely increased our knowledge of phenomena parallel to those of the Crookes tube. But I think we may still be glad to use Sir William's definition.' "

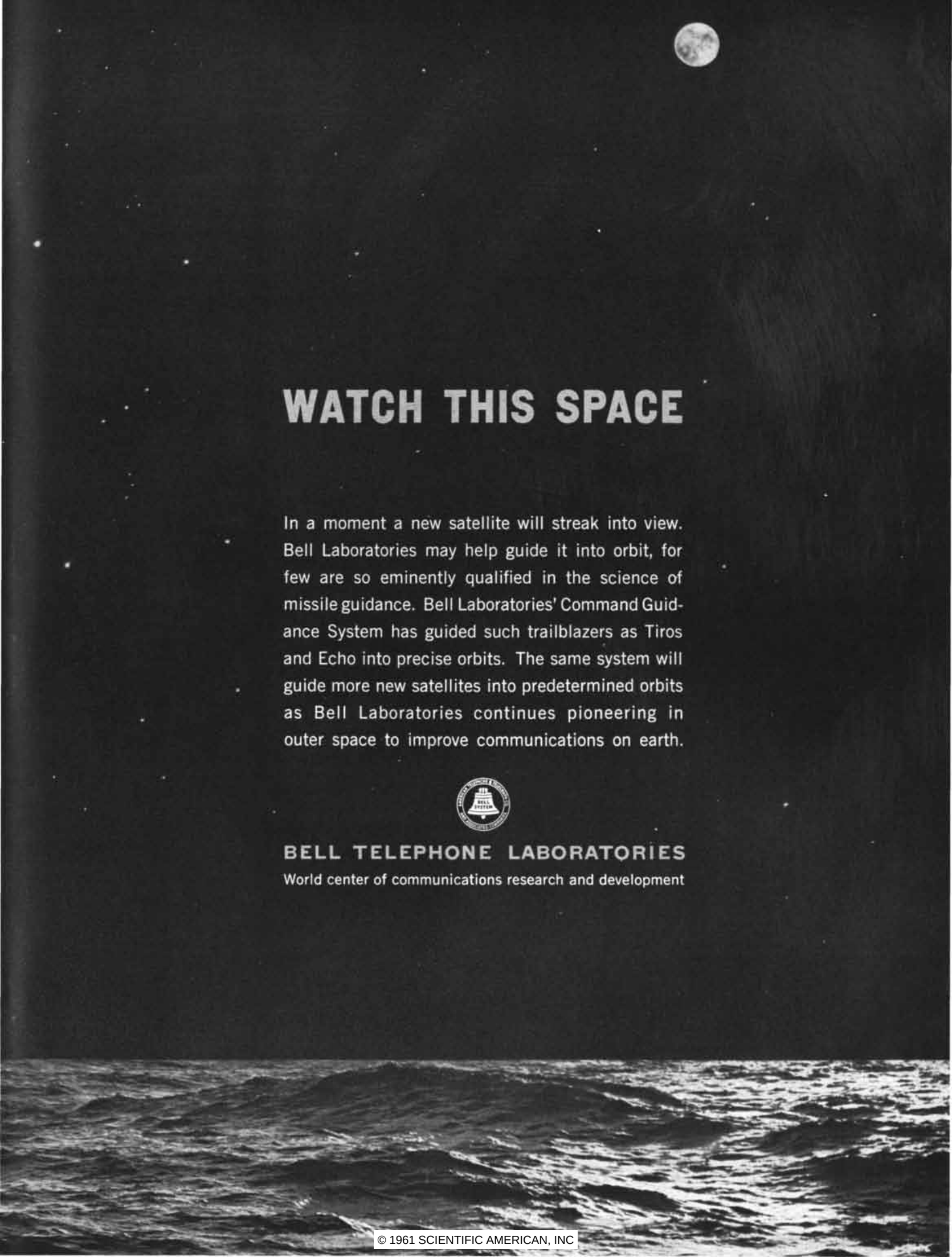
MAY, 1861: "The new mode of analysis by the lines of the spectrum is rapidly yielding fruit. Mr. William Crookes, of London, editor of the *Chemical News*, has just discovered by its means a new element, probably of the sulphur group."

"The most remarkable scientific event of modern times is the publication of a treatise on chemistry proceeding on the same plan in organic chemistry as has been adopted for a century past in mineral chemistry; that is, forming organic substances synthetically by combining their elements with the aid of chemical forces only. The author who has performed demonstrations by this method is Berthelot, who has been occupied with organic synthesis since he first devoted himself to chemistry. Berthelot is not a vitalist; he is convinced that 'we may undertake to form, *de novo*, all the substances that have been developed from the origin of things, and to form them under the same conditions, by virtue of the same laws and by means of the same forces that nature employs for their formation.' "

"On the fifteenth of April, 1861, Abraham Lincoln, President of the United States, issued a proclamation calling out the militia of the several States, to the aggregate number of 75,000, for the purpose of suppressing illegal combinations in the States of South Carolina, Georgia, Alabama, Florida, Mississippi, Louisiana and Texas. This proclamation, in combination with the attack of the rebels on Fort Sumter, immediately united all parties at the North in support of the Government, while it threw the Border States of Maryland, Virginia, Kentucky and Missouri into greater trouble than ever. The Governors of the three last-named States refused to comply with the President's requisition for troops. The Northern States responded with remarkable alacrity and unanimity. On the seventeenth, in a secret convention, Virginia, which has a population of 1,500,000, much larger than that of any other Southern State, passed an ordinance of secession. At the same time, 2,500 men were sent to seize the arsenal at Harpers Ferry. On the approach of the secessionists, the commander of the arsenal, in obedience to orders from Washington, burned the arsenal and retired. This attempt was probably part of a plan to seize the capital, as this had been boldly threatened by the leaders of the rebels. On the twentieth, the bridges on the railroads leading from Baltimore to Washington were broken down and burned, and the telegraph wires cut, doubtless to prevent the arrival of reinforcements at Washington. Communication with the North is, however, open by way of Annapolis on Chesapeake Bay, which is connected with Washington by a railroad 39 miles in length. Troops are now being rapidly sent by this route."

"From an early acquaintance with some of the officers of the engineer corps of our army, we have always looked upon them as a very superior body of men, thoroughly conversant with everything relating to the science and art of their profession. But we find it difficult to reconcile this opinion with the result at Fort Sumter. Why was this great fortification, which cost millions of dollars, so constructed that a single shell or red-hot shot would render it untenable? Why are combustible wooden barracks erected in the midst of our solid stone fortresses?"

"A discovery throwing considerable light on the propagation of contagious miasma has recently been made by Dr. Eiselt, of Prague. In the Foundling Hospital at Repy, out of 250 children between the ages of 6 and 10 years, 92 cases of blennorrhœa of the ocular conjunctiva occurred. This epidemic ophthalmia fully convinced Dr. Eiselt that the contagion was transmitted by means other than contact. Dr. Eiselt thought of examining the atmosphere of one of the wards of the hospital containing many patients, by means of an aeroscope, and in the first portion of air that passed into the instrument he distinctly recognized small pus cells, which certainly served as vehicles of contagion."



Basic Research at Honeywell
Dr. Finn Larsen
Vice President for Research

Studies in the Light Sensitivity of Silver Halides

Great strides have been made in photographic emulsions since the glass plate and tintype days. But the demands of modern day science for faster recording techniques have steadily pressed the art and now have overreached it.

Ever since Matthew Brady and other pioneering photographers went through the tedious process of coating glass plates, silver halides have been considered the best photosensitive materials. After trying numerous other approaches over the years, it has been found that silver halides—with sophisticated modifications—are still the best we have.

For many years, the photographic process was an empirical science. It worked . . . and people were satisfied. Then, in 1938, Gurney and Mott developed a photographic theory that is still generally accepted. They deduced that a microscopically invisible latent image is produced in two steps by exposure to light. First, light reacts with the halide ions and releases electrons into the conduction band. These electrons then move freely through the crystal, leaving bromine atoms or "positive holes" behind them. Secondly, the electrons combine with silver ions in a localized crystalline spot to produce silver atoms. Groups of such atoms constitute the latent image.

There is still controversy as to how this takes place. Gurney and Mott theorized that the electrons are trapped by sensitivity specks (impurities). Others believe electrons are trapped by mechanical imperfections in the crystal and that the impurities trap bromine atoms.

The latent image can be made visible in two ways. During the normal development process, latent images serve as nucleation centers and promote the reduction to metallic silver of the whole crystal which has been exposed to light. Latent images also become visible by further exposure to light simply by a continuation of the process through which they were formed. Until recently both processes have been too slow to meet requirements for direct readout. For example, scientists today require direct reading oscillographs with writing speeds of up to 50,000 inches per second.

In addition to the need for high writing speed a recording paper should exhibit good contrast and stability and almost instantaneous appearance of the trace. Because available papers were deficient in these requirements, Honeywell assigned Battelle Memorial Institute a project on silver halides and simultaneously undertook its own investigation of light sensitive dyes. The latter techniques proved to be too slow, and the Honeywell Research Center began a supplementary halide research program.

The reciprocity law states that density produced by exposure depends on the product of the intensity and time. In practice most emulsions do not hold strictly to this law. For print out papers, it is desirable to promote the failure of this law because it is important to increase a high speed paper's sensitivity to high intensity light and reduce its sensitivity to low intensity light. Battelle and Honeywell scientists have developed doping agents that accomplish this. Working to a read out time requirement of one second, a paper has been developed with a write out speed of 20,000 in./sec. If the read out time is relaxed slightly, the paper can write at speeds up to 100,000 in./sec.

Stability and contrast of the paper were improved by an overcoating of a weak reducing agent or bromine acceptor that would prevent destruction of the silver image by bromine.

Research in photoconductivity and its correlation with photosensitivity seems most likely to lead to further improvements in this field. As Gurney and Mott stated: the first step in the photographic process is the reaction of light on the halide to create free electrons and positive holes, both of which are current carriers.

In pursuing this theory, Honeywell scientists are applying a voltage across silver bromide as an emulsion and also as a single crystal and measuring the increase in current when the silver bromide is exposed to light. Applying this technique to compare pure silver bromide with doped silver bromide, it is possible to determine whether the doping agents strengthened or weakened either the electron traps or hole traps in the silver bromide. Strengthening electron traps will increase photosensitivity. Strengthening hole traps prevents recombination and also increases sensitivity.

As research continues and we understand more about basic fundamentals, it is probable that new advances will be made. Information gained from these fundamental studies should tell us where to look for more effective doping agents. Silver bromide is most sensitive to ultraviolet light (with a peak near 3500 A°.). If this sensitivity can be extended to longer wave lengths, less expensive light sources can be used. If stability can be improved further, these papers could be used for photocopying.

If you are engaged in scientific work involving light sensitive materials or high speed recording techniques and would like to know more about Honeywell's research in this area, you are invited to correspond with Dr. Troy Scott, Honeywell Research Center, Hopkins, Minnesota.

The secret ingredient in this computer's spaghetti is petrochemicals!

It's a specialty of the house—making petrochemicals that help create the new materials that step up the efficiency of the many products we rely on every day. Here's one of them—part of a data processing computer. Protecting the intricate wiring network is color coded spaghetti—the tough polyvinyl chloride insulation that refuses to crack, melt or peel even under extreme temperature conditions.

In electronics, you'll find petrochemicals helping make TV sets slimmer, radios smaller, TV pictures clearer. Even the style and color of your modern telephone is fashioned in large measure by petrochemicals. If your product plans call for the use of basic petrochemicals, see how Gulf can provide you with an unbroken stream of supply and uniformity shipment after shipment. Write or call our Sales Office, 360 Lexington Ave., N. Y. 17, N. Y.

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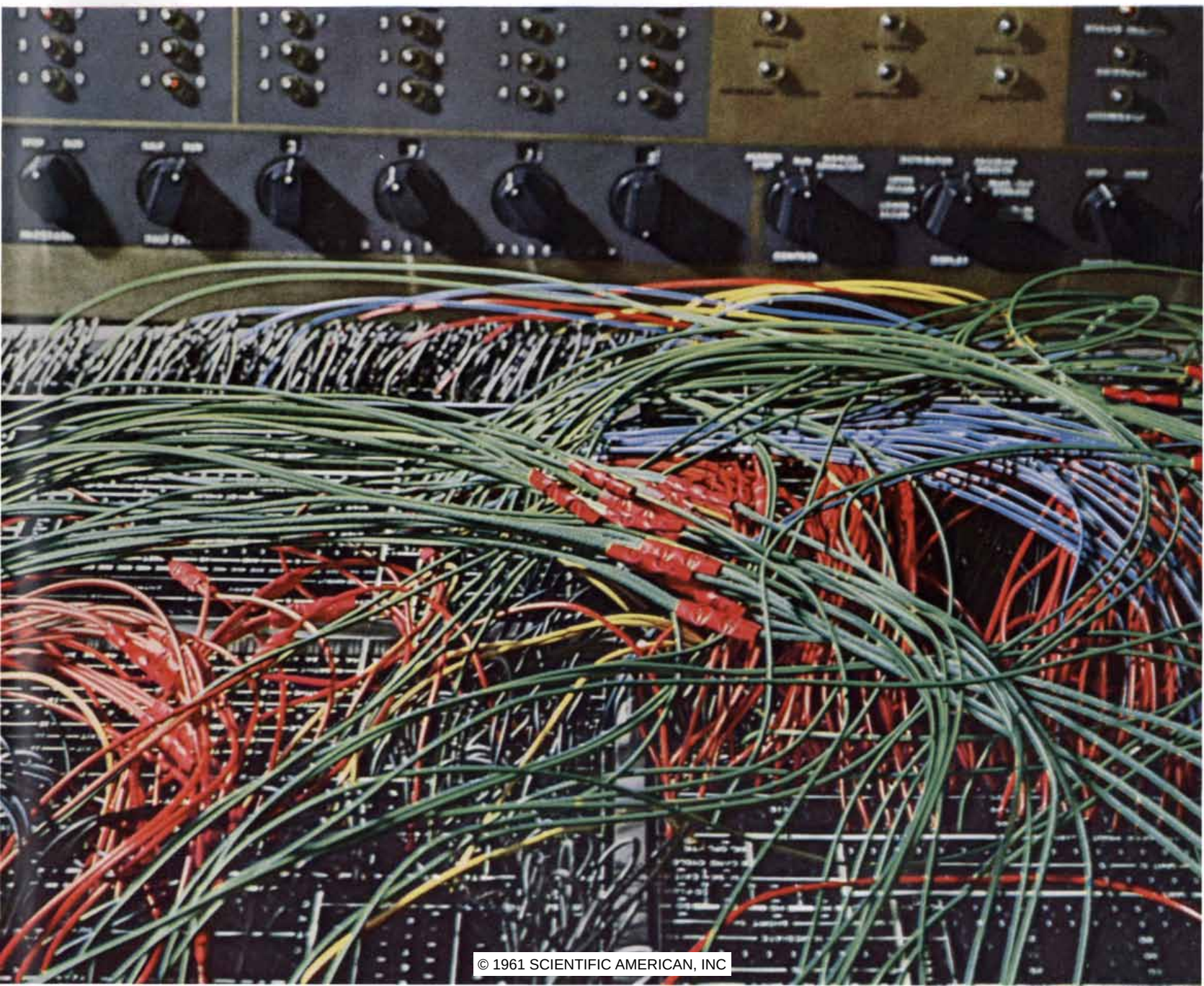
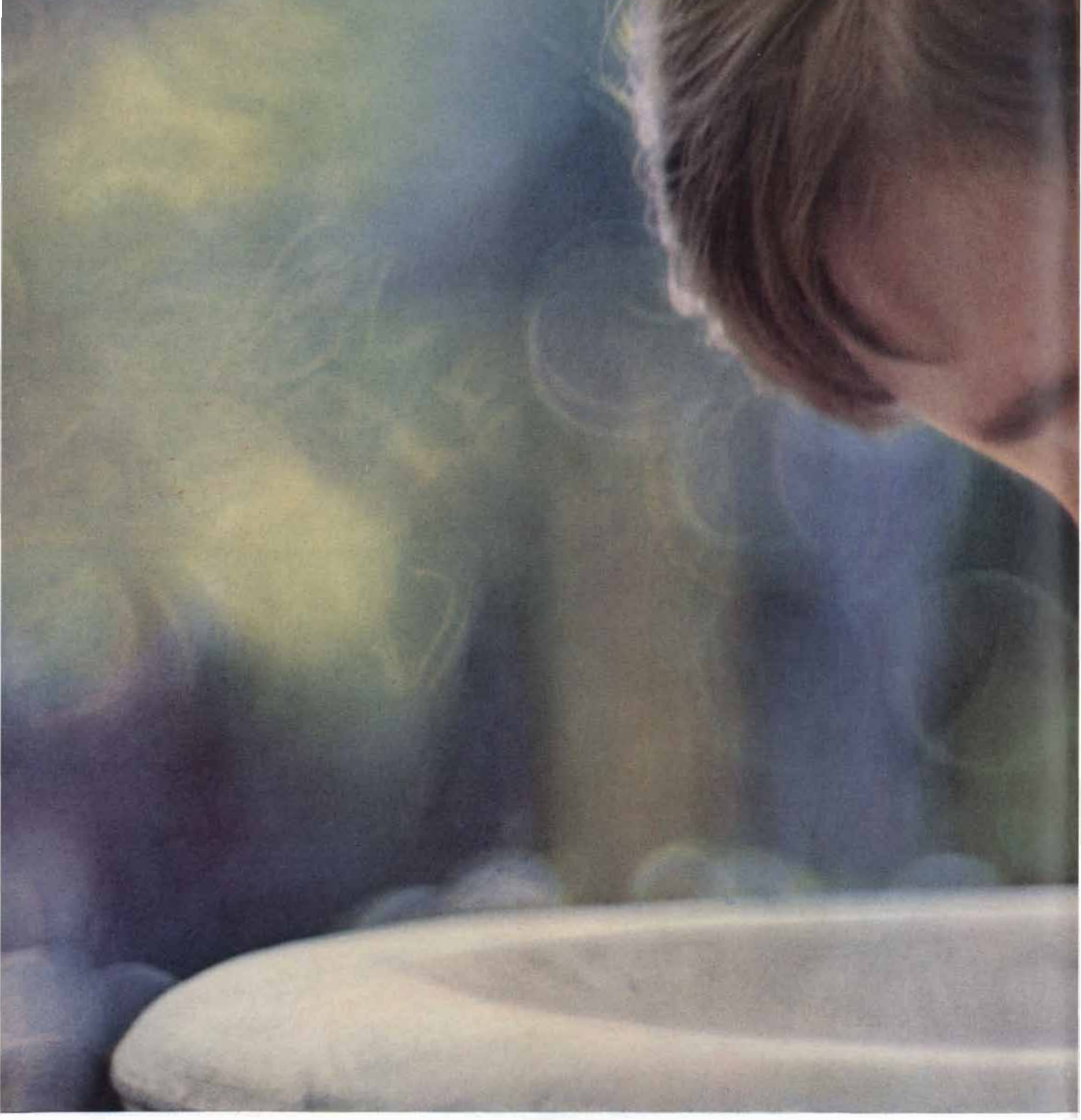
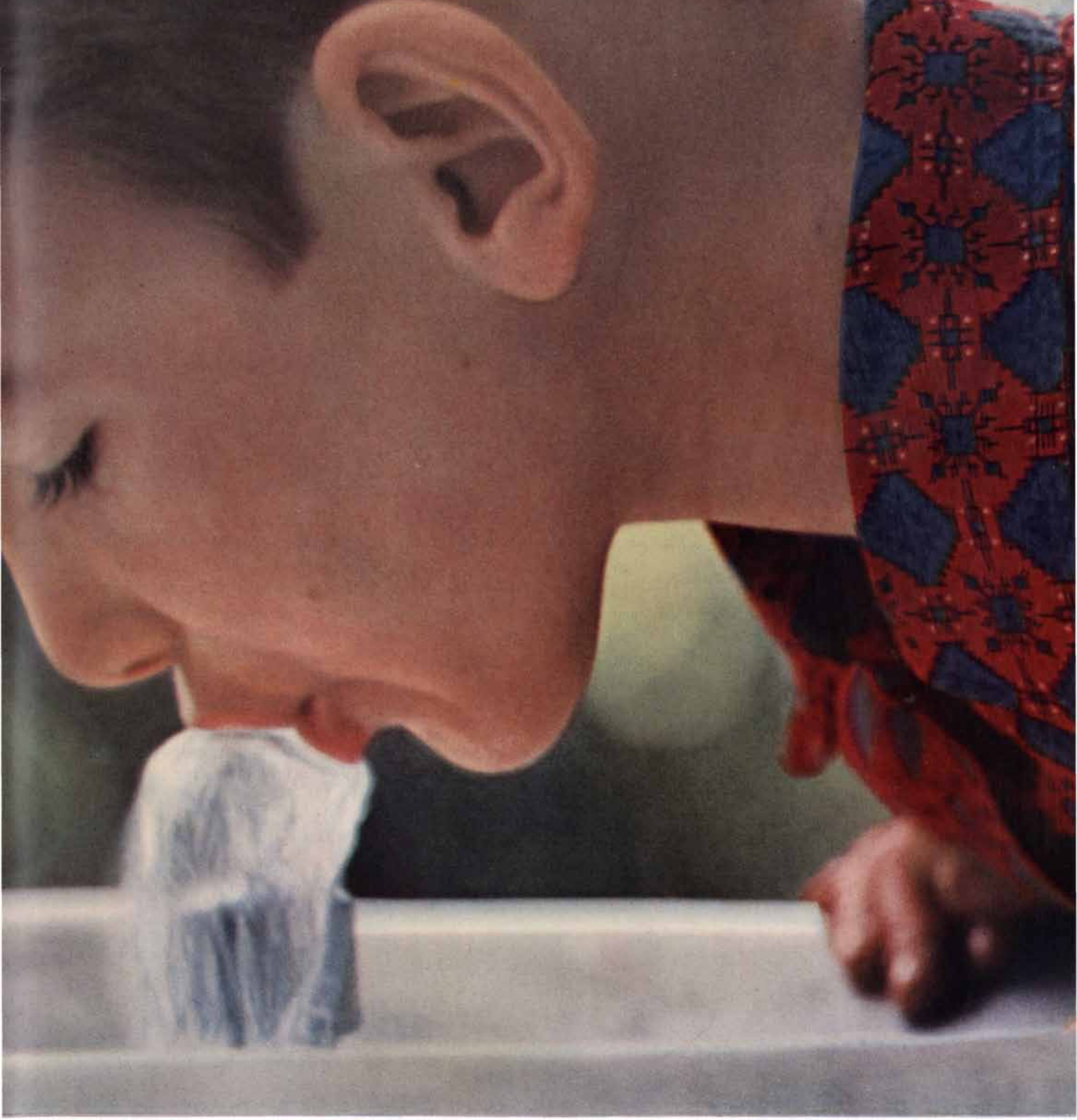




Who makes the water safe?



Whether we're quenching our thirst or plunging into the pool, we take the purity of our water pretty much for granted. Chlorine is the chief reason why. Olin, a major force in the field of chemicals, helped put typhoid and other water-borne diseases out of business with its work in chlorine. For public water systems, Olin actually pioneered the production of liquid chlorine. For swimming pools, Olin developed an easy-to-use granular and tablet form of chlorine. There's no label on water, but today when Tommy slurps his fill at the public fountain, it *could* read "made safe by Olin."

Olin

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OVER... UNDER

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High over the Rockies, Raytheon microwave relays beam TV programs to remote valley towns. This dependable equipment, almost inaccessible in winter, operates unattended day after day.

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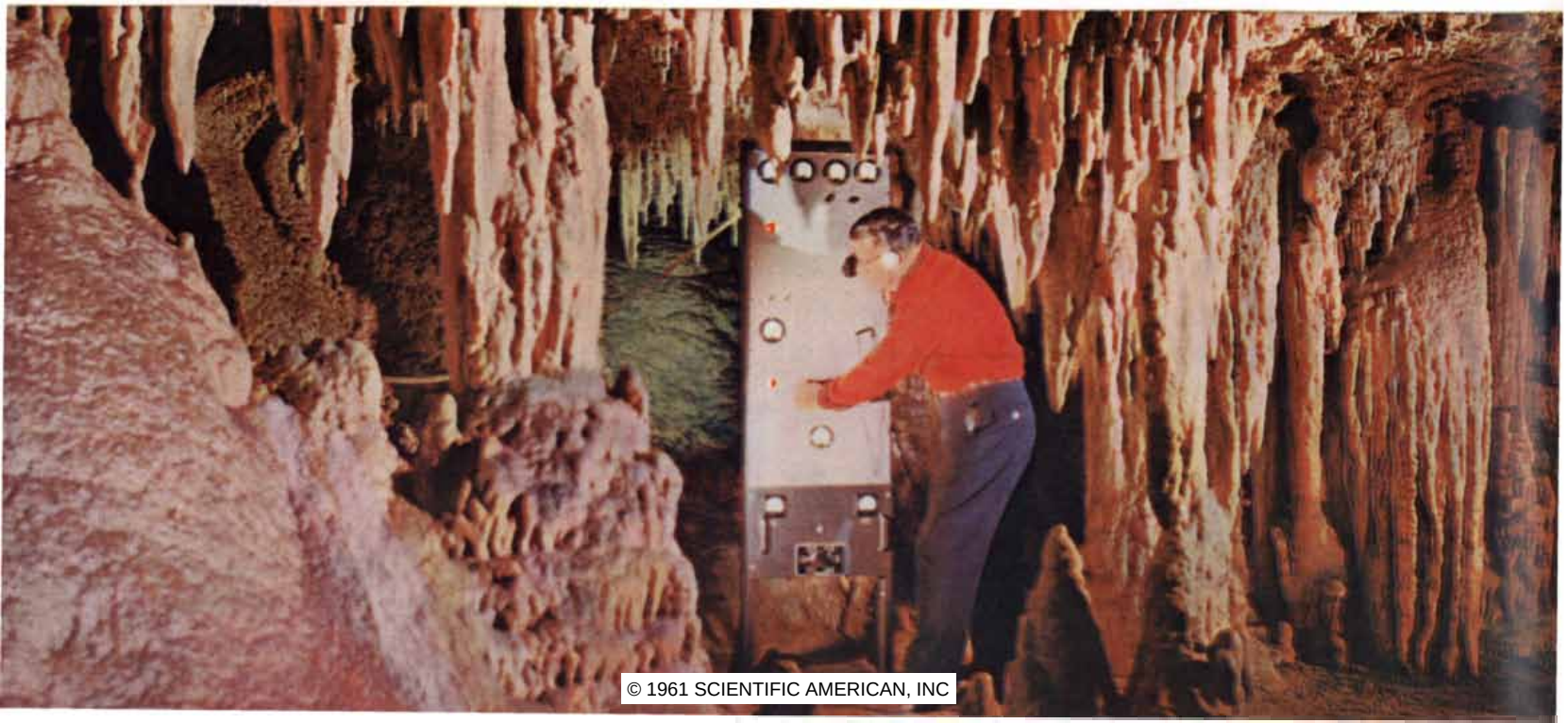
Almost everywhere, Raytheon electronics are at work—strengthening our defenses, making industry more efficient, increasing our comforts, and extending the scope of our knowledge.

RAYTHEON

EXCELLENCE IN ELECTRONICS

RAYTHEON COMPANY

LEXINGTON, MASSACHUSETTS



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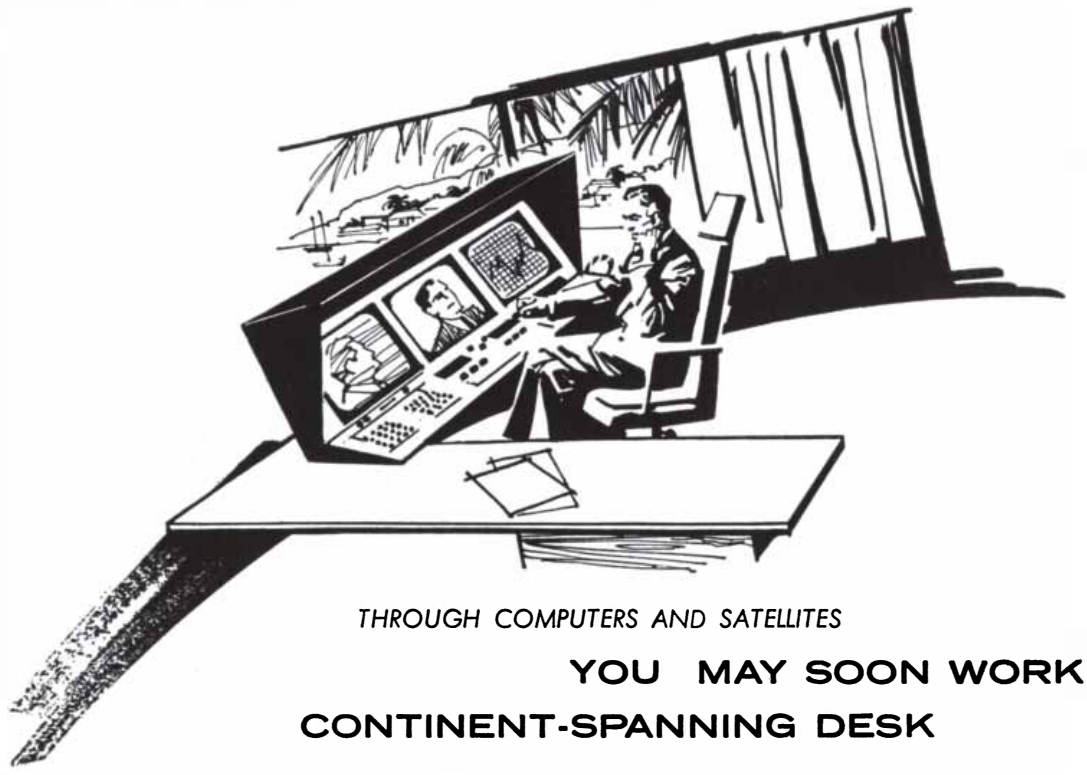

THROUGH COMPUTERS AND SATELLITES

YOU MAY SOON WORK AT A CONTINENT-SPANNING DESK

The executive of the not-so-distant future may see his associates by video more often than face-to-face. He—and they—will not even need a central office from which to administer the company's business. Yet, in the new Age of Communications, executives a continent apart will be in close touch with corporate affairs and with each other.

That is the sober prediction of many leading scientists. The method: worldwide communication by microwave radio and TV through communications satellites orbiting in near-space.

Who will do the paper work? Where will be the filing cabinets in which it's kept? Distant electronic data handling and processing machines will make and store all the records any business wants to keep. At the press of a button, high-speed printers will reproduce desired information, a TV screen on the executive's desk will display it.

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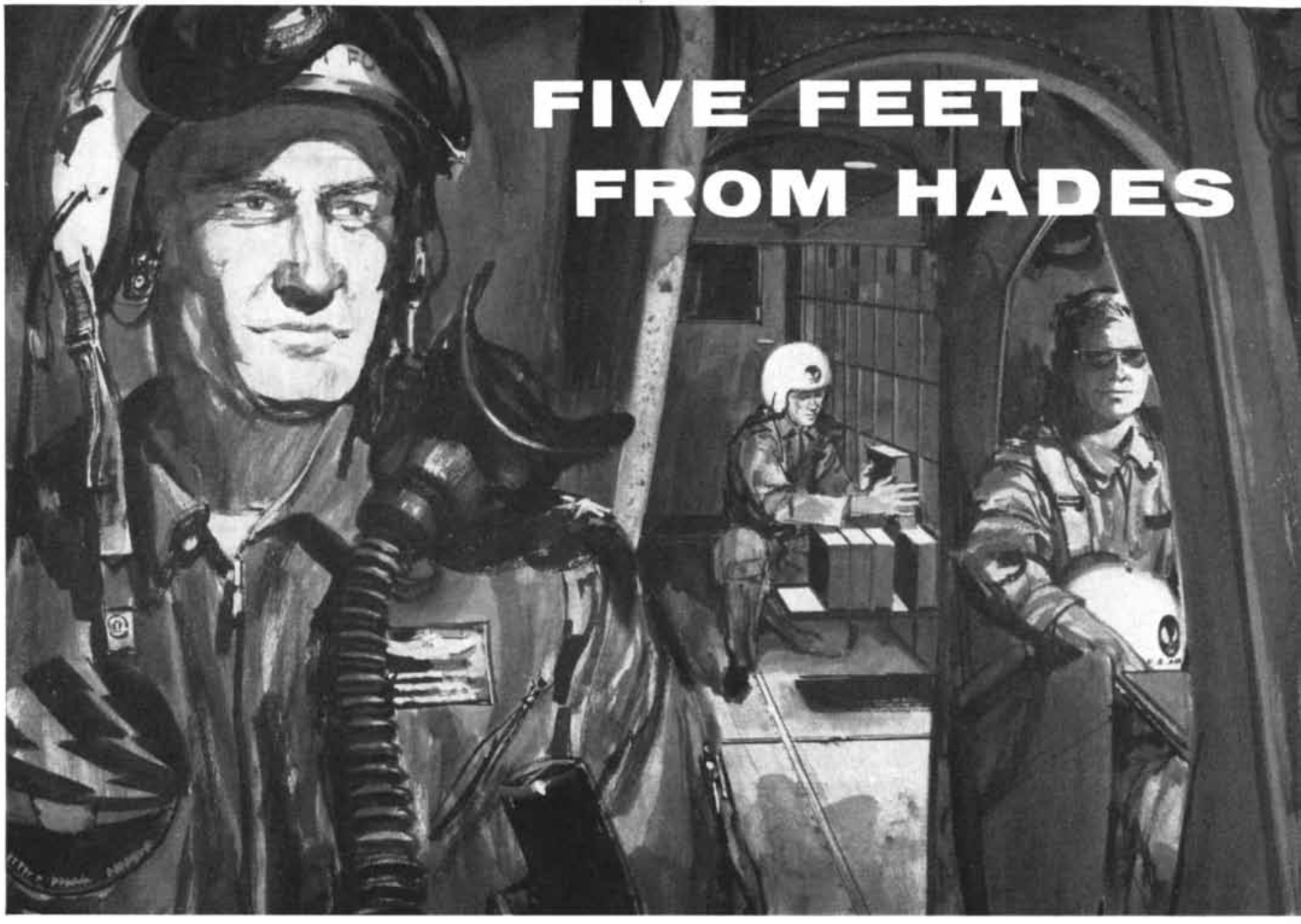

At 2,000 mph, surfaces of the B-70 bomber will reach a blistering 600°F . . . yet the crew will work in safety and comfort!

The new Air Force North American B-70 bomber will streak through the sky at 2,000 miles an hour . . . at altitudes over 70,000 feet. At such speeds, the plane's surface temperatures will soar to 600 degrees—hot enough to cook the crew.

Inside the B-70's cabin, however, the temperature will hover at all times around 70 degrees . . . the air will be continually decontaminated . . . excess moisture will be removed . . . and safe, comfortable pressures will be maintained, even in the rarefied atmospheres over 70,000 feet.

Hamilton Standard is presently developing the extraordinary environment conditioning system, which will assure this safety and comfort in the B-70. The system is the most comprehensive ever planned for an aircraft. It will eliminate the need for the crew to wear pressure suits or other special clothing and permit easy access to electronic components for adjustment or replacement during flight.

Environment conditioning systems for the B-70, the Convair B-58 bomber and 880 Jet-Liner, missiles and ground support installations typify Hamilton Standard's expanding activities. Today the company's work also includes aircraft engine controls and starters . . . solar power generators . . . missiles and space systems . . . ground support equipment . . . electron beam welding and cutting machines . . . and new propellers.

UNITED AIRCRAFT CORPORATION

HAMILTON STANDARD DIVISION

ENVIRONMENT CONDITIONING SYSTEMS

THE AUTHORS

ALICK ISAACS ("Interferon") is a staff member in the Bacteriology and Virus Division of the National Institute for Medical Research in London. He was born in 1921, attended medical school in Scotland and was graduated with a bachelor's degree in medicine and surgery in 1944. From 1948 to 1950 Isaacs worked with Sir Macfarlane Burnet at the Walter and Eliza Hall Institute of Medical Research in Melbourne. He joined the National Institute in 1950 and acquired an M.D. degree in 1954. Isaacs will succeed Sir Christopher Andrewes as head of the Bacteriology and Virus Division when the latter retires next month.

CORNELL H. MAYER ("The Temperatures of the Planets") is associate head of the Radio Astronomy Branch of the U. S. Naval Research Laboratory in Washington. Born and raised in Ossian, Iowa, Mayer acquired a B.S. in electrical engineering at the University of Iowa in 1943 and an M.S. at the University of Maryland in 1951. From 1943 to 1947 he served with the Navy, a period that included a year of research on the development of microwave radar antennas and components under Fred T. Haddock and John P. Hagen at the Naval Research Laboratory. Hagen introduced radio astronomy at the Laboratory in 1947 and it was there that Mayer began several years of radio observations of the sun. Since 1956 Mayer has been chiefly engaged with T. P. McCullough and R. M. Sloanaker in making radio observations of discrete sources at centimeter wavelengths, in particular the planets and the Crab Nebula.

ROBERT L. FANTZ ("The Origin of Form Perception") is assistant clinical professor of psychology at Western Reserve University. Born in Muncie, Ind., in 1925, Fantz took two degrees at the University of Chicago, receiving his Ph.D. in 1954. As a graduate student he did research with Eckhard H. Hess, Austin H. Riesen and L. L. Thurstone and became particularly interested in the early development of vision in animals and humans. This interest, he says, "began perhaps with the study of D. O. Hebb's theory of perceptual development through learning, representing the culmination of the experimental-psychological approach in this area, and the work of Konrad Lorenz, N. Tinbergen and W. H. Thorpe, showing a high degree of innate perceptual organization in the instinctive behavior of animals."

P. A. GORDIENKO ("The Arctic Ocean") is deputy director of the Arctic and Antarctic Scientific Research Institute in Leningrad. He was born in 1913 in Yenakievo, a small town in southern Russia. Before he entered the Moscow Hydrometeorological Institute at the age of 20, Gordienko worked for a time as a lathe operator in a factory. During this period, he writes, "I read with fascination travel books and stories about the sea. Like many young people in the Soviet Union at the time, I was greatly influenced by reports of the journeys of the ice-breakers *Krasin, Litke* and *Sibiriakov* and also by the works of Jack London." On the advice of N. N. Zubov of the Hydrometeorological Institute, Gordienko began training for Arctic exploration, a program to which he added skiing, sailing and mountain climbing. Since his graduation in 1938 he has participated in more than 30 expeditions to the Arctic. Until 1942 he served as hydrologist at the polar station on Cape Schmidt (Chukchi Peninsula); in 1955 and 1956 he was director of North Pole IV, a drifting ice station of the type described in his article. Gordienko's work has also taken him to the Antarctic, where in 1956 he headed the group of scientists accompanying the expedition of the *Lena*.

HAROLD I. SHARLIN ("From Faraday to the Dynamo") is assistant professor of economics and the history of science at the Polytechnic Institute of Brooklyn and adjunct assistant professor of history at New York University. Sharlin began his career as an electrical engineer and was graduated from Drexel Institute of Technology with a B.S. in 1948. While working as a partner in a small electrical company, he started taking evening courses at Rutgers University in 1949. He became interested in history and was encouraged to enter graduate school. Sharlin returned to Drexel Institute in 1952 to teach electrical engineering and received an M.A. in history from Columbia University the following year. He acquired a Ph.D. in history at the University of Pennsylvania in 1958. Since going to Brooklyn Polytech in 1956, Sharlin has concentrated on the history of electrical theory, technology and engineering.

JEROME GROSS ("Collagen") is assistant professor of medicine at the Harvard Medical School and associate biolo-

gist at Massachusetts General Hospital. Gross studied biophysics at the Massachusetts Institute of Technology, receiving a B.S. in 1939. His interest in approaching problems of medicine from the viewpoint of physical biology took him to the New York University College of Medicine; there his original interests were further stimulated by work in the rheumatic fever clinic, by a lecture he heard in 1941 on the recently developed electron microscope and by a visit to M.I.T., where F. O. Schmitt was using the electron microscope in his research on collagen. He received his M.D. degree in 1943, served for three years in the Army Medical Corps and then returned to M.I.T. as Schmitt's assistant to do research on the molecular biology of connective tissue. Gross joined the faculty of the Harvard Medical School in 1948 and the staff of Massachusetts General Hospital in 1951.

EDWARD S. HODGSON ("Taste Receptors") is professor of zoology at Columbia University. He was born in Wilmington, Del., in 1928 and received his B.S. from Allegheny College at the age of 18. He did graduate work in sensory physiology under V. G. Dethier at Johns Hopkins University, acquired a Ph.D. in biology at that institution in 1951 and joined the faculty of Columbia later the same year. The research discussed in the present article was begun at Tufts University, where Hodgson worked for a year in the laboratory of Kenneth D. Roeder.

SHERMAN K. STEIN ("The Mathematician as an Explorer"), himself a mathematician, teaches in the College of Letters and Science of the University of California at Davis. He is a graduate of the California Institute of Technology and of Columbia University and received his Ph.D. from the latter institution in 1953.

CHARLES E. RAVEN, who in this issue reviews *The Royal Society: Its Origins and Founders,* edited by Sir Harold Hartley, is a canon of the Church of England and since 1919 has served as a chaplain to the reigning English monarchs. A graduate of the University of Cambridge, Canon Raven was Master of Christ's College, Cambridge, from 1939 to 1950 and vice-chancellor of the University of Cambridge from 1947 to 1949. He has published some 20 books on such varied subjects as Christianity, science, naturalists and birds. His most recent work, *Science, Medicine and Morals,* appeared in 1959.

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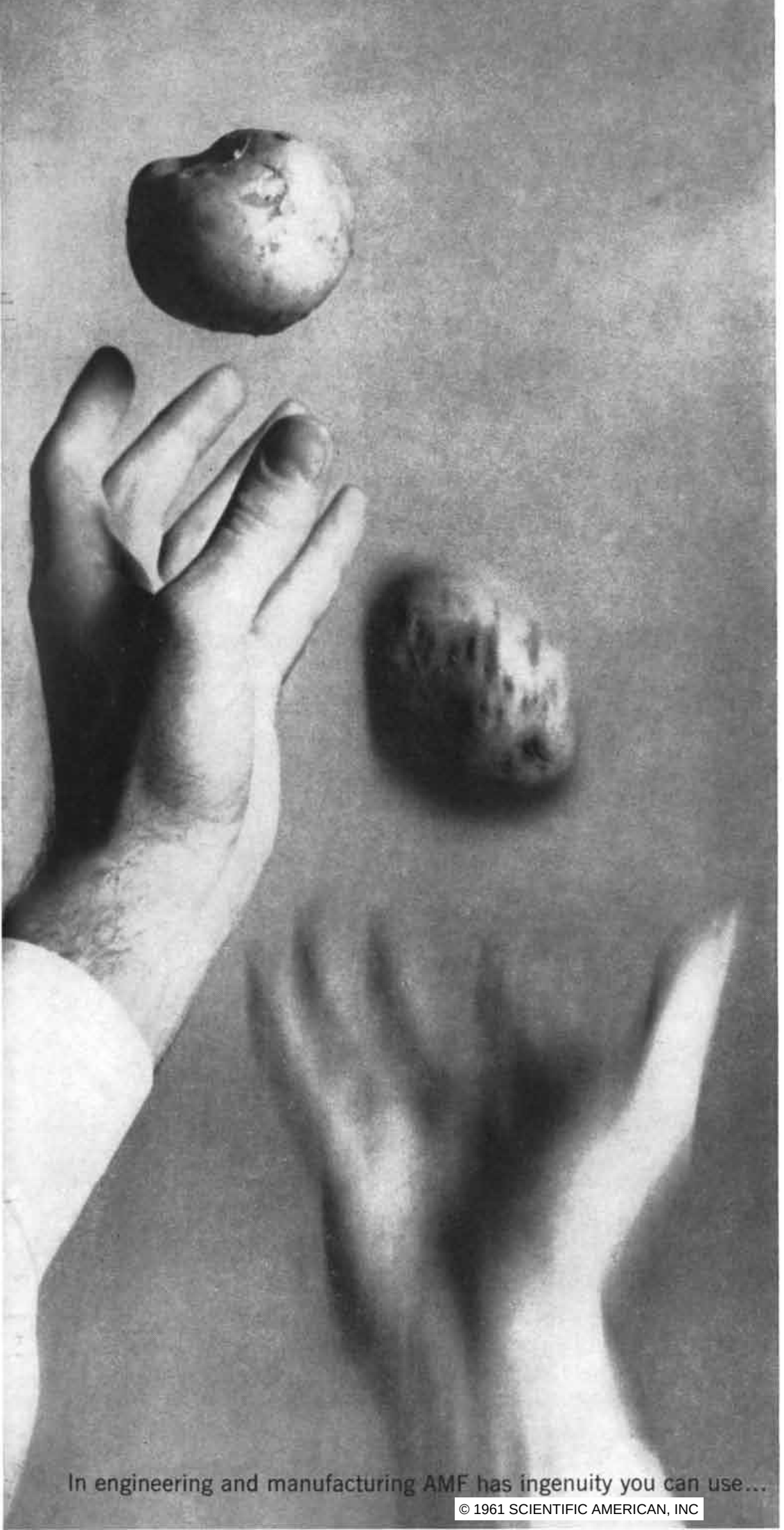

He juggled the hottest potatoes in the Seawolf

...the fuel elements for its nuclear power plant.

Periodically, spent elements must be removed and replaced with fresh ones. The problem—utterly original and fiendishly difficult—was to do the job safely, quickly, and, above all, surely.

This AMF engineer designed the refueling system that did the job. One of his major problems was the fuel elements' liquid sodium environment. Sodium burns fiercely when brought in contact with either air or water. Yet, it had to be exposed during element transfer. Solution: an inert helium blanket to isolate the sodium.

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A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

HOW TO STUDY A BLIP

When you go to all the trouble of generating two opposed gas waves, each travelling eighty times the speed of sound, you like to get a permanent visual record of what happens when they meet.

A gas physics group at Boeing Scientific Research Laboratories is doing this with the help of a twelve-foot length of PYREX® glass pipe . . . believed to be the largest tube ever used in work of this sort.

At wave impact the tube blips light for a few microseconds, and a camera stops the action and spectra of the radiation for further study.

The data collected could show important results in effective ion- and plasma-propulsion systems. The tube is also expected to be useful in measuring gas temperatures up to several million degrees.

The tube is made from the same tough borosilicate glass as our pipe for chemical and food processing plants and our drainlines and heat exchangers.

If you would like to know more about it, so that you could put its strength and transparency to work on some task of yours, send the coupon.

WE NEVER MADE A TEST TUBE GREEN; WE NEVER HOPE TO MAKE ONE, BUT . . .

Should you want a test tube green or yellow or blue or a mirror-blank red, a piece of pipe cerise, or anything else that can be made from glass in any color known to man, we can make it.

That's no trick. Anyone can make colored glass.

But to make a glass the same color, right on the beam, every time . . . that, sir, is a trick, a trick we perform to perfection.

We helped set the color standards for railroad and airport and traffic signal lenses and then were able to duplicate and reduplicate the standard colors a million times.

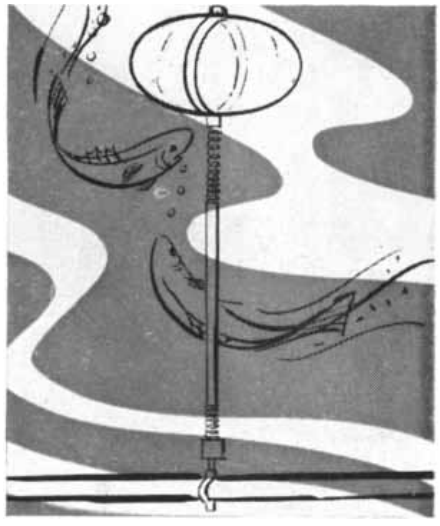
This man is looking through one of many drawers of samples of colored glasses we have melted and can duplicate for you. Among these glasses you will find many that can take thermal shock or corrosive environments, glasses with high dielectric constants or low, glasses that are transparent, translucent, or practically opaque . . . in short, glasses that not only have carefully controlled color but are replete with the many other desirable properties you connect with Corning products.

From these glasses we can make you things that are big. Or small. One. Or a million. Intricate. Or simple.

That's our story on color in glass . . . capability.

All we need are your ideas. All you need to get started is our bulletin on colored filters to get an idea of the range we're speaking of. Send the coupon for a copy.

NEW WAY TO HOLD THINGS UP WHEN YOU GO DOWN TO THE SEA



Glass goes well with the briny. That's more than you can say for most materials.

It's also why we think glass may make the perfect flotation capsule.

We've already made an 8″ by 4″ capsule that withstands 17,500 psi. It has a density of 0.45 that of water. You can lower it to 3000 fathoms and retain a net upward force of about one pound.

You can put it into the saltiest sea and leave it for centuries, and it will never let you, or the objects you suspend, down. (Remember those wine bottles they found sleeping at the bottom of the Mediterranean some twenty centuries after the ship had sunk?)

With a capsule like this you should find it a simple, inexpensive matter to suspend instruments for the study of marine life, ocean currents, and underwater topography. You could suspend transoceanic communications equipment.

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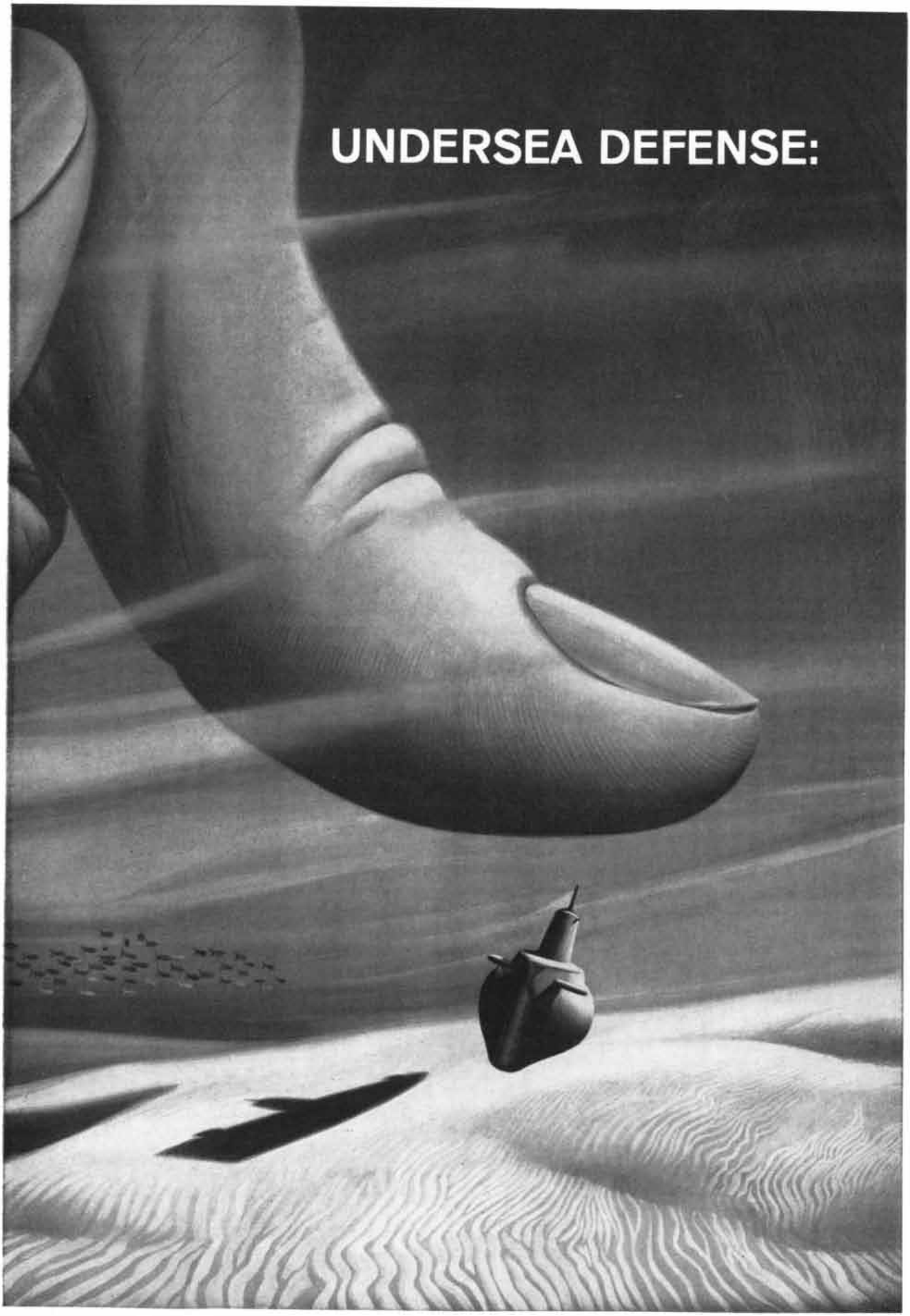

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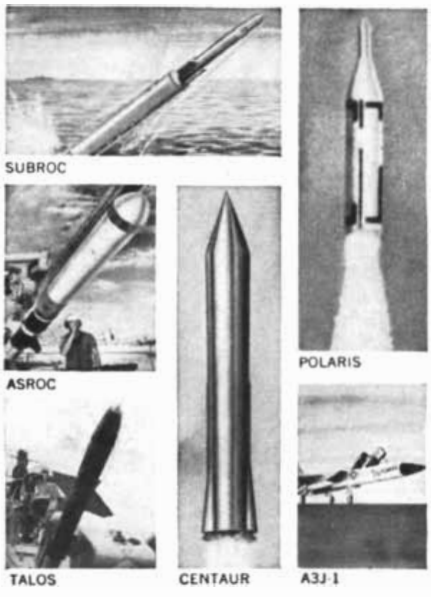

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Roger Bacon . . . on the causes of error

"There are in fact four very significant stumbling-blocks in the way of grasping the truth, which hinder every man however learned, and scarcely allow anyone to win a clear title to wisdom, namely, the example of weak and unworthy authority, long-standing custom, the feeling of the ignorant crowd, and the hiding of our own ignorance while making a display of our apparent knowledge. Every man is involved in these things, every rank is affected. For every person, in whatever walk of life, both in application to study and in all forms of occupation, arrives at the same conclusion by the three worst arguments, namely, this is a pattern set by our elders, this is the custom, this is the popular belief: therefore it should be held." —*Opus Majus*, I.1, 13th Cent.

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Interferon

This natural product of animal cells protects them against attack by a variety of viruses. If it proves to be effective in humans, it should have considerable medical importance

by Alick Isaacs

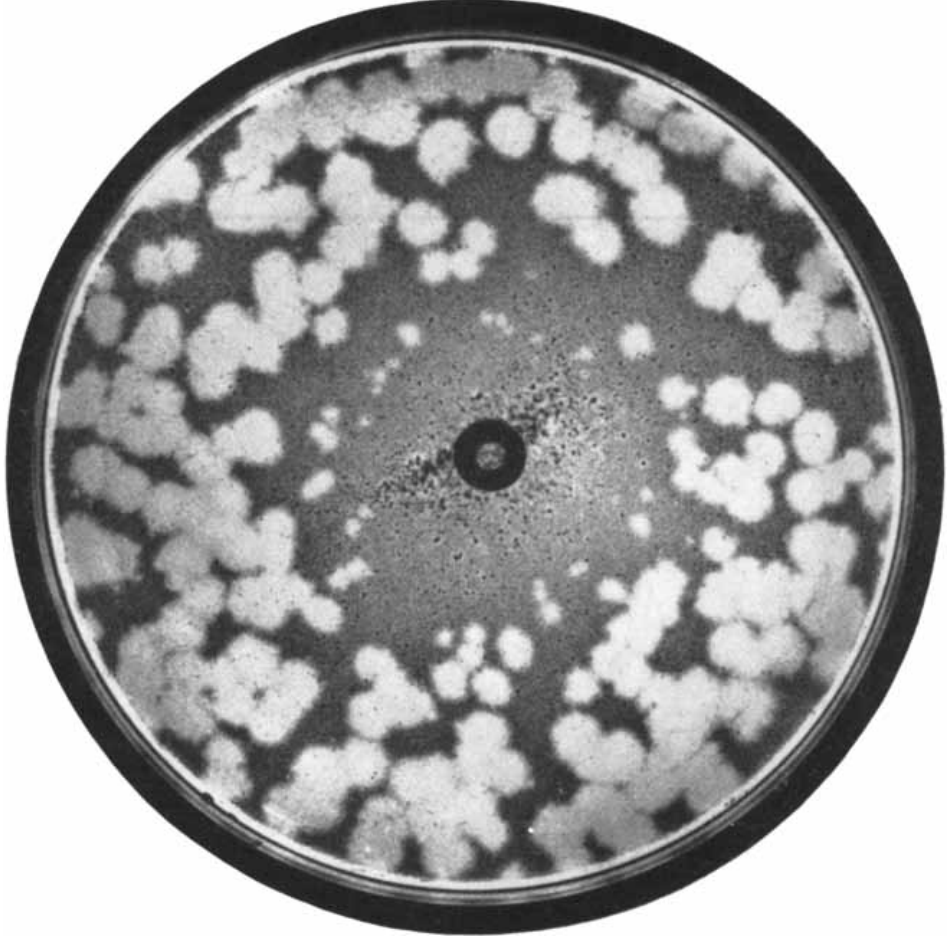
Finding ways to combat virus infections has proved to be a difficult and long-drawn-out medical problem. The usual approach since the early 19th century has been to try to prevent infections by developing vaccines—biological substances that stimulate the human organism to produce antibodies of a specific and desired kind. The antibody then acts against the virus when it enters the bloodstream. Unfortunately, we humans are under relentless attack by so many kinds of virus that it may be impractical, if not impossible, to develop specific vaccines against them all. Within the past few years, however, another approach to the problem has begun to seem hopeful; it is the purely empirical finding that a substance produced by cells and given the name "interferon" has a very broad antiviral action.

Interferon was discovered during a study of the phenomenon known as virus interference. Virus interference has been known in the laboratory for 25 years, and it is possible that Edward Jenner observed it as long ago as 1805. Perhaps the first clear example of virus interference under natural conditions was described in 1937 by G. W. M. Findlay and F. O. MacCallum of Great Britain, who found that monkeys infected with Rift Valley fever virus were protected from the fatal effects of yellow fever virus. The protection could not have been due to the antibody mechanism, because antibodies against the Rift Valley fever virus have no effect on the yellow fever virus. Findlay and MacCallum, who adopted the term "virus interference," believed that when one virus invades a group of cells, a second virus is somehow excluded. It was subsequently shown in the laboratory, using fertilized hens' eggs and tissue cultures, that virus interference is a very general occurrence. An important observation was made in 1943 by Werner and Gertrude Henle at the Children's Hospital of Philadelphia; they found that viruses could be killed by gentle heat or ultraviolet light and still retain the ability to interfere with the growth of other viruses.

Presumably virus interference can also take place, in greater or lesser degree, within our bodies. There is recent evidence bearing on this point. During field trials in Mexico of live poliomyelitis-virus vaccine given orally it was found that many Mexican children were resistant to the vaccine virus. The specially weakened virus is designed to cause a mild infection in the intestine, thereby stimulating production of antibodies capable of resisting virulent strains of poliomyelitis virus. It turned out that many Mexican children resisted this mild infection because they were already harboring in their intestines another virus, a common enterovirus, which induced virus interference. This experience may help to explain why paralytic poliomyelitis is fairly rare in countries where the levels of public health and sanitation are not up to those in the U. S., Great Britain and other relatively prosperous countries. Where low-grade virus infections are widespread in the population, the more harmful viruses cannot get a foothold.

Twenty years after Findlay and MacCallum had described virus interference its mechanism was still a mystery. How did infection of a cell by one virus prevent infection by a second? Even more puzzling, the first virus could be killed, and the interference would still take place. In 1957 Jean Lindenmann and I, working at the National Institute for Medical Research in England, were investigating the action of heat-killed influenza virus when we found an unexpected handle on the problem. We found that a few hours after we had treated a cell culture with killed virus the cell-free culture medium had acquired a surprising property. When the medium was mixed with fresh cells, it made them resistant to virus infection. This resistance had all the earmarks of virus interference, since the fresh cells proved resistant not just to one virus but to many different viruses. We were soon able to isolate the active substance responsible for conferring resistance, and we named it interferon. In retrospect it is possible to find hints of such a substance in earlier work, particularly in the factor associated with tissue immunity, which Sven Gard of Sweden described in 1944.

Interferon is a protein, with a molecule of approximately the same size as



INHIBITION OF VIRUSES is achieved by interferon. This Petri dish contains chick cells infected with encephalitis virus. Interferon placed in the tiny cup in the center has diffused outward, creating a zone of protected cells. Clear areas show where cells are destroyed.

that of hemoglobin. The molecular weight of interferon, as determined by my colleagues James S. Porterfield, Derek Burke and Anthony C. Allison, is about 63,000; that of hemoglobin is 66,800. (Molecular weights are expressed as multiples of the weight of the hydrogen atom, taken as one.) Interferon is stable when stored at low temperature, and if freeze-dried it can be kept in an ordinary refrigerator for months without loss of activity.

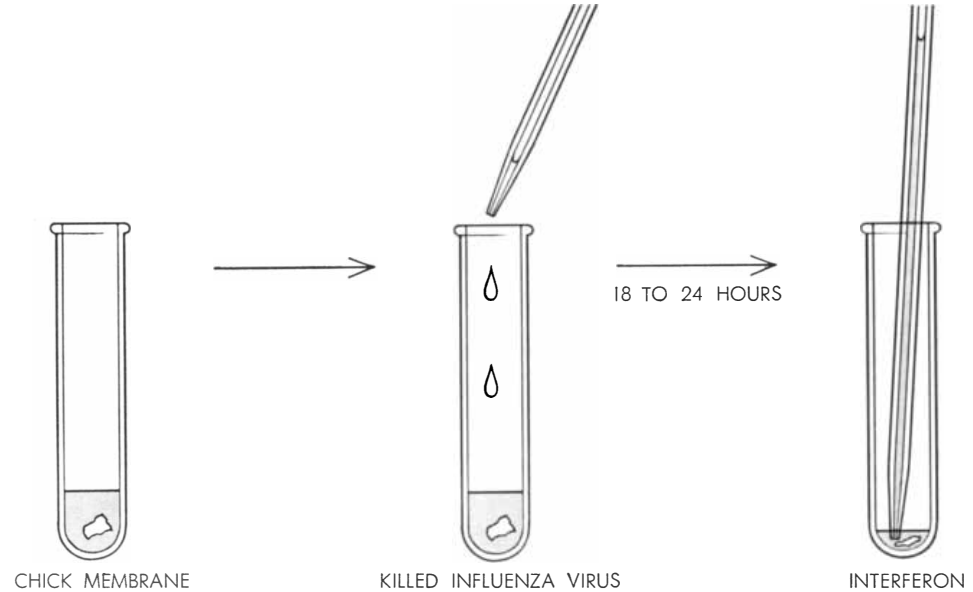
Interferons prepared in various animal species differ slightly from one another in the same way that protein hormones, enzymes and antibodies differ among species. Although we find that interferon produced in one species is most effective in protecting cells of animals of the same species, the specificity is not absolute. We find, for example, that interferon prepared in monkey cells is active when tested with human cells. So far as we know, interferon produced by the cells of a given species is always the same substance regardless of the virus used to infect the cell.

It has been surprising to find that when interferon from one species is injected into an animal of a different species, it does not appear to stimulate the formation of antibody. We would have expected a protein the size of interferon to do so. Our only suggestion to account for interferon's antigenic docility is that the "business end" of the interferon molecule may have much the same structure no matter what species produces it. As a result the interferon made by an animal of one species cannot be recognized as foreign when it is injected into an animal of another species, and it does not stimulate antibody production. Whatever the true explanation, the consequences are valuable: it should be possible to administer interferon repeatedly without its effect wearing off after one or two injections because of antibody formation by the recipient.

Having established that the release of interferon is a general reaction of cells to virus infection, it occurred to us that interferon might be an important part of an organism's defense against virus invasion. Since interferon is liberated spontaneously from infected cells, it should be able to protect cells surrounding those that were first infected.

Out of curiosity I have asked a number of fellow investigators what they consider to be the most important factor in helping men or animals to recover from virus infections. The commonest answer was antibody. No one would dispute for a moment that immunity to *reinfection* by a particular virus is due to antibody; the question is, should antibody receive the credit for beating back the *first* attack by a virus?

Doubts were awakened by observing patients with a rare disease known as hypogammaglobulinemia. These patients have a defect in their ability to manufacture gamma globulin, the fraction of the blood serum that contains antibody. As a result, when hypogammaglobulinemic patients are infected with either bacteria or viruses, no antibody against the in-



PRODUCTION OF INTERFERON is relatively straightforward. When a killed virus is added to a cell culture, the cells spontaneously release interferon, a protein with broad antiviral properties. The solution containing interferon is withdrawn from the cell culture

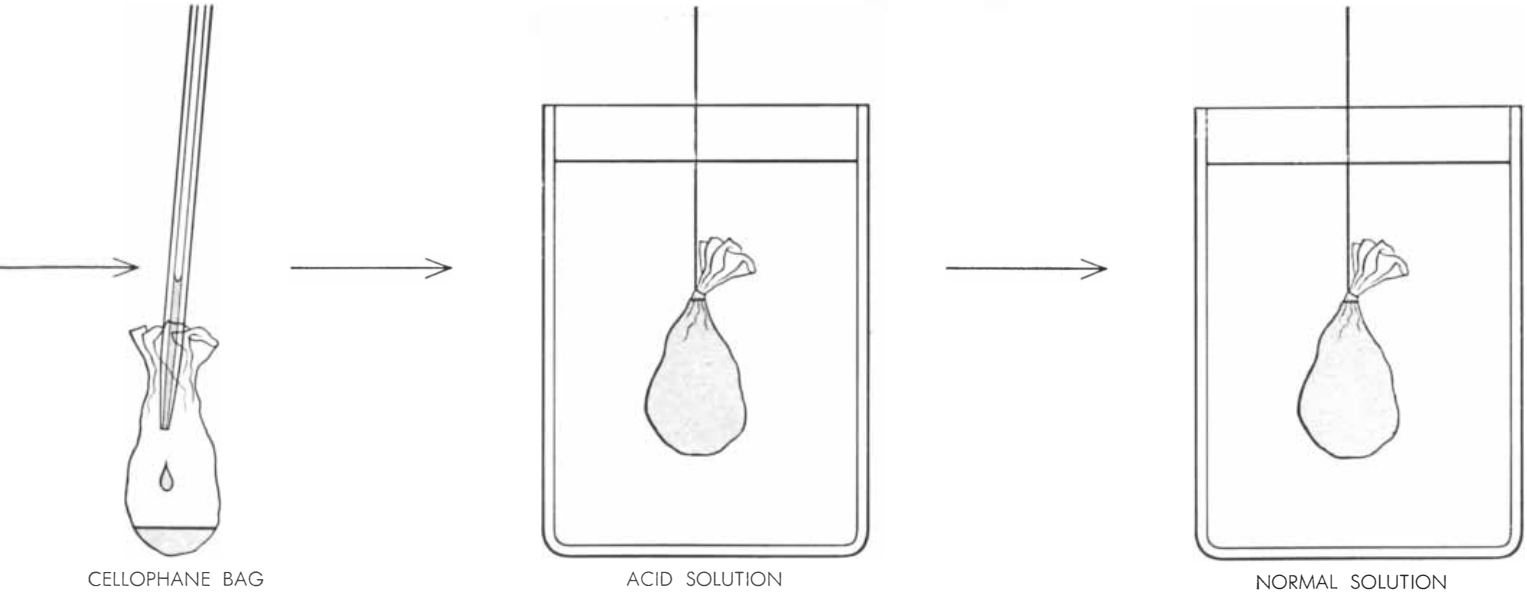
fecting organism can be detected in their serum. Until about 20 years ago nearly all these patients died as a result of bacterial infections, which are more likely to be fatal than virus infections. Now that there are antibiotics to rescue them from bacterial infection it is possible to see how they react to the common viruses. If recovery from virus infection is due to antibody production, hypogammaglobulinemic patients should suffer severe virus infections with a prolonged course. In fact, they generally suffer virus infections of normal severity and recover from them in a normal period of time. This suggests that they resist virus infections by a mechanism that does not require antibody. Could their recovery be due to interferon?

One way of trying to answer a question such as this is to study the behavior toward viruses of cells grown in test tubes, where antibody can be rigidly excluded. This approach was adopted by Monto Ho and John F. Enders of the Harvard Medical School and by the Henles and their colleagues at the Children's Hospital of Philadelphia. Under certain conditions of prolonged cultivation it is possible for a virus and a culture of cells to come to terms with each other, so that the virus no longer destroys the cells but is propagated along with them. In this situation the cells have therefore recovered from a virus infection in the absence of antibody. Both the Harvard and Children's Hospital investigators have found that in cultures of this kind interferon is produced in amounts sufficient to account for the resistance of most of the cells to virus invasion.

In our laboratory Griselda Hitchcock and I sought to settle the question directly in living animals. We produced viral pneumonia in mice by obliging them to inhale influenza virus. The virus enters the lungs of the mice and multiplies there. We watched the day-by-day growth of virus in the lungs, the production of antibody in the bloodstream and in the lungs, and the development of interferon in the lungs. When the results were plotted [*see top illustration on page 56*], they showed that the virus concentration in the lungs was at its peak on the third day of infection and that it declined slowly after that. At about the same time, or a little later than the peak of virus growth, a high concentration of interferon was found in the lungs. The concentration remained high until the fifth day after infection, when it declined. Antibody came on the scene very late. We could not detect its presence until nearly a week after the peak of virus growth. These experiments show that interferon is present at the right place, at the right time and in high enough concentration to play an important role in recovery from viral infections. Antibody, by contrast, is produced not in the lungs but in the lymphatic tissues and does not seem to be produced in sufficient quantity early enough to be able to account for the animal's recovery.

More than that we cannot say at the moment, but it is interesting to let one's imagination run free and to speculate on how the interferon and antibody mechanisms may have developed in relation to man during evolution. The Australian virologist Sir Macfarlane Burnet has suggested that the antibody mechanism probably evolved well before the appearance of man. We may assume further that man's ancestors were probably not very sociable animals; hence they were less exposed than we are to viruses such as those which cause influenza and poliomyelitis, spread primarily by social contact. Our ancestors would have been exposed chiefly to viruses such as those which cause yellow fever and encephalitis, spread by mosquitoes and other biting insects. After infection with a mosquito-borne virus, antibody would be present in the animal's blood in high concentration, and this would act as a barrier to subsequent infection by that virus and related ones. The antibody mechanism is therefore well suited to dealing with infections spread by biting insects, in which the virus is injected almost straight into the bloodstream while the insect is feeding. Provided that the animal survives its first infection, it will have acquired protective immunity.

Later in evolution, when primitive man arose and began to develop more sociable ways, he undoubtedly coughed and sneezed at his neighbors, spreading colds, influenza, poliomyelitis and all the other respiratory viruses and enteroviruses to which men are so susceptible. (Presumably these viruses were lurking in the environment but not flourishing.) The antibody mechanism, which seems so well designed to deal with infections spread by the bloodstream, is badly placed strategically to deal with this new class of surface attackers. These viruses



and transferred, with other interferon samples, to a cellophane bag. The bag is placed in an acid bath to make the interferon solution acidic, thereby killing any viruses that may be present. The acidity of the interferon is then neutralized. The method of producing interferon shown here is an early one; it is possible to use many other types of virus and tissue culture.

EFFECTIVENESS OF INTERFERON is shown in the contrasting appearance of these two Petri dishes. Dish at top contains a sheet of mouse cells infected with encephalomyocarditis virus. Clear patches show where cells have been killed. Dish at bottom contains cells similarly infected at the same time but treated with interferon. Cells remain healthy.

enter by the nose or throat and remain in the respiratory or intestinal tract, where the concentration of antibody is very low compared with that in the blood. It is here that local cell defenses are likely to be of much greater value, and here that the interferon mechanism may finally have come into its own.

In these speculations I am suggesting that at a particular time the antiviral action of interferon may have evolved. The implication is that interferon has some other function in normal cells, and that the antiviral action represents an adaptive response of our bodies to deal with what we might call the sociable viruses. (It may or may not be significant that the cells of a rather unsociable animal, the ferret, are poor producers of interferon, which suggests that ferrets have little need for this adaptive response.) But what could be the function of interferon in the absence of virus infection? We think we have found a clue to help answer this question in the metabolic changes that interferon produces in normal cells.

From the first it was clear that interferon, unlike antibody, did not act directly on the virus but acted instead on cells. Interferon-treated cells take up the virus normally, but after that stage the virus is unable to multiply. Since interferon is effective against a wide range of viruses, its action must be directed toward some key point in virus growth common to viruses of different size and different composition.

We were looking for some metabolic change in interferon-treated cells, without being too sure where to look, when a chance observation gave us an important lead. We noticed that cells treated with interferon produced acid more rapidly than untreated cells did; the acid turned out to be lactic acid, formed at a stage in the breakdown of glucose. This increased glycolysis sometimes occurs when the cells' respiratory apparatus is damaged, but then the cells take up less oxygen than normally. Interferon-treated cells, on the other hand, took up *more* oxygen than normal cells, so another explanation for the increased glycolysis was required.

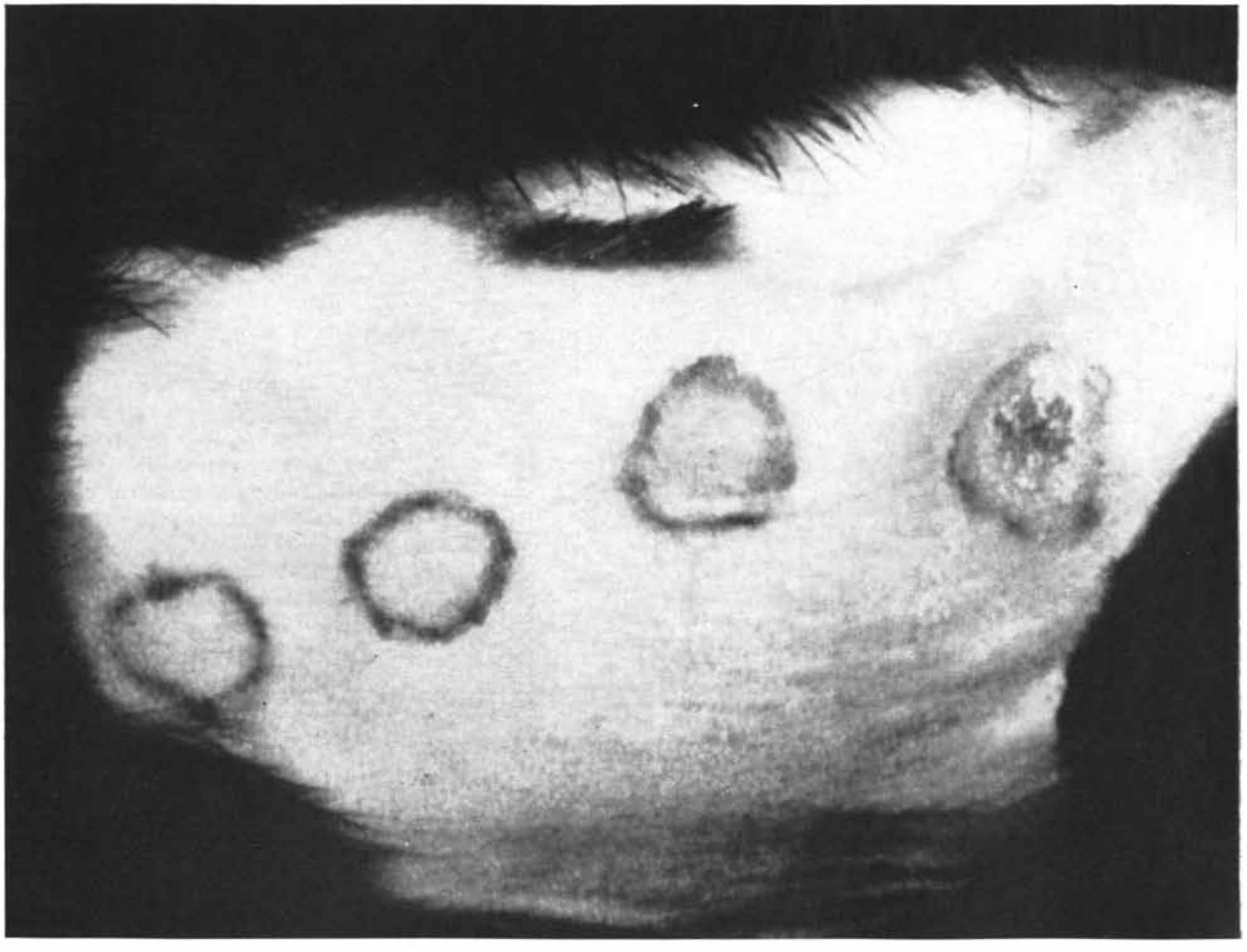
In normal cells glycolysis is the first step in the complex metabolic process that turns glucose into carbon dioxide and water. The net result of the process is the transfer of the energy originally contained in the glucose to the phosphorus compound adenosine triphosphate (ATP), which carries the energy in a form that the cell can readily use for a

wide range of metabolic functions. In glycolysis one molecule of glucose yields two molecules of pyruvic acid (a close relative of lactic acid) and two molecules of ATP. Subsequent steps eventually transform the two molecules of pyruvic acid into six molecules of carbon dioxide and four of water, yielding another 36 molecules of ATP. The whole process is called oxidative phosphorylation [see "Energy Transformation in the Cell," by Albert L. Lehninger; SCIENTIFIC AMERICAN, May, 1960].

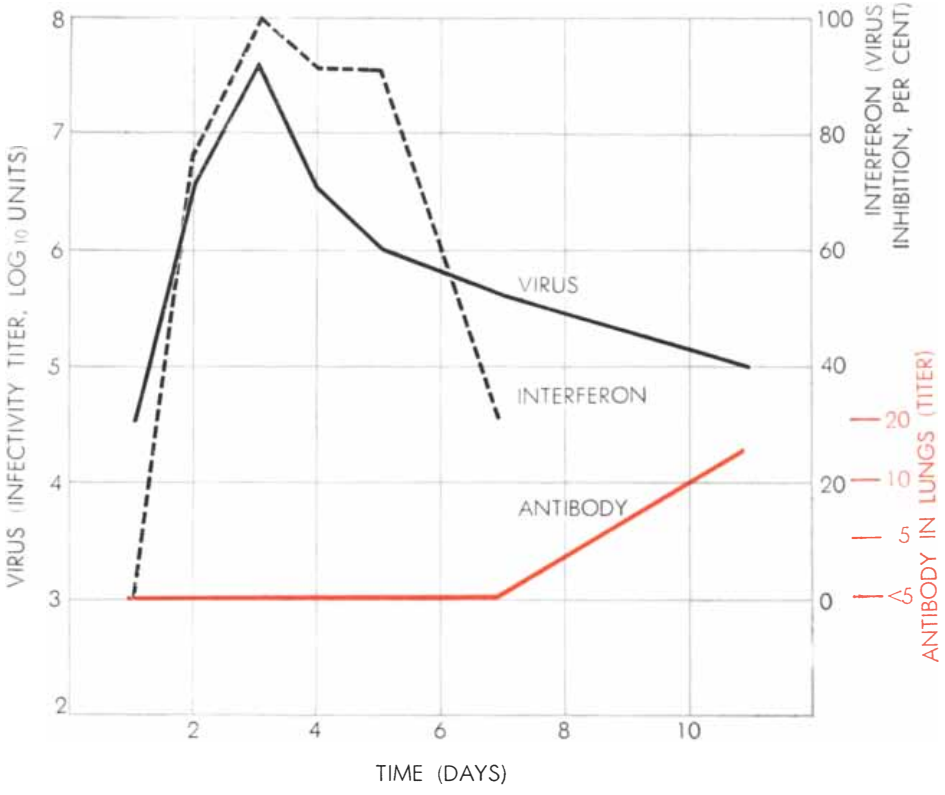
The hypothesis we now favor, after considering many, is that interferon acts by uncoupling oxidation from phosphorylation. This means that glucose is still metabolized (as indicated by its oxidation product, lactic acid) but that the process no longer produces a normal yield of the energy-rich substance ATP. It is known, moreover, that viruses cannot multiply inside a cell unless plentifully supplied with ATP. Evidently interferon allows a cell to make enough ATP for its own needs but not enough to fuel viral synthesis as well.

This particular hypothesis has the virtue of explaining a puzzling aspect of interferon's behavior. Interferon fails to stop virus growth in cancer cells when applied in doses that stop viruses in normal cells. A striking characteristic of cancer cells, pointed out by the German biochemist Otto Warburg, is that they can make all the ATP they require anaerobically, that is, without oxidation. One can understand, therefore, that if interferon can disrupt only the oxidative route to ATP, it will have no effect on ATP production in cancer cells. Thus when a virus invades a cancer cell, it finds ample ATP for multiplication, in spite of the presence of substantial amounts of interferon.

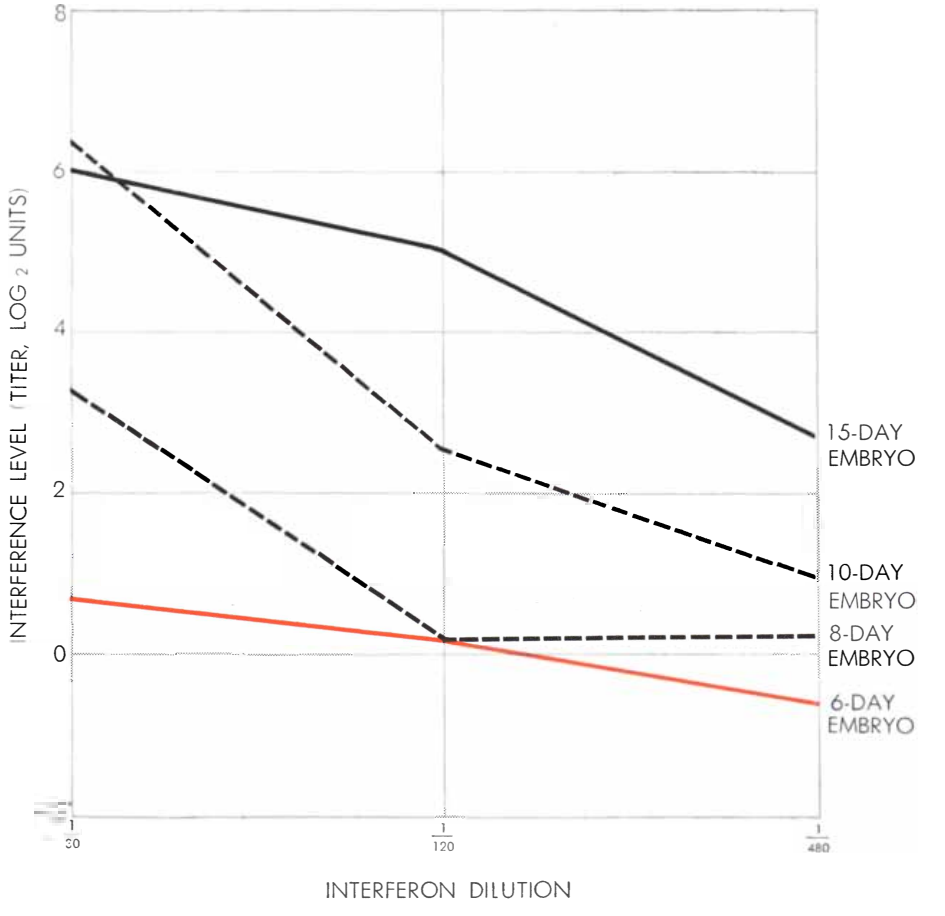
At least one kind of normal cell has a metabolism quite like that of the cancer cell: the cell of a very young embryo. In the course of embryonic development the embryo cell gradually shifts to the metabolic behavior of a normal adult cell. My colleague Samuel Baron and I set out to learn if interferon is as ineffective in young embryo cells as it is in cancer cells and, if so, to determine at what stage of embryo development interferon could become effective. Before doing the experiments we made a guess as to how they would turn out. The guess was based on an apparently unrelated fact: pregnant women infected with rubella (German measles) virus during the first three months of their pregnancy sometimes bear infants with congenital defects. If the infection occurs after the third month, however, congenital defects do not appear. We reasoned that during the first three months the interferon mechanism was not able to protect the embryo but that it was effective thereafter. We therefore predicted that during the first third of the period of embryonic development the cells of the embryo would not be protected by the antiviral section of interferon and that



SKIN OF RABBIT has been infected at four sites with vaccinia virus, one of the pox viruses. A typical vaccinia lesion occurs at the control site at far right. The site second from right has been partially protected by a small dose of interferon applied directly to the skin. The other two sites have been completely protected by larger doses of interferon. Other animal tests are in progress.



STUDY OF TWO ANTIVIRAL AGENTS, antibody and interferon, shows that interferon may be decisive in combating infection. Daily examination of lungs of mice infected with influenza virus reveals that interferon and virus peak together; antibody appears late.



FAILURE OF INTERFERON to protect very young embryos from virus attack provided a clue to its mode of action. Cells from six-day chick embryos are insensitive to antiviral action of interferon. Sensitivity becomes evident on eighth day, then increases rapidly.

response to interferon would increase thereafter.

We then tested the action of interferon on cells of the chick embryo at various stages during its development and were pleased to find that the results were just as we had predicted [*see bottom illustration on this page*]. Actually, the behavior of the human embryo toward infection with rubella virus may be connected with the state of development of the organs rather than with the interferon mechanism alone. Whatever the explanation, our experimental results favor the idea that interferon acts by uncoupling oxidation from the formation of ATP. A number of pieces of indirect evidence support the same hypothesis, but we shall not be happy until we have direct evidence, which we are actively seeking. We would also like to know how viruses and cells differ in their requirements for ATP, because the antiviral action of interferon is selective and does not stop all cellular syntheses.

We can now return to the question of what function interferon could have in the normal cell. Perhaps a clue can be found by considering what it is that stimulates the cell to produce interferon. And since we know that killed virus is effective we can conclude that virus multiplication is not the stimulus; instead we must look for something that the virus delivers to the cell.

It is known from much recent work that a virus infection can be started by injecting cells with naked viral nucleic acid, either deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). These are the genetic core substances that in a complete virus are surrounded by a protective coat of protein. It has been found that the viral nucleic acid contains all the information needed to instruct cells to synthesize whole virus particles. Could a foreign nucleic acid be the common stimulus that makes cells produce interferon? This idea has many interesting implications. Just as the antibody mechanism is designed to distinguish between our own proteins and foreign proteins, so the interferon mechanism may be designed to distinguish between our own nucleic acids (the materials that carry our own genetic blueprints) and foreign nucleic acids. One can appreciate the need for some mechanism to help the cell deal with foreign nucleic acids, which otherwise might insert the wrong instructions into the cell's blueprints. The evolutionary success of viruses lies in their ability to do just this.

Recent experiments I have carried out in collaboration with Samuel Baron and Anthony Allison tend to support these speculations. We took preparations of nucleic acid derived from cells not infected with viruses and found that some preparations made cells resistant to virus growth, just as a killed virus preparation would do. Although the resistance conferred was not very strong, this is presumably because nonviral nucleic acids are poorly taken up by cells, whereas viruses are organisms that specialize in delivering their nucleic acid safely and efficiently to the interior of cells. We were nonetheless able to show that the virus-inhibiting action of the nonviral nucleic acids closely resembles the action of interferon. So it looks as if a foreign nucleic acid, whether viral or not, may provide the stimulus to trigger off interferon production.

These experiments also suggest that in normal cells interferon may help to control the synthesis of nucleic acid. Perhaps the control is exercised by regulating the supply of ATP, which provides energy for synthesizing nucleic acids. At an early stage of embryonic development, when the cells are growing and dividing rapidly, this control has not yet come into play. The cancer cell seems to have escaped from the control of interferon by using the alternative route to ATP, so that the cell grows without hindrance. These are speculations, not established facts, but they can and will be tested experimentally. What they imply is that the antiviral action of interferon, which caught our attention first, may be an evolutionary accident, and that when we understand its full role in normal cells we shall have learned a great deal about the remarkable mechanisms that so nicely regulate cell growth and division.

Interferon has four points in its favor as a potential antiviral agent in man. First, it acts against a wide range of viruses, which probably includes most of the viruses that plague our noses and throats during the winter. Second, it does not seem to be toxic. Third, it does not stimulate the production of antibody, so it should be possible to administer it frequently without its effect wearing off. Fourth, it is active not only in experiments in test tubes but also in animals. It has proved effective in experimental virus infections of the rabbit eye and skin [*see illustration on page 55*] and in generalized virus infections of mice.

The main obstacle to the use of interferon in man is the large number of cells (which will probably be monkey cells) required to manufacture it in commercial volume. But this will not prevent us from carrying out trials of its action in man. Indeed, colleagues of Flash Gordon have already reported such trials [*see illustration below*]. Since we are not faced with a similar emergency we can proceed more cautiously, watching out for all possible pitfalls.

With any substance being tried out in man for the first time there are always hazards, but in the case of interferon it will be a great comfort to realize that we are not so much administering a foreign substance as we are supplementing a natural mechanism of resistance to virus infection. If interferon shows up as favorably in trials in man as it has in laboratory animals, the task ahead will be to learn how to improve the yield of interferon, and to see that its activity is carefully standardized, before attempting general distribution. This may prove to be a very difficult task, but it is not beyond the powers of modern pharmaceutical technology.

FIRST HUMAN TRIAL OF INTERFERON was "described" last year in the Flash Gordon comic strip. Although such trials have not yet been reported elsewhere, they can be expected. Making interferon in commercial volume may prove a difficult matter.

The Temperatures of the Planets

The development of ultrasensitive receivers has made it possible to use the weak radio waves emitted by a planet as an index to the temperature at its surface and at various levels in its atmosphere

by Cornell H. Mayer

The approaching era of space exploration cannot help sharpening men's curiosity about the other planets in the solar system. In a few years at most, instruments landed on Venus and Mars will be sending back answers to many ancient questions about the earth's nearest neighbors. Similar investigations of the more distant planets are undoubtedly further off. Meanwhile astronomers are intensifying their efforts to learn as much as possible about the solar system from the vantage point of the earth. The motive is not only impatience; the more that is known in advance, the more efficient the exploratory probes can be made.

TEMPERATURE (DEGREES FAHRENHEIT)

	A	B
MERCURY	666	
VENUS	124	−47
EARTH	169	−17
MARS	93	−69
JUPITER	−198	−276
SATURN	−267	−323
URANUS	−335	−371
NEPTUNE	−359	−387
PLUTO	−351	−384

THEORETICAL TEMPERATURE of each planet is calculated on two assumptions: (*A*) that one side of the planet always faces the sun and (*B*) that the planet is rotating rapidly. *A* is specifically the maximum temperature of the point nearest the sun on the planet's solid surface; *B*, the average surface temperature. It is also assumed that the planet is a perfect radiator. These values are taken from *The Atmospheres of the Earth and Planets*, edited by Gerard P. Kuiper of the Steward Observatory.

One of the most interesting questions concerns the climate, and in particular the temperature, at the surface of the planets. In the last few years radio astronomy, which has opened so many new channels of information about the heavens, has been applied to the problem. Various observers have now used radio techniques to measure the temperatures of Venus, Mars, Jupiter and Saturn. Some of the results are in line with advance expectations; others have come as quite a surprise.

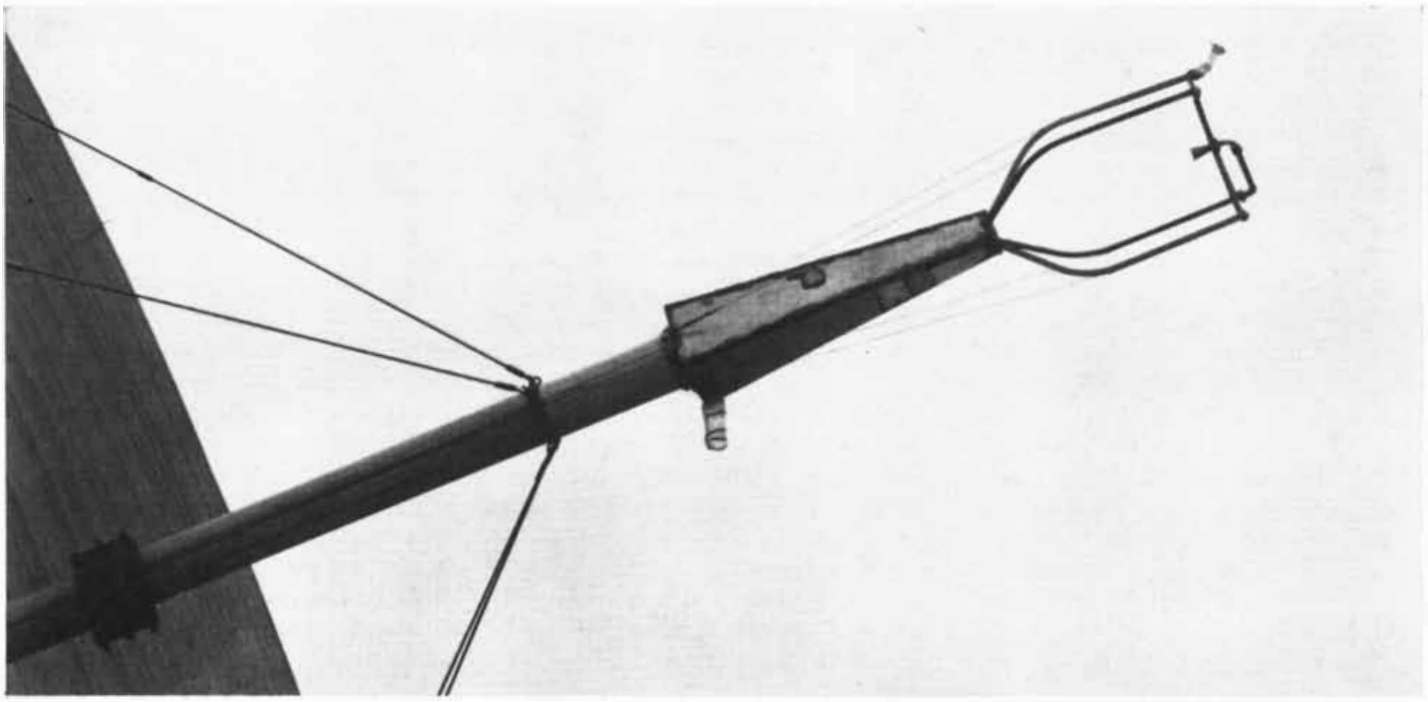
A rough idea of the temperatures of the planets can be gained simply by comparison with the temperature of the earth. Each planet (including both the solid body of the planet and its surrounding atmosphere) is in thermal equilibrium. It must radiate energy as fast as it receives energy from the sun, and the rate of this radiation depends on the temperature of the planet. The inflow of solar energy to the earth has been measured, and from this value the inflow to the other planets can be calculated: the amount of energy reaching each one is inversely proportional to the square of its distance from the sun. By setting outflow equal to inflow an average temperature can also be calculated [*see table at left*].

The value thus obtained may differ substantially, however, from the actual temperatures at various points on the surface of the planet. These temperatures depend on a number of additional factors. In the first place, if the planet spins slowly on its axis, a given spot will be hotter during the day and colder during the night than if the planet spins faster. Secondly, the temperature necessary to provide a given rate of energy outflow varies with the efficiency of the surface as a radiator; the higher the efficiency, the cooler the body will be at equilibrium. Thirdly, heat flowing outward from the interior of the planet may throw off the calculation. On earth the effect is negligible compared with solar heating because of the low conductivity of surface rocks. This may not be true on all the other planets.

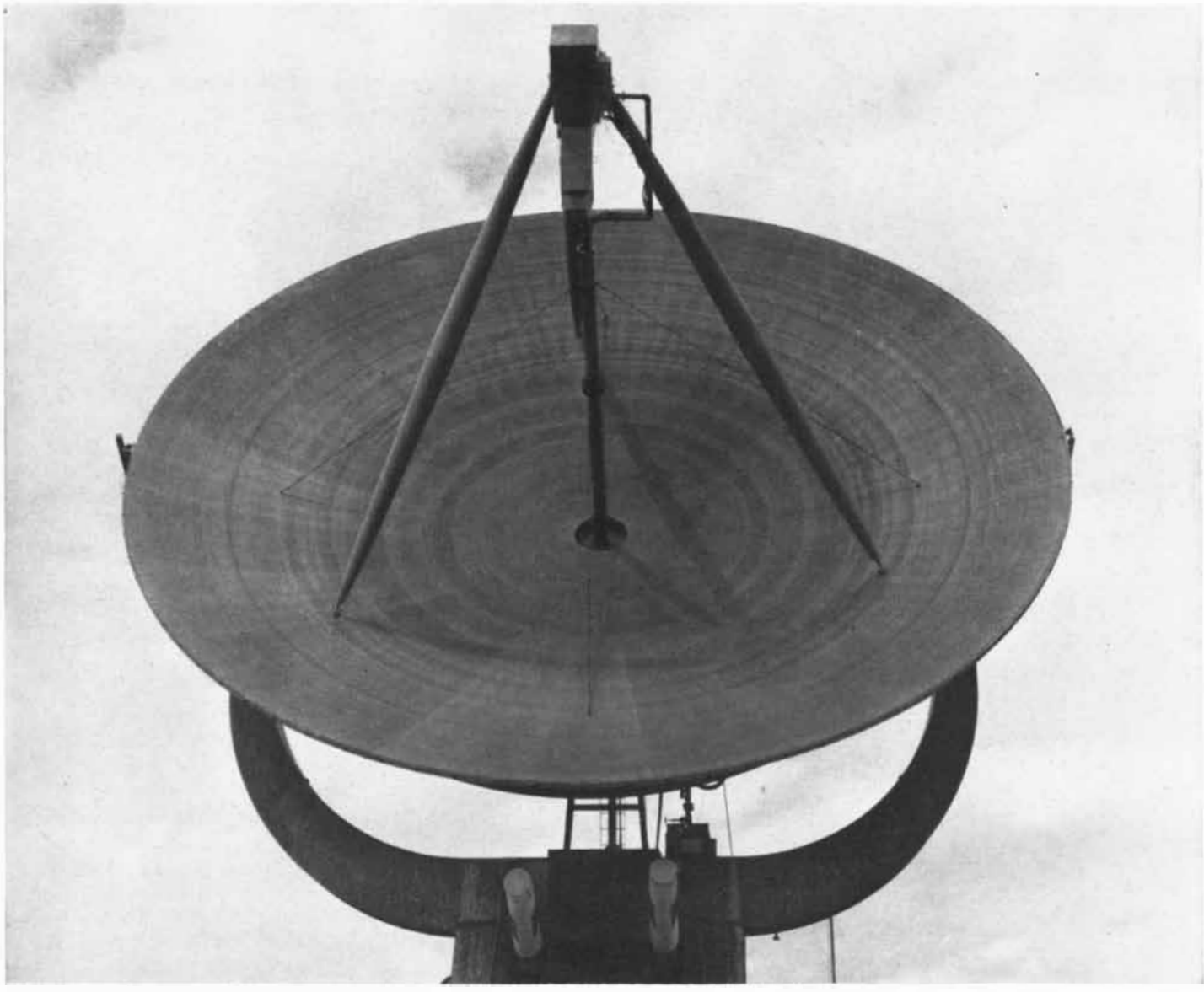
The most important sources of uncertainty are the atmospheres of the planets. On the one hand, they screen out some of the sun's radiation, preventing it from reaching the surface; on the other, they trap some of the outgoing heat radiation and raise the surface temperatures by a "greenhouse" action. Without knowing the exact make-up of the atmosphere of a planet, it is impossible to predict accurately its effect on the incoming and outgoing radiation.

Indeed, if it were not for atmospheric filtering, the heat radiation emitted by the planets would furnish a direct index to their temperatures. Every body sends out electromagnetic waves in a mixture of wavelengths that depends on how hot it is. If the body is hot enough, some of the radiation is in the visible range, and the temperature of the body can be determined from the color of its light. But other parts of the spectrum serve equally well as indicators.

The planets are not incandescent; they radiate most of their energy in the infrared region of the spectrum. Except in the case of the two most distant planets—Neptune and Pluto—this heat radiation has actually been measured, by means of sensitive thermocouples



RADIOMETER mounted at focus of 50-foot radio telescope of the Naval Research Laboratory in Washington, D.C., was used by the author for observations of three-centimeter radio waves from the planets. Inverted-L-shaped object at upper right is horn antenna.



SOLID-STATE MASER is mounted at the focus of the 50-foot radio telescope as a preamplifier for the radiometer shown at top. The maser makes it possible to measure planetary radiations 12 times weaker than those detected by the radiometer alone.

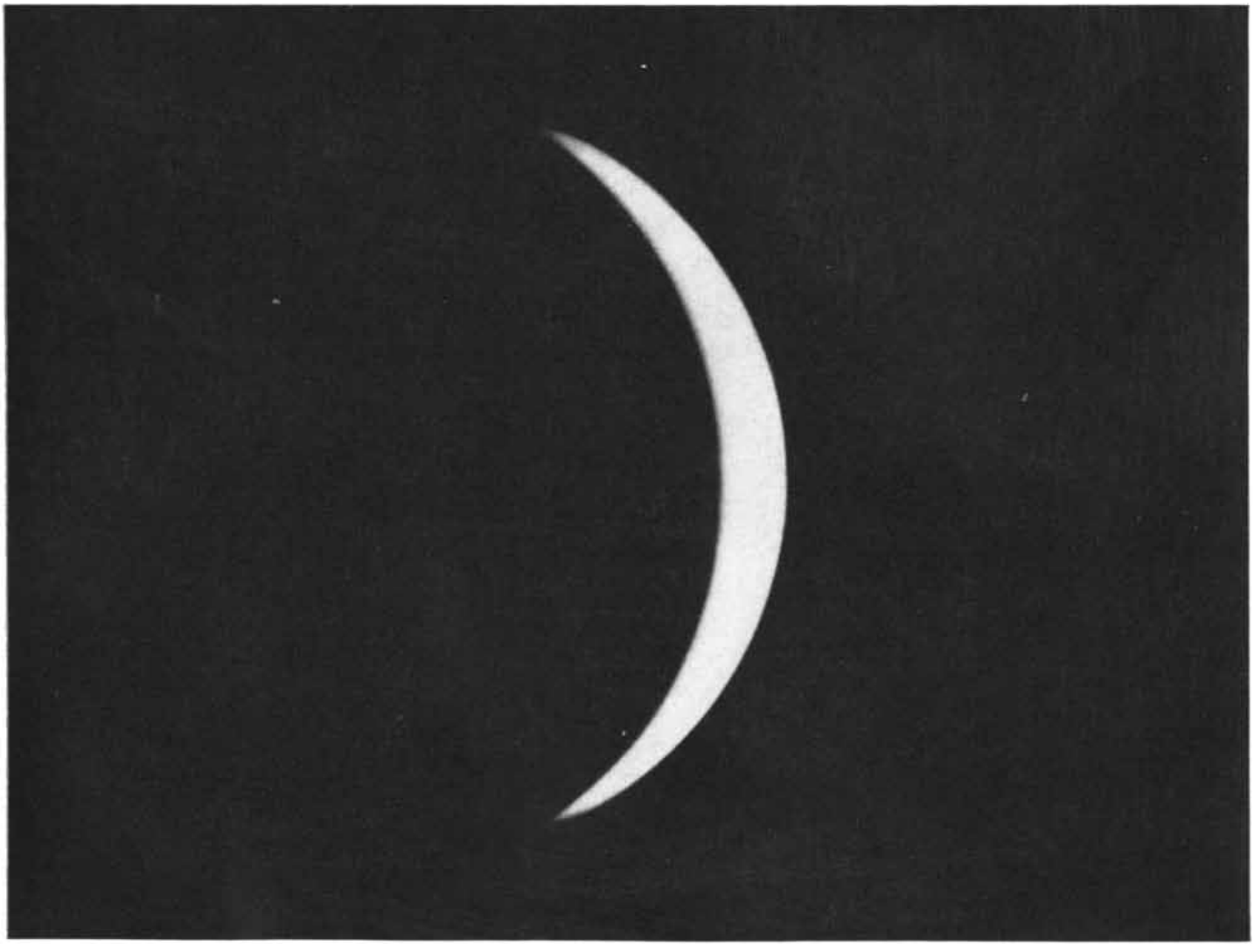
attached to large telescopes. Unfortunately some of the heat radiation from a planet originates high in its atmosphere, above the layers that absorb and scatter the radiation from the planet's solid surface. Consequently the temperature that can be deduced is a blend of the radiation from various levels.

Infrared radiation, then, cannot give unequivocal information about conditions at the surface of a planet with a cloudy or very dense atmosphere. Are there any waves that can? In looking for a type of radiation that penetrates most gases and clouds one thinks at once of radio waves. Radio waves are not usually considered to be indicators of temperature. They can nonetheless be used in this way. Although the greater part of planetary thermal radiation is concentrated in the infrared, there is always some at the longer radio wavelengths. As one would expect, the intensity of thermal radio waves increases with the temperature of the emitting body and hence is a measure of temperature. From all that is known of other planetary atmospheres, radio waves should pass through them about as easily as through our own and should therefore bear information about surface temperature.

All this has been known for some time. The problem is to detect and measure the extremely weak thermal radio signals that arrive at the earth. As the top illustration on page 62 shows, the intensity of planetary thermal radiation falls off steadily with increase in wavelength. Although the intensity is greater at the millimeter end of the radio spectrum than in the centimeter and meter portions, larger antennas that can gather much more energy are available at centimeter wavelengths. This, together with the greater sensitivity of centimeter-wave receivers, more than offsets the fainter signal, so most of the observations have been made in the centimeter region. At meter wavelengths the intensity is simply too low for even the largest radio telescopes now available.

The first successful measurements were made in 1956 at the Naval Research Laboratory in Washington. T. P. McCullough, R. M. Sloanaker and the author scanned Venus, Mars and Jupiter with the laboratory's 50-foot parabolic antenna at periods when the planets were closest to the earth. A sensitive receiver placed at the focus of the paraboloid picked up a distinct three-centimeter signal from each of them. The next year F. D. Drake and Harold I. Ewen, using a 28-foot paraboloid, were able to detect radio waves from Saturn at about four centimeters.

These first observations were performed with receivers of extremely high amplifying power but utilized standard radio techniques. In dealing with very weak signals it is not amplification that sets a limit on the performance of the receivers but the random noise generated by their own electronic circuits. The noise causes a continual jiggle of the pen that records the output, and the deflections are of roughly the same size as those produced by the planetary thermal radiations at their strongest [*see*



VENUS, one of four planets whose temperatures have been measured with radio telescopes, shows phases like those of the moon when observed by optical telescope. Photographs on these two pages were made with the 200-inch telescope on Palomar Mountain.

illustration on page 63]. As a planet recedes from the earth and its signals grow weaker, they are soon totally obscured by the noise generated in the receiver.

To increase range and accuracy, the 50-foot antenna was later equipped with a "maser" designed and built by Charles H. Townes, J. A. Giordmaine and L. E. Alsop of Columbia University. This is an amplifying device that operates at very low noise levels [see "The Maser," by James P. Gordon; SCIENTIFIC AMERICAN, December, 1958]. It reduced the output flicker of the radio telescope by a factor of 12, making possible the measurement of planetary radiations 12 times weaker than before. Working together, the Columbia and Naval Research Laboratory groups refined and considerably extended the observations of Venus, Jupiter and Mars. Subsequently a number of other radio astronomers measured the signals from these planets in different regions of the centimeter-wave spectrum.

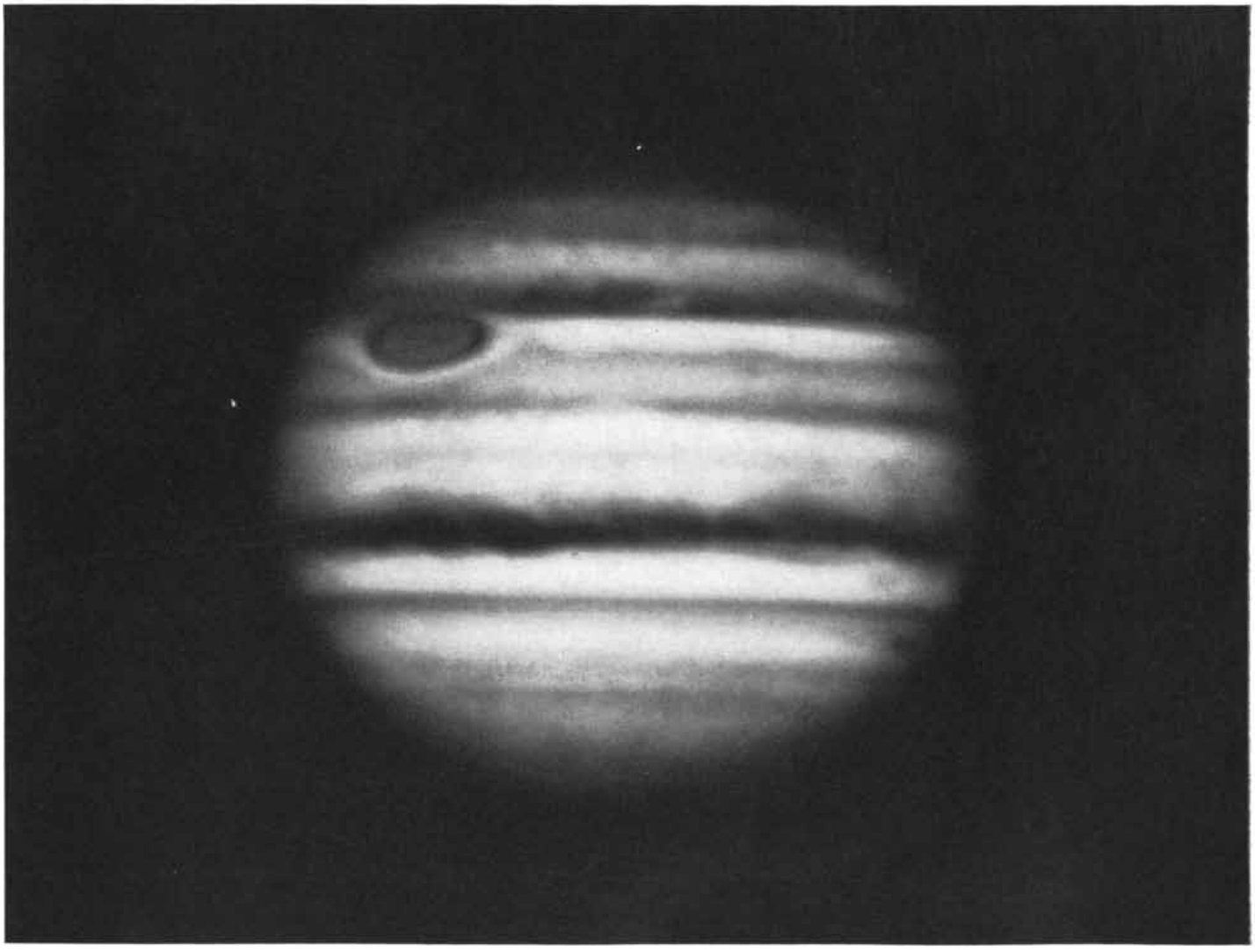
In discussing the results of the radio temperature studies it is appropriate to begin with Venus, the planet closest to the earth in distance, size and mass. Venus is a particularly intriguing object because its surface is permanently hidden by dense, yellowish-white clouds made up of small particles of unknown composition. The clouds themselves have a remarkably uniform appearance, with only vague and temporary markings. As a result even the rate at which Venus turns on its axis is unknown.

Optical studies of the Venusian atmosphere above the clouds show that the main constituent that can be detected through our own atmosphere is carbon dioxide. Recently a little water vapor also has been discovered. Some gases, such as nitrogen, would not show up in the usual observations. The fact that no oxygen has been detected, however, means that it is present only in small quantities, if at all.

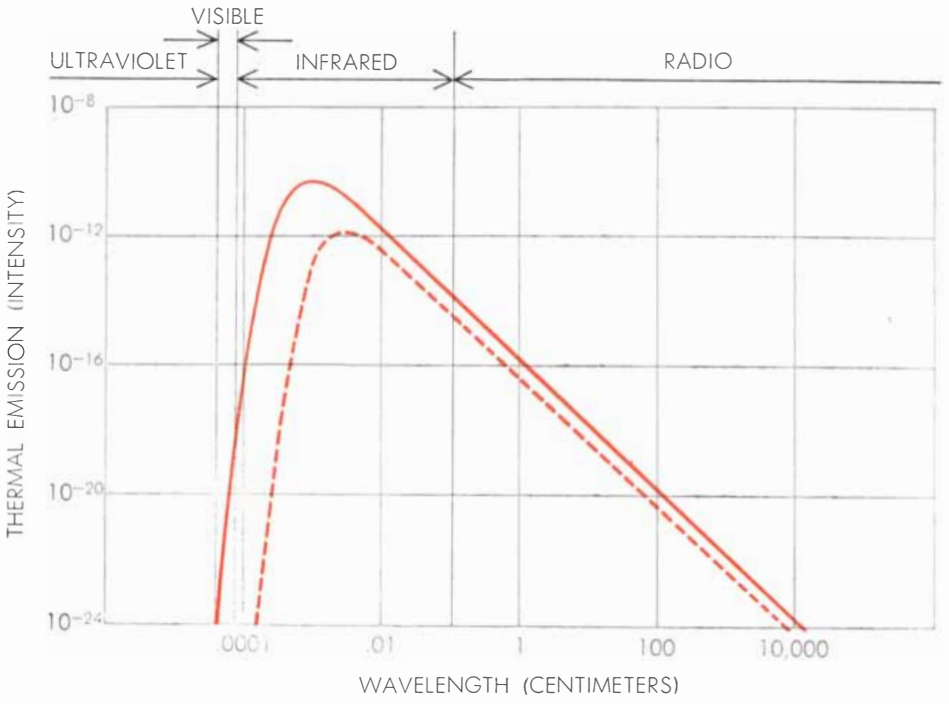
Recent measurements of the infrared radiation of Venus indicate a temperature of about —35 degrees Fahrenheit for both dark and light hemispheres. On the other hand, according to Gerard P. Kuiper of the Steward Observatory, studies of the absorption spectrum of carbon dioxide yield an estimated maximum of 115 degrees F. The two results are not necessarily inconsistent; they may refer to different levels in the atmosphere of Venus, the higher temperature applying in or near the cloud layer and the lower temperature in the region above it. Moreover, both temperatures are reasonable for a planet only a little nearer the sun than the earth is.

Radio waves tell a different story. The radio emission of Venus has been measured at several wavelengths between three and 10 centimeters by groups at the Naval Research Laboratory and Columbia University and by F. D. Drake at the National Radio Astronomy Observatory in Green Bank, W.Va. All the observations are consistent with a temperature of almost 600 degrees.

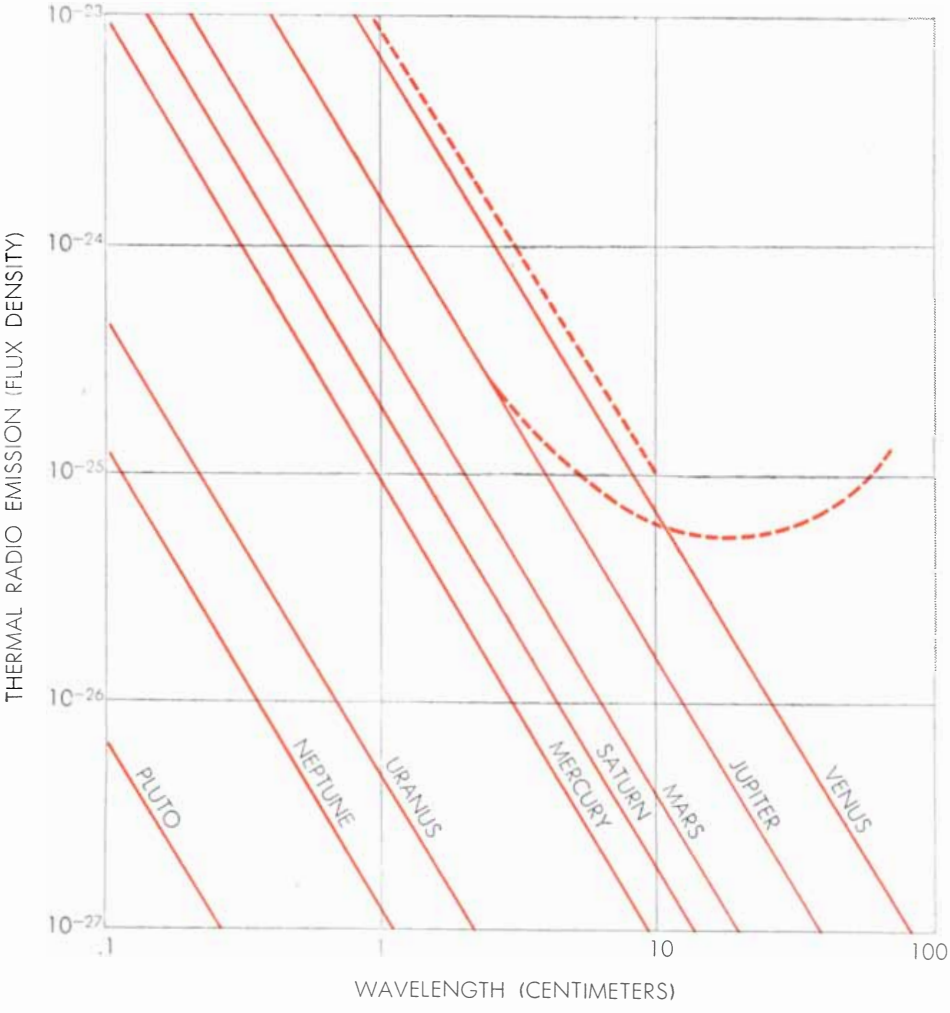
This temperature almost certainly applies in a region below the clouds, perhaps the solid surface of the planet. The temperature is much higher than anyone



JUPITER has been observed with radio telescopes at wavelengths ranging from three to 68 centimeters. Measurements indicated and later confirmed that part of the Jovian emission was nonthermal in origin. The dark oval at upper left is the Great Red Spot.



PLANETARY THERMAL EMISSION at various wavelengths is a function of temperature. Shown here are two spectra of thermal radiation: at a temperature of —100 degrees Fahrenheit (*broken colored line*) and at 620 degrees F. (*solid colored line*). The intensity of thermal emission is expressed in watts per square meter per cycle per second per steradian.



PREDICTED MAXIMUM INTENSITY of planetary thermal radio emission reaching the earth (*solid colored lines*) is based on the temperatures listed in table on page 58; calculations do not include effect of atmospheric absorption. Predicted intensities for Jupiter and Venus can be compared with measured intensities (*broken colored lines*). Flux density (*i.e.*, intensity) is expressed in watts per square meter per cycle per second.

would have predicted. Some elevation had indeed been looked for because of the high concentration of carbon dioxide in the atmosphere of Venus. An efficient trap for infrared radiation, the gas exerts a strong greenhouse action. In the latest calculation of the effect of carbon dioxide, however, Kuiper has arrived at a maximum temperature of only 170 degrees. If the surface is really at 600 degrees, the atmosphere must trap nearly all the heat radiation from the surface, or there must be some source of surface heat in addition to solar radiation. A theoretical investigation by Carl Sagan of the Yerkes Observatory suggests that water vapor in the Venusian atmosphere may in fact hold in the necessary extra heat.

The problem has now been further complicated by some observations in the millimeter-wave region. Observing at 8.6 millimeters, J. E. Gibson and R. J. McEwan of the Naval Research Laboratory found a temperature of 280 degrees; and at eight millimeters A. D. Kuzmin and A. E. Salomonovich in the U.S.S.R. obtained a value of only 110 degrees. Part but not all of the apparent discrepancy could arise from inaccuracies in measurement. The rest may be due to a partial absorption of millimeter waves in the atmosphere of Venus. Water vapor absorbs millimeter radiation, and, as A. H. Barrett of the University of Michigan has pointed out, so will the carbon dioxide on Venus if the atmospheric pressure is high enough.

In view of these surprising results astronomers have considered if part of the radio waves from Venus may come from nonthermal sources and so not represent temperature at all. This has proved to be true of Jupiter, as will appear later. In the case of Venus, however, all the evidence is against it. The spectrum is consistent with thermal emission and not with nonthermal; the intensity varies only slowly, in keeping with the change in the phase of Venus (the portion of the illuminated hemisphere visible from the earth); the radiation does not seem to be polarized, as it would be if it were produced by coherent motions of charged particles.

It seems most likely that the radiations at various wavelengths are all thermal but come from different parts of the Venusian atmosphere. Presumably the centimeter wavelengths originate farthest down, possibly at the solid surface, and the temperature there is actually close to 600 degrees. The millimeter wavelengths probably come from a high-

er level, and the infrared from a higher level still. The actual heights will depend on the temperature gradient in the atmosphere. Assuming that the centimeter radiation does come from the surface and that the atmospheric absorption is due chiefly to carbon dioxide, the millimeter radiation must originate at least 11 miles above the surface, and the infrared at least 21 miles above the surface. If the temperature at the cloud layer is taken to be 115 degrees, the layer is at least 16 miles high. To the extent that water vapor exists in the atmosphere, all the heights must be increased. Even as listed they indicate a very deep atmosphere for Venus.

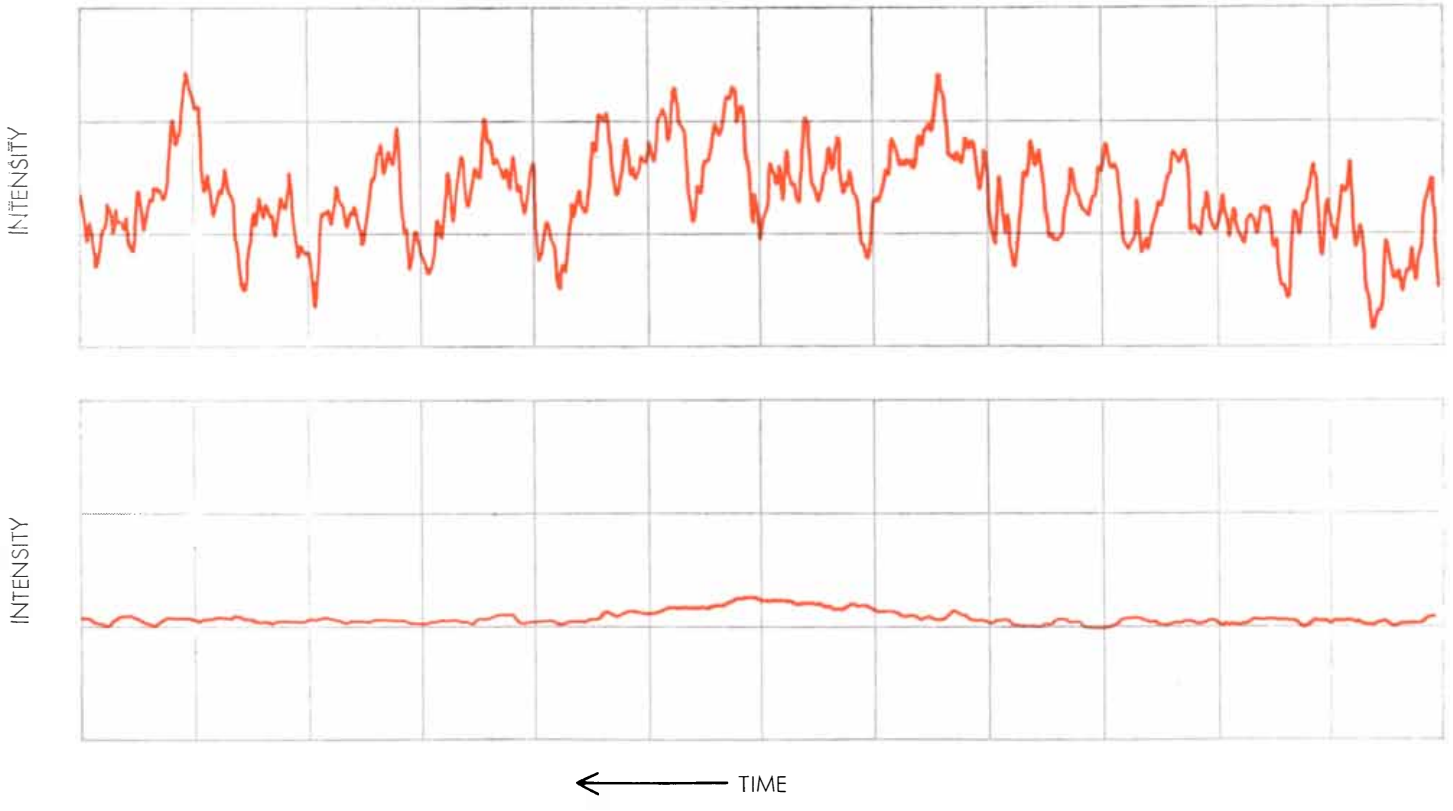
It should be remembered that most of the radio measurements give the temperature mainly of the dark side of Venus, since Venus is at a phase resembling that of the new moon when the planet is nearest the earth. As with the infrared radiation, however, there seems to be little temperature difference between the dark and the sunlit parts of Venus, although more measurements are needed to say just how much. Eventually radio astronomers hope to measure accurately the radio waves from Venus at all times and not just when the planet is near the earth. Then it should be possible to find the difference in temperature between the day and night sides and perhaps to deduce the period of rotation of the planet.

Radio observations of Mars inevitably provide less new information than those of Venus. Our nearest outer neighbor has a thin atmosphere, transparent to the infrared radiation emitted at the surface. Being farther away from the sun than Venus is, Mars is much colder and its radio emission weaker. The orbit of Mars never brings the planet nearer the earth than 34 million miles, as compared with 26 million miles for Venus. So far radio waves from Mars have been measured only twice, both times at the Naval Research Laboratory and at a wavelength of about three centimeters. The first measurement, during the favorable opposition of 1956, indicated a temperature of —65 degrees; the second, made with the maser in 1958, was more accurate and gave a value of —80 degrees. Both agree reasonably well with previous estimates and with infrared measurements.

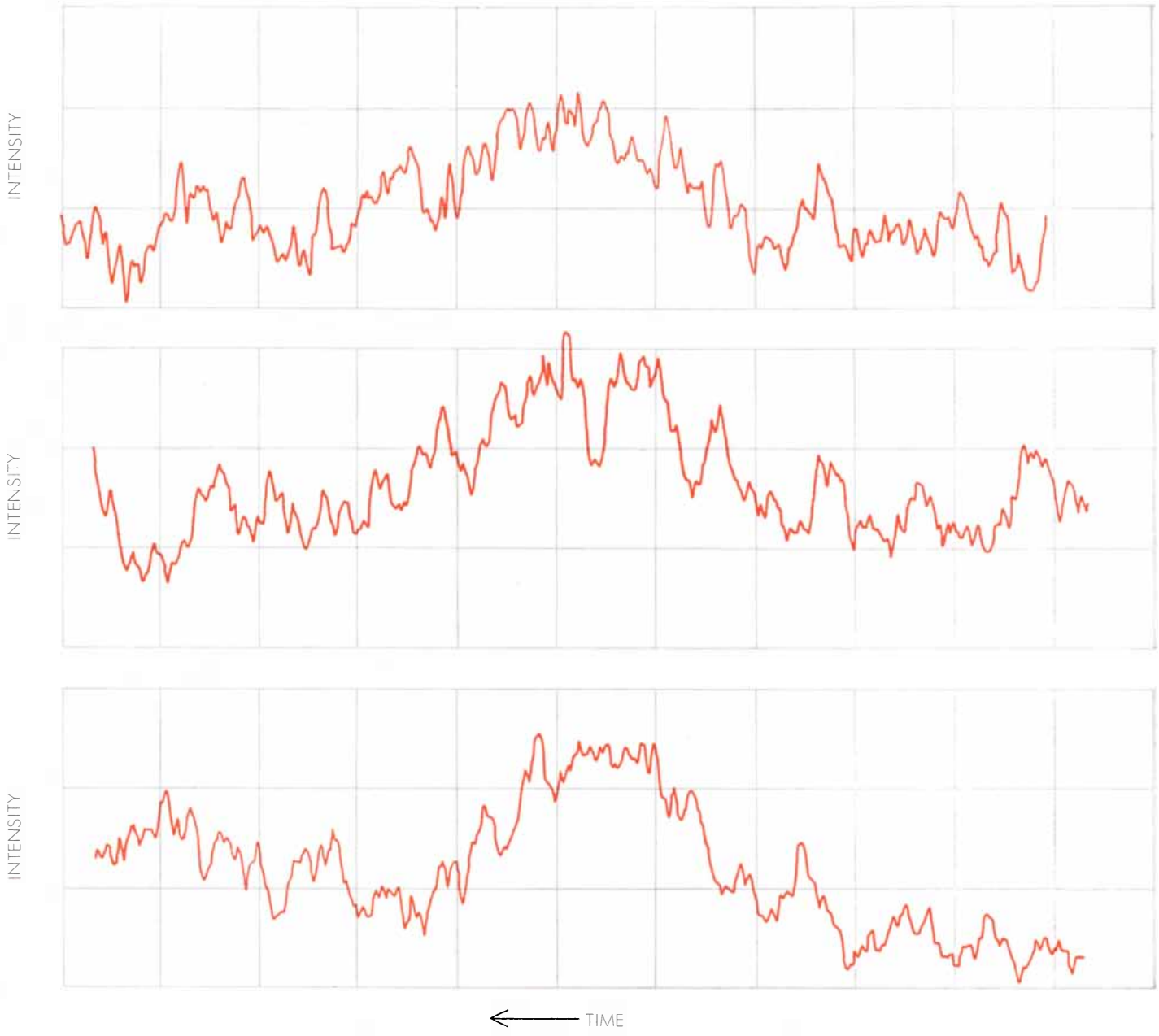
If the radio spectrum of Mars can ever be determined with greater accuracy, it may tell something about the temperature below the surface of the planet. Radio waves can penetrate some distance through rocklike materials, the attenuation decreasing as the wavelength increases. Therefore the radiation should come in part from a depth of between a few inches and several feet below the Martian surface.

Beyond Mars lies the giant planet Jupiter. Although it is much farther from the earth, Jupiter is so large that it emits a stronger radio signal than Mars does. Like the other major planets (Saturn, Uranus and Neptune), Jupiter is enveloped in an atmosphere much deeper than the atmospheres surrounding Mars, Venus and the earth. Hydrogen and perhaps helium constitute the bulk of the gas, and there is also some methane and ammonia. Not only in chemical make-up but also in physical conditions the Jovian atmosphere differs sharply from that of the earth. It receives much less heat from the sun, and its pressure must be extremely high beneath the visible cloud surface. Therefore it was difficult to know what to expect from radio measurements.

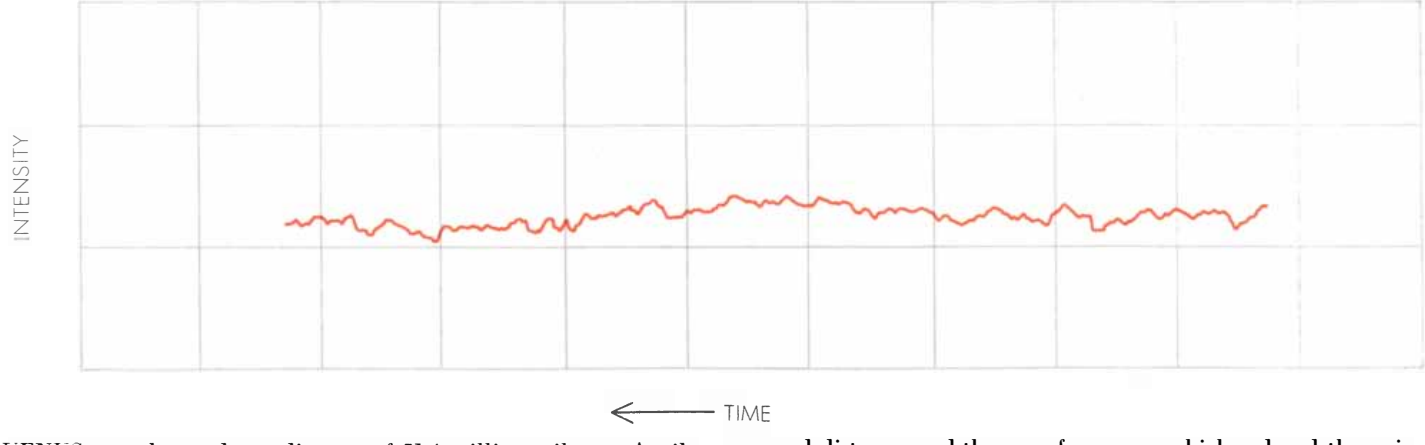
The first observations, made at a wavelength of three centimeters at the Naval Research Laboratory in 1956 and 1957, led to a calculated temperature of —200 degrees. Later studies at the same wavelength with the maser gave a higher value of —140 degrees. At about the same time Drake and Ewen obtained a value of —100 degrees at four centi-



RADIO OBSERVATIONS OF JUPITER made with the 50-foot radio telescope at the Naval Research Laboratory are compared in these two graphs. In the graph at top the recording of waves from Jupiter has been masked by random noise generated in the electronic circuits of the telescope. In the graph at bottom most of this noise has been eliminated by employing a maser in the telescope. The slight hump in the center represents the radio emission from Jupiter. Each horizontal division represents 20 seconds.



RADIO OBSERVATIONS OF VENUS recorded in these graphs were made on three days in 1956: May 26 (*top*), June 17 (*middle*) and June 23 (*bottom*). The distances between Venus and the earth on those dates were respectively 35.7 million, 27.2 million and 27 million miles. The large jagged humps in the fifth, sixth and seventh squares of each graph represent radio emission from Venus. The observations were made without using a maser. Each of the horizontal divisions represents 20 seconds; each vertical division represents an increase of about 3.6 degrees F. in antenna temperature, corresponding to the increased intensity of the radio waves.



VENUS was observed at a distance of 71.4 million miles on April 19, 1958. The "smoothness" of this graph in comparison with those above results from the decreased intensity of radio waves with increased distance, and the use of a maser, which reduced the noise contributed by the radio telescope itself. The horizontal and vertical divisions have the same value as those in the graphs above.

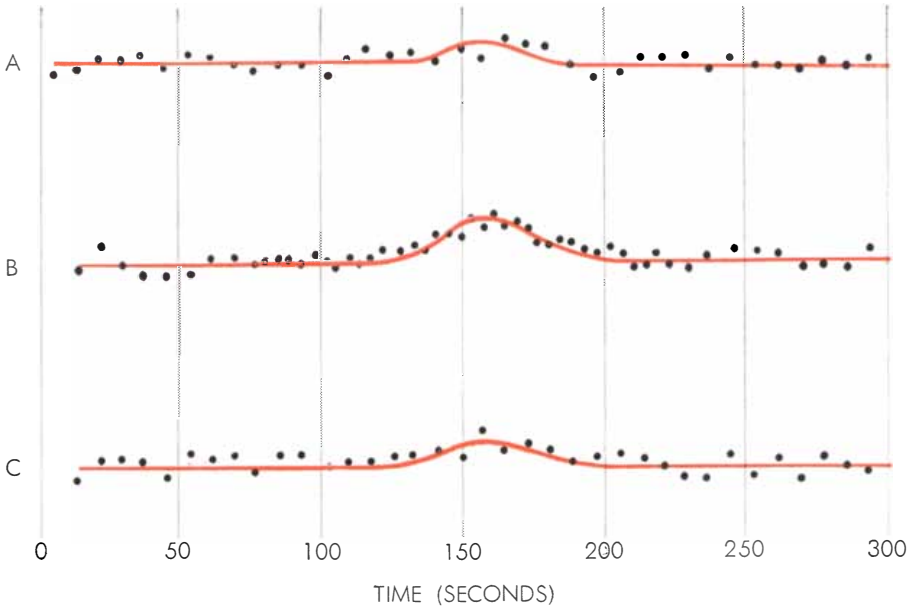
meters. These results were not badly out of line with the estimated equilibrium temperature or with the figure of —225 degrees derived from infrared measurements.

Then R. M. Sloanaker tuned in the 10-centimeter radiation from Jupiter and found a temperature of 690 degrees. One possible explanation was that the longer waves originated deeper in the atmosphere, as in the case of Venus, and that the temperature increases rapidly with depth. Alternatively, part of the 10-centimeter radiation could be of nonthermal origin. A little later Drake and H. Hvatum of the National Radio Astronomy Observatory found a temperature of about 5,000 degrees at 21 centimeters and 90,000 degrees at 68 centimeters! Other observers obtained comparable results at 21 centimeters and a value of 9,400 degrees at 31 centimeters.

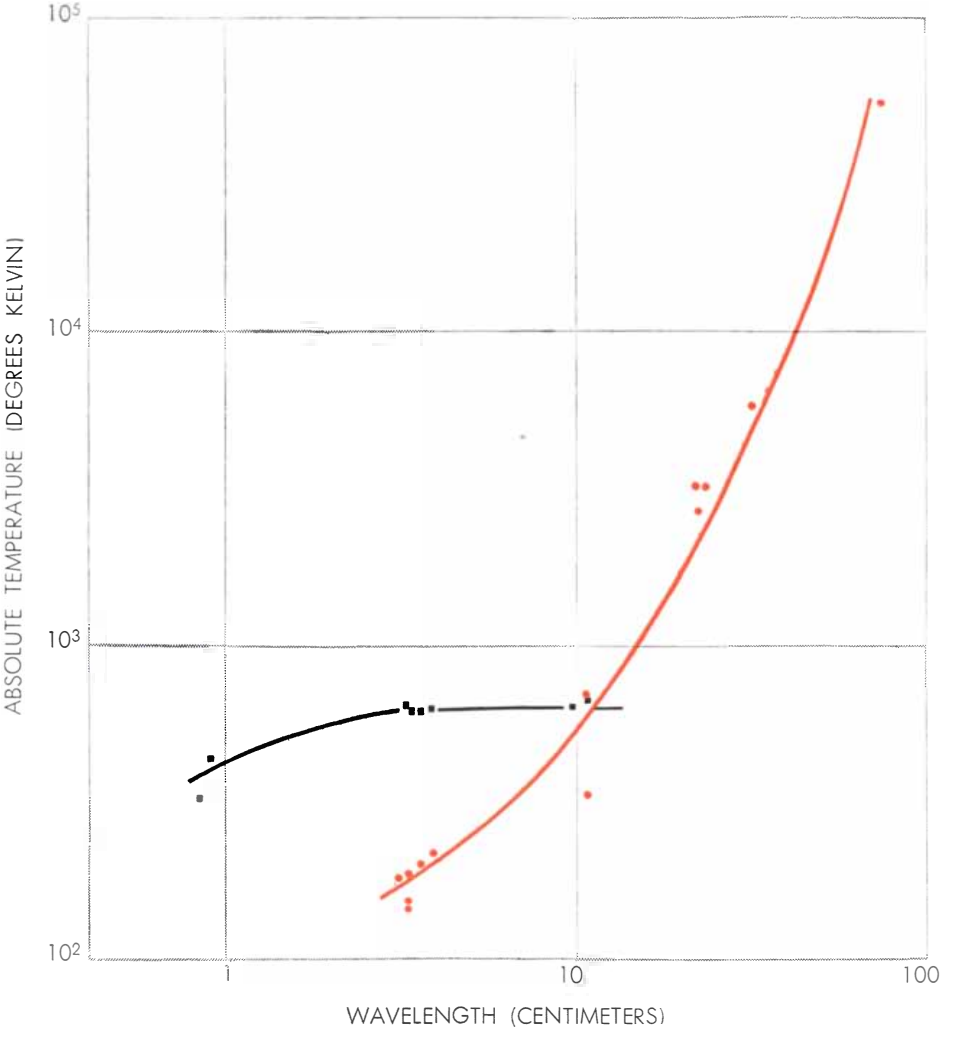
These "temperatures" are obviously too high to represent thermal radiation. Drake suggested that the longer waves are generated by high-energy electrons trapped in the magnetic field of Jupiter in regions similar to the Van Allen belts around the earth. If so, the waves should be linearly polarized and should come from an area larger than the solid disk of the planet. In the past few months V. Radhakrishnan and J. A. Roberts at the California Institute of Technology have verified both these predictions for 31-centimeter waves. Presumably there is also a thermal component in the Jovian radiation from 10 to 68 centimeters. Extensive studies will be required, however, to separate that component from the much stronger nonthermal portion and arrive at meaningful temperatures.

The latest planetary measurement, completed in the past few months at the University of Michigan, provides a radio temperature for Saturn. In 1957, when Drake and Ewen first picked up a signal from Saturn with their 28-foot antenna, they were able only to detect it. Now, with an 85-foot dish and a maser amplifier, the temperature has been measured at 3.45 centimeters. The value of —270 degrees coincides quite well with the equilibrium estimate.

Thus Saturn and Mars "look" about as expected in the radio telescope, while Venus and Jupiter do not. As has been indicated, there is much more information to be extracted from the radio spectra of these planets. With larger telescopes and improved techniques it should also be possible to measure the thermal emission of Mercury and perhaps Uranus within the next few years.



RADIO DRIFT SCANS of Jupiter were made at four minutes of arc above and below the Jovian disk (*"A" and "C" respectively*), and across the disk (*B*) in March, 1957. The large hump in *B* represents an increase of .9 degree F. in antenna temperature, caused by radiation from Jupiter, and corresponds to a planetary temperature of —200 degrees F. The three graphs reproduced here represent the averages of between 45 and 50 drift scans.



APPARENT TEMPERATURES of Venus (*black curve and squares*) and Jupiter (*colored curve and dots*) are plotted from observations made at different wavelengths from 1956 through 1959. The temperatures (in degrees Kelvin) were calculated on the assumption that both planets are perfect radiators. On a Fahrenheit scale the temperatures range from —210 degrees (*colored dot nearest bottom of graph*) to 90,000 degrees (*dot nearest top*).

The Origin of Form Perception

Is man's ability to perceive the form of objects inborn or must it be learned? Experiments indicate that it is innate but that maturation and learning play important roles in its development

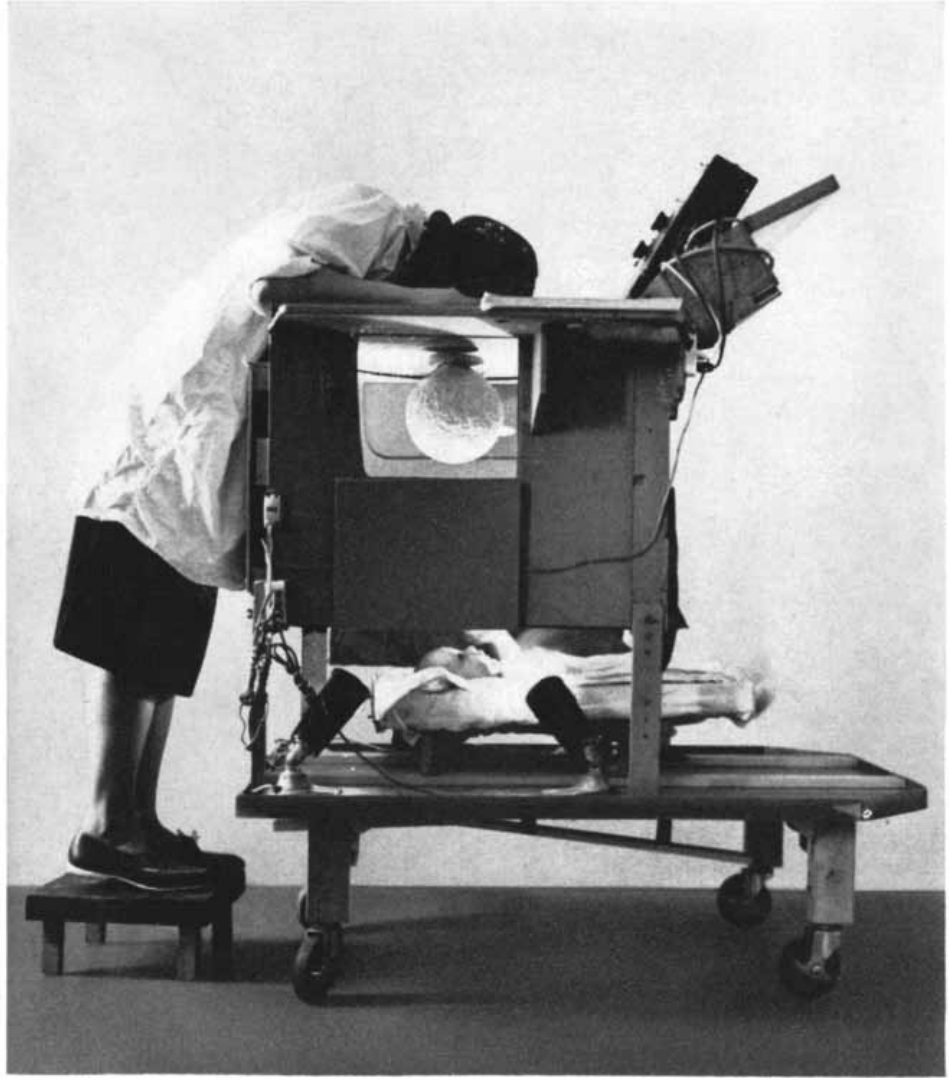
by Robert L. Fantz

Long before an infant can explore his surroundings with hands and feet he is busy exploring it with his eyes. What goes on in the infant's mind as he stares, blinks, looks this way and that? Does he sense only a chaotic patchwork of color and brightness or does he perceive and differentiate among distinctive forms? The question has always fascinated philosophers and scientists, for it bears on the nature and origin of knowledge. At issue is the perennial question of nature *v.* nurture. On one side is the nativist, who believes that the infant has a wide range of innate visual capacities and predilections, which have evolved in animals over millions of years, and that these give a primitive order and meaning to the world from the "first look." On the other side is the extreme empiricist, who holds that the infant learns to see and to use what he sees only by trial and error or association, starting, as John Locke put it, with a mind like a blank slate.

It has long been known that very young infants can see light, color and movement. But it is often argued that they cannot respond to such stimuli as shape, pattern, size or solidity; in short, that they cannot perceive form. This position is the last stronghold of the empiricist, and it has been a hard one to attack. How is one to know what an infant sees? My colleagues and I have recently developed an experimental method of finding out. We have already disposed of the basic question, that of whether babies can perceive form at all. They can, at least to some degree, although it appears that neither the view of the simple nativist nor that of the simple empiricist tells the whole story. Now we are investigating the further question of how and when infants use their capacity to perceive form to confer order and meaning on their environment.

The technique grew out of studies with lower animals, which are of importance in themselves. They were undertaken in 1951 at the University of Chicago with newly hatched chicks. Paradoxically, chicks can "tell" more directly what they see than higher animals can. Soon after they break out of the shell they go about the business of finding things to peck at and eat. Their purposeful, visually dominated behavior is ideally suited for observation and experiment.

We presented the chicks with a number of small objects of different shapes.



"LOOKING CHAMBER" was used to test the visual interests of chimpanzee and human infants. Here a human infant lies on a crib in the chamber, looking at objects hung from the ceiling. The observer, watching through a peephole, records the attention given each object.

Each object was enclosed in a clear plastic container to eliminate the possible influence of touch, smell or taste, but this did not prevent the chicks from pecking at preferred forms for hours on end. An electrical circuit attached to each container recorded the number of pecks at it.

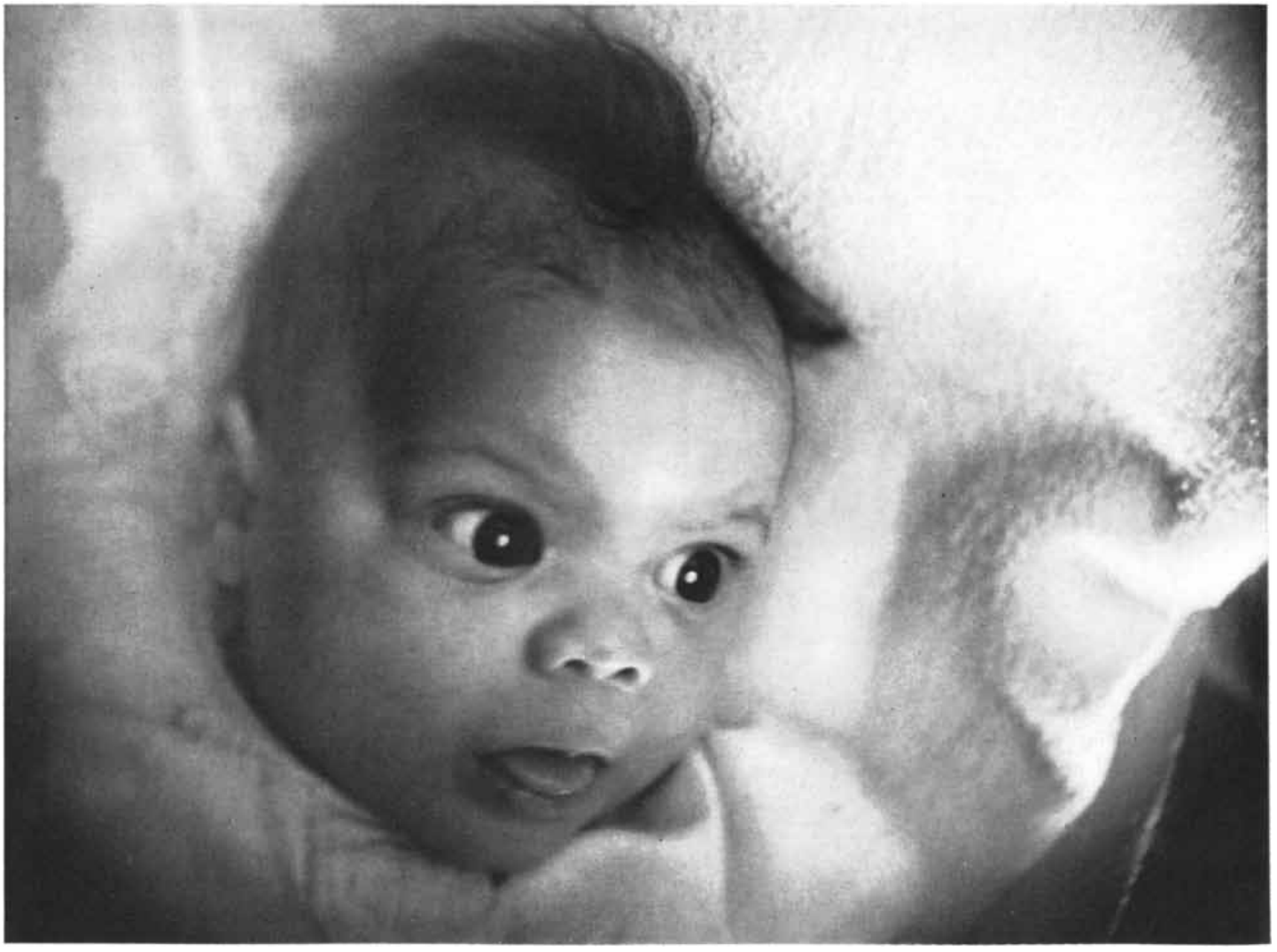
More than 1,000 chicks were tested on some 100 objects. To exclude any opportunity for learning, the chicks were hatched in darkness and tested on their first exposure to light, before they had had any experience with real food. Presented with eight objects of graded angularity, from a sphere to a pyramid, the subjects pecked 10 times oftener at the sphere than they did at the pyramid. Among the flat forms, circles were preferred to triangles regardless of comparative size; among circles, those of ⅛-inch diameter drew the most attention. In a test of the effect of three-dimensionality the chicks consistently selected a sphere over a flat disk.

The results provided conclusive evidence that the chick has an innate ability to perceive shape, three-dimensionality and size. Furthermore, the chick uses the ability in a "meaningful" way by selecting, without learning, those objects most likely to be edible: round, three-dimensional shapes about the size of grain or seeds. Other birds exhibit similar visual capacity. For example, N. Tinbergen of the University of Oxford found selective pecking by newly hatched herring gulls. These chicks prefer shapes resembling that of the bill of the parent bird, from which they are fed [see "The Evolution of Behavior in Gulls," by N. Tinbergen; SCIENTIFIC AMERICAN, December, 1960].

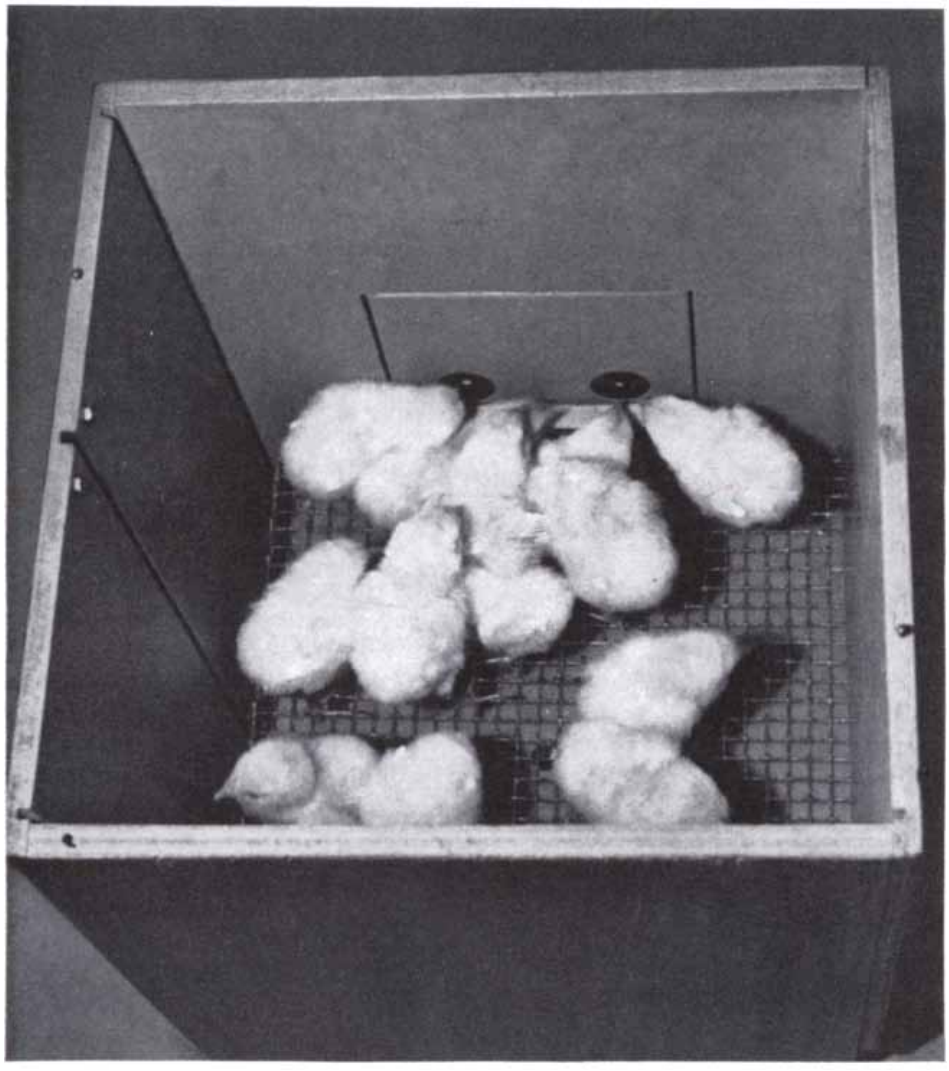
Of course, what holds true for birds does not necessarily apply to human beings. The inherent capacity for form perception that has developed in birds may have been lost somewhere along the evolutionary branch leading to the primates, unlikely as it seems. Or, more plausibly, the primate infant may require a period of postnatal development to reach the level of function of the comparatively precocious chick.

When we set out to determine the visual abilities of helpless infants, the only indicator we could find was the activity of the eyes themselves. If an infant consistently turns its gaze toward some forms more often than toward others, it must be able to perceive form. Working on this premise, we developed a visual-interest test, using as our first subjects infant chimpanzees at the Yerkes Laboratories of Primate Biology in Orange Park, Fla.

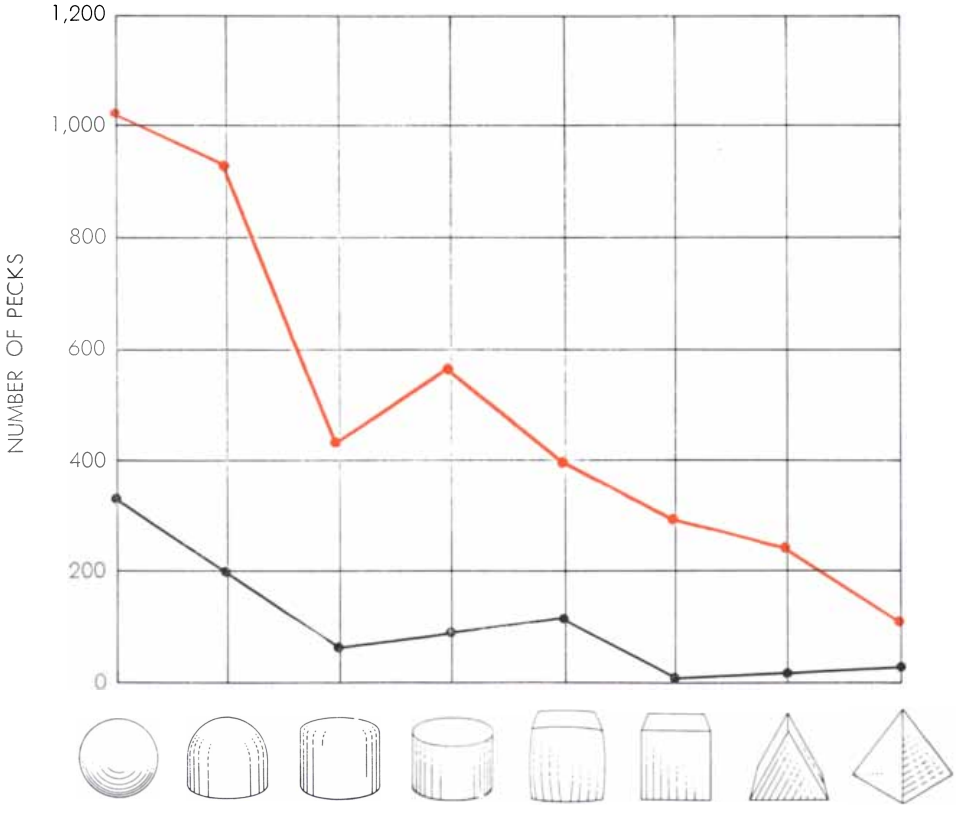
A young chimpanzee lay on its back in a comfortable crib inside a "looking chamber" of uniform color and illumination. We attached to the ceiling of the chamber pairs of test objects, slightly separated from each other. They were exposed to view, alternately at right and left, in a series of short periods. Through a peephole in the ceiling we could see tiny images of the objects mirrored in the subjects' eyes. When the image of



VISUAL INTEREST in various shapes was determined by noting reflections in the subject's eyes. In this case, with the reflection over the center of the infant's eye, the reflected object is being fixated, or looked at directly. (Because this young infant's binocular coordination is poor, only the right eye is fixating the object.) The length of each such fixation was recorded electrically.



PATTERN PREFERENCE of newly hatched chicks is studied by recording their pecks at each of a number of different shapes in plastic containers set into the wall of a test box.



PREFERENCE FOR ROUNDNESS is shown by this record of total pecks by 112 chicks at the eight test objects shown across the bottom of the chart. The results are for the chicks' first 10 minutes (*black line*) and first 40 minutes (*colored line*) of visual experience.

one of the objects was at the center of the eye, over the pupil, we knew the chimpanzee was looking directly at it. The experimenter recorded on an electric timer the amount of attention given each target. The results were then analyzed to determine their statistical significance. Our first subject was a five-month-old chimpanzee. Later we followed a chimpanzee from birth, keeping it in darkness except during the tests. In both cases we found a definite preference for certain objects, indicating an inborn ability to distinguish among them.

Turning to human infants, we made no major change in our procedure except that we did not tamper with their everyday environment. The experiments did not disturb the infants but they did demand great patience of the investigators. Human infants are more rapidly bored than chimpanzees and they tend to go to sleep.

In the first experiment we tested 30 infants, aged one to 15 weeks, at weekly intervals. Four pairs of test patterns were presented in random sequence. In decreasing order of complexity they were: horizontal stripes and a bull's-eye design, a checkerboard and two sizes of plain square, a cross and a circle, and two identical triangles. The total time spent looking at the various pairs differed sharply, the more complex pairs drawing the greater attention. Moreover, the relative attractiveness of the two members of a pair depended on the presence of a pattern difference. There were strong preferences between stripes and bull's-eye and between checkerboard and square. Neither the cross and circle nor the two triangles aroused a significant differential interest. The differential response to pattern was shown at all ages tested, indicating that it was not the result of a learning process. The direction of preference between stripes and bull's-eye, on the other hand, changed at two months of age, due either to learning or to maturation.

Later we learned that a Swiss pediatrician, F. Stirnimann, had obtained similar results with still younger infants. He held cards up to the eyes of infants one to 14 days old and found that patterned cards were of more interest than those with plain colors.

Clearly some degree of form perception is innate. This, however, does not dispose of the role of physiological growth or of learning in the further development of visual behavior. Accordingly we turned our attention to the influence of these factors.

By demonstrating the existence of form perception in very young infants we had already disproved the widely held notion that they are anatomically incapable of seeing anything but blobs of light and dark. Nevertheless, it seems to be true that the eye, the visual nerve-pathways and the visual part of the brain are poorly developed at birth. If this is so, then the acuteness of vision—the ability to distinguish detail in patterns—should increase as the infant matures.

To measure the change in visual acuity we presented infants in the looking chamber with a series of patterns composed of black and white stripes, each pattern paired with a gray square of equal brightness. The width of the stripes was decreased in graded steps from one pattern to the next. Since we already knew that infants tend to look longer and more frequently at a patterned object than at a plain one, the width of the stripes of the finest pattern that was preferred to gray would provide an index to visual acuity. In this modified version the visual-interest test again solved the difficulties involved in getting infants to reveal what they see.

The width of the finest stripes that could be distinguished turned out to decrease steadily with increasing age during the first half-year of life. By six months babies could see stripes 1/64 inch wide at a distance of 10 inches—a visual angle of five minutes of arc, or 1/12 degree. (The adult standard is one minute of arc.) Even when still less than a month old, infants were able to perceive ⅛-inch stripes at 10 inches, corresponding to a visual angle of a little less than one degree. This is poor performance compared to that of an adult, but it is a far cry from a complete lack of ability to perceive pattern.

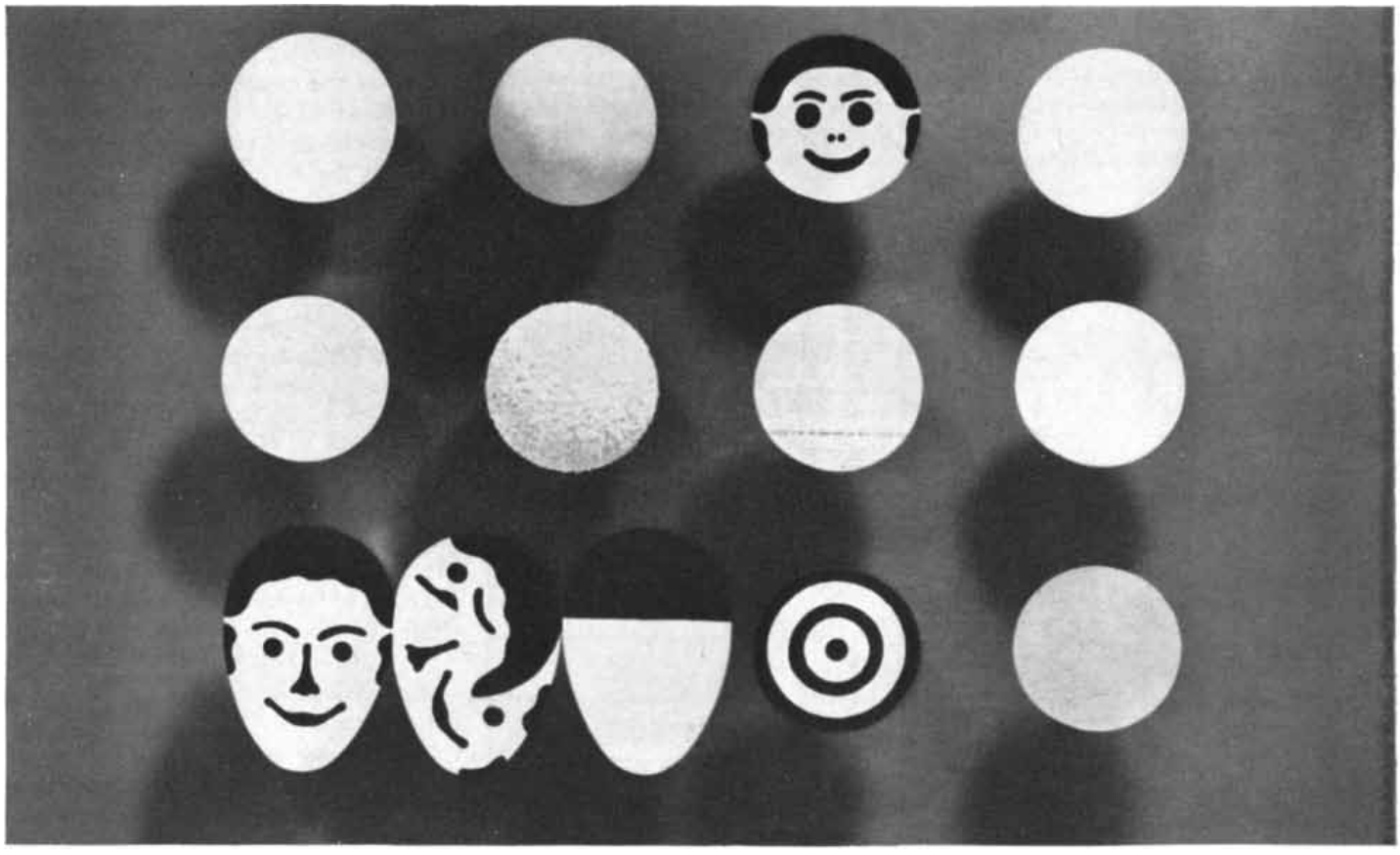
The effects of maturation on visual acuity are relatively clear and not too hard to measure. The problem of learning is more subtle. Other investigators have shown that depriving animals of patterned visual stimuli for a period after birth impairs their later visual performance, especially in form perception [see "Arrested Vision," by Austin H. Riesen; SCIENTIFIC AMERICAN, July, 1950]. Learned behavior is particularly vulnerable, but even innate responses are affected. For example, chicks kept in darkness for several weeks after hatching lose the ability to peck at food.

Research is now under way at Western Reserve University on this perplexing problem. We have raised monkeys in darkness for periods varying from one to 11 weeks. In general, the longer the period of deprivation, the poorer the performance when the animals were finally exposed to light and the more time they required to achieve normal responses. When first brought into the light, the older infant monkeys bumped into things, fell off tables, could not locate objects visually—for all practical purposes they were blind. It sometimes took weeks for them to "learn to see."

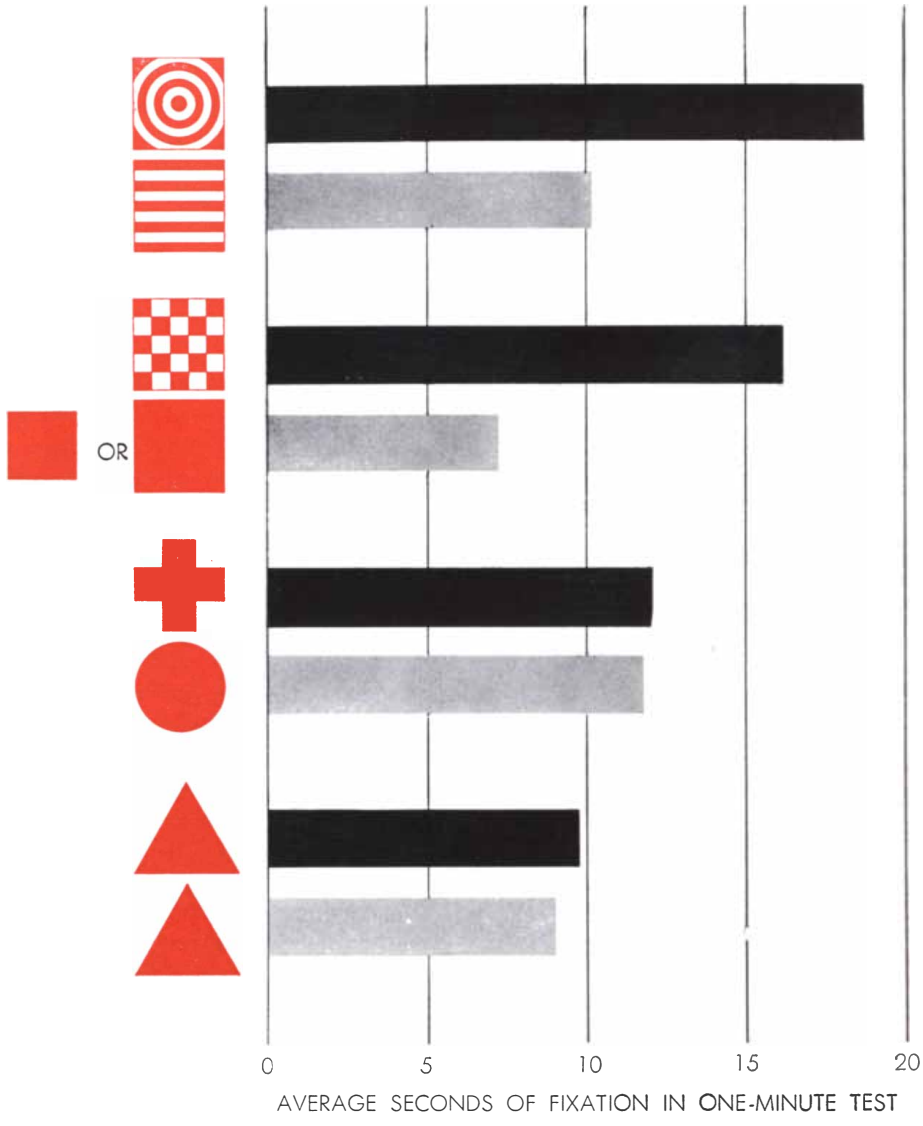
Monkeys kept a shorter time in the dark usually showed good spatial orientation in a few hours or days. Moreover, they showed normal interest in patterned objects, whereas the animals deprived of light for longer periods seemed more interested in color, brightness and size.

These results cannot be explained by innate capacity, maturation or learning alone. If form perception were wholly innate, it would be evident without experience at any age, and visual deprivation would have no effect. If maturation were the controlling factor, younger infant animals would be inferior rather than superior to older ones with or without visual experience. If form perception were entirely learned, the same period of experience would be required regardless of age and length of deprivation.

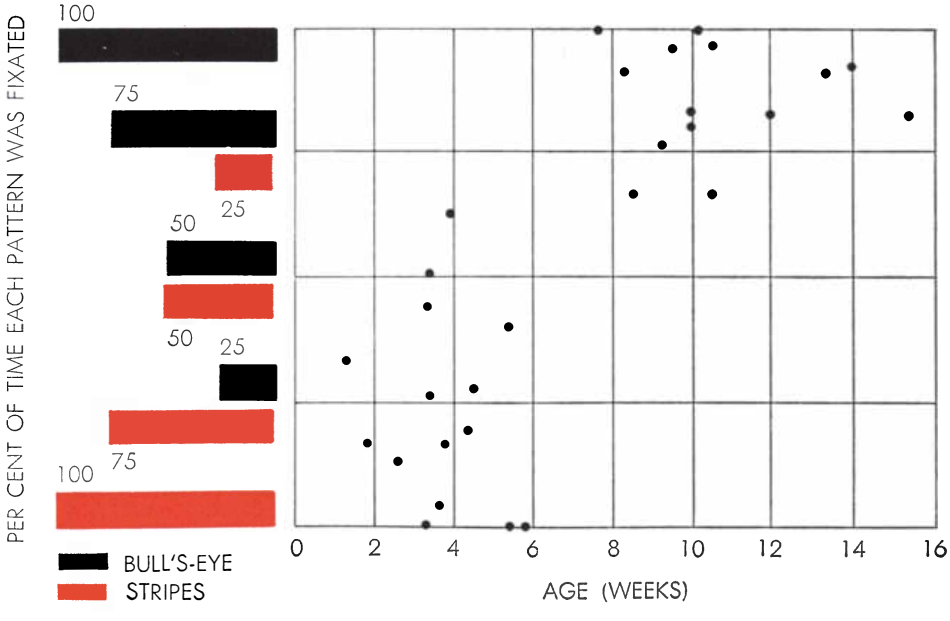
Instead there appears to be a complex interplay of innate ability, maturation



TEST OBJECTS included smooth and textured disks and spheres (*upper left*) to check interest in solidity. Attention to faces was tested with three patterns at lower left. The six round patterns at the right included (*top to bottom, left to right*) a face, a piece of printed matter, a bull's-eye, yellow, white and red disks. Round objects are six inches in diameter; "faces," nine inches long.



INTEREST IN FORM was proved by infants' reactions to various pairs of patterns (*left*) presented together. (The small and large plain squares were used alternately.) The more complex pairs received the most attention, and within each of these pairs differential interest was based on pattern differences. These results are for 22 infants in 10 weekly tests.



REVERSAL OF INTEREST from the striped pattern to the bull's-eye was apparent at two months of age. Each dot is for a single infant's first test session. It shows the time spent looking at the bull's-eye and at the stripes as a per cent of the time spent looking at both.

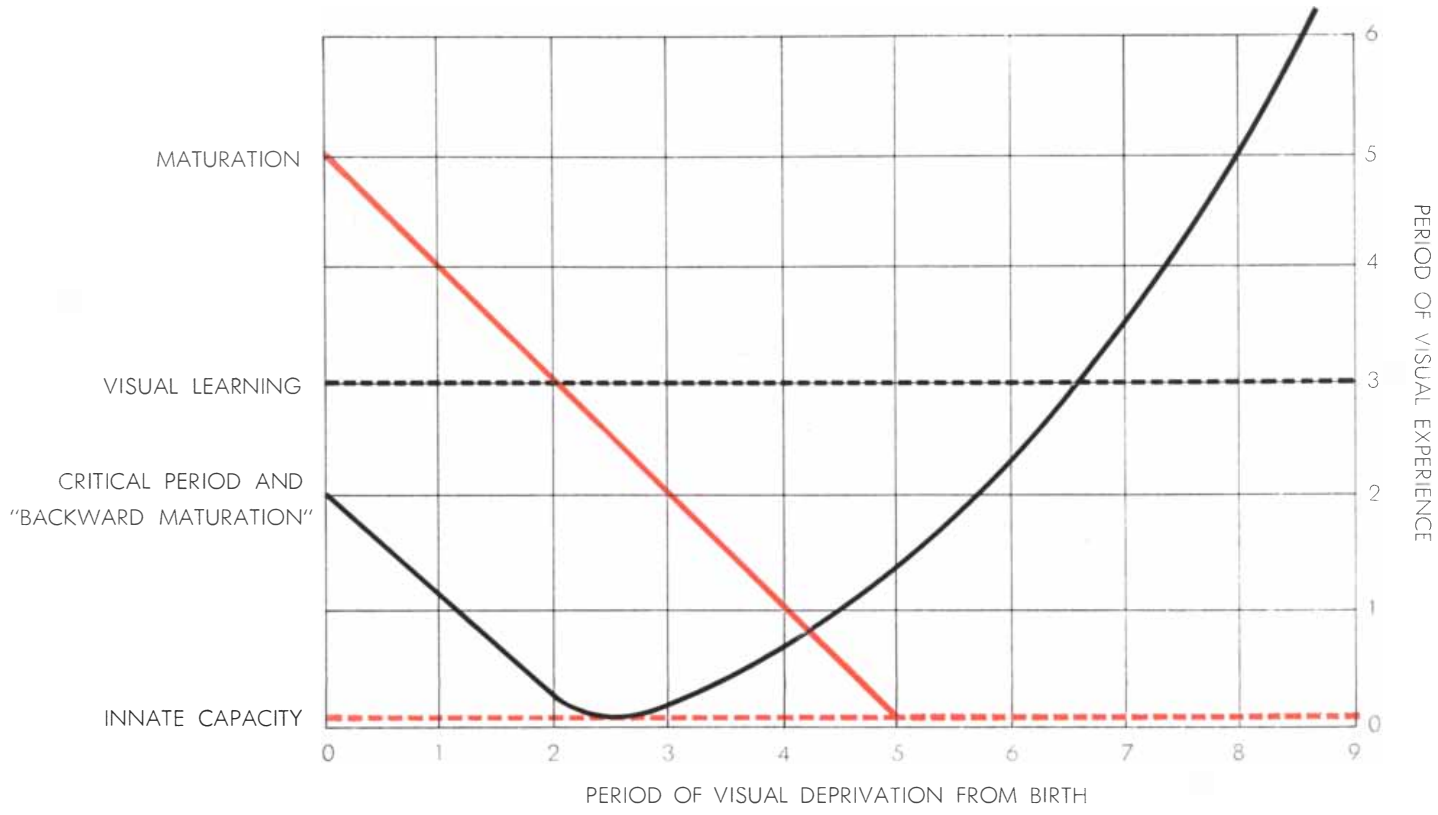
and learning in the molding of visual behavior, operating in this manner: there is a critical age for the development of a given visual response when the visual, mental and motor capacities are ready to be used and under normal circumstances will be used together. At that time the animal will either show the response without experience or will learn it readily. If the response is not "imprinted" at the critical age for want of visual stimulus, development proceeds abnormally, without the visual component. Presented with the stimulus later on, the animal learns to respond, if it responds at all, only with extensive experience and training. This explanation, if verified by further studies, would help to reconcile the conflicting claims of the nativist and the empiricist on the origin of visual perception.

To return to human infants, the work described so far does not answer the second question posed earlier in this article: whether or not the infant's innate capacity for form perception introduces a measure of order and meaning into what would otherwise be a chaotic jumble of sensations. An active selection process is necessary to sort out these sensations and make use of them in behavior. In the case of chicks such a process is apparent in the selection of forms likely to be edible.

In the world of the infant, people have an importance that is perhaps comparable to the importance of grain in the chick's world. Facial pattern is the most distinctive aspect of a person, the most reliable for distinguishing a human being from other objects and for identifying him. So a facelike pattern might be expected to bring out selective perception in an infant if anything could.

We tested infants with three flat objects the size and shape of a head. On one we painted a stylized face in black on a pink background, on the second we rearranged the features in a scrambled pattern, and on the third we painted a solid patch of black at one end with an area equal to that covered by all the features. We made the features large enough to be perceived by the youngest baby, so acuity of vision was not a factor. The three objects, paired in all possible combinations, were shown to 49 infants from four days to six months old.

The results were about the same for all age levels: the infants looked mostly at the "real" face, somewhat less often at the scrambled face, and largely ignored the control pattern. The degree of preference for the "real" face to the other one was not large, but it was



HYPOTHETICAL RESULTS that might be expected if any one developmental factor operated alone are plotted. The horizontal axis shows the period of rearing without visual experience; the vertical axis, the time subsequently required in the light until a given response is shown. Units of time are arbitrary. If innate capacity alone were effective, the response would always come without any experience (*broken colored line*). If maturation were necessary, the response would not be shown before a certain age, in this case five units, regardless of deprivation (*solid colored line*). If learning alone were operative, the required amount of experience would be constant (*broken black line*). Actually tests with chicks and monkey infants suggest the result shown by the solid black curve: after a short period of maturation, a "critical period" is reached when innate capacity can be manifested; more deprivation brings on "backward maturation," in which more and more experience is required before a response is shown.

consistent among individual infants, especially the younger ones. The experiment suggested that there is an unlearned, primitive meaning in the form perception of infants as well as of chicks.

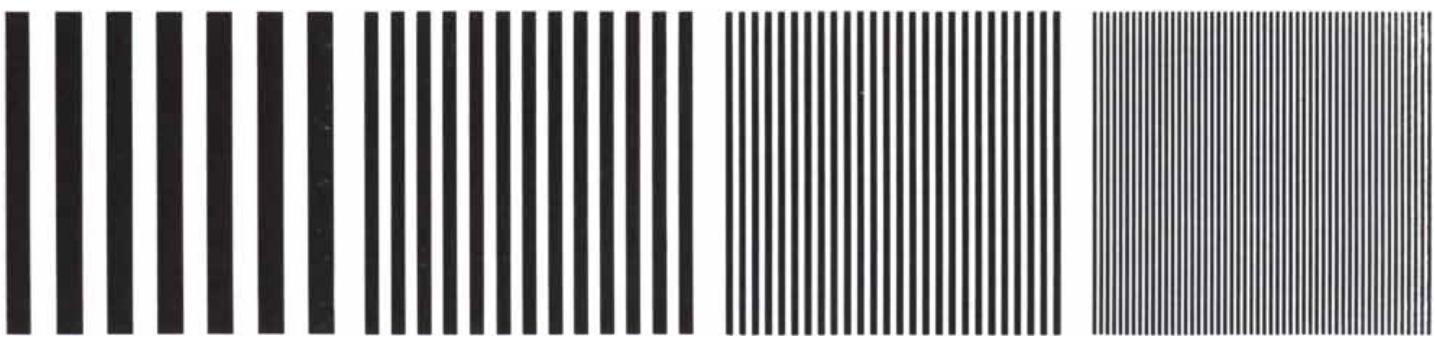
Further support for the idea was obtained when we offered our infant subjects a choice between a solid sphere and a flat circle of the same diameter. When the texture and shading clearly differentiated the sphere from the circle —in other words, when there was a noticeable difference in pattern—the solid form was the more interesting to infants from one to six months old. This unlearned selection of a pattern associated with a solid object gives the infant a basis for perceiving depth.

The last experiment to be considered is a dramatic demonstration of the interest in pattern in comparison to color and brightness. This time there were six test objects: flat disks six inches in diameter. Three were patterned—a face, a bull's-eye and a patch of printed matter. Three were plain—red, fluorescent yellow and white. We presented them, against a blue background, one at a time in varied sequence and timed the length of the first glance at each.

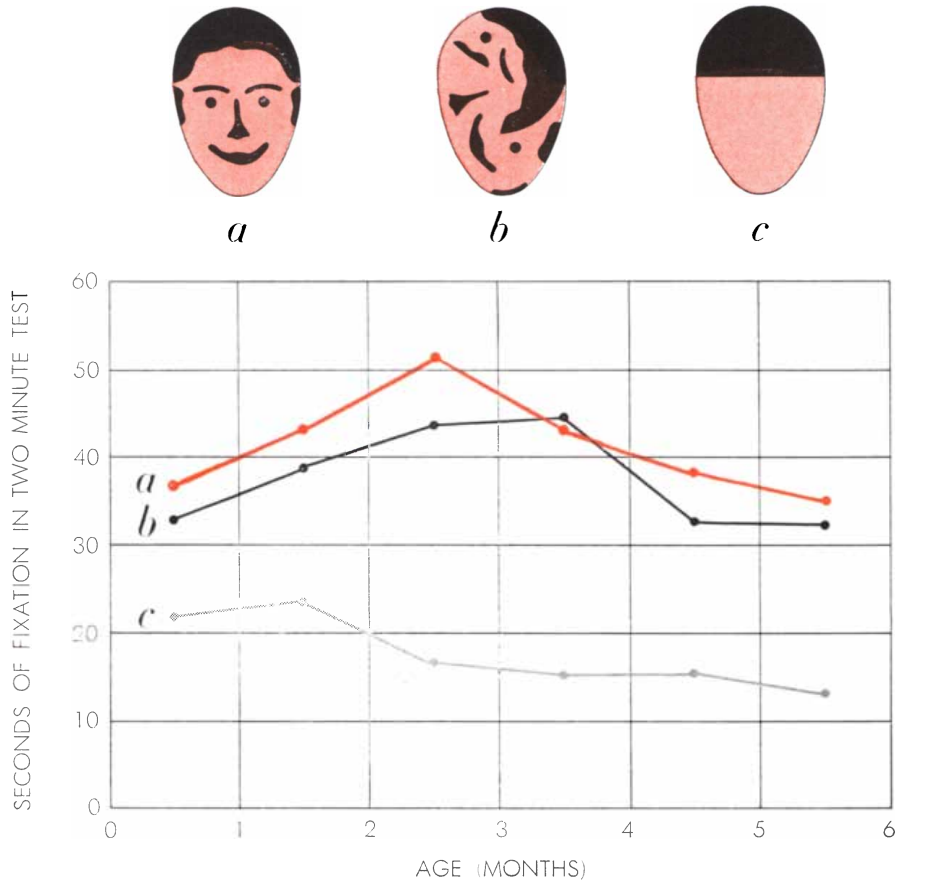
The face pattern was overwhelmingly the most interesting, followed by the printing and the bull's-eye. The three brightly colored plain circles trailed far behind and received no first choices. There was no indication that the interest in pattern was secondary or acquired.

What makes pattern so intrinsically interesting to young infants? It seems to me that the answer must lie in the uses of vision for the child and adult.

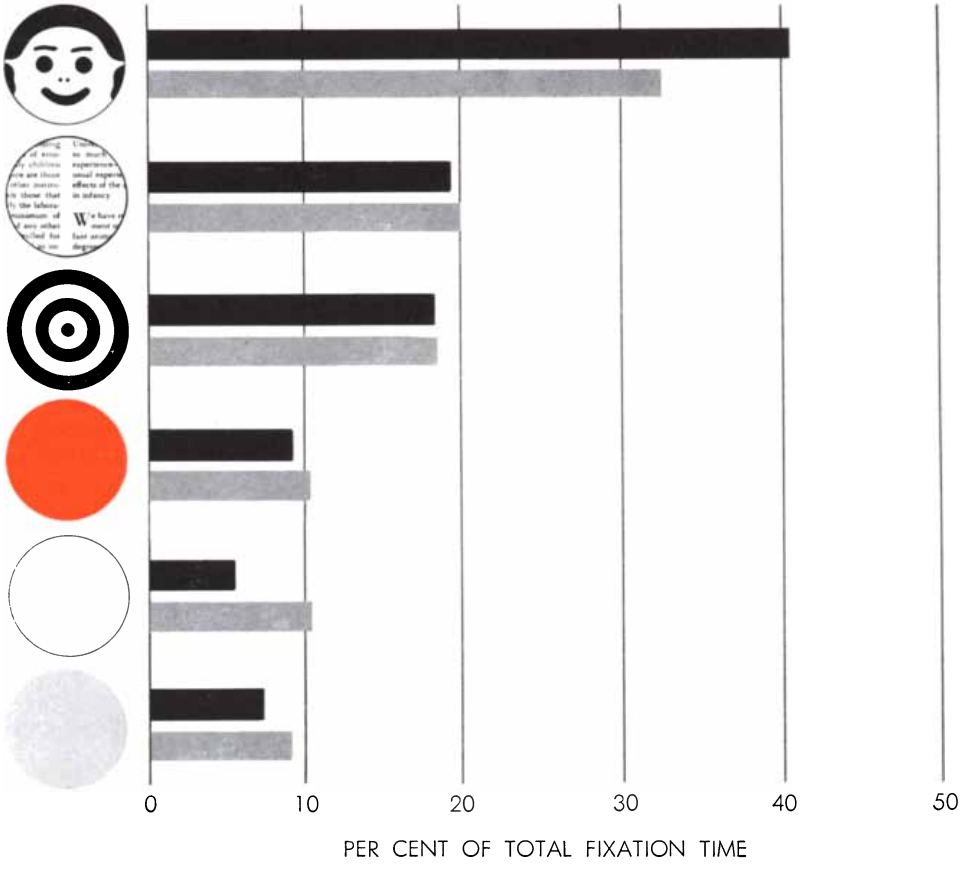
One of these functions is the recognition of objects under various conditions. The color and brightness of objects



VISUAL ACUITY was tested with these stripes: 1/8, 1/16, 1/32 and 1/64 inch wide. Each pattern was displayed with a gray square of equal brightness 10 inches from the infants' eyes. The finest pattern consistently preferred to gray showed how narrow a stripe the infant could perceive. Infants under a month old could see the 1/8-inch stripes and the six-month-olds could see 1/64-inch stripes.



ADAPTIVE SIGNIFICANCE of form perception was indicated by the preference that infants showed for a "real" face (*a*) over a scrambled face (*b*), and for both over a control (*c*). The results charted here show the average time scores for infants at various ages when presented with the three face-shaped objects paired in all the possible combinations.



IMPORTANCE OF PATTERN rather than color or brightness was illustrated by the response of infants to a face, a piece of printed matter, a bull's-eye and plain red, white and yellow disks. Even the youngest infants preferred patterns. Black bars show the results for infants from two to three months old; gray bars, for infants more than three months old.

change with illumination; apparent size changes with distance; outline changes with point of view; binocular depth perception is helpful only at short range. But the pattern of an object—the texture, the arrangement of details, the complexity of contours—can be relied on for identification under diverse conditions.

A good example is social perception. As noted earlier, the general configuration of a face identifies a human being to an infant. At a later age a specific person is recognized primarily by more precise perception of facial pattern. Still later, subtle details of facial expression tell the child whether a person is happy or sad, pleased or displeased, friendly or unfriendly.

Another important function of vision is to provide orientation in space. For this purpose James J. Gibson of Cornell University has shown clearly the importance of a specific type of pattern: surface texture. For example, texture indicates a solid surface, whereas untextured light usually indicates air or water. Gradual changes in texture show whether a surface is vertical or horizontal or oblique, flat or curved or angular—and therefore indicate whether it can be walked on, walked around or climbed over. Discontinuities in texture mark the edges of objects and abrupt changes in surfaces.

From these few examples there can be no question of the importance of visual pattern in everyday life. It is therefore reasonable to suppose that the early interest of infants in form and pattern in general, as well as in particular kinds of pattern, play an important role in the development of behavior by focusing attention on stimuli that will later have adaptive significance.

Further research is necessary to pin down this and other implications more concretely, but the results to date do require the rejection of the view that the newborn infant or animal must start from scratch to learn to see and to organize patterned stimulation. Lowly chicks as well as lofty primates perceive and respond to form without experience if given the opportunity at the appropriate stage of development. Innate knowledge of the environment is demonstrated by the preference of newly hatched chicks for forms likely to be edible and by the interest of young infants in kinds of form that will later aid in object recognition, social responsiveness and spatial orientation. This primitive knowledge provides a foundation for the vast accumulation of knowledge through experience.

Kodak reports on:

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Small print

This little file holds some 10,000 unabridged pages of technical reports of the French Atomic Energy Commission. The lady who lives in the house across the road may find this astonishing. Your boss may be astonished. Even you may be astonished. But to the reasonably alert librarian the micro-opaque card idea is old hat. Anything we can tell you about it your librarian can tell you better.* We merely draw attention to the following accretions to the available micro-opaque literature:

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  Even reduced 20× as they are in micro-opaque form, the complete set published to date would fill 250 boxes like the one above. The indexing mechanism for this incredible mass of information is *Nuclear Science Abstracts*, a periodical sold by the Superintendent of Documents, Washington 25, D.C.

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  Contains the roots of many a chemical concept since proliferated beyond the scope of a single mind. On some 60 3″ x 5″ cards sold by the American Chemical Society (1155 16th St. N. W., Washington 6, D. C.).

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*The reason *we* try to tell you is that we want to sell the raw photographic materials on which microprint cards are printed. We also want to sell microfilm. The librarian can tell you about *that*, too. A new, conventional-sized reference, "Guide to Microforms in Print" ($4, Microcard Editions, Inc.) summarizes everything available.

Our connections with the heavens

We have three connections with the heavens:

1. Years ago we threw our weight on the side of the angels by a Good Deed. We went to work for the astronomers, a group noted for the slimness of their budgets. We made them the special photographic plates needed for all the projects that have seemed pressing to them, like measuring the angular momentum of galaxies. This work has netted us a medal or two but no wealth. That's all right. Questions about these plates are answered by Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y. Professional astronomers know that address very well.

2. Amateur astronomers are among the most numerous of scientific-type hobbyists. Many thousands of persons who have to deal all day with tiresome human affairs like to reach out toward the ultimate verities through a backyard telescope. But, being human themselves, they hanker for tangible trophies of the sport. These photography can provide. To guide, we provide a free booklet, "Astrophotography with Your Camera," from the same address the professionals know. The amateur astronomers far outnumber the professionals and buy standard Kodak films at popular prices.

3. A protostar evolving from clouds of dust a million light-years away and an ICBM a thousand miles from the U. S. border have a certain resemblance in the infrared. At Ohio State University we have some astronomers working for us on an astronomical job which lack of suitable equipment has long delayed—preparation of an atlas of infrared emitters on the celestial sphere to 13.5 microns. We made them the missing equipment. We need the atlas. We have our reasons. The equipment includes a drift-free homodyne amplifier which takes a signal from our liquid-helium-cooled copper-doped germanium detector on the 69-inch Perkins Observatory telescope. It can cramp down to a .0011 cycle/sec scanning bandwidth so that in 20 minutes it can distinguish the emission of a single star from intergalactic infrared noise. Those who have need and funds for such up-to-date infrared systems should get in touch with Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y.

Latest advice on instrumentation film

Background: A photographic material is said to be "fast" if it requires little energy to deliver an image. The term comes from an olden time when portraitists were reducing the duration that the subject had to "hold it" from 5 minutes to 1 minute to a few seconds and on down. Only professors and their brighter students had clear notions of what energy meant. When the photographers did acquire an intuitive grasp of the concept, the physicists kept a step ahead of them by pointing out that the time rate of energy delivery to the emulsion was also important. At this, they were probably accused of pedantry, but unjustly.

The common man came to equate speed with merit in photography. The wise men were sad. "No," they countered patiently, "the faster the emulsion the larger the grains must always be. There is no escape." But there was.

Kodak Royal-X Pan Recording Film, given the proper low-contrast development, is the fastest material we have. This holds true both for hand-camera exposure times and for the very short exposure times of high-speed instrumentation. Royal-X Pan is very good to have when you need every bit of sensitivity you can get, but it is grainier than other Kodak films. Furthermore, its speed advantage over other good Kodak recording films shrinks and disappears altogether for high contrast and very short exposure times.

Very recent advances in emulsion technology have produced the new *Kodak Double-X Panchromatic Negative Film*. For very short exposure times and 8 minutes in Kodak Developer D-19, it is just about as fast as Royal-X Pan Recording Film, but its graininess is much less—on a par with the fine-grain and sharpness formerly attainable only in comparatively slow films.

If you want high contrast for very short exposure to green light, *Kodak Linagraph Ortho Film* is your ticket.

All of which tells you nothing of the physical forms of these and other Kodak films for instrumentation, including color film. If you are aware of the omission, you are a person who should send for the capsule-summary sheet "F3-297" from Eastman Kodak Company, Photorecording Methods Division, Rochester 4, N.Y.

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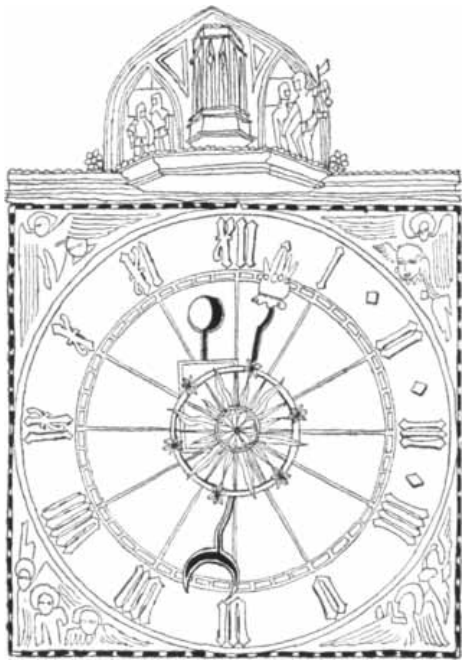

SCIENCE AND

Cosmonaut

On April 12, 1961, Yuri Alekseyevich Gagarin, a citizen of the U.S.S.R., achieved the distinction of being the first man to cross the border between the earth and interplanetary space. The rocket bearing the five-ton spaceship *Vostok* (meaning "East") was fired aloft at 9:07 a.m. Moscow time. The vehicle went into a satellite orbit, made one circuit of the earth at altitudes between 110 and 190 miles and landed at 10:55 a.m. While Gagarin was in orbit he radioed messages such as: "I am watching the earth. The visibility is good. I feel well and cheerful. The machine is functioning normally." When he had landed, he said: "Please report . . . that the landing was normal. I feel well, have no injuries or bruises." Flown by helicopter to a nearby town, he said: "The sky is very dark. The earth is bluish. Everything is seen very clearly."

The flight was the culmination of a series of Soviet rocket firings to launch large satellites and bring them safely back to earth. The first of the satellites to be successfully landed was sent aloft last May; the second, carrying two dogs, was brought down in August. A vehicle carrying two dogs was placed in orbit in December, but it burned up in the atmosphere. In March two vehicles, each carrying a dog, were launched and landed.

Third Scientist

With President Kennedy's appointment of Leland J. Haworth to the Atomic Energy Commission, the five-member commission now consists of three scientists and two laymen. This is the largest number of scientists ever to serve simultaneously on the AEC in the 15 years of its existence. Haworth, who is 56 years old, is a nuclear physicist and an authority on the design of high-energy particle accelerators. From 1948 until his present appointment Haworth was director of the Brookhaven National Laboratory.

The other four commissioners are: Glenn T. Seaborg, chairman of the AEC and a Nobel prize winner in chemistry; Robert E. Wilson, an industrial chemist and former chairman of the board of the American Oil Company; John S. Graham and Loren K. Olson, both of whom are lawyers.

Three Billion People

The world "population explosion" is even more explosive than has been suspected, a United Nations report indicated in March. Forecasting that the world's population would pass three billion this year, the UN Department of Economic and Social Affairs suggested that current population projections would have to be revised upward on the basis of recent censuses in a number of countries.

India's latest census, conducted in February, illustrates the trend in the populous nations of southeast Asia. The provisional figures for India show a population of 438 million, eight million more than the previous estimate. This represents a 21.5 per cent rise since 1951, when the last census was taken, compared with a 14.5 per cent increase in the 10 years from 1941 to 1951.

An even sharper rise in population was reported from Pakistan, where a new census earlier this year showed a population of 93,812,000. This is an increase of 23.7 per cent in 10 years. Recent census figures from Thailand and the Philippines also show population increases sharper than expected.

World population figures are, of course, estimates, based on data of uneven quality from the various nations. The UN put the world's population at 2,495,000,000 in 1950 and 2,907,000,000 in mid-1959. The annual rate of increase has been running at about 1.7

per cent but now seems to be approaching 2 per cent; hence the three billion estimate for 1961.

India furnishes statistics to illustrate both the basic cause and the economic effect of the population explosion in the underdeveloped nations. The cause is a lowered death rate. While India's birth rate has held fairly steady at about 40 per 1,000 people per year, the death rate dropped from 25.9 per 1,000 between 1951 and 1956 to 21.6 between 1956 and 1961, and is projected at 18.2 per 1,000 for the period of the new five-year plan of 1961 to 1966. The economic effect is to make it much more difficult to raise the standard of living: a substantial rise of 40 per cent in the national income since 1951 was cut by population growth to an increase of only 19 per cent in per capita income.

After the I.G.Y., the I.Q.S.Y.

During 1964 and 1965, when the number of spots on the sun will be at a minimum, scientists of many nations will collaborate on an 18-month study of the effects of a "quiet" sun on the earth and its atmosphere. The program will be known as the International Year of the Quiet Sun, or I.Q.S.Y. It will complement studies conducted during the International Geophysical Year of 1957 and 1958, when solar activity was at a maximum.

The I.Q.S.Y. program has been endorsed by the International Committee on Geophysics, successor to the international scientific committee that directed the I.G.Y. U. S. participation is being planned by a number of panels under the Geophysics Research Board of the National Academy of Sciences. The program will not be so extensive as that of the I.G.Y. It will concentrate mainly on a world-wide survey of the earth's magnetic field and on the investigation of phenomena ranging from the Van Allen radiation belts to the propagation of radio waves.

The decline in solar activity may result in a crisis in radio communications, predict two radio specialists of the United States Information Agency, George Jacobs and Edgar T. Martin. During the recent period of high solar activity, broadcasting stations in many parts of

the world were assigned frequencies at the upper end of the range of frequencies reflected by ionized layers of the earth's atmosphere. These frequencies are usable during the years of high solar activity, when ionization of the earth's atmosphere is also high Many of the higher frequencies are poorly reflected, however, by the weakly ionized atmosphere of low-solar-activity years. Hence these frequencies are proving increasingly undependable for broadcasting and long-distance communications. Unhappily the difficulties come at a time of rapidly rising demand for broadcast frequencies, particularly from Africa and Asia. Jacobs and Martin suggest, among other things, speedier development of artificial-satellite communication systems as a means of filling the gap.

Practice Moholes

As a step toward drilling through the crust of the earth into the mantle, four holes have been bored into the ocean floor in deep water off the Pacific coast. Early in March a drilling rig mounted on the barge *Cuss I* penetrated 310 feet into sediments in 3,000 feet of water 18 miles off San Diego. Later the barge was towed to a site near Guadalupe Island, off the coast of Lower California, and the drillers undertook to bore a 1,000-foot hole in 12,000 feet of water. At a depth of 560 feet the bit unexpectedly encountered a layer of volcanic basalt. After the drillers had penetrated 44 feet into the basalt, the bit was withdrawn and two other holes were bored to the same layer.

Above the basalt the drillers had made "cores" of sediment recording 20 million years of geologic history. Measurements made in the last hole indicated that the temperature of the earth's crust in the region is unusually high. Such a high temperature is usually associated with volcanic activity, and it suggests that the region is not typical of the ocean floor and is unsuited for a hole to the mantle.

The drilling tests were carried out under the direction of the National Academy of Sciences–National Research Council AMSOC-Mohole Committee, originators of the scheme for drilling through the Mohorovicic discontinuity: the boundary between the crust and the mantle. The "Mohole" will be drilled in the deep ocean because the crust there is only two to three miles thick, whereas on the continents the crust is some 20 miles thick [see "The Mohole," by Willard Bascom; SCIENTIFIC AMERICAN, April, 1959]. The Mohole will not be drilled by *Cuss I*, a former Navy barge originally converted to a rig for drilling in waters only a few hundred feet deep; a much larger rig will be needed to carry the materials required for the Mohole.

In the *Cuss I* tests a conventional oil-well-drilling system was used: a rotating pipe tipped with a diamond bit. A novel system was required, however, to keep the barge in position over the hole, since the water was too deep for conventional anchoring. At each of the barge's four corners was a special propulsion engine; a single master control enabled a steersman to vary the output of the engines in response to sonar signals from six buoys anchored 200 feet down in a ring around the barge. The arrangement worked well enough to keep the barge satisfactorily in position in spite of winds that at times reached a velocity of 25 miles an hour.

Two Neutrinos or One?

The neutrino—the elusive fundamental particle that has no charge and no mass and travels with the speed of light—is engaging the attention of experimental physicists at Brookhaven National Laboratory and at the European Organization for Nuclear Research (C.E.R.N.) in Geneva. Workers at the two laboratories are preparing experiments using neutrinos more energetic than any available heretofore. The neutrinos will be generated by the particle accelerators recently completed at Brookhaven and at C.E.R.N., each rated at about 30 billion electron volts (bev).

The experiments are designed to answer the question: Is the neutrino one particle, as now believed, or two different particles with nearly the same properties? There are theoretical reasons for believing that the neutrinos produced by decay processes in accompaniment with electrons may differ in some way from the neutrinos produced along with mu mesons, or muons. As an example of the first process, a neutron (if it is not bound in a nucleus) decays into a proton, an electron and an antineutrino. As an example of the second, a negative pi meson decays into a negative muon and an antineutrino. Antineutrinos are the antiparticles of ordinary neutrinos; the distinction between the two is well established and not at issue. The deeper question is whether or not there is a difference between the antineutrinos produced in the two processes and hence a difference in neutrinos.

The powerful new machines at Brookhaven and C.E.R.N. offer an opportunity

CALIFORNIA INSTITUTE OF TECHNOLOGY

Space Science Resident Research Appointments

The Jet Propulsion Laboratory of the California Institute of Technology is accepting applications for resident research appointments in the space sciences. These appointments are open to U.S. citizens and foreign nationals. Security clearance is not required. Applicants must have training equivalent to that represented by a doctorate degree and must have demonstrated superior ability for creative research.

JPL has the responsibility of executing lunar, planetary, and interplanetary space exploration programs for the National Aeronautics and Space Administration, and is supporting research activities related to these programs.

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Applications will be accepted for positions in the following areas of research and development:

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Astronomy . . .
development of new astronomical instruments for use on space probes; cosmology; celestial mechanics.

Solar Physics . . .
solar-terrestrial relationships; measurements in the ultra-violet and x-ray regions of the spectrum; magnetohydrodynamics.

Geology, Geophysics and Geochemistry . . .
chemical and physical nature of lunar and planetary surface and subsurface material; study of lunar and planetary interiors.

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pressure, temperature, density, and composition of the atmosphere of the planets and the moon; the study of meteors and comets.

Exobiology . . .
nature of extraterrestrial life forms; techniques of sterilization and decontamination of space probes.

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for a test proposed by Bruno Pontecorvo of the U.S.S.R. and Melvin Schwartz of Brookhaven and Columbia University. If protons accelerated to some 30 bev strike other protons in a suitable target, they will produce very energetic pi mesons, which will promptly decay to produce very energetic antineutrinos. These antineutrinos, having an average energy of 1 bev, will be about a million times more reactive than the almost inert antineutrinos previously available for study. (An ordinary neutrino could travel through 50 light years of solid lead before interacting with another particle and being stopped.)

If a high-energy antineutrino reacts with a proton, it should yield a neutron plus either a positive muon or a positive electron. If antineutrinos are all of one kind, muons and electrons should be produced in roughly equal numbers. If, however, there are two kinds of antineutrinos, the experiment will yield only muons. In other words, the experiment may not generate the kind of antineutrinos needed to produce electrons. This would be a momentous finding, but it is one for which theorists are prepared.

As a by-product, the experiment may also provide evidence for or against the existence of a new particle that has been dubbed the "vector meson," or "intermediate boson." Some theorists suspect that such a particle may have what is called a "virtual" existence when a neutron decays into a proton, an electron and an antineutrino. It cannot "really" exist under the circumstances because there is not enough energy available to maintain its existence. In the Brookhaven and C.E.R.N. experiments, however, the antineutrinos will carry sufficient energy to produce the vector meson, if it is producible. If it appears at all, it will probably vanish again within 10^{-17} second.

If all goes well, C.E.R.N. may begin its antineutrino experiments this month. Brookhaven workers hope they will not be far behind.

Tolerated Transplants

A new means of suppressing the "host reaction" that ordinarily destroys tissue transplanted from one animal to another is reported by J. Vrubel of the Institute for Clinical and Experimental Surgery in Prague. In Vrubel's procedure a rabbit receives two grafts at the same time. One is a graft of skin tissue. The other is a graft of lymph-node tissue from a rabbit that has earlier received a skin graft from the "graftee" animal and has manufactured antibodies against the

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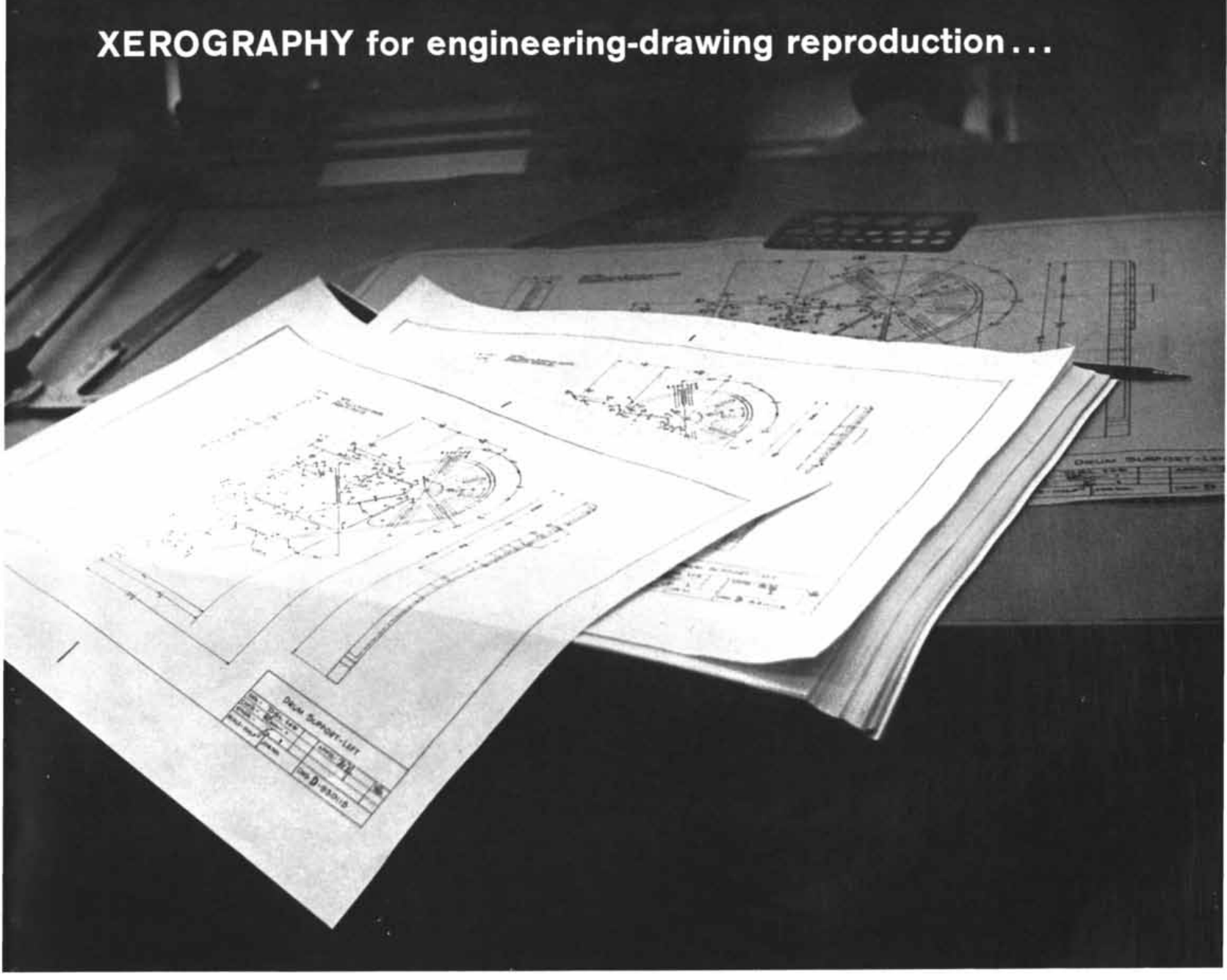

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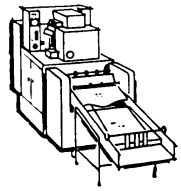

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graftee's tissue. The purpose of the lymph-node graft is to knock out the graftee's own lymph nodes in the region of the skin graft—nodes that would normally form antibodies against the skin graft.

Until now there have been two main procedures for carrying out experimental tissue grafts. One is based on "neonatal tolerance": if before birth or shortly afterward an animal is injected with cells from another animal of the same species, the first animal will thereafter accept grafts from the second. In the other procedure the graftee animal is given a dose of X rays that destroys its bone marrow and its capacity to manufacture antibodies of any kind; when the bone marrow is replaced by transfusion from another animal, the first animal will tolerate a graft from the second. Neither procedure has been wholly satisfactory. Cells and marrow of the donor animal sometimes attack the graftee, causing a lethal wasting illness known as homologous, or "runt," disease.

Vrubel, whose report appears in *Nature*, conducted his procedure with 15 rabbits. In 12 animals the graft—a patch of skin transplanted to the ear—survived for 54 to 86 days, as against 8 to 13 days for control grafts. In three other animals the grafts were still intact in whole or in part after six months, a year and two years respectively.

Seagoing National Laboratory

The National Science Foundation will operate its first research ship on more or less permanent station in Antarctic waters. The vessel, which will be open to qualified scientists in much the same way that institutions such as the Brookhaven and Oak Ridge national laboratories are, is a 3,000-ton converted Navy freighter named the *Eltanin*. A ship with a reinforced hull, last used for carrying supplies to radar stations in the Arctic, she should be ready to sail on her next mission by the end of the year.

The *Eltanin* will have accommodations for a scientific party of 38 and a crew of about 40. The National Science Foundation will operate the vessel by inviting proposals for work aboard her from universities, Government agencies and other interested institutions. When a program covering several months has been drawn up, a senior scientist from one of the participating institutions will be designated chief scientist for the period of the program. Scientists and crew will be rotated by air from the U. S. The ship itself will remain in the

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far south for two to three years at a time.

The foundation's unusual venture was born of the need for increased studies of Antarctic waters. In recent years most Antarctic work has been done on the ice. Only one U. S. oceanographic institution, Columbia University's Lamont Geological Observatory (whose schooner *Vema* is currently on her sixth campaign in Antarctic waters in six years), has had substantial experience in research in Antarctic seas. Lamont is among eight institutions co-operating in designing equipment for the *Eltanin*, which will be fitted out for research in meteorology, cosmic rays, radio propagation and geomagnetism as well as in oceanography, marine geophysics and marine biology.

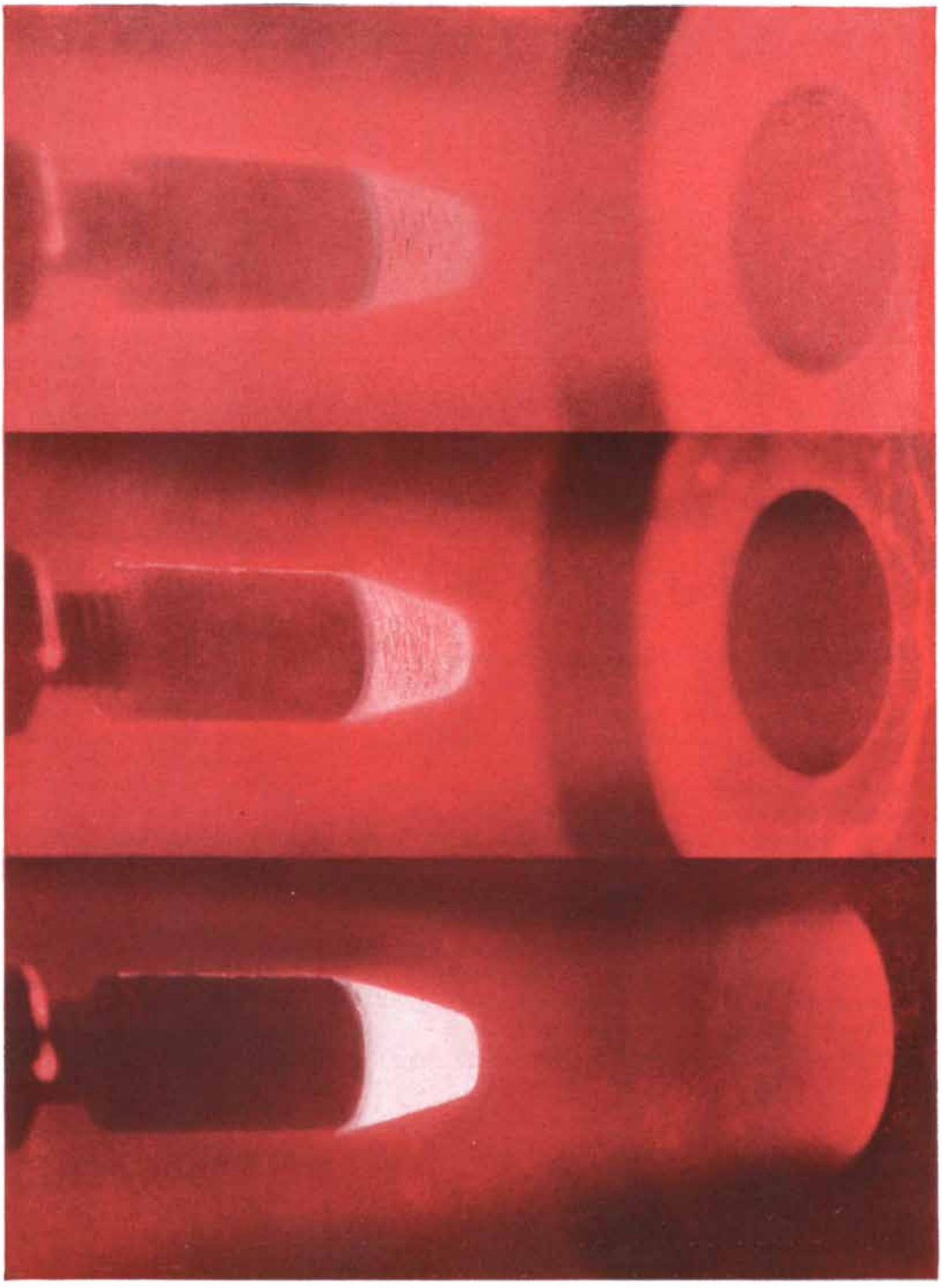
Echo from Venus

Clear, immediately recognizable radar echoes have been obtained from the planet Venus by the Goldstone Tracking Station, a satellite-monitoring installation in the Mojave Desert. The feat was performed by a crew under Robertson Stevens and Walton K. Victor on the night of March 10 and was repeated on the nights of March 14 and 15. The radar signal took six and a half minutes to make the trip to Venus, which was then about 35 million miles from the earth, and back again.

Radar contact with Venus was first made three years ago by a Massachusetts Institute of Technology radar research station. On that occasion, however, the echo was so obscured by radio noise that a year of analysis was required to distinguish it. With its ability to obtain unambiguous echoes, the Goldstone group hopes to be able to use radar to determine if Venus—the surface of which is completely obscured by clouds—turns on its axis. Changes in the frequency of the radar signal would also indicate the planet's speed of rotation.

The Ph.D.'s High School

Recent recipients of Ph.D. degrees—whether in science, education or the humanities—are much more likely to be graduates of a large high school than of a small one. A study of the high school records of more than 6,000 graduate students who received doctoral degrees in 1958 has shown that high schools with 800 or more in their graduating classes produced 22.18 graduates who subsequently earned Ph.D.'s for every 1,000 students graduated. Schools with 400 to 799 in a class produced future doctoral students at only half this rate. Schools with fewer than 100 students in



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a class yielded only 6.16 graduates who later obtained doctorates for every 1,000 awarded secondary school diplomas.

The study, carried out by Lindsey R. Harmon of the National Academy of Sciences—National Research Council Office of Scientific Personnel, also covered other aspects of the 1958 Ph.D.'s high school backgrounds. Schools in the New England and Middle Atlantic states still steer a larger proportion of their graduates toward advanced postcollege study than do schools elsewhere in the country. Moreover, mathematics and physical science Ph.D.'s are still coming from the top of the high school class, as determined by high school intelligence tests and class rank. Humanities and social science Ph.D.'s ranked next in high school class rank and intelligence test scores, with biological science and education Ph.D.'s last. But social science Ph.D.'s ranked behind biological science Ph.D.'s in high school science and mathematics.

Random Road to the Top

What separates the boss from the bossed? The frequent answer of the latter—luck—is given mathematical support in a recent paper in *Behavioral Science* by Karl W. Deutsch of Yale University and William G. Madow of the Stanford Research Institute. The paper, called "A Note on the Appearance of Wisdom in Large Bureaucratic Organizations," suggests that a man may sometimes be given credit for wisdom and promoted to high rank because he has been infallibly right when in fact he has only been infallibly lucky.

The authors note that if a group of 256 bureaucrats are evaluated on the basis of their success in making eight important decisions, one man, on the average, will emerge with a perfect record by chance alone. If it is assumed further that the probability of being right in each decision is not merely one-half but is somewhat higher, say two-thirds, then on the average 10 bureaucrats in 256 will score a perfect record on eight successive decisions. On the basis of these and other analyses the authors conclude that in large organizations in which advancement is heavily influenced by a few major decisions the upper echelons will probably contain a number of "spurious 'wise men.'" One remedy proposed by the authors is for large organizations to "deliberately increase the number of crucial or at least nontrivial decisions with which they are confronting a candidate for promotion before they decide about his career."

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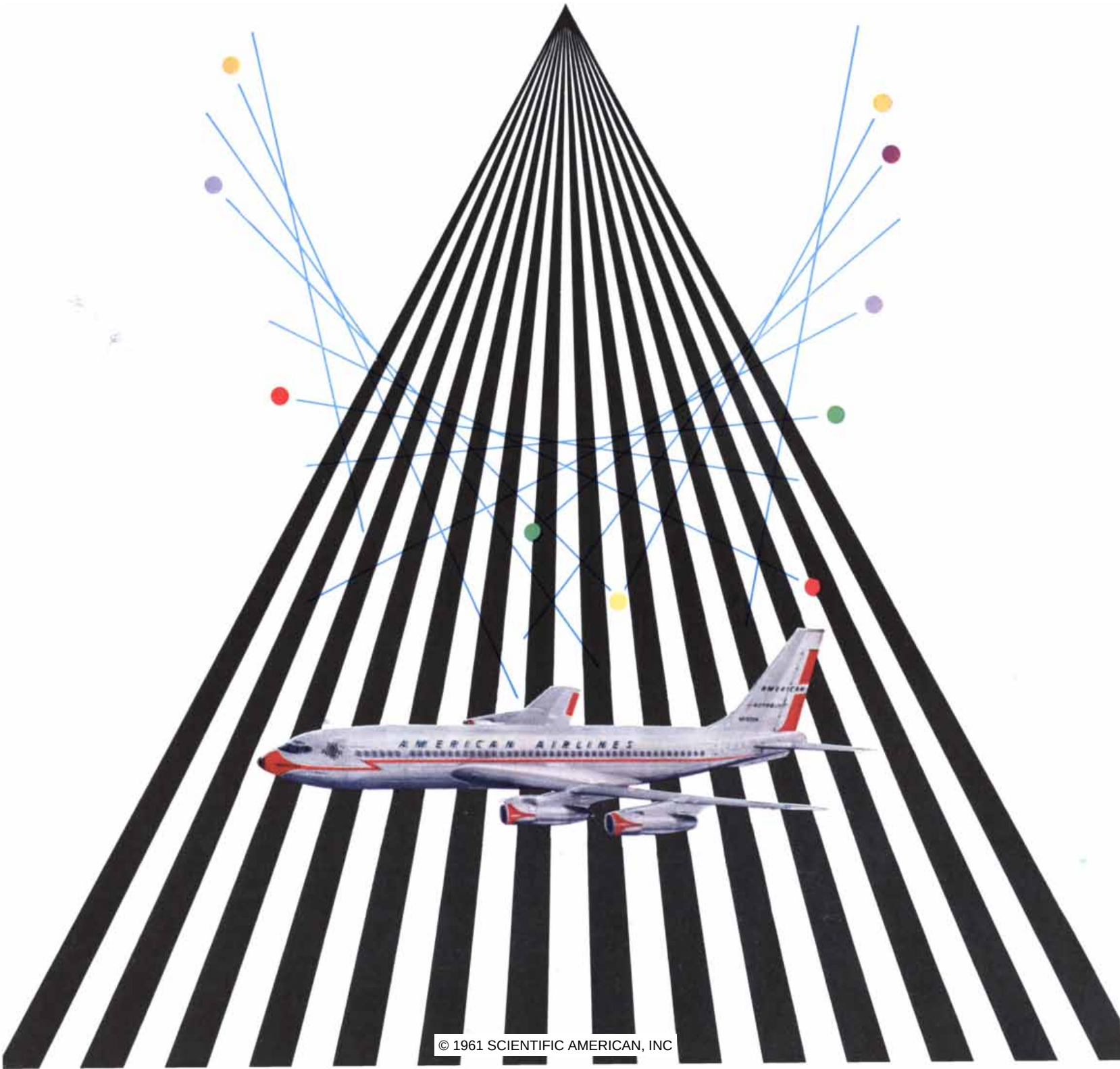

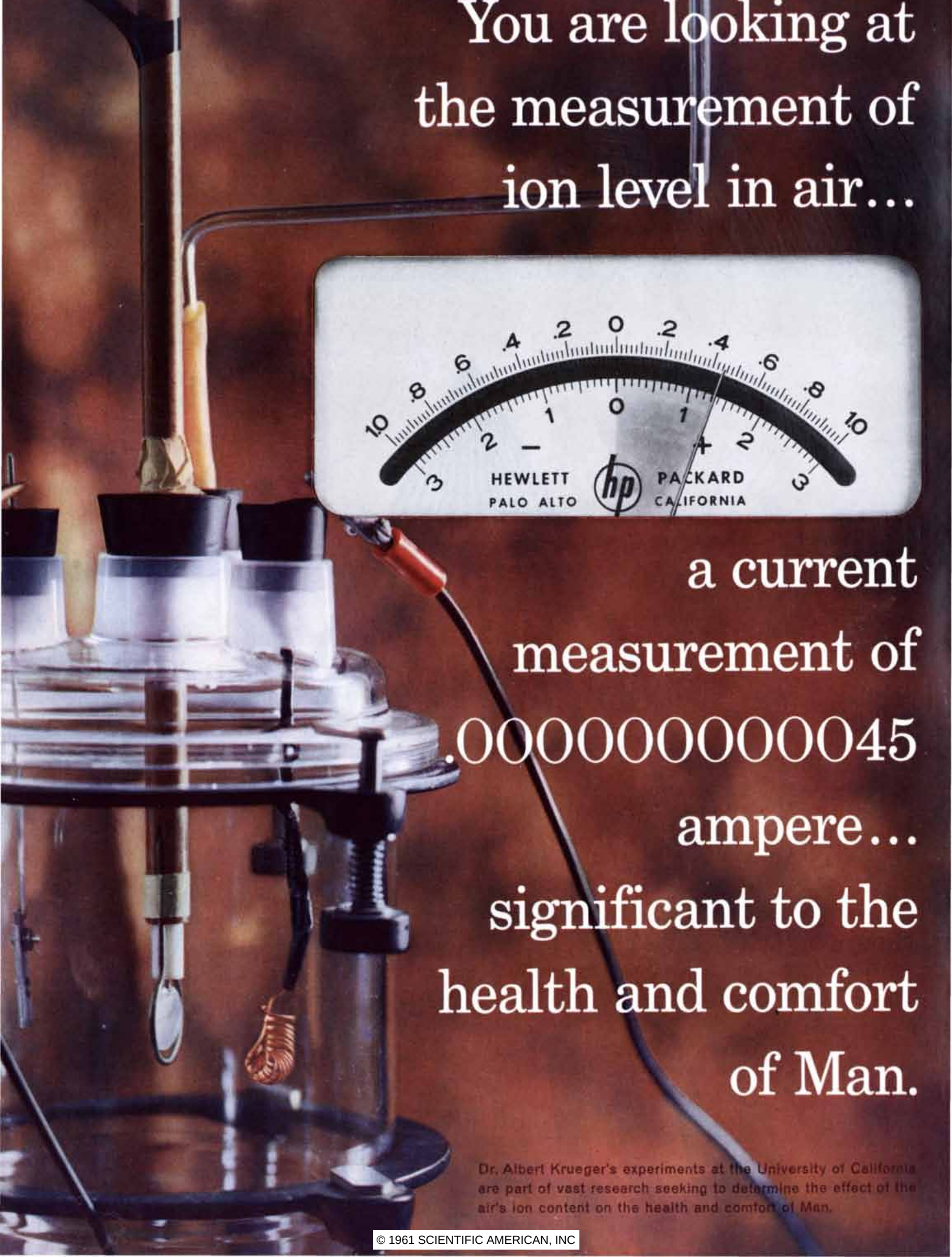

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THE ARCTIC OCEAN

An account of Soviet investigations of the region, which are descended from the efforts of early explorers to find a northeast passage between the Atlantic and the Pacific

by P. A. Gordienko

Large regions of the U.S.S.R.—nearly a third of the country—lie within the Arctic Circle. South of this frigid zone lie the forests and prairies of the one-sixth of the earth's land that is encompassed by the borders of the Soviet Union. Great rivers—the Dvina, the Pechora, the Ob, the Yenisei, the Lena, the Yana, the Indigirka and the Kolyma—rise far to the south and run northward to the Arctic seas: the Barents, the Kara, the Laptev, the East Siberian and the Chukchi. The seas are arms of the Arctic Ocean, embayed by the northward-reaching peninsulas and archipelagoes of the Eurasian continent and hemmed in by the oceanic ice. During the few months of the year when the ice clears the straits and headlands, the rivers, seas and oceans provide the shortest overwater transportation route between the metropolitan centers of the country and the interior frontier.

The Northeast Passage from the Atlantic to the Pacific Ocean was one of the challenging objectives sought by the mariners of all the European powers during the age of discovery. For the economy of the Soviet Union the Northeast Passage constitutes a life line. Without it, the resources of the interior must be hauled at much greater cost overland, and shipping from Leningrad in the west to Kamchatka in the east must travel through the Panama or Suez canals—journeys of more than 14,000 miles to accomplish a distance only half as great. During the past 40 years Soviet explorers and scientists have filled in the last blank spots in the map of the Arctic and have opened the way to a full understanding of the relationship of this remote region to the geography and geophysics of the planet as a whole. Particularly during the past 15 years, large and small expeditions borne by icebreakers and oceanographic vessels have mapped the Arctic lands and waters; flying laboratories have made numerous landings on the ice pack; scientific settlements established on drifting ice islands have traced by their own wanderings the currents of the polar seas, and dozens of permanent observatories have been built on the outermost reaches of the land. As a result cargo vessels are proceeding east and west in increasing numbers each year between the European and Siberian centers of the Soviet economy. The centuries-old vision of the Northeast Passage has been realized, and man's knowledge of his planet has been considerably enriched.

Early Explorations

"If we compare Russia to a building," the 19th-century Arctic explorer Admiral Stepan O. Makarov wrote, "we see at once that it faces the Arctic Ocean." It was inevitable that Russia should play a prominent role in Arctic research. In this account of the most recent phases of that long effort it would be less than just not to begin with an excursion into the past and a brief account of the achievements of our forefathers and of the explorers from other nations who preceded us into the region.

Russians first appeared on the frozen shores of the Arctic in the 12th and 13th centuries. While the geographers of western Europe were writing imaginative treatises about fearsome monsters that inhabited the unexplored North, settlers from ancient Novgorod pushed through the wilderness and settled along the coast of the White Sea and later moved on to Murmansk. Russian hunters sailed across the icy Barents Sea in primitive boats, landed on Novaya Zemlya ("New Land") and Spitsbergen and followed the Arctic coast line to the East. Somewhat later eastward-migrating Cossacks crossed the Urals and penetrated into Siberia. Making their way across wild rivers, braving the polar night and the intense cold, these men charted lands that had never been visited by Europeans, established settlements and made the first contacts with the Chukchi, the aboriginal inhabitants of the Eurasian Arctic. Even the northernmost point of

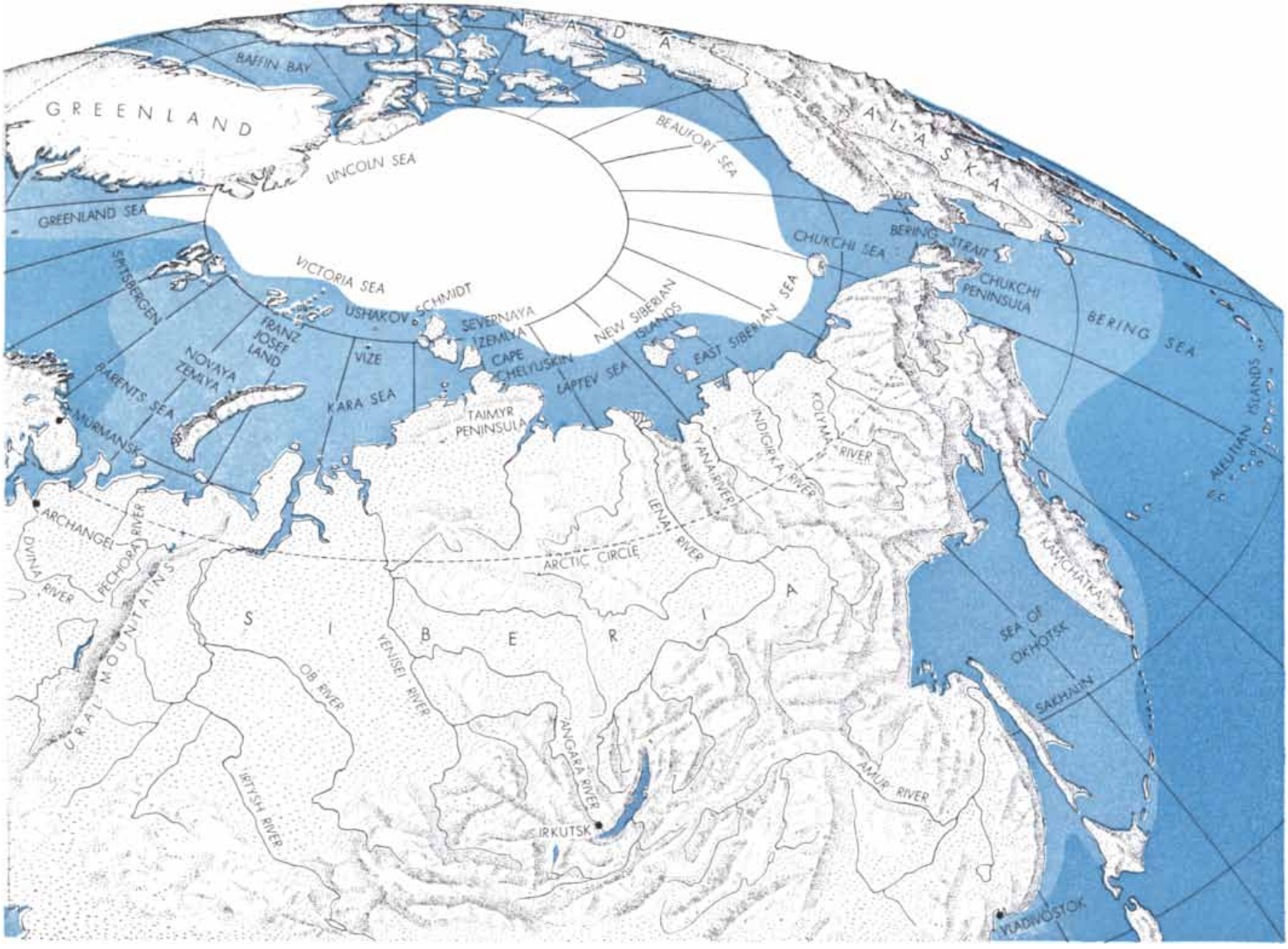
THE ARCTIC OCEAN, its islands and the lands adjoining it are shown from a

Asia, Cape Chelyuskin on the Taimyr Peninsula, was no barrier to the early Russian seafarers. They sailed around that cape some 350 years ago and left remains of their craft and dwellings on its eastern shore, where they were discovered only in 1940.

In the 16th century, with the riches of Cathay and India luring them on, the nations of Europe embarked on the age of discovery. Spain and Portugal soon pre-empted the warm-water routes to the East, and with the land routes all but closed by hostile Islam, the other nations of Europe looked to the Arctic for a northeast or a northwest passage to the Pacific. In the course of the next 300 years the search occupied the English, the Dutch and the French. They established colonies in the New World but they found no short routes to the East. The northern passage to Cathay remained a hope and a challenge.

It is little known that the scope of Russia's enterprises in her northern lands and in Siberia during the age of discovery was of the same magnitude. In 1648 a Cossack detachment under the leadership of Semen Dezhnev and the prospector Fedot Popov, looking for a way east from the mouth of the Kolyma River, rounded the Chukchi Peninsula and discovered the strait that separates Asia from America. This remarkable discovery proved that the two continents are separate and established the existence of the Northeast Passage. Under Peter the Great, in the early years of the 18th century, Russia expanded her domains in the East. The search for an alternative to the interminable and exhausting journey across the Siberian wilderness now assumed urgent priority. Peter planned and organized a tremendous geographical undertaking, the Great Northern Expedition of 1733 to 1743. Over the decade the various parties of the expedition succeeded in exploring and mapping the northern coast of Europe and Asia from the White Sea to Kamchatka. The names of Bering, Chirikov, Chelyuskin, the Laptev brothers, Pronchishchev and his wife Maria, Sterlegov, Ovtsin, Malygin and dozens of others live today in the maps of the north. Across land and sea these explorers proceeded to their objectives in the face of hardships and perils that can only be imagined by those who now venture into the Arctic with the protections and conveniences of modern technology. They made their way through the trackless wilderness on horseback and on foot; they set out to sea in ships they built themselves, and manned the oars when the storms carried away their sails. Yet they took soundings as they went and drew maps with a cartographic skill that is impressive even today. In 1741 the ships *St. Peter* and *St. Paul*, under the command of Vitus Bering and Alexei Chirikov, rounded the Kamchatka Peninsula and proceeded across the sea to Alaska.

Mikhail Lomonosov—scientist, histori-



point high above central Asia. White area around the North Pole indicates the permanent ice pack; the light color represents waters that are frozen in winter but open to navigation in summer; dark color indicates seas that are open to navigation all year round.

ICE ISLAND NORTH POLE VI, a Soviet observatory established on the drifting ice, began a 700-mile journey in 1956 and ended it 27 months later. Hemispherical structures are laboratory tents; rectangular ones, living quarters. At right are radio antennas.

FISSURE IN ICE ISLAND, a constantly recurring threat, is dangerous because it may split campsite. Station buildings are therefore set on sled runners to facilitate relocating them. Action that breaks pieces off floe just as often fuses other pieces on.

an and reformer of the Russian language—set the capstone on this decade of adventure and achievement. In 1763 he brought the diverse findings of the Northern Expedition together in a comprehensive treatise under the name *Brief Account of Travels in the Northern Seas*. This work laid the foundations of the oceanography and meteorology of the polar region, the physics of Arctic ice and a theory of the aurora borealis.

In the first quarter of the 19th century Russians explored the Bering Sea and Bering Strait, discovered Kotzebue Sound (north of the Bering Strait off the western coast of Alaska), proved the existence of Wrangel Island in the Chukchi Sea and visited the New Siberian Islands and Novaya Zemlya. During this period a Russian expedition discovered the Antarctic continent. Then in 1878, with the financial backing of the merchant A. Sibiriakov (Peter's successors in power did not observe the bold precedents he set for the development of the Russian Empire), the Swedish explorer N. A. E. Nordenskjöld made the first passage across the northern waters, from the Barents Sea to the Pacific. Nordenskjöld's achievement, and the discovery of Franz Josef Land a few years earlier, inspired the organization of the first International Polar Year in 1882 and 1883. Russia participated by establishing a meteorological station at Novaya Zemlya and another in the delta of the Lena River.

In 1893 the Norwegian explorer Fridtjof Nansen took his ship the *Fram* on a daring voyage. Nansen was convinced that ocean currents carried ice from Siberia across the Arctic and through the Greenland Sea into the Atlantic. He advanced an ingenious scheme in which he proposed to use the forces of the Arctic rather than fight them. He would sail into the polar ice pack off the New Siberian Islands, anchor to a floe and allow the currents to carry his ship as they did the ice itself. In support of his hypothesis he pointed to the appearance on the Greenland coast of flotsam from Siberia—more particularly to the wreckage of the *Jeannette*, the ship of an ill-fated expedition commanded by George Washington DeLong of the U. S. Navy, which had been crushed in the ice off the New Siberian Islands in 1881. The drift of the *Fram* lasted three years and carried Nansen across the Arctic Ocean at high latitudes.

At the turn of the century the Arctic became an arena in which Englishmen, Americans, Italians, Norwegians, Russians, Austrians and Germans pitted their perseverance and courage against the ice and one another in an international contest to reach the Pole. Robert E. Peary won the prize for the U. S. in 1909.

The advent of the icebreaker, the airplane and the radio revolutionized Arctic exploration early in the 20th century. With the icebreaker the polar ice pack was no longer an impassable obstacle to navigation. The airplane opened previously inaccessible areas to reconnaissance; and radio not only alleviated the isolation of the Arctic explorer but also made possible the co-ordination of scientific work at opposite ends of the polar basin. But the knowledge was not yet dependable or comprehensive enough to equip man to live with safety in the Arctic region, to open up its resources and navigate its waters. It was not possible, for example, to forecast the weather and the related phenomena of the seasonal movement and drift of the ice. Roald Amundsen undertook in 1919 to repeat Nansen's drift on the *Fram*, embarking on the same course aboard the schooner *Maud*. But whereas it had taken Nansen only 40 days to drift from Novaya Zemlya to the New Siberian Islands, it took Amundsen more than a year to complete the same journey. Amundsen had assumed that the climatic and oceanic processes of the Arctic follow a regular cycle year after year. Actually they are subject to great and irregular fluctuations that yield a predictable pattern only in ultimate correlation with the cycles of solar activity. By chance Amundsen had chosen the worst possible time for his voyage. This, however, is hindsight that has been made possible by the most recent investigations in the Arctic.

Modern Exploration

The Soviet era of Russian Arctic exploration began soon after the October Revolution. Very much aware of the problems of the North, the Soviet Government, headed by V. I. Lenin, in one of its first acts in the year 1918 authorized hydrographic surveys to develop navigation in the Arctic seas. The immediate plan was to open the Kara Sea to shipping that would carry grain from the southerly steppes of Siberia, down the Ob and Yenisei rivers and westward through the Kara and the Barents seas to Archangel—a scheme analogous to the opening by the St. Lawrence Seaway of the plains of the American Middle West to ocean traffic. By 1921, 23 parties totaling 400 men had gone to work in the Arctic. Important maritime expeditions followed, and geophysical observatories were built in Novaya Zemlya, Franz Josef Land, the Severnaya Zemlya Archipelago and the New Siberian Islands.

By 1930 the original plan had been enlarged. No longer was the aim simply to open the Kara Sea to navigation; it was to open the entire Northeast Passage and to make the route feasible for scheduled traffic on a large scale. There were many authorities at home and abroad who categorically denied that the passage could be navigated in one season; previous expeditions, beginning with Nordenskjöld's, had required two years or more. The passage is icebound nine months of the year and is made hazardous by fog and heavy weather and by drifting ice even in the "open" months. The Kara Sea, while open three months of the year in favorable circumstances, holds its ice much longer than do other parts of the passage. But the Soviet Government backed the country's Arctic enthusiasts. It placed the program of polar exploration under the direction of a central agency that was ultimately to become the Arctic and Antarctic Research Institute. The institute assumed responsibility for all hydrometeorological, geophysical and physical-geographic investigations of the Arctic; schools to train engineers and scientific workers were organized; icebreakers were designed and ordered.

In 1932—aided by aerial reconnaissance, radio and the network of observatories that had been established—the icebreaker *Sibiriakov*, under the command of O. Schmidt and V. Voronin, sailed the entire Northeast Passage in a single season, demonstrating that there was now a practicable alternative to the route through the Panama Canal half a world away. A few years later the icebreaker *J. Stalin* underscored the feat by completing a trip from the Barents to the Bering Sea and back in a single season.

The voyage of the *Sibiriakov* (which had been appropriately named for Nordenskjöld's sponsor) was the prologue to even greater undertakings. Recognizing that the weather and ice conditions of the Arctic seas, across which the Northeast Passage lies, are directly influenced by the rest of the Arctic Ocean, the Arctic Institute now extended its research program to embrace the entire North Polar Basin.

A major vehicle for this undertaking is of course the airplane. Soviet polar pilots have mastered the art of locating places to land and making successful landings on the ice pack and thereby have vastly extended the range of scientific reconnaissance. In the spring of

HYDROLOGIST installs a winch on ice-island station preparatory to measuring submarine currents. Helicopter in the background supplies the station and is used for reconnaissance.

MARINE BIOLOGISTS lower specimen collector through floor of protective pit dug in ice island. Arctic waters are populated by crabs, medusas and plant and animal plankton.

1941 the Soviet airplane *N-169* made a historic sortie to the Pole of Inaccessibility—the point in the Arctic Ocean at 83 degrees 40 minutes North latitude and 170 degrees West longitude, which is the most distant from land in all directions—for the purpose of geophysical and oceanographic observations.

One of the most fruitful of the institute's innovations was the ice station North Pole I. In May of 1937 a hazardous airplane landing delivered a four-man team of scientists to a drifting ice floe in the heart of the Arctic Ocean. For the next nine months they lived on the floe, recording the sea and weather conditions that the floe encountered on its meandering course. When North Pole I, which was the forerunner of a series of ice stations, finally drifted to destruction in the Greenland Sea, an icebreaker picked up the team and its precious data. In the fall of the same year the icebreaker *G. Sedov* set out on an ice-locked drift that started in the Laptev Sea, traversed the Arctic Ocean along a line very close to the one followed by the *Fram* (but in higher latitudes) and ended after 812 days in the Greenland Sea. The oceanographic, geophysical and meteorological work of these expeditions into the heart of the Arctic Ocean, combined with the data issuing from the network of fixed stations ashore, began to yield an entirely new understanding of the weathermaking processes of the Arctic—and of the earth as a whole—even before the outbreak of World War II.

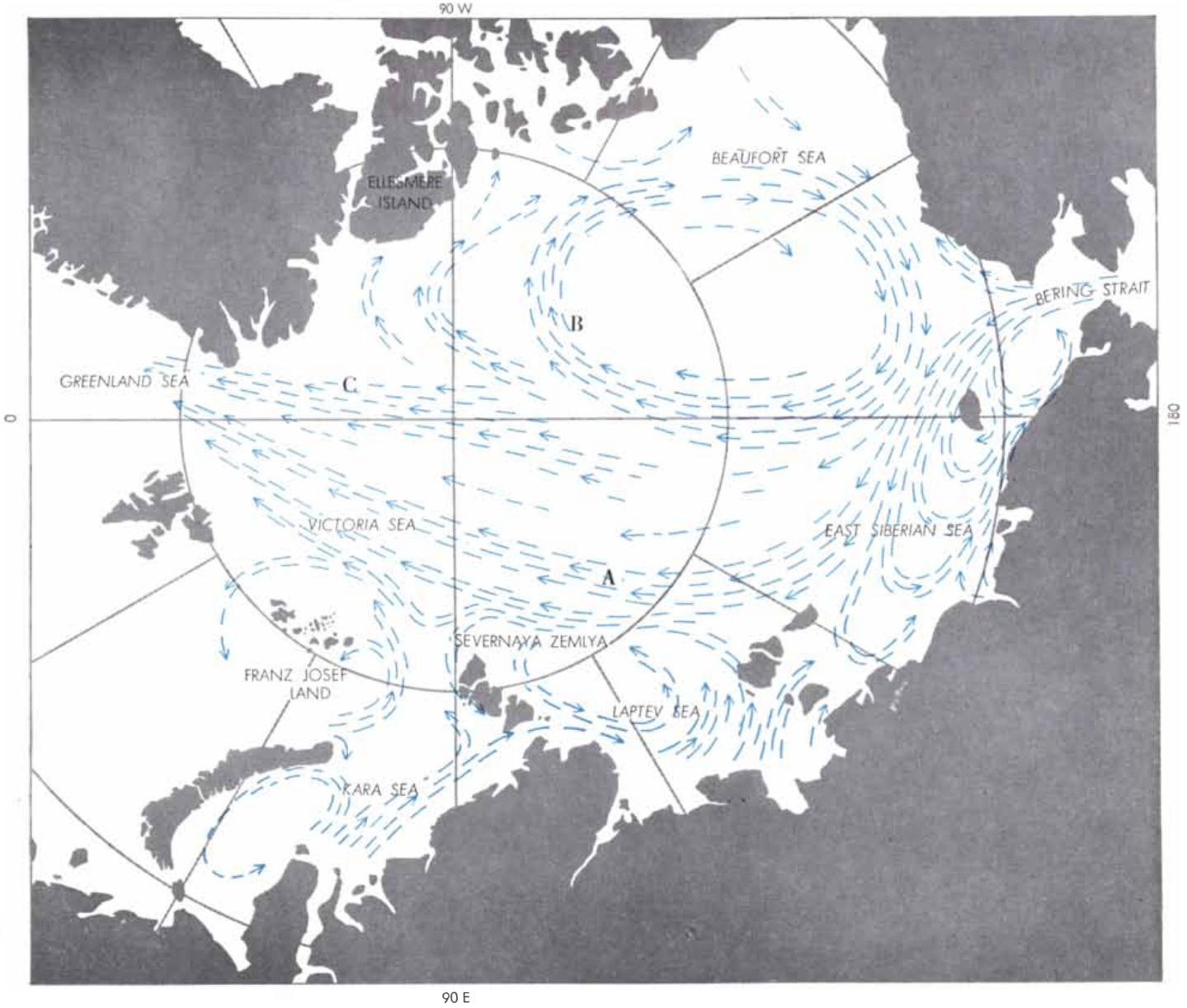
The Arctic and the Weather

The old theory regarded the Arctic as a kind of weather kitchen. The Arctic troposphere—the layer of the atmosphere nearest the earth—was believed to be the prime mover in the manufacture of temperate-zone weather. This uniformly cold, high-pressure mass of air, the so-called polar cap, seeped southward to interact with the warmer and wetter air there and generate the familiar cyclonic storms of the Temperate Zone. But it was supposed that the polar cap itself was only rarely penetrated by cyclones. Such cyclonic penetration as did take place must come mainly from the Atlantic side of the Arctic Basin rather than from the Pacific side.

This picture was reasonable but it was based upon incomplete evidence. We have found that the Arctic is frequently penetrated by cyclones. (The North Pole I station counted 78 days of deep cyclonic penetrations in one six-month period.) Secondly, cyclones enter from the Pacif-

ic side much more frequently than was thought. According to our present understanding, a high-pressure air mass does indeed blanket the Arctic. The cold, dense polar air mass builds up its identity particularly in the winter months. During this period the Arctic tropopause (the roof of the troposphere) descends to correspondingly low altitudes. But in the spring and summer the polar air mass warms, expands and rarefies, and the tropopause rises. Toward the end of April one year it rose to more than 34,000 feet from about half that height in only four days. As a result the warmer air from the south is able to invade the Arctic air mass and generate frontal storms within the Arctic region. At such times the tropopause of the Temperate Zone air is both higher and colder than the Arctic tropopause; the effect of this disparity is to set up vertical as well as horizontal movement, resulting in exchange of air between the two masses. The Arctic, far from generating the weather of the Northern Hemisphere, is itself subject to wide changes of weather that reflect fluctuations in the general circulation of the earth's atmosphere. In brief, the manufacture of weather is not merely an Arctic process but a global one. Such understanding of the Arctic weather now makes long-range weather forecasting a practical matter. When a high-latitude aeronautical expedition was being planned in 1954, for example, forecasters were able to take into account a large influx of warm air into the Arctic and correctly predict flying conditions.

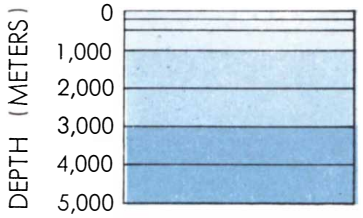
World War II brought a temporary restriction in scientific investigation of the high-latitude Arctic. Nevertheless, regular aerial reconnaissance of ice conditions continued, with larger numbers of aircraft bringing larger areas of the Polar Basin under observation. The work of the Arctic Institute was resumed on an even larger scale as soon as the war ended. Shipping in the Northeast Passage now required three- to six-month forecasts of weather and ice conditions, and short-term (one- to 15-day) forecasts for each voyage and for each leg of the long journey. The expansion of polar aviation, not only for scientific purposes but also for the transportation



ARCTIC CURRENTS are traced by ice drifts, which originate chiefly in Siberian seas and follow three major systems. One (*A*) moves westward from East Siberian and Laptev seas; it has major branches east of Severnaya Zemlya and around Franz Josef Land. Young ice flows into both branches from the Kara Sea. So-called anticyclonic drift system (*B*), centering in Beaufort Sea, forms zone of stagnation in which ice moves slower, remains longer, grows thicker. A third system (*C*) originates in the Bering Strait and adjacent waters to the west and moves directly across the Pole. A branch carries ice around Ellesmere Island; main body converges with the first system and flows into the Greenland Sea. In passage across Arctic, ice may switch from one system to another.

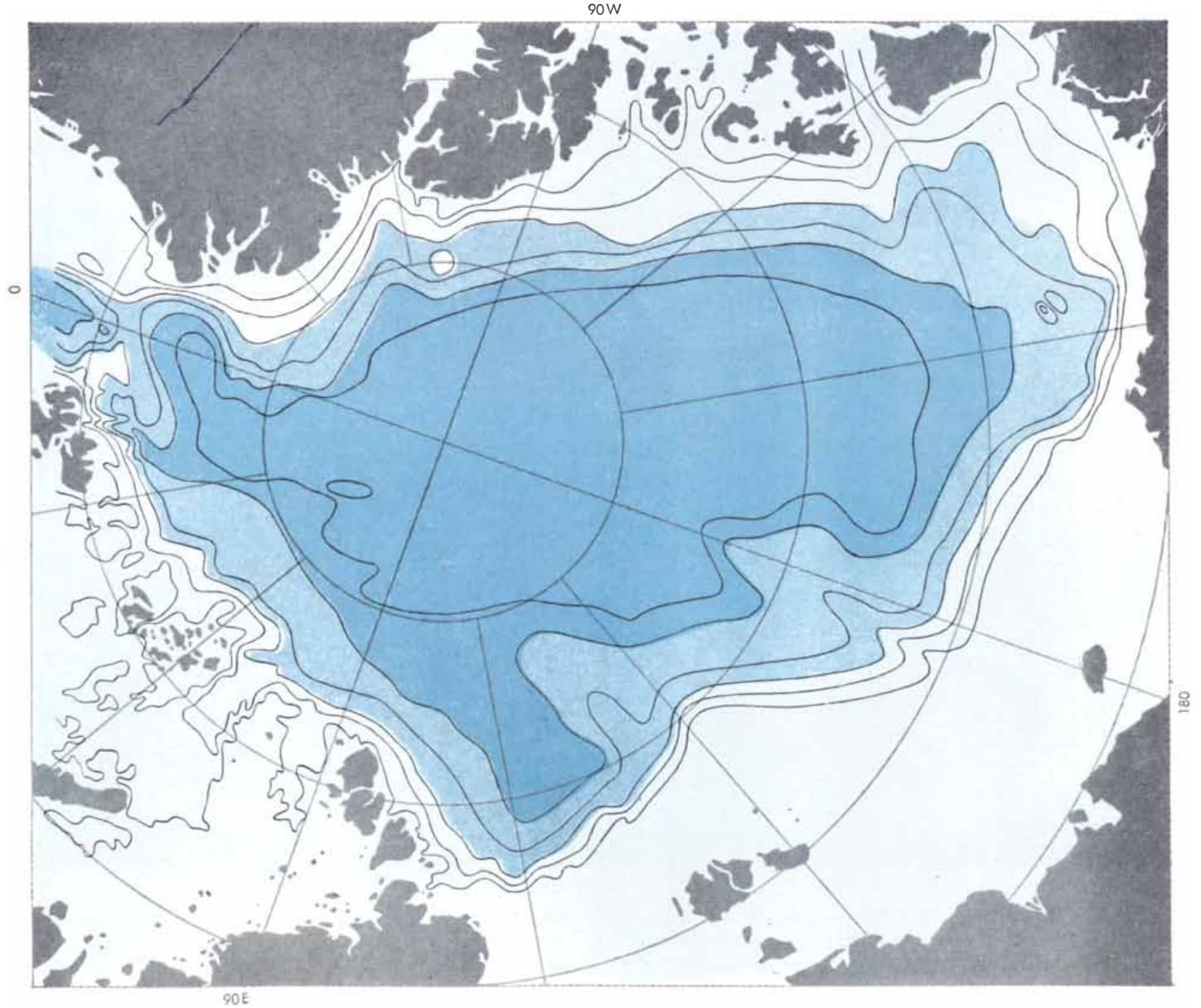
of cargoes and passengers, called for a still finer-grained system of weather forecasting and improved knowledge of the earth's magnetic field and its strange high-latitude anomalies. Such practical objectives raised all kinds of fundamental questions. The scientific effort that the Arctic Institute has directed during the past 15 years has explored these questions on a broad front.

A network of some 100 fixed hydrometeorological stations and geophysical observatories on remote mainland points and on the islands of the Arctic makes continuous year-round observations. During the summer months the vessels of the ice patrol and the hydrological patrol extend the reach of this network to the edge of the retreating ice pack. These missions consist of groups of five to eight scientific workers, who spend three or four months crossing and recrossing the icy waters. Powerful new diesel-electric ships, carrying the larger parties of major expeditions, make it possible to penetrate to still more inaccessible areas. With the coming of spring, every year since 1948, the Arctic Institute has also launched a series of aerial expeditions. Each plane is a flying oceanographic laboratory manned by a staff of three to five scientists. Landing on the treacherous natural runways of carefully prospected ice floes, the men spend one to three days sounding the ocean depths, measuring the thickness of the ice and snow and the temperature of the waters below, taking samples from the ocean floor and making magnetic, astronomical and meteorological observations. The flights are necessarily suspended during the two or three dark months of the polar winter.



The Drift of the Ice

Much of the data about the drift of the ice, especially in the lower latitudes, is nowadays a by-product of the surveillance maintained on behalf of Arctic shipping. Shore stations keep the ice under constant observation. Technicians travel to specified ice floes by sea or air and set up radio markers to measure the speed and direction of drifts in the open seas and in the Arctic Ocean [*see illustration on page 97*]. For the six to 12 months of their useful lives these robot observatories intermittently broadcast



BATHYMETRIC CHART OF 1947 shows what was known of Arctic depths at that time. The area that lies within the contour nearest the Pole corresponds roughly to what had yet to be explored. View looks across the Pole from the Eurasian side of the region.

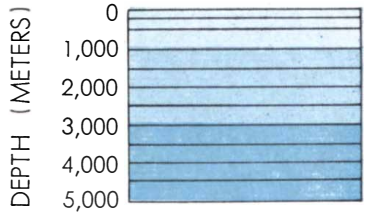
signals giving the velocity and direction of the wind and the temperature and pressure of the air. Directional fixes on the markers, recorded along with the information they transmit, chart the drift of the floe. By tracking 15 to 20 floes in various parts of the ocean at a time the shore stations keep a running account of drifts and climatic conditions.

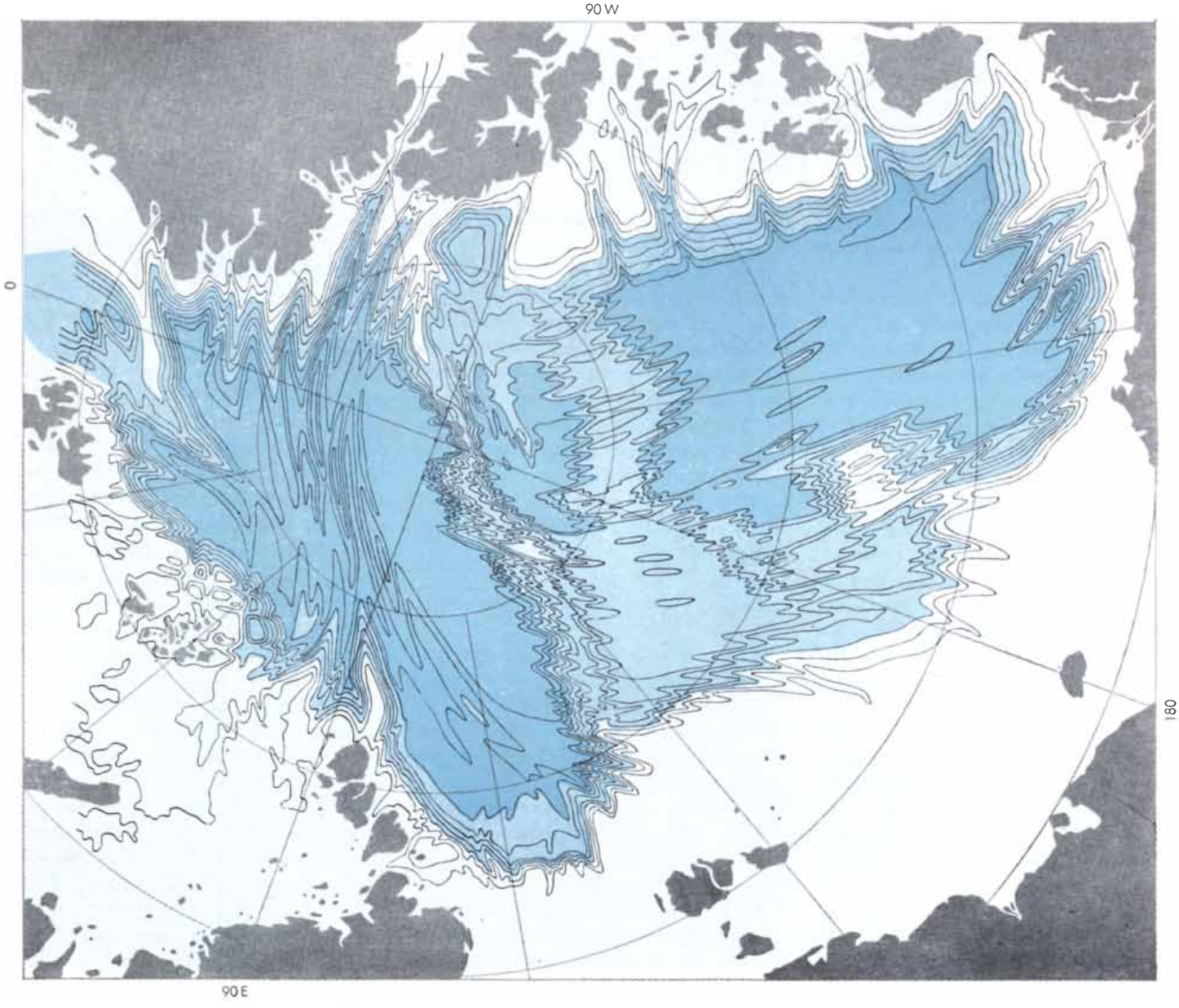
The accumulation of this information over the years has now revised some long-standing misconceptions about the drifting of the Arctic ice. One notion was that the floes in the eastern Arctic seas rotated in closed and "eternal" trajectories. Another, based upon Nansen's experience, was that winds and currents carried the ice across the central Arctic toward the Greenland Sea in a steady stream. There is truth in both hypotheses, but our tracking stations have found that the drift pattern is far more complex.

There are three systems rather than one. The ice that enters all of them originates principally in the cold waters of the relatively shallow Siberian seas [*see illustration on page 93*]. One major drift sweeps westward from the East Siberian and Laptev seas, following a broad path between the 86th and 87th parallels, toward the Greenland Sea. This is the drift that carried the *Fram* on its voyage. Two loops branch off the mainstream. One, turning in the cyclonic or counterclockwise direction, is confined substantially to the Laptev Sea; the other swings, also cyclonically, around the islands in the region of Franz Josef Land, cutting through the Victoria and Barents seas north of Novaya Zemlya. Into both of these branches flows young ice from the Kara Sea.

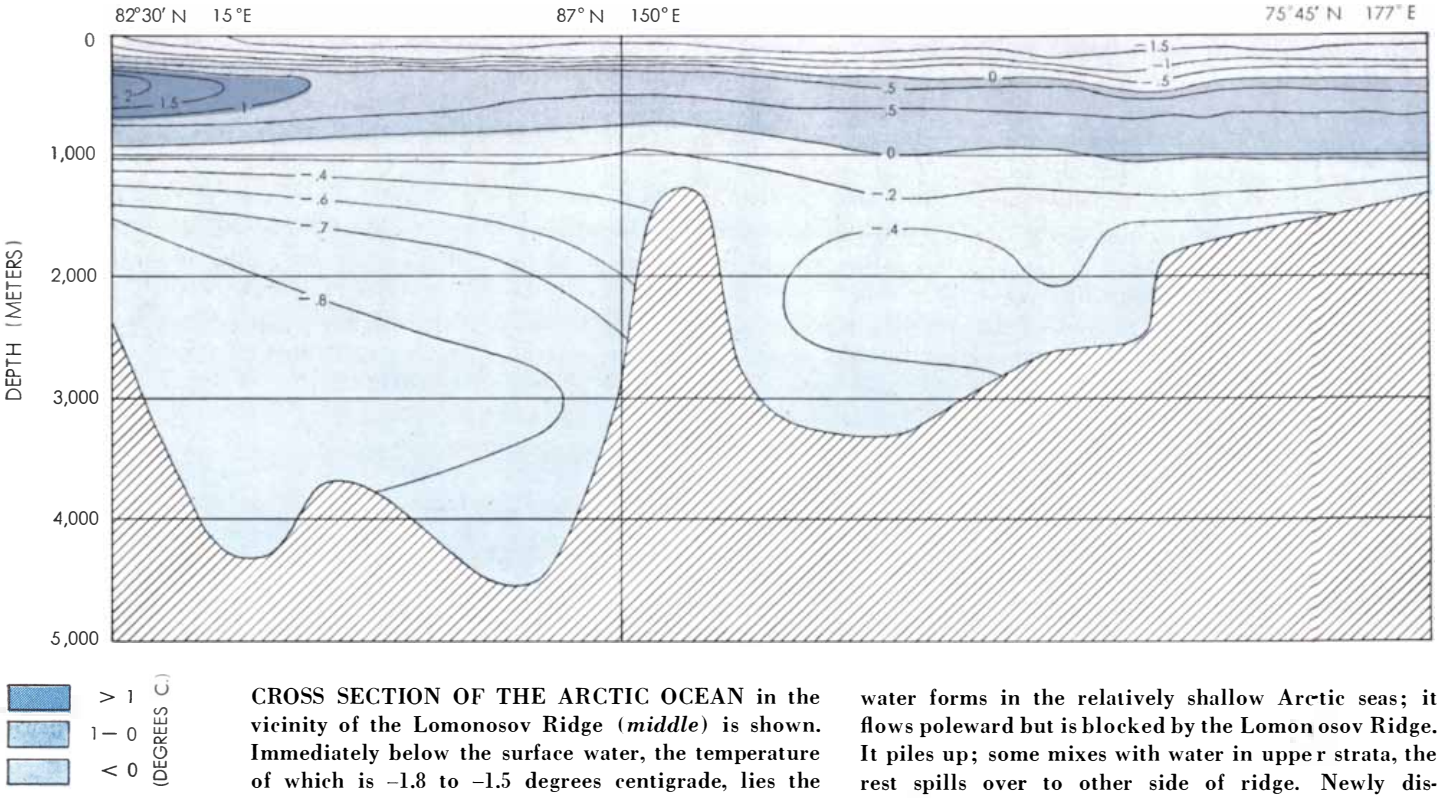
A second system at the Pacific side of the Arctic—the so-called anticyclonic, or clockwise, drift system—describes a closed curve in the Beaufort Sea. This system forms a zone of stagnation in which the ice moves slower and remains for a longer time. As it rotates through a cycle of two or more years, the ice here grows thicker than elsewhere in the Arctic.

Both of these major systems may contribute some ice to a third, which originates in the East Siberian and Chukchi seas and in the Bering Strait. This system sweeps directly across the Pole and, converging with the first system, flows into the Greenland Sea. A branch of this third





BATHYMETRIC CHART OF 1955 is far more detailed than earlier one on opposite page. Major discovery that emerged from additional data is existence of submarine Lomonosov Ridge, which, passing near Pole, extends from one continental shelf to the other.



CROSS SECTION OF THE ARCTIC OCEAN in the vicinity of the Lomonosov Ridge (*middle*) is shown. Immediately below the surface water, the temperature of which is –1.8 to –1.5 degrees centigrade, lies the somewhat cooler intermediate cold layer of water. The next layer down consists of water from the North Atlantic; it is about 3 degrees C. (*darkest color*) when it enters the Polar Basin but cools to .6 or .8 degree (*next darkest color*) as it moves northward. Bottom water forms in the relatively shallow Arctic seas; it flows poleward but is blocked by the Lomonosov Ridge. It piles up; some mixes with water in upper strata, the rest spills over to other side of ridge. Newly discovered stratum of water from the Pacific enters basin through the Bering Strait and spreads beyond the Pole. It is somewhat colder than surface water and lies just below it. The Atlantic side of the basin is at left, the Pacific side at right. Temperatures are representative.

system carries ice floes down through the straits of the Canadian Arctic Archipelago to Baffin Bay.

On its course through the various drift systems an ice floe perpetually exchanges its substance with the sea. During the summer months the sun melts off the upper third of its mass; during the winter the frigid waters freeze on a like amount from below. As the cycle progresses the new ice moves toward the surface, and in three to five years the floe is completely reconstituted. The shape of a floe constantly changes; cracks divide it and collisions either break pieces off or fuse pieces on. In the course of a few years a 25-square-mile floe may trade ice with its environment for a net gain of a few square miles or a loss of all but a fraction of its original area.

The inevitable fluctuations in natural conditions, especially the seasonal variations in the circulation of the atmosphere over the central Arctic, make each new drift cycle different from the preceding one. After completing one or several cycles in an eddy of one of the mainstreams, a floe may be thrown off into the outward-flowing stream that goes to the Greenland Sea or pass through the straits of the Arctic Archipelago into Baffin Bay or even turn up in one of the outlying Arctic seas. The outflow into the North Atlantic is correspondingly irregular from year to year.

Our detailed studies of the drift pattern show that its main cause is the circulation of the atmosphere. The drift is also influenced by the so-called prevailing winds and permanent ocean currents. But these too are affected by fluctuations in the atmospheric circulation. With the general warming of the earth's climate the melting zone has been moving farther north. As the pack has retreated, its average thickness has diminished.

Ice Islands

As recently as 1946 Soviet investigators discovered a hitherto unrecognized form of Arctic ice. Flying over the anticyclonic drift system on the Pacific side of the Polar Basin, I. S. Kotov saw in the jumble of old and new sea ice below an island where no island was supposed to be. The "island" had an area of some 200 square miles; it was relatively flat, with a corrugated surface that contrasted sharply with the surrounding floes and towered above them by 30 feet or more. It was the first of more than 30 ice islands that have since been found. Observation from the air and by scientific stations established on the islands has shown that such formations originate in the stagnant zone of the anticyclonic system at the Pacific side of the Arctic.

When U. S. fliers rediscovered the first of these ice islands, they named them T-1, T-2 and T-3. In 1952 the U. S. established an ice station on T-3 and maintained it for a year, during which time the island drifted through a typical cycle of the anticyclonic drift system: from Ellesmere Island it traveled west to the Beaufort Sea, then north to the vicinity of the Pole and finally back to Ellesmere Island [see "Ice Islands in the Arctic," by Kaare Rodahl; SCIENTIFIC AMERICAN, December, 1954].

In the spring of 1950 the Arctic Institute established its second drifting station, North Pole II, on the ice pack. The station, under the direction of M. M. Somov, was in operation for a full year. Since 1954 the institute has had at least two such stations continuously at work. By January, 1959, these ice stations had totaled more than 3,400 days of operation and more than 5,000 miles of travel —actually three times that distance if one considers the meandering course of the islands. The stations have made more than 15,000 meteorological observations in synchrony with the network of permanent observatories and some 6,000 more independent observations. They

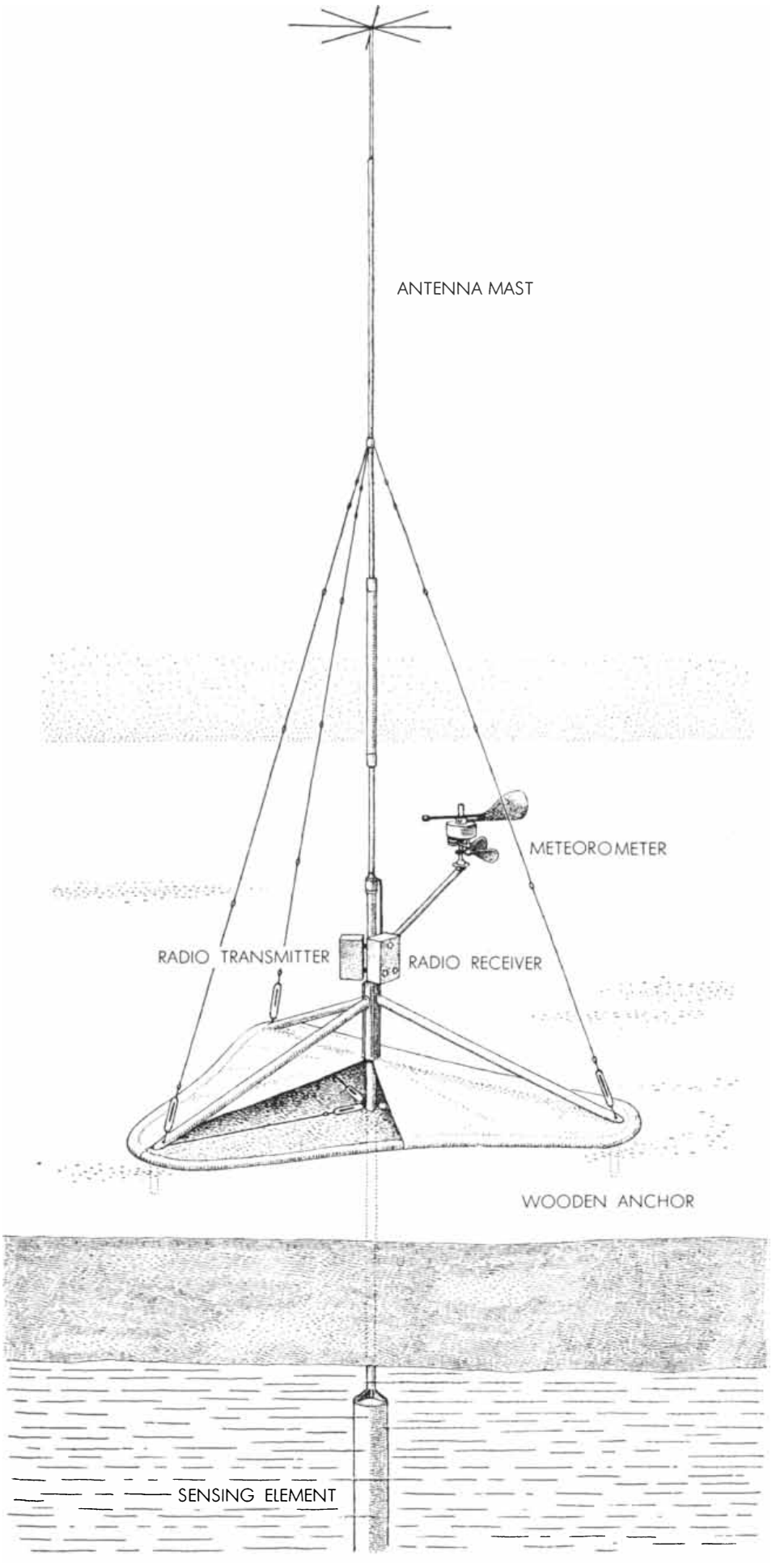
have sent more than 8,000 radiosonde balloons into the upper atmosphere, measured the ocean depths at more than 3,000 points, made 40,000 readings of water temperatures and 100,000 readings of the speed and direction of various submarine currents. The synchronized observations are particularly important for understanding the general pattern of atmospheric circulation. Indeed, a synoptic weather map of the Northern Hemisphere would look downright peculiar nowadays in the absence of meteorological data gathered by the drifting ice stations.

The typical station consists of a cluster of sturdy houses not unlike small railroad cars. The houses are set up on sled runners so that they can be dragged by tractor or pushed by the personnel of the station should a crack threaten to split the campsite. Each foam-insulated cabin shelters three men in its 13 square meters; separate huts and hemispherical tents house the wardroom, kitchen and laboratories. A central diesel engine, supplemented by portable units, supplies the station's power and heat to the indoor living spaces; a small wind-driven generator serves the radio. Tractors, a helicopter, sledges and rubber boats provide transportation.

The 10 to 14 scientists who man each station are supported by a physician, a radio operator, a mechanic, a cook and a four-man helicopter crew. This permanent population, which is completely replaced each April, may occasionally be augmented by five- to 10-man groups that come for a month or two on special missions.

Much of the repetitive data is gathered automatically. A new vane-type meter, for example, measures the velocity and direction of deep submarine currents and records the information every hour or so for as long as two months between maintenance visits. Special integrating meters gauge surface currents and telegraph the information to instrument panels in the observers' huts. Other devices measure the melting and evaporation of the ice and monitor its thickness.

Since the station operates all day every day, and supply problems limit the size of the crew, a good deal of versatility is expected from each man. The magnetologist usually serves also as astronomer, the physician doubles as housekeeper, the meteorologist takes readings of the direct-heating power of the rays of the sun and the fliers assist the hydrologists and aerologists. All hands take turns at kitchen duty, which in addition to helping the cook in the traditional



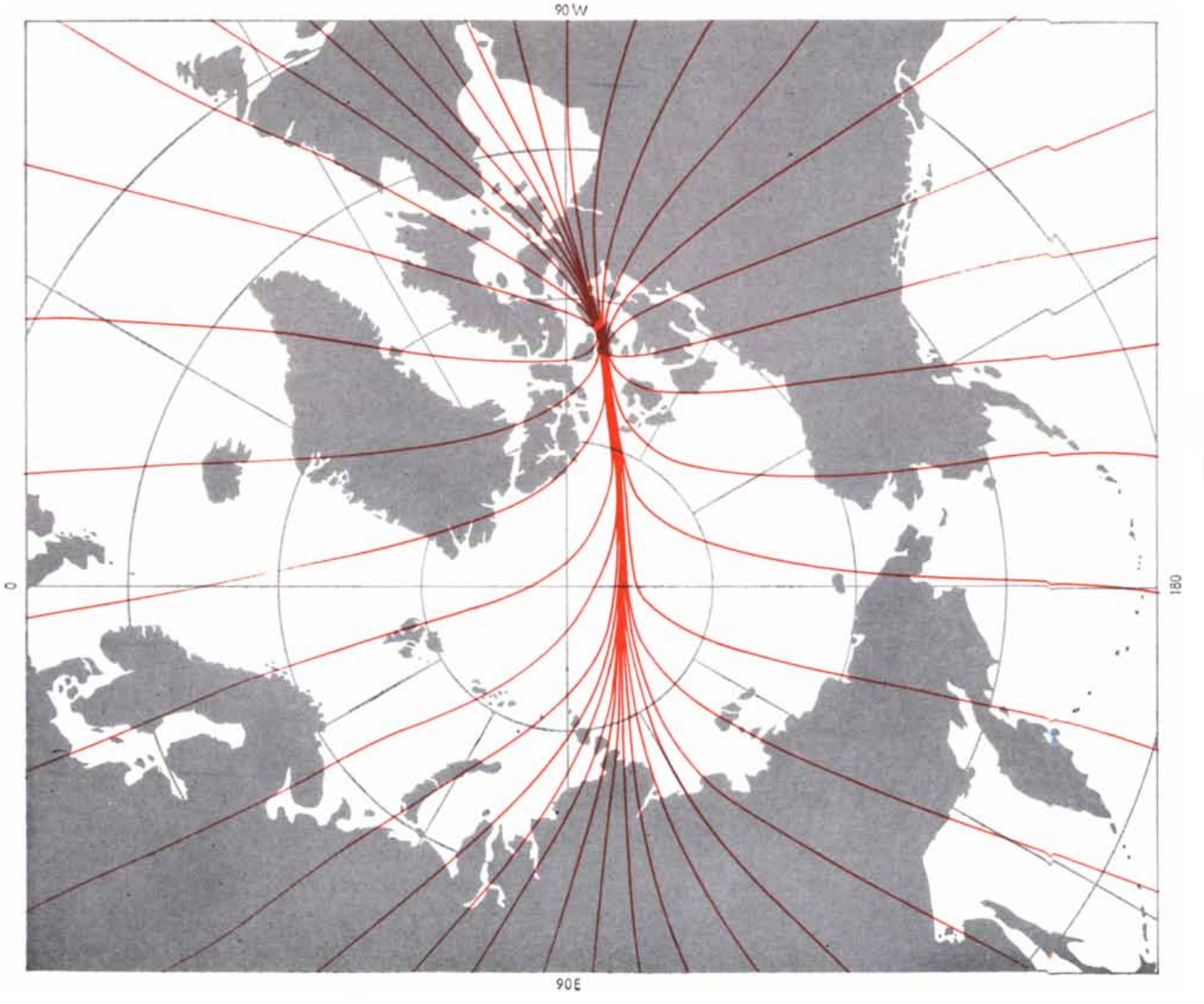
AUTOMATIC OBSERVATORY, of the type installed on selected ice floes, intermittently transmits data on ocean currents and temperatures, wind direction and velocity, air temperature and pressure. Tracking markers from land yields pattern of drift systems.

ways means supplying snow for the diesel and for such personal use as drinking and washing. And all lend a hand in hacking a runway out of the ice for the landing of airlifted fruits and vegetables, mail, reading matter, fuel, movies and specially designed clothing suited to the various seasons.

Whatever the season, life on a drifting ice station is severe. Frequent and lengthy snowstorms howl through the five-month polar night and the air temperature falls to 50 degrees below zero centigrade (90 degrees below freezing Fahrenheit). In summer persistent fogs throw a gray wall around one's head, and the otherwise welcome zero-degree "warmth" brings the nuisance of melting ice. At this period, with water standing in numerous deep (three feet or so) little lakes, the camp looks like a polar Venice. The thaw also brings the danger that the "land" on which one has lived for a whole year may suddenly split apart, that a black abyss a mile or more deep may open right under a hut. But man is wonderfully adaptable. One soon learns to live with the threat; the unpleasant expectancy subsides, although vigilance does not. As a member of the North Pole IV party in 1955 and 1956, I learned that the ice field will break apart on sunny days as well as during storms. Fortunately the crack does not always go through the camp!

The rigors of polar life are not altogether unrelieved. Those who take part in a drift through the Arctic night find a pleasant and reliable friend in the moon. The light suffusing the icy waters is so bright that in good weather we could confidently make excursions several kilometers away from camp and were always able to keep the camp in view. During the polar day visiting bears occasionally broke our isolation. We usually succeeded in chasing them off by firing rockets. Only once did we have to shoot one—when it began to wreck a laboratory tent.

Spring and summer bring a startling flare-up of life in the seemingly barren Arctic. Charming Arctic sparrows came to keep us company, and our hydrologists' jars were constantly catching tiny crabs, medusas, seaweed and curious representatives of the phytoplankton and zooplankton. Our biologists have found that the entire mass of water to depths of 10,000 or 15,000 feet, to the bottom itself, teems with microorganisms. The processes of life go on as actively in the Polar Basin as in the other oceans of the world. Toward the end of one polar night, at 86 degrees North, we found a small roe-filled cod in our Nansen net



THE NORTH MAGNETIC POLE, once thought to be virtually a point in the Arctic Archipelago, has been shown by recent investigations to extend across the Polar Basin to the Taimyr Peninsula in Siberia. The colored lines represent magnetic meridians.

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and thereby set some kind of record for catching a fish at such a latitude and in such a season.

The Waters of the Ocean

The oceanic fauna on the Atlantic side of the Arctic differ from the fauna on the Pacific side, and those found in one layer of ocean are not found in another. Among the factors that account for these differences are the variations in the temperature and circulation of the layers of ocean. Of the major waters of the Arctic Ocean the surface water is ubiquitous; it is identified by its relatively low temperature (about −1.8 degrees C. in winter and −1.5 degrees in summer) and low salinity (about .3 per cent). Between 150 and 600 feet below the surface lies the so-called intermediate layer. Its temperature, always a little lower than that of the surface layer, falls from about −1.6 degrees in summer to −1.9 degrees in winter, with water from the surface layer becoming heavier and sinking downward. The same exchange with the surface waters increases the salinity of the intermediate layer; the salt is not bound in the formation of the ice at the surface and is carried downward to the intermediate layer.

On the Pacific side of the basin a newly discovered layer of water separates the surface waters from the intermediate cold layer. Hydrochemical and hydrobiological research has shown that these somewhat warmer waters enter the Polar Basin through the Bering Strait and occupy a stratum between 250 and 350 feet below the surface.

NUCLEAR-POWERED "LENIN" is late addition to Soviet fleet of icebreakers. Ships are used for scientific research and for clearing paths through ice for commercial vessels.

The great layer of Atlantic waters, which lies below the intermediate cold water, enters the Polar Basin in a powerful submarine current that travels mainly between Greenland and Spitsbergen. This current replaces much of the water that the Arctic Ocean loses through the surface currents and ice floes that sweep out of the Polar Basin. Upon entering the basin, part of the Atlantic current moves eastward, hugging the Eurasian continental shelf, and part spreads north. The eastern branch flows into the shallow Arctic seas, where it cools and sinks and flows along depressions in the sea bottom into the deep ocean. When the Atlantic current enters the polar region, it has a high salinity and a temperature of three to four degrees C. and is almost 2,000 feet thick. But as it rolls farther into the basin through the shallow seas and mingles with the colder Arctic waters it cools and becomes a thinner stratum of water. By the time it reaches the Pole its temperature is not above .8 degree, and as it continues east into the Beaufort Sea its temperature falls to between .6 and .8 degree.

Beneath the Atlantic waters is the great mass of cold (−.8 to −1 degree) bottom water that fills the submarine depressions. According to earlier accounts the bottom water was formed mainly in the Greenland Sea as a result of winter cooling and the sinking of colder strata. We now know that much of the water in this layer forms, largely from Atlantic water, at the edge of the shelf of the Eurasian continent and in the shallow Arctic seas, whence it flows into the depressions of the Polar Basin. In its poleward movement the bottom water encounters the great submarine barrier of the Lomonosov Ridge, discovered and investigated by Soviet polar explorers in 1948 and 1949. Welling up on the Atlantic side of this undersea mountain range, the bottom water mingles with the warmer Atlantic waters above and, spilling over the barrier, fills

the depressions in the ocean floor on the Pacific side.

The Lomonosov Ridge

The Lomonosov Ridge reaches like a gigantic bridge about 900 miles from the Asian continental shelf, some 250 miles north of the New Siberian Islands, past the vicinity of the Pole to the edge of the continental shelf of North America near Ellesmere Island. Its peaks rise to within 3,200 feet of the surface, and it divides the abyss of the Arctic Ocean into two parts. On the Atlantic side the ridge slopes steeply to a bottom that is more than 13,000 feet down. On the other side of the barrier the slopes descend to somewhat more than 11,000 feet. Thus the ridge towers from 6,000 to 11,000 feet above the basins.

The discovery of the Lomonosov Ridge is of unparalleled importance to an understanding of every aspect of the Arctic region. The ridge plays a decisive role in determining the circulation and exchange of water among the different parts of the ocean, in setting the pattern of the ice drift (especially the anticyclonic drift on the Pacific side) and in establishing the major provinces of life in the Arctic waters. In the light of this discovery, geologists have also had to revise their view of the history of the earth's crust in the northern regions. The topography and specimen cores taken from the slopes of the ridge have persuaded Y. Gakkel to the conclusion that the Lomonosov Ridge has been the site of volcanic activity in the past and that renewed volcanic activity is within the realm of possibility in the future. V. N. Saks has advanced the hypothesis that the Arctic was once dry land that sank not later than the Devonian period, about 325 million years ago.

In recent years the building of sturdy and powerful diesel-electric icebreakers has made it possible for Soviet scientists to undertake extended oceanographic expeditions in hitherto inaccessible regions of the Arctic, notably the northern part of the Greenland Sea and the adjacent reaches of the Arctic Ocean. In this vicinity the icebreaker *Litke* in 1955 sounded the greatest known depth in the Arctic Ocean, a depth of 17,880 feet, and discovered a rift running northward at depths of 9,190 to 12,800 feet.

Geomagnetism

Navigators in the high latitudes have always been troubled by the odd behavior of their magnetic compasses

caused by apparent irregularities and asymmetries in the magnetic field of the earth. Early magnetic maps had been drawn on the assumption, based upon hopeful guesses, that the North Magnetic Pole is virtually a point. Accordingly it was expected that the compass needle, which dips more steeply as it approaches the Magnetic Pole, would point straight down, or very nearly so, at the Magnetic Pole itself. But data from the North Pole I, the *G. Sedov* and other expeditions showed that the compass needle points straight down for a very long distance across the Arctic Ocean, from a point northwest of the Taimyr Peninsula to another point in the Arctic Archipelago. This discovery first inspired the hypothesis that there is a second North Magnetic Pole, tentatively located at 86 degrees North latitude and 182 degrees East longitude. More refined observation has disposed of this idea. The map of the magnetic field now shows the magnetic meridians running close together in a thick bunch of lines from the North Magnetic Pole in the Arctic Archipelago to Siberia.

Our program of geomagnetic studies, in co-ordination with that of the International Geophysical Year, has been extended to high altitudes. This work has clarified the interaction of the magnetic field with the charged particles emitted by the sun, especially with respect to the formation of the belts of radiation that surround the earth, the generation of magnetic storms and the production of auroral displays. Today our stations in the Arctic conduct regular simultaneous observations with our stations in the Antarctic. Along with its great theoretical interest, the program has given improved accuracy to navigation charts of the Arctic regions.

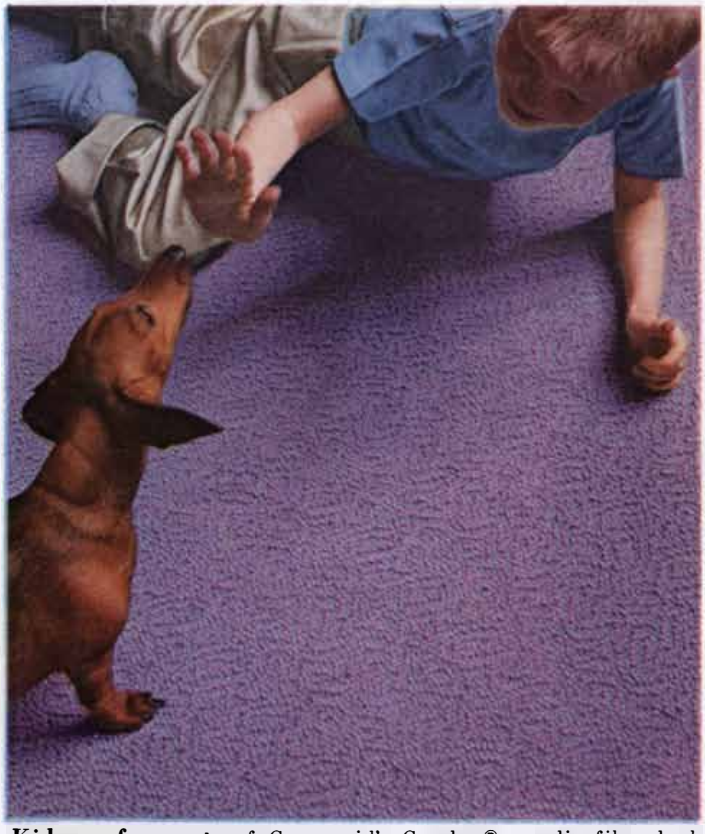
New Lands

In completion of the task begun in the age of discovery, the Arctic Institute has also made some significant revisions in the geography of the Arctic. The map shows the newly discovered Schmidt, Vize and Ushakov islands in the Kara Sea, and new bays, straits and islands in the Severnaya Zemlya Archipelago. Missing from the map are some places that have been "undiscovered." Makarov Land, Gillis Land and Petermann Land, all in the vicinity of Franz Josef Land, and Sannikov Island and Andreev Land in the Laptev and East Siberian seas have had to be erased from the map. In each of these cases either accumulations of ice or thick fogs over open water had congealed in the heads of imaginative cartographers as land masses.

With its broadly conceived and rigorously prosecuted program of exploration and research, the Arctic Institute has shown that an enormous region of the earth's surface and correspondingly large realms of the unknown may be brought within the compass of human understanding in a very few years. Moreover, the often perilous undertakings have been carried out with a high regard for the safety of the personnel; despite gales, snowstorms, fogs and treacherous ice floes, not a single life has been lost during the entire postwar program. The data thus far amassed by the institute's expeditions and ice stations fill more than 120 volumes; the list of books, monographs and articles that is emerging from that data already exceeds 600 titles. And while the main purpose of these expeditions was to delve into the mysteries of nature, they also served to train young scientists in nearly every branch of polar science. For the most part, these men are in love with the Arctic and see great prospects for its development. Many of them plunged into Arctic exploration immediately upon leaving school and have already devoted 20 and 30 years of their lives to this work. They have shown themselves to be worthy of their predecessors.

Full-scale Arctic navigation is now a reality. Guided by aerial reconnaissance, the way through the ice having been cleared by icebreakers, and with ice movements and weather changes monitored by the network of observatories, hundreds of ships are carrying many thousands of tons of cargo through the Northeast Passage on a regular and dependable basis through a season that has been extended to a full four months.

As recently as 30 years ago more than half of the total area of the Polar Basin was unexplored, and 16 per cent was still terra incognita only 15 years ago. Today, disappointing as this may be to young geographers, the area of the blank spots on the map of the Polar Basin has shrunk to almost nothing. At the same time, to the regret of the older explorers and the understandable pleasure of the younger ones, there are still blank spots elsewhere in the Arctic. The ocean, the air and the ionosphere still hold many mysteries. Responding to that challenge, the Soviet ice stations North Pole VIII and North Pole IX are even now adrift in the Arctic Ocean. And the nuclear-powered icebreaker *Lenin* has given Soviet scientists a new capability in the task of subjugating the Arctic and exploiting it for the needs of the community.



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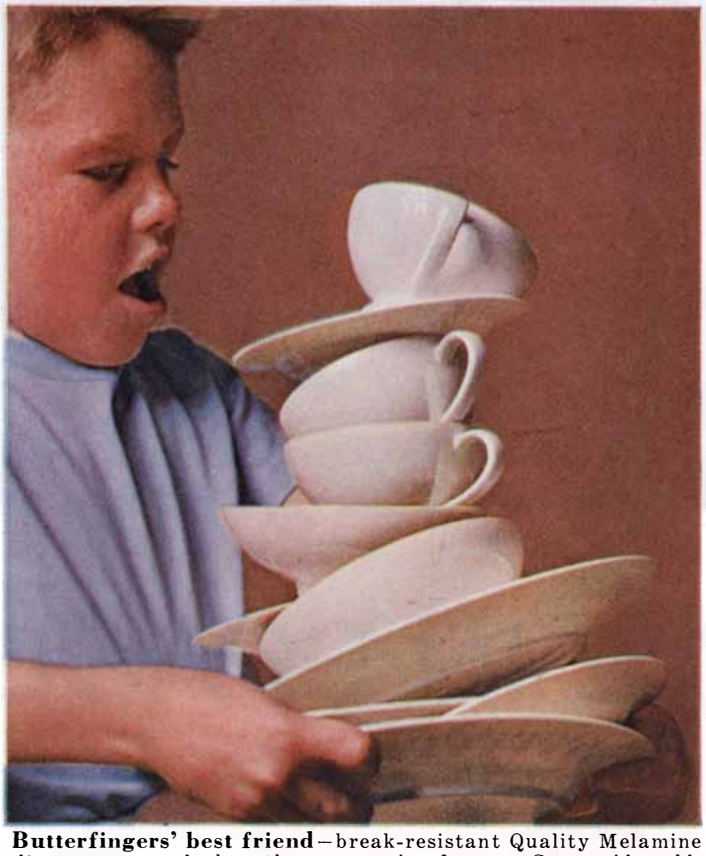

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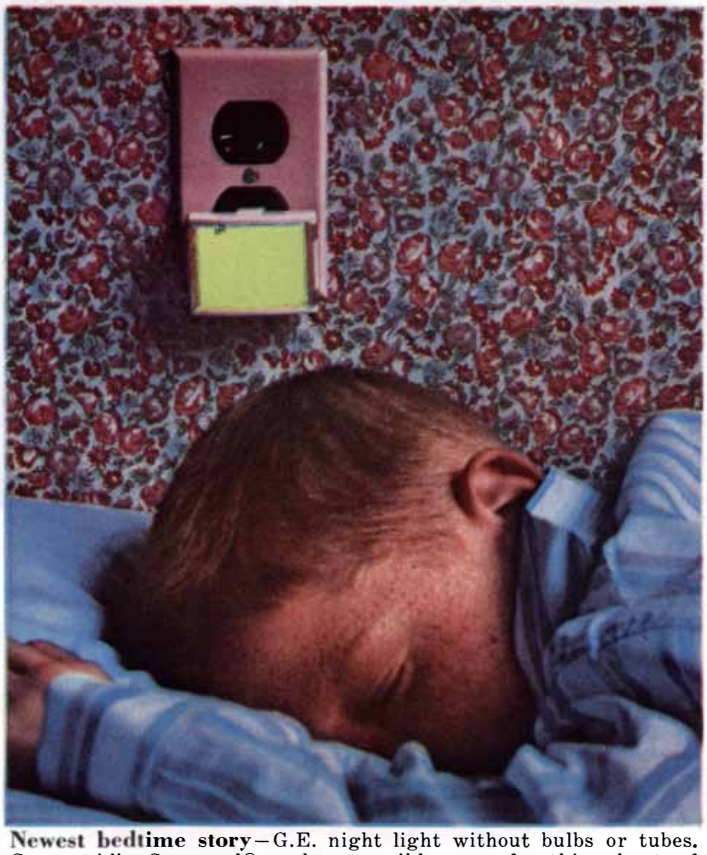

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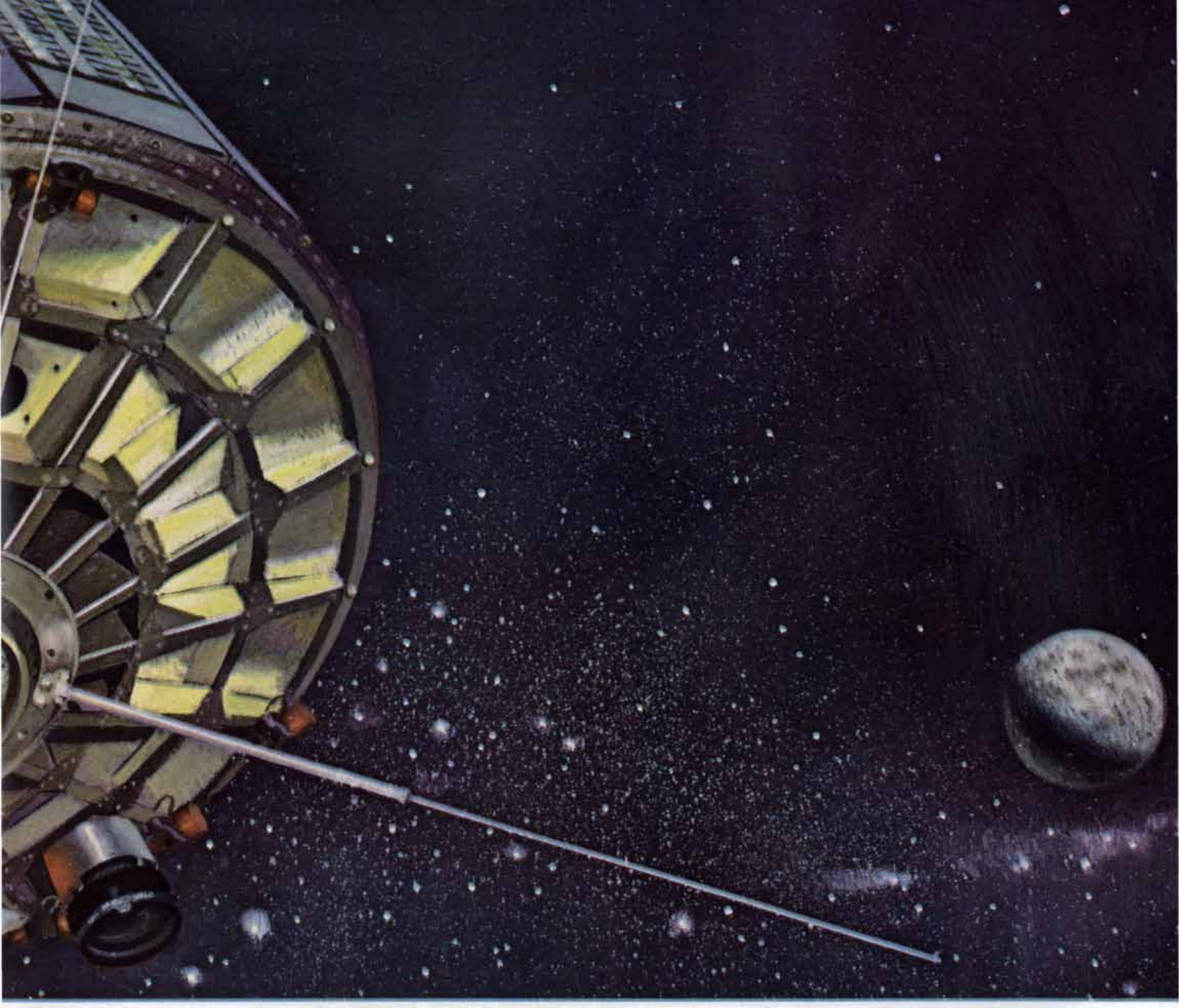

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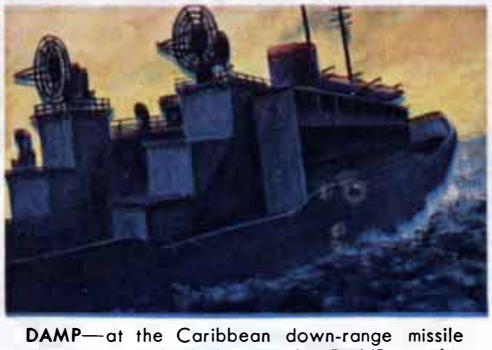

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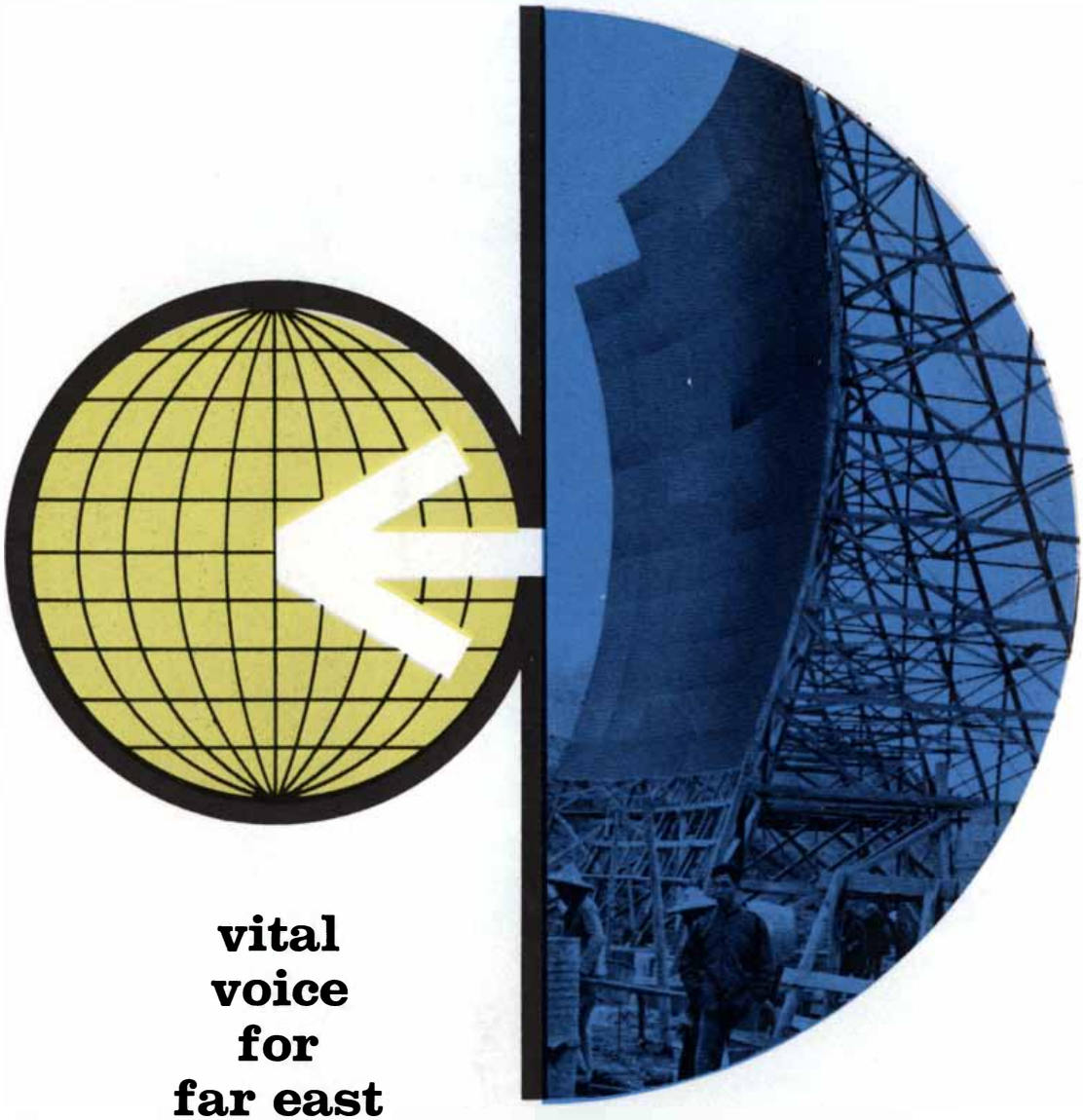

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From Faraday to the Dynamo

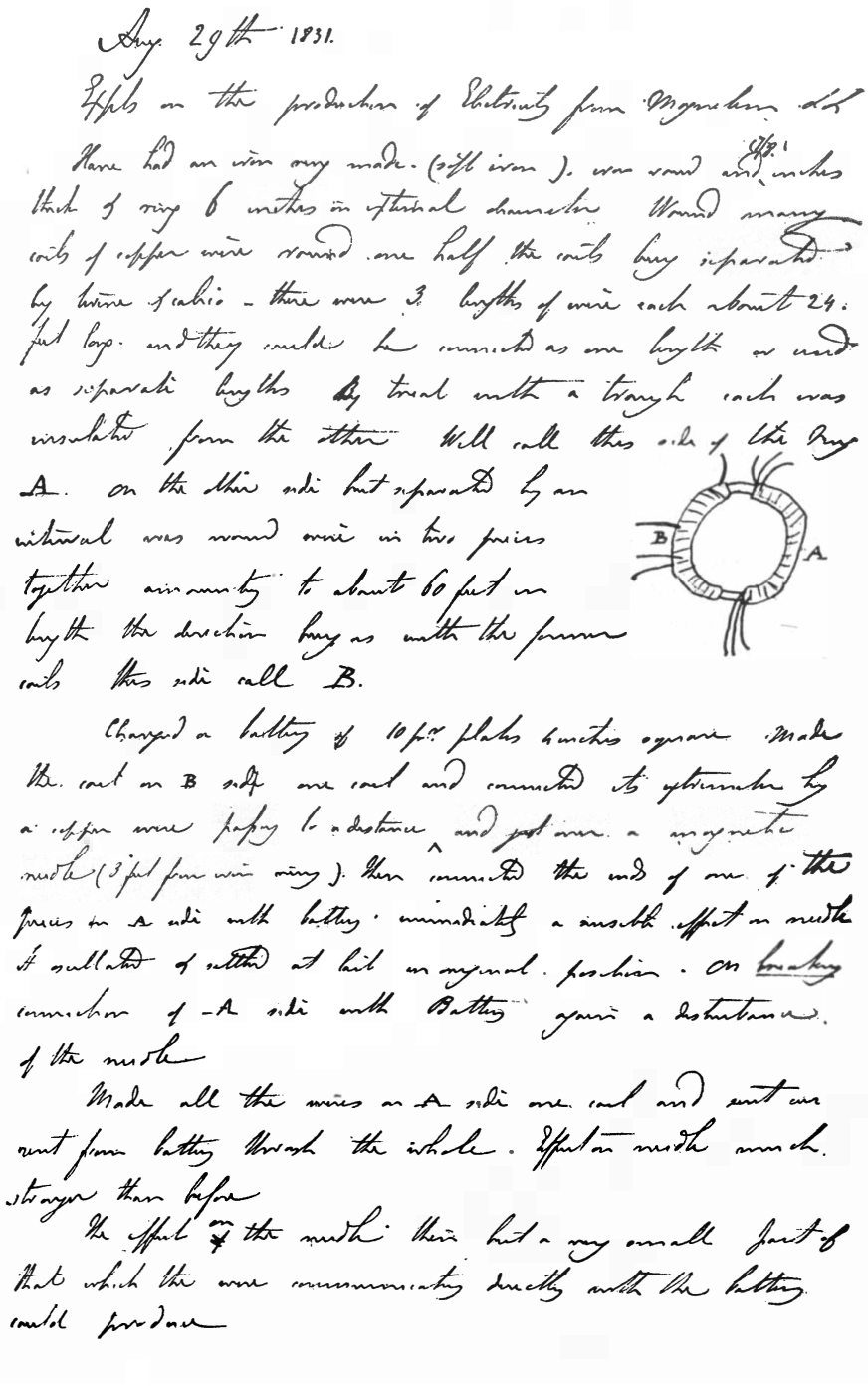
Between the discovery of electromagnetic induction and the development of the electric generator 50 years elapsed. Why did it take so long for Faraday's basic work to be applied?

by Harold I. Sharlin

In 10 inspired days during the fall of 1831 Michael Faraday discovered electromagnetic induction, found essentially all the laws that govern it and built a working model of an electric dynamo. Then he moved on to other research. "I have rather," he wrote, "been desirous of discovering new facts and new relations dependent on magneto-electric induction, than of exalting the force of those already obtained; being assured that the latter would find full development hereafter."

Full development took a long time. Not until the 1880's were Faraday's theories, and the technical clues he provided, embodied in really efficient electric generators. The 50 years in between constitute an engineering gap: the period that separates a piece of basic research from its practical application.

PIONEERS OF ELECTRICITY assembled by Bernarda Bryson for this imaginary seminar are (*left to right*) André Marie Ampère, Alessandro Volta (*standing*), Hans Christian Oersted, Michael Faraday, James Clerk Maxwell and Dominique François Arago.



KEY EXPERIMENT is reported by Faraday on this page from his diary, a day-by-day laboratory notebook. The passage reads: "Aug. 29, 1831. Expts. [Experiments] on the production of Electricity from Magnetism, etc. etc. Have had an iron ring made (soft iron), iron round and 7/8 inches thick and ring 6 inches in external diameter. Wound many coils of copper wire round one half, the coils being separated by twine and calico—there were 3 lengths of wire each about 24 feet long and they could be connected as one length or used as separate lengths. By trial with a trough [battery cell] each was insulated from the other. Will call this side of the ring A. On the other side but separated by an interval was wound wire in two pieces together amounting to about 60 feet in length, the direction being as with the former coils; this side call B. Charged a battery of 10 pr. plates 4 inches square. Made the coil on B side one coil and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (3 feet from iron ring). Then connected the ends of one of the pieces on A side with battery; immediately a sensible effect on needle. It oscillated and settled at last in original position. On *breaking* connection of A side with Battery again a disturbance of the needle. Made all the wires on A side one coil and sent current from battery through the whole. Effect on needle much stronger than before. The effect on the needle then but a very small part of that which the wire communicating directly with the battery could produce." This experiment showed Faraday that it was making or breaking the magnetic circuit—in other words, changing the field—that induced a current in the second coil. This was the key to the understanding of electromagnetic induction.

The history of the 10 days and the half-century furnishes an excellent example of the process by which science passes into technology.

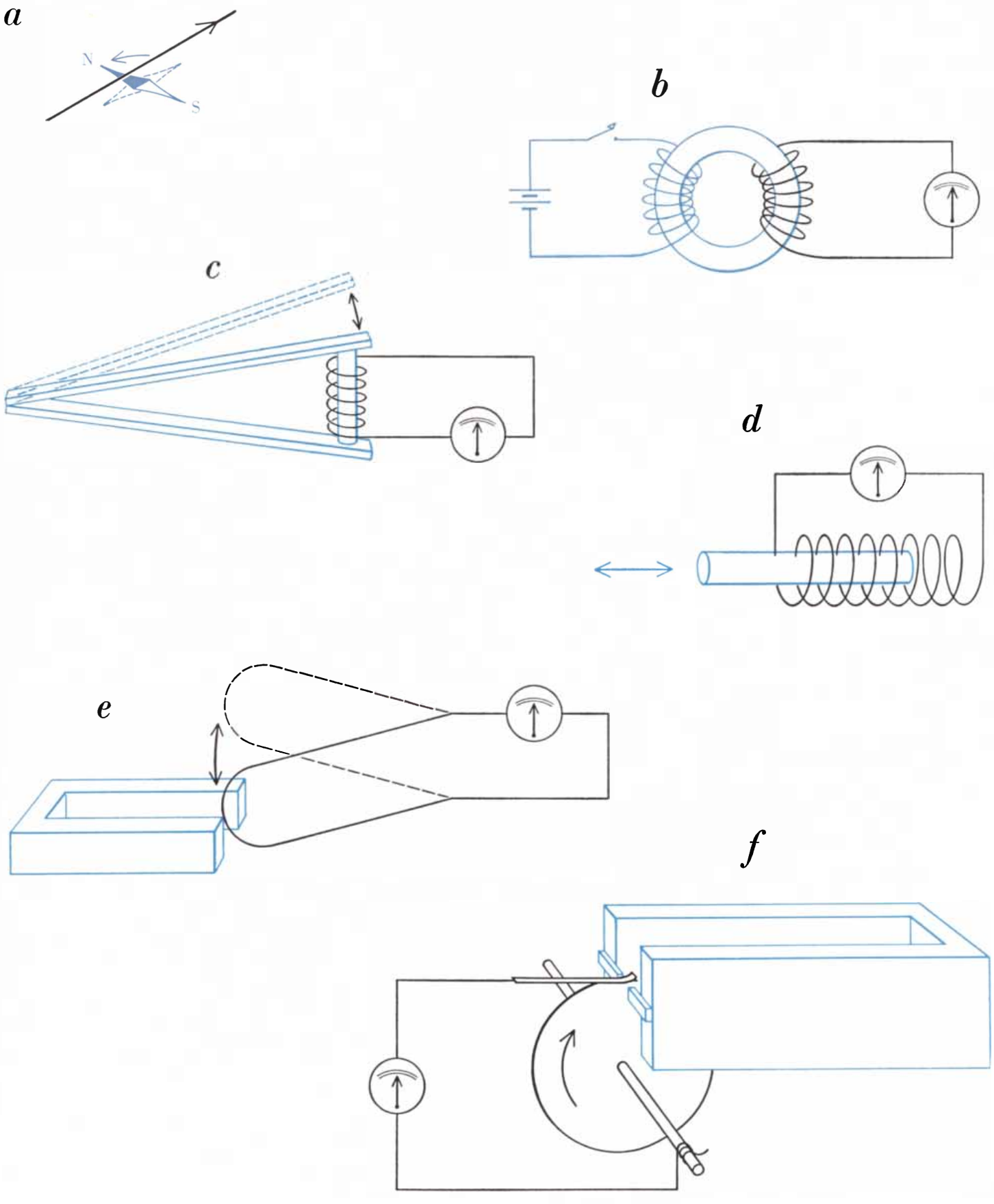
The process is typically divided into two phases. During the first, a fundamental discovery has been made but no one sees a possibility of using it. The new field attracts only the pure scientist and the dabbler in curiosities, neither one aiming at a practical goal. This is the time when theory is ahead of application.

Then there appears a technological niche for the discovery, usually as a result of advances in some collateral area. The niche may open up in months or in years—perhaps never. When it does, the engineer, the inventor and the businessman enter the arena. But now they are likely to find that theory is inadequate to their purposes or that they do not understand it well enough to use it. In this second phase application suffers from inadequate theoretical support. Catalyzed by economic incentive, the pace quickens. A growing technology begins to contribute to science, as well as the other way around, and theory is extended and deepened; devices based on what man thinks he knows about nature are mirrors of truth that bring him closer to understanding the material world. Eventually the interaction closes the engineering gap.

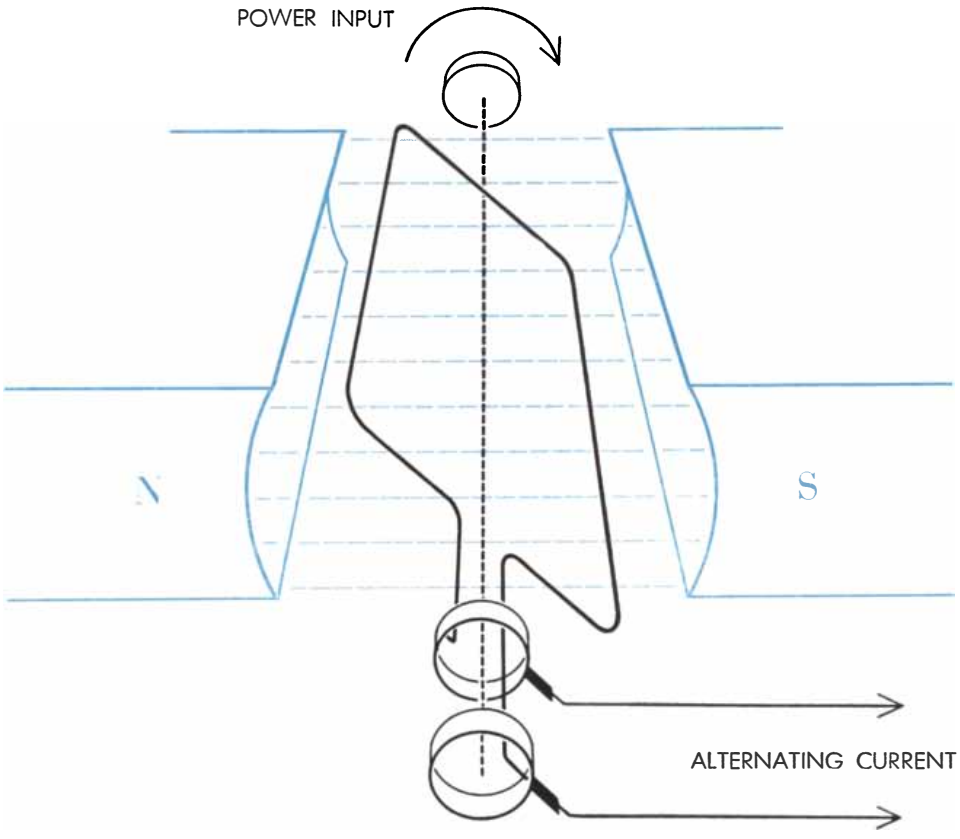
When Faraday began, he knew just what he was looking for. He undertook his experiments with the explicit "hope of obtaining electricity from ordinary magnetism." That hope was prompted by Hans Christian Oersted's demonstration that magnetism could be obtained from electricity. Oersted had been trying to find out if electric current, made available by the recent invention of the chemical battery, exhibited the same attractive power as static electric charge. In 1820 he found that while a current flowing through a wire does not attract objects, it does cause a magnetic needle to line up perpendicularly to the wire.

As early as 1822 Faraday wrote in his notebook: "Convert magnetism into electricity." The same idea occurred to the two great French physicists André Marie Ampère and Dominique François Arago, but both soon decided there was nothing in it. There was no way to arrive at electromagnetic induction by reasoning from the scanty theory of the time. The effect would have to be discovered by experiment, and Faraday was the supreme experimenter.

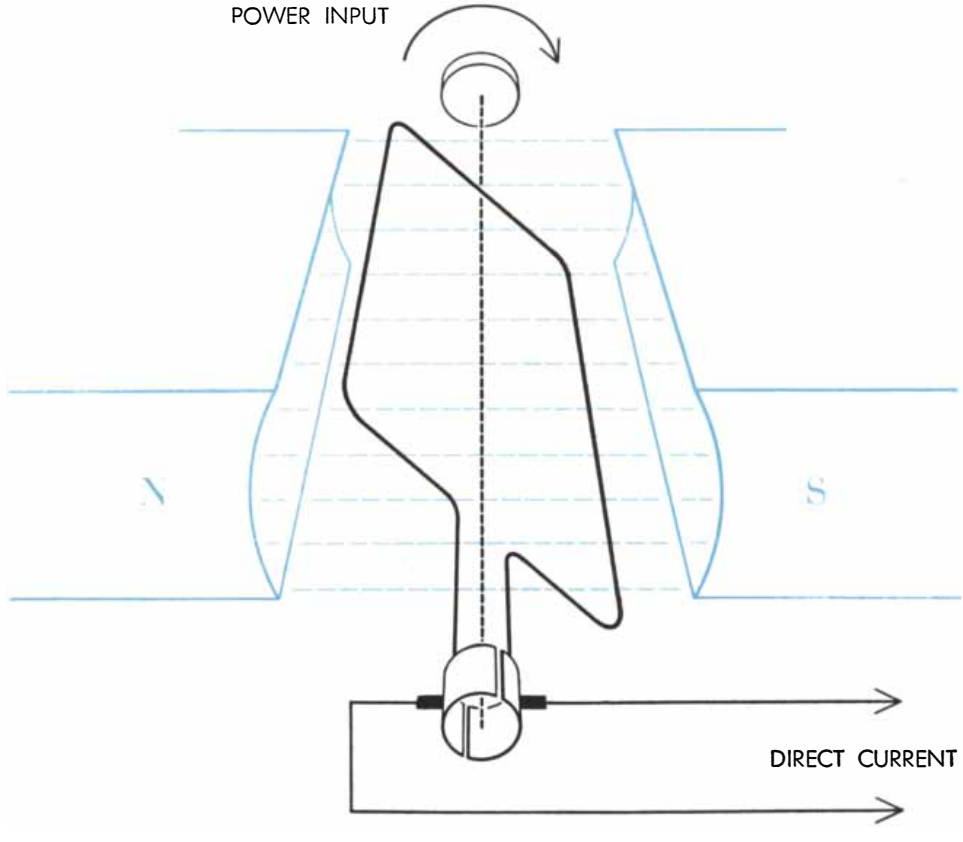
Four times between 1822 and 1831 he



FARADAY'S EXPERIMENTS were prompted by Oersted's discovery that a current-carrying wire made a compass needle near it (*a*) swerve at right angles to the wire, showing that electricity produced magnetism. Faraday sought to show that magnetism could produce electricity. He found first that when a coil on one side of an iron ring (*b*) was connected to or disconnected from a battery, a surge of current was sent through a coil on the opposite side of the ring. Then he found that the same effect could be obtained by making or breaking the magnetic contact between two bar magnets and a coil wound on an iron core (*c*), by thrusting a magnet into a coil of wire or withdrawing it (*d*), or simply by moving a loop of wire up and down in a magnetic field (*e*). Finally he rotated a copper disk between the poles of a powerful magnet and found that a steady electric current was induced across the disk (*f*).



DYNAMO PRINCIPLE is illustrated. A loop of wire (the armature) is rotated so as to cut the lines of force between magnetic poles. A current—clockwise in this case—is induced in the loop, which is connected to brass slip rings, and the current is led to the external circuit by two brushes. The current alternates because it reverses directions as the two sides of the loop cut the magnetic field first in one direction and then in the other.



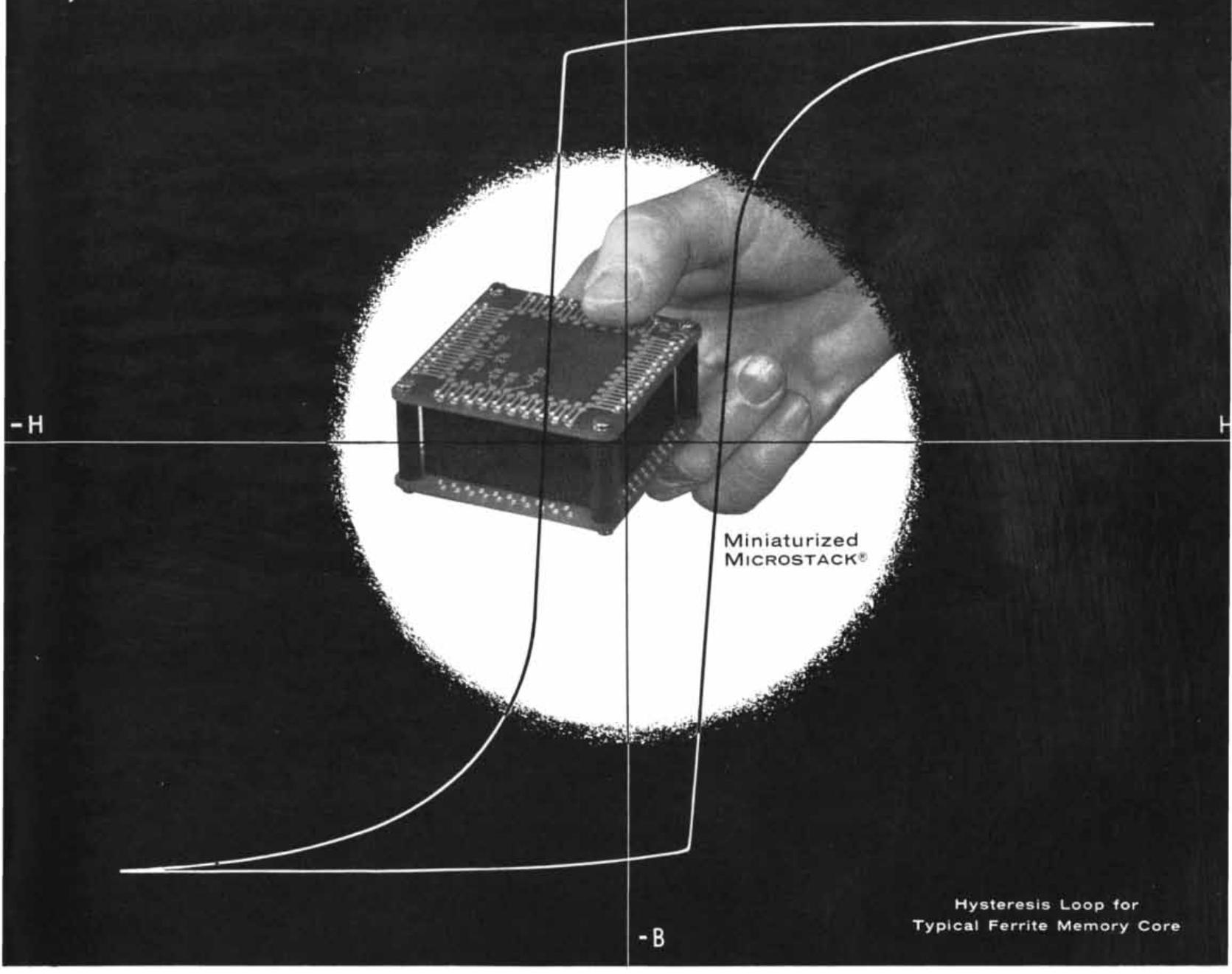
DIRECT-CURRENT DYNAMO is made by substituting a commutator for slip rings. The commutator, a ring divided into two segments, switches the sides of the loop from brush to brush so that the current flowing through each brush always goes in the same direction.

tried and failed. On August 29, 1831, he began his fifth attempt and was rewarded almost at once by the happy accident that every experimenter hopes for. He had wound two coils of wire on opposite sides of an iron ring, insulated from each other and from the ring. A battery sent current through the first coil, magnetizing it, and a galvanometer was connected to the end of the second. As in all the previous trials, no current was detected in the second coil. But then Faraday noticed that whenever the battery was connected to or disconnected from the first coil, the galvanometer indicated a momentary current. He had at last found the key: a *change* in the magnetic field created by the first coil produced a current in the second.

Faraday immediately set out to investigate all possible types of this "transient effect," as he called it. He wound a coil of wire around a straight core and placed the core between two bar magnets arranged to form a V. When he pulled the magnets away, a current flowed through the coil. "Hence," he noted in his diary, "distinct conversion of Magnetism into Electricity." Similarly, he induced a current by thrusting a bar magnet into a coil of wire and obtained a current in the opposite direction by withdrawing the magnet. And he reduced his apparatus to its fundamentals when he induced a current in a simple loop of wire merely by passing it through a magnetic field.

All these experiments produced intermittent surges of current, lasting only as long as the relative motion of conductor and magnetic field. Faraday now arranged for continuous motion by rotating a copper disk between the poles of a permanent magnet. A wire around the axle of the disk ran to a galvanometer, and another wire led back from the meter to a metallic conductor held against the rim of the disk. As long as the disk was turned, the galvanometer indicated a continuous current. "Here therefore," Faraday wrote, "was demonstrated the production of a permanent current of electricity by ordinary magnets." He called the device a "new electrical machine" and suggested that its power could be increased by using several disks. Then he dropped the matter.

Faraday's experiments and his observations on them actually contained a number of clues to effective generator design. Had they been recognized, much of the trial, and more of the error, of



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the next half-century would have been avoided.

The most important clues were contained in his general statement: "If a terminated wire [*i.e.*, one forming part of a complete circuit] move so as to cut a magnetic curve, a power is called into action which tends to urge an electric current through it." This revolutionary idea of magnetic curves or lines of force was not accepted by most of the physicists of the time. It was not until James Clerk Maxwell published his mathematical interpretation of Faraday's model in 1864 that the idea took hold.

But Faraday had already shown in 1831 that, in each of his methods of producing electricity from magnetism, the cutting of lines of magnetic flux by a conductor is the crucial factor. This was true whether he changed the field (by connecting or disconnecting the battery), moved the magnet or moved the conductor. He had discovered the principle that came to be called Faraday's law, which states that the voltage induced in a conductor is directly proportional to the rate at which the conductor cuts lines of magnetic flux. To maximize the rate, the conductors in an ideal generator should pass through the field at right angles to its lines of force. This is perfectly obvious, but only to someone who visualizes the magnetic field as being made up of lines of force. Those who followed Faraday did not, and as a result an efficient armature did not appear for many years.

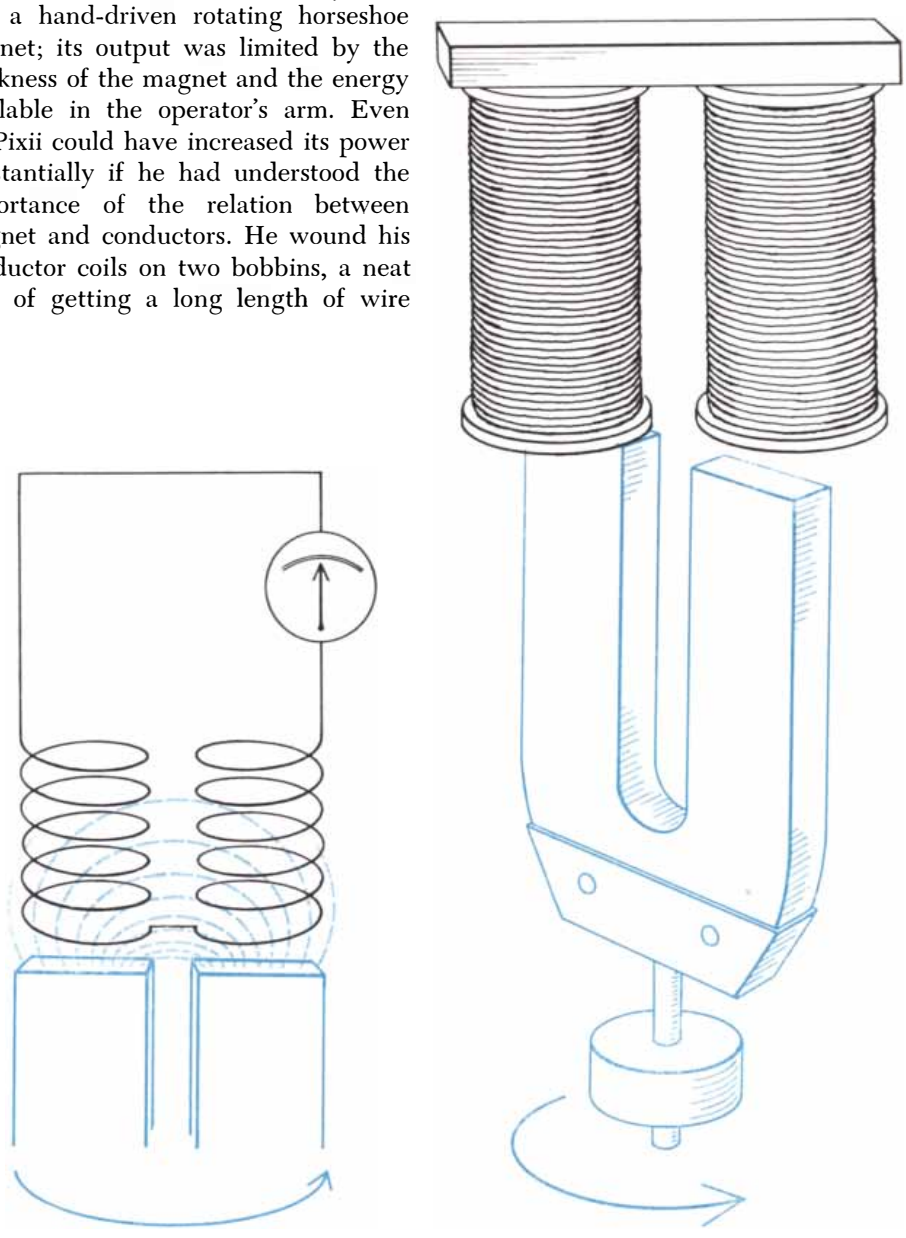
Another clue lay in the fact, duly recorded by Faraday, that coils wound on an iron ring gave an induced current "far beyond" that obtained from coils on a wooden core. The current was stronger because the iron provided a better magnetic circuit, concentrating the flux so that more lines of force passed through and cut the second coil. Neither Faraday nor his successors realized this, and in the early development of the dynamo the question of the magnetic circuit was ignored. It was simply adapted to fit each change of shape in the armature, sometimes by chance increasing the flux cut by the conductor, but just as often decreasing it.

Having used both permanent magnets and electromagnets in his experiments, Faraday remarked on the "similarity of action, almost amounting to identity, between common magnets and either electro-magnets or volta-electric currents." Yet he continued to distinguish between the two sources of magnetism. And the early builders of generators for some reason used clumsy permanent magnets exclusively, although electromagnets are lighter and more powerful. It was not until the 1860's that electromagnets were generally adopted.

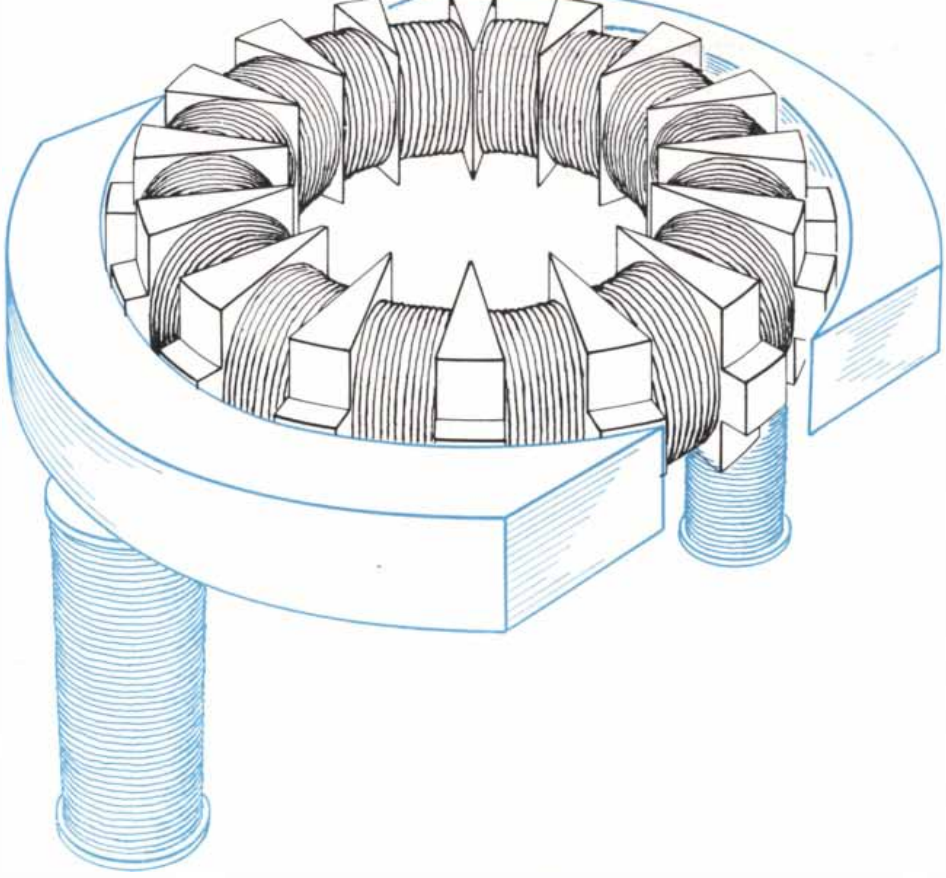
With the conclusion of Faraday's 1831 experiments the first phase in the development of dynamo technology opened. The basic discovery had been made; there was theory, but no immediate interest in applying it. Electromagnetic induction seemed a far less powerful source of current than the chemical battery. More important, there was no apparent use for large currents of electricity and no incentive to develop machines to generate them.

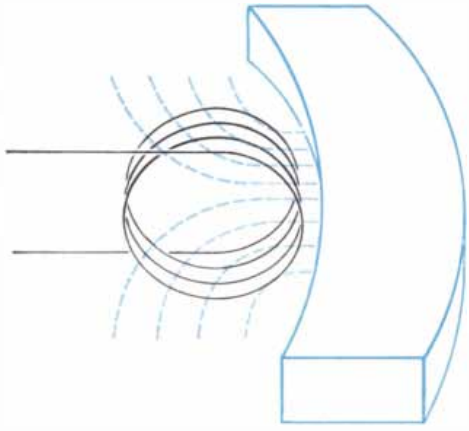
As always, there were tinkerers. In 1832 Hippolyte Pixii exhibited a machine based on Faraday's principles in Paris. Producing very little power, it was in effect no more than a model of a generator. The device had stationary coils and a hand-driven rotating horseshoe magnet; its output was limited by the weakness of the magnet and the energy available in the operator's arm. Even so, Pixii could have increased its power substantially if he had understood the importance of the relation between magnet and conductors. He wound his conductor coils on two bobbins, a neat way of getting a long length of wire into a small space. At best, however, only a small proportion of the wire can ever be perpendicular to the field in this arrangement.

Pixii's first model produced alternating current as the rotating field cut the conductors first in one direction and then in the other. Alternating current seemed altogether pointless, and at Ampère's suggestion Pixii equipped his second version with a commutator so that it would deliver direct current, as a battery does. (A commutator is a rotating switch that reverses the connection between the armature winding and the outside circuit each time the current changes direction in the winding,

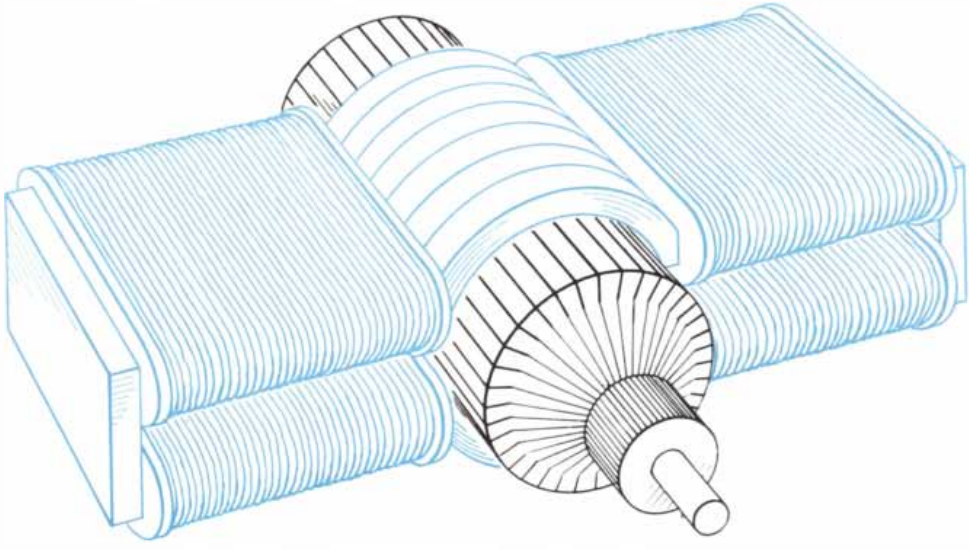


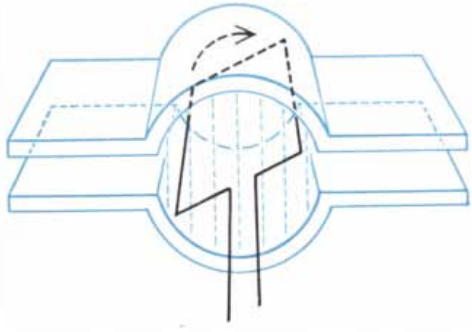
PIXII'S GENERATOR of 1832 had a permanent horseshoe magnet rotated by hand beneath two stationary coils wound on bobbins. Its shortcoming (*illustrated by the drawing at left*) was that, because of the manner of winding, only a small part of each coil was cut perpendicularly by the rotating magnetic field. This was a fault of all bobbin-wound generators.





PACINOTTI'S GENERATOR of 1860 introduced the ring-wound armature, improved the magnetic circuit and utilized electromagnets. The advantage of his design (*illustrated at right*) was that the iron ring provided a good path for the magnetic flux and more of each coil was in position to cut lines of force at right angles. But the inner portion of each turn of wire was still ineffective.





HEFNER-ALTENECK'S GENERATOR of 1872 brought the final basic step in armature design: the drum winding. In this method (*as shown at right*) almost all the armature wire was arranged so as to cut perpendicularly through the lines of magnetic force.

so that the external current always flows in the same direction.) Actually alternating current is better suited to electric power transmission, but it was many years before engineers broke away from the tradition of direct current that was established at this time.

Another experimental generator was built in 1833 by an American, Joseph Saxton. In his design a pair of bobbin-wound coils rotated just beyond the poles of a stationary horseshoe magnet. In the next few years similar machines, still very small, were developed in response to a prevalent medical fad. It was widely believed that a weak electric current sent through the body had a therapeutic effect. This was the first "commercial" application of Faraday's discovery.

The first real economic impetus, however, appeared only in 1839 with the invention of electrotyping. This process, in which copper is deposited by electrolysis on a mold of an engraving, shortly led to the general development of electroplating. Now there was a need for more current than batteries could conveniently supply.

An English engineer, John Stephen Woolrich, saw the possibilities here for an electric generator, and in 1842 he patented a modification of the spinning-bobbin machine. He increased the strength of the magnetic field by stacking several flat horseshoe magnets together and improved the design of the commutator to produce the more constant current required for electroplating. Woolrich's generator was driven by steam instead of by hand, and it delivered useful amounts of current for an industrial process, but it was essentially a beefed-up version of the simple permanent-magnet machine, or magneto-electric generator.

About a decade later a much broader field of application began to open—electric lighting, originally for lighthouses. A Frenchman, F. Nollet, seems to have been the first to think of the dynamo in this connection, but he did so in a rather indirect way. His source of illumination was to be a "limelight," a block of lime heated to incandescence by an oxyhydrogen flame. He proposed to get the necessary oxygen and hydrogen from electrolysis of water, and for this purpose constructed a generator in which a number of coils rotated past the poles of horseshoe magnets. The system was unsuccessful but it suggested to Frederick Hale Holmes, an English engineer, that similar generators might better supply power for the new carbon-

arc lamps then being developed. In 1857 he rigged up a machine in which 36 permanent magnets rotated past stationary coils. It weighed 4,000 pounds and produced less than 1,500 watts. But the carbon arcs it powered did provide a brilliant light, and it was the precursor of several practical, if inefficient, generators.

With Holmes's big lighthouse installations the magnetoelectric design had gone about as far as it could. The next step was to switch from permanent magnets to the far more efficient electromagnet. Suggested by Søren Hjorth of Denmark in 1855, the idea was patented in 1863 by Henry Wilde of England. In the first models the electromagnets were supplied with current by batteries or by small magnetoelectric generators. Soon a number of workers recognized that the auxiliary source is not necessary—that the generator itself can supply the current needed to excite the magnets. The small amount of residual magnetism that always remains in the iron core of the electromagnet provides the initial field, and thereafter the strength of the field increases as the output of the generator builds up.

The self-excited "dynamoelectric machines" represented a considerable advance over the earlier magnetoelectric machines. In their armature design and magnetic circuits, however, they still reflected serious gaps in the theoretical understanding of induction. In 1860 an Italian physicist, Antonio Pacinotti, built a machine that incorporated large improvements in both. First of all he wound his coils on a ring that revolved in the plane of the lines of force between two electromagnets. This arrangement put a larger proportion of the winding in position to cut the lines of force perpendicularly than could any type of bobbin armature. Secondly, he made the ring out of iron, which, as has already been mentioned, increases the magnetic flux that threads the coil. Pacinotti's description of his apparatus in an Italian scientific journal attracted little attention. The electroplaters, who were still the major consumers of electric current, probably never saw the report, and the physicists who did read it presumably were not interested in application. In this case a gap between discovery and application resulted from lack of communication between scientists and engineers.

The ring winding was rediscovered by Zénobe Théophile Gramme of France in 1870. In principle his machine did not differ at all from Pacinotti's, but Gramme was associated with capable businessmen, who saw to it that the invention did not go unnoticed. Very soon the Gramme machine and modifications of it became standard equipment both for electroplating and for arc lamps in lighthouses and factories.

The final improvement in armature design came in 1872 with the invention, by F. von Hefner-Alteneck in Germany, of the drum winding. On a ring only the outer portion of each turn of wire produces a useful voltage; the voltage in the inner portion actually works in the wrong direction. The drum eliminates the inner portion completely and puts a much greater length of wire in a position to cut the field perpendicularly.

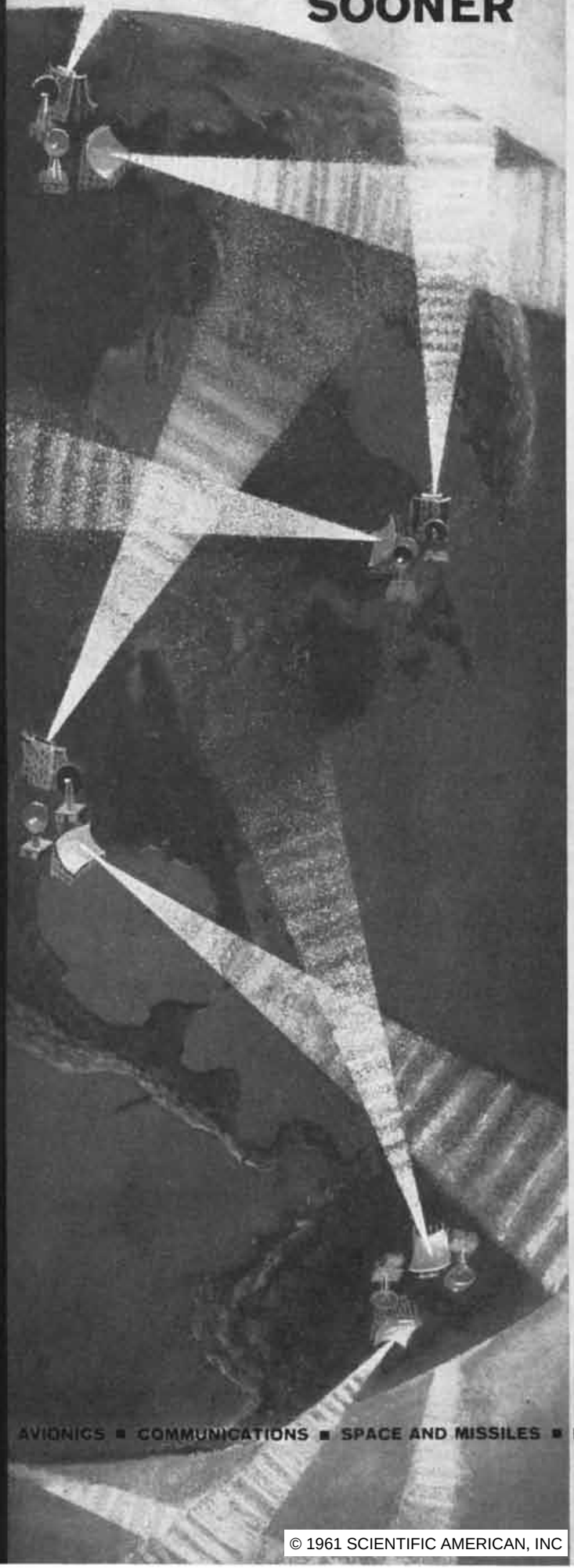
Hefner-Alteneck had started with a wooden drum but he shifted to iron. At that point the generator had almost reached its present form. Subsequent builders discovered the importance of minimizing the air gap in the magnetic circuit. This they did by such measures as curving the pole pieces of the magnets to fit around the armature and countersinking the windings in slots in the drum so that its iron surface could be brought closer to the magnets. In 1886 the British engineers John and Edward Hopkinson showed how to predict the performance of magnetic circuits, thereby finally taking generator design out of the trial-and-error stage.

By 1890 a flourishing electroplating industry, as well as the mushrooming lighting companies, could obtain direct-current generators about as efficient as those available today. One more giant step in electrical technology remained: the generator had yet to be teamed with the electric motor.

When Faraday sought to produce electricity from magnetism he was looking for the reverse effect of the motor principle—the force exerted by a magnet on a wire carrying a current—that he had demonstrated in 1825. But the electric motor was developed along different lines, and for the most part by different inventors, from the generator. Only gradually did it appear that the motor is the simple converse of the generator and the generator's natural complement in industry and transportation. The importance of reversibility was overlooked until central-station plants for lighting demonstrated that electricity is above all an efficient means of transmitting energy over long distances. By the end of the 19th century centrally generated electricity was beginning to replace steam as the motive power in railroading and, during the opening years of the 20th century, in industry generally.

IN COMMUNICATIONS... ITT MAKES THE FUTURE HAPPEN SOONER

In 1941, Andre G. Clavier, an ITT scientist, detected the phenomenon now known as tropo-scatter.



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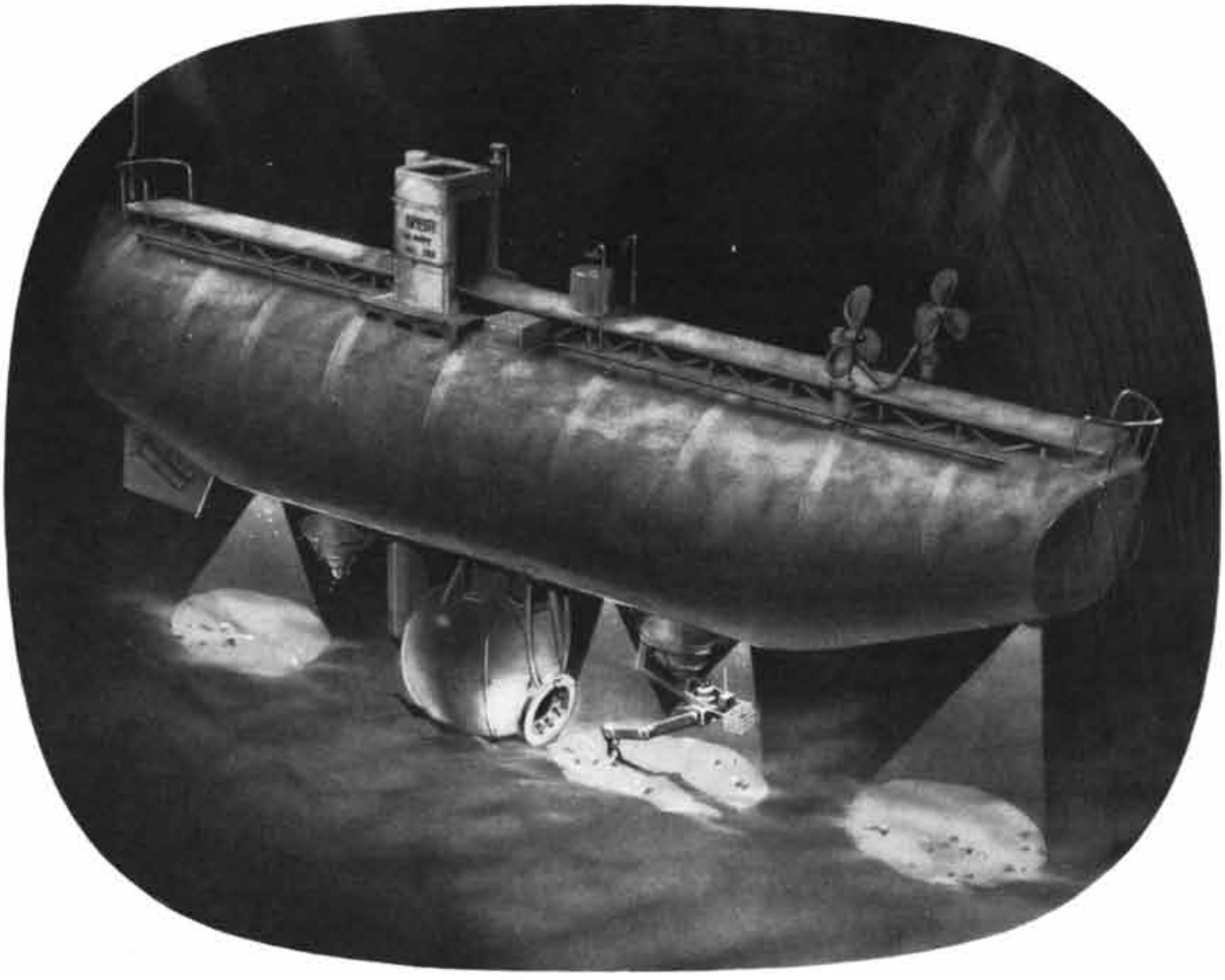

Navy "arms" Trieste to explore ocean bottom

When the Navy's deep-diving bathyscaph, Trieste, makes its next descent to the ocean floor, it will be equipped with an "Arm" that can reach out and pick up samples of material from the mysterious and little-known depths some seven miles below the surface.

A General Mills Mechanical Arm manipulator, adapted to withstand the tremendous pressures of 8-9 *tons* per square inch encountered at the deepest parts of the ocean, will provide this unique capability. The Trieste "Arm" will be modified by means of special oil-filled units designed to equalize pressures on motors and other critical parts. Oceanographers riding in the steel ball suspended beneath the Trieste will control the "Arm" by means of a compact control box with individual lever-action switches to provide direction and variable speed for each of six motions.

The Trieste program is under the joint sponsorship of the Bureau of Ships and the Office of Naval Research, who have indicated that the next dive will come sometime this summer in the Atlantic.

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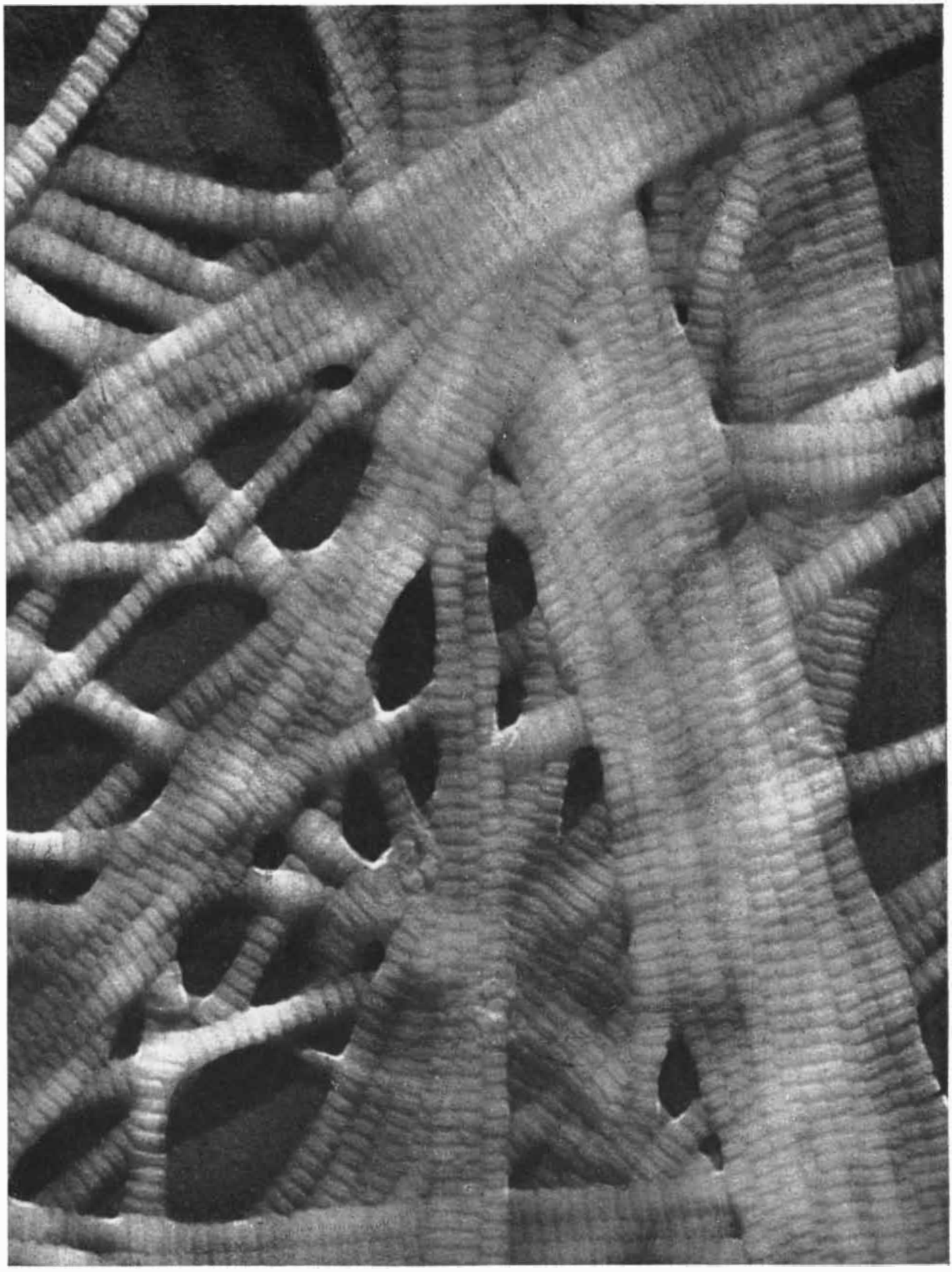


COLLAGEN FIBRILS, carefully pulled away from human skin, show bands spaced about 700 angstrom units (A.) apart. It was first believed that this represented the length of the underlying collagen molecule; actually the length is about four times greater (*see illustration on page 123*). This electron micrograph by the author is reproduced at a magnification of 42,000 diameters.

COLLAGEN

The main constituent of connective tissue, it accounts for a third of the protein in the human body. Its nature has been clarified by dissolving it and allowing its molecules to reassemble into fibers

by Jerome Gross

Collagen is perhaps the most abundant protein in the animal kingdom. It is the major fibrous constituent of skin, tendon, ligament, cartilage and bone. Its properties are diverse and remarkable. In tendon it has a tensile strength equal to that of light steel wire; in the cornea it is as transparent as water. It accounts for the toughness of leather, the tenacity of glue and the viscousness of gelatin. It also underlies the development of crippling deformities associated with the rheumatic diseases and with a number of congenital defects of the skeleton, blood vessels and other connective tissue.

By piecing together information derived from X-ray diffraction, chemical analysis, electron microscopy and many other techniques, it is now possible to present a reasonable account of the way collagen fibers are built up from long-chain molecules. Particularly instructive was the discovery that tiny collagen fibers, or fibrils, can be dissociated into their constituent molecules and then reaggregated, outside the living organism, into their original form. This disassembly-reassembly technique, which was perhaps first clearly demonstrated with collagen, has since been successfully applied to other giant molecules and to even more complex biological systems [see "Tissues from Dissociated Cells," by A. A. Moscona; SCIENTIFIC AMERICAN, May, 1959]. The procedure of taking biological materials apart and putting them together again provides much more insight into dynamic mechanisms than does the traditional biochemical approach of breaking things to bits and analyzing the pieces.

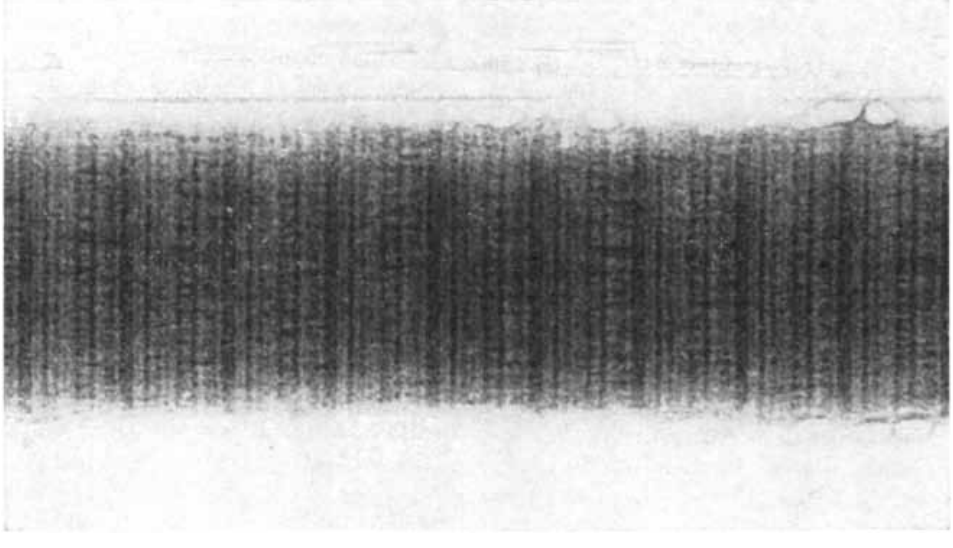
Collagen appeared very early in evolution, at least as far back as the coelenterates (a phylum including jellyfishes and sea anemones) and sponges, and it seems to have changed very little in structure and composition since then. It usually appears as bundles of individual, nonbranching fibrils, varying greatly in diameter from tissue to tissue. In skin, under an ordinary light microscope, these bundles appear to be woven together at random, but a definite order emerges if larger areas of tissue are examined. In tendon, collagen fibers are arranged in long parallel bundles. In the cornea of the eye, transparency depends upon the orderly arrangement of collagen fibrils that probably have a refractive index identical to that of the substance in which they are embedded. (The same type of order appears in the translucent skin of the developing amphibian embryo, but after metamorphosis the skin acquires a somewhat random intermeshing structure.) In bone, the collagen fibrils are organized much like the struts and girders of a bridge; the mineralization of bone follows the detailed fine structure of the fibrils. In cartilage, which coats the inner surface of joints and which must have considerable elasticity and smoothness, the collagen fibrils are usually very thin, randomly oriented and embedded in a large volume of extracellular matrix.

Collagen is synthesized primarily by cells called fibroblasts. The basic collagen molecule is a group of three polypeptide chains each composed of about a thousand amino acid units linked together. In ordinary proteins the chains are assembled from the standard assortment of 22 amino acids, and once linked together end to end the acids are not further altered. In the synthesis of collagen, however, two unusual amino acids, hydroxyproline and hydroxylysine, seem to be formed *after* the molecular chain has been assembled; the new amino acids are created by addition of hydroxyl (OH) groups to some of the proline and lysine units in the chain. This alteration of the primary molecular structure has not been observed in the synthesis of other proteins.

Proline and hydroxyproline, which together make up as much as 25 per cent of the links in the collagen molecule, prevent easy rotation of the regions in which they are located, thus imparting rigidity and stability to the collagen molecule. The higher the content of proline and hydroxyproline, the higher the resistance of the molecule to heat or chemical denaturation. Preliminary studies suggest that collagens have another distinctive feature: in long stretches of the molecular chain every fourth position seems to be occupied by glycine, which is followed immediately by proline or hydroxyproline. In any case, all collagens studied so far, regardless of their source, contain about 30 per cent glycine, with a variation of less than 5 per cent.

Collagen owes its properties not only to its chemical composition but also to the physical arrangement of its individual molecules. The basic molecular chain is twisted into a left-handed helix, and three such helices are wrapped around each other to form a right-handed superhelix [*see illustration on page 123*]. The three chains appear to be held together by hydrogen bonds established between the oxygen atoms, located where amino acids are joined by peptide linkages in one chain, and the nitrogen atoms, located at peptide linkages in an adjacent chain. This picture of the structure was first proposed in 1954 by the Indian workers G. N. Ramachandran and G. Kartha, and later refined by two British groups: Alexander Rich and F. H. C. Crick in Cambridge and Pauline

COLLAGEN MOLECULES, dissolved from the collagen of the fish swim bladder, are enlarged 140,000 diameters. They are 2,800 to 2,900 A. long and 14 to 15 A. wide. This electron micrograph was made by Cecil E. Hall of the Massachusetts Institute of Technology.



COLLAGEN FIBRIL is built up of collagen (or tropocollagen) molecules that overlap as shown on the opposite page. The intricate fine structure repeats about every 700 A.; the magnification is 250,000 diameters. Alan J. Hodge made electron micrograph at M.I.T.

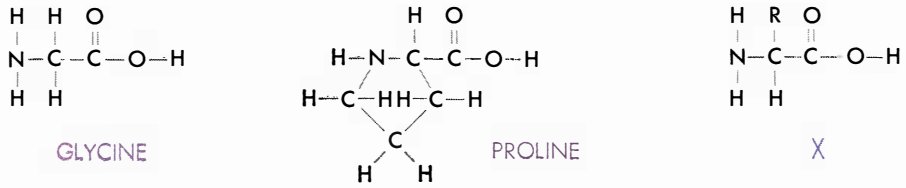
M. Cowan and S. McGavin in London. The superhelix varies in cross section and electric charge along its length. There is convincing evidence from recent electron micrographs that these variations, or "bumps," are irregularly spaced. Alan J. Hodge and Francis O. Schmitt of the Massachusetts Institute of Technology have suggested that the molecule also has a short flexible "tail" at each end that participates in fibril formation.

For a long time it was believed that the collagen molecule was about 700 angstroms long (an angstrom is one ten-billionth of a meter). This length was inferred from early electron micrographs of collagen fibrils, which showed a series of regular bands with such a spacing. It was assumed that the bands marked the places where the molecules were joined end to end. As so often happens in science, things turned out to be more complex and more interesting than they had seemed at first.

The clue to the currently accepted value for length came from experimentally reconstituted collagen. It has been known since at least 1872 that if collagen fibers are dissolved in acid, reconstituted fibers will automatically appear when the acid is neutralized. The experiment remained little more than a curiosity until 1942, when it was repeated by Schmitt and his associates. It was this group's electron micrographs of natural collagen that had first shown the 700-angstrom periodicity. They were pleased but not greatly surprised to find that the same periodicity appeared in the reconstituted fibers [*see top illustration on page 124*]. The molecular length of 700 angstroms seemed to be confirmed.

Several years later V. N. Orekhovich and his associates in the U.S.S.R. found needle-like entities when they observed samples of reconstituted collagen under a light microscope. They believed that these entities, which they called procollagen, were newly formed collagen molecules capable of linking up to form the native fibril. Upon learning of this work Schmitt and his co-workers were naturally curious to examine the new material in the electron microscope. When Schmitt, John H. Highberger and I followed the Orekhovich method, we discovered a new type of reconstituted collagen fibril different in structure from any seen before. This new fibril showed bands spaced at about 2,800 angstroms, and a fine structure that surprised us by being symmetrical [*see middle illustration on page 124*]. We designated

a FREE AMINO ACIDS

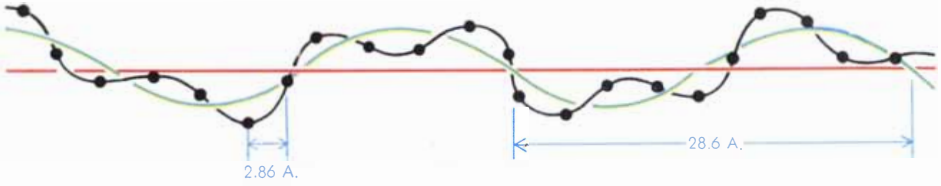


b MOLECULAR CHAIN

—X—GLY—PRO—HYPRO—GLY—X—

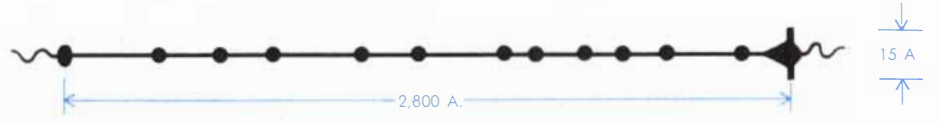
c SINGLE-CHAIN MOLECULAR HELIX
MAGNIFICATION: 17,500,000

d SINGLE-CHAIN COILED HELIX
MAGNIFICATION: 17,500,000

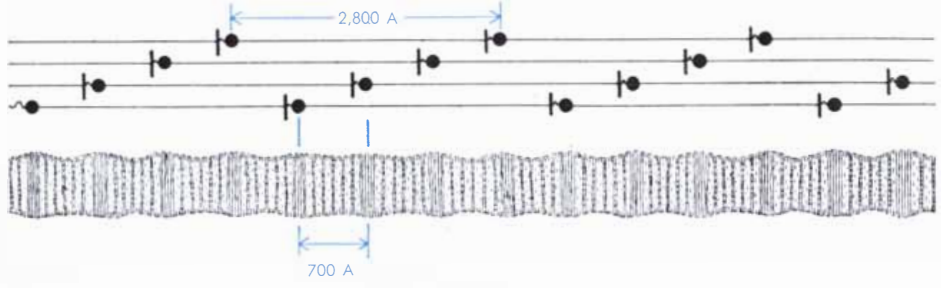


e THREE-CHAIN COILED HELIX
MAGNIFICATION: 17,500,000

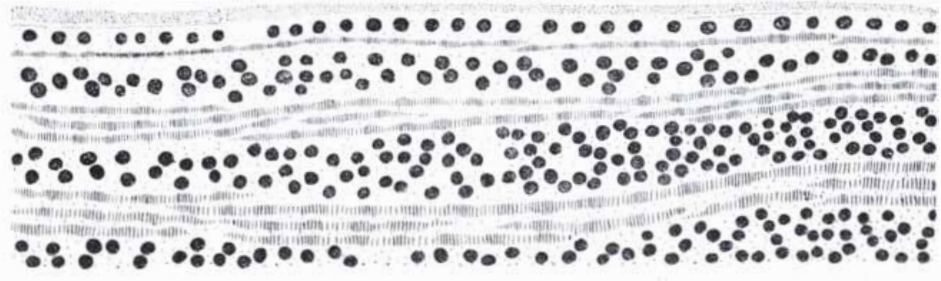
f TROPOCOLLAGEN MOLECULE
MAGNIFICATION: 330,000



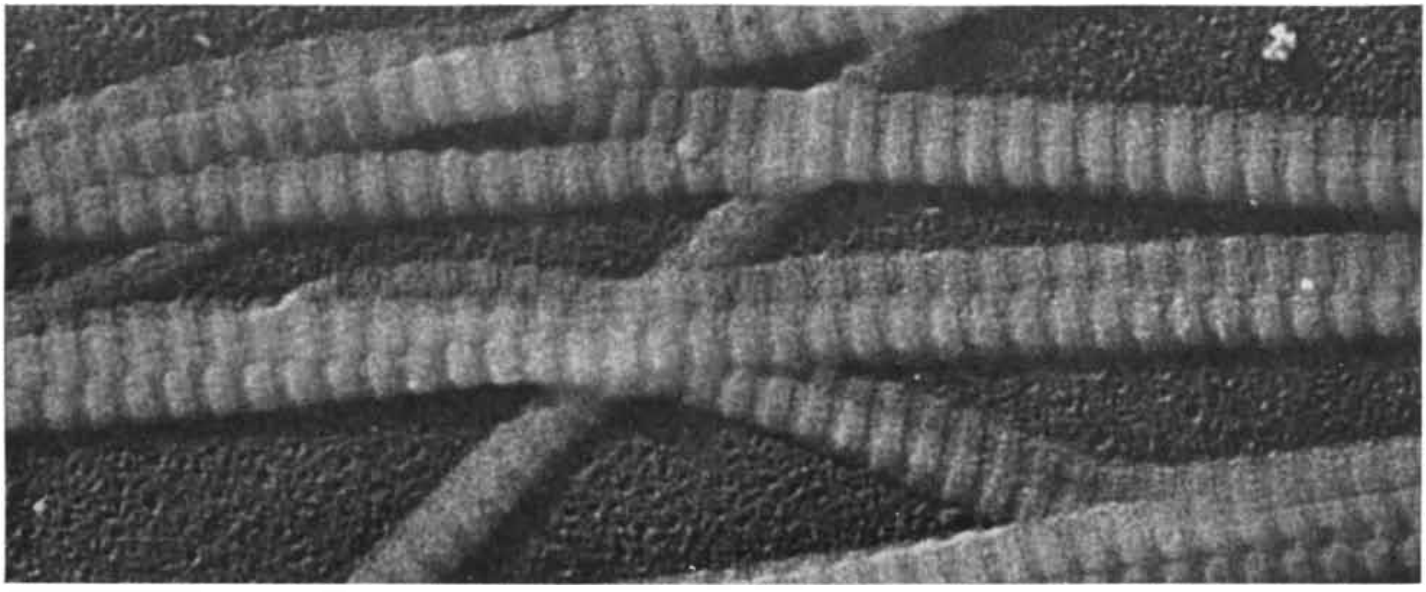
g COLLAGEN FIBRIL
MAGNIFICATION: 120,000



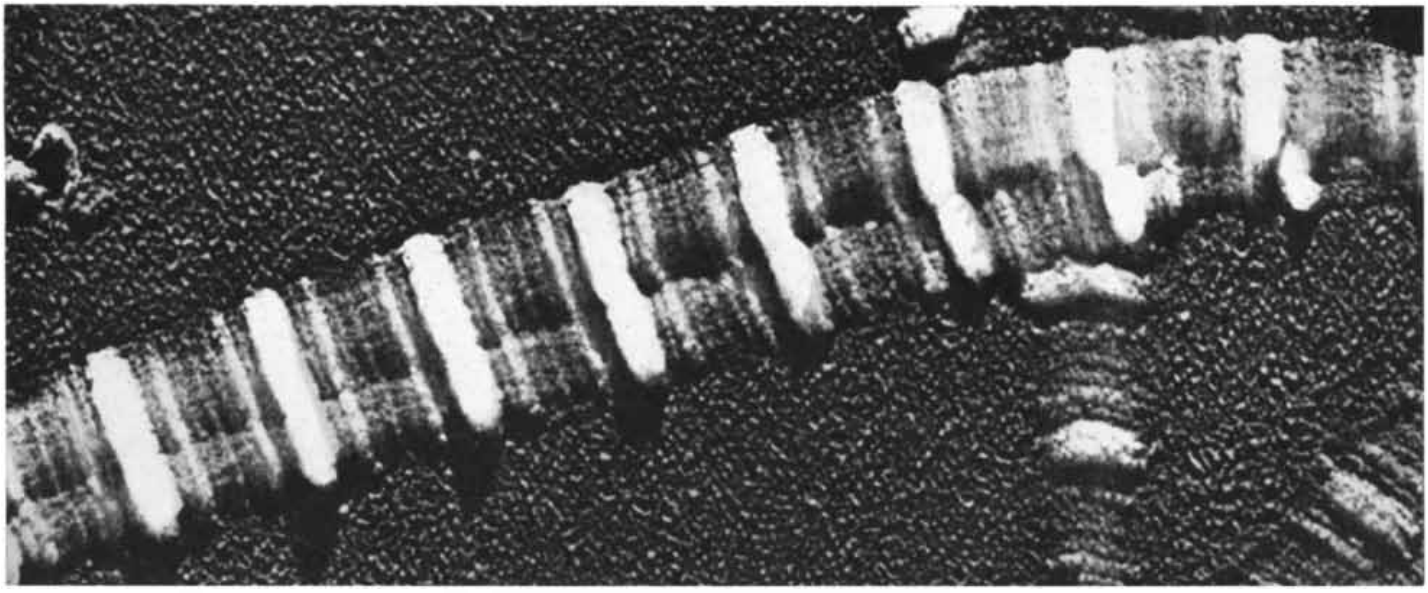
h CONNECTIVE TISSUE
MAGNIFICATION: 50,000



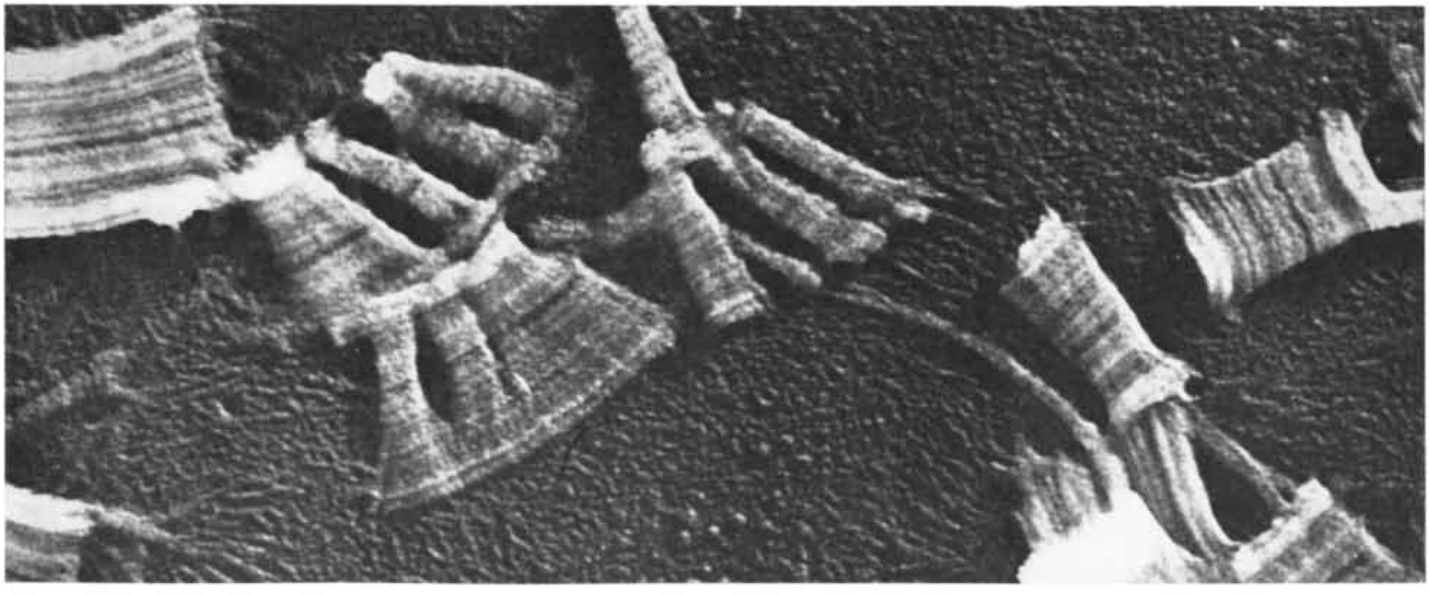
FORMATION OF COLLAGEN can be visualized in seven steps. The starting materials (*a*) are amino acids; the letter "R" in amino acid X represents any of some 20 different side chains. "Hypro" stands for hydroxyproline, created from proline after the molecular chain (*b*) has been formed. The chain twists itself into a left-handed helix; three chains then intertwine to form a right-handed superhelix, which is the tropocollagen molecule. Many molecules line up in staggered fashion (*g*), overlapping by one-quarter of their length, to form a fibril. Fibrils in tissue (*h*) are often stacked in layers with fibrils aligned at right angles.



RECONSTITUTED COLLAGEN fibrils form spontaneously when an acid solution of native collagen is neutralized. The reconstituted fibrils duplicate the native form. The three electron micrographs on this page are all at the same magnification: 70,000 diameters.



"FIBROUS LONG SPACING" form of collagen is produced by adding glycoprotein to an acid solution of native collagen. The chief feature of this form is its symmetrical intraperiod fine structure. The spacing of the period is about 2,800 angstroms.



"SEGMENT LONG SPACING" form of collagen is produced by adding adenosine triphosphoric acid to an acid solution of collagen. The fine structure is asymmetrical, reflecting the underlying asymmetry of the tropocollagen molecule. The molecular arrangements that produce these three forms of collagen are depicted in the illustration at the bottom of pages 126 and 127.

this new type of structure "fibrous long spacing," or FLS, simply to indicate that it was fibrous and had a long period. The FLS material can be produced in almost 100 per cent yield by adding a negatively charged large molecule (such as the alpha-one acid glycoprotein derived from blood serum) to a dilute acetic acid solution of purified collagen.

We soon discovered that collagen could be recrystallized into still a third type of structure, which lacked the characteristic fibrous or beltlike appearance of the two other forms. The new material looked superficially like isolated segments of FLS, but closer examination revealed that the numerous crossbands were asymmetrically spaced [*see bottom illustration on opposite page*]. This structure is composed of threadlike units running perpendicularly to the bands. We called the arrangement "segment long spacing," or SLS, to indicate a nonfibrous material with a long period. SLS can be obtained by adding adenosine triphosphate (ATP) to acid solutions of collagen.

Any of the three structurally different forms can be dissolved and converted into either of the other two forms. We concluded that all three forms were being created from threadlike units about 2,800 angstroms long and less than 50 angstroms wide. Since this was evidently the fundamental unit of collagen structure, we named it "tropocollagen" (from the Greek meaning "turning into collagen"). The tropocollagen molecule, as we now know, is composed of the three helical chains.

A more refined estimate of the dimensions of tropocollagen was subsequently made by Helga Boedtker and Paul Doty after they had studied collagen in solution. They estimate that the molecule is 2,900 angstroms long by 14 angstroms wide. Cecil E. Hall of M.I.T. has confirmed these dimensions by electron microscopy of individual molecules [*see top illustration on page 122*]. On the basis of these and other studies we can postulate how the three basic forms of collagen are assembled from the tropocollagen molecule.

In the native collagen fibril the molecules are lined up facing in the same direction and overlapping by about one-quarter of their length [*see illustration at bottom of next two pages*]. It is this overlapping that creates the periodicity of about 700 angstroms.

In the FLS form the molecules again lie side by side, but they are not all facing in the same direction and they do not overlap. Since there is no overlapping, the major periodicity measures

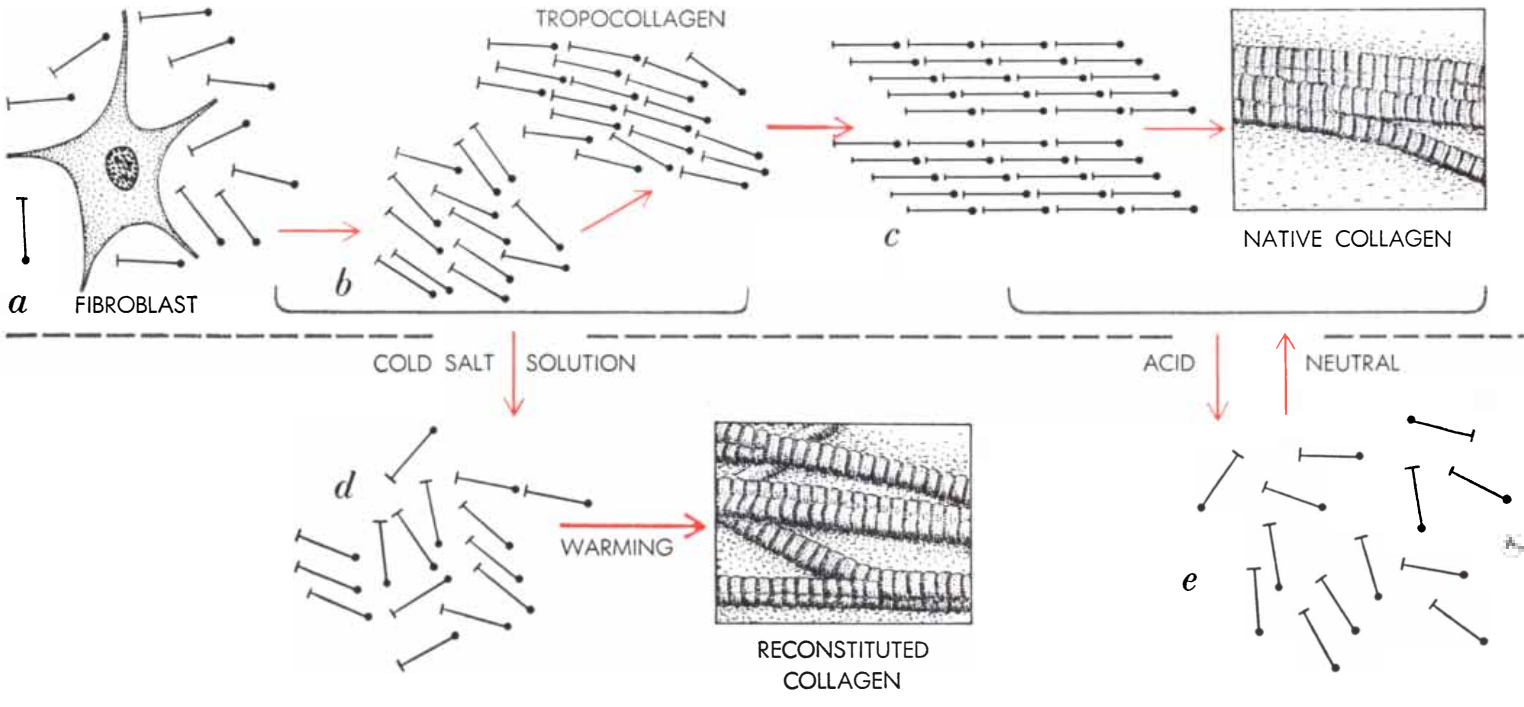
about 2,800 angstroms. The random positioning of "heads" and "tails" of the adjacent molecules accounts for the symmetrical fine structure, even though the discontinuities, or "bumps," along the length of the individual molecule are asymmetrically spaced. This can be understood by imagining two identical but nonsymmetrical molecules lying side by side and facing in opposite directions. If one were to take a blurred photograph, the two molecules would seem to blend into one and the two sets of irregularities would merge so that they would appear to be symmetrically spaced.

In the SLS form the molecules are also nonoverlapping but they all face the same way. As a result the discontinuities of the individual molecules are revealed in the electron microscope as an asymmetrical pattern of bands. Actually it is this pattern in electron micrographs that leads one to infer that the basic molecule contains irregularly spaced discontinuities.

Since these in vitro experiments employ acids in concentrations considered "unphysiological," they left us puzzled as to how fiber formation actually occurs in an animal. We began to gain insight into the natural process about eight years ago when we discovered that a certain fraction of collagen from young animals could be dissolved in cold neutral salt solution, and that simply by warming such solutions to body temperature we could make the dissolved collagen molecules polymerize spontaneously to form a typical cross-striated fibril with the native periodicity. The more rapidly the animal grows, the larger is the amount of collagen that can be extracted. If growth ceases as a result of starvation for a period as short as two days, this collagen fraction disappears from tissues. British investigators have demonstrated that the collagen extractable in cold salt solution is newly synthesized by the cells; it is still soluble because it is not yet tightly aggregated. As the collagen becomes older, dilute acids are required to extract it; upon further aging it becomes insoluble even in acids.

A similar aging process can be demonstrated in vitro with collagen extracted in cold neutral salt solution. When the solution is warmed to body temperature, a gel composed of typical banded fibrils forms; if it is quickly cooled again, most of the fibrils redissolve. If, however, the gel is allowed to stand at body temperature for 24 hours, it no longer dissolves upon cooling. And if it is aged at body temperature for two weeks, it becomes completely insoluble in dilute acids as well. Since the collagen is highly purified, we do not believe that this time-dependent aging results from interaction with enzymes or other substances. The aging is probably a function of the highly specific structure of the molecule alone. It is likely that if two parallel collagen molecules overlap by a quarter of their length, the charge distribution and three-dimensional configuration of adjacent sections are complementary and therefore attract each other; the "bump" of one fits into the "groove" of the other. The decreasing solubility with time can be explained by the increasing perfection of fit between the molecules as they gradually pack together in a "lock and key" type of association along their length. The "glue" binding the molecules ever more tightly is fundamentally a secondary bond created by electric forces, which rise sharply in strength as surfaces are brought closer and closer together.

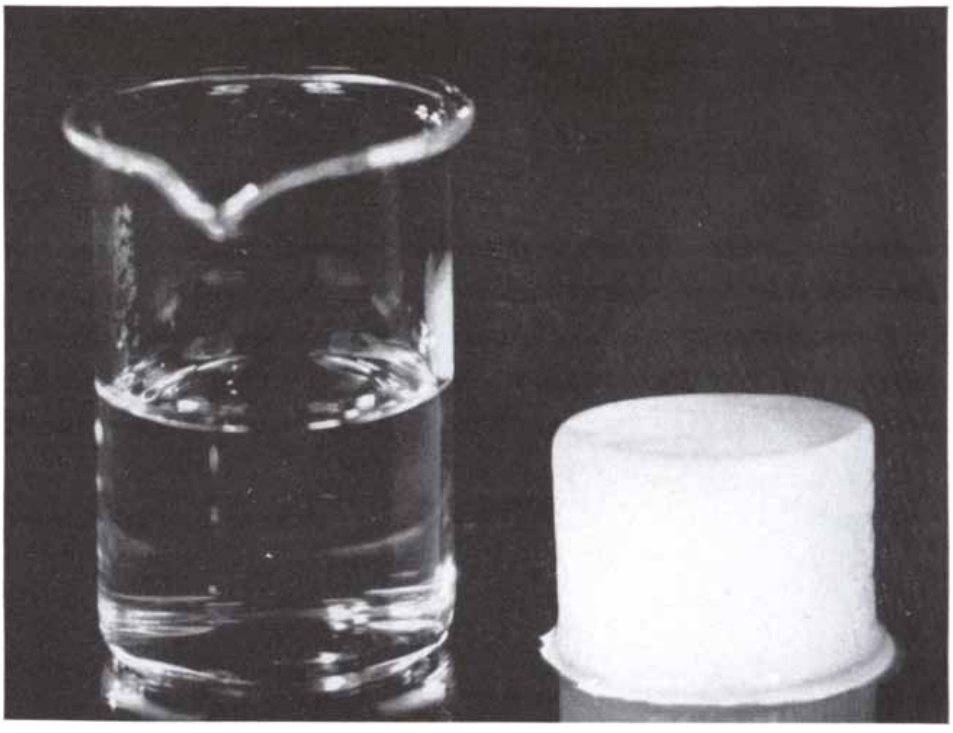
These studies suggest a reasonable picture for the first steps in the process by which the body produces collagenous or connective tissue. The fibroblast evidently synthesizes complete collagen molecules (the three-stranded tropocollagen) and extrudes them into the space outside the cells, where they polymerize into fibrils. Although polymerization may require nothing more than time and body heat, other substances in the extracellular environment may play a regulatory role.



RECONSTITUTION OF COLLAGEN can take place in three basic ways. In an animal, tropocollagen molecules (*b*), manufactured by cells called fibroblasts (*a*), overlap to form native collagen (*c*). Newly formed molecules are soluble in cold salt solution (*d*); simple warming yields reconstituted fibrils duplicating the native form. Alternatively, native collagen can be dis-

We are having difficulty explaining what happens next. How do collagen fibrils become organized into the highly ordered patterns that can be seen in skin, bone and cornea? The cornea, in particular, has a plywood-like structure in which successive layers of fibrils are laid down at right angles to each other in near-crystalline array [*see illustrations on next page*]. In studying sections of cornea, Marie A. Jakus of the Retina Foundation in Boston has observed that the fibrils of one layer lie along dark cross-striations in the fibrils below, which are oriented at right angles.

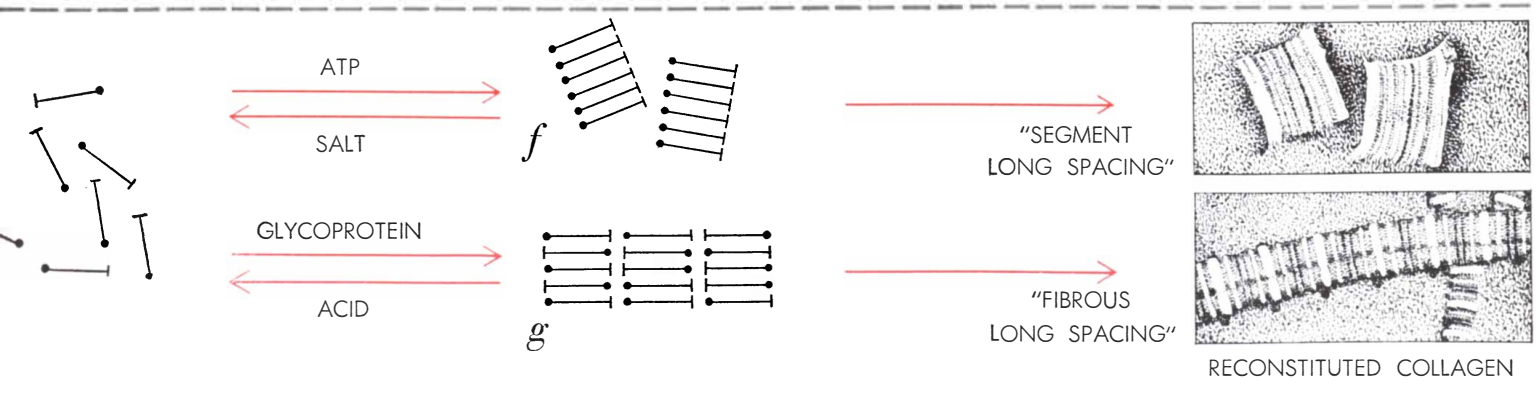
There is still no generally accepted mechanism to explain this intricate ordering. I am inclined to think that the tropocollagen molecules, after extrusion from the fibroblast, form a suspension of liquid crystals (loose semicrystalline aggregates). From such a suspension fibrils could be expected to condense in an orderly fashion. It has been shown that such suspensions of certain rod-shaped giant molecules will turn spontaneously into aggregates that display order in three dimensions. While we have not yet been able to duplicate this experiment with collagen, we have been able to precipitate collagen in broad sheets with a periodicity extending laterally over many square microns [*see illustration on page 130*]. A significant aspect of this pattern is the appearance of two degrees of order that are mutually perpendicular. Whereas the molecules themselves are laid down in parallel rows, other rows having like electric charge (visible as bands in the collagen fine structure) run at right angles to the molecular rows. One can imagine that with a suitable adjustment of conditions another layer of collagen molecules might precipitate on the first and follow not the molecular rows but the rows of electric charge.



BLOCK OF COLLAGEN (*right*) forms when a cold neutral salt solution of collagen (*left*) is warmed to body temperature for 10 minutes. Gel redissolves if cooled promptly.

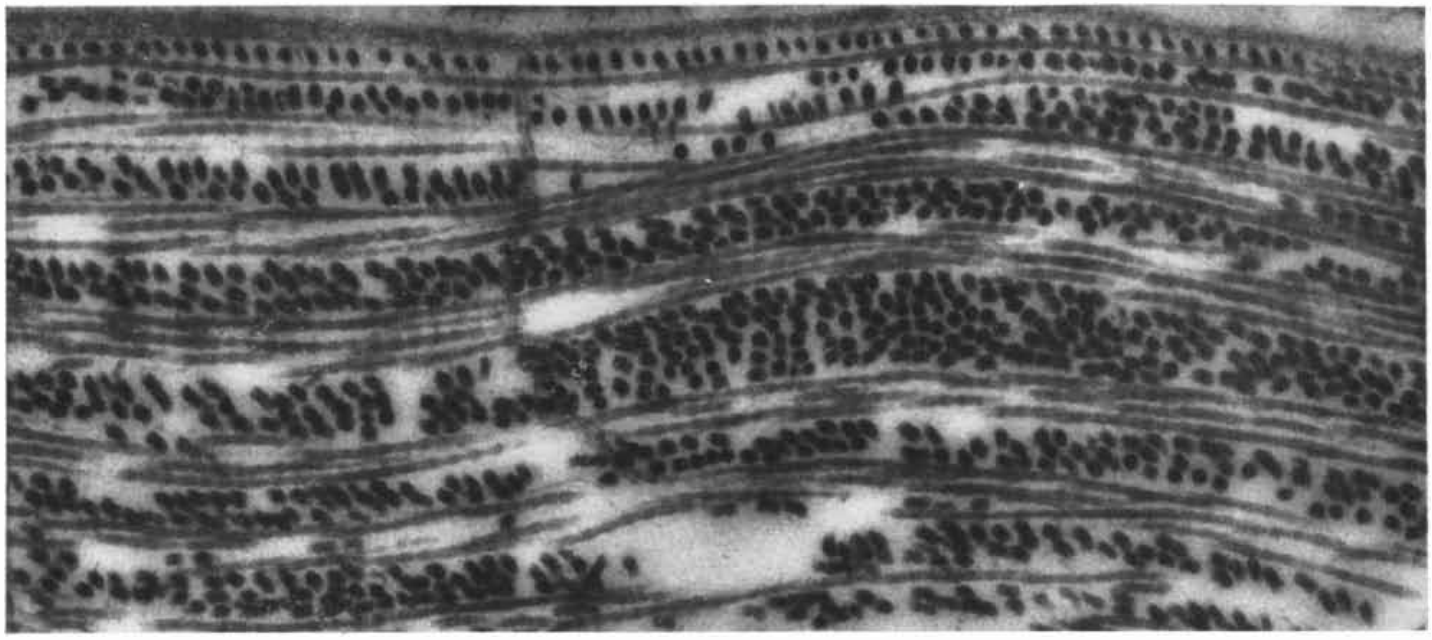
There are a number of questions to answer: If collagen molecules are being secreted at a constant rate from the cells, why should they not form fibrils all oriented in the same direction? And why should there be variations in the number of fibrils stacked one above the other within different layers? These puzzles might be explained if the secretion of collagen molecules from the cells were discontinuous in time, or "pulsed." In different sites at different times the duration of the pulse and the total amount of collagen secreted may differ. The thickness of the collagen layer would be determined by the duration of the "secretion pulse" and the amount of collagen secreted. The interval between pulses would allow time for fibrils to polymerize and would prevent intermingling of collagen in one layer with the next. The collagen molecules laid down during the single secretion pulse would be oriented in one direction only. Molecules secreted in the next pulse might then be oriented perpendicularly to the molecular rows of the preceding layer, being laid down along the rows of electric charge created by the periodicities lying in register.

We would also like to account for the remarkable uniformity in diameter of fibril bundles. Although the diameter

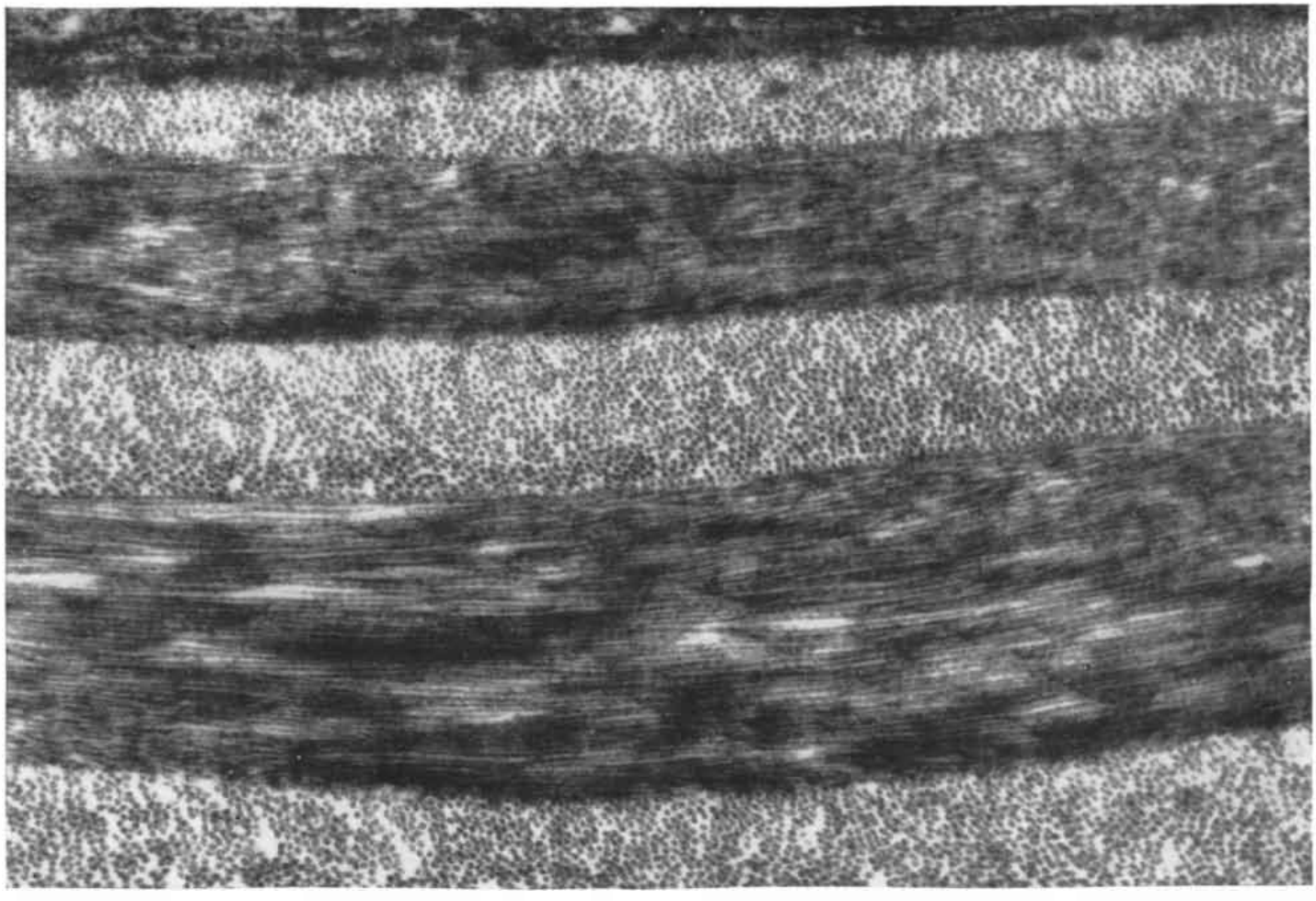


solved in acetic acid (*e*). Treating the resulting solution with adenosine triphosphoric acid produces the nonoverlapping. segment-long-spacing form of collagen (*f*). Treating the solution with glycoprotein produces the fibrous-long-spacing form (*g*), in which molecules face randomly in addition to not overlapping. The fine structure reflects the asymmetry of the tropocollagen molecule.

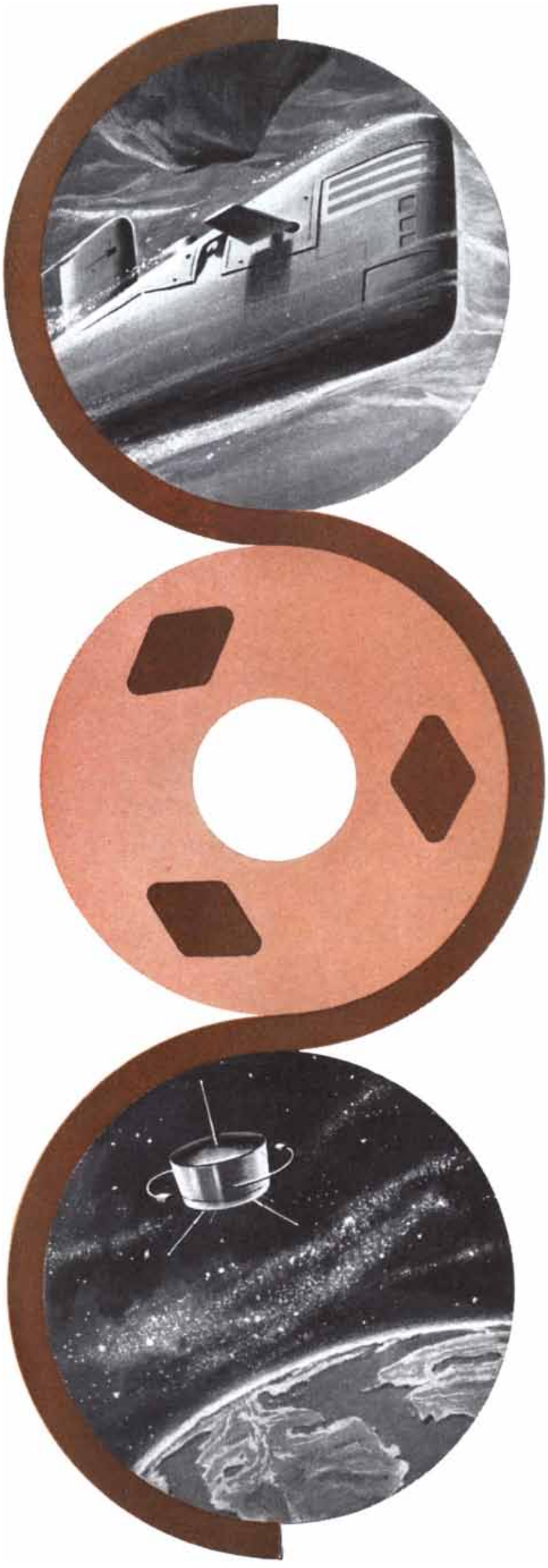
varies from one type of tissue to another, it is often constant for each type. Again the idea of discontinuous secretion of collagen molecules seems useful. As a first step we can imagine that a single group of molecules is secreted at about the same time and that these molecules are rather evenly distributed as a loose liquid crystal in a particular layer of extracellular space. The next step calls for the appearance of nuclei of some sort around which the molecules can begin to condense. It seems reasonable that nuclei would appear at about the same time throughout a given volume of space. In the last step the fibrils grow in size until the original supply of collagen molecules is exhausted. We need only specify that the fibrils grow at the same rate to explain how they all end up having about the same diameter. It is possi-



TADPOLE CORNEA consists of layers of collagen fibrils; the fibrils in one layer are at right angles to those in the next. The magnification is 56,000 diameters. This electron micrograph and the one below were made by Marie A. Jakus of the Retina Foundation.



FISH CORNEA surpasses that of the tadpole in precision. In some unexplained manner a random collection of collagen molecules is converted into fibrils that are stacked neatly into layers lying at right angles to each other. The magnification is 28,000 diameters.



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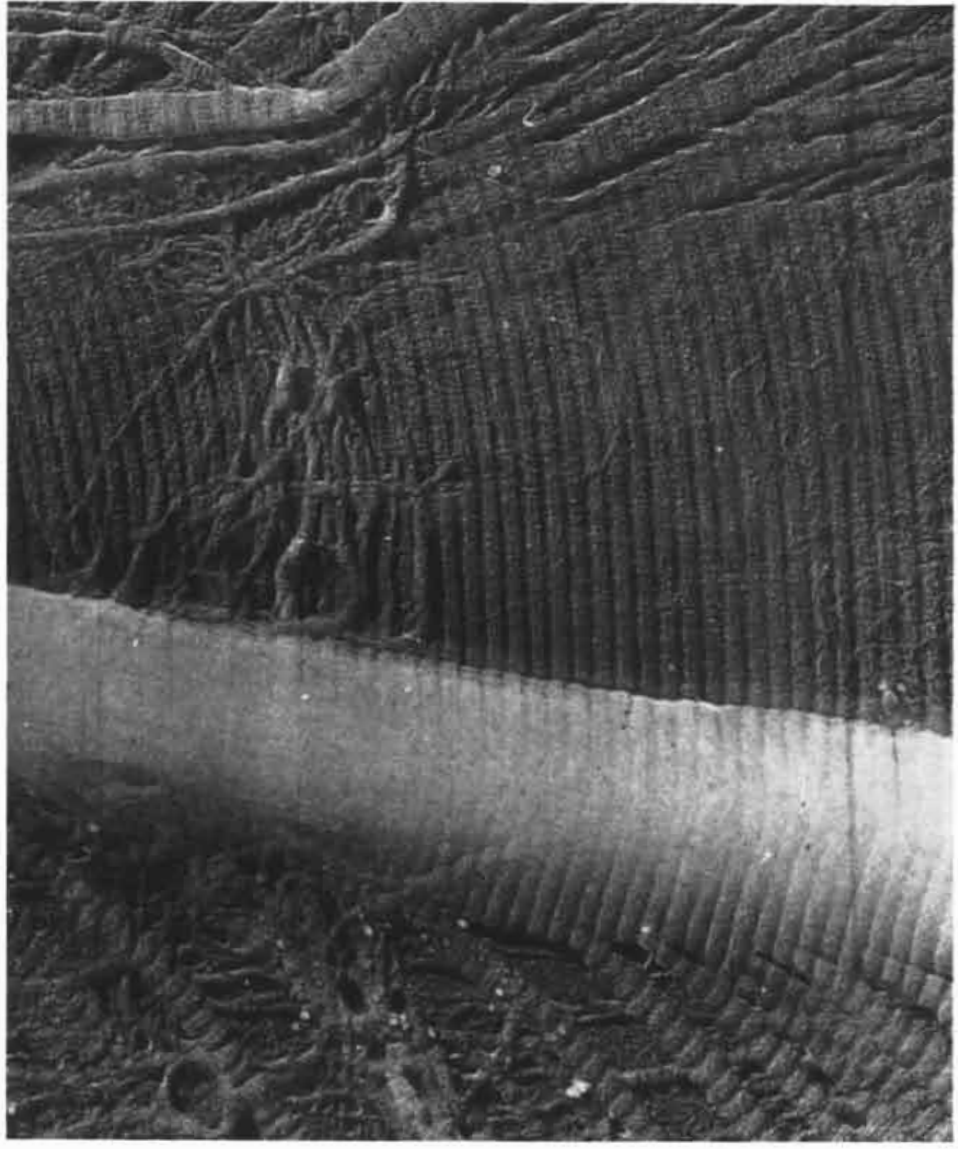

SHEET OF COLLAGEN precipitated from solution shows that tropocollagen molecules will lock themselves into an orderly two-dimensional array. Investigators are seeking conditions that will produce order in three dimensions. Magnification is 40,000 diameters.

ble that the timing and the rate at which fibrils form and grow are determined by noncollagenous substances in the matrix; the viscosity and charge distribution of this matrix might control the freedom of movement of the individual collagen molecules. Attempts at explanation such as these prove nothing in themselves. Their principal value is that they suggest experiments that may lead to better understanding.

One incentive for studying collagen so intensively is that it provides a valuable model for investigating the way in which the body assembles complex, reproducible structures from simple molecular building blocks. Another incentive is the medical one. In its growth and development the organism is continuously remodeling its tissues, a process of exquisite precision with regard to place, time and degree. It is possible that disturbances in the precise sequences of remodeling are responsible, at least in part, for some congenital malformations, for the crippling end results of rheumatic diseases and perhaps even for some of the changes in aging. Whether or not collagen itself is a target for the causative agent in diseases affecting connective tissue, such as rheumatoid arthritis, is still a matter of dispute. There is little doubt that severe crippling deformities of bones and joints, and the scarring of the heart, kidneys, blood vessels, lungs and other organs, are a manifestation of excessive production and aberrant arrangement of collagen in the affected tissues.

It is characteristic of medicine that frontal attacks on problems such as these seldom yield quick results. There is every reason to hope, however, that studying collagen at the fundamental level of molecular structure will lead ultimately to knowledge that can be applied in medicine.

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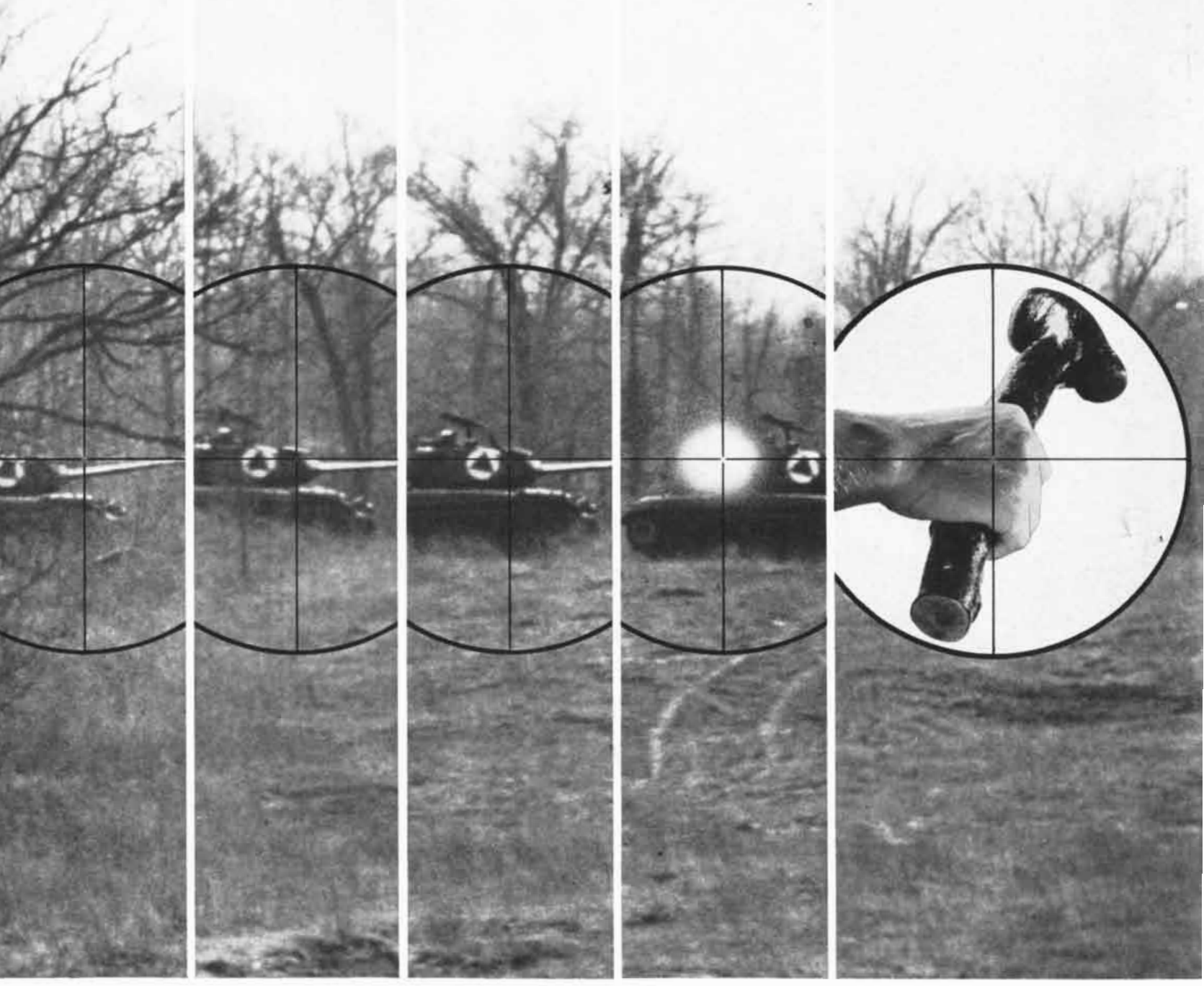

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TASTE RECEPTORS

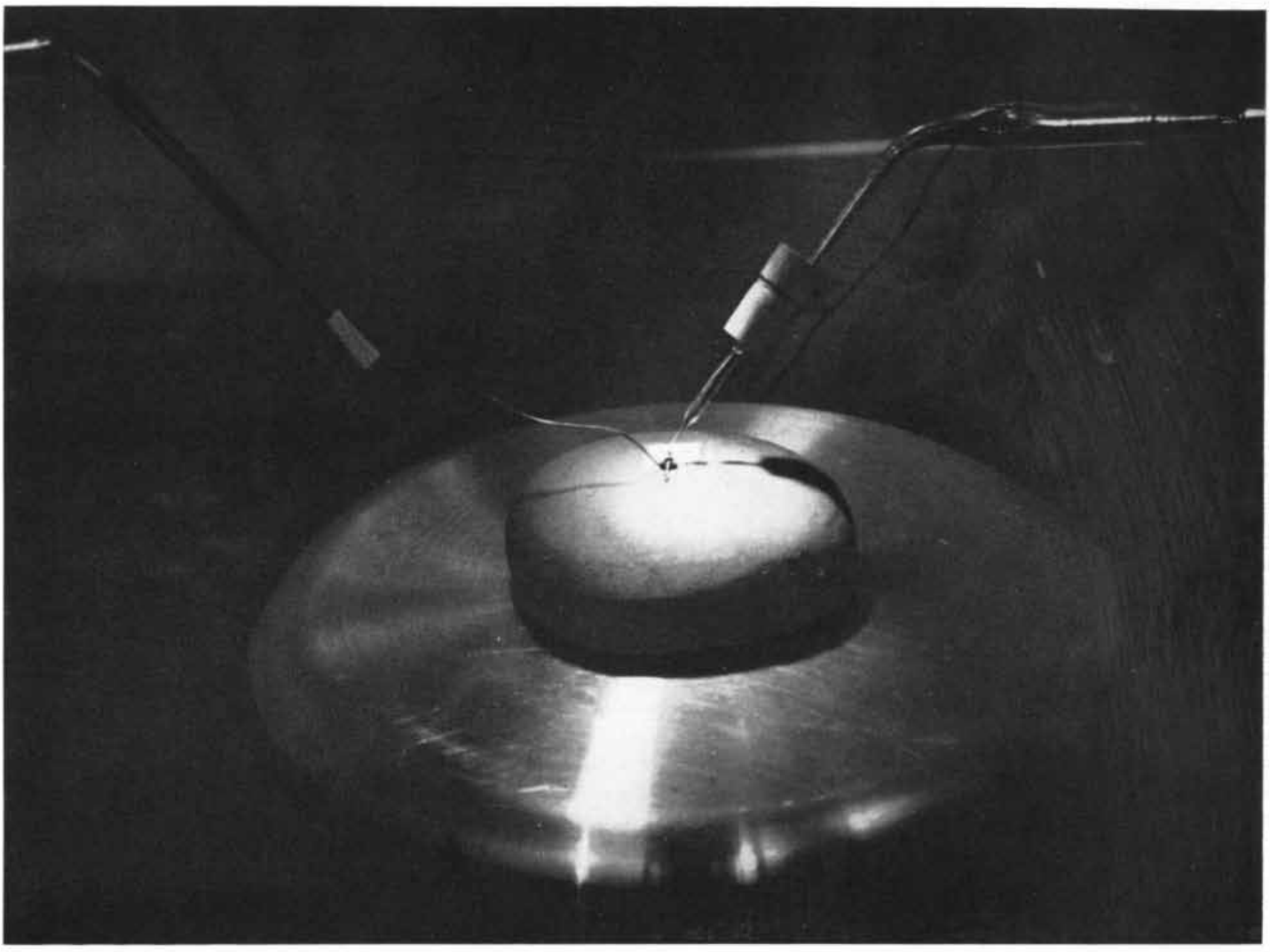
In the blowfly the organs of taste are located in hairs on the fly's proboscis. By slipping a slender tubular electrode over such a hair, investigators can learn much about the mechanism of taste in general

by Edward S. Hodgson

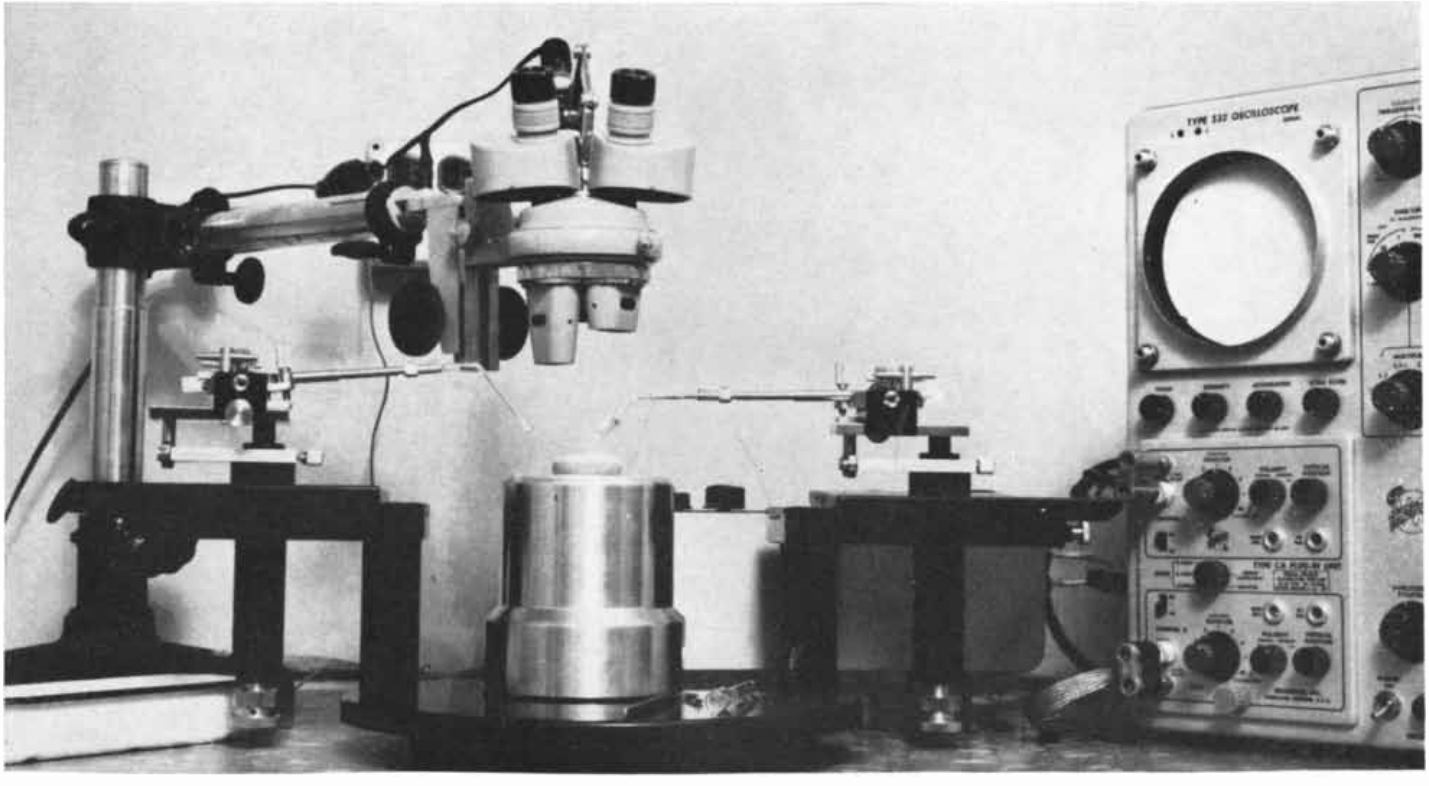
The severed head of a fly, a lump of wax and a minute glass tube filled with salt water were the novel ingredients of the experiment. The other items, including an amplifier, a cathode-ray oscilloscope and a motion-picture camera, were conventional tools for exploring the workings of the nervous system. When this improbable collection was appropriately hooked up, it provided the long-sought means of measuring directly the electrical impulses by which a single taste cell sends a taste sensation to the brain. At last the workings of one of the least understood types of sensory receptor cell could be subjected to direct observation.

Blowflies began losing their heads to such good purpose in 1955, when I collaborated in a study of taste mechanisms with Jerome Y. Lettvin of the Massachusetts Institute of Technology and Kenneth D. Roeder of Tufts University. In our experiments we fastened the fly's head upside down to the lump of wax and subjected the head to slight pressure, causing the proboscis to extend. Then, using a micromanipulator, we could slip the water-filled glass tube over one of the fine sensory hairs on the tip of the proboscis. A silver wire inserted into the other end of the tube connects it with the amplifier and the oscilloscope.

BLOWFLY PROBOSCIS with water-filled glass tube slipped over a single hair (*right*) is in position for experiment. The shiny horizontal object is a staple that keeps the proboscis extended. Part of one of the fly's eyes is just below the staple (*right of center*).



ELECTRICAL CONNECTION carries impulse from taste cells. Blowfly head is on lump of wax. Electrode at right is glass tube filled with salt water. Electrode at left, connected to amplifier, is implanted in severed head to complete the electrical circuit.



COMPLETE LABORATORY SETUP for measuring impulses from blowfly taste cells includes microscope, micromanipulators (*at left and right of center stand*) and oscilloscope (*right*). Electrodes that make contact with fly's head are just above lump of wax.

To complete the circuit, another wire from the amplifier is inserted into the fly's head. Contact between the sensory hair and the solution in the tube causes the taste nerve to produce a series of electrical impulses that register as a fleeting trace on the face of the oscilloscope tube. This visible image of the nerve impulse is recorded by the motion-picture camera.

Although the chemical senses—taste and smell—may seem less important than other sensory systems in man, they have always had a central role in the behavior of other animals. Cells particularly sensitive to the chemical environment were among the earliest to appear, no doubt because the murky aquatic environments that were the scene of so much evolutionary history made chemical perception essential for survival. Chemical detectors are found in one of the oldest of multicellular creatures: the jellyfish. In flatworms, the simplest bilaterally symmetrical animals, chemoreceptors on the sides of the head direct the search for food. Knowledge of the operation of these primitive receptors is so meager, however, that the concepts of "smell" and "taste" must be reserved for the animals that evolved later.

When animals emerged from the water, they continued to depend heavily on the chemical senses. In most insects and in many other land animals, taste and smell play a key part in detecting a suitable environment, finding sustenance and initiating reproductive behavior. The chemical senses do much more than provide pleasurable sensations for gourmets: they are essential to the survival of many animal species.

The study of taste and smell not only sheds light on one of the fundamental processes in nature; it also can be of help in combating insects and other pests that share with man a taste for certain foods. By understanding the mechanism of the chemical senses, man may be able to interfere with their operation, to anesthetize them or even to exploit them with chemicals that attract or repel pests.

Quantitative studies of the chemical senses largely awaited the development of equipment sensitive enough to measure nerve impulses. The first such study was made less than three decades ago by E. D. Adrian and C. Ludwig at the University of Cambridge. They recorded impulses from the olfactory stalk of a catfish brain while flushing the fish's nasal sac with fluid from decaying earthworms or from a putrefying alligator head. They found that the olfactory nerves carry some impulses even without stimulation. The fluid from decaying meat greatly increases the number of impulses, which signal the brain that food is nearby. Adrian and Ludwig also discovered that the olfactory stalk will not show a response to stimulation twice in quick succession: full sensitivity reappears only after a recovery period. (Nerve physiologists would say that the olfactory system is "slow-adapting.") Subsequent studies have shown that the chemoreceptor systems of most animals, including many only distantly related to the catfish, have the same general characteristics.

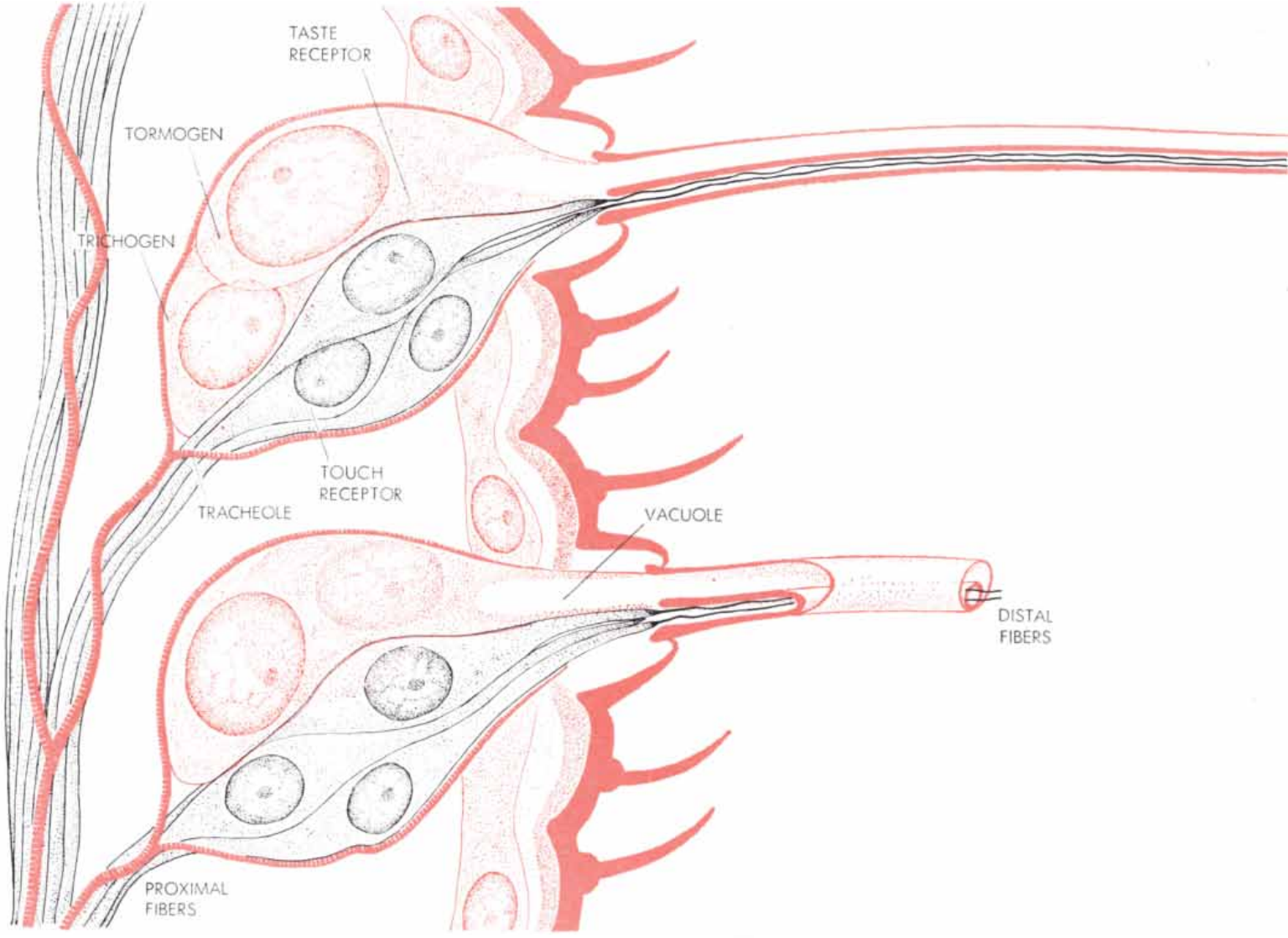
From the point of view of the investigator, however, the taste and smell receptors of vertebrate animals usually share certain drawbacks. The actual receptor cells are too small or too inconveniently located to be probed with electrodes; hence recordings of nerve impulses are customarily taken from nerve fibers connected to the receptor cells rather than from the receptors themselves. Since each nerve fiber is connected to several receptor cells, the original messages must be condensed and delayed by the time they reach the recording electrodes. The situation can be further complicated by a layer of mucus over the receptor cell; it is extremely difficult even to estimate the time it takes a stimulating chemical to penetrate the mucus or wash out of it.

The line of investigation that was eventually to lead to the making of direct and convenient contact with single receptor cells began even before the work of Adrian and Ludwig. In the 1920's D. E. Minnich of the University of Minnesota applied a sugar solution to the sensory hairs on the mouth parts of flies and on the feet of butterflies. When the solution touched even a single hair, the proboscis would extend as if the insect were trying to feed. Each hair seemed to be a taste receptor.

More recently V. G. Dethier, working at Johns Hopkins University, dipped the feet of blowflies into a variety of solutions. He observed which solutions caused extension of the proboscis and so was able to compile a long list of molecules that the fly apparently found tasty. By 1950, largely as a consequence of Dethier's work, more was known about the taste receptors of blowflies than about those of any other organism, including man.

The taste hairs of the fly are merely the inert housings of the living taste-receptor cells. By means of microscopic studies of thin sections of the hairs and the surrounding tissue, Dethier found that each sensory hair on the proboscis of the blowfly has three receptor cells at its base. Two of the cells send thin filaments through the hollow shaft of the hair to its tip. Dethier concluded that these two cells are the taste receptors because when he rolled a droplet

LIVING AUSTRALIAN SHEEP BLOWFLY is shown here with proboscis (*between two front legs*) extended. The fly, which lays its eggs on sheep, is a serious pest in Australia.



SENSORY HAIR of blowfly proboscis ends in papilla (*far right*) capable of detecting chemicals. A "bag" of cells (*left*) lies at base of each hair. The smaller cells in the bag are the two taste receptors, which send filaments ("*distal fibers*") through hollow hair, and between them is a touch receptor. The tormogen and trichogen are not receptors but give rise to the hair structure. The proximal fibers connect the taste and touch receptors directly with the brain. The entire chemoreception system is shown in black.

of sugar water along the shaft of the hair, the proboscis extended only after the solution had reached the tip. The third receptor cell, which sends no filament into the hair, was found by Myron L. Wolbarsht and Dethier to be a touch receptor, sensitive to the bending of the hair. From each of the three cells an extension goes directly to the brain.

The blowfly's two taste-receptor cells, made accessible to external stimuli by the extension of their sensitive filaments in hairs outside the body, seemed to offer an ideal opportunity for observing the chemoreceptor mechanism. No mucus or saliva flows over the cells. Moreover, the hairs on the end of the proboscis are so far apart that experiments on a single hair do not disturb neighboring hairs.

One important difficulty remained to be overcome: making an electrical connection to detect the nerve impulse. Near the tip of a sensory hair the filaments from each receptor are only about a ten-thousandth of a millimeter in diameter—too small to generate much voltage or withstand conventional techniques of making electrical connections with cells. At its largest the diameter of the receptor-cell body may be 22 thousandths of a millimeter, but this part of the cell lies buried at the base of the hair, shielded by the tough, nonconducting waxy cuticle of the hair wall and by the surrounding proboscis tissue.

A clue to the technique for making the electrical connection without injuring the delicate receptor cell came from a beautifully simple experiment performed by Eleanor H. Slifer at the State University of Iowa. By dipping hairs on the antenna of a grasshopper into water containing a dye she showed that aqueous solutions penetrate the tips of sensory hairs. These antenna hairs resemble in miniature the taste hairs of the blowfly proboscis. Lettvin, Roeder and I guessed that if water passes through the cuticle at the tip of a sensory hair, a solution that conducts electricity might pick up a nerve impulse through the same permeable spot. Perhaps the solution could both stimulate the taste-receptor cell and provide a workable connection between the receptors inside the fly hair and the electrical recording system outside. Thus it was that we performed the experiment described at the beginning of this article.

As we had hoped, the salt water in the tiny glass tube at once stimulated the receptors and conducted a current away from them. Now that we could record messages directly from the taste receptors, we were able to attack the more interesting problem of how the receptors work. Their reactions to various chemical stimuli would, we felt, provide im-

portant clues to the chemical events that generate the electrical impulses in the receptors.

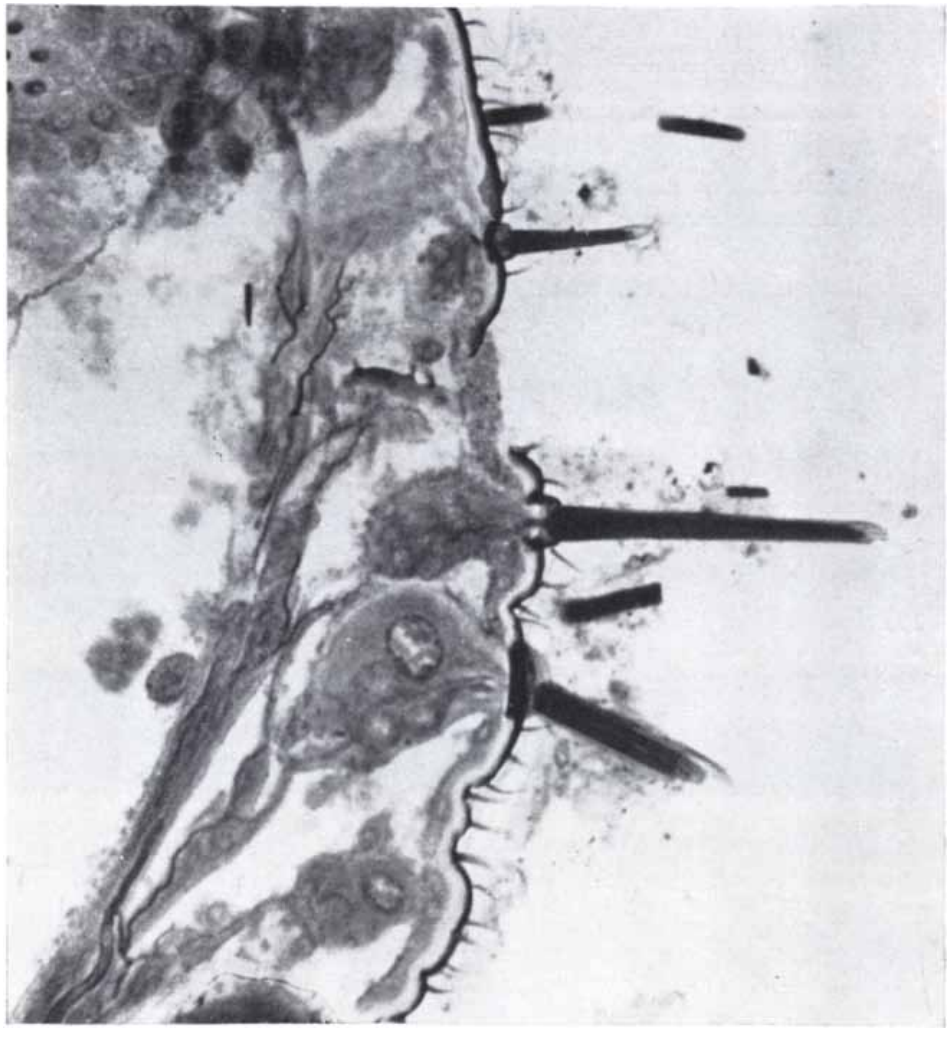
We were especially curious to see if both of the taste receptors in a sensory hair are sensitive to the same kinds of chemical. It quickly became apparent that they are not. Salts, acids, most alcohols and most other compounds, except sugars, elicited electrical impulses with a constant amplitude of about 300 microvolts (300 millionths of a volt). Test solutions of sucrose and many other sugars, mixed with a trace of salt to provide electrical conductivity, elicited predominantly smaller impulses, about 200 microvolts in amplitude. Since a given nerve cell normally produces impulses of only one amplitude, the two distinct amplitudes from the taste hair provided a way to tell the response of one cell from that of the other. Actually the impulse amplitudes varied somewhat in recordings from different hairs, but the impulses of the two taste cells were usually distinguishable.

For easy reference we called the cell producing the larger impulses the "L" receptor and the cell producing the smaller impulses the "S" receptor. Our first generalization was that the S cell appears to be a sugar receptor and the L cell a less specific nonsugar receptor. Since blowflies feed on sugars and avoid most of the chemicals that stimulate the L receptor, the electrical activity of the nerves seemed to match the flies' feeding behavior.

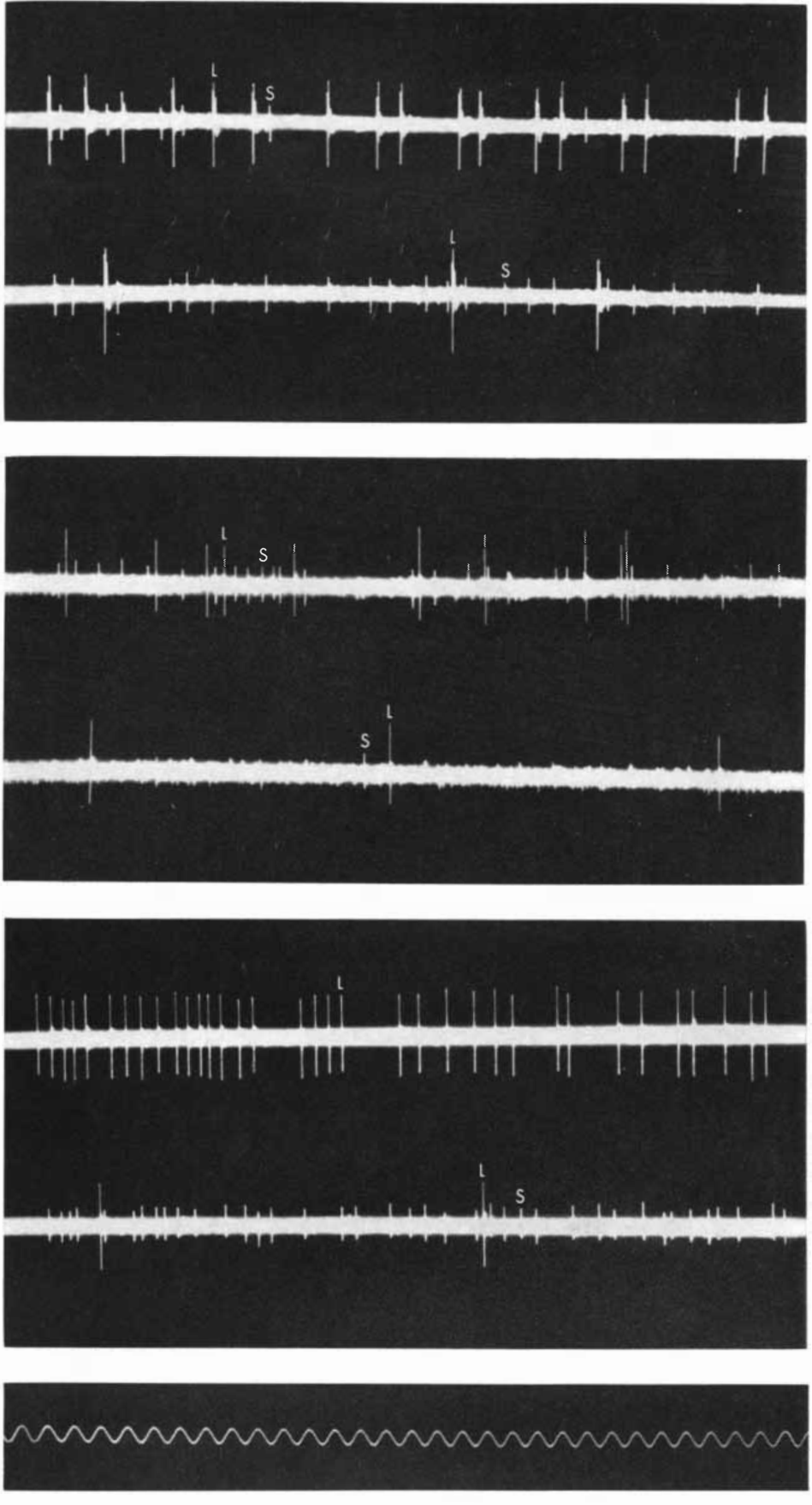
Further work in my laboratory at Columbia University supported the idea that compounds "acceptable" to the fly stimulate the S receptor, whereas "unacceptable" compounds stimulate the L receptor. We found that the electrical recordings from L and S receptors in single hairs correlate well with the proboscis behavior that follows stimulation of single hairs with a droplet of each test solution. For example, fructose and glucose, both sugars that trigger proboscis extension, strongly stimulate S receptors, even when applied in relatively low concentration. Two other sugars, cellobiose and mannose, must be applied in high concentration or to many sensory hairs in order to produce a proboscis response. Correspondingly, they evoke only a few S impulses when observed electrically.

The most striking correlation between taste-receptor activities and behavior occurs with four polyhydric alcohols. All these compounds are composed of exactly the same atoms; only the arrangement of the atoms differs. Sorbitol, dulcitol and mannitol stimulate the L receptor. Inositol, however, strongly stimulates the S receptor; it is also the only one of these alcohols that evokes the feeding response of the proboscis. These reactions indicate that the architecture of a stimulating molecule plays a part in the function of the S receptor, because inositol is the only polyhydric alcohol with a ring-shaped molecule, resembling the sugars we found to be most stimulating.

The selective response of the S receptor suggests that enzymes mediate the chemical reaction that triggers the impulse. These biological catalysts are



SENSORY HAIRS AND CELLS of blowfly proboscis are shown in section in photomicrograph by V. G. Dethier of University of Pennsylvania. Magnification is 600 diameters.



OSCILLOSCOPE TRACES show reactions of taste hairs to various chemicals. Each hair has two receptors, one giving an "L" (large amplitude) response on the oscilloscope, and one giving an "S" (small) response. In top picture top trace resulted from application of the sugar raffinose, which caused many L impulses, while bottom trace shows reaction of same hair to fructose, which caused more S than L impulses. Middle picture shows how another hair reacted to fructose (*top trace*) and to another sugar, ribose (*bottom trace*). Ribose stimulated scarcely any impulses. The bottom pair of traces was made by a third hair exposed to two polyhydric alcohols. The alcohol dulcitol (*top trace*) strongly stimulated L impulses, whereas inositol, made up of same atoms in a different arrangement, primarily stimulated S responses. At bottom is time scale for traces; it has 100 peaks a second.

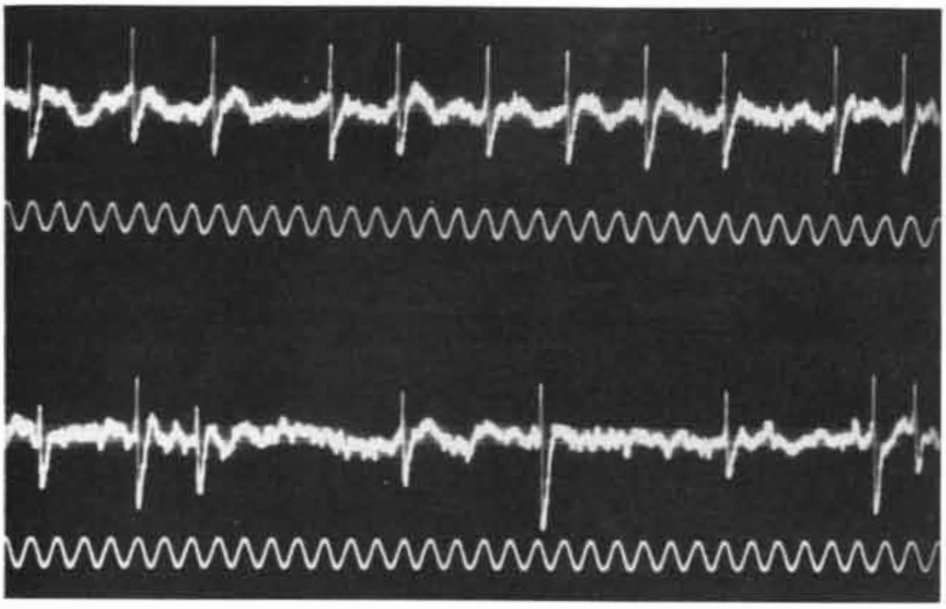
highly specific in their activity. The far less specific responses of the L receptor, which is stimulated by salts and a variety of other nonsugars, suggest that a different mechanism is involved here. It might be sufficient for ions of the stimulating compounds to become loosely bound to the surface of the L receptor. This possibility is particularly interesting, because the same mechanism has been postulated for the salt-taste receptors in mammals.

Further support for the idea of different mechanisms of S and L activity comes from experiments that Lindsay Barton-Browne and I performed on the Australian sheep blowfly at the Australian National University and at the Australian Commonwealth Scientific and Industrial Research Organization. We were able to measure the time interval between the applications of the stimulus and the first receptor impulse in 141 individual taste-receptor cells. It happens that the oscilloscope beam shows a slight deflection the instant our experimental circuit is closed by contact between the stimulating solution and the sensory hair [*see bottom illustration on opposite page*]. The deflection is followed by a brief interval before the taste cell fires the impulse that goes to the brain. We found that the impulses from the L receptors appear within as little as a millisecond (a thousandth of a second) after a salt solution is applied. With S receptors, however, the delay after contact with a sugar solution is always at least five milliseconds. (These speeds are only a fourth to a 20th as long as those generally observed in experiments with vertebrates, showing again the value of making recordings as close as possible to the site of receptor stimulation.) The sugar molecules would be expected to move slower than the salt ions to the receptor site. Only part of the difference in the response times of S and L receptors can, however, be explained on this basis alone, and some fundamental difference in their mechanism of operation again seems indicated.

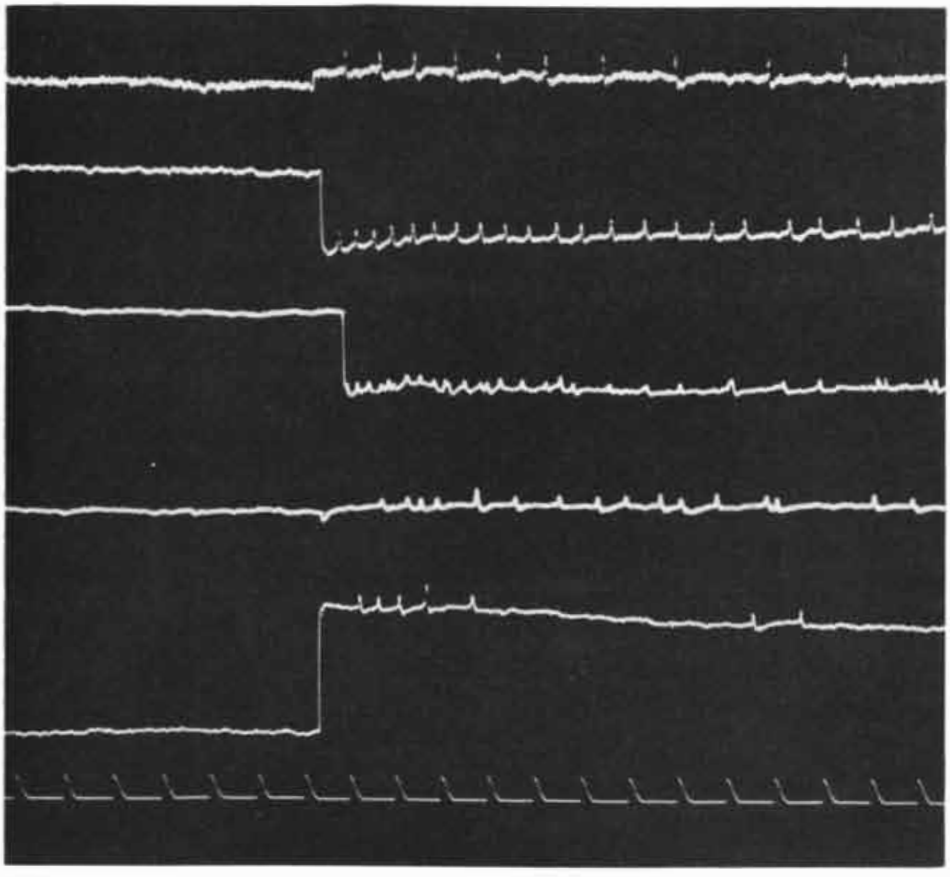
Of course, a fly does not normally encounter chemicals in the pure forms employed in our experiments. In nature, feeding behavior may depend on the proportions of L and S impulses reaching the brain. Experiments at Columbia have shown that mixtures seldom produce impulses that are the simple sum of the impulses obtained when the chemicals are tried singly. The addition of sucrose to a solution of sodium chloride, for example, not only activates the S receptor; it also lowers the frequency

of the L impulses caused by the salt. This may be due in part to interactions of the ions and molecules in solution. Whatever the mechanism, this effect tends to increase the discrepancy between frequencies of L and S impulses, enhancing the contrast between acceptable and unacceptable chemicals. Thus the fly's taste receptors would signal the brain that a substance is either "very acceptable" or "very unacceptable."

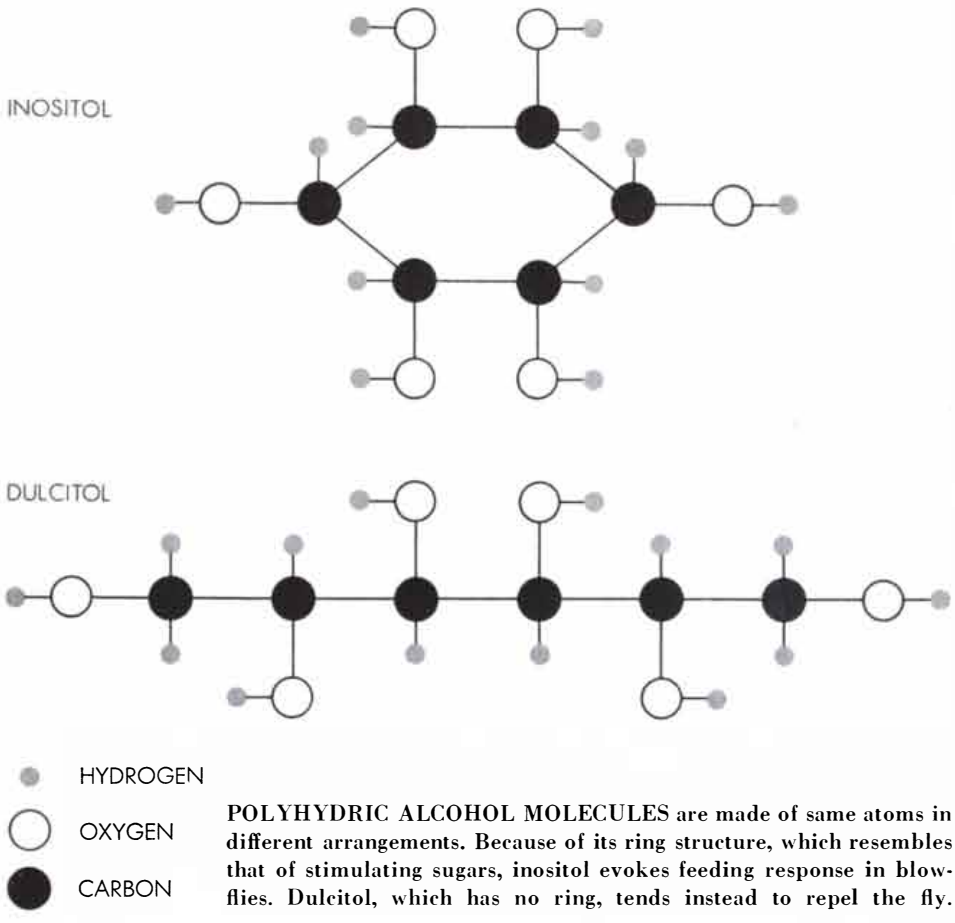
The individual sensory hairs on the fly's mouth parts exhibit further refinements that provide additional informa-



ONLY L FIBER RESPONDS when solution consists of sodium chloride alone (*top*). A much weaker salt solution plus the sugar sucrose causes five S and only three L impulses in same time period (*bottom*). The time scales here contain 100 peaks to the second.



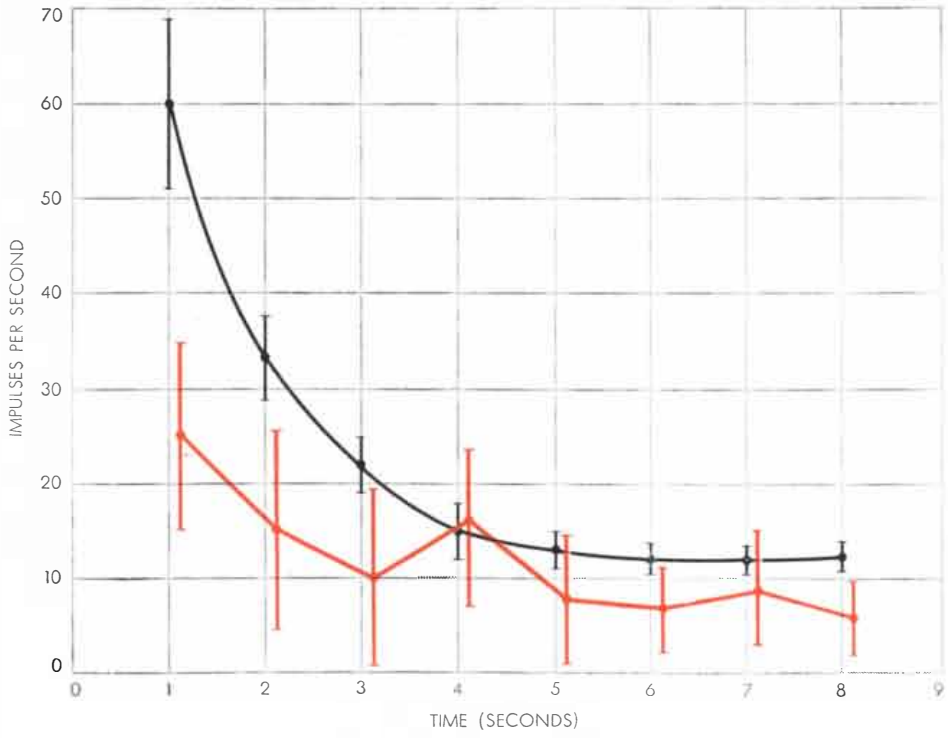
TIME OF RESPONSE after application of stimulus can be seen on these tracings. Each peak on time scale (*bottom*) marks passage of 10 one-thousandths of a second. First deflection of beam indicates application of stimulus. Second deflection is first receptor response. The three top traces show response of L receptors to salt. The two bottom traces, showing response of S receptors to sucrose, illustrate how the S receptor reacts slower.



POLYHYDRIC ALCOHOL MOLECULES are made of same atoms in different arrangements. Because of its ring structure, which resembles that of stimulating sugars, inositol evokes feeding response in blowflies. Dulcitol, which has no ring, tends instead to repel the fly.

tion to the brain. Barton-Browne and I found that the receptors in some hairs are slow in responding to stimuli and are relatively inexcitable, while those in other hairs always fire rapidly. Thus strong stimulation that would virtually inactivate the sensitive receptors would still be affecting the less active receptors. The reverse would be true of barely perceptible stimuli.

Temperature changes of less than a degree can also modulate the frequency of firing of some receptors during a period of otherwise regular discharge. This



TASTE CELLS "ADAPT" to stimulus by decreasing number of impulses sent to brain. L receptor (*black line*) sends more impulses than S receptor (*color*) and rate decreases faster. The vertical lines indicate the range of impulses found in repeated tests on one hair.

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temperature effect is not produced at the tips of the hairs and apparently does not involve the chemosensory processes occurring there. Since the bending of a sensory hair can also provide information about tactile properties of the environment, the range of sensations provided by even a single sensory hair can be wide indeed.

It is amusing to imagine the sensations experienced by the living fly when a taste receptor hair is stimulated in various ways. In contact with heated sirup a single hair might signal not only a strong and acceptable taste but the temperature and stickiness of the sirup as well. Other situations and the sensations they excite are not too difficult to imagine. The wire tapping that brings the nerve impulse to the oscilloscope has probably provided far more accurate information about the fly's taste sensations than could be obtained if the insect could talk.

Although microelectrodes attached to the tip of a fly's taste hairs have revealed a great deal about nerve cells sensitive to chemicals, they have failed to detect one of the very first steps that was expected to occur in the process of tasting: the initial electrical changes that trigger the fly's taste cell to send an impulse to the brain. Recently two Japanese investigators, Hiromichi Morita and Satoru Yamashita of Kyushu University, reached this objective. Through an opening in the side wall of a fly's sensory hair they managed to connect a microelectrode to the filaments inside. Before being stimulated, the receptor-cell filaments registered some spontaneous activity like that found by Adrian and Ludwig in the catfish olfactory stalk. More important, Morita and Yamashita have demonstrated that, upon stimulation, a relatively slow change in electrical potential in the filament precedes and leads to the generation of the brief but much stronger impulse going to the brain. These slow electrical changes occur only in the filaments that lie within the shaft of the sensory hair and are elicited by chemical reaction with the stimulating chemical. They correspond to the "generator" potentials observed in other receptor cells, which cause the main bodies of the cells to fire impulses into the central nervous system [see "Biological Transducers," by Werner R. Loewenstein; SCIENTIFIC AMERICAN, August, 1960]. Further study of these generator potentials in taste-receptor cells will undoubtedly lead to a more complete description of the mechanisms of the chemical senses.

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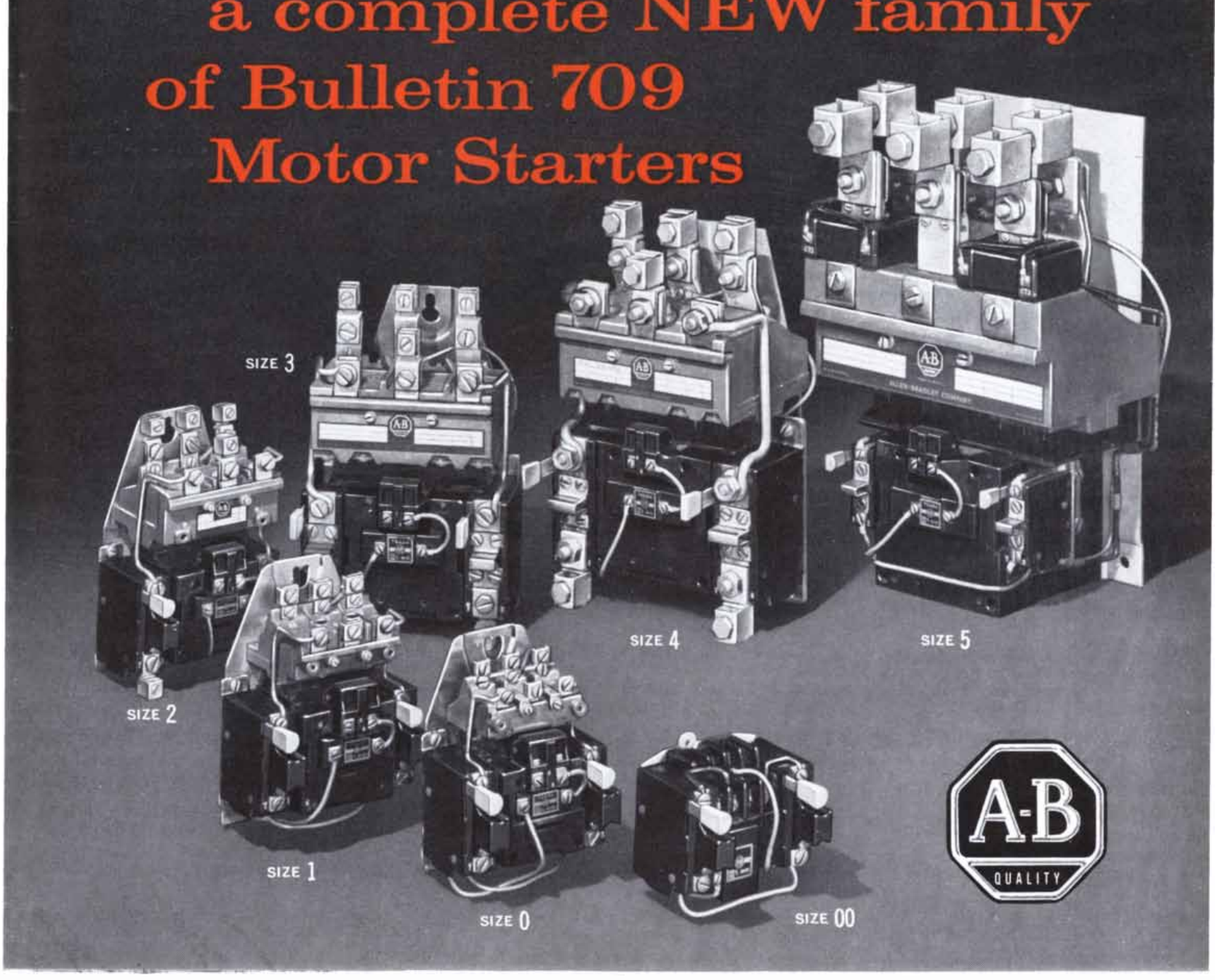

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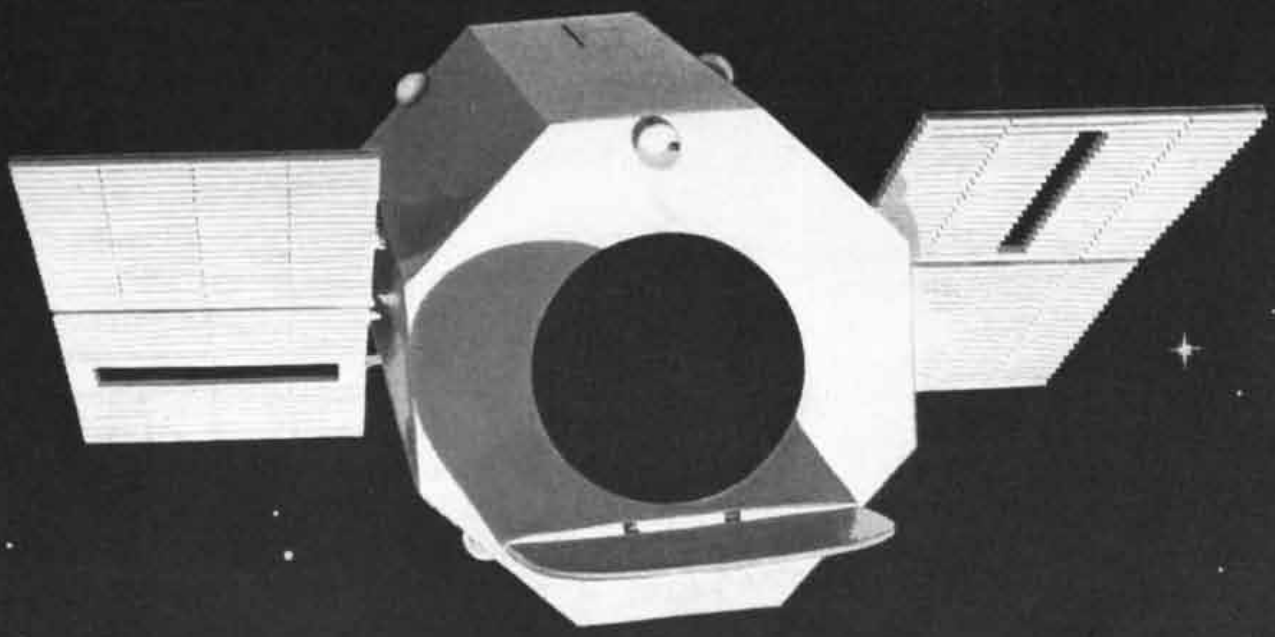

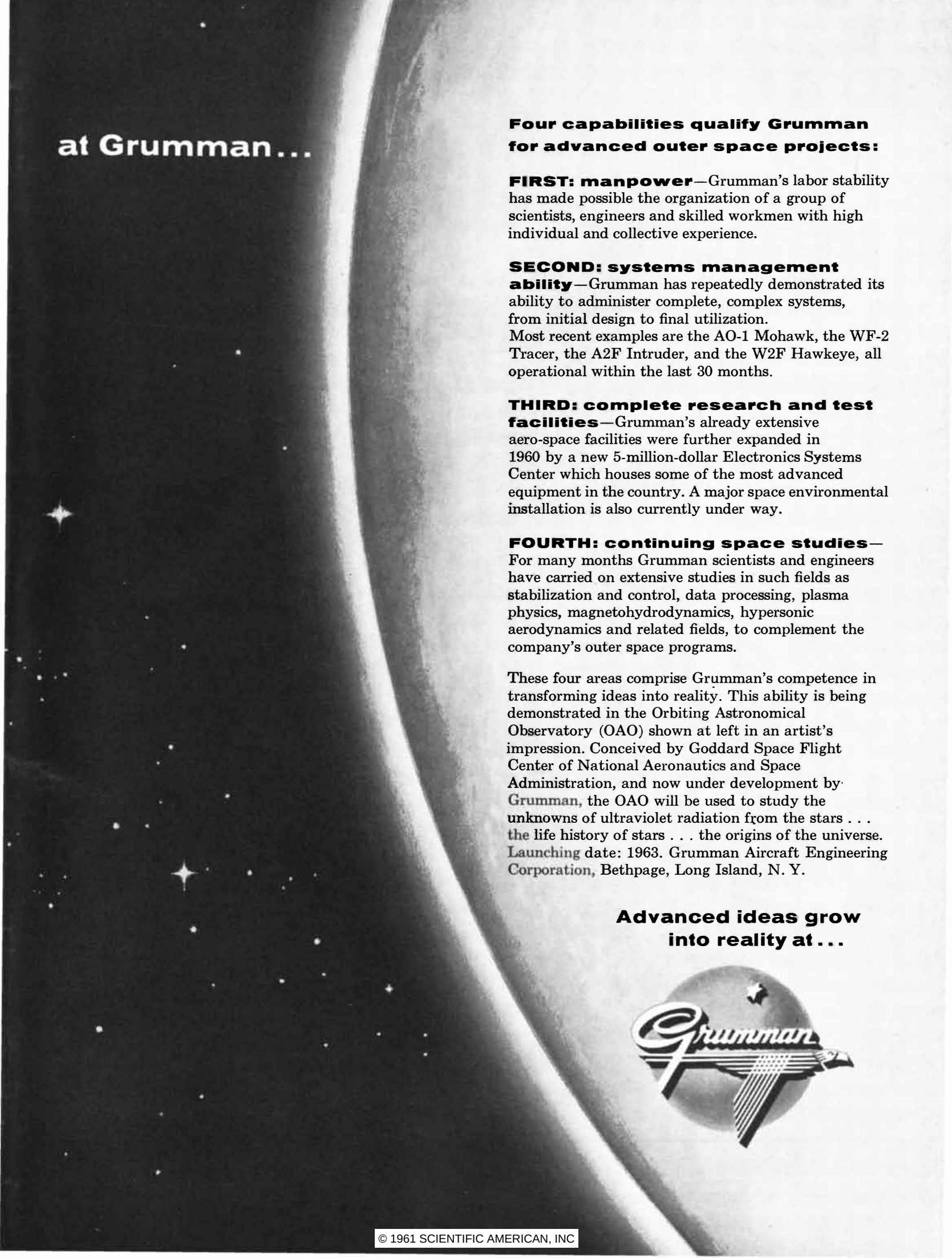

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Advanced ideas grow into reality at . . .

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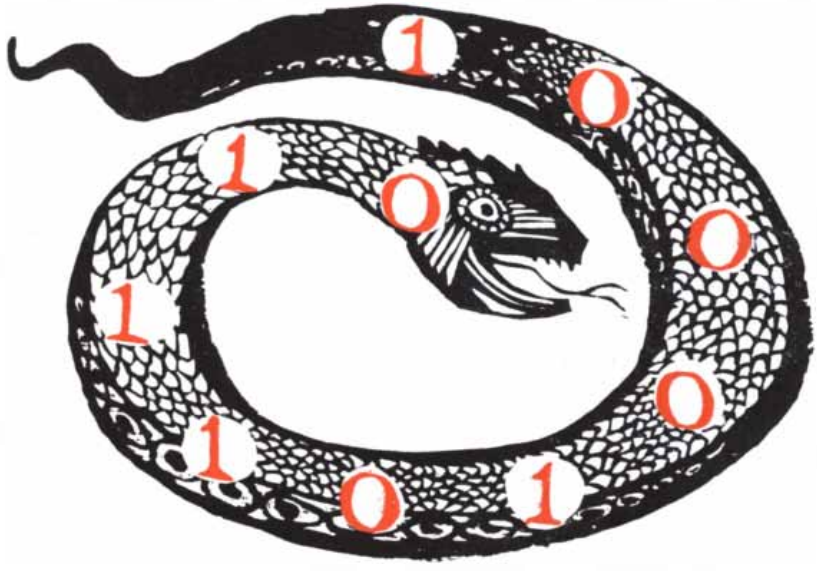
yamátárájabhánasalagám

0 1 1 1 0 1 0 0 0 1



ANCIENT SANSKRIT WORD (*top*) was a memory aid for drummers: it lists all possible triplets (combinations of short and long beats in groups of three) exactly once. Substitution of 0's for short beats and 1's for long yields number on second line, which reveals basic structure of word. Because 01 occurs at both ends of the word, the author was reminded of a snake swallowing its tail.

The Mathematician as an Explorer

The nature of mathematics is elucidated by one mathematician's account of how a memory word used by drummers in ancient India led him to the classic problem of the traveling salesman's route

by Sherman K. Stein

Mathematics, like every branch of knowledge, is the product of the interplay between past and present, between accumulated knowledge and curiosity, between an autonomous structure and the tastes and needs of the time. What one age considers a pressing question, another may not ask at all. The pure mathematics of one era may be applied in another, perhaps centuries later.

A problem with which I recently tangled illustrates these aspects of the growth of knowledge, and its solution captures the adventurous flavor of mathematical research. Pushing into the unknown, the mathematician is an explorer who is likely to find what he did not seek and who cannot predict how others will use his discoveries.

This particular adventure began when the composer George Perle told me about an elaborate theory of rhythm that had been developed in India more than a thousand years ago. "While reading about this theory," he said, "I learned my one and only Sanskrit word: *yamátárájabhánasalagám*." I asked him what it meant.

"It's just a nonsense word invented as a memory aid for Indian drummers."

"If a drummer can remember that," I replied, "he can remember anything."

"There is a lot in those ten syllables," said Perle. "As you pronounce the word you sweep out all possible triplets of short and long beats. The first three syllables, *ya má tá*, have the rhythm short, long, long. The second through the fourth are *má tá rá:* long, long, long. Then you have *tá rá ja:* long, long, short. Next there are *rá ja bhá:* long, short, long. And so on."

I wrote down the word and saw that what Perle said is true. Each successive triplet of syllables displays a different pattern, and the whole word displays all the possible patterns, giving each one once and only once. As a mathematician I was fascinated to find that such a sequence could exist.

That night I returned to the ancient word. To strip it of irrelevancies I replaced the syllables with digits, letting 0 stand for short beats and 1 for long. In this notation *yamátárájabhánasalagám* became 0111010001.

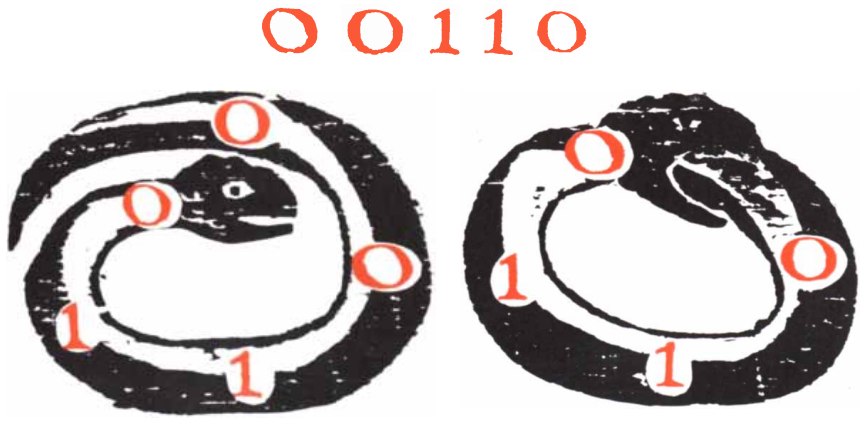
Staring at the simplified string for a while, I noticed a lovely thing. The first two digits are the same as the last two; so if I bent the string into a loop, it would look like a snake swallowing its own tail. That is, the last 01 could be placed over the first 01, so that the two pairs of digits would merge into a single pair [*see illustration on opposite page*]. Instead of a line of 10 digits I now saw a circle of eight.

I could begin anywhere on this "memory wheel" and move around it in either direction, sweeping out triplets of 0's and 1's. Starting at the top and reading clockwise, for example, gave 011, 111, 110, 101, 010, 100, 000, 001.

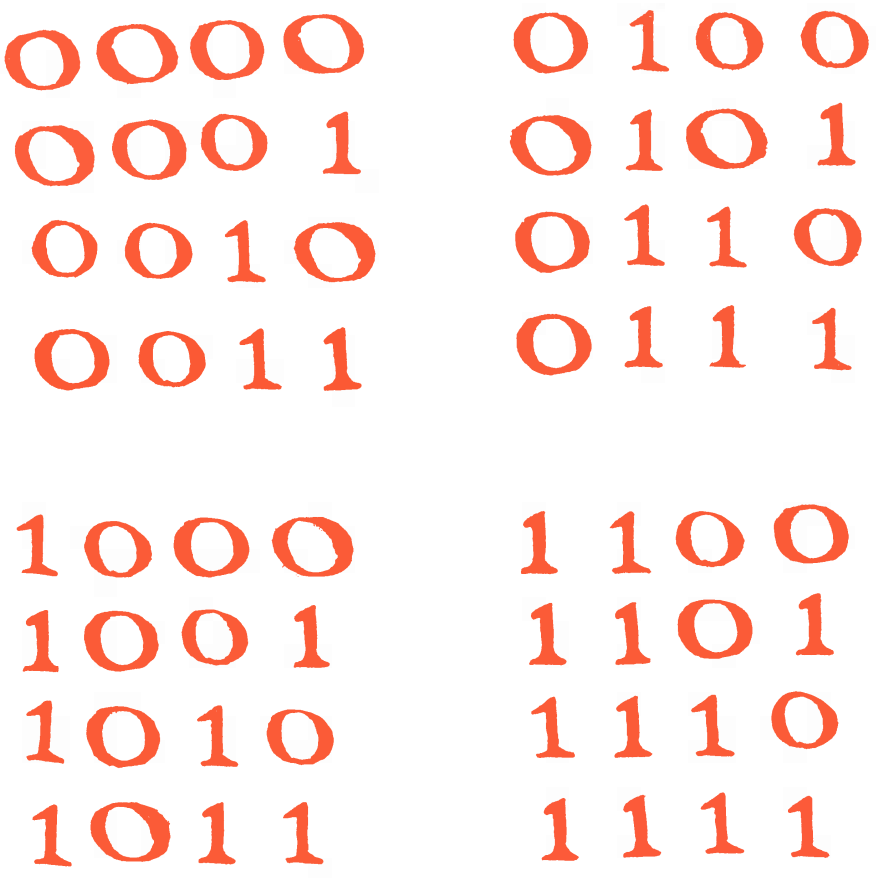
The next thing that occurred to me, as it would automatically to any mathematician, was to generalize what I had found. Is there a "word" for listing all quadruplets of 0's and 1's once and only once? For quintuplets? For groups of any size? And if so, does the snake always swallow its tail?

Before attacking the problem for quadruplets it seemed sensible to go back and look at couplets. Is there a word that lists each of the four couplets 00, 01, 10, 11 exactly once? Does it close up on itself? Writing down the sequence 0011, I saw that I already had the three couplets 00, 01, 11. Adding one 0 more, to form 00110, gave the final couplet: 10. I noted that the first and last digits are 0's, so that the snake swallows its tail. The five-digit word could be bent into a four-digit wheel containing each couplet once and only once [*see illustration below*].

Now I was ready to take on the quadruplets. I began methodically by listing all the possible groups of four digits composed of 0's and 1's. To do this I first wrote down the eight triplets and



MNEMONIC NUMBER (*top*) **lists all couplets, or pairs, of short beats (0's) and long (1's). As in number on opposite page, duplication of first and last digits suggests a snake.**



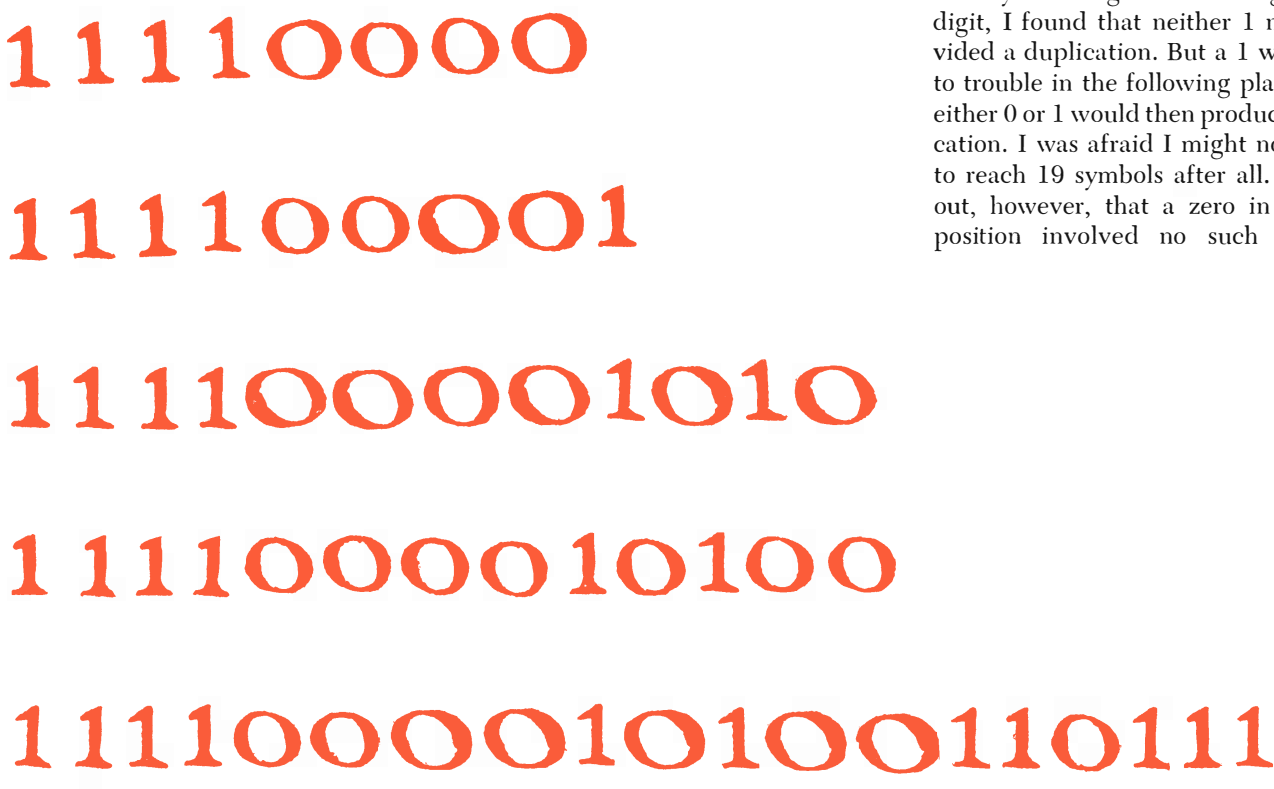
ALL POSSIBLE QUADRUPLETS of 0 and 1 are listed. Half the list consists of triplets preceded by 0's (*top blocks of numbers*); the rest are triplets preceded by 1's (*bottom*).

placed a zero in front of each. This gave me all the quadruplets beginning with 0. Then I repeated the triplets and preceded them with 1's, obtaining the quadruplets beginning with 1 [*see illustration at left*]. Since the list contained 16 quadruplets, I saw that a memory word to sweep out each of them once (if it exists) must have 19 digits. The first four digits make one quadruplet, and each of the next 15 digits completes another.

Now to find the word. Somewhere in it there would have to be a string of four 1's and somewhere four 0's. Why not put them together and see what would happen? I wrote down the eight symbols 11110000. Then I checked off my list the five quadruplets it contained: 1111, 1110, 1100, 1000, 0000. So far so good. To avoid getting 0000 twice, I next had to add a 1, obtaining 111100001. I checked off 0001 on the list. Adding 010 produced three more quadruplets, all new, and brought the sequence to 111100001010.

From here I proceeded one digit at a time, checking the list to make sure there were no duplications. At each of the next three places the choice was clear: one of the digits would form a quadruplet already checked; the other would not. I had then reached the 15-symbol word: 111100001010011.

Only four to go. Considering the next digit, I found that neither 1 nor 0 provided a duplication. But a 1 would lead to trouble in the following place, where either 0 or 1 would then produce a duplication. I was afraid I might not be able to reach 19 symbols after all. It turned out, however, that a zero in the 16th position involved no such difficulty,



CONSTRUCTING MEMORY NUMBER for quadruplets, author began by stringing together 1111 and 0000 (*first line*) from list at top of page. Addition of 1 yielded quadruplet 0001 (*second line*). Adding 010 (*third line*) and 0 (*fourth line*) gave four more nonrepeating quadruplets. Continuation of process produced number (*bottom*) containing all the quadruplets of 0 and 1 exactly once.

and the last three places again presented unambiguous choices. I had my word of 19 symbols, containing each of the 16 quadruplets precisely once: 1111000010100110111.

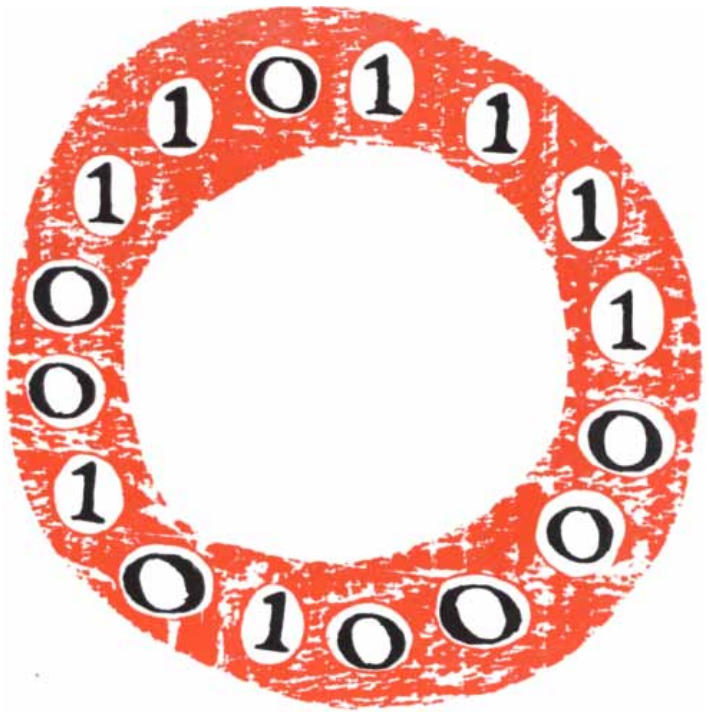
As soon as I had finished, I looked at the first three symbols and the last three. They were the same. So this snake also could swallow its tail. The 19-symbol word could be bent into a wheel of 16 symbols [*see top illustration at right*].

Inspired by this success, I decided that there must be memory words for quintuplets, sextuplets and so on. Furthermore, I felt sure they would all close up into wheels. It was time to stop experimenting, however, and look for a proof of the conjecture.

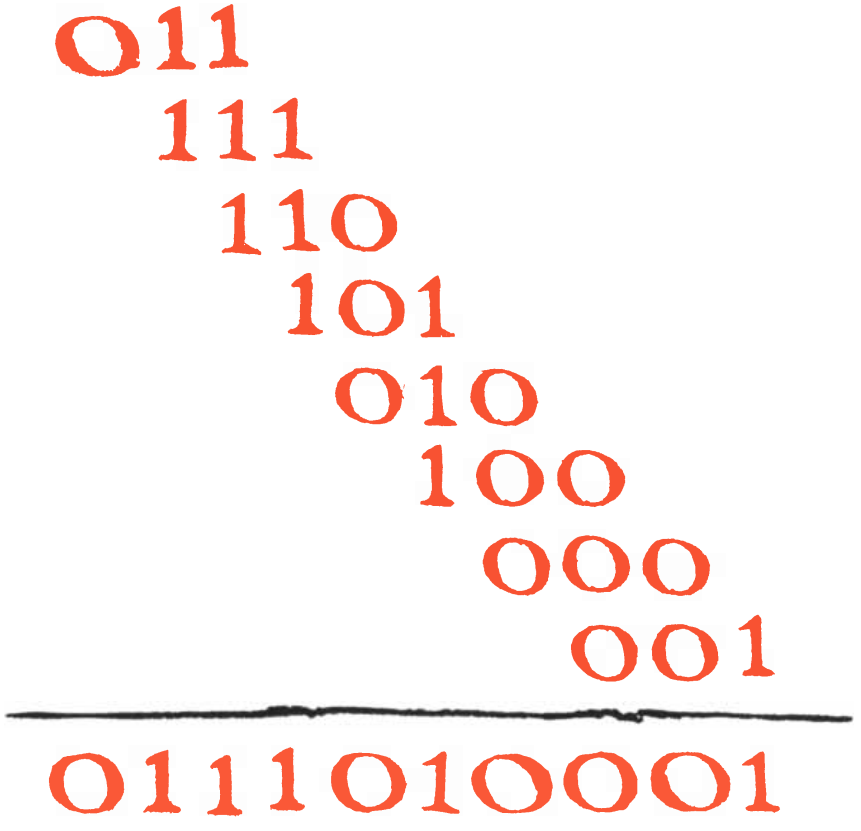
Grappling with the problem, I began to look at the Indian memory word in a slightly different way, concentrating on the eight overlapping triplets it contains [*see bottom illustration at right*]. In this light the word appeared as a means of arranging the triplets so that the last two symbols of one are the same as the first two of the next. Suppose the word had not been invented. How would one have gone about finding one? I decided to spread the triplets over a piece of paper and connect the appropriate pairs with arrows. That is, I would draw an arrow from one triplet to another whenever the last two symbols of the former were the same as the first two symbols of the latter; for example, 001→010 and 001→011. After moving the triplets and arrows around a little to make a simple pattern, I obtained the diagram on page 153.

As I gazed at the configuration, I suddenly saw it as a map in which the arrows were one-way roads and the triplets were towns. The problem of arranging the eight triplets into a memory word could now be stated in terms of a different kind of drummer: a traveling salesman who is looking for a route over the one-way roads that will take him through each town just once. With the help of the Indian memory word I traced one possible route. As the illustration on page 154 shows, the "town" in which the journey ends is adjacent to the one in which it starts. There is a section of road that will take the salesman from the finishing point back to the start. This, of course, reflects the fact that the memory word closes into a wheel.

Clearly the same scheme would apply for overlapping couplets, quadruplets or groups of any size. The general problem had been translated into a new



MEMORY WHEEL for quadruplets is formed by superimposing first three and last three digits of memory number shown at bottom of opposite page. Starting anywhere on wheel and proceeding in either direction reproduces the list shown at top of opposite page.



MNEMONIC NUMBER FOR TRIPLETS (*bottom*) is a condensed statement of a list of all triplets, the list being so arranged that the second and third digits of one triplet duplicate and overlap the first and second digits of the next. The relationship obtains between the last and first members of the list (and therefore between first two and last two digits of the memory number), thus making formation of a memory wheel possible.

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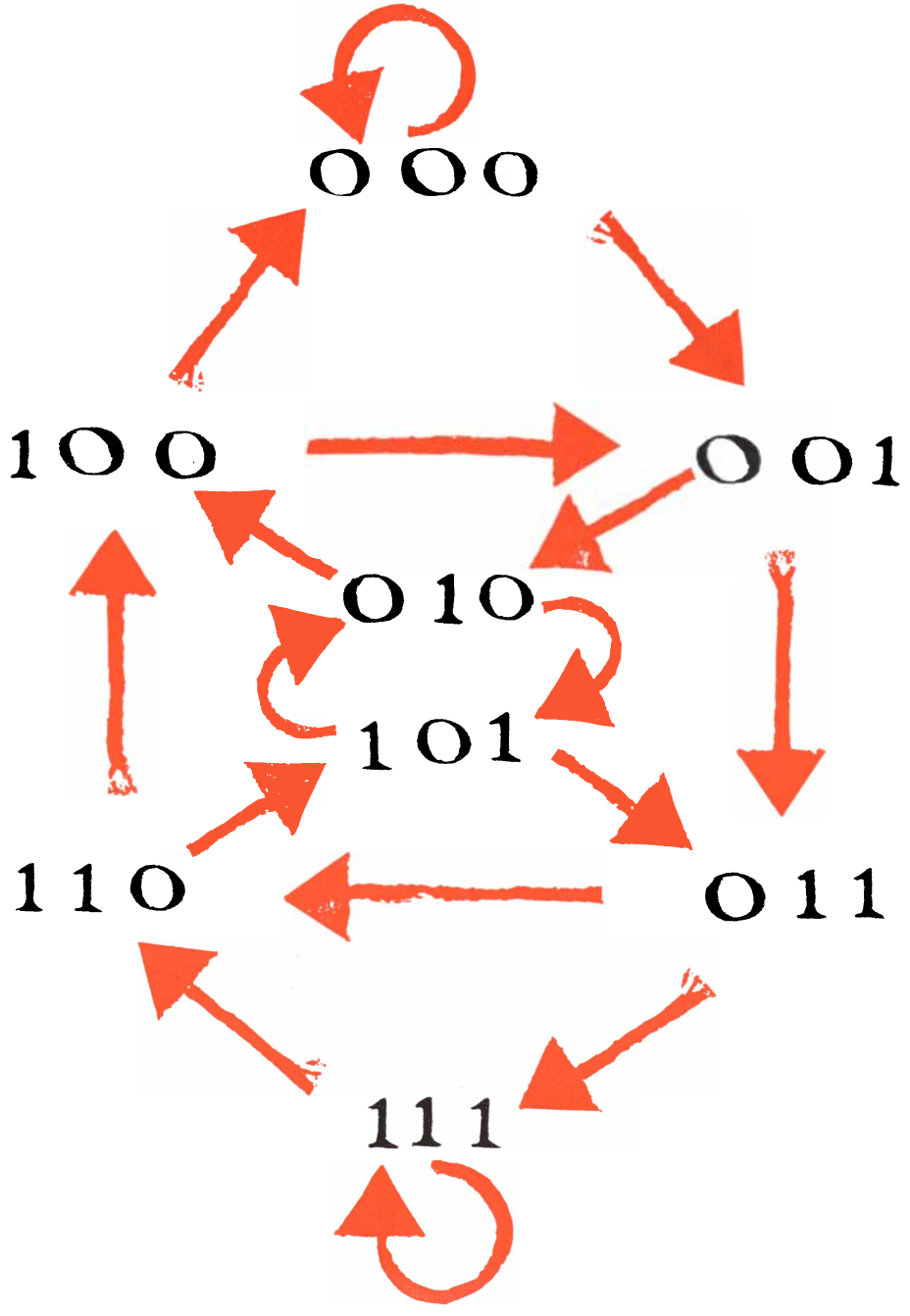
language. The question "Is there always a memory word?" now read "Is there always a route for the salesman?" The question "Does every memory word close up on itself?" now read "Does the salesman always finish his trip in a town adjacent to the town in which his trip began?"

Unhappily the translation did me no good. I had absolutely no luck in solving either of the salesman problems. There is no known way other than trying all paths to tell whether a highway system has a route passing just once through every town.

After several days without progress I had no choice but to put the matter aside and worry about other things. A few months later, as I was leafing through the 1946 volume of *The Journal of the London Mathematical Society*, I saw a diagram that resembled my highway system. It appeared in a paper entitled "Normal Recurring Decimals," by I. J. Good. A quite different topic had brought Good to a consideration of the memory wheel problem—and he had solved it! He was chiefly interested in showing how to produce an endless string of 0's and 1's in which each of the possible sextuplets of 0's and 1's appears with equal frequency. His solution was

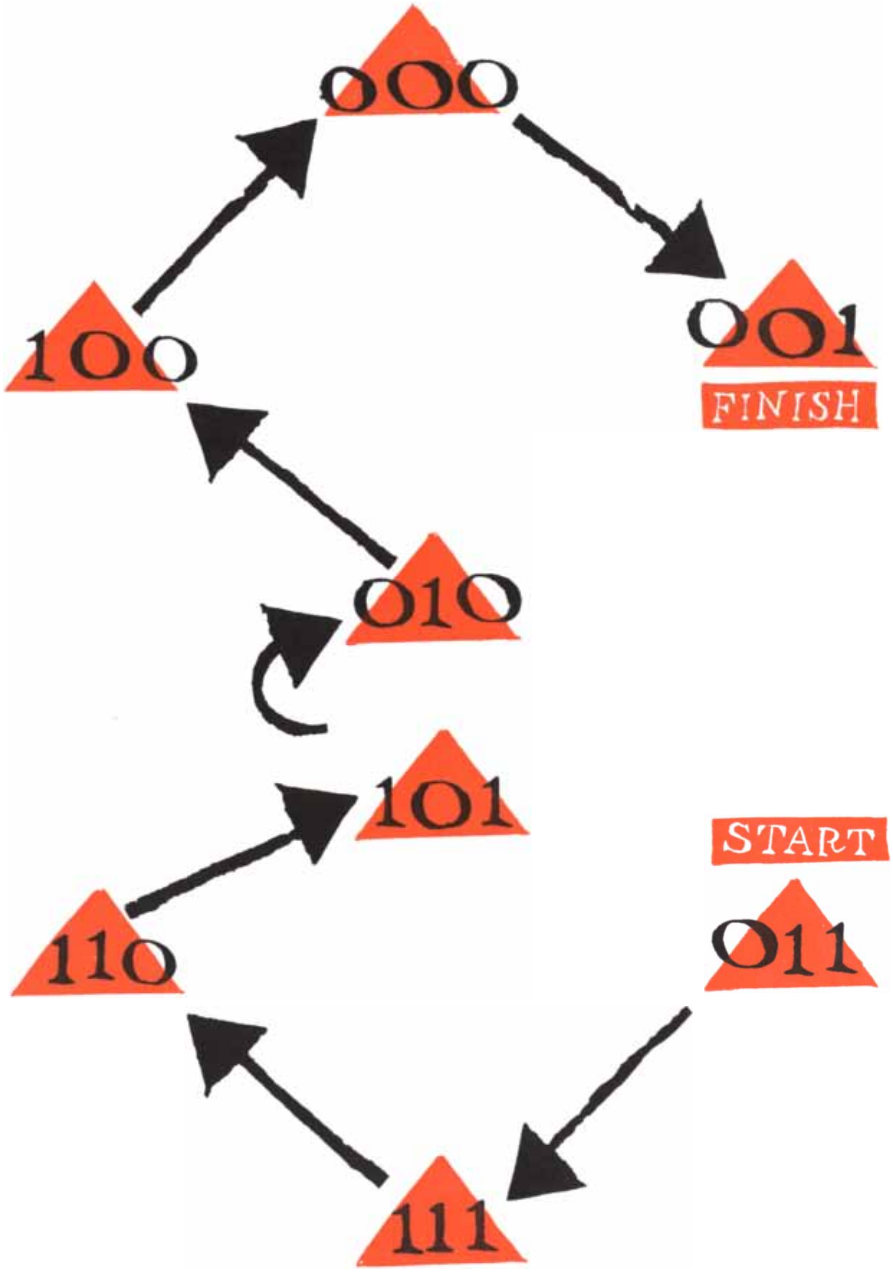


MAZE OF TRIPLETS and arrows shows possible orders in which triplets may be listed in overlapping pattern to make memory numbers. Not all numbers, however, yield memory wheels. Curved arrows at 000 and 111 indicate that last two digits of each overlap first two.

perfectly general and applied to groups of any size. He noted further that "the result has an application to the construction of teleprinters that use alphabets whose letters consist of a finite number (usually five or six) of 0's and 1's."

Good also had recognized that the problem is related to a highway system, but his system was different from mine. I had seen the triplets (or groups of any other size) as towns and the roads between them as representing overlaps. Good saw it the other way around: the triplets themselves are roads and they join towns made up of pairs of digits—the overlapping portions of the triplets [*see illustration on page 157*]. For example, the highway 011 runs from the town 01 to the town 11. To put it another way, there are four towns: 00, 01, 10, 11. One of these is joined to another if the last digit of the former is the same as the first digit of the latter: 01 is joined to 11 by 011.

A glance at the diagram makes it clear that two roads lead into, and two out of, every town. They all represent triplets, and every incoming triplet overlaps every outgoing triplet for every town. This means that if a person—say an efficient highway inspector—could find a route taking him over each road just once, he would in effect trace a memory wheel. For example, suppose the inspector began at town 01. He could follow a route consisting of highways 011,



ROAD MAP EMERGES FROM MAZE on preceding page when triplets are thought of as towns and arrows as one-way roads. Problem is to find route that touches each town once, begins and ends in proximate towns. Route shown is given by memory number 0111010001.

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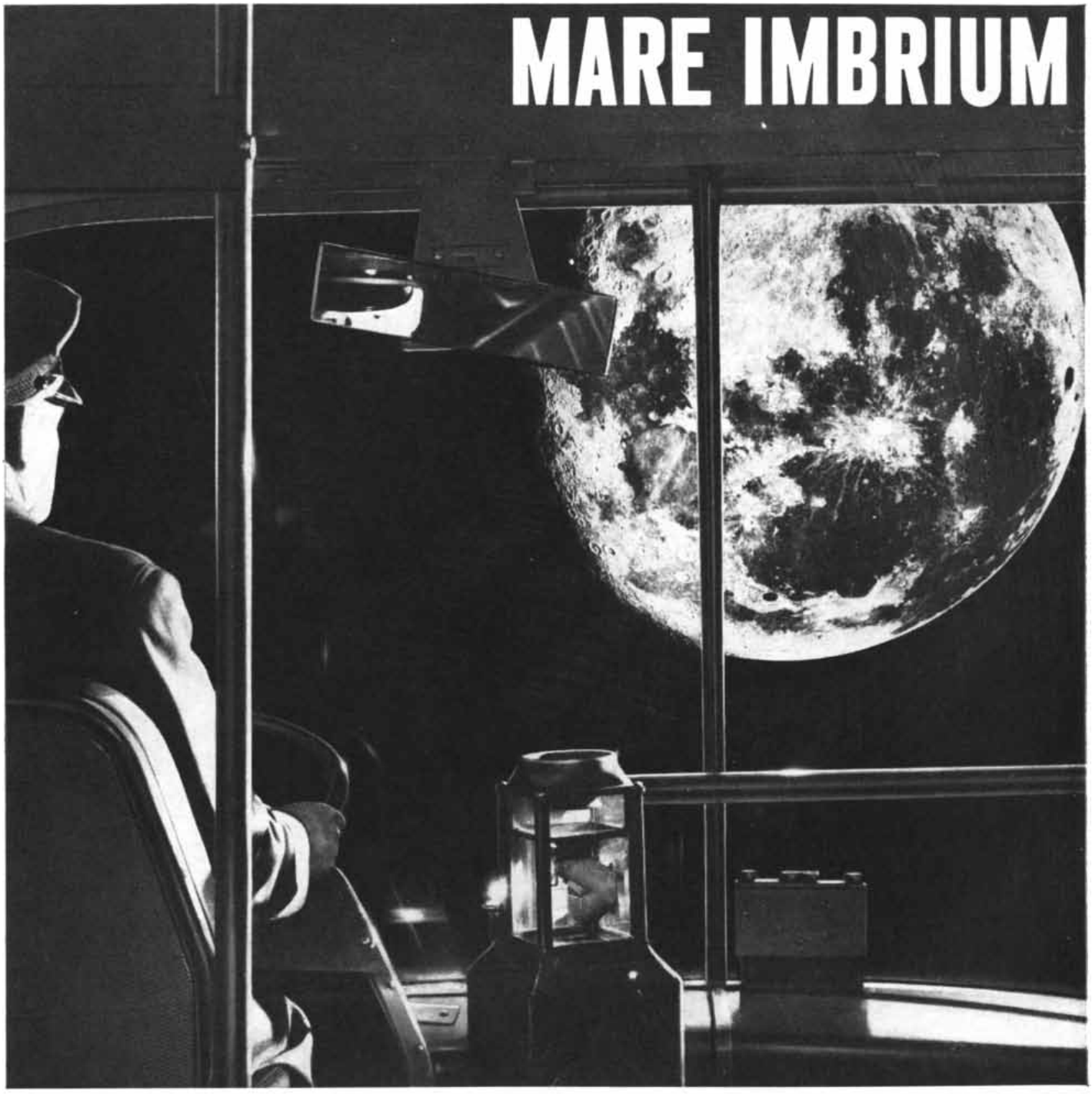

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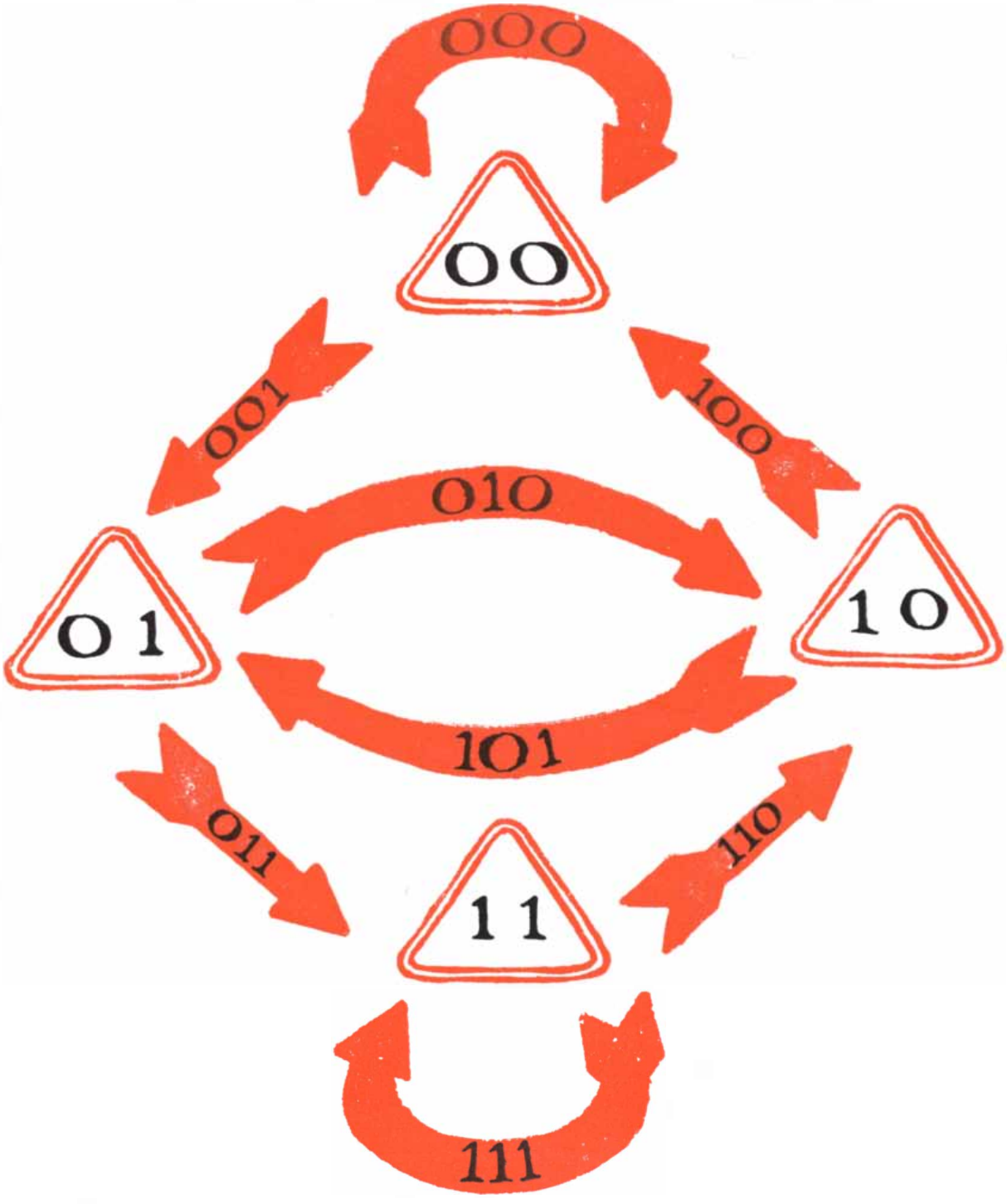
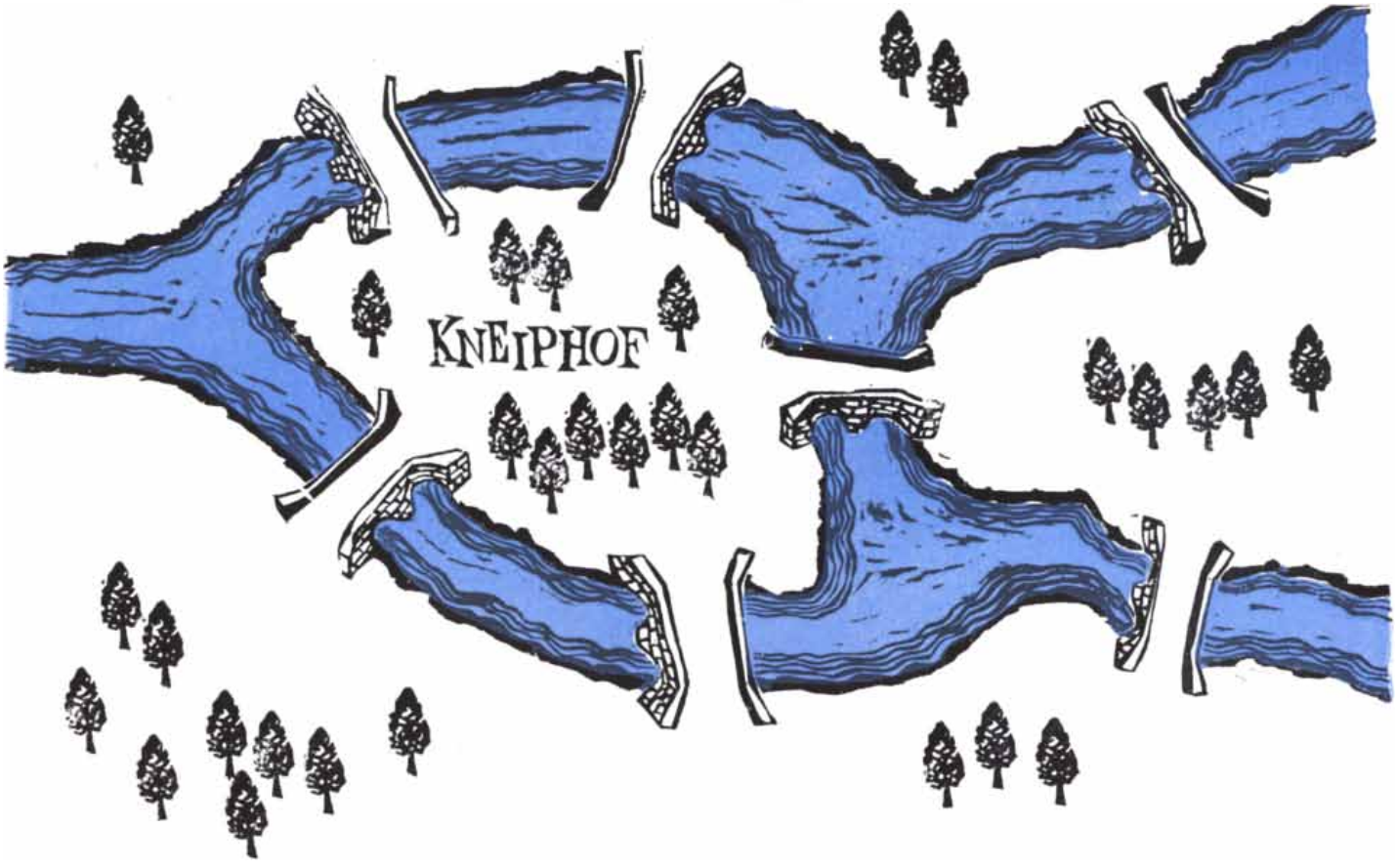
111, 110, 101, 010, 100, 000 and 001. The trip is, of course, exactly the one given by *yamátárájabhánasalagám*. Notice also that the last highway, 001, leads into the first one, 011.

Now it happens that the problem of whether the efficient inspector always has a route through a highway system such as Good's was solved some 200 years ago by Leonhard Euler, the renowned Swiss mathematician. Euler's attention had been attracted to a puzzle known as the problem of the Koenigsberg Bridges. "In the town of Koenigsberg," he wrote, "there is an island called Kneiphof, with two branches of the river Pregel flowing around it [*see illustration on next page*]. There are seven bridges crossing the two branches. The question is whether a person can plan a walk in such a way that he will cross each of these bridges once but not more than once.... On the basis of the above I formulated the following very general problem for myself: Given any configuration of the river and the branches into which it may divide, as well as any number of bridges, to determine whether or not it is possible to cross each bridge exactly once." [See "Leonhard Euler and the Koenigsberg Bridges"; SCIENTIFIC AMERICAN, July, 1953.]

Euler broke down the problem into several cases, the last of which was: "If, finally, there is no region with an



ALTERNATIVE FORM OF ROUTE PROBLEM on page 154 conceives of couplets as towns and triplets as highways. Task is to choose between the roads that leave each town and to travel each exactly once. Problem is like classical one illustrated on next page.



PROBLEM OF THE SEVEN BRIDGES of Koenigsberg requires that a route be found that crosses each bridge exactly once. It is the classic form of route problems; the bridges and land masses correspond to the roads and towns of the other forms.

odd number of approach bridges, the required journey can be effected, no matter where it begins" [and must end where it begins].

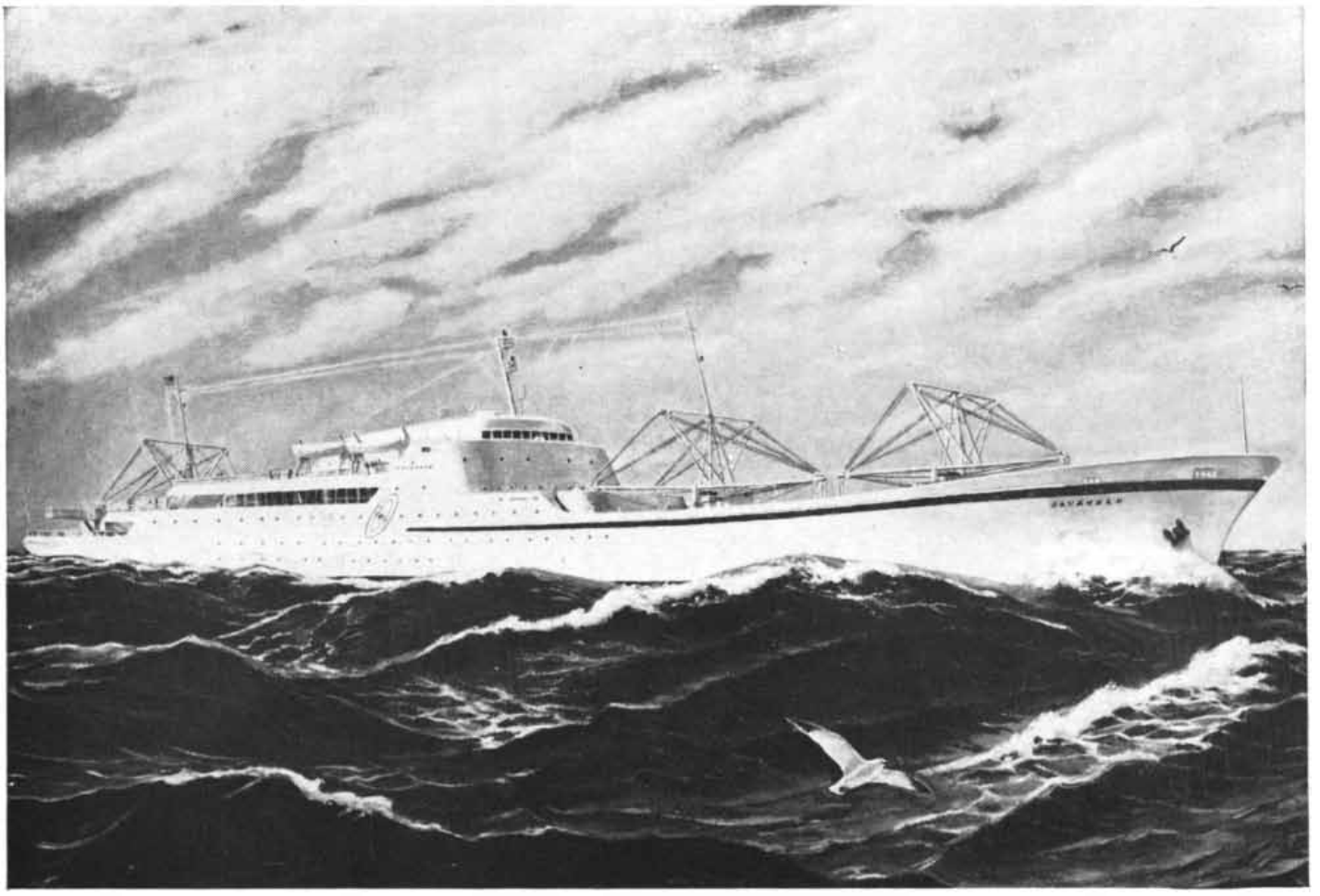
I shall not present Euler's proof here. It is obvious, however, that the inspector's highway system satisfies the condition just quoted. Each town has exactly two roads entering it and two leaving, or, in Euler's terms, each region has four bridges. In the case of quadruplets the towns are the eight triplets and the roads are the 16 quadruplets: there are two entrances and two exits to each town.

Since the salesman's problem is equivalent to the inspector's, he also has a route and his journey must end in a town adjacent to the one in which he starts. Thus I had quite unintentionally found a special class of highway systems for which the salesman has a route, and so had shed some light on a famous problem raised by the Irish mathematician William Rowan Hamilton in 1859: Which highway systems have a salesman route? Curiously, in this special class the salesman finds a route by pretending to be a highway inspector of a related but quite different highway system.

The story does not end here. Through *Mathematical Reviews* I learned that other mathematicians in various parts of the world had been involved with the memory-word problem in one guise or another. Twelve years before Good had published his paper M. H. Martin had solved the problem in a completely different way; he had been led to it by a problem of dynamics. D. Rees, in a paper published adjacent to Good's, solved the problem by considering certain divisors of polynomials of the type $X^m - 1$. In 1951 a Russian mathematician who was studying the fractional part of multiples of numbers described an entirely different technique for constructing memory wheels. K. Posthumus, a French engineer working on the theory of telephone circuits, posed another question about memory wheels: How many different wheels are there for couplets, triplets, quadruplets and so on? He found that there is one for couplets, two for triplets, 16 for quadruplets, 2,048 for quintuplets, and he guessed at a general formula for groups of any size (n-tuplets): 2 raised to the power $2^{n-1}-n$. In 1946 a Dutch mathematician proved the conjecture.

I learned also that memory wheels have found technological applications. A computer made in Czechoslovakia employs a memory wheel of 1,024 symbols to search through an equal number of storage locations on a memory drum. And in the Damodar Valley near Calcutta (the wheel of fate has now made a full turn) a memory wheel in a central office scans automatically transmitted reports from 64 rain gauges.

This has been a fable with many morals. It deals with a question that could have been raised a thousand years ago in India but was not. And little did Euler dream that his work on a puzzle would be of practical use in the 20th century. Moreover, the variety of applications reflects both the mathematical mood of our time and the fantastic amount of mathematics being created all over the world. The fact that so many of the workers were ignorant of the others' results, and therefore duplicated much effort, points to another problem: how to record the myriad discoveries constantly flowing into man's store of knowledge. Above all, the story shows the power of curiosity that makes men explore the unknown to find the truth, whether it be of stars, continents or mathematics.



N.S. Savannah, built by New York Shipbuilding Corporation, can sail for three years on 138 pounds of nuclear fuel. A conventional ship would burn 80,000 tons of oil.

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This is the Nuclear Ship Savannah, first of her kind. Capable of sailing over 350,000 nautical miles without re-fueling, she points the way to a new era in transport and travel at sea.

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Wherever you look, inside the reactor, almost everything is Nickel Stainless Steel. 200,000 pounds of it are used in the reactor area: for the lining of the reactor vessel, for the coolant pumps and tubing that circulate corrosive "hungry" water, and for the control rods inside the atomic pile.

At the design stage, engineers anticipated the high operating pressures—1,750 pounds per square inch—and temperatures up to 508° F. They selected Nickel Stainless Steels to provide the strength and resistance to heat and corrosion needed to withstand these rigorous conditions.

So the next time you need more from a metal, remember the N.S. Savannah. Nickel Stainless Steel, or another Nickel alloy, may be the solution to *your* problem, too.

A note to Inco will bring you "First Steps Towards Solving Specific Corrosion Problems" and "High Temperature Worksheet"... simplified forms you can use to describe your metal problem. Perhaps our technical staff has information that will help you find the solution.

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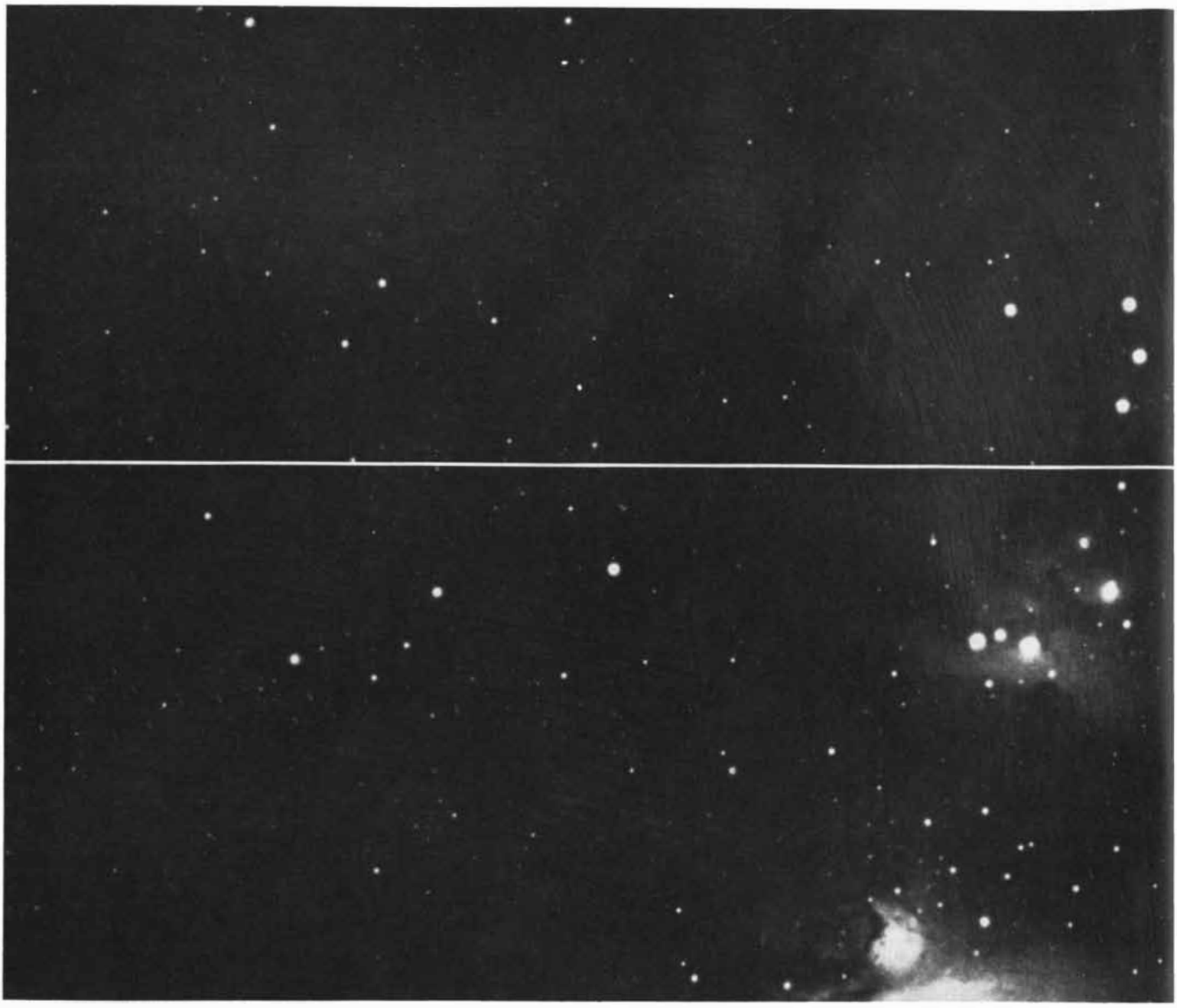


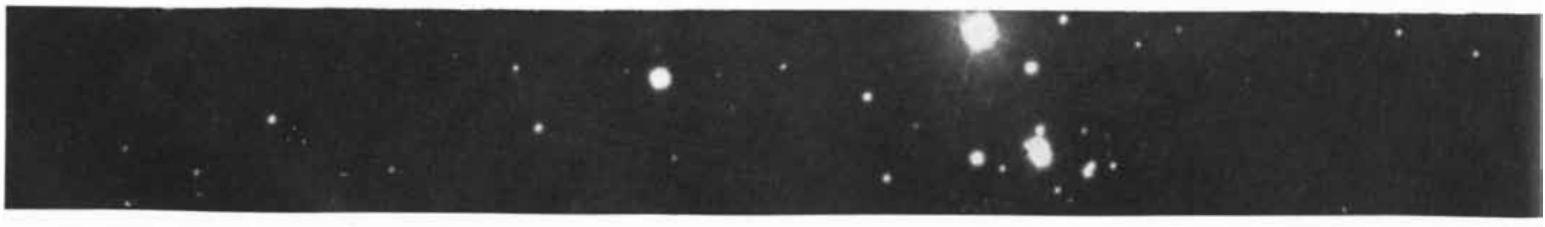
This is Colidar—a dramatically new kind of radar for satellites and other space vehicles.

Unlike conventional radar, which "sees" with microwaves, the Hughes-developed Colidar probes with incredibly narrow, high-intensity beams of light.

The secret is a new *kind* of light. *Coherent light*. This is a projection of electromagnetic energy at a *precise* frequency—100,000 times higher than conventional radar frequencies.

This high concentration of energy into a narrow beam gives Colidar amazing powers of discrimination—and makes possible ranges far beyond the abilities of present-day radar.

In orbit, a Colidar-equipped satellite could survey vast areas of space—tracking other satellites, space vehicles and other objects. Add this to Colidar's small size, light weight and low power needs, and the result is the most practical radar for use in space.



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MATHEMATICAL GAMES

In which the editor of this department meets the legendary Bertrand Apollinax

by Martin Gardner

When Mr. Apollinax visited the United States
His laughter tinkled among the teacups.
—T. S. ELIOT

P. Bertrand Apollinax, the brilliant protégé of the fictitious French mathematician Nicolas Bourbaki, was little known even in France until the spring of 1960. It was then, as everyone knows, that the mathematical world was shattered by the disclosure, in a French mathematical journal, of what is now known as the Apollinax function. By means of this remarkable function Apollinax was able at one stroke to (1) prove Fermat's last theorem, (2) provide a counterexample (a map with 5,693 regions) to the famous four-color theorem of topology, (3) lay the groundwork for Channing Cheetah's discovery, three months later, of a 5,693-digit integer—the first of its kind known—that is both perfect and odd.

The reader will understand my excitement when Professor Cheetah, of New York University, invited me to his apartment for an afternoon tea at which Apollinax would be guest of honor. (Cheetah's apartment is in Greenwich Village, in a large brownstone building off Fifth Avenue. The building is owned by Mrs. Orville Phlaccus, widow of the well-known financier, and is called Phlaccus Palace by students at nearby N.Y.U.) When I arrived, the tea was in full swing. I recognized several members of the N.Y.U. mathematics faculty and guessed that most of the younger people present were graduate students.

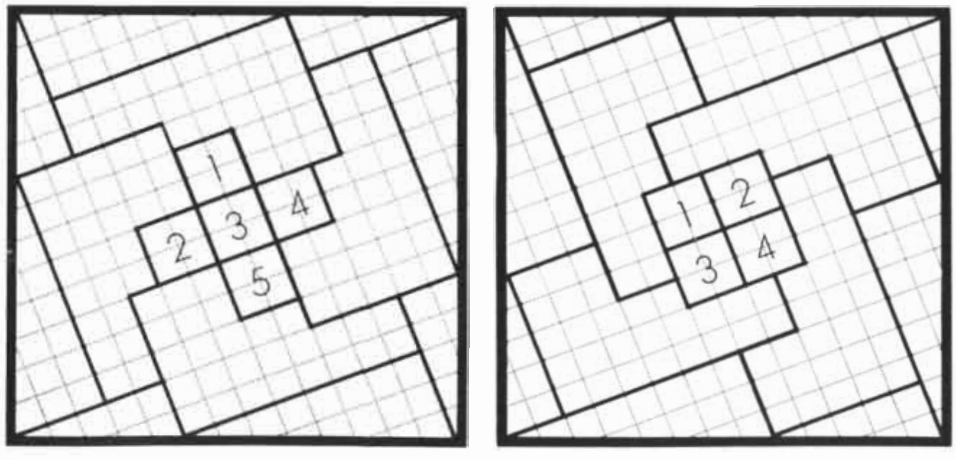
There was no mistaking Apollinax. He was the obvious center of attention: a bachelor in his early thirties, tall, with rugged features that could not be called handsome but nevertheless conveyed a strong impression of physical virility combined with massive intellect. He had a small black goatee and rather large ears with prominent Darwin points. Under his tweedy jacket he sported a bright red vest.

While Mrs. Phlaccus served me a cup of tea, I heard a young woman say: "That silver ring on your finger, Mr. Apollinax. Isn't it a Möbius strip?"

He removed the ring and handed it to her. "Yes. It was made by an artist friend of mine who has a jewelry shop on the Left Bank in Paris." He spoke with a husky French accent.

"It's crazy," the girl said as she handed back the ring. "Aren't you afraid it will twist around and your finger will disappear?"

Apollinax chuckled explosively. "If



The mystery of the disappearing tile

ARMY'S NEW "SHOOT-AND-SCOOT" MISSILE SCORES SUCCESS

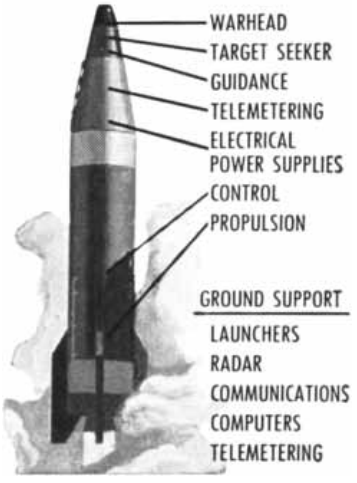
A new technique in warfare was dramatically demonstrated recently when the Army's latest missile, the Pershing, was successfully tested, using its new Bendix inertial guidance system.

This all-weather, ground-to-ground weapon—sometimes called a "shoot-and-scoot" missile by engineers at The Martin Company, its prime contractor—requires no fixed launching site. It can be rushed to an unprepared site either by highly mobile ground launching equipment, or by aircraft, and fired in minutes. The installation then "scoots" before the enemy can zero in on the launching site.

Largely responsible for Pershing's deadly accuracy is the Bendix inertial guidance system. Bendix was selected for this job because of its previous experience in building similar types of equipment. Some of the more critical components are held to tolerances of *10 millionths of an inch.*

This is but one of many Bendix activities in the missile and space fields. We are prime contractor for the Navy's Talos missile. This *surface-to-air* missile is the principal armament of our new missile cruiser fleet, and because it has accuracy and far greater range than the big guns of yesterday, it has helped put the battleship in moth balls.

Bendix built, operates and maintains Minitrack and SPASUR, two of the three U. S. satellite tracking systems. The Bendix Satellite Tracker—a unique telescopic lens-TV combination recently developed for visual tracking—took what was probably the best telephoto of the Russian space ship, Sputnik IV, prior to its breakup.



The general location of various Bendix-made systems and their components are shown here. No particular missile or satellite is represented in this drawing.

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you think that's crazy, then I have something here you'll think even crazier." He reached into his side pocket and took out a square, flat wooden box. It was filled with 17 white plastic tiles that fitted snugly together [*see illustration at left on page 162*]. The tiles were of such thickness that the five small pieces in the center were cubes. Apollinax called attention to the number of cubes, dumped the tiles onto a nearby table, then quickly replaced them in the box in the manner shown in the illustration at right on page 162. They fitted snugly as before. But now there were only four cubes. One cube had completely vanished!

The young woman stared at the pattern with disbelief, then at Apollinax, who was shaking with high-pitched laughter. "May I study this for a while?" she asked, taking the box from his hand. She carried it off to a quiet corner of the room.

"Who's the chick?" Apollinax said to Cheetah.

"I beg your pardon?" replied the professor.

"The girl in the sweat shirt."

"Oh. Her name is Nancy Ellicott. A Boston girl. She's one of our undergraduate math majors."

"Very attractive."

"You think so? I've never seen her wear anything but dungarees and that same dirty sweat shirt."

"I like your Village nonconformists," Apollinax said. "They're all so much alike."

"Sometimes," remarked someone in the group, "it's hard to distinguish nonconformity from neurosis."

"That reminds me," I said, "of a mathematical riddle I just heard. What's the difference between a psychotic and a neurotic?"

Nobody said anything.

"A psychotic," I went on, "thinks that two plus two is five. A neurotic knows that it's four, but it makes him nervous."

There was some polite laughter, but Apollinax looked grave. "He has good reason to be nervous. Wasn't it Alexander Pope who wrote: 'Ah why, ye gods! should two and two make four?' Why indeed? Who can say why tautologies are tautological? And who can say that even simple arithmetic is free from contradiction?" He took a small notebook from his pocket and jotted down the following infinite series:

$$4 - 4 + 4 - 4 + 4 - 4 + 4 \ldots$$

"What," he asked, "is the sum of this

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"Astounding" is more like it, because we use your principle to buoy the "heart" of our precision gyroscopic instruments. Floatation eliminates frictional forces on pivots and thereby reduces drift rates. Consequently, we are able to develop precise gyros and pendulous accelerometers for missile guidance and ship navigation.

If you are interested in putting ancient laws to work in the missile age, and if you have a BS, MS or PhD in EE, ME, Physics or Math, contact Mr. G. F. Raasch, Director of Scientific and Professional Employment, Dept. E, 7929 S. Howell, Milwaukee 1, Wisconsin.

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series? If we group the numbers like this,

$$(4-4)+(4-4)+(4-4)\ldots$$

the sum is obviously zero. But if we group them so,

$$4-(4-4)-(4-4)-(4-4)\ldots$$

the sum is clearly four. Suppose we try them still another way:

$$4-(4-4+4-4+4-4\ldots)$$

Now the sum of the series is four minus the sum of the same series. In other words, twice the sum is equal to four, so the sum must be equal to half of four, or two."

I started to make a comment, but Nancy pushed her way back through the group and said: "These tiles are driving me batty. What happened to that fifth cube?"

Apollinax laughed until his eyes teared. "I'll give you a hint, my dear. Perhaps it slid off into a higher dimension."

"Are you pulling my leg?"

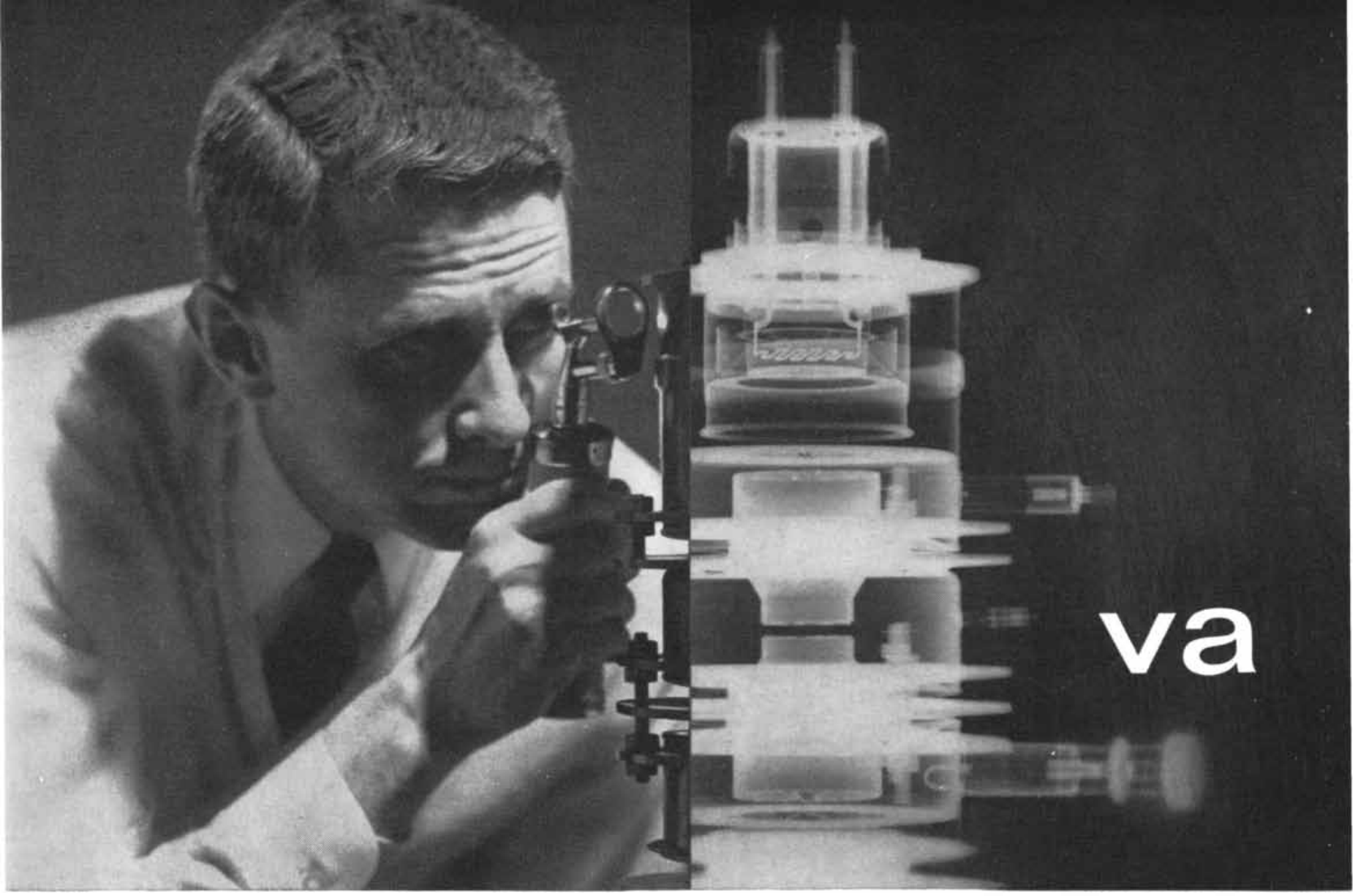
"I wish I were," he sighed. "The fourth dimension, as you know, is an extension along a fourth co-ordinate perpendicular to the three co-ordinates of three-dimensional space. Now consider a cube. It has four main diagonals, each running from one corner through the cube's center to the opposite corner. Because of the cube's symmetry, each diagonal is clearly at right angles to the other three. So why shouldn't a cube, if it feels like it, slide along a fourth co-ordinate?"

"But my physics teacher," Nancy said with a frown, "told us that *time* was the fourth dimension."

"Nonsense!" Apollinax snorted. "General relativity is as dead as the dodo. Hasn't your professor heard about Hilbert Dongle's recent discovery of a fatal flaw in Einstein's theory?"

"I doubt it," Nancy replied.

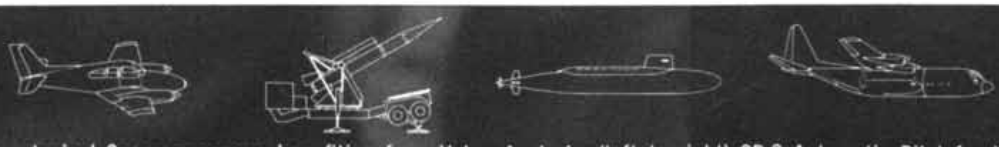
"It's easy to explain. If you spin a sphere of soft rubber rapidly, what happens to its equator? It bulges. In relativity theory, you can explain the bulge in two different ways. You can assume that the cosmos is a fixed frame of reference—a so-called inertial system. Then you say that the sphere rotates and inertia makes the equator bulge. Or you can make the sphere a fixed frame of reference and regard the entire cosmos as rotating. Then you say that the masses of the moving stars set up a gravi-



Value Analysis (VA) is an X-ray-like Sperry program designed to take a "second look" at products in the hardware stage. Every component part, material and production technique is challenged. The objective: lowest product cost at no sacrifice to essential quality and performance.

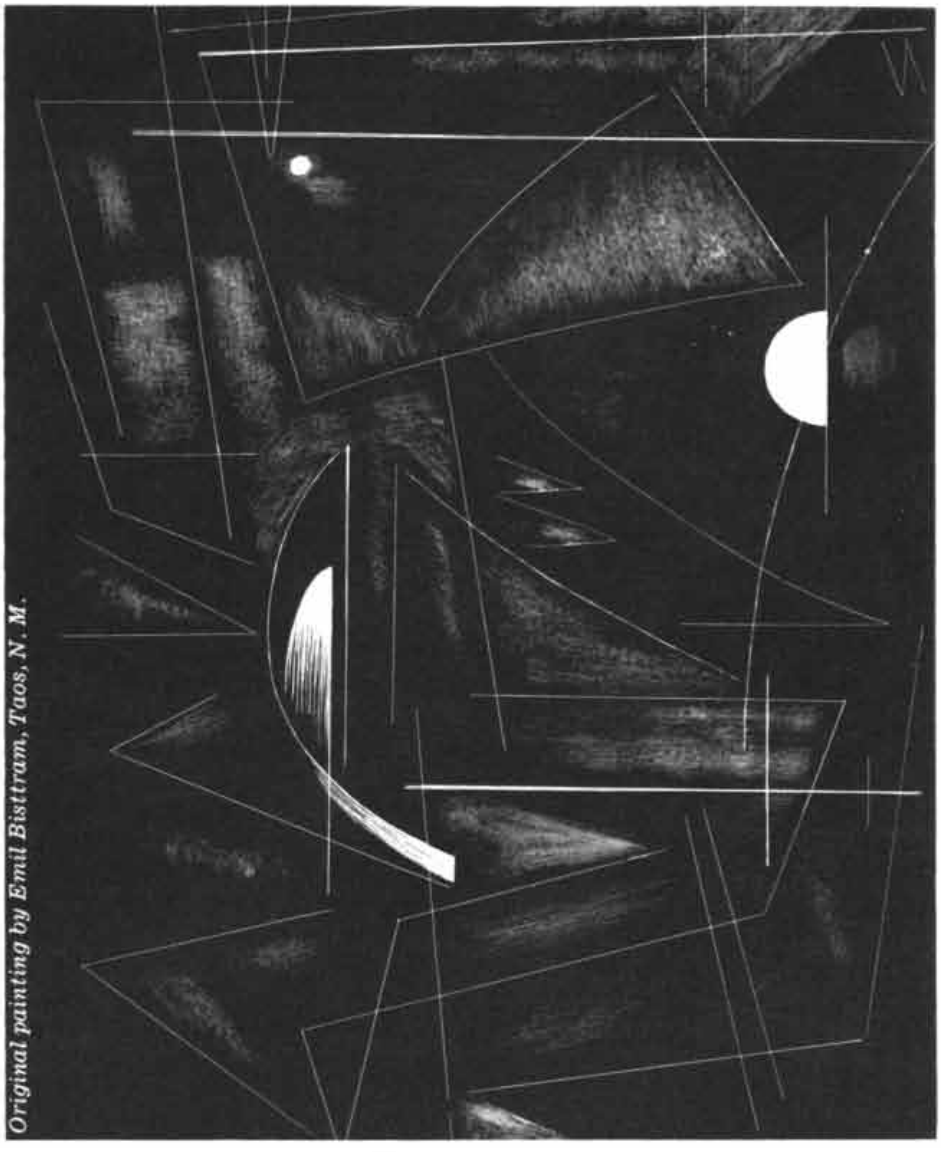
Sperry VA teams—specialists in engineering, product methods, purchasing and quality control—are attaining dramatic reductions in costs in a wide range of products and systems.

By introducing value analysis in the design stage as well, additional millions of dollars will be saved for the customer and the taxpayer. General offices: Great Neck, N. Y.



Some typical Sperry programs benefiting from Value Analysis: (left to right) SP-3 Automatic Pilot for light aircraft; Army's SERGEANT missile system; Navy's Mark 19 Gyro-Compass; USAF's APN-59 Airborne Radar System; Klystron tubes for long range radar systems (main illustration).

SPERRY



Original painting by Emil Bisttram, Taos, N. M.

tational tensor field that exerts its strongest pull on the equator of the motionless ball. Of course—"

"I would put it a bit differently," Cheetah interrupted. "I would say that there is a relative movement of sphere and stars, and this relative motion causes a certain change in the space-time structure of the universe. It is the pressure, so to speak, of this space-time matrix that produces the bulge. The bulge can be viewed either as a gravitational or inertial effect. In both cases the field equations are exactly the same."

"Very good," Apollinax replied. "Of course, this is exactly what Einstein called the principle of equivalence—the equivalence of gravity and inertia. As Hans Reichenbach liked to put it, there's no truth distinction between the two. But now let me ask you this: Does not relativity theory make it impossible for physical bodies to have relative motions greater than the speed of light? Yet if we make the rubber ball our fixed frame of reference, it takes only a slow spin of the ball to give the moon a relative motion much faster than the speed of light."

Cheetah did a slow double-take.

"You see," Apollinax continued, "we just can't keep the sphere still while we spin the universe around it. This means that we have to regard the ball's spin as absolute, not relative. Astronomers run into the same sort of difficulty with what they call the transverse Doppler effect. If the earth rotates, the relative transverse velocity between the observatory and a ray of light from a distant star is very small, so the Doppler shift is small. But if you view the cosmos as rotating, then the transverse velocity of the distant star relative to the observatory is very great, and the Doppler shift would have to increase accordingly. Since the transverse Doppler shift is small, we must assume it is the earth that rotates. Of course, this defenestrates relativity theory."

"Then," Cheetah mumbled, looking a trifle pale, "how do you account for the fact that the Michelson-Morley experiment failed to detect any motion of the earth relative to a fixed space?"

"Quite simple," Apollinax said. "The universe is infinite. The earth spins around the sun, the sun speeds through the galaxy, the galaxy gallops along relative to other galaxies, the galaxies are in galactic clusters that move relative to other clusters, and the clusters are parts of superclusters. The hierarchy is endless. Add together an infinite series

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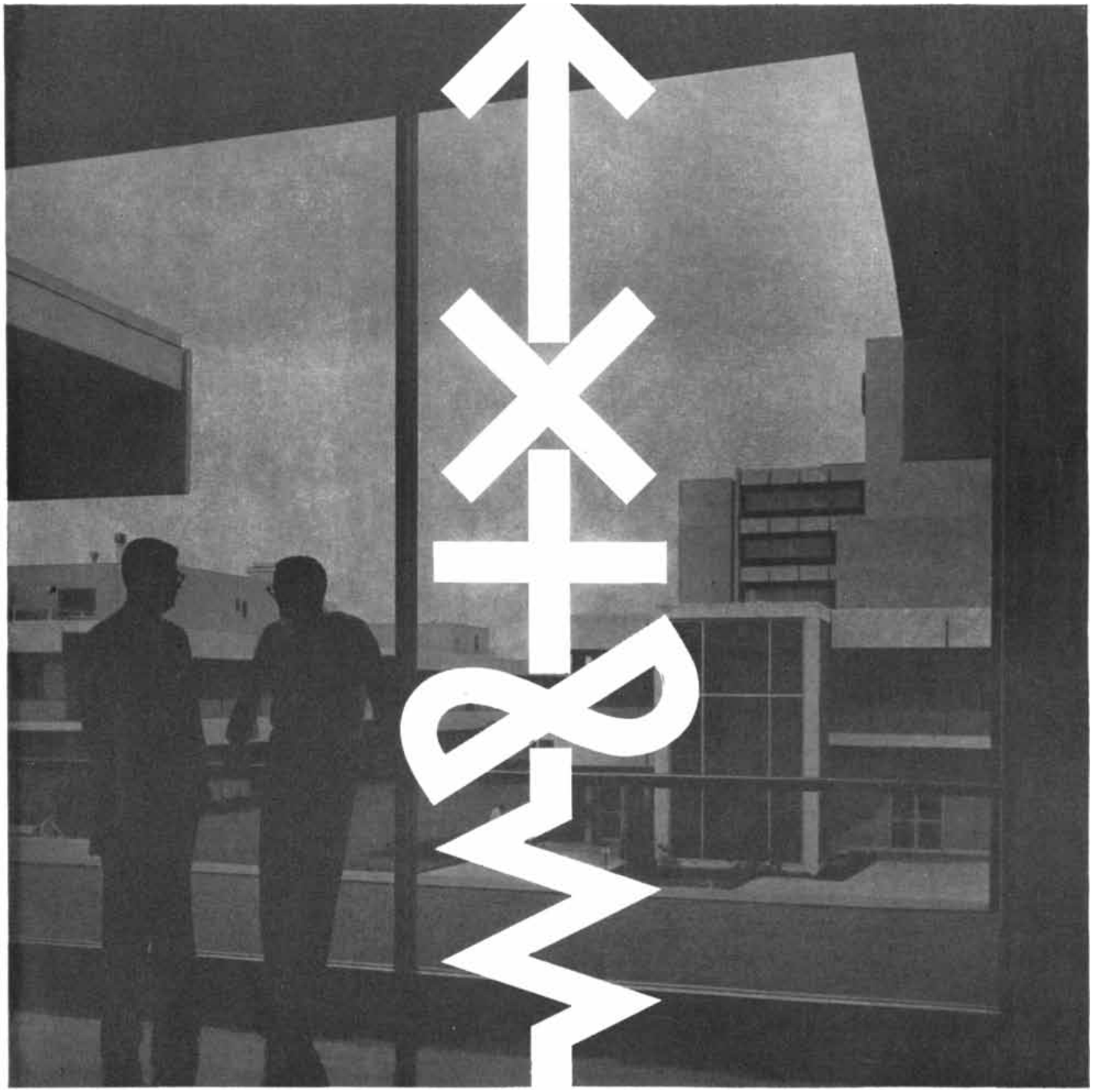


of vectors, of random speeds and directions, and what happens? They cancel each other out. Zero and infinity are close cousins. Let me illustrate."

He pointed to a large vase on the table. "Imagine that vase empty. We start filling it with numbers. If you like, you can think of small counters with numbers on them. At one minute to noon we put the numbers 1 through 10 into the vase, then take out number 1. At one-half minute to noon, we put in numbers 11 to 20 and take out number 2. At one-third minute to noon we put in 21 to 30, take out 3. At one-fourth minute to noon we put in 31 to 40, take out 4. And so on. How many numbers are in the vase at noon?"

"An infinity," said Nancy. "Each time you take one out, you put in ten."

Apollinax cackled like an irresponsible hen. "There would be *nothing* in the vase! Is 4 in the vase? No, we took it out on the fourth operation. Is 518 in the vase? No, it came out on the 518th operation. The numbers in the vase at noon form an empty set. You see how close infinity is to zero?"

Mrs. Cheetah approached us, bearing a tray with assorted cookies and macaroons. "I think I shall exercise Zermelo's axiom of choice," said Apollinax, tugging on his goatee, "and take one of each kind."

"If you think relativity theory is dead," I said a few minutes later, "what is your attitude toward modern quantum theory? Do you think there's a fundamental randomness in the behavior of the elementary particles? Or is the randomness just an expression of our ignorance of underlying laws?"

"I accept the modern approach," he said. "In fact, I go much further. I agree with Karl Popper that there are *logical* reasons why determinism can no longer be taken seriously."

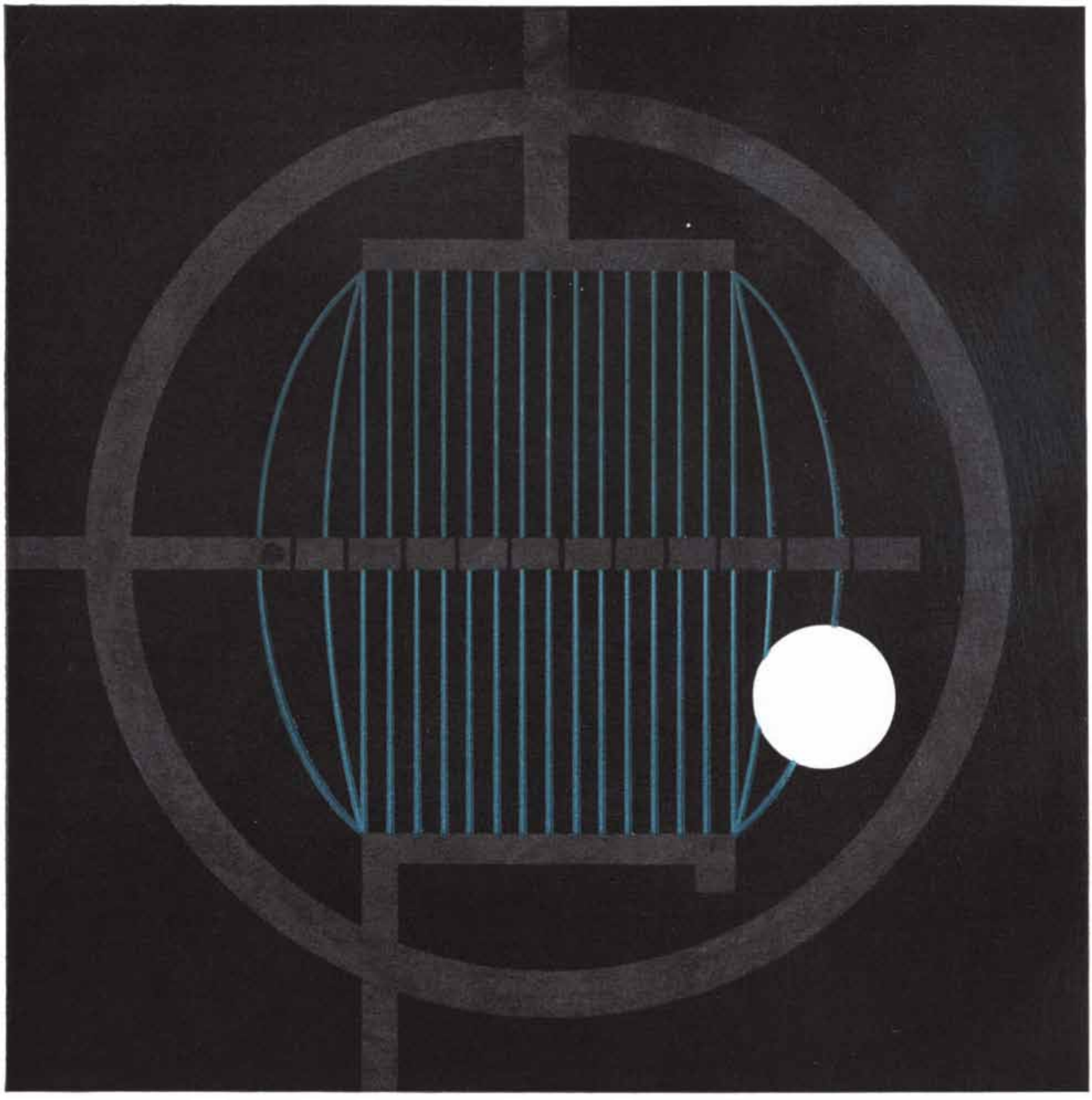
"That's hard to believe," someone said.

"Well, let me put it this way. There are portions of the future that *in principle* can never be predicted correctly, even if one possessed total information about the state of the universe. Let me demonstrate."

He took a blank file card from his pocket, then, holding it so no one could see what he was writing, he scribbled something on the card and handed it to me, writing side down. "Put that in your right trouser pocket."

I did as he directed.

"On that card," he said, "I've described a future event. It hasn't taken place yet, but it positively either will or



Electronics at Boeing

Electronics, symbolized by this diagrammatic representation, is a rapidly expanding field of activity at Boeing. Here engineers and scientists are at work in research, design and test areas of electronics. Activities cover a broad spectrum, from advancement of the state-of-the-art to the development, manufacture and installation of electronic systems.

Boeing scientists and engineers are also advancing the state-of-the-art in many other areas, including military jet aircraft, commercial jet transports, hypersonic flight, helicopters, vertical and short take-off and landing aircraft, gas turbine engines, space systems, antennas and hydrofoils. In addition, scientists of Boeing's Allied Research Associates subsidiary developed techniques and interpretive methods to analyze data transmitted to earth by Tiros I and Tiros II meteorological satellites.

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will not take place before"—he glanced at his wrist watch—"before six o'clock."

He took another blank card from his pocket and handed it to me. "I want you to try to guess whether the event I just described will take place. If you think it will, write 'Yes' on the card you hold. If you think it won't, write 'No.' "

I started to write, but Apollinax caught my wrist. "Not yet, old chap. If I see your prediction, I might do something to make it fail. Wait until my back is turned, and don't let anyone see what you write." He spun around and looked at the ceiling until I had finished writing. "Now put the card in your left pocket, where no one can see it."

He turned to face me again. "I don't know your prediction. You don't know what the event is. Your chance of being right is one in two."

I nodded.

"Then I'll make you the following bet. If your prediction is wrong, you must give me ten cents. If it's right, I'll give you one million dollars."

Everyone looked startled. "It's a deal," I said.

"While we're waiting," Apollinax said to Nancy, "let's go back to relativity theory. Would you care to know how you can always wear a relatively clean sweat shirt, even if you own only two sweat shirts and never wash either of them?"

"I'm all ears," she said, smiling.

"You have other features," he said, "and very pretty ones too. But let me explain about those sweat shirts. Wear the cleanest one, say sweat shirt *A*, until it becomes dirtier than *B*. Then take it off and put on the relatively clean sweat shirt *B*. The instant *B* is dirtier than *A*, take off *B* and put on the relatively clean sweat shirt *A*. And so on."

Nancy made a face.

"I really can't wait here until six," Apollinax said. "Not on a warm spring evening in Manhattan. Would you by any chance know if Thelonious Monk is playing anywhere in the city tonight?"

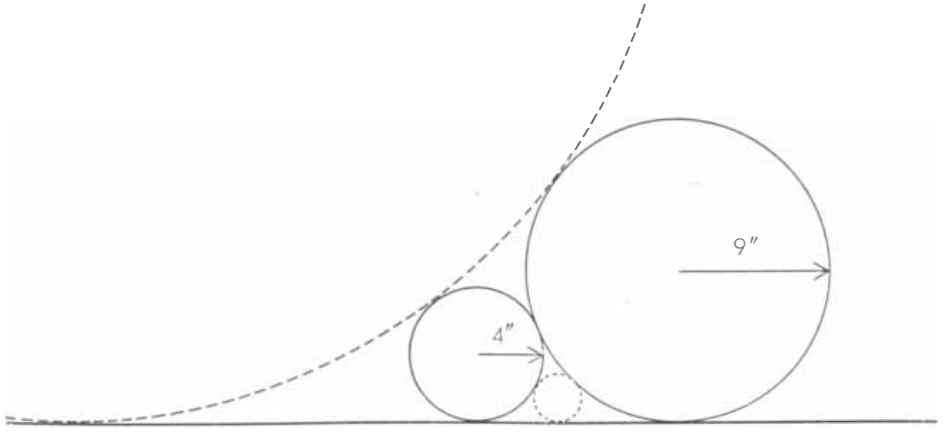
Nancy's eyes opened wide. "Why, yes, he's playing right here in the Village. Do you like his style?"

"I dig it," Apollinax said. "And now, if you'll kindly direct me to a nearby restaurant, where I shall pay for your dinner, we will eat, I will explain the mystery of the tiles, then we will go listen to the Monk."

After Apollinax had left, with Nancy on his arm, word of the prediction bet spread rapidly around the room. When six o'clock arrived, everyone gathered around to see what Apollinax and I had written. He was right. The event was logically unpredictable. I owed him a dime.

The reader may enjoy trying to figure out just what future event Apollinax described on that card. The details will be given next month, together with a full explanation of what happened to the fifth cube.

Last month, readers of this department were asked to find the radius of the largest sphere that can be placed on a straight line (drawn on a plane) so that it is tangent to two touching spheres, also on the line, with radii of four and nine inches. This can be viewed in cross section [*see illustration below*] as a problem involving four mutually tangent circles, the straight line considered a circle of zero curvature. Frederick Soddy's formula for "the kiss precise," explained last month, gives the two circles (drawn with dotted lines) radii of 1 and 11/25 inches and 36 inches respectively. The larger circle is the mid-section of the sphere that answers the problem.



The answer to last month's problem

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Unlike other automatic landing systems, the Bell ALS is ground-based so a ground observer monitors every approach and landing. It can operate either fully automatically or under pilot control.

Military versions of the ALS have been ordered by the Air Force. The Navy has selected it for installation aboard the nuclear-powered aircraft carrier USS Enterprise as well as for its other large carriers.

The Bell ALS is but one among many contributions which Bell Aerosystems Company is making to the scientific progress and defensive strength of the free world. We invite qualified engineers and scientists to inquire about sharing our challenging and rewarding future.

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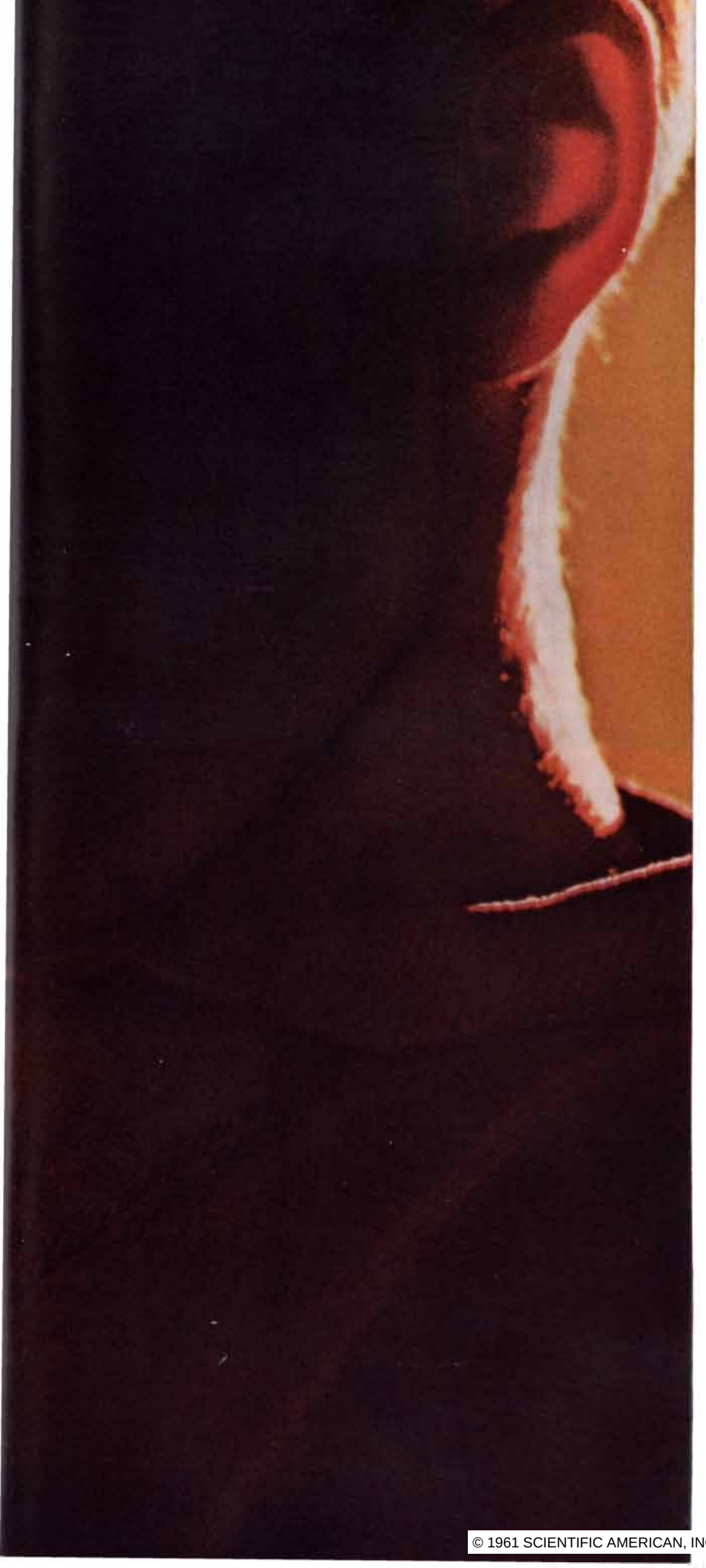

Why did the bird die?

Didn't he get enough to eat? Did he break his wings? Why did he have to die? Why?

A child's whys seem as numberless as the moments that march him toward adulthood. Too often, the end of questioning comes with the end of childhood; for many, the wonder of the world is lost with growing up.

Others—all too few—never outgrow the joy of asking, searching, and finding.

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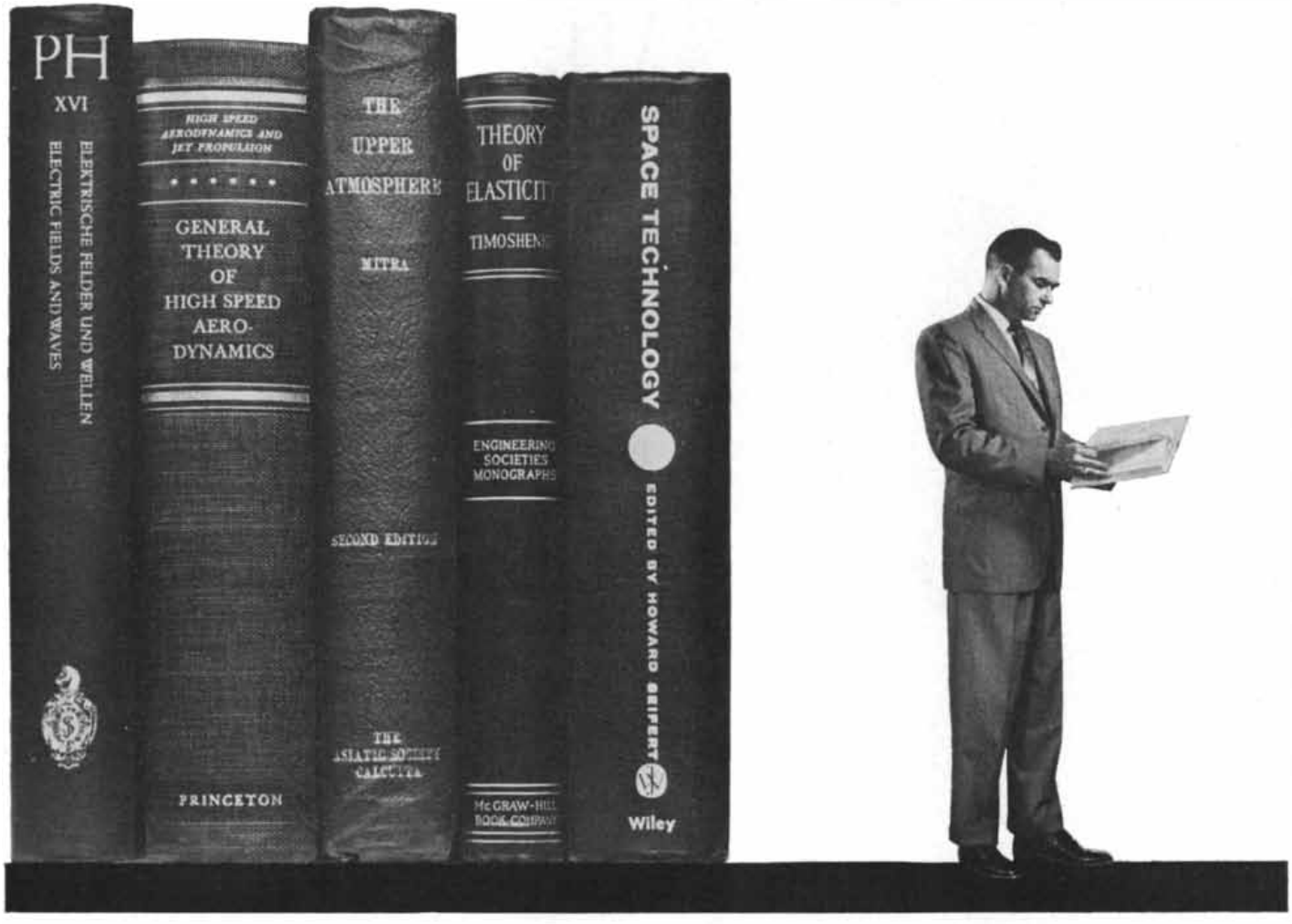

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THE AMATEUR SCIENTIST

Mostly on how to make impressions of biological specimens in plastic

Conducted by C. L. Stong

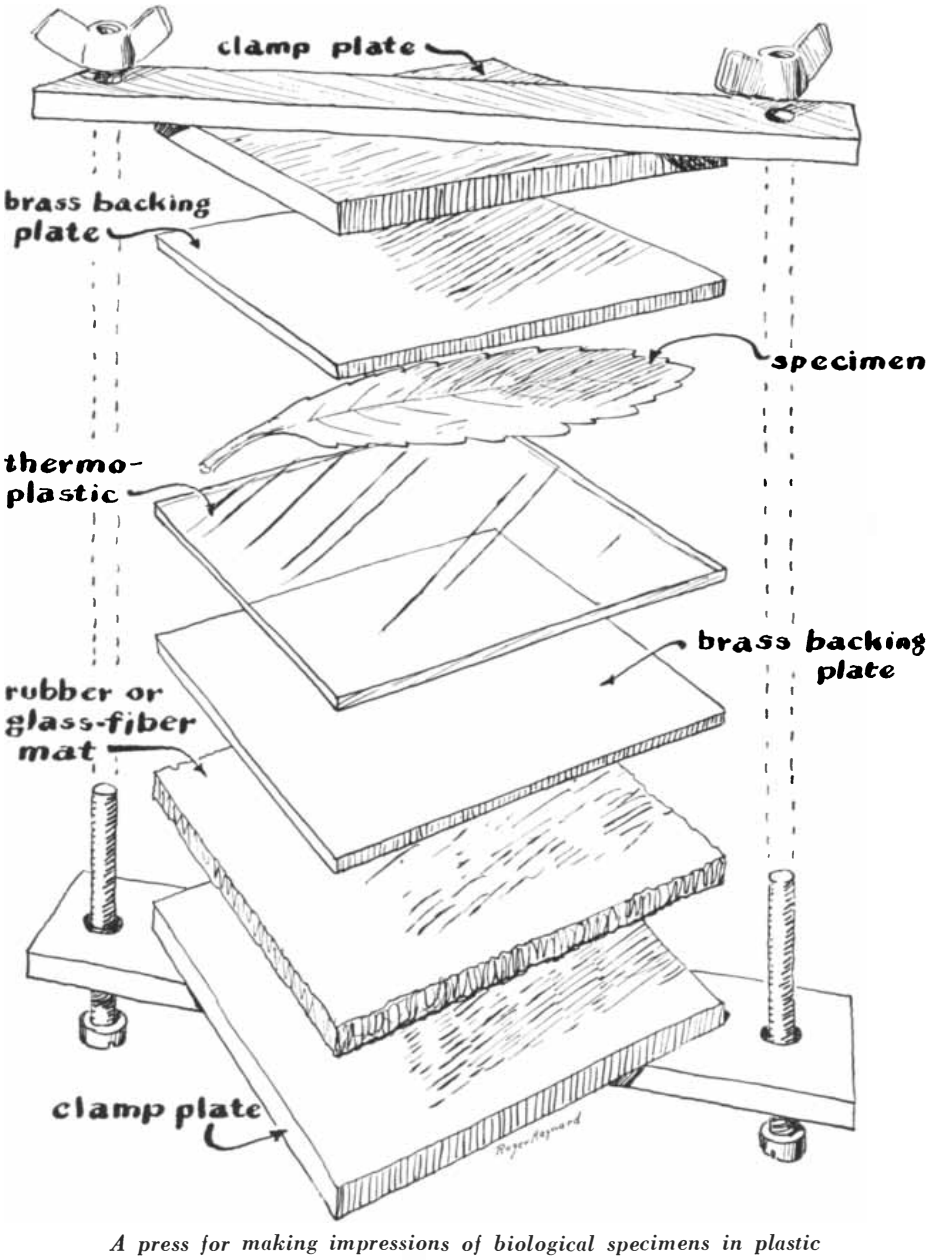
A novel method of recording the form of biological specimens has been developed by George and Anna Higley of Snoqualmie, Wash. They make transparent impressions of small plants and animals (or parts of large specimens) in clear plastic. Their technique may well open a new field of activity to amateur naturalists. The impressions are simple and inexpensive and result in three-dimensional records of fine detail that can be enlarged for study as much as 100 diameters by an ordinary 35-millimeter slide projector.

"We call our reproductions 'fossilides,'" write the Higleys. "They were developed as part of a college course on the preparation of biological material for use in elementary schools. The course required the collection and preservation of specimens in a form suitable for subsequent use in classrooms. A number of preserving techniques were demonstrated as examples, including the method of making contact prints of leaves on photographic paper. Such prints are little better than silhouettes, so we decided either to find or develop a method that would preserve the detail of a specimen as well as its gross form.

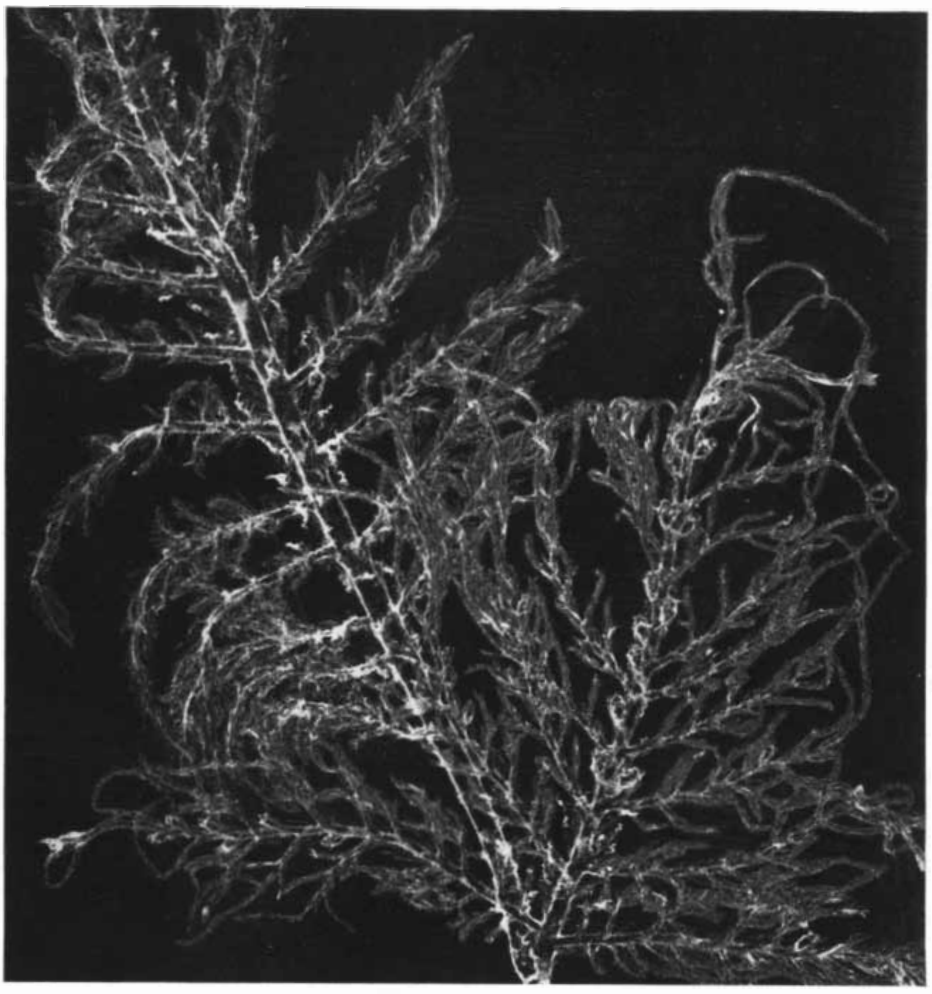
"Plastics seemed to offer interesting possibilities. Leaves could be sandwiched between two sheets of clear plastic and bonded with plastic cement, embedded in liquid resin that would harden upon exposure to air or bound between strips of adhesive cellophane tape. After a number of experiments the last two methods were dismissed. Results were unsatisfactory because either the materials exhibited poor characteristics or the technique was impractical. The sandwiching method appeared to hold more promise than the others, but at first only slightly more.

"The specimens were placed between two sheets of plastic that had been coated with cement, and the two sheets were clamped together with a small press. The assembly was then placed in a preheated kitchen oven until the bond formed. During several experiments the cement was omitted so that the minimum temperature and pressure required for uniting sheets of plain acrylic plastic could be observed. In one case the sheets were removed from the oven prematurely and they separated. A faint impression of the specimen, a leaf, had been made in each sheet. The outline and vein structure had been registered in the soft plastic with as much sharpness as one would expect in a leaf print and the plastic impression contained considerably more fine detail!

"The press was simply two pieces of sheet steel 3/16 inch thick, four inches wide and eight inches long. At first the steel plates were pressed together by a "C" clamp but this made them bend.



A press for making impressions of biological specimens in plastic



A plastic impression of Western moss

An impression of the spine of a herring

The difficulty was avoided by drilling holes in the corners of the plates for bolts. This turned out to be a fortunate solution because pressure initially applied by tightening the bolts is relieved as the plastic softens and so the flow of the soft material is automatically limited. Spring clamps that maintained a constant pressure would make the specimen push through the soft sheets.

"Although the impression faithfully reproduced the contours of the specimen, the surfaces of the plastic in contact with the metal plates came out of the press with a frosted texture—a reproduction of the mill finish on the plates. Polished liners were obviously required, so we tried a series of materials, including polished brass, glass and chromium-plated sheet steel polished to a mirror finish. All the materials worked, but metal was more convenient to use than glass, which breaks unless sharp changes in temperature are avoided.

"The initial experiments were made with acrylic plastic, a relatively expensive material. Hence cellulose acetate, a less costly material, was tested. The impressions showed more detail than those made with acrylic but subsequent experiments disclosed several disadvantages. The sheets tend to curl when heated. Vinylite was tried next. It reproduced as much detail as cellulose acetate and remained flat at all temperatures. Finally a friend who is a specialist in plastic vacuum-forming suggested cellulose acetate butyrate and solved the problem. Butyrate records fine detail, remains flat under heat, is easier to cut than Vinylite and does not become brittle or discolored with age.

"Thermoplastics are easily deformed by light pressure when hot, but like all fluids they respond to the forces of surface tension. When the pressure is relieved, some plastics, depending on their temperature, tend to return to their former shape and others to assume the minimum surface-to-volume ratio. This means that pressure must be maintained on the plastic until the press has cooled to room temperature, otherwise the plastic will flow, bubbles may develop and detail will be lost. A large press may require as much as two to four hours to reach room temperature, an impractical interval if a number of impressions are wanted over a weekend. The solution is to cool the press with water. Water must not come in contact with the hot plastic, however, or the material will turn milky. Some presses are cast with an internal channel for circulating water, like the motor block of a gasoline engine. Small presses can be

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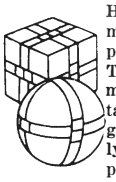

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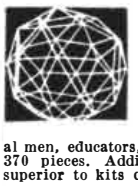

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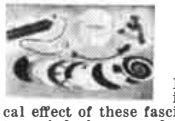

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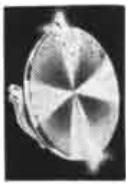

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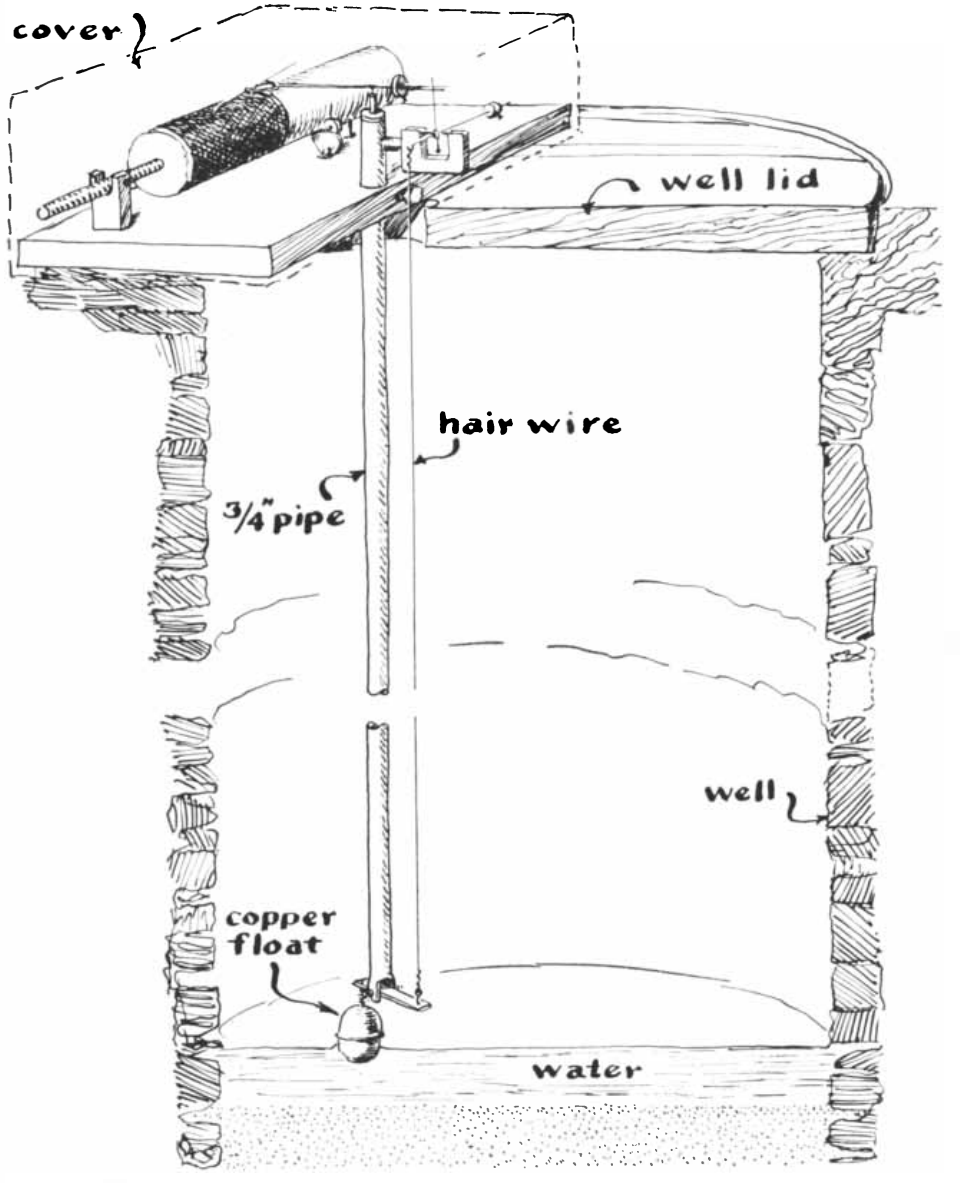
fitted with a similar cooling arrangement by soldering to the pressure plates a length of quarter-inch copper tubing bent into a spiral or zigzag pattern. The tubing is connected to a cold-water tap when the assembly is removed from the oven. Construction details can be improvised according to the materials at hand. The sequence of elements in the press pile-up, except for the cooling coils, is shown schematically in the accompanying drawing [*page 177*].

"To produce fossilides of leaves and other relatively thin specimens the experimenter will need sheets of cellulose acetate butyrate in three thicknesses: .015 inch, .02 inch and .03 inch. The plastic can be bought from dealers who specialize in art supplies. The pressure plates should be made of quarter-inch steel plate. Boiler plate is satisfactory and can be procured from garages that service large trucks and from most machine shops. We have discovered that the plates that impart a glossy surface to the plastic can be made of sheet brass, copper or aluminum. The inner surface of tin cans finished with gold-colored lacquer can also be used. The most satisfactory liners, however, are a pair of chromium-plated metal mirrors. One liner must be backed by a cushioning material such as glass-fiber matting or hard rubber to equalize the pressure on the specimen. We prefer hard rubber. If the reproductions are to be projected they should be inserted into slide mounts of appropriate size. Mounts can be bought from dealers in photographic supplies.

"To make the fossilide cut a plastic rectangle a quarter of an inch larger than the desired slide. Assemble the press in the sequence indicated by the schematic drawing, with the side of the specimen to be reproduced in contact with the plastic. Tighten the bolts, but not enough to crush the specimen. Pre-



A mechanical seismograph that detects the vibrations of water in a well

heat the oven to 210 degrees Fahrenheit, place the press inside and tighten the bolts a half-turn every five minutes for 20 minutes. (If acrylic plastic is used instead of cellulose acetate butyrate, preheat the oven to 300 degrees F.) Remove the press from the oven, cool and disassemble. Trim the plastic as required for a snug fit with the slide mount and assemble the slide.

"If the impression is generally faint, or faint in some areas, the specimen may not have been in good contact with the plastic. If the specimen was in contact and if the impression is uniformly faint, insufficient pressure was exerted by the press. Try again and tighten the bolts a little more after each five-minute interval. Too much pressure results in grossly distorted impressions. Occasionally excessive pressure also makes a blank spot form in the center of the impression.

"The technique is not without its limitations. Specimens must have some rigidity and enough strength to maintain their shape under the pressure required to deform the heated plastic. Fragility must not be mistaken for lack of rigidity, however. Fragile specimens such as a butterfly wing or a moth's proboscis reproduce beautifully. Flaccid tissue such as raw beef does not yield satisfactory impressions. The hobby of making fossilides tends to be a seasonal activity for the simple reason that interesting specimens are more plentiful during the summer. This may be considered a limitation. On the other hand, some specimens can be dried without injury and processed during winter months. Incidentally, specimens having a high moisture content tend to yield milky slides and must be partially dried.

"Although the slides are clear and transparent, they project as black and white unless colored plastic is used or the impression is dyed. We have experimented with color and find that in general it has little effect except to reduce the brightness of the screen. Interesting color effects can be achieved, however, and may serve some purpose.

"Our collection runs the gamut of the botanical kingdom from simple mosses and lichens through the bark, needles and seeds of coniferous and deciduous trees. Flower petals, stems, roots and stalks reproduce well. Longitudinal sections and cross sections of stems are especially interesting. Leaf impressions constitute the largest category in the collection. Ferns give the most striking impressions. The spore cases show up vividly, as does the structural architecture of the fronds.

"We have selected our zoological spe-

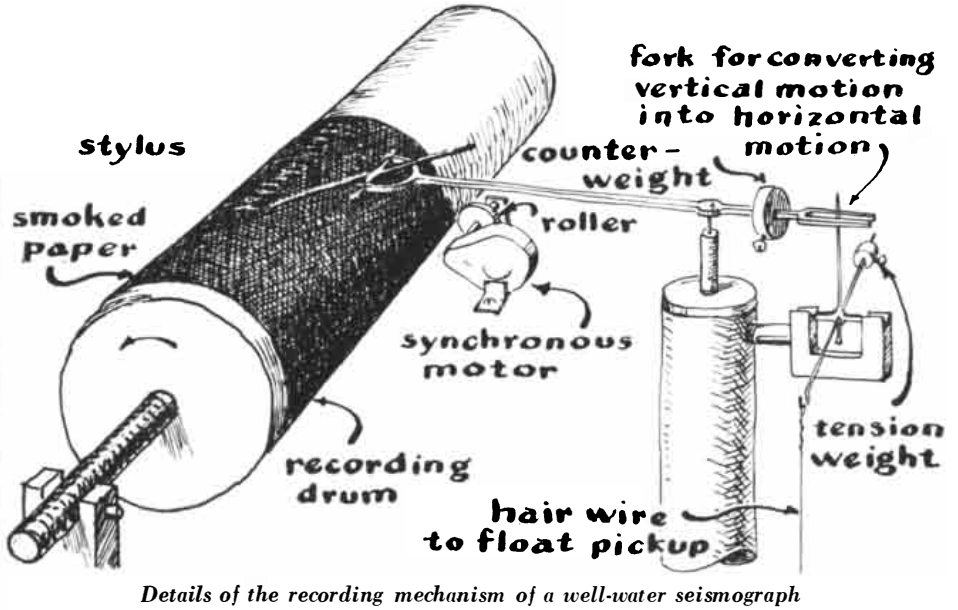
cimens with an eye to the rigidity of cellular structure. The collection is dominated by insects. Body details, leg joints and even the compound eye reproduce well. So do spiny-skinned animals, the skeletal portions of fishes, the feet and feathers of birds and the skins of vertebrates such as snakes.

"Teachers at both the secondary and college level who have viewed our collection have stated that it should be a valuable new adjunct to the teaching of biology. The leg of a bumblebee, for example, can be viewed on a screen in three dimensions, showing its joints and the minute projections that serve as pollen catchers. Amateurs who take up this hobby can not only have the fun of assembling a unique and valuable collection but can also experiment with new plastics and perhaps extend the method to specimens that cannot be reproduced with the materials now available."

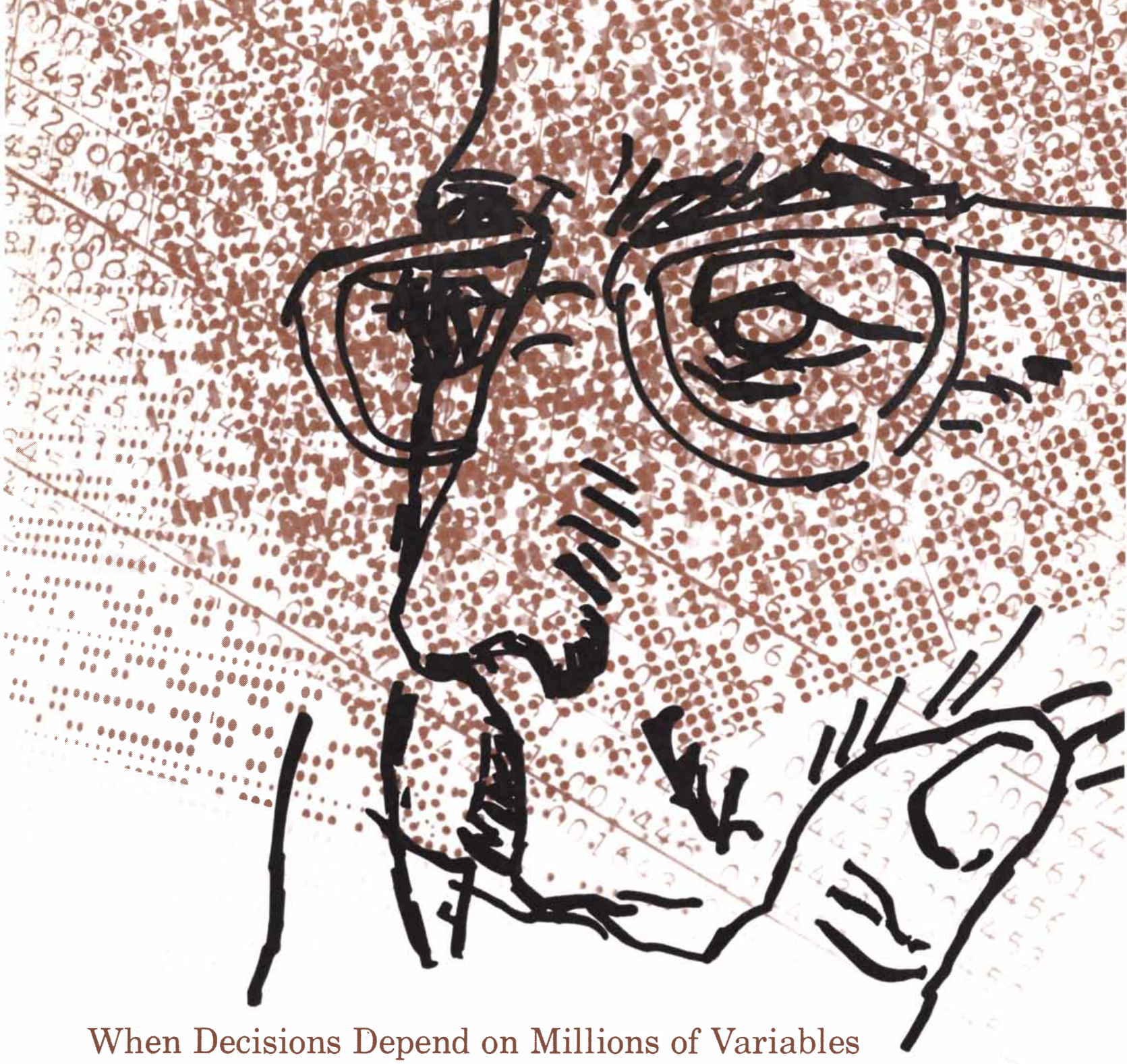
In June, 1953, this department presented a description of an unusual seismograph made by Elmer Rexin of Milwaukee, Wis. Rexin's device detects earthquake waves by measuring changes in the level of water in a well. Evidently the well is somehow connected to Lake Michigan, because Rexin now reports that his device detects not only earthquake waves but also seiches, the oscillations in the level of a lake that are caused by variations in atmospheric pressure. The effect of earthquakes on ground water is not unknown. In some regions of frequent earthquake activity the ground is dotted with small conical mounds of sand that mark points where water has erupted under the pressure generated by a quake.

Until two years ago, however, the editor of this department had supposed that opportunities for constructing hydroseismographs were confined to a few areas. Now I am not so sure. During the past two years I have heard about the phenomenon in half a dozen states. In 1959, for example, I arranged for a well to be drilled at my house in Pennsylvania's Monroe County. The driller brought in a high-pressure artesian well. A gauge was tapped into the casing at the time the well was capped. A few days later I noticed that the pointer was moving up and down slightly. The afternoon newspapers reported a large earthquake in the Aleutian Islands. The time of the quake and the movement of the gauge matched (when the travel time of the waves was taken into account). Oil-well drillers in Oklahoma City and water-well drillers in Burlington, N. C., Haverhill, Mass., and Omaha, Neb., have made similar observations. Can it be that all subterranean fluid, oil as well as water, responds to seismic waves? Amateurs are uniquely equipped to investigate the question. They are widely distributed geographically and presumably have the time.

An apparatus for recording earthquakes by means of wells has been worked out by Gerald J. Shea of Terre Haute, Ind. He writes: "In the summer of 1954, while fishing in a strip mine pond near Riley, Ind., I saw a variation in the water level of the pit a few seconds before I heard the sound of a very large blast about a mile away. The water level seemed to drop slightly at first and then rise and fall in a series of decaying vibrations. This made me wonder if ground water could be used for detecting elastic waves in the earth. An apparatus for observing the effect



Details of the recording mechanism of a well-water seismograph



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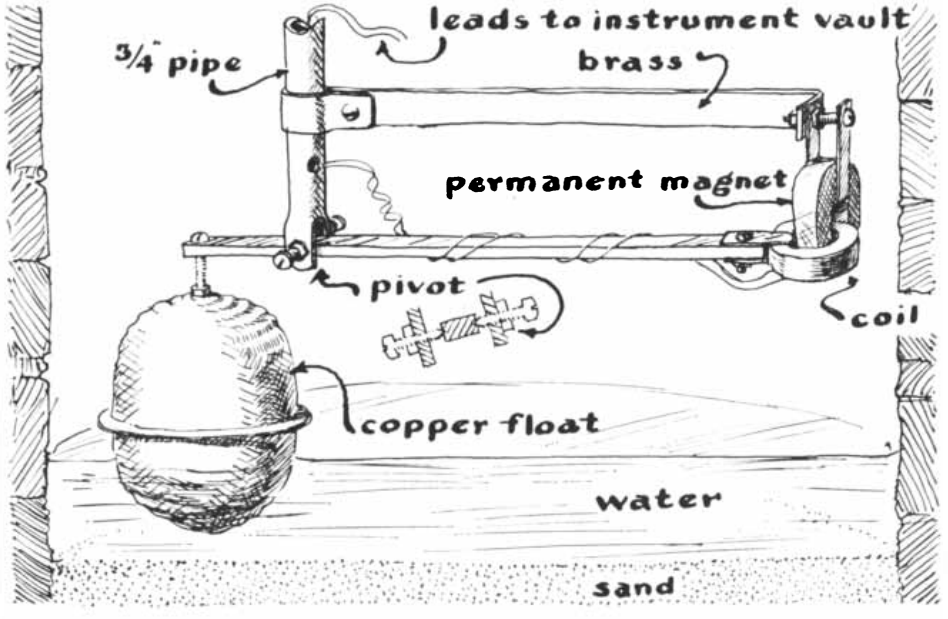
could consist of a float linked by a system of amplifying levers to a pen recorder. It was obvious that the open pond could not be used, however, because surface waves stirred up by the wind would be transmitted to the pen and confuse the record. It occurred to me that there would be no 'noise' of this sort in a well, but that the water level in a well might vary in response to elastic waves set up in the earth by blasts. (At this time I had not even thought that a well could react to earthquake waves.)

"The well selected for the experiment had been dug into earth that gradually changed to gravel at the level of the local water table. The well is about three miles west of the center of Terre Haute at 400 feet above sea level. It is 10 feet wide in diameter, 65 feet deep, cased to the top with vitrified brick and cement and is normally half-full of water.

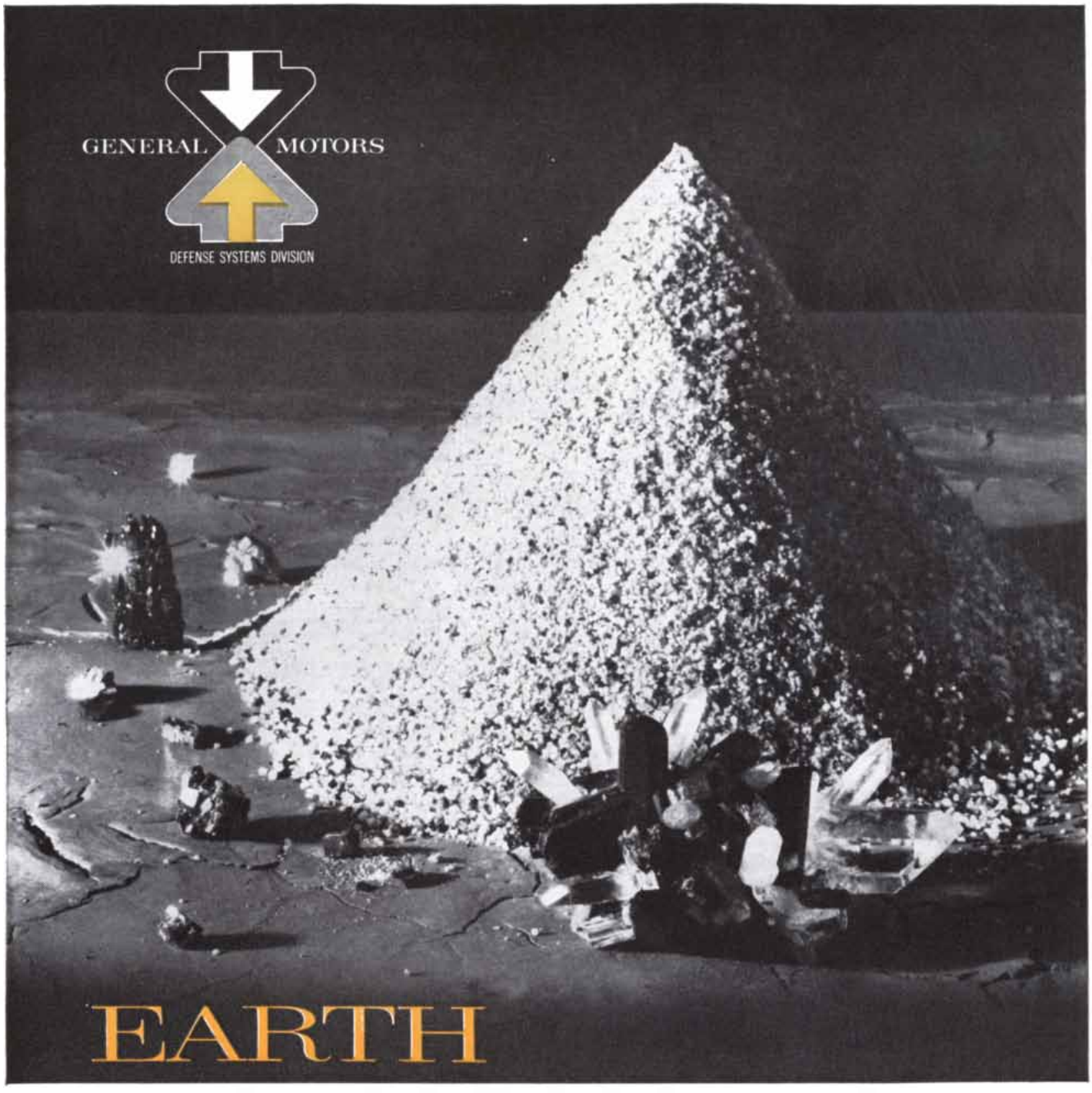
"My initial apparatus consisted of a hollow copper float at one end of a lever that was linked by a wire to a second lever at the surface. The upper lever actuated a recording stylus that made a trace in a smoked cylinder, as shown in the accompanying diagram [*page 182*]. It turned out that the excursions of the stylus overlapped so much that the insertion of time marks was impractical. Later a pen equipped with an ink feed was substituted for the stylus, but capillary attraction between the ink and the paper reduced the sensitivity of the apparatus. The installation, though crude, was worth its cost, because, much to my astonishment, recordings of seventh-magnitude earthquakes at distances up to 4,000 kilometers appeared occasionally. They resembled the records made by the Bosch-Omori and modified Milne-Shaw seismographs. In some respects the well recordings were superior to Bosch-Omori recordings because differences between the three kinds of earthquake waves were more distinct.

"To increase the sensitivity of the apparatus and provide positive control of pen excursion, I replaced the mechanical system with an electric drive. The end of the float lever was fitted with a coil of fine wire that moves in the field of a permanent magnet, as shown in the accompanying drawing [*below*]. Currents induced in the coil are transmitted to the surface by a pair of leads and amplified to drive a galvanometer recorder. [A similar apparatus is described in *The Scientific American Book of Projects for the Amateur Scientist.*]

"Changes in water level are amplified about 100 times in terms of pen excursions, and the character of the graph compares well with that of the modified Milne-Shaw seismograph. Surface earthquake waves (S waves) record but do not yield good magnitude determinations. Professional seismograph observatories are equipped with a minimum of three instruments: one for east-west vibrations, one for north-south vibrations and one for vertical vibrations. The water in the well moves vertically. But because water level is determined by forces acting on the water-bearing sand from all directions my recordings are the result of all three motions [*see illustration on page 186*]. Seismographs of this type have no clear-cut advantage over conventional instruments, but they do provide the amateur with an inexpensive means of investigating the fascinating



Details of the float of an electrically actuated well-water seismograph



...a yielding mystery

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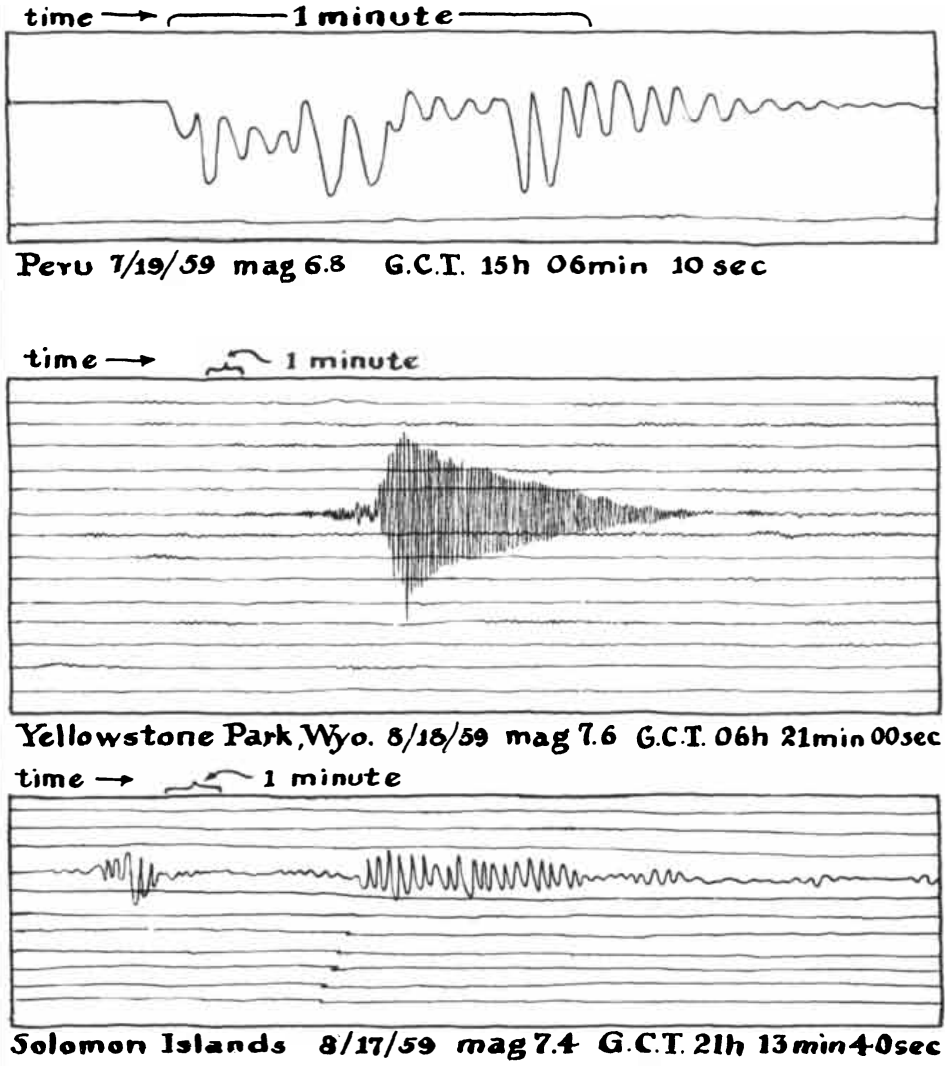


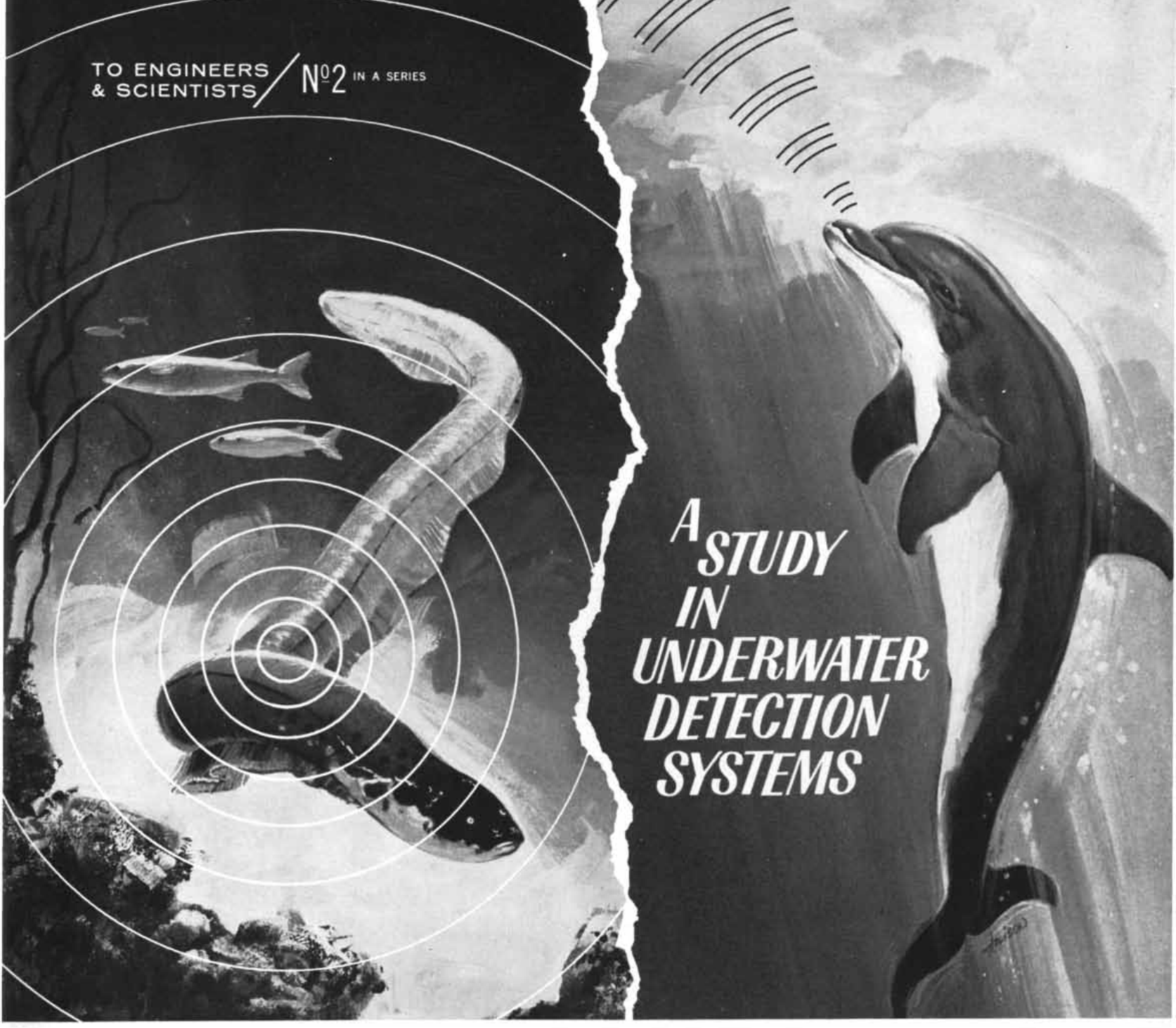
Reproductions of earthquake records made by a well-water seismograph

question of whether or not ground water everywhere measurably responds to seismic disturbances."

A red-letter day on the calendar of serious amateur telescope makers is the annual gathering of the clan at "Stellafane," near Springfield, Vt. Hundreds of amateurs, and a few professionals, come from all parts of the U. S., and they are joined by a sprinkling of confreres from abroad. Many veteran telescope makers regularly schedule their vacations to coincide with the conclave, which is an admixture of socializing and high-level telescope talk.

This year, according to James W. Gagan of the Stellafane Committee, the convention will be held on August 12, the first Saturday after the new moon of August 11. Edgar Everhard of Mansfield Center, Conn., will preside. Stanley W. Brower of Plainfield, N.J., will conduct the afternoon session, "Techniques of Polishing and Figuring Glass." Alan Mackintosh of Glen Cove, N.Y., will preside at a meeting of the Maksutov Club at 4:15 p.m. The evening session will be given over to talks by Walter Scott Houston ("Deep Sky Wonders"), Henry Specht ("Photographic Measurements of Variable Stars") and Walter Semerau ("Solar Research"). Many of those in attendance will enter telescopes in the traditional competition for excellence of craftsmanship.

The first Stellafane meeting was held in 1925. Stellafane ("Star Temple") is the observatory of the late Russell W. Porter, the dean of U. S. amateur telescope makers. Present at the meeting were Porter; Albert G. Ingalls, for 28 years the editor of this department; G. N. Bower of the department of astronomy at the University of New Hampshire; R. M. Wilson of the U. S. Geological Survey and his assistant R. W. Walton. Also in attendance were O. S. Marshall, Roy Lyon, Frank Whitney, Fred Barber, C. B. Damon, Oscar Fullam, Everett Redfield and John M. Pierce. To the best of our knowledge Fred Barber is the sole surviving charter member.



THESE ARRAYS OF SIGNALS — so suggestive of man-made sonar patterns — are indicative of two distinct approaches to underwater detection long employed by technically gifted Pisces and Delphinidae. **Gymnotus carapo** (left) utilizes diphasic emissions of 50-60 pulses/sec. **Tursiops truncatus** (right) utters ultrasonic boops, aimed in the specific direction of foes, friends, food or obstructions.

Though many kinds of fish, as well as dolphins, have been operating successful detection systems (electrical and acoustical) long before *Homo sapiens* arrived on the scene, HMED engineers today have surpassed the original inventors of such undersea devices.

Take range. Where *G. carapo* and *T. truncatus* must be satisfied with range measured in feet, HMED engineers think in terms of (classified) miles. Right now they are engaged in creating the AN/SQS-26 Search Sonar System to hunt out vastly larger predators than ever worried fish or porpoise—leviathans with metal skins, displacing thousands of tons, roaming all the oceans.

Or take frequency. Where *T. truncatus* operates at high frequency (in which area he can still teach humans a thing or two) HMED engineers, recognizing the problems imposed by high frequency attenuation of acoustical signals in water, are now developing *low* frequency systems that would make a dolphin flip.

Opportunities are now open for engineers to join HMED on the AN/SQS-26 program; on follow-on versions of the HMED developed sonar systems that successfully detected ice conditions for USS Nautilus on its historic under-the-North Pole voyage; on a new underwater system that will enable man to maintain surveillance on millions of cubic miles of inner space; on other projects in long range underwater detection.

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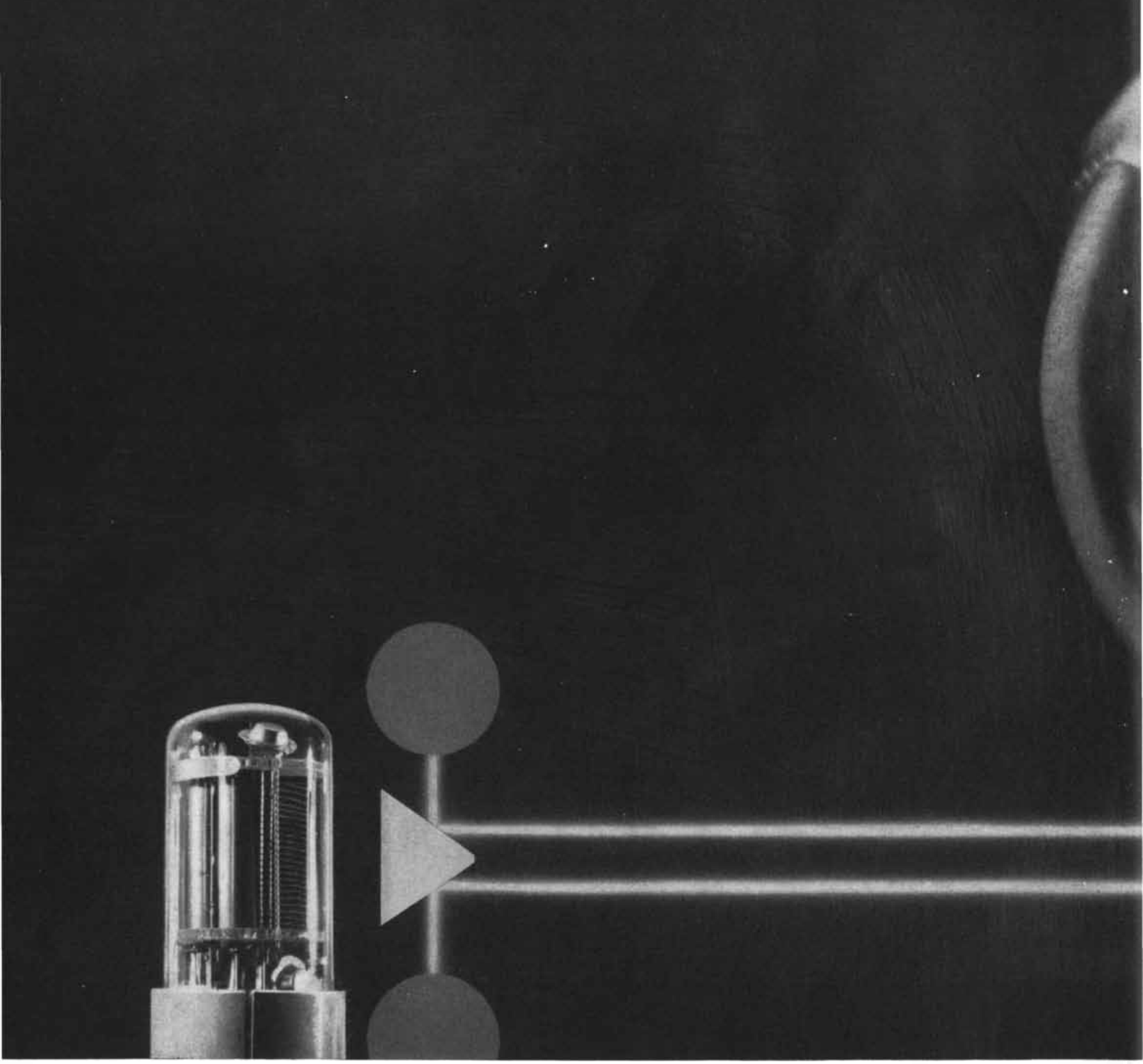

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Once the brain of a ballistic missile comes alive it must concentrate on a fine target point beyond the horizon. Even after the inertial guidance system has been oriented, tiny influences may cause it to deviate from its prescribed azimuth or compass heading before the missile is launched. A continuous correction is needed until the moment of flight.

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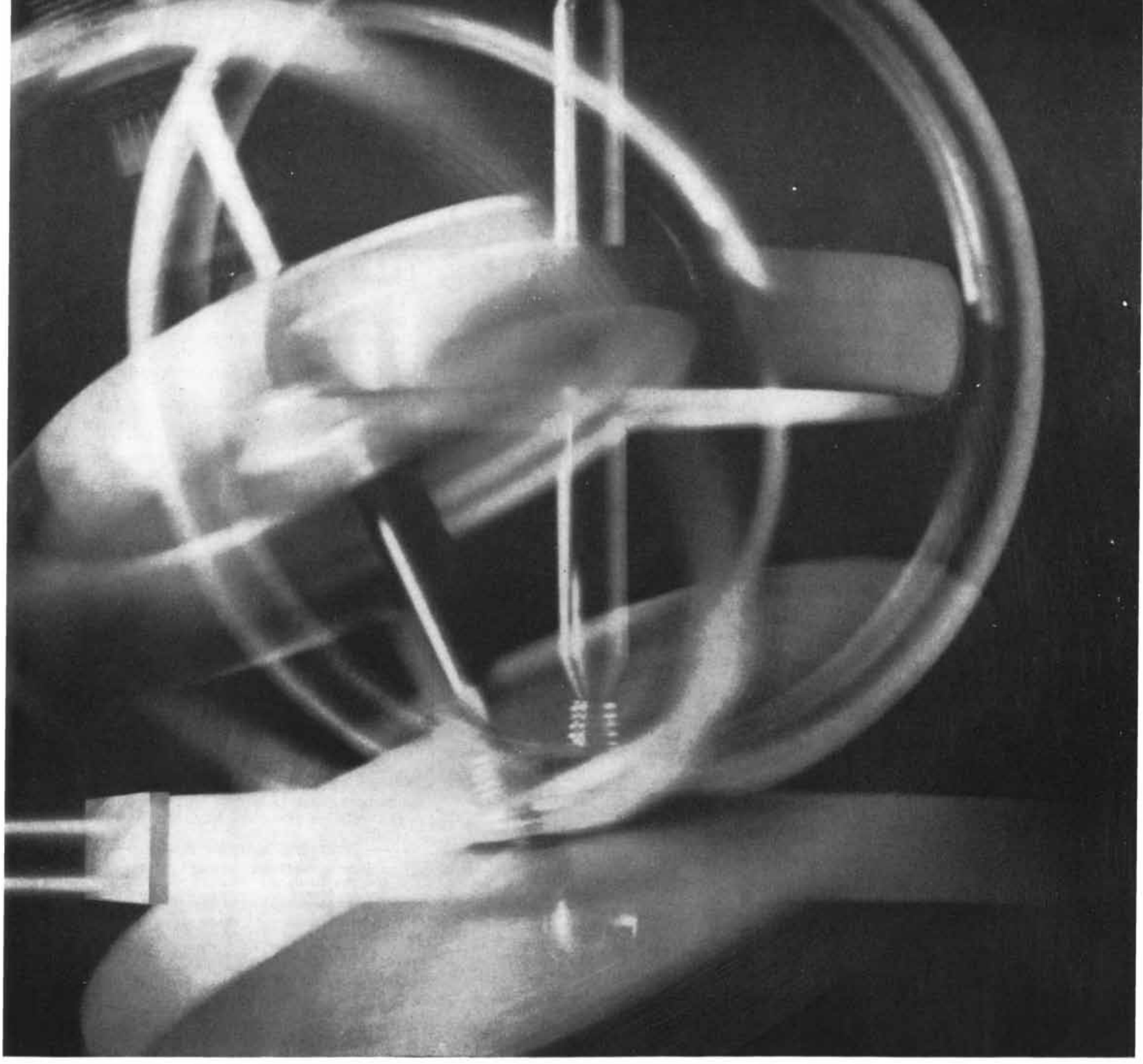

and direction of misalignment. The resulting error voltage is amplified and sent as a correction signal to a servo loop in the missile which resets the guidance platform to proper orientation within ±1.5 seconds of arc!

Perkin-Elmer has developed theodolite systems to set and monitor the inertial guidance systems of such missiles as Titan, Atlas, Mace, Thor and Pershing. In allied fields of navigation, P-E has developed alignment equipment for Polaris submarines and miniature optical pickoffs for super-gyros.

Theodolites are another example of Perkin-Elmer instruments for scientific measurement. P-E's experience with precise measurement techniques is applied in building other complex electronic-optical systems. These do vital jobs such as determining the structure of molecules, controlling chemical process streams, photographing heavenly bodies from the stratosphere.

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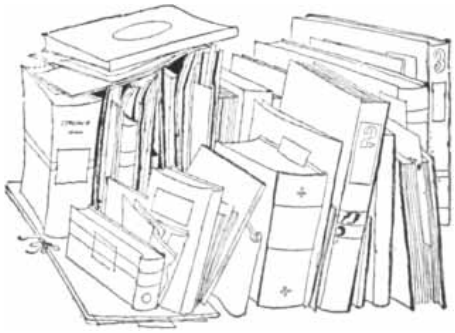

BOOKS

About the founding of the Royal Society, on the occasion of its 300th anniversary

by Charles E. Raven

THE ROYAL SOCIETY: ITS ORIGINS AND FOUNDERS, edited by Sir Harold Hartley. The Royal Society (35 shillings).

In the history of the making of modern man the meeting at Gresham College in London on November 28, 1660, will always be reckoned significant. There and then we might fix the birth of our Western scientific and industrial civilization. For plainly the decision to form "a Colledge for the Promoting of Physico-Mathematicall Experimentall Learning" marked the division between the old world of chaos and the new world of natural law. Anyone who studies the whole record of the change will realize that in a movement extending over two centuries and involving all Europe the decisive period was not the Renaissance of the late 15th century or the Reformation and its upheavals in the 16th century but the formulation and acceptance of the New Philosophy in the first half of the 17th century, and that the critical time was about the year in which the Royal Society of London was founded. The movement was due not to the merits of English civilization but to the coincidence of political and religious opportunity with the appearance of a group of half a dozen men of genius and their co-operation in a single society. Two of them, John Wilkins and Henry Oldenburg, were the society's "organizers of success."

The novelty of the movement itself can be exaggerated. Science, and indeed the "scientific method" of observation and experiment, are as old as man: gastronomy, not astronomy, is the oldest of the sciences. Medicine, whether science or art, enshrined the tradition, and through the Dark Ages, Dioscorides and Galen preserved something of the glory that was Greece. When in the 13th century the influence of Plato and Aristotle was revived by the Dominicans Albertus Magnus and Thomas Aquinas and the Franciscans Robert Grosseteste and Roger Bacon, it was not strong enough to affect the dogma and institutionalism of the medieval church or the exclusiveness and guild-secrecy of the social economy or the power of fable and witchcraft. Even the Renaissance did not restore the outlook of the Greco-Roman world, any more than the Reformation recovered the quality of early Christianity. The spell of tradition and superstition was not broken (though in certain fields such as botany it was seriously challenged) until well into the second half of the 17th century. In Europe the power of the Church and of the princes made any freedom of speech or thought difficult. It was only when Britain rebelled against the despotism of the Crown and cut off the head of Charles I that the principles of the *Areopagitica* and free inquiry could be promoted. In no other country could Catholics and Protestants, royalists and republicans have co-operated as they did at Gresham College.

This is not to say that the scientific movement originated or at first flourished in Britain. In the universities of Padua and Bologna, Montpellier and Paris, Basel and Cologne, Antwerp and Leyden the medical and biological sciences flourished and good beginnings were made in mathematics and geometry, chemistry and physics, astronomy and geology. Konrad Gesner, the polymath of Zürich, had laid the foundations for international co-operation among physicians and scientists by his vast output of books, his personal correspondence and circular letters and his integrity, energy and intellect. Galileo had opened a new epoch in physics and cosmology. The Czech scholar Comenius had traveled widely to promote meetings for universal knowledge and had established centers of "pansophic" study and teaching. Institutes and groups of learned men began to work from Portugal to Poland and from Naples to Aberdeen. But the medieval tradition, the antagonism of Catholics and reformers, the wars of religion and the scourge of disease prevented the new outlook from gaining strong and impartial support.

In England the situation was easier. Although there were pioneers (going back to Sir Thomas More and Thomas Linacre and including William Turner, John Caius and Thomas Penny), there had been little in the way of sustained or corporate scientific effort until the days of Francis Bacon and the foundation of Gresham College and its professorships, and there were no outstanding scientists except William Gilbert and William Harvey. There was widespread interest in science, due largely to explorers such as John White and herbalists such as Thomas Johnson. But when Comenius came to London in 1641, his mission was supported by Samuel Hartlib and Theodore Haak (both emigrants from the Continent) and by John Dury and a small number of others. These men, together with Robert Boyle and Oldenburg, were the members of the so-called Invisible College—one of the groups that Francis Bacon's *New Atlantis* had inspired and Edmund Bolton, the poet Abraham Cowley and others promoted. The idea of such societies was in the air, and in 1660 both Church and State were favorably disposed to them.

The tercentenary volume edited by Sir Harold Hartley is a full and excellent memorial to the origin and founders of the Royal Society. Douglas McKie, who contributes the account of the actual founding, has done valuable work in recording the history of Gresham College, its first and not very distinguished professors and its claim to be the birthplace of the society. His record is careful, detailed and informative and draws attention to facts not previously noted. But in this article and in the book in general there is a tendency to equate the original phrase "the Promoting of Physico-Mathematicall Experimentall Learning" with the words adopted in the second charter: "The Royal Society of London for Improving Natural Knowledge." Many of the biographical sketches show this limited and inadequate view of the society's scope and purpose; they concentrate on the mathematical and technological interests of their subjects to the

neglect of their contribution to medicine and anatomy, physiology and biology. This restriction of science to measurement, which historians of science have followed for two generations, is still sufficient to deprive the botanists and zoologists, and with them the physicians, surgeons and apothecaries, of their fair share in the rise and development of "natural knowledge."

McKie similarly does valuable service in pointing out how dominant at the founding of the society was the royalist element in it. This involved the inclusion of certain founders whose claim to learning, or to any natural knowledge, was slight almost to the vanishing point. Sir Kenelm Digby was a picturesque survival, a privateer and an alchemist, a hangover from the Elizabethan age. Lord Kincardine was an industrialist and mineowner, a good man interested in developing his property commercially. Sir Robert Moray, though he had abundant energy and a real interest in nature, was a courtier and a careerist. Jonathan Goddard was "the great confidant" of Cromwell and an eminent physician whose remedies were closer to sympathetic magic than to scientific pharmacy. John Evelyn was a cultured gentleman with a taste for art and gardens. Fifteen of the 53 proposed members were physicians, and several others were deeply interested in medicine. But the best and most influential members were men who could not easily be classified as either medical or mathematical. They were, however, men of outstanding genius: Wilkins, Boyle, Christopher Wren, Robert Hooke, Oldenburg and William Petty. Without them the society could never have exerted its unique influence.

This brief résumé of the founders indicates not only something of the scope of the society but also its capacity to include two distinct types of member, on the one hand the aristocratic virtuosi, amateurs of high position and culture, and on the other the professional experts: physicians, engineers and scientists of every sort and from all ranks of society. At times the cleavage was a source of trouble and weakness—even down to Darwin's time patronage on the one side and resentment on the other were damaging. But on the whole it kept the society above feudal stratification and made it possible for men such as Hooke and John Ray and James Petiver to share the common adventure. And if the first membership of the society was royalist and could easily have been exclusive, the two secretaries and Boyle took care to broaden it and give it cosmopolitan status. This is insufficiently appreciated in the tercentenary volume, probably because it is strictly confined to the original charters and membership of the society. Its officers should be credited with bringing into it men of world-wide fame and entering into correspondence with the greatest scientists on the Continent. That Britain, which in 1660 did not stand high as an abode of science, should by 1680 have become the outstanding center for the publication of scientific work and should have produced at least half a dozen men of genius is mainly due to the wide sympathies and tireless efforts of the first secretaries of the Royal Society.

The essays on these secretaries are appreciative and understanding, particularly the one on Wilkins. This describes Wilkins' courage in standing up to the king, his refusal to take advantage of his marriage to Cromwell's sister, his generosity and integrity, his wide range of knowledge, his charm as a host and his skill in promoting friendship. But there is no mention of the important work that he did in bringing into the society a number of brilliant Cambridge men whom he had known during his short term of office there as Master of Trinity College: Walter Needham of Queens' College, the pioneer of embryology; Francis Willughby of Trinity, the zoologist; John Ray, the greatest of British naturalists; John Mapletoft, later professor of physic at Gresham College; and Henry More of Christ's College, an eminent philosopher who was instrumental in introducing René Descartes to British students.

More was a chief representative of the remarkable group known as the Cambridge Platonists, whose other outstanding members were Benjamin Whichcote, Provost of King's College; Ralph Cudworth, Master of Christ's College; John Worthington, Master of Jesus College; and John Smith of Queens' College. They were deeply interested in the New Philosophy and exerted a powerful influence not only on the universities but also on the religious life of all England.

This is a factor of profound importance in explaining the speed and the smoothness of the change from old to new, from tradition to science, at this time; and the histories, including this tercentenary volume, almost wholly ignore it. On the Continent the Church, both Catholic and Protestant, exercised a mainly repressive influence. The Inquisition had put Copernicus on the Index, had burned Giordano Bruno, silenced Galileo and terrified Descartes. Luther had denounced the study of nature and broken with the humanists and followers of Erasmus. Calvin had burned Servetus and encouraged the killing of witches. Scientists had cause to walk warily and to avoid public interest. In Britain, after the Elizabethan persecutions and the bitter conflicts that led to the Civil War, it was by the Platonists that the advocacy of a tolerant attitude and a reasonable theology was carried to success, so that in the latter half of the 17th century a learned and inquiring liberalism was characteristic both of Anglicans such as Archbishop Tillotson and of Independents such as Richard Baxter. A climate of opinion was thus created exactly suited to encourage those who were disgusted by the warfare and mismanagement of the State and the controversies and dogmatism of the Church, and who found an outlet in the new worlds that exploration and research, inventions and engineering were opening up for study. The Royal Society had followed Bacon in refusing to allow religion to be brought within the discipline of observation and experiment; but its members, though forbidden to debate religious and political issues in public, were deeply involved in the problems of the time and inescapably concerned with finding solutions for them. Fortunately they could freely follow their full range of activities without restriction, and no one was better qualified than Wilkins to equip them for the adventure.

Of Henry Oldenburg no adequate estimate has yet been given, in spite of his voluminous correspondence and his editorship of the *Philosophical Transactions*. This monthly record of the society's proceedings was first published in March, 1664, and continued for 136 issues. In the tercentenary volume R. K. Bluhm has done well to provide so informative a sketch of Oldenburg. Born in Bremen, the son of a professor at Dorpat, Oldenburg was appointed in 1653 to represent his city at Cromwell's court. This led to his friendship with John Milton and put him in touch with the poet's neighbor Lady Ranelagh, whose son became his pupil. This resulted in his going to Oxford and meeting Boyle (Lady Ranelagh's brother) and the group that met in John Wilkins' lodgings at Wadham. Oldenburg was already known to Hartlib and Haak, and in 1668 he married the daughter of John Dury, the friend of Comenius. By so doing he was doubly linked with the Invisible College and with the Continent. It was this that made him so valuable to the society. Its archives contain 715 letters personally addressed to him from foreigners or from Englishmen at home or traveling abroad, and these were in re-

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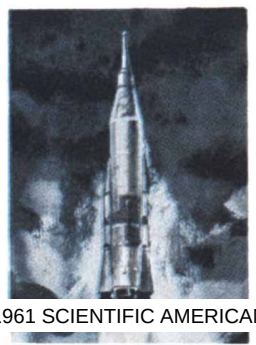

CONVAIR DIVISION OF GENERAL DYNAMICS

sponse to inquiries or requests from him. Like Konrad Gesner in the previous century, he built up a fraternity of scientists by his correspondence and made British discoveries and workers familiar in the European centers of learning. The society owed to Oldenburg's industry the fact that Huygens sent his horological problems, Leeuwenhoek his discovery of spermatozoa and Malpighi his treatise on the formation of the chick in the egg to London for publication. As editor and principal writer of the first scientific periodical and a regular circulator of newsletters, he was an outstanding source of information.

The two contributions to the enlarging of the scope and influence of the society made by its first secretaries were united and symbolized in the person of Robert Boyle—"father of chemistry and son of the Earl of Cork." Boyle was the most venerated member of the society from its founding and, in the words of the tercentenary volume essay, his "stature both as a man and a scientist looms larger with the passage of time." Few men have ever more fully combined the service of science and of religion; few scientists have established more human and cosmopolitan contacts with their fellow men. Author of 43 books, friend and benefactor of all with whom he came in contact, transparently good, universally studious, he represents more adequately than any other the range and quality of the new age. In Florence as an Etonian of 14, but already familiar with Copernican astronomy and with Hebrew, Greek and Latin, he was deeply moved by the death of Galileo at Arcetri. Five years later, from his home at Stalbridge, he was in touch with Hartlib and the Invisible College and with the great European scientists Mersenne, Spinoza and Pascal. He devoted himself to medicine and anatomy, chemistry and physics; indeed, to the whole range of natural knowledge. Two years in Ireland brought him face to face with human poverty and suffering, deepened his religious insight and established his vocation.

With this background he went to Oxford in response to an urgent invitation from John Wilkins and so met the Gresham College group at Wadham. Here also he took into his service a student at Oxford, Robert Hooke; and the partnership thus formed gave him the technical assistance, the creative imagination and the practical efficiency without which much of his achievement would have been impossible. Without Hooke, Boyle might well have been a dreamer and a dilettante; without Boyle, Hooke might never have been more than a skilled craftsman and mechanic.

The foundation of the Royal Society gave Hooke his opportunity. He was appointed curator—the laboratory expert and technician responsible for providing experiments and apparatus for them—and rewarded by a small stipend and an apartment. He proved to be one of those men of genius for whom all knowledge is fascinating. He could entertain the society as competently with a discourse on the nature of human memory or the oarsmanship of the ancient Greek trireme as on the construction of a spring-driven watch or the anatomy of the flea. To write a life worthy of him would require expert knowledge not only in the physical sciences but in contemporary archaeology, architecture, optics, acoustics and psychology, and no one has yet been found to deal fully with such matters. Moreover, to do justice to his character would require not only a sensitive understanding of the psychology of frustrated genius but also a delicate appreciation of the social traditions and behavior patterns of an elaborate culture in a period of rapid transition. Margaret 'Espinasse, who has attempted the task in her book *Robert Hooke*, failed in the second of these requirements; she has ascribed to the poor curate's son a status and attractions that he never possessed and consequently has made of Oldenburg and Newton monsters of jealousy and snobbishness. Hooke suffered all his life from the necessity of working too hard and working under other men. He touched nothing without adorning it, but he seldom had time to follow his insights to their depths. As he grew older he began to claim not only priority but creativity for his half-explored suggestions, to fling out charges of plagiarism and develop a morose and embittered habit of mind. A student of his moral as well as intellectual life will realize how complex and how fascinating he is, and how difficult, if not impossible, it is to do him justice. In the tercentenary volume E. N. da C. Andrade pays him an attractive tribute and sets out many of his main achievements. But Andrade does not give any adequate account either of the scope of Hooke's interests or of the complexities of his character. Perhaps this is partly accountable to the fact that Hooke was the prototype of a new subspecies of man—the professional scientist.

To sum up, it was the peculiar combination of scientific eminence and cosmopolitan status that gave the Royal Society its special importance in the history of modern man. The tradition founded by Oldenburg of exchanging scientific information is the essence of the international co-operation of scholars. This co-operation can do much to help us recover the "public philosophy" that the world so desperately needs. The remembrances of the tercentenary of the Royal Society of London serve as a reminder that such a philosophy, in which the knowledge of specialists and the understanding of nonspecialists are unified, is within our grasp.

Short Reviews

LETTERS OF SIGMUND FREUD, selected and edited by Ernst L. Freud. Basic Books, Inc. ($7.50). These 315 letters written over a period of 66 years open windows on Freud's private life. The largest group by far, made up of the letters the young doctor wrote to his fiancée Martha Bernays during their four-year engagement, gives a clearer picture than can be got even from Ernest Jones's massive biography of Freud's character traits: his energy and driving force and ambition, his jealousy and paternalism, his *petit bourgeois* outlook, his largeness and self-honesty, his respect for cozy conventionality and his willingness at every cost to break with it in his passion for understanding. Many of his letters to Martha are simply a bore, but there are touching and enchanting exceptions and even masterpieces (for example, his account of the circumstances which led to the suicide of his friend Weiss). The other letters—to friends and disciples, to his children, to Thomas Mann, to Einstein, to Romain Rolland—are often of interest more for their illumination of the writer than for their intrinsic content. Freud was of one piece, made of many contradictory pieces fired together; it is this oneness which always comes through, which is the inimitable style and stamp of his greatness.

LINCOS: DESIGN OF A LANGUAGE FOR COSMIC INTERCOURSE, PART I, by Dr. Hans Freudenthal. North Holland Publishing Company ($6). J. B. Priestley once observed that people who claim to be getting messages from the void are in truth getting them from the void within. Still, if there really are somebodies, human or human-like, in the remote worlds of outer space, it is possible that they are trying to communicate with us. Some thought has been given to the study of the radio astronomy signals received on earth as though they were intelligent messages. This book deals with a related question: how we on our little

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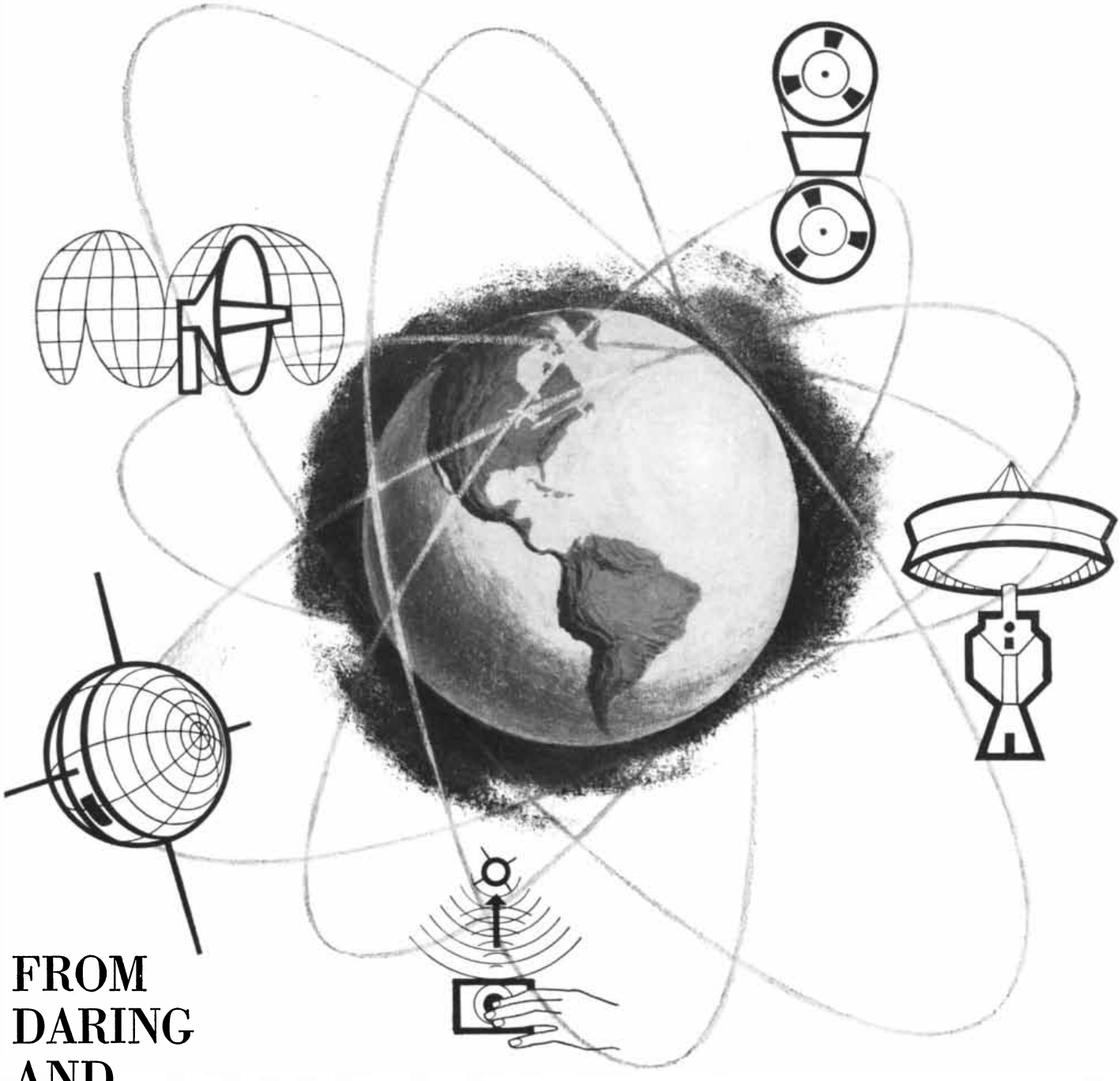
planet might go about *sending* messages which would be comprehensible to other-worldlings. The author, a Dutch mathematician, has devised a language for this purpose, a language he calls Lincos, short for *lingua cosmica.* It is a moderately formalized vehicle, based on the language of logic and using logical syntax, expanded to meet the needs of a program which will not only express the simpler propositions of mathematics and the fundamental notions of physics but will also be supple and rich enough to convey information on human behavior and other aspects of human experience. Freudenthal proposes to make use of radio signals of various duration and wavelength; this will suffice to contact possible inhabitants of other planets; if we get through to these chaps and they don't dismiss our messages as mere noise or music of the spheres, they may learn to interpret what we are saying. For the present our messages will not be fascinating; for example, we will run off strings of numbers, explain how we do arithmetic and handle fractions, pose problems, introduce function theory. We will describe events, recite statistics, tell about birth and death, ventilate our cares and anxieties and aspirations, and even report on our philosophical concerns, *e.g.*, state the paradox of the liar. If the beings on other planets are brighter than we are, which is not hard to imagine, we may bore them. All the same they will probably not deny our persistence and our small ingenuities, and in time they may even come to feel sorry for us and offer to help. At any rate, judged by earthling standards, this is a very ingenious, even fascinating, book, and one waits to see how the author will expand his language in a promised continuation of the work.

A Treatise on Universal Algebra, by Alfred North Whitehead. Hafner Publishing Company, Inc. ($10.75). This classic work, too long out of print, was first published more than 60 years ago. Whitehead, then at Trinity College, Cambridge, had studied very carefully the two great books by the German mathematician Hermann Günther Grassmann on the geometry and calculus of extension (*Ausdehnungslehre*). These books, which had appeared in 1844 and 1862, were so abstract, difficult and strange, so out of keeping with the mathematical fashions of the time, that they were almost entirely unread. The importance of Grassmann's ideas was not lost on Whitehead, and they inspired him to produce this treatise (of which he completed only the first volume). In it he sought to exhibit the algebra of symbolic logic and the calculus of Grassmann "both as systems of symbolism, and also as engines for the investigation of the possibilities of thought and reasoning connected with the abstract general idea of space." The unity of the subject matter of their interpretation provided him, as he said, with a natural mode of comparison between the algebras. And to this "comparative anatomy" of the subject, to this new calculus which would go much beyond the traditional sciences of number or quantity and extend reasoning in connection with every province of thought or of external experience—in short, to all thought "which is not philosophy, or inductive reasoning, or imaginative literature"—he gave the name "universal algebra." Like Grassmann's books, Whitehead's treatise was also neglected. Yet it unquestionably served, whether it was explicitly recognized or not, as a stimulus and a work of influence in mathematics and logic. It is gratifying to see it in print again; this fact alone may impel contemporary students of mathematics and philosophy to return to it and to accord it its proper place in the history of thought.

An Encyclopedia of the Book, by Geoffrey Ashall Glaister. The World Publishing Company ($17.50). Some 2,600 definitions of terms used in papermaking, printing, bookbinding and publishing. Here you can learn about foxing, letterpress, signatures, embroidered bindings, babewynnery, *doublures,* serifs, Sotheby's, marbling, offset, halftones, folding machines, the Aldine Press, Fleischhack overlay, foolscap, fore-edge painting, peculiars, remainders, incunabula, ultrasonic cleaning of type, verso, collation, Japanese woodcuts, Wynkyn de Worde, work and turn, bookworms (with six legs), quads, Philip the Good (bookworm with two legs), obscene libel, music printing, *Minnesängerhandschriften,* linotype, book jackets, ink fly, herbals, historiated letters, French joints, Johann Fust, Baskerville type, copyright, collotype, *Codex Sinaiticus* and bourgeois. A good-looking, very satisfying book. Excellent illustrations.

World Railways, 1960–1961, edited and compiled by Henry Sampson. Simmons-Boardman Publishing Corp. ($20). The sixth edition of this work has 412 pages of text, with a tabular section of 125 pages containing data under 32 headings relating to more than 1,500 railways in 160 different coun-



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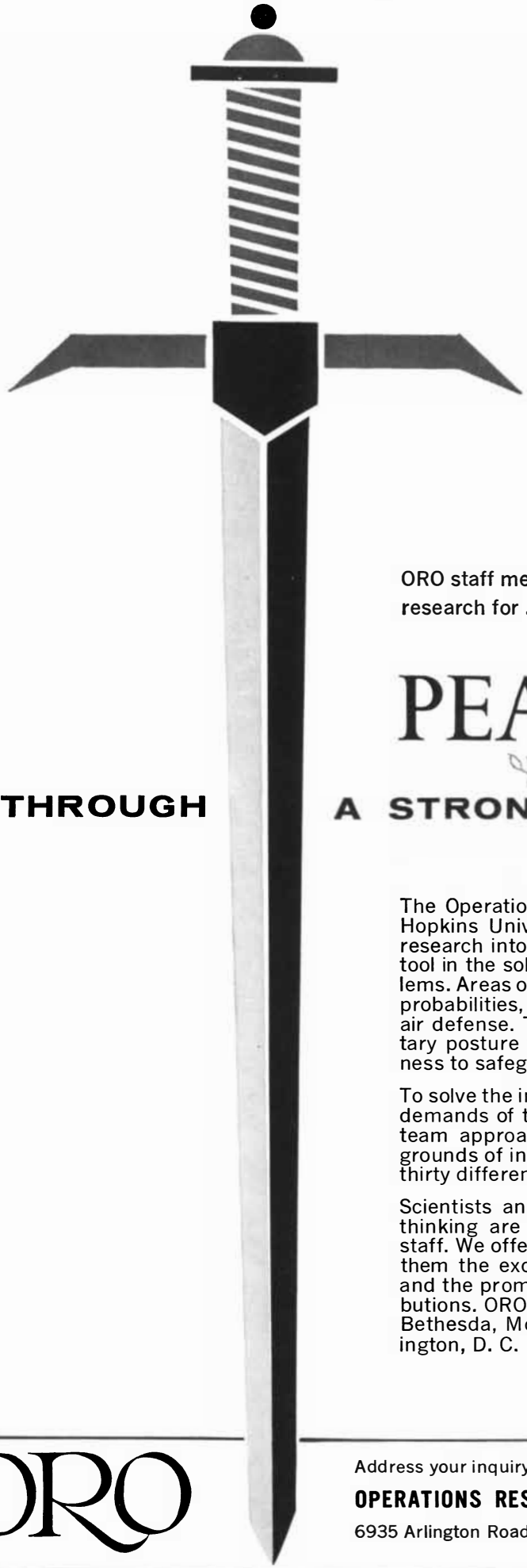
tries. It is interesting to note that the movement away from steam traction is accelerating. Of the 120,000 steam locomotives in service throughout the world some 75 per cent are scheduled to be scrapped in the next 10 to 15 years. U. S. diesel operation is almost 100 per cent; Canadian, about 95 per cent. In Europe electrification is preferred for heavy-traffic trunk lines but a large number of diesels are being put into service and in the next 15 to 20 years steam will have been "virtually eliminated." The rest of the world picture is similar, even in countries such as South Africa and India, where coal is cheap and oil has to be imported. Photographs and diagrams.

CLASSICS OF MEDICINE AND SURGERY, collected by C. N. B. Camac ($2.25); SOURCE BOOK OF MEDICAL HISTORY, compiled with notes by Logan Clendening ($2.75); EXPERIMENTS AND OBSERVATIONS ON THE GASTRIC JUICE AND THE PHYSIOLOGY OF DIGESTION, by William Beaumont, M.D. ($1.50). Dover Publications, Inc. A very nice trio of paperbacks, containing original papers or excerpts from books which advanced the study and practice of medicine. Camac's volume, first published in 1909 (and formerly called *Epoch-making Contributions to Medicine, Surgery and the Allied Sciences*), contains unabridged texts of writings by Lord Lister (antisepsis), William Harvey (motion of the heart and blood), Leopold Auenbrugger (percussion of the chest), R. T. H. Laënnec (auscultation and the stethoscope), Edward Jenner (smallpox), William Morton (anesthesia), James Young Simpson (chloroform), Oliver Wendell Holmes (puerperal fever). A biographical sketch and portrait precede each selection. Clendening's 685-page source book assembles significant medical writings, from the Kahun Papyrus, which prescribes treatment for a woman whose back aches and thighs hurt ("Say to her it is the falling of the womb. Do thou for her thus: uah grains; shasha fruit 1–64, hekt, cow's milk 1 henu, cook, let it cool, make it into gruel, drink four mornings"), to Wilhelm Roentgen's preliminary communication "On a New Kind of Rays." Altogether there are 124 papers, documented with critical and biographical notes, covering items as various as conversations between medical students in *Pickwick Papers*, Chaucer's picture of a medieval physician (the "parfit practisour" who "knew the cause of everich maladye were it of hoot or cold, or moiste or drye"), Fracastorius on syphilis, Thomas Sydenham on epidemic diseases, Ambroise Paré's "On Wounds Made by Gunshot," Molière's "Love's the Best Doctor," Walter Reed on yellow fever, Louis Pasteur on rabies, Anton van Leeuwenhoek's "On Capillary Circulation," Marcello Malpighi's "De Pulmonibus," James Parkinson's "An Essay on the Shaking Palsy," Jean Martin Charcot's "On the Diseases of the Nervous System," Florence Nightingale's "Notes on Nursing," Luigi Galvani's "On the Effect of Electricity on the Motion of the Muscle," Rudolf Virchow's "Cellular Pathology," Paulus Bagellardus' "The Little Book of Diseases of Children," Sir John Floyer's "The Physician's Pulse Watch." The third volume is a facsimile of the original edition (1833) of Beaumont's famous study of the mechanism of digestion—courtesy of the hole in the abdomen of Alexis St. Martin, who managed to live much longer than most of us who are intact (*viz.*, more than half a century after the shotgun made the 2½-inch hole directly in his stomach), thereby favoring himself, Beaumont and mankind in general. Added to the facsimile is Sir William Osler's biographical essay on Beaumont: "A Pioneer American Physiologist."

THE MEANING OF WILDERNESS TO SCIENCE, edited by David Brower. Sierra Club Books ($5.75). Proceedings of the Sixth Biennial Wilderness Conference, with papers on plants and animals in natural communities; ecological islands as natural laboratories; ecological systems and water resources; the outlook for conservation in Alaska; science and the wilderness; population pressure and natural resources; the wilderness, science and human ecology. The Robert Rausch paper on Alaska is particularly persuasive, and with the help of a superb set of photographs (some by Ansel Adams, some from the air by Lowell Sumner) it becomes irresistible.

THE FOUNDATIONS OF MATHEMATICS, by Frank Plumpton Ramsey. Littlefield, Adams & Company ($1.95). Softcover reprint of a collection of logical essays by Ramsey, a brilliant British philosopher who died shortly before his 27th birthday in January, 1930. Ramsey was a hard, clear thinker who, as G. E. Moore said, had a most uncommon power of explaining lucidly to others what he thought and why he thought it. In addition to the title essay there are papers on mathematical logic, truth and probability, knowledge, causal qualities and philosophy, Ludwig Wittgenstein's



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Tractatus Logico-Philosophicus, and Ramsey's famous lecture to a Cambridge discussion society on why there is no longer anything to talk about.

COMMUNITY RESOURCES IN MENTAL HEALTH, by Reginald Robinson, David F. deMarche and Mildred K. Wangle. Basic Books, Inc. ($8.50). This volume, the fifth in a series of monographs published by the Joint Commission on Mental Illness and Health, deals with community resources in mental health in the continental U. S. The authors' nation-wide findings (which include such melancholy information as the fact that fewer than 10 per cent of the 3,103 counties of the U. S. have family casework agencies, either public or private) are supplemented by data based on intensive studies of 15 representative U. S. counties.

THE UNIVERSE AROUND US, by Sir James Jeans. Cambridge University Press ($1.95). A paper-backed edition of James Jeans's attractive, simply written survey of the methods and results of modern astronomical research, special attention being given to problems of cosmogony and evolution and to the general structure of the universe. The fourth edition of this book, here reprinted, was last revised in 1944; inevitably, therefore, some of the material is out of date. It would have been preferable to refurbish this minor classic of popularization with a preface sketching at least the advances in cosmological theory since Jeans's death.

THE FASCINATING WORLD OF ASTRONOMY, by Robert S. Richardson. McGraw-Hill Book Company, Inc. ($5.95). A layman's guide cast in the form of questions and answers: What is an eclipse? Why do the planets show phases? What is the anomaly of Encke's Comet? What are Fraunhofer lines? What are variable stars? How do we know the distances of the galaxies? What is the Doppler shift? Why does the moon always keep the same side turned toward the earth? And so on, about telescopes, stars, planets, constellations, cosmologies. Straightforward, relaxed and informative.

Notes

INHIBITION IN THE NERVOUS SYSTEM AND GAMMA-AMINOBUTYRIC ACID, edited by Eugene Roberts and others. Pergamon Press, Inc. ($15). Proceedings of an international symposium sponsored by the U. S. Air Force Office of Scientific

Research, primarily concerned with the effects on the nervous system of gamma-aminobutyric acid.

LIFE ON THE ENGLISH MANOR, by Henry Stanley Bennett. Cambridge University Press ($1.95). Soft-cover reissue of an essay which gives a picture of the economic and social life of the English peasant in the Middle Ages. A delightful piece of scholarship, clearly written, human and full of sustenance and light.

THE ARCHAEOLOGY OF WEAPONS, by R. Ewart Oakeshott. Frederick A. Praeger, Inc. ($7.50). An account by a leading specialist on medieval arms of their development and use from the Bronze Age to the age of chivalry. Full of intriguing antiquarian details. Fine illustrations.

THE FOUNDATIONS OF GEOMETRY, by David Hilbert. The Open Court Publishing Company (95 cents). Paper-bound reissue of Hilbert's famous mathematical essay in which he examines the principles of Euclidean geometry.

UNITS, DIMENSIONS, AND DIMENSIONLESS NUMBERS, by D. C. Ipsen. McGraw-Hill Book Company, Inc. ($6.50). A reference text which discusses the concept of units and dimensions.

A HISTORY OF THE THEORIES OF AETHER AND ELECTRICITY, by Sir Edmund Whittaker. Harper & Brothers ($3.80). A soft-cover, two-volume reprint of Whittaker's excellent history of the classical and modern theories of electricity. A book bargain which will appeal to every serious student of physical science and to historians of thought.

PROBLEMS OF LIFE, by Ludwig von Bertalanffy. Harper Torchbooks ($1.35). A fascinating exposition of the author's "organismic" conception of life, which will appeal both to scientists and philosophers.

THE TEXT BOOK OF FIELD ASTRONOMY, 1958. Her Majesty's Stationery Office ($10.35). This well-illustrated manual, replacing another published in 1932 and now out of print, is intended to meet all the needs of the land surveyor required to carry out astronomical observations for position or azimuth.

A SURVEY OF PHYSICAL THEORY, by Max Planck. Dover Publications, Inc. ($1.15). This paperback, formerly called *A Survey of Physics,* consists of several

of Planck's essays and lectures on topics such as the unity of the physical universe, the place of modern physics in the mechanical view of nature, dynamical laws and statistical laws, the principle of least action, the nature of light, the origin and development of the quantum theory.

LOUISIANA BIRDS, by George H. Lowery, Jr. Louisiana State University Press ($7.50). A revised edition of this state bird book, adding new species of birds and modifying information on others. Photographs, drawings (some in color).

HENRY E. SIGERIST ON THE HISTORY OF MEDICINE, edited by Felix Marti-Ibañez. MD Publications, Inc. ($6.75). A collection of essays on medical history, ancient and medieval medicine, Renaissance, baroque and age of enlightenment medicine, by the late Henry E. Sigerist, who was not only a first-class historian but also an elevated man who touched nothing without warming it with his humanity and his sense of social responsibility.

WILDLIFE OF MEXICO, by A. Starker Leopold. University of California Press ($12.50). An illustrated survey of the game birds and mammals of Mexico describing habits, natural history and distribution, and dealing with game management and the ecological principles of successful conservation. Drawings and photographs.

G. E. MOORE, by Alan R. White. Basil Blackwell & Mott, Ltd. (25 shillings). A critical exposition of the philosophy of the late G. E. Moore, concerned with his method, his ethical theories, his views on sense perception.

ADVANCES IN BIOLOGICAL AND MEDICAL PHYSICS: VOL. VII, edited by Cornelius A. Tobias and John H. Lawrence. Academic Press, Inc. ($10). Contains articles on genetic and physiological effects of the decay of radioactive phosphorus in bacterial viruses and bacteria, micro-X-ray diffraction, autoradiography, effects of nuclear radiations on the central nervous system, radiation carcinogenesis and related topics.

THÉORIE DES GROUPES EN PHYSIQUE CLASSIQUE ET QUANTIQUE, VOL. I: STRUCTURES MATHÉMATIQUES ET FONDEMENTS QUANTIQUES, by Théo Kahan *et al.* Dunod (75 francs). The first volume of a treatise dealing with all phases of the application of the theory of groups to theoretical physics and chemistry.

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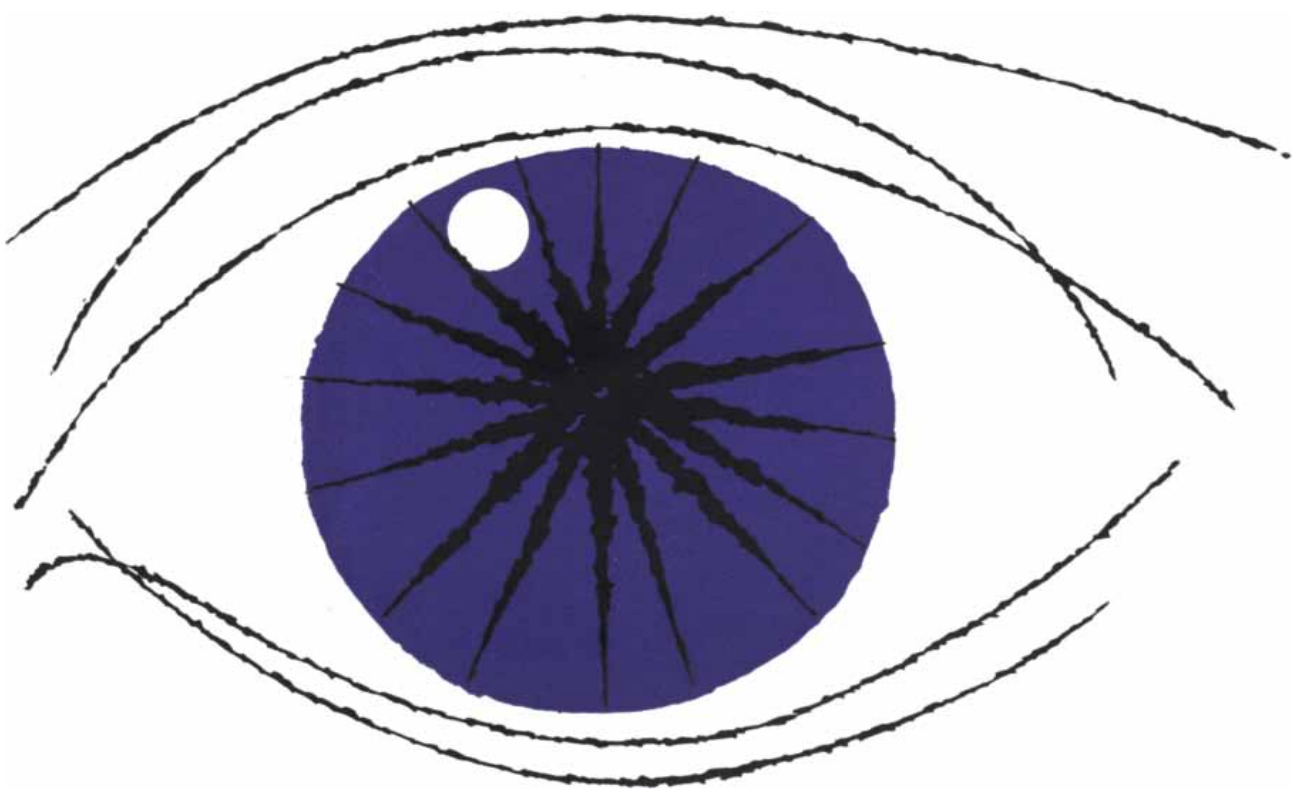

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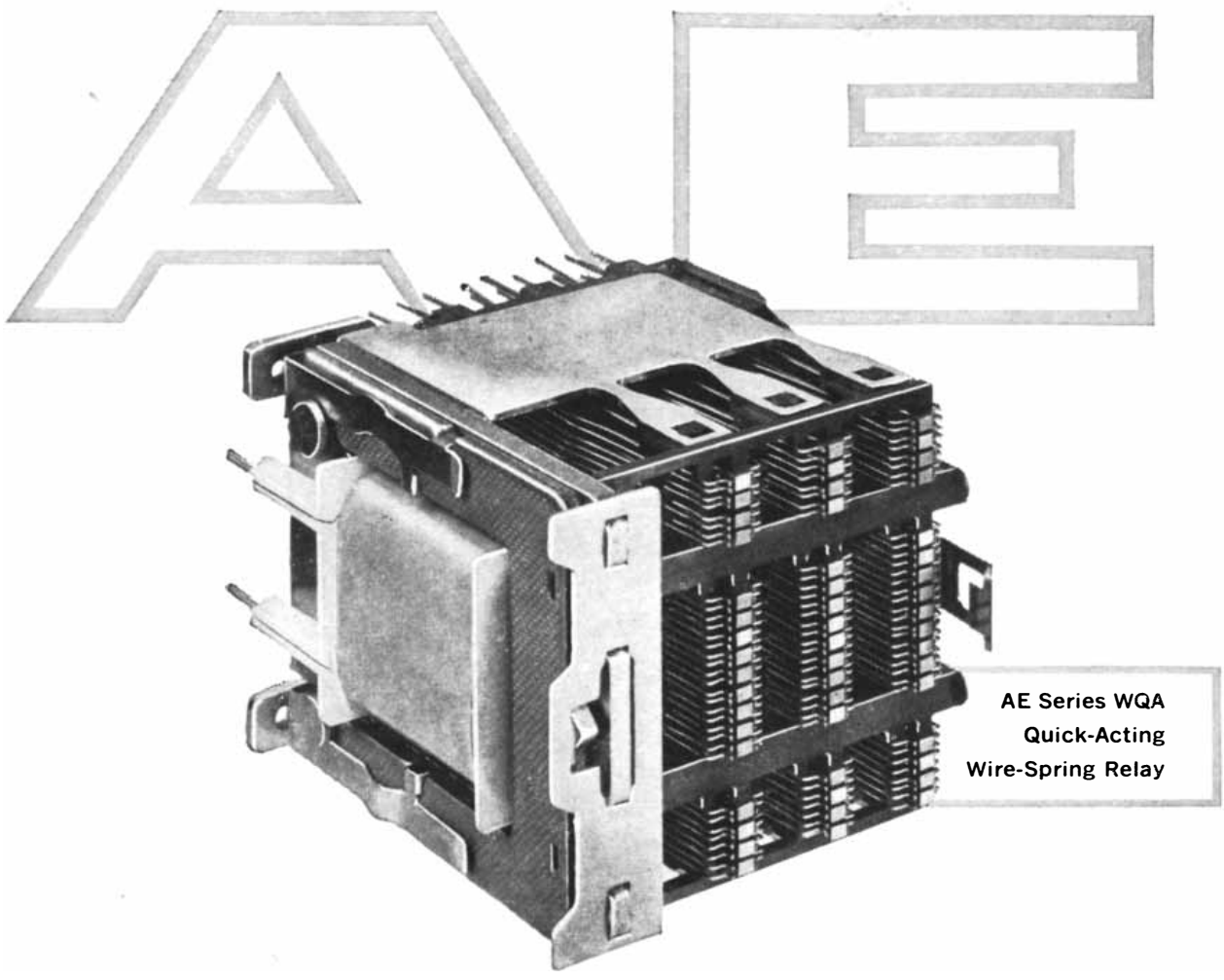

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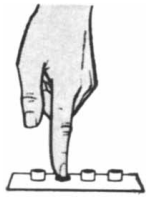

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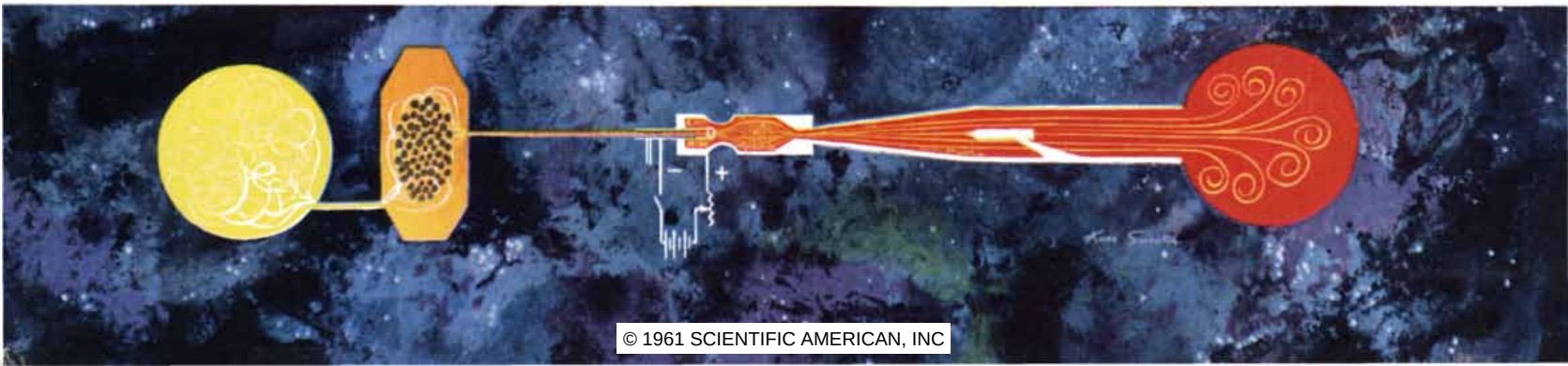

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