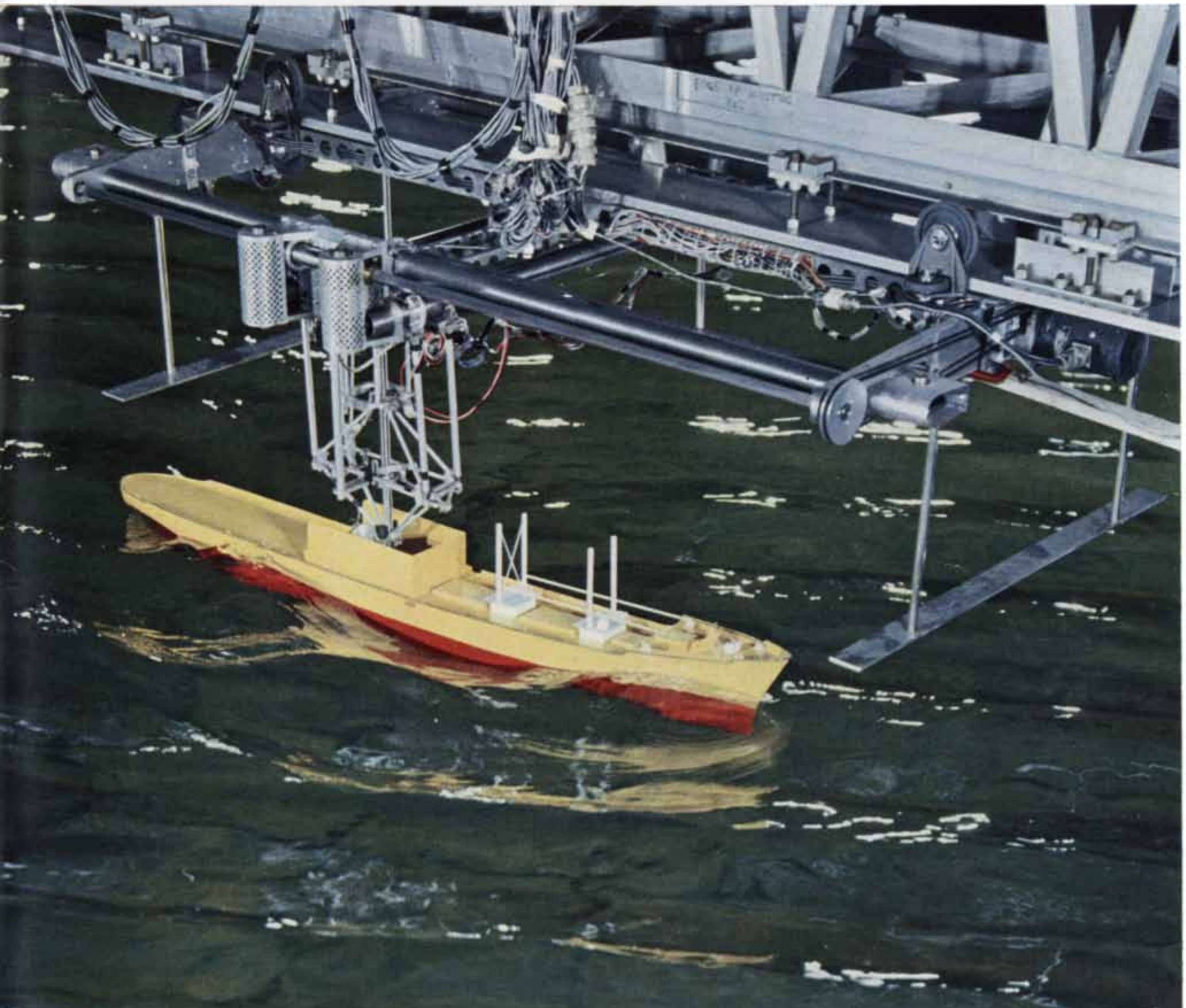
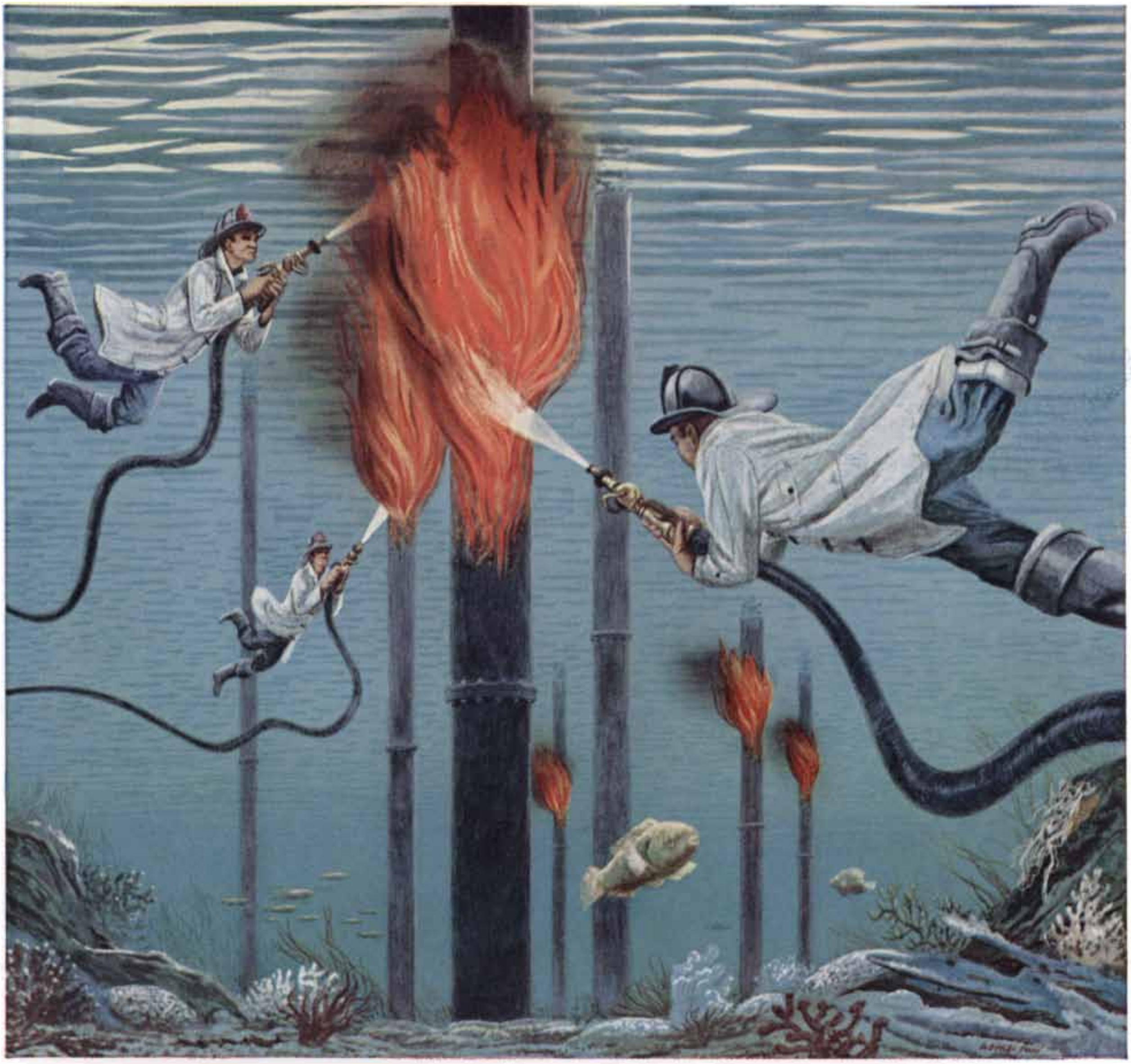
SCIENTIFIC AMERICAN



WAVES IN EXPERIMENTAL TANK

FIFTY CENTS

August 1959



How to fight fire beneath the sea

GO DOWN TO THE SEASHORE and you'll see metal doing a slow burn. Air and water combine to corrode it, and *salt* water adds fuel to these fires of *rust*.

But now there's an excellent way to fight oxidation of iron and steel—from ship hulls to offshore oil drilling rigs. The method: protect the metal above and below the waterline with a paint based on Shell Chemical's Epon® resin.

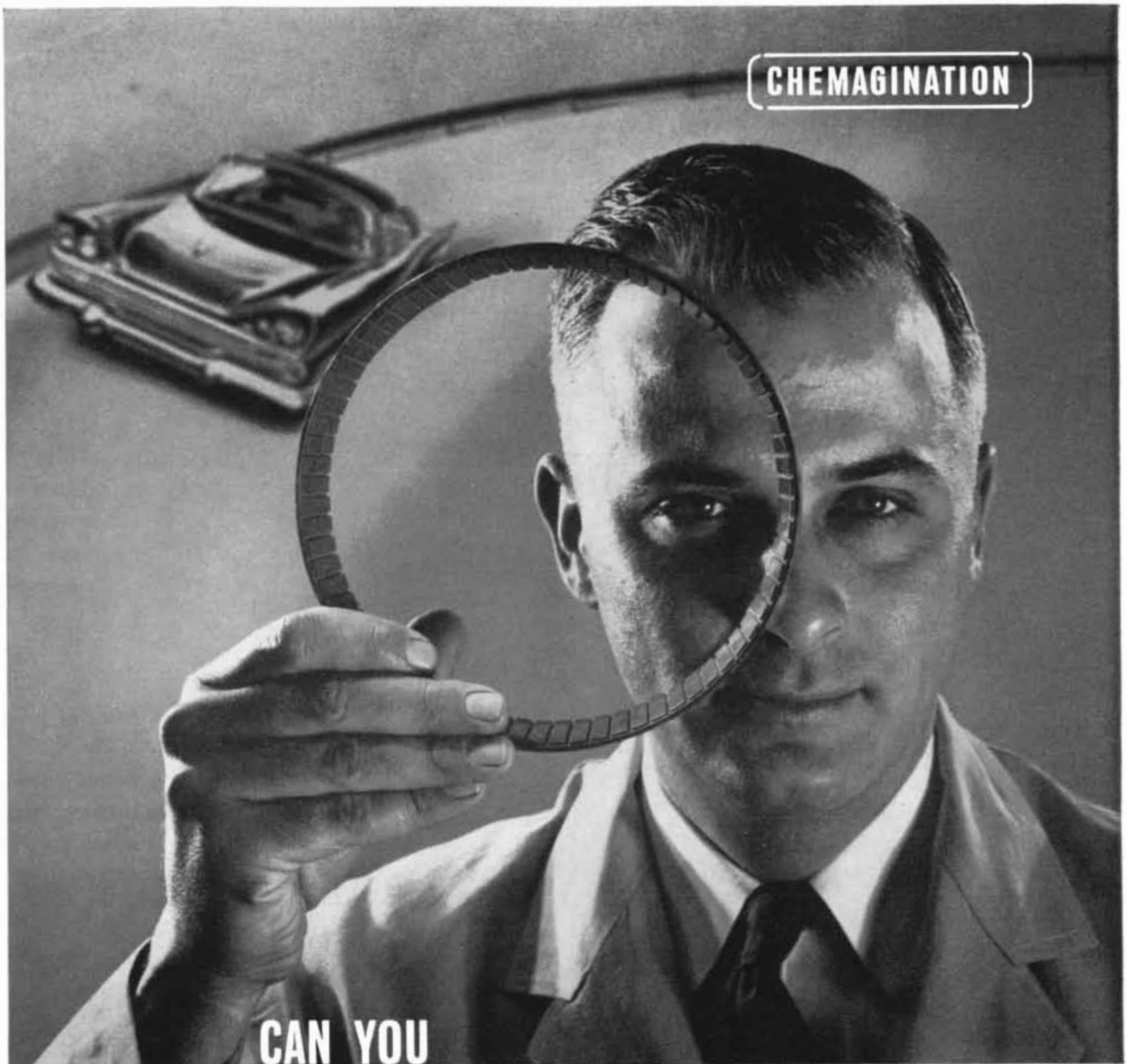
Because Epon resin chemically links to the metal surface, it forms an adhesive armor that wards off corrosion better than anything we know. Hard, yet so flexible that a wallop will dent rather than shatter it, tough Epon resin coating also guards against corrosion in underground pipelines, washing machines, air conditioners, refrigerators, outdoor metal furniture . . . it's worth your knowing.

With Epon resins that shield man-made structures from wear and weather, Shell Chemical helps contribute permanence to a world of change.

Shell Chemical Corporation

Chemical Partner of Industry and Agriculture

NEW YORK



CAN YOU TURN THIS TOUGH PLASTIC INTO DOLLARS?

Where can you use a material that's so tough it will outwear even metal—yet takes almost any shape with little or no machining?

Automotive engineers picked this Durez super-plastic for the ring-shaped clutch cone used in big-car automatic transmissions. When the transmission is shifted to reverse, this 3½-ounce cone transmits full engine power to move a 2¾-ton car!

Look what else this Durez plastic does for the car manufacturer: it outlasts the material previously used . . . easily resists high transmission temperatures . . . remains dimensionally stable under all operating conditions . . . eliminates the tendency to gall, or roll up, which would cause too-small clutch clearances.

In addition, it cuts manufacturing cost, because hardly any finishing is needed. The part comes out of the mold just as you see it here, to highly accurate tolerances.

This Durez material is one of the new super-phenolics. It's reinforced with fibrous glass; specially formulated to achieve high impact strength and all the other properties a hard-working part must have. It's called *Durez 16771*.

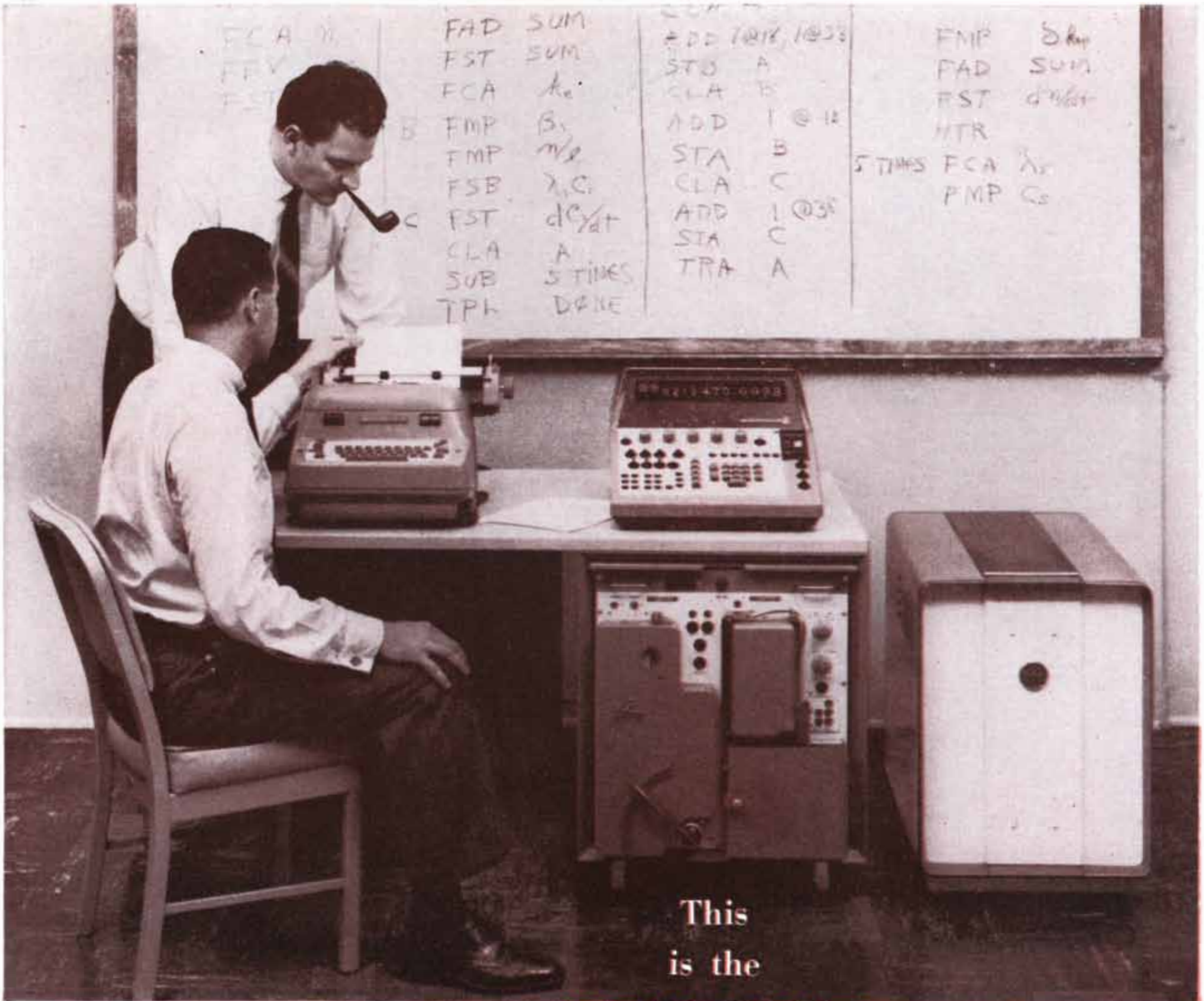
Your custom molder knows about this new plastic and can help you put it to work. To explore how you can use it to get a better-functioning product or reduce manufacturing costs, check with your molder now. Or, for more information, write to DUREZ PLASTICS DIVISION, Hooker Chemical Corporation, 9408 Walck Road, North Tonawanda, N. Y.

DUREZ PLASTICS DIVISION

9408 WALCK ROAD, NORTH TONAWANDA, N. Y.

HOOKER CHEMICAL CORPORATION

HOOKER CHEMICALS PLASTICS


This
is the

Established 1845 **SCIENTIFIC AMERICAN** August, 1959 Volume 201 Number 2

ARTICLES

37 **SATELLITES AND THE EARTH'S ATMOSPHERE, by Robert Jastrow**
Particles from the sun influence the physical properties of the upper atmosphere.

44 **THE RADIO GALAXY, by Gart Westerhout**
Radio telescopes are now mapping out the spiral structure of our island universe.

52 **INCUBATOR BIRDS, by H. J. Frith**
Some cousins of the domestic fowl hatch their eggs by putting them in hot places.

74 **OCEAN WAVES, by Willard Bascom**
Beautiful but often destructive, they result from the interaction of many forces.

89 **CONDITIONING AND BRAIN WAVES, by Vernon Rowland**
Learning can produce significant changes in the electrical emissions of the brain.

98 **CHARLES LYELL, by Loren C. Eiseley**
The founder of historical geology, he paved the way for the theories of Darwin.

110 **GLAUCOMA, by Sidney Lerman**
It is a major cause of blindness, brought on by increased pressure on the eyeball.

119 **THE ENZYME-SUBSTRATE COMPLEX, by Earl Frieden**
Certain transitory compounds play a vital role in the chemistry of life processes.

DEPARTMENTS

10 LETTERS
20 50 AND 100 YEARS AGO
29 THE AUTHORS
60 SCIENCE AND THE CITIZEN
128 MATHEMATICAL GAMES
137 THE AMATEUR SCIENTIST
149 BOOKS
168 BIBLIOGRAPHY

PUBLISHED MONTHLY BY SCIENTIFIC AMERICAN, INC., 415 MADISON AVENUE, NEW YORK 17, N. Y. COPYRIGHT © 1959 BY SCIENTIFIC AMERICAN, INC. ALL RIGHTS RESERVED. SECOND CLASS POSTAGE PAID AT NEW YORK, N. Y., AND AT ADDITIONAL MAILING OFFICES. SUBSCRIPTION RATE $6 PER YEAR.

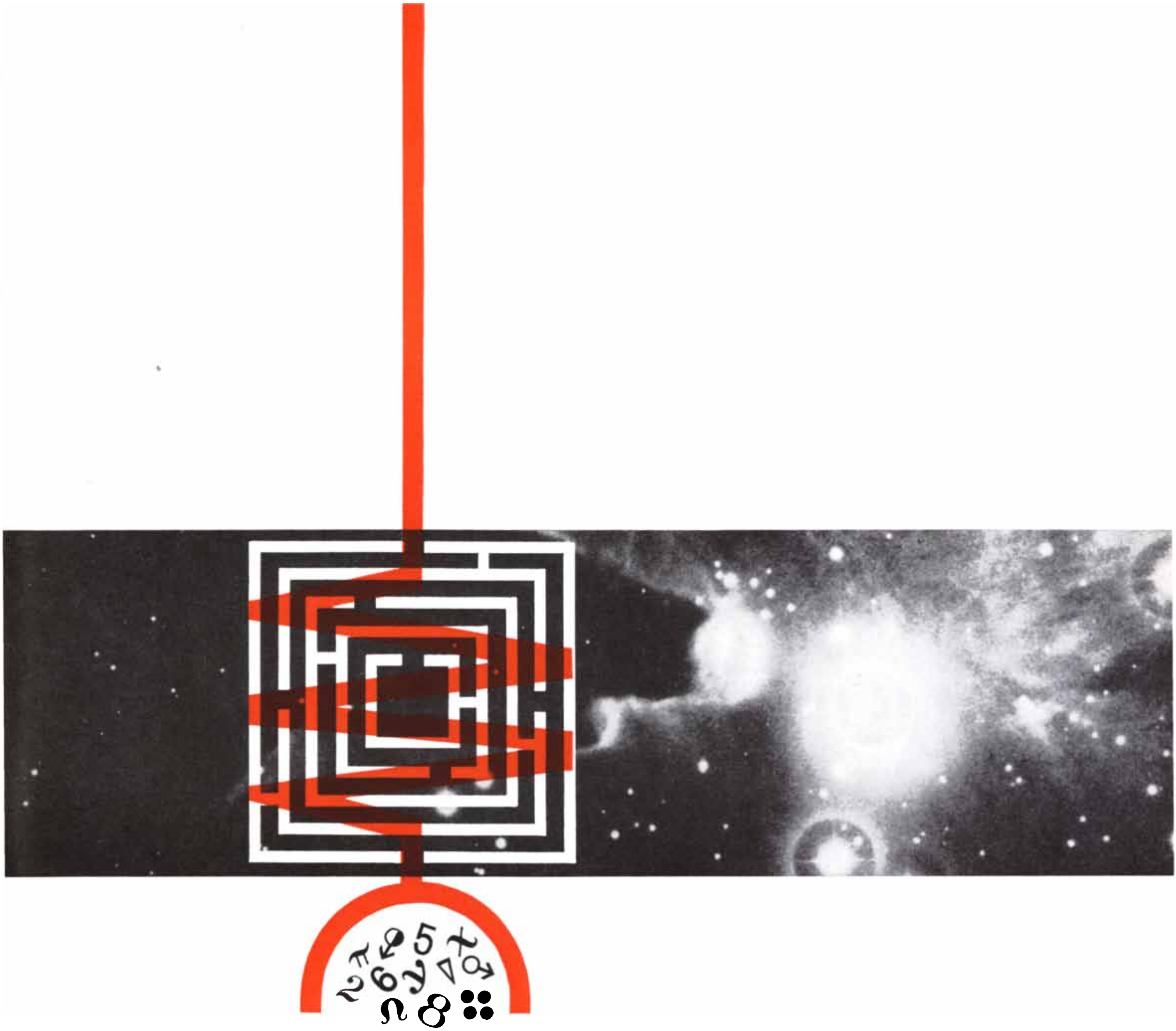
THE COVER

The photograph on the cover shows a five-foot ship model under test in an experimental tank at the Davidson Laboratory of the Stevens Institute of Technology. The model proceeds under its own power; its motions are recorded by means of the apparatus above it. In this tank, which is 75 feet square, waves of many forms can be generated; here the waves move at an angle to the course of the model. By studying waves in such a tank engineers can predict their effects on ships and the shore (see "Ocean Waves," page 74).

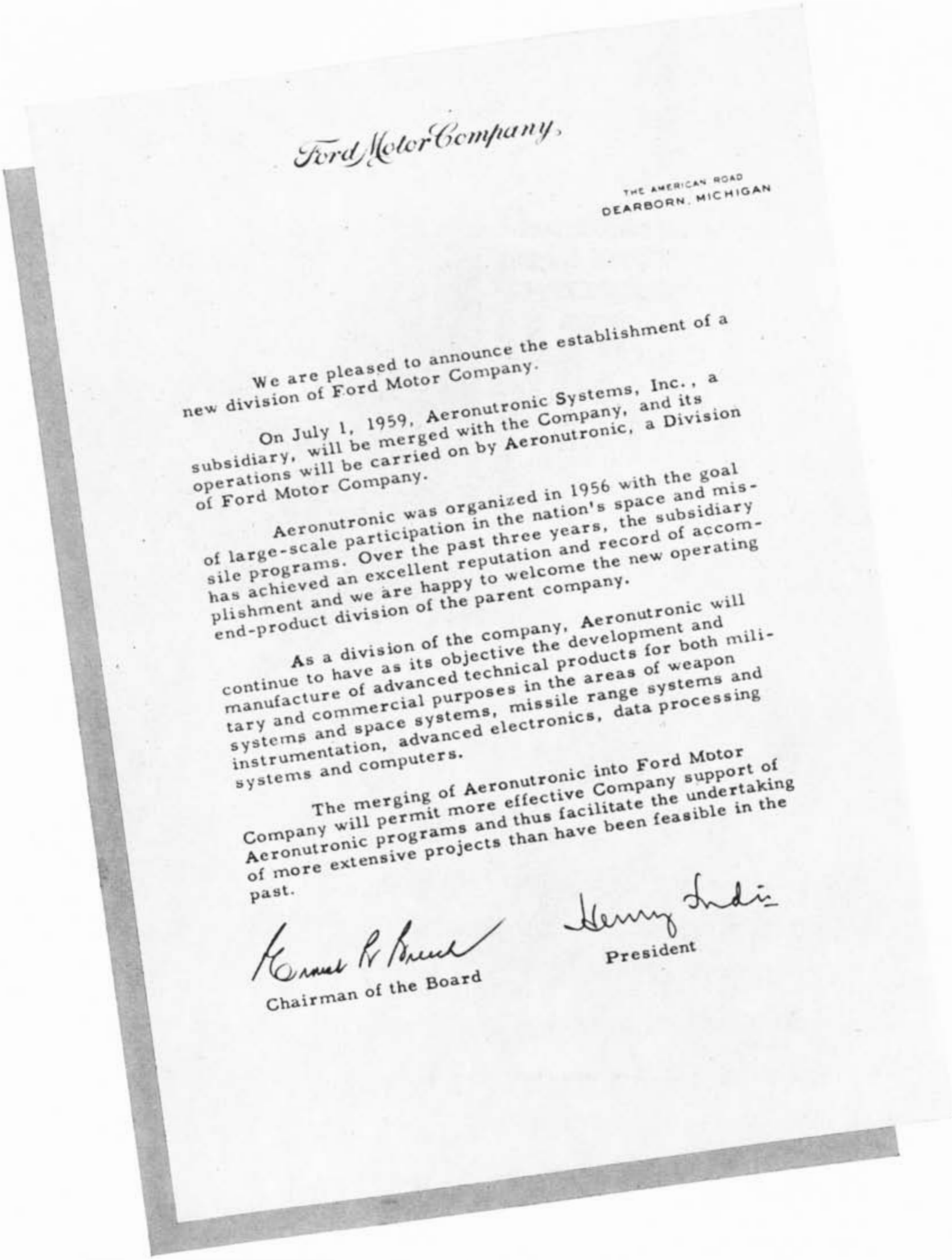
THE ILLUSTRATIONS

Cover photograph
by William Vandivert

Page	Source
37-43	Bunji Tagawa
44-46	Leiden Observatory
47-49	James Egleson
50	Mount Wilson and Palomar Observatories
51	James Egleson
52-53	H. J. Frith
55-58	Eric Mose
74	Institute of Engineering Research, University of California
76-80	Irving Geis
81	Bay Photo Service, Pacific Grove, Calif.
82	U. S. Coast Guard
84	Irving Geis
90	René Martin (*top*), René Martin and Emi Kasai (*bottom*)
92-93	René Martin and Emi Kasai
94-95	Emi Kasai (*top*), René Martin (*bottom*)
96	Fred Worden and James Marsh, University of California at Los Angeles
99	George Eastman House
100-106	New York Public Library
111	Sidney Lerman
112-117	Bunji Tagawa
119	Moses Kunitz and John H. Northrop, The Rockefeller Institute
120-134	James Egleson
138-144	Roger Hayward



FORD MOTOR COMPANY DIVISION–AERONUTRONIC, FOR THE



Ford Motor Company

THE AMERICAN ROAD
DEARBORN, MICHIGAN

We are pleased to announce the establishment of a new division of Ford Motor Company.

On July 1, 1959, Aeronutronic Systems, Inc., a subsidiary, will be merged with the Company, and its operations will be carried on by Aeronutronic, a Division of Ford Motor Company.

Aeronutronic was organized in 1956 with the goal of large-scale participation in the nation's space and missile programs. Over the past three years, the subsidiary has achieved an excellent reputation and record of accomplishment and we are happy to welcome the new operating end-product division of the parent company.

As a division of the company, Aeronutronic will continue to have as its objective the development and manufacture of advanced technical products for both military and commercial purposes in the areas of weapon systems and space systems, missile range systems and instrumentation, advanced electronics, data processing systems and computers.

The merging of Aeronutronic into Ford Motor Company will permit more effective Company support of Aeronutronic programs and thus facilitate the undertaking of more extensive projects than have been feasible in the past.

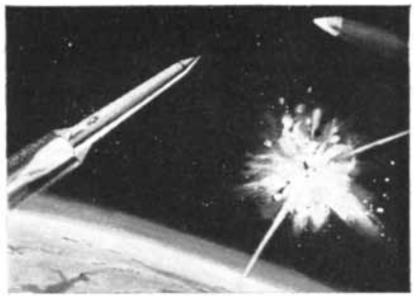
Ernest R. Breech
Chairman of the Board

Henry Ford II
President

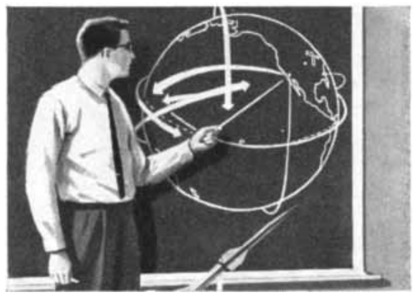
AERONUTRONIC – MEETING THE REQUIREMENTS OF THE

ANNOUNCES A NEW
SPECIALIZING IN PRODUCTS
SPACE AGE

NEW 200-ACRE ENGINEERING AND RESEARCH CENTER. An artists' concept of Aeronutronic's new 20-million dollar Research Center under construction at Newport Beach in Southern California. Here, Ford resources provide the finest facilities for carrying out complete engineering, research and prototype manufacturing operations on advanced projects. Over 40 government and commercial programs are now underway at the new Center and at other Aeronutronic facilities nearby.



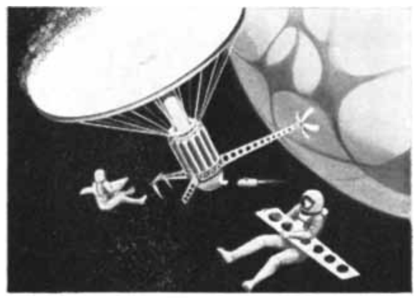
OFFICE OF ADVANCED RESEARCH. Basic research is conducted in areas of long-range company interests, with special emphasis in the fields of atomic and molecular physics, physical chemistry and atmospheric physics.



RANGE SYSTEMS OPERATIONS provides total capability to study and plan missile range instrumentation and to staff and manage complete missile range operations for U. S. military and civilian agencies.

TACTICAL WEAPON SYSTEMS OPERATIONS. The function of TWSO is to research, develop and manufacture tactical weapons for the military services. Under development now is the Army's $23-million SHILLELAGH surface-to-surface guided missile system.

COMPUTER OPERATIONS is engaged in research, development, manufacturing and marketing of computer components and communications systems for military and commercial use. New products developed are revolutionizing present data processing techniques.



SPACE TECHNOLOGY OPERATIONS is devoted to solving problems dealing with man's new frontier. Typical development programs include satellite communication, ICBM detection, space vehicle design and research rockets, such as Project Far Side.

For information regarding interests, facilities, products or positions, write to Aeronutronic, a Division of Ford Motor Company, Ford Road, Newport Beach, California.

Ford Motor Company

MILITARY AND INDUSTRY IN SCIENCE AND TECHNOLOGY

Controls Company of America

(why is CC comfort always in season?)

how can we work for you?

Pick a season from one to four! Add temperature control by CC. What have you got? The right degree of comfort for indoor living regardless of the weather.

When it's cold outside — CC can supply A-P controls . . . A-P thermostatic accessories . . . Breese burners for both makers and users of oil heating equipment. Gas heaters and furnaces gain efficiency and style when equipped with A-P single-unit gas controls. Redmond motors, blowers and fan blades find wide application. And CC's Milwaukee valves and fittings are standard wherever hydronic heating is required.

When it's time to cool off — manufacturers of residential, commercial and automobile air conditioning look to A-P controls and Redmond motors. For example, CC pioneered automobile air conditioning with its single source for A-P valves, regulators and distributors. Redmond fractional hp motors and blowers too are nation-wide favorites on ventilating and air conditioning equipment.

If you have a temperature control problem, why not put it completely under CC control. Write today for full facts on this most comprehensive service.

This is our line

Time Control

Flow Control

Temperature Control

Motion Control

If you're looking for a better way to control time, flow, temperature or motion, our creative engineering service may help you find it. We can supply single controls or complete, integrated systems.

Creative Controls for Industry

CONTROLS COMPANY OF AMERICA

EXECUTIVE OFFICES: SCHILLER PARK, ILLINOIS

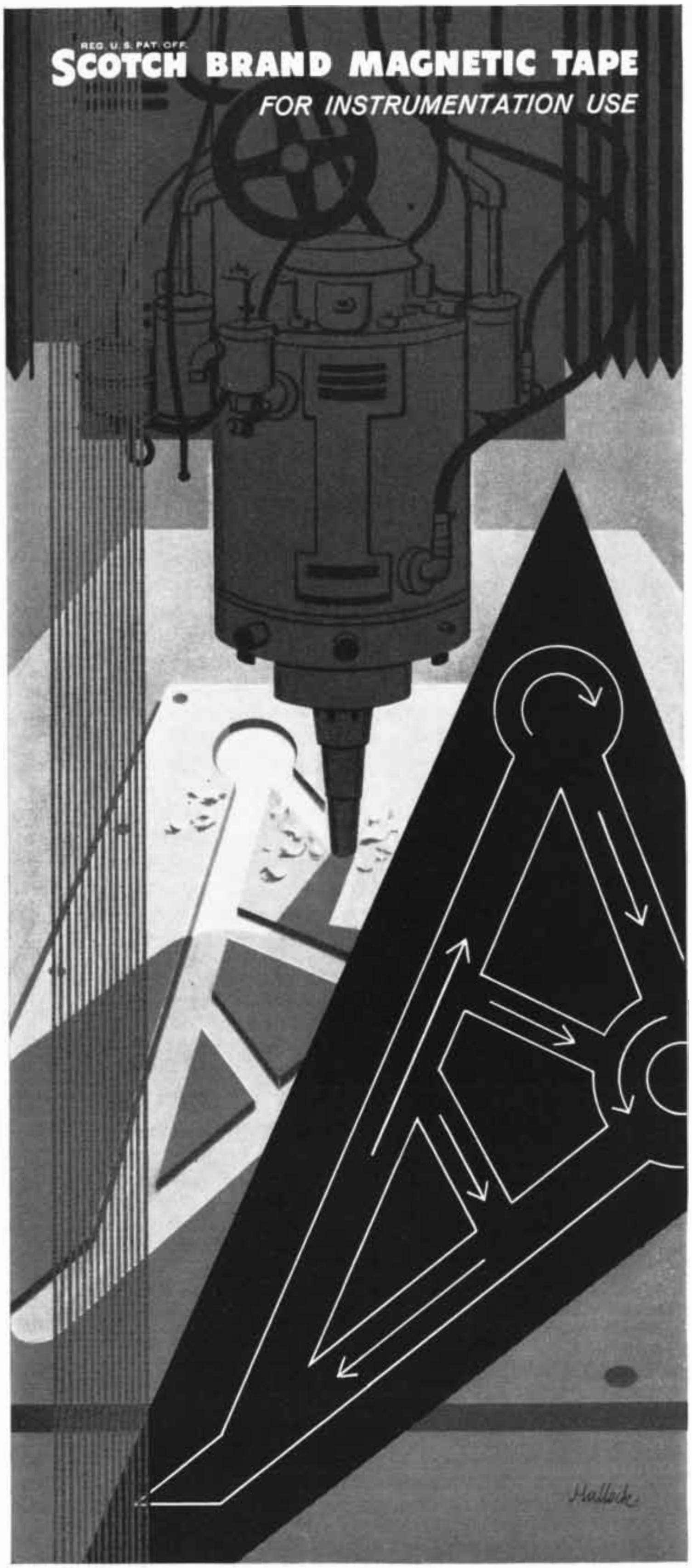
HEATING AND AIR CONDITIONING CONTROLS DIV. MILWAUKEE, WIS.

APPLIANCE AND AUTOMOTIVE CONTROLS DIV. SCHILLER PARK, ILL.

REDMOND COMPANY, INC. OWOSSO, MICHIGAN

HETHERINGTON, INC. FOLCROFT, PENNSYLVANIA

MILWAUKEE VALVE CO., MILWAUKEE, WIS. • LAKE CITY, INC., CRYSTAL LAKE, ILL. CONTROLS COMPANY OF AMERICA (CANADA) LTD., COOKSVILLE, ONTARIO, CANADA • INTERNATIONAL DIVISION, SCHILLER PARK, ILL., U.S.A. • CONTROLS AG, ZUG, SWITZERLAND • CONTROLS MAATSCHAPPIJ EUROPA N.V., NIJMEGEN, HOLLAND • CONTROLS COMPANY OF AMERICA (ARGENTINA) SRL, BUENOS AIRES.



MAGNETIC MEMORY OF COMMANDS GUIDES MILLING MACHINE THROUGH 27 MOVES

Where once only the human brain could guide a complex milling operation, "SCOTCH" BRAND Magnetic Tape now commands. Automated tools now mill contoured aircraft parts requiring as many as 27 movements of cutting axes and auxiliary machines.

Such programs are carried out in response to a series of timed commands, computer-plotted and recorded as multi-channeled frequency signals on "SCOTCH" BRAND Magnetic Tape. Production parts are turned out to tolerances of 0.001 inch — at costs of only one-third to one-fourth those of conventional machining.

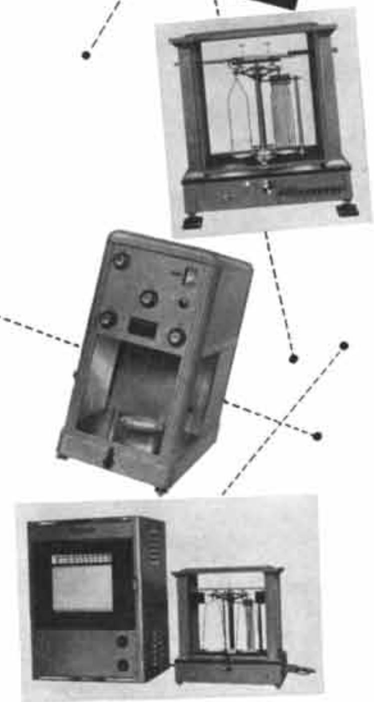
In this and other automated programs, "SCOTCH" BRAND Magnetic Tape, first practical magnetic tape devised, serves as both director and computer's memory. It helps, too, to explore sea and space, keep the records of business—and remains the leader as new, more sensitive tapes are developed for science, business and industry. For information on tape constructions for your needs, write Magnetic Products Div., Dept. MBO-89, 3M Company, 900 Bush Ave., St. Paul 6, Minnesota. © 1959 3M Co.

"SCOTCH" BRAND Magnetic Tape —for instrumentation use

The term "SCOTCH" is a registered trademark of 3M Company, St. Paul 6, Minnesota. Export: 99 Park Avenue, N.Y. Canada: London, Ont.

MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW



LETTERS

Sirs:

"An Ancient Greek Computer," by Derek J. de Solla Price [SCIENTIFIC AMERICAN, June], was of particular interest to me because in my personal collection of antique watches there is a complicated astronomical watch which performs, among many functions, some of those so far attributed to the Greek mechanism made almost 18 centuries earlier. The watch is by the English master George Margetts, and bears the London hallmark for 1783.

Had the discovery of the Greek instrument been made 200 years earlier, it might have spared Margetts, a brilliant astronomer as well as a watchmaker, a great deal of the research that must have gone into the preparation of this pocket watch, for there appear to be certain similarities in the layout and gearing of the two pieces.

The watch has five superimposed dials, all of which are constantly in motion. The small center dial indicates mean time. Arranged within the hour circle, in spokelike fashion, are the names of eight English and Irish ports. The position of the tides in these ports is shown on an enamel ring outside the hour circle, which is inscribed "High Water, Tide Fall, Low Water, Tide Rise, High Water. . . ."

The enamel ring, which is coordinated with the movement of the moon, has a small aperture through which appears the age of the moon in figures from 1 to 29½. Solar and lunar eclipses, which occur in cycles of approximately 18⅔ years, are also indicated in the aperture—a small black dot appearing for a lunar eclipse and a large black dot for a solar eclipse.

A gold pointer, which has a crescent moon near the tip, shows on a broad, engraved gold band near the outer circumference of the big dial, the position, by degrees, of the moon in the heavens. Another gold pointer, with the sun engraved near the tip, shows the month and day of the year. Still other pointers indicate signs of the zodiac and the sun's declination.

The large enamel dial, which has the constellations painted near its center, makes one revolution in a sidereal day of 23 hours, 56 minutes and 4 plus seconds. A gold frame with parallel arcs that covers the lower part of the dial represents the horizon of the earth. The area above the arcs reveals the constellations currently in view, and also the relative positions of the sun and moon in their orbit. The narrow space between the two arcs represents the twilight hours—the hour before sunrise and the hour after sunset. . . .

DAVID R. SCHWARTZ

Beverly Hills, Calif.

Sirs:

We read with great interest V. L. Ginzburg's article on the use of earth satellites to test certain predictions of the theory of relativity ["Artificial Satellites and the Theory of Relativity"; SCIENTIFIC AMERICAN, May]. The transportation of the physics laboratory to interplanetary space, with its vast distances, high vacuum and free-fall conditions is an exciting prospect. As Dr. Ginzburg says early in his article, "The history of physics has seen no end of cases in which the certain turns out to be false." The constancy of the velocity of light versus frequency, while less subject to question than many assumptions, could be considered in the above category of "certainty." We have been searching for a number of years for a direct way to measure the variation of "c" with frequency. A straightforward experimental test of the constancy of the velocity of light in free space over a very wide frequency range would be desirable, considering the implications of any variation for the validity of the theory of relativity. Unfortunately, a specific *comparison* of

Scientific American, August, 1959; Vol. 201. No. 2. Published monthly by Scientific American, Inc., 415 Madison Avenue, New York 17, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer.

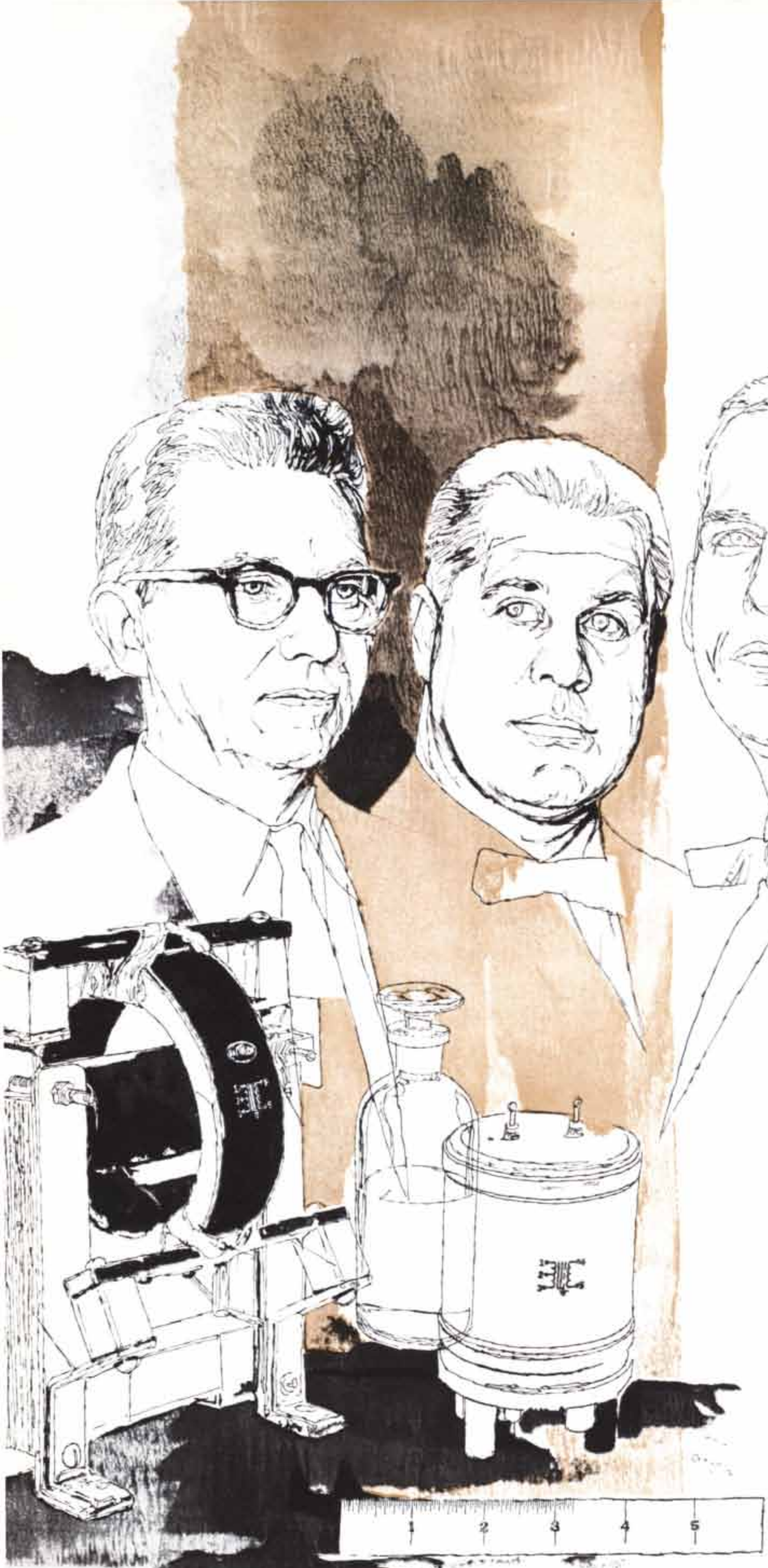
Editorial correspondence should be addressed to The Editors, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York 17, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

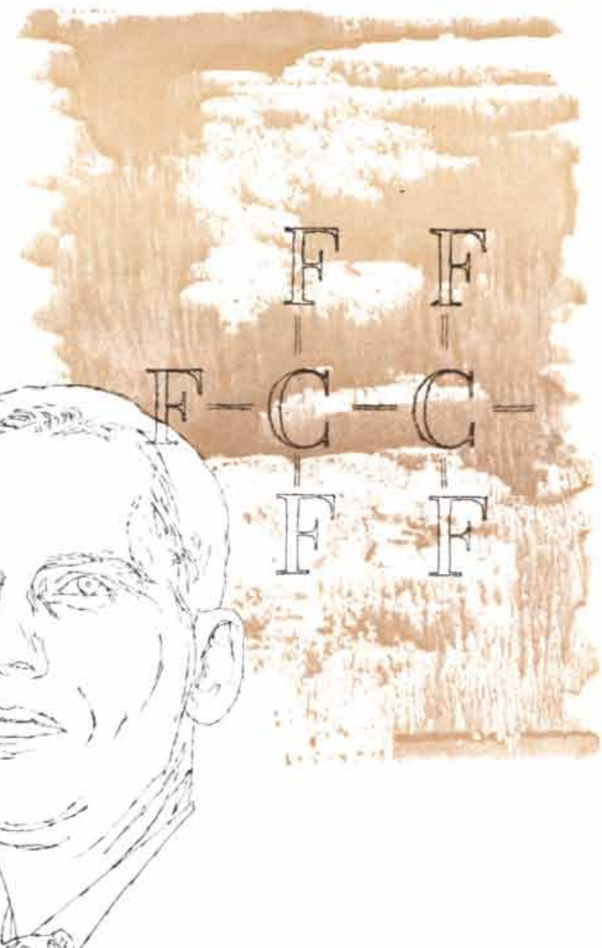
Advertising correspondence should be addressed to Martin M. Davidson, Advertising Manager, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York 17, N. Y.

Subscription correspondence should be addressed to Jerome L. Feldman, Circulation Manager, SCIENTIFIC AMERICAN, 415 Madison Avenue, New York 17, N. Y.

Subscription rates: one year, $6; two years. $11; three years, $15. These rates apply throughout the world. Subscribers in the United Kingdom may remit to Midland Bank Limited, 69 Pall Mall, London S. W. 1, England, for the account of Scientific American, Inc.: one year, two pounds four shillings; two years, three pounds 19 shillings; three years, five pounds eight shillings.

Change of address: Please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.





AT RAYTHEON

Scientific imagination focuses on NEW APPROACHES TO MINIATURIZATION . . .

Save one pound of excess weight and a missile travels 18,000 feet higher, a jet fighter costs $7,000 less! That's why weight reduction in airborne equipment is an imperative need.

Of all electronic components, transformers are intrinsically the heaviest, but radical new techniques developed by Raytheon scientists reduce size and weight of these units by as much as 75%. The keys to transformer miniaturization are efficient heat transfer and excellent dielectric properties – realized by using fluorochemicals. These compounds, originally developed for atomic energy applications, remove heat from transformer windings by vaporizing and then condensing on the inner surface of the transformer case. This unique application of fluorochemistry to electromagnetic design saves hundreds of pounds, improves electrical performance and reliability.

The scientific teamwork at Raytheon of men such as J. F. Ahearn, L. F. Kilham, Jr. and R. R. Ursch is responsible for this major advance in electronic packaging—one of many fields in which Raytheon is contributing to fundamental knowledge.

Excellence in Electronics RAYTHEON **RAYTHEON COMPANY, Waltham, Mass.**

"c" for photons of different frequencies could hardly be made in a laboratory.

However, in interplanetary space there is a good way to make this comparison of photon velocities. About a year ago we proposed an experiment along the following lines: A nuclear bomb is used as a very broad-band pulse source of radiation. If such a bomb is exploded far enough away from the earth, then any differences in propagation velocities for photons of different frequencies will result in different arrival times at the earth of these photons. To study this effect over a really broad band of frequencies, say from radar waves to gamma rays, the detection equipment must be put above the atmosphere. This could be done either by using orbiting satellites with radio relay to earth, or by probe rockets. . . .

ROBERT K. SQUIRE

Aerojet-General Corp.
Azusa, Calif.

SHELDON D. SOFTKY

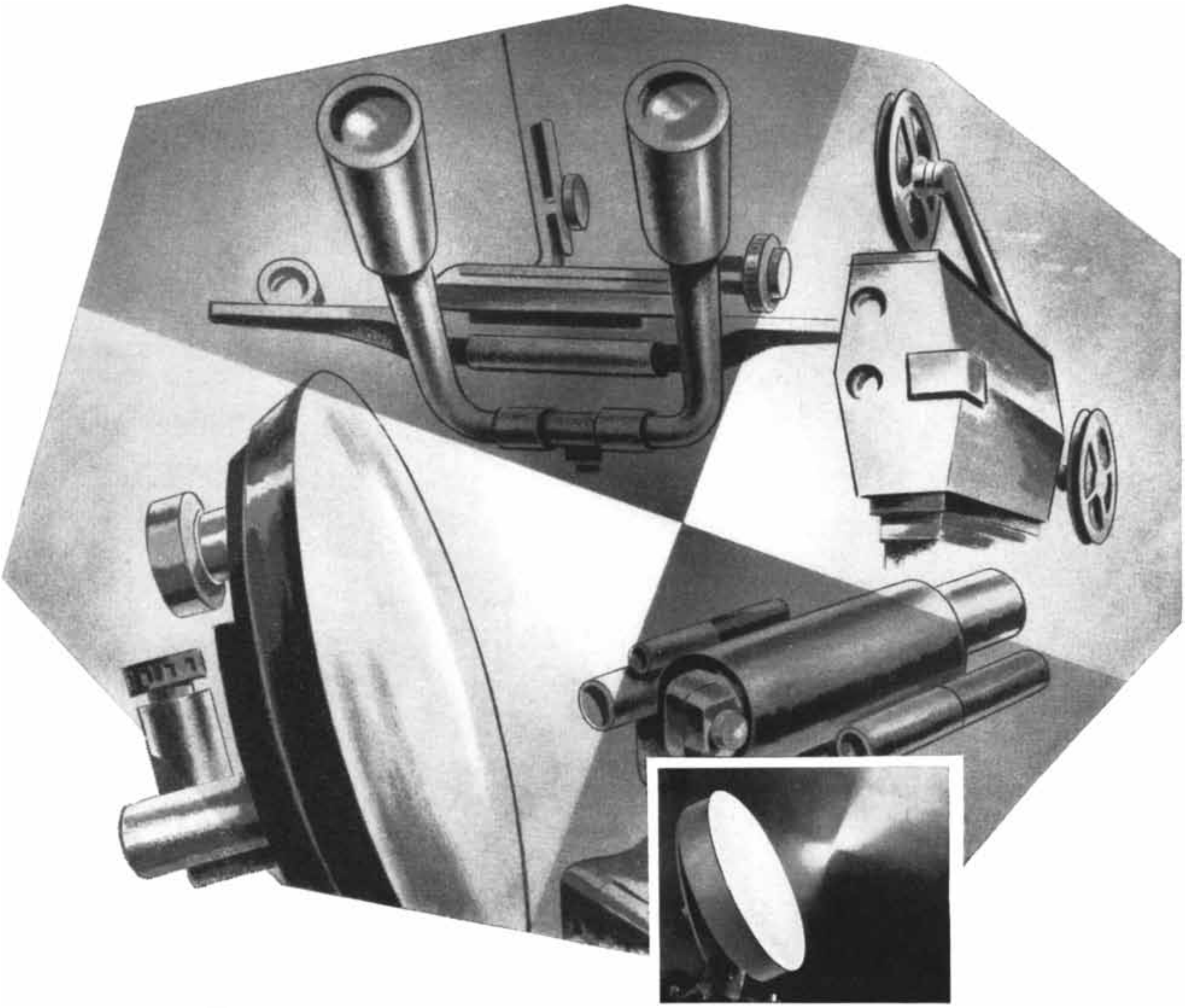
Stanford Research Institute
Menlo Park, Calif.

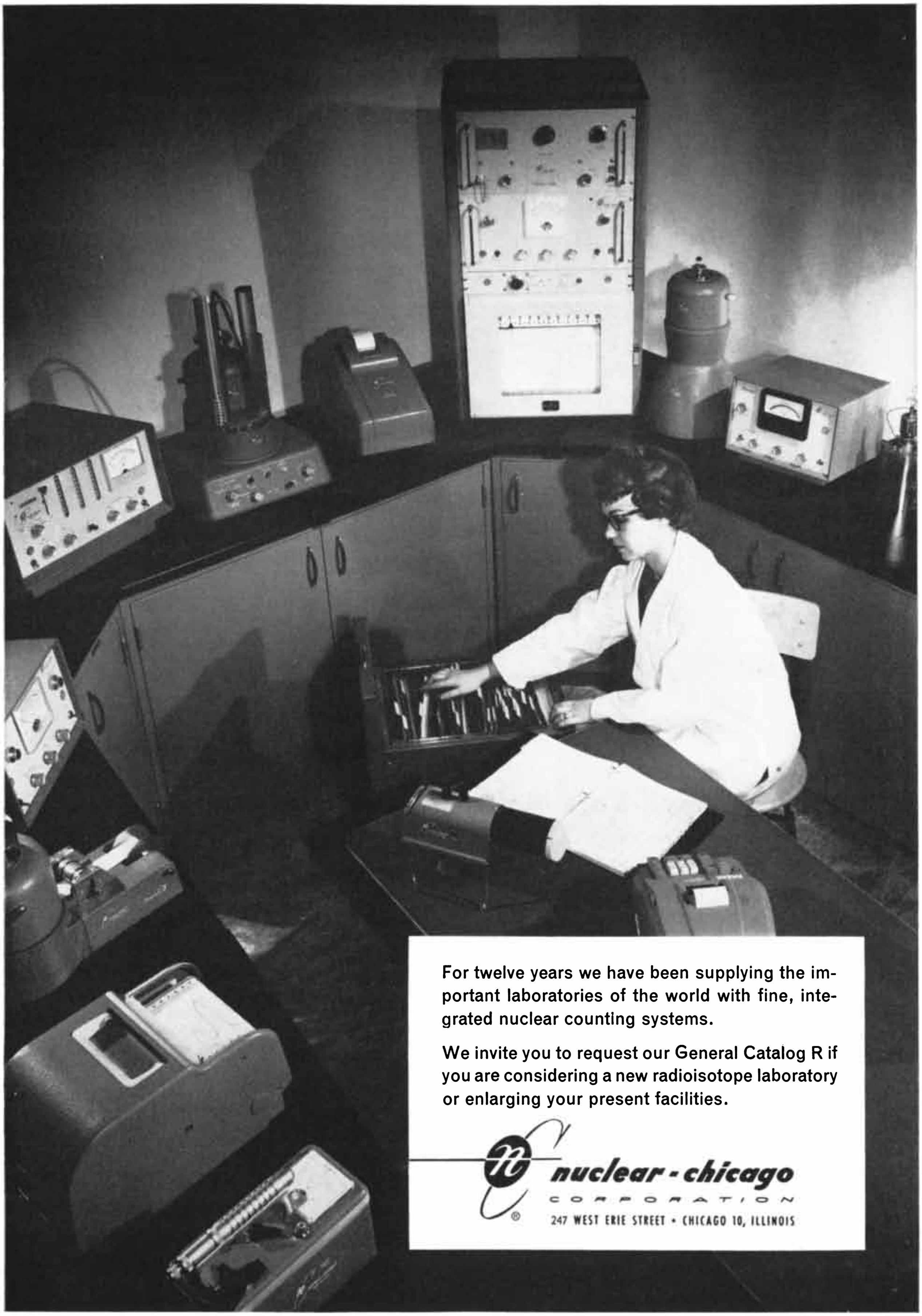
Sirs:

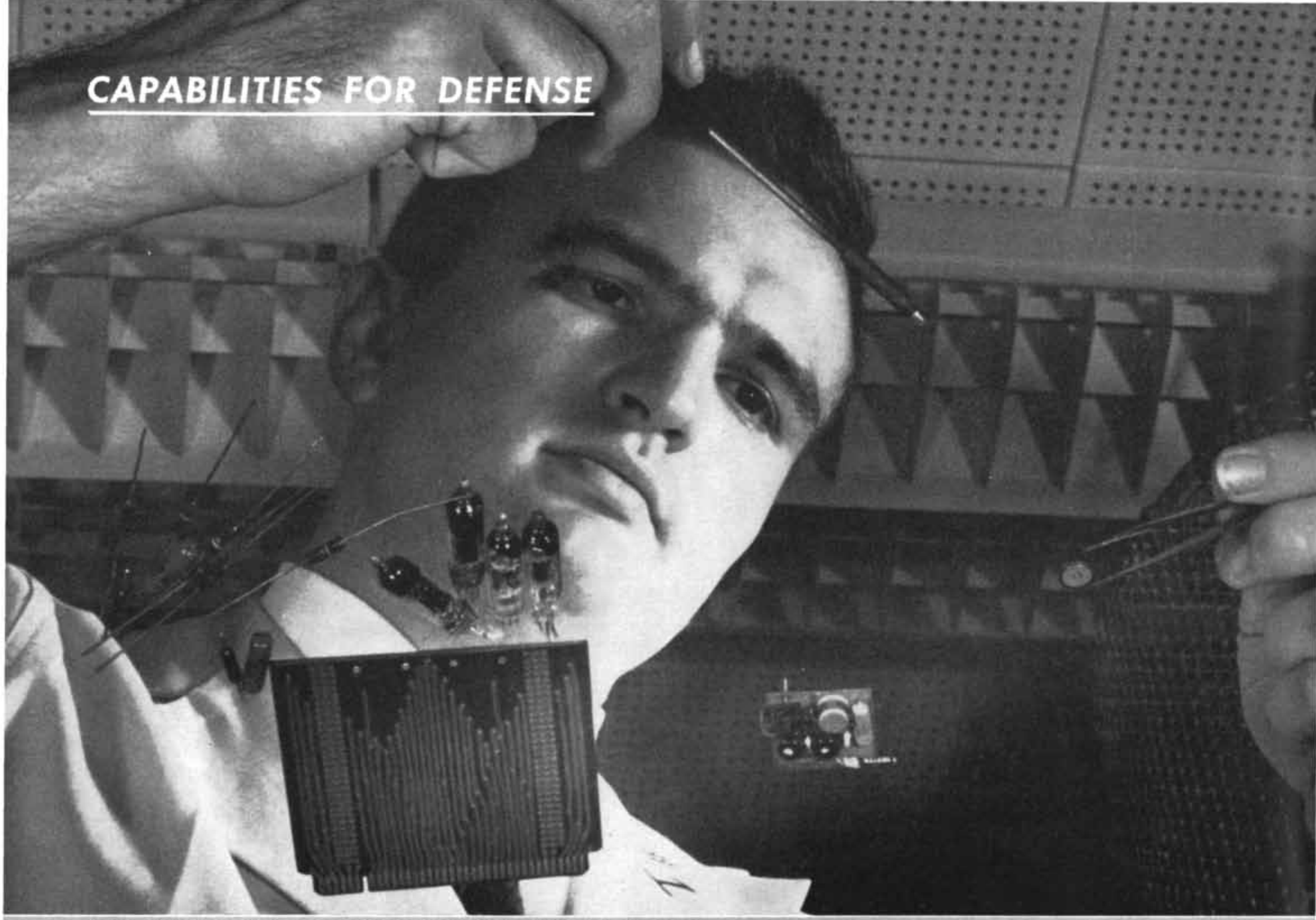
The term "bock beer" does not come from the German word for goat . . . the zodiacal sign for . . . March ["Beer," by Anthony H. Rose; SCIENTIFIC AMERICAN, June]. It comes from the German "*bockbier,* corrupt. of *einbecker bier,* from the town *Einbeck* in Germany" (Webster's New International Dictionary). So also in *Etymologisches Wörterbuch der deutschen Sprache:* "BOCKBIER . . . first around 1800 as OAMBOCK or AMBOCK, Munich dialect versions (for EIMBECKER BIER); compare derivation of *Taler*. The term may have originated under the influence of other beer types bearing animal names (Schöps, . . . *Stehr, Geiss, Ente*)." *Taler,* incidentally, comes from *Joachimst(h)aler,* a coin from *Joachimst(h)al,* a town in the Erzgebirge. From this word stems the American *dollar*. For their metaphysical needs in relation to beer Bavarians would not turn to such newfangled, unheard-of, outlandish, eggheadish and pagan concepts as the zodiac but to other sources; see beer and brewery names like *Thomaner, Franziskaner, Paulaner* and *Salvator.*

HEINRICH LAMM, DR. MED. (MONAC.)

Harlingen, Tex.

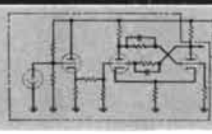



For twelve years we have been supplying the important laboratories of the world with fine, integrated nuclear counting systems.
We invite you to request our General Catalog R if you are considering a new radioisotope laboratory or enlarging your present facilities.
nuclear-chicago
CORPORATION
247 WEST ERIE STREET • CHICAGO 10, ILLINOIS



THESE THREE LIGHT SENSING SYSTEMS PERFORM EXACTLY THE SAME FUNCTION

	SIZE	WEIGHT	INPUT POWER	COMPONENTS	SOLDERED CONNECTIONS
VACUUM TUBE	4 cu. in.	26 grams	5 watts	16	18
TRANSISTORIZED	1 cu. in.	7 grams	0.75 watts	14	15
MOLECULAR SYSTEM	0.001 cu. in.	0.02 grams	0.06 watts	1	2



Westinghouse laboratory produces molecular electronic systems 1/1000th of present size

Molecular electronics—a technological breakthrough at Westinghouse—is producing electronic systems 1,000 times smaller and lighter than anything now in existence.

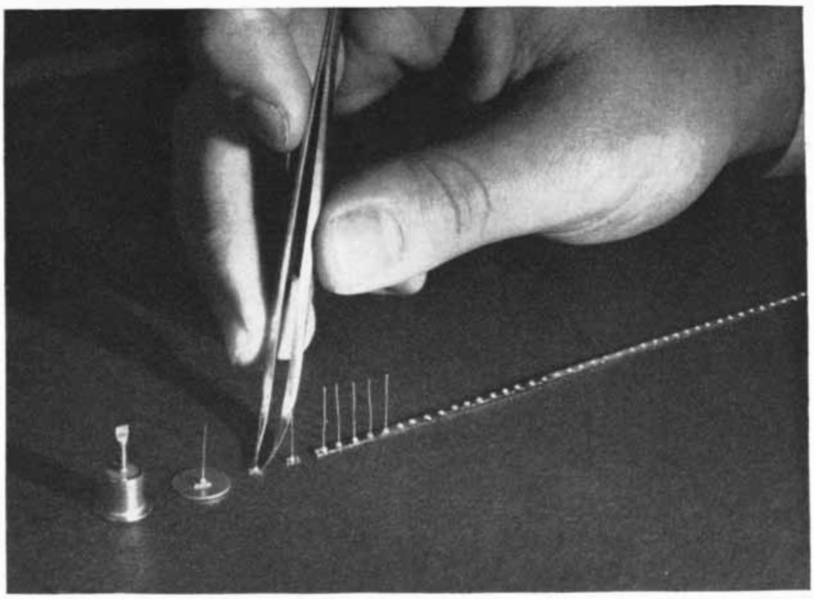
Recently, the Air Research and Development Command of the U. S. Air Force awarded a development contract to Westinghouse as a part of a broad program effort in this new electronic area. Experimental "hardware" is being fabricated by Westinghouse for infrared, reconnaissance, communications, telemetry, flight control and other military applications for the Air Force.

For some time, the Solid State Advanced Development Laboratory of the Semiconductor Division, located at the Baltimore defense divisions, has been producing for special equipment applications a single material which accomplishes all the functions normally performed by several components in a conventional assembly.

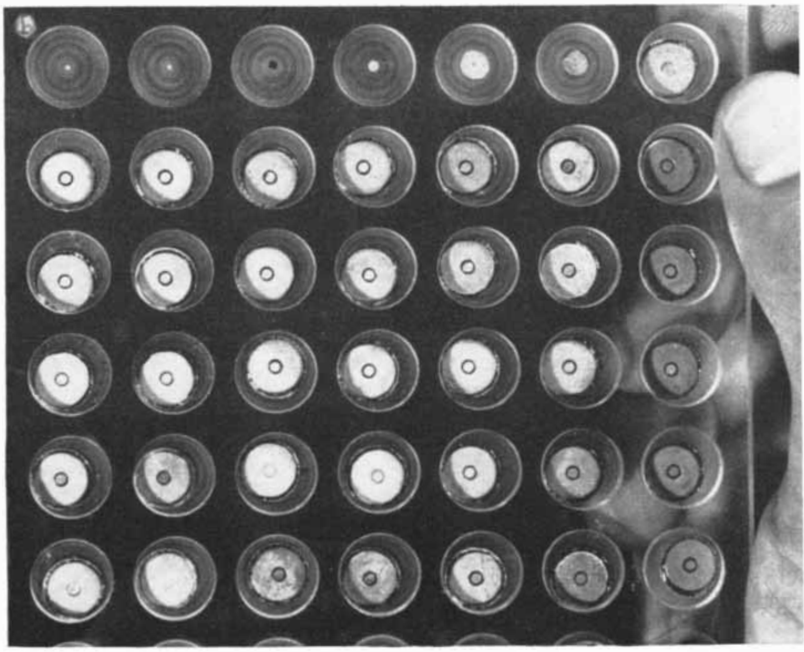
Pictured above at right, a single wafer—less than ½" in diameter and about 1/100th of an inch thick—performs all the functions of much larger conventional and transistorized light modulated oscillators shown at left and center. This tiny complete functional system, a light sensing device for satellite telemetry, is one of several including pulse generators, multiple switches and similar subsystems built and demonstrated by Westinghouse.

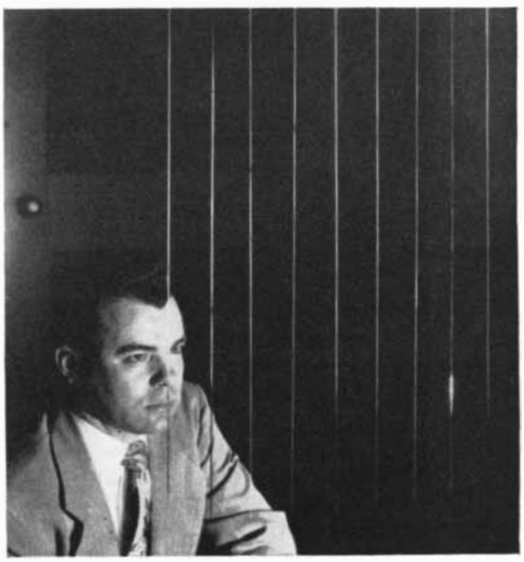
Through molecular electronics, drastic reduction in weight, size, power, and heat dissipation requirements will permit space vehicles and satellites to perform a greater number and wider range of tasks. Greatest advantage is vastly improved reliability achieved by the replacement of numerous components by a single solid state unit.

Westinghouse arrangement of component laboratory side by side with systems manufacturing divisions—unusual in industry—is providing a steady flow of information between component and systems scientists and engineers. A coordinated program involves the Air Arm Division, the Semiconductor Division, the Materials Engineering Department and the Research Laboratories. At all of these locations, continuing research is determining greater uses for this new approach to the building of better, more efficient electronic systems.



AUTOMATIC PRODUCTION of diodes at high speed and with great reliability may be possible as a result of molecular electronics. Shown above, individual diodes are sliced from ribbon following electrical connections. Each crystal in photo below is a self-contained subsystem, performing all the functions of a component-assembled unit. Row at top shows varying sizes to almost the vanishing point.





HIGH-SPEED GROWTH of semiconductor crystals has been achieved by Westinghouse. Crystals are formed as a mirror-finish ribbon of required width and thickness. Method eliminates costly and time-consuming sawing and polishing of germanium ingots, drastically cuts normally large loss of original material.

Westinghouse

DEFENSE PRODUCTS

1000 CONNECTICUT AVENUE, N.W., WASHINGTON 6, D.C.

AIR ARM DIVISION
AVIATION GAS TURBINE DIVISION
ELECTRONICS DIVISION
AIRCRAFT EQUIPMENT DEPARTMENT
ORDNANCE DEPARTMENT
WASP

YOU CAN BE SURE... IF IT'S Westinghouse

FROM ONE EXTREME TO ANOTHER

Challenging jobs requiring engineering skill as well as metal fabricating experience have a way of coming to Bliss. They may be projects involving massive size, like the 140-foot diameter radio telescope shown above ... or the precision machining of missile parts similar to the one at the left.

Whatever it is, if it's made of metal, you'll find that Bliss has the skills and facilities to take it from idea to completed project.

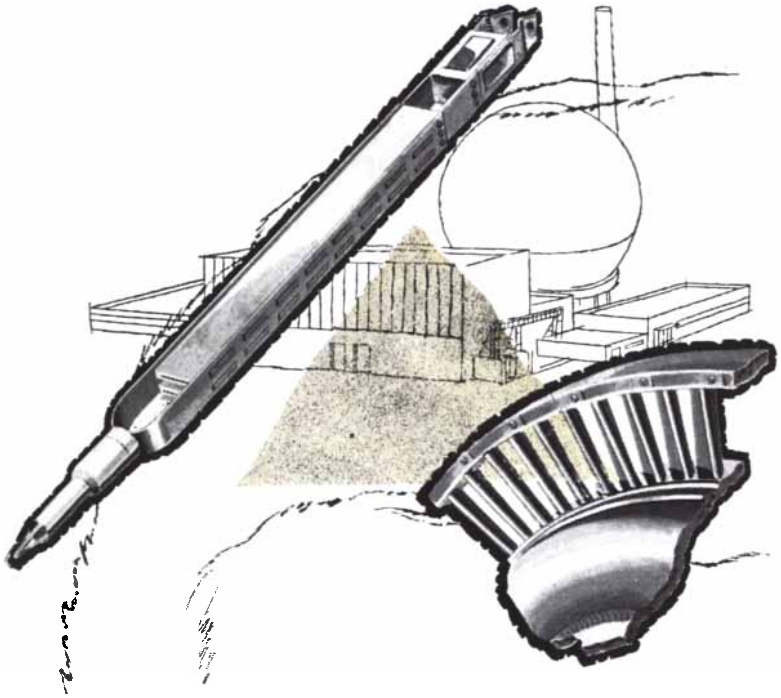
These abilities have made Bliss a leading producer of steam catapults for carrier aircraft, overrun barriers, precision machined missile parts, antennas, atomic assemblies and special machinery; everything from small parts with tolerances running to the ten-thousandths to complete turn-key plants.

What does your job involve?

BLISS is more than a name
... it's a guarantee

E. W. BLISS COMPANY
Canton, Ohio

BLISS
SINCE 1857 ®



Today's metallurgical engineers and scientists are constantly meeting the challenge of sweeping technological advances. Electronic brains that solve "impossible" problems . . . jets and space craft which open brand-new horizons . . . reactors that produce fantastic amounts of nuclear energy. Advances such as these *demand* better metals . . . metals free of inclusions, with better electrical conductivity, increased hot strength, extended creep resistance and fatigue limits. In turn, better refractories are a "must" in order to precisely control purity and composition during the development of these metals.

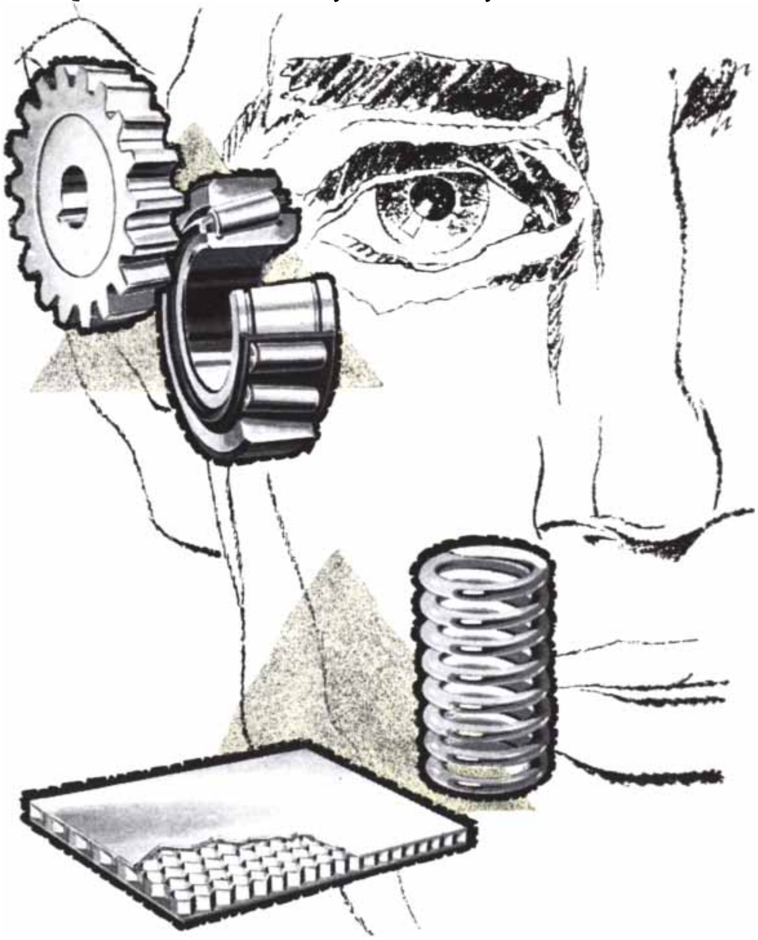
Metal processors have long relied on the wide range of Norton Refractory products to precisely meet their requirements. High purity (99.5%) ALUNDUM* aluminum oxide, outstandingly stable to both oxidizing and reducing atmospheres . . . dense, fused, stabilized Zirconia for operations requiring an inert refractory for extremely high temperatures . . . non-wetting, nitride-bonded CRYSTOLON* silicon carbide...low boron MAGNORITE* magnesium oxide, ideal for vacuum melting. In addition, the Norton Man is constantly helping in process and product development. Backed by Norton Company's extensive engineering facilities, he can offer time and money-saving advice on all refractory problems.

Meet *your* processing requirements more efficiently and economically with Norton Products and Engineering. For complete details write NORTON COMPANY, Refractories Division, 547 New Bond Street, Worcester 6, Mass.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

Dynamic Achievements With Purer Metals

...reflect the positive protection of Norton Refractories



Making better products . . . to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories • Electro-Chemicals — **BEHR-MANNING DIVISION:** Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

AUGUST, 1909: "Six days after the first attempt at flying across the English Channel was made by Hubert Latham, M. Louis Blériot, who had brought his 'No. XI' monoplane from Paris to Calais especially for the purpose, made a successful flight and landed on the English shore. On Sunday, July 25th, M. Blériot started off over the strait at 4:35 a.m. The air was clear and a southwest breeze was blowing. Ten minutes after leaving the French coast the monoplane was out of sight. Blériot flew for 10 minutes without steering to right or left. There was nothing to go by, and flying at a 40-mile clip without compass or any other guide must indeed have been a thrilling sensation. After the English shore came into view, he recognized that the strong southwest wind had carried him to the eastward. As soon as he found this out he turned to the left, and following the coast for two or three miles until, within a mile or two of Dover, he turned into an opening between the cliffs. A strong wind caught him and swung him completely around, but he managed to make an abrupt descent upon suitable ground between the cliffs, where a fellow countryman was awaiting him. The running gear and propeller were damaged but the aviator landed without hurt. The 25-mile flight was accomplished in 37 minutes, or at the rate of about 40 miles an hour. After his record flight M. Blériot was decorated with the ribbon of the French Legion of Honor. In addition to winning the prize of the London *Daily Mail* ($5,000) Blériot also won a prize of $2,500 offered by a French wine firm two years or more ago."

"The approach of Halley's comet is the most important astronomical event of the years 1909 and 1910. It will come nearest to our earth the first week of June, 1910, being then only 20 million miles distant from us. Those observatories endowed with large telescopes are vying as to which one will be the first to pick up the returning voyager. It is expected that this will be done in August or September of this year. The comet will then be a faint, nebulous star not far from Orion."

"The sixth annual tour of the American Automobile Association, better known as the Glidden Tour, was completed at Kansas City, Mo., on July 31st after a more than usually strenuous journey of 15 running days from Detroit *via* Chicago to Denver and back to Kansas City. The roads, the worst ever encountered, varied from axle-deep sand to mud as deep and, perhaps worst, axle-deep ruts in hard-baked 'gumbo.' Despite these difficulties eight cars finished with perfect road scores (without losing marks for delay, breakage, repairs or adjustment *en route*). The Glidden trophy for the largest cars and the Hower trophy for run-abouts were won by 'Pierce-Arrow' cars, three of which finished with perfect road scores. The Detroit prize in intermediate cars was won by a 'Chalmers-Detroit' car."

"With the completion of the 10-mile cross-country speed test by Orville Wright at Fort Myer on July 30th, the Government requirements in a heavier-than-air flying machine were completely fulfilled. The speed averaged by the machine carrying Orville Wright, and Lieut. Foulois as passenger, was 42.58 miles an hour. As the bonus offered by the Government was $2,500 for each mile per hour in excess of 40, without consideration of portions of a mile, the Wright brothers received a bonus of $5,000, which made a total of $30,000."

"Public interest in the present attempt by Peary to reach the North Pole has been reawakened by the recent start of the schooner *Jeanie* from St. John's, Newfoundland, for Etah, West Greenland, for the purpose of getting into communication with the explorer, who has now been absent over 12 months on his present expedition. When Peary left in the *Roosevelt*, he planned to push as far north as the ice would admit, and then establish winter quarters and make preparation for a dash by sled between March and June of the present year. If he was successful, he planned to return to Etah with the ship, if possible, and if not, without it. If he failed to reach the Pole, it was his purpose, should another attempt seem to promise success, to remain in the north till the summer of 1910."

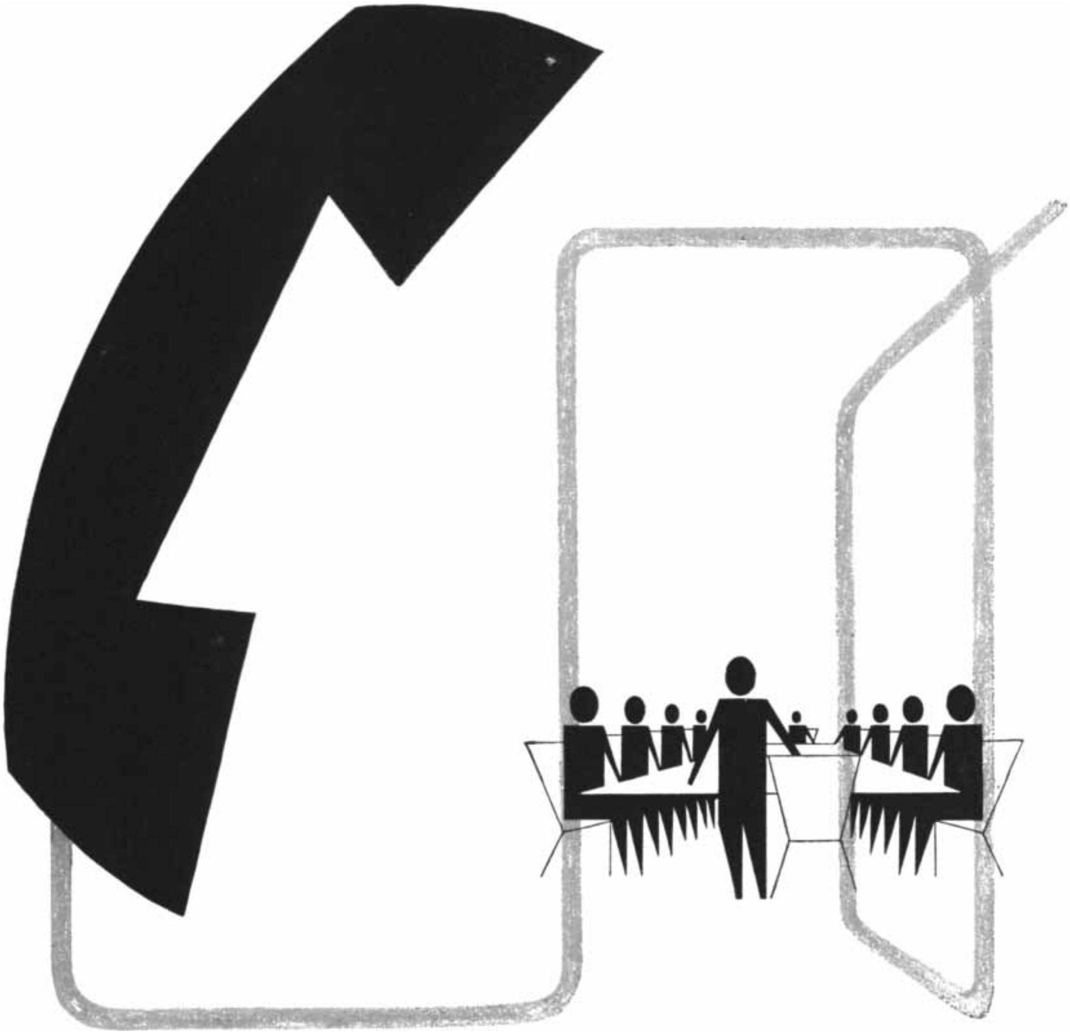
"Of the molecular construction of enzymes, ferments or diastases the world of science is almost entirely ignorant. However, we may console ourselves with

the reflection that we are at least on the eve of important discoveries. Emil Fischer of Berlin, having vied with Nature herself in the manufacture of sugars, has now turned his attention to protein substances. Fischer has traced the connection between the configuration of a sugar and its behavior toward ferments. This is the famous 'Schloss und Schlüssel' theory, happy analogy of 'lock and key.' It is our everyday experience that yeast cells assimilate more easily the sugars of which the molecular configuration closely resembles that of the most digestible of all carbo-hydrates, namely, glucose. Many of the artificially produced sugars, as for example the aldoses, gulose and talose, are quite indifferent to the fermentive efforts of yeast."

SCIENTIFIC AMERICAN

AUGUST, 1859: "Among the thousand marvelous inventions which American genius has produced within the last few years are the following, compiled in an abstract from the Patent Office Report. An ice-making machine has been patented, which is worked by a steam engine. In an experimental trial it froze several bottles of sherry and produced blocks of ice the size of a cubic foot when the thermometer was up to 80 degrees. Another is an electro-magnetic alarm which rings bells and displays signals in case of fire and burglars. Another is an electric clock which wakes you up, tells you what time it is and lights a lamp for you at any hour you please. There is an invention that picks up pins from a confused heap, turns them heads up and sticks them in papers in regular rows. There is a parlor chair patented that can be tipped back on two legs, and a railway chair that can be tipped back in any position without any legs at all. Another patent is for a machine that counts passengers in an omnibus and takes their fares. When a very fat gentleman gets in, it counts two and charges double. There is a machine by which a man prints, instead of writes, his thoughts. It is played like a pianoforte."

"The present population of London is about 2,800,000. The entire population of Paris, including that of all its metropolitan suburbs, is about 1,500,000. That of New York, estimated in the same way, is 1,100,000."



How to turn your telephone into a conference room

Another of the many ways ITT electronics saves time and money and speeds output

Flick the dial of an ITT intercommunication telephone.

Instantly, it becomes a "conference room"—linking 10 key people simultaneously.

They talk together, exchange ideas, reach decisions — *without leaving their desks!*

ITT electronics—a help for business

This ten-party conference telephone is one of hundreds of ideas developed by ITT's Kellogg Switchboard and Supply Company and other ITT units to help perform tasks—faster.

ITT supplies telephone systems for entire countries. It develops communications and guidance for missiles; radio aids for aircraft and ships; microwave systems that control the flow of oil, gas, and electric power.

Nations are joined by ITT coaxial cable systems; news of the world is broadcast by ITT transmitters and power tubes—in fact, ITT equipment is produced for every communications need of business, industry, and government.

Skills for international projects

ITT has decades of experience in operating nationwide telephone networks. ITT System commercial circuits—cables, radiotelephone, radiotelegraph, and marine radio—cover the earth.

An ITT System company operates and maintains the 3,000-mile DEW Line in the Arctic, the White Alice communication network in Alaska, and other vital lifelines of defense. ITT has the senior part in planning the modernization and extension of the Air Force's global communications concept called AIRCOM.

In countless other ways ITT System research, production, and service are speeding the world's growing communications traffic.

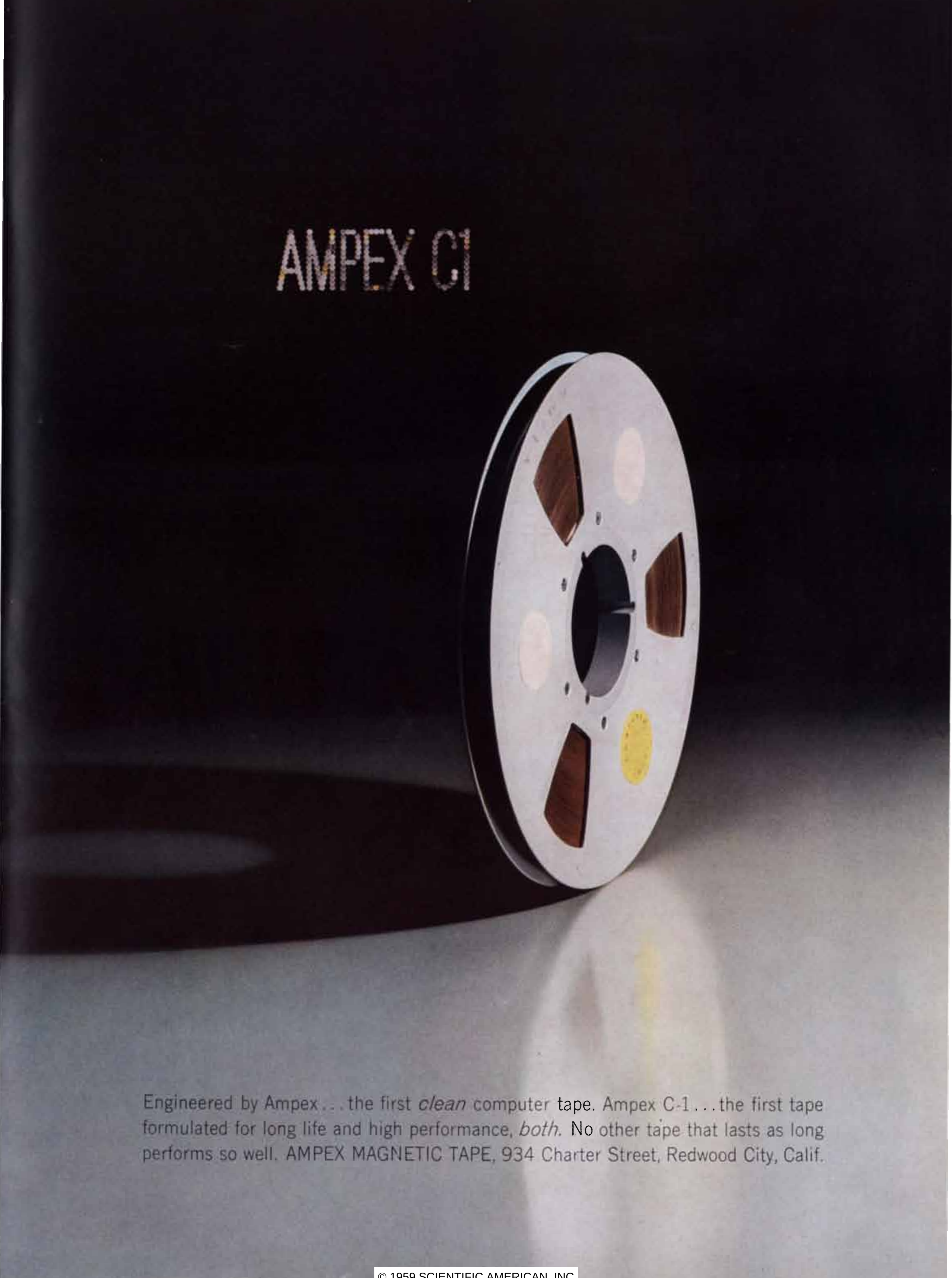
For information on any communications system write to ITT, 67 Broad Street, New York 4, N.Y.

ITT

. . . the largest American-owned world-wide electronic and telecommunication enterprise, with 101 research and manufacturing units, 14 operating companies and 130,000 employees.

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION 67 Broad Street, New York 4, N.Y.

ITT COMPONENTS DIVISION • ITT FEDERAL DIVISION • ITT INDUSTRIAL PRODUCTS DIVISION • ITT LABORATORIES • INTELEX SYSTEMS INCORPORATED AIRMATIC SYSTEMS CORPORATION • KELLOGG SWITCHBOARD AND SUPPLY COMPANY • ROYAL ELECTRIC CORPORATION • AMERICAN CABLE & RADIO CORPORATION • FEDERAL ELECTRIC CORPORATION • ITT COMMUNICATION SYSTEMS, INC. • INTERNATIONAL ELECTRIC CORPORATION • INTERNATIONAL STANDARD ELECTRIC CORPORATION • LABORATORIES AND MANUFACTURING PLANTS IN 20 FREE-WORLD COUNTRIES


AMPEX C1
Engineered by Ampex . . . the first *clean* computer tape. Ampex C-1 . . . the first tape formulated for long life and high performance, *both*. No other tape that lasts as long performs so well. AMPEX MAGNETIC TAPE, 934 Charter Street, Redwood City, Calif.


Ruffins

How to wrap up 2000°F!

Searing heats up to 2000°F can now be contained in "packages" of tough, lightweight FIBERFRAX® ceramic fiber insulation. Woven into cloth, twisted into rope; pressed into felt, paper and board; formed into tubes and shapes or used as bulk packing; it offers the ultimate in versatility for high temperature insulation. From the handling of molten metals to advanced problems of missile design the unique properties of FIBERFRAX, *discussed on the opposite page,* are attracting the increased interest of designers. For help on problems involving extreme heat, abrasion or corrosion, write Carborundum, Dept. AMT, Research & Development Div., Niagara Falls, N. Y.

Where conventional materials fail . . . call on

ADVANCED MATERIALS TECHNOLOGY

CARBORUNDUM

Registered Trade Mark

THE AUTHORS

ROBERT JASTROW ("Artificial Satellites and the Earth's Atmosphere") is chief of the Theoretical Division of the National Aeronautics and Space Administration and chairman of the N.A.S.A. Lunar Explorations Working Group. He was born in New York in 1925, graduated from Columbia College in 1945 and took his Ph.D. in physics at Columbia University in 1948. Jastrow started out with an interest in psychology and biology, intending to go to medical school. He studied calculus to cope with the mathematical side of experimental psychology, and liked it so well that he switched to biophysics and then to physics. After he took his Ph.D. he wanted to travel, so he took a postdoctoral fellowship at the University of Leiden in the Netherlands. He says: "While I learned a lot of physics, it was the only year of my postdoctoral career in which I did not publish a paper." Instead he saw a good deal of Europe. He returned to be a member of the Institute for Advanced Study at Princeton, and in 1950 became a research associate at the University of California. At these two institutions he learned nuclear physics, a field which he pursued until about two years ago. In 1953 and 1954 he was an assistant professor of physics at Yale University, and from 1954 to 1958 he was a consultant to the Naval Research Laboratory in Washington. There he asked the Vanguard people "if they could use any theoretical help on some little problem, and they suggested I look into the calculation of the drag coefficient on the Vanguard satellite." He and a former student of his, Arnold Pearse, worked for some months on a paper on this topic and then he took off on a series of meetings in Europe. He returned about five days before *Sputnik I* went up, and when it did, he says, "I wandered into the Vanguard control center and asked whether I could help them out with their orbit calculations. There was a lot of chaos and confusion. I sat down and started to work, and that's how I learned about orbits. A little later, after we learned something about orbit calculation and satellite tracking, I did a calculation that showed that the *Sputnik I* rocket probably fell in Mongolia, not in Alaska as the Russians had claimed. I submitted that paper for the I.G.Y. conference in Moscow, and went to Moscow to deliver it and two other papers. Then I went on to Geneva to accompany an exhibit in nuclear theory I had constructed for the United Nations atomic energy conference. It was my last job as a nuclear physicist."

GART WESTERHOUT ("The Radio Galaxy"), one of five or six full-time radio astronomers in the Netherlands, is in charge of radio astronomy at the Leiden Observatory. He was born 32 years ago in The Hague, and decided to become an astronomer at the age of 12, after attending lectures at the planetarium in The Hague. "By the time I was 14," he says, "I was lecturing friends and neighbors on astronomy." He studied at the University of Leiden under Jan H. Oort, now president of the International Astronomical Union, and H. C. van de Hulst, both pioneers in radio astronomy. Westerhout has been doing research in that field since 1951, when the 21-centimeter emission line of neutral hydrogen was first detected. In 1958 he became the first astronomer in the Netherlands to receive a doctor's degree in radio astronomy.

H. J. FRITH ("Incubator Birds") is a member of the Wildlife Survey Section of the Commonwealth Scientific and Industrial Research Organization in Australia. He joined the C.S.I.R.O. in 1946 as an agronomist, but in 1950 changed to wildlife work "mainly because my citrus-culture notebook contained more notes on the birds in the trees than on the trees themselves." He enjoys similar difficulties today, since he is "officially paid to study the ecology of wild ducks and geese, but keeps getting involved with the incubator-building megapodes on the side." He was born in Kyogle, New South Wales, an agricultural town 80 miles south of Brisbane, in an area inhabited by some of the mound-building birds, and has studied them since boyhood. In 1941 Frith took a bachelor-of-science degree in agriculture at the University of Sydney, and then served in the field artillery until 1945, first in the Middle East, then in New Guinea, where he was able to watch megapode species unknown in Australia. He began a full-scale study of his favorite mound-builder, the mallee fowl, when he went to live at Griffith, New South Wales, in 1946. This interest continues, and since 1954 Frith has added studies of magpie geese and jungle fowl.

WILLARD BASCOM ("Ocean Waves") is technical director of the Mohole project for the AMSOC Committee of the National Academy of Sciences. He wrote the article "The Mohole" [Scientific American, April], which described the proposed hole through the earth's crust to the mantle. Bascom was born in New York City and studied at the Colorado School of Mines. He was a mining engineer from 1942 until he switched to oceanography in 1945, as head of a University of California field party studying waves, beaches and shoreline structures. He has since been involved in studies of amphibious operations, underwater swimmers, mine countermeasures, antisubmarine warfare, the future of the Navy, and oceanography.

VERNON ROWLAND ("Conditioning and Brain Waves") is assistant professor of psychiatry at the Western Reserve School of Medicine in Cleveland, and is a Career Investigator of the National Institute of Mental Health. He was born in Cleveland in 1922 and took his M.D. degree at the Harvard Medical School in 1946, followed by internship and residency in Cleveland and in the U. S. Army. He received board certification in neurology and psychiatry in 1955. "I took my graduate training at the time of rapid developments in cybernetics and servomechanism theory, much of which I became aware of through Scientific American articles," Rowland says. "Reconciling these with certain psychiatric and psychologic theories seemed possible only through direct study of the nervous system." In order to study the nervous system Rowland spent a year in the laboratory of Horace W. Magoun at the University of California at Los Angeles. "It is perhaps symbolic of Dr. Magoun's wide-ranging interest and facility for attracting people to neurophysiology that I found myself, a psychiatrist, working in a department of anatomy on a problem of brain physiology using the techniques of psychology." He gives credit to the National Institute of Mental Health appointment, which he has held since 1955, for the opportunity to start the studies described in his article, and for the development of a laboratory for further work in this area.

LOREN C. EISELEY ("Charles Lyell") heads the department of anthropology at the University of Pennsylvania. His eight previous contributions to Scientific American include articles on Charles Darwin and Alfred Russel Wallace, reflecting his great interest in the theory of evolution and its history. His recent book *Darwin's Century* re-

SERVING SAFETY THROUGH SCIENCE

HERE are two incidents. Can you find the thread that ties them together?

A busy man's wife and little daughter receive a long-distance telephone message from him. His plane arrived at its destination safely, in spite of a continent-wide overcast. A normal event today.

Over a hundred years ago (so the story goes) a man and his daughter were walking by a railroad track. A train passed. It blew its whistle — a high-pitched sound as it approached and a deep-pitched moan as it disappeared. The little girl asked: "Why is that?" The question intrigued her father, and Christian Doppler investigated. His research—and the effect it defined — became part of our scientific heritage.

The Doppler Effect—a scientific truth which explained the change in pitch of sound waves—applied equally to light waves. It enabled astronomers to measure the speed at which distant stars move toward or recede from us. It applied to radio waves as well and led to the development of AID (Automatic Instantaneous Direction-finding) which enabled the busy man's plane to arrive at its destination safely.

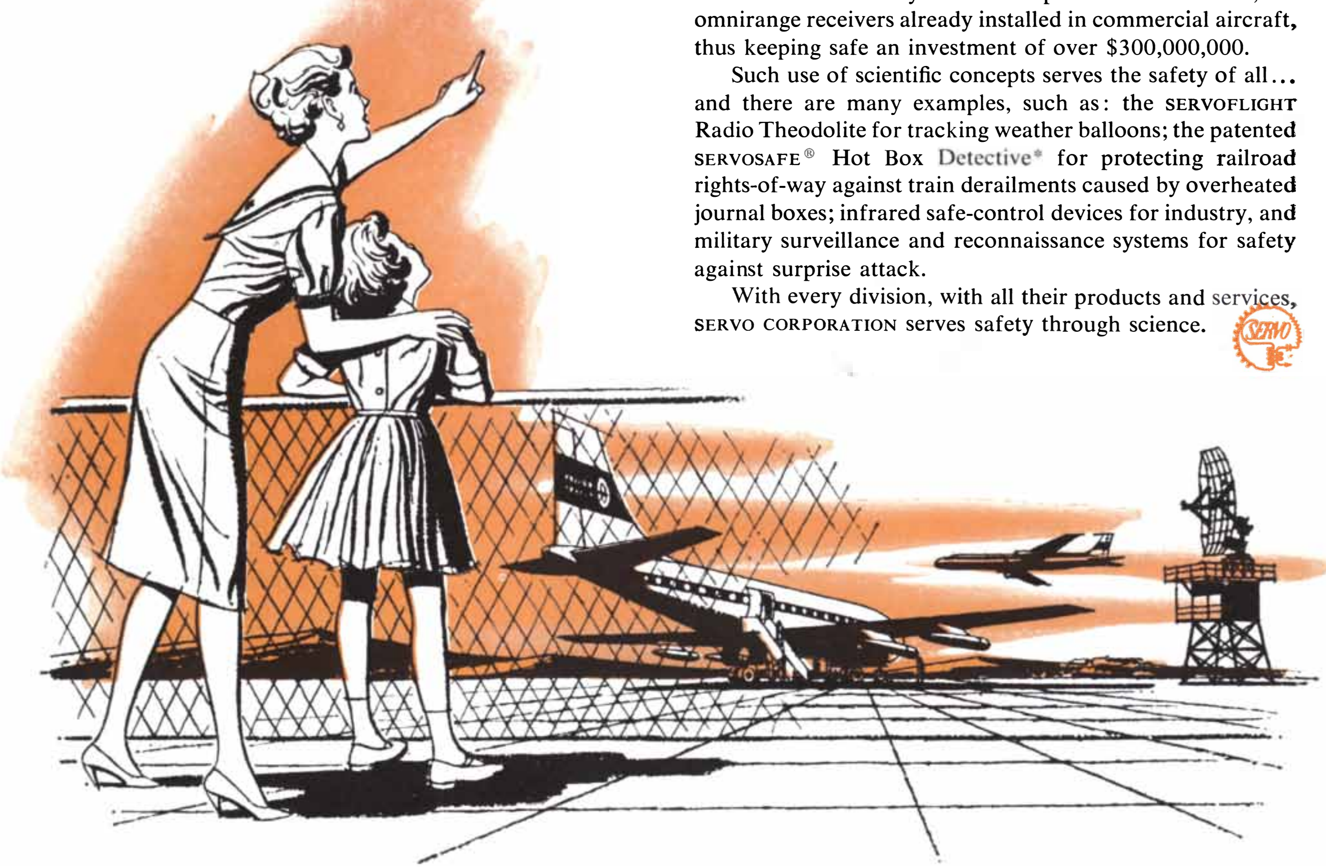
For some time now the SERVOFLIGHT® Doppler Direction Finding System has been demonstrating a reliability, bearing stability, and speed never before attainable...even at intercontinental ranges as well as near crowded airports. At this very moment a pilot may be asking: "What is my bearing?"—and before his last word is out, his exact bearing is known.

This is but *one* aircraft...*one* aspect of air safety. Taking a larger perspective, we see *thousands* of aircraft filling the airlanes and approaching airports every day of the week the world over. Every one of them, minute-by-minute, needs *accurate* navigational bearings—undistorted by signal interference—if increasing air traffic is to move with safety.

SERVO CORPORATION OF AMERICA is meeting the need for such an air navigation system by utilizing the Doppler Effect in a newly developed way. The SERVOFLIGHT VHF Doppler Omnirange System provides reliable guidance and navigation along airways throughout the world. It provides "on course" indications so reliable that even mountains, bridges, hangars, and tall buildings cannot distort the accuracy of the ground station signals. Of great significance, too, is the fact that this system is compatible with the 104,000 omnirange receivers already installed in commercial aircraft, thus keeping safe an investment of over $300,000,000.

Such use of scientific concepts serves the safety of all... and there are many examples, such as: the SERVOFLIGHT Radio Theodolite for tracking weather balloons; the patented SERVOSAFE® Hot Box Detective* for protecting railroad rights-of-way against train derailments caused by overheated journal boxes; infrared safe-control devices for industry, and military surveillance and reconnaissance systems for safety against surprise attack.

With every division, with all their products and services, SERVO CORPORATION serves safety through science.



SERVO CORPORATION OF AMERICA 20-20 Jericho Turnpike, New Hyde Park, L. I., N. Y.

*Protected by U.S. Patent No. 2,880,309. Other U.S. & Foreign Patents Applied For.

ceived the Athenaeum of Philadelphia Literary Award for nonfiction in 1958. Eiseley was born in Nebraska in 1907, and took degrees at the universities of Nebraska and Pennsylvania.

SIDNEY LERMAN ("Glaucoma") directs the eye-research program and teaches ocular pathology to medical students at the Strong Memorial Hospital in Rochester, N. Y., and at the University of Rochester medical school. "Since I believe that continuing contact with clinical ophthalmology is vital to the researcher, I have continued with a small private practice." A native of Montreal and now 31 years old, Lerman was graduated from McGill University in 1948. He took his M.D.C.M. (Doctor of Medicine, Master of Surgery) degree there in 1952, and then went to the Montreal General Hospital for his internship and ophthalmology residency. From 1955 to 1957 he held a fellowship in ophthalmology at the Johns Hopkins Hospital in Baltimore, where the late Jonas S. Friedenwald "was responsible for stimulating and developing my interests in ophthalmic research." Lerman also did research at the Institute of Ophthalmology of the University of London. He went to Rochester in August, 1957.

EARL FRIEDEN ("The Enzyme-Substrate Complex") is a member of the chemistry faculty at Florida State University. He was born in 1921 in Norfolk, Va., but was reared and educated in Los Angeles. He took his bachelor's degree in chemistry at the University of California at Los Angeles in 1943, and spent four years in industrial research. He returned to U.C.L.A. to take his Ph.D. in chemistry in 1949, and then joined the Florida State faculty. In 1955 Frieden studied on a fellowship at the Institute for Enzyme Research at the University of Wisconsin, and from June, 1957, to September, 1958, he was at the Carlsberg Laboratories in Copenhagen, among the last group of biochemists to work with K. U. Linderstrøm-Lang, who died in May. "My interest in biochemistry," Frieden says, "arose out of a common interest in life and chemistry. Enzymes are principally the domain of the biochemist and the relationship between enzyme structure and catalytic activity encompasses the secret of life. The enzyme-substrate complex interests me because it may hold the key to the nature of enzyme catalysis." In addition to his research, which has resulted in more than 30 papers, Frieden teaches graduate students.

Bendix G-15

PUNCHED CARD AND TABULATOR COUPLER

...a new accessory for the Bendix G-15 Digital Computer for low cost, high performance punched card computing

Now, at a cost significantly below that of any similar equipment, Bendix provides a complete computing system with 100 card per minute punched card input and output, and 100 line per minute tabulation.

Heart of the system is the Bendix G-15 general purpose digital computer, which has proven its performance in well over 150 successful installations.

The CA-2 coupler, a newly developed G-15 accessory, enables the computer to operate in conjunction with conventional punched card and tabulating equipment.

A full 80 columns of numeric, alphabetic, or special character information can be accommodated using only the CA-2 as a connecting link between the card equipment and the G-15. Any column of the card can contain any one of the three types of information.

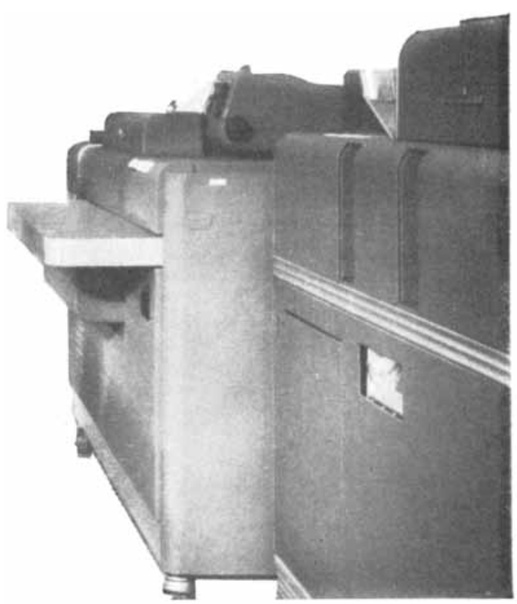
Three input-output units may be connected simultaneously . . . one for input, one for output, and a third for input or output. Data may be read or punched by standard card units, or printed by standard tabulators. All input and output is under complete control of the computer. Computation can proceed during the input or output cycle, thus assuring maximum over-all computing speed.

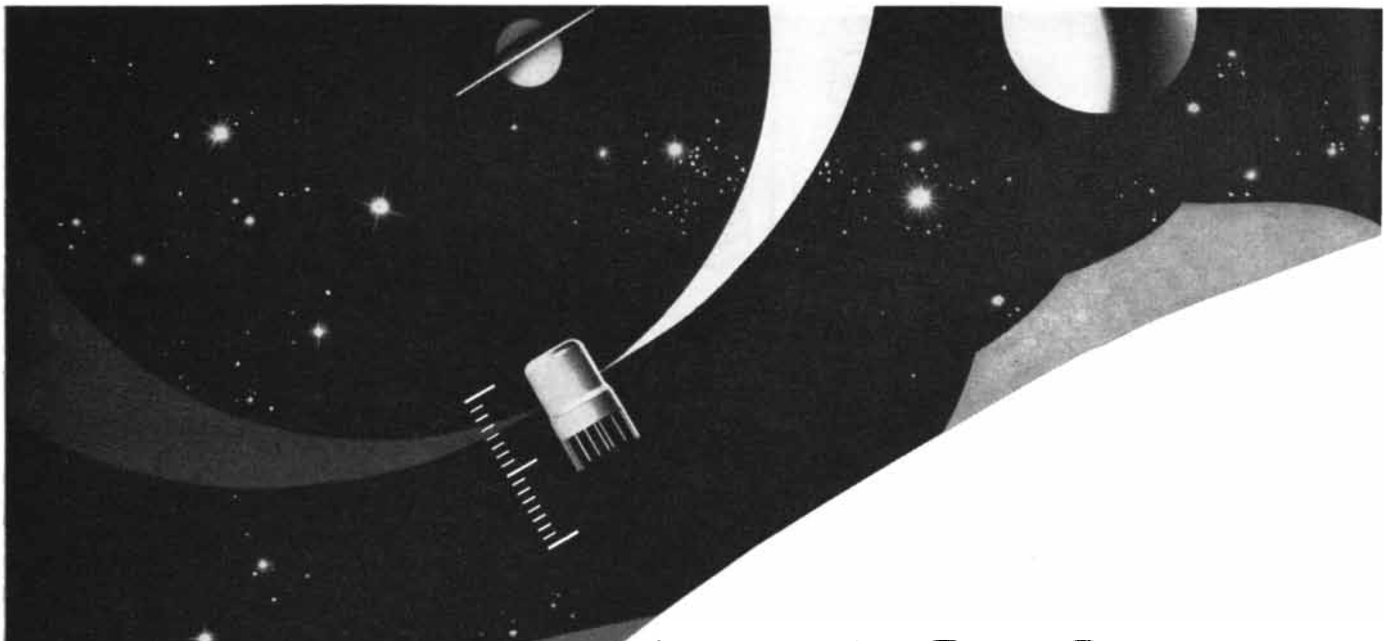
In addition to the CA-2, the computer's typewriter and paper tape equipment, and auxiliary magnetic tape storage units may be used for completely versatile input, output, and storage. Both power and space requirements of the complete punched card computer system are approximately half that of other systems of this type.

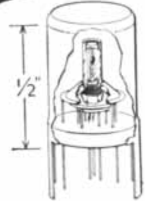
A system that includes the G-15 computer, the CA-2 coupler, two summary punches and a tabulator, leases for approximately half the price of a typical medium-priced system with similar capabilities.

Whether you are now using punched card or computing equipment, or if you are delaying such plans due to high costs, you will want to learn more about this inexpensive, efficient equipment. Detailed technical information on the G-15 and the CA-2 will be sent on request. Write to the Bendix Computer Division of Bendix Aviation Corporation, Los Angeles 45, California. Department C-11.

Bendix® Computer







NUVISTOR small-signal TRIODE

Ready now... on a limited sampling basis... for experimental equipment designs. First developmental Nuvistor type to be sampled.

High-frequency amplifier performance...

The Nuvistor triode has shown its mettle as a radio-frequency amplifier in experimental TV-tuner tests. Compared to miniature types 6BQ7-A and 6BN4-A in cascode and neutralized-triode VHF amplifiers, Nuvistor has provided improved gain and at least 1 db less noise measured at television channel 13. In addition, Nuvistor has indicated greatly reduced B+ power drain—about ⅓ the voltage and ½ the current used for the miniature types. Experimental cascode-type tuners using Nuvistors have demonstrated substantially higher performance than commercial tuners, even those using the latest commercial types of receiving tubes... and they required less heater power and only about one watt of B+ power input, as compared to about 7 watts for commercial cascode-type tuners.

Oscillator performance...

The Nuvistor is a remarkably stable and efficient tube for local oscillator service. Oscillations are obtainable at more than 1000 megacycles with the Nuvistor triode in conventional molded-type sockets. Oscillator efficiency is essentially independent of frequency up to about 450 megacycles, and typical circuits start oscillating with 7 volts or less at the plate of the tube. The low power input needed for the oscillator, as well as amplifier and mixer circuits, helps reduce temperature rise and consequent frequency drift of tuned circuits. The tube itself is particularly stable. Note the accompanying graph which shows the warm-up drift of a 200-megacycle oscillator compared to type 6EA8, a notably good VHF tuner tube by present standards. Each type produces the same output voltage in a conventional circuit from which other causes of drift were removed—yet the Nuvistor triode has less than ¼ the warm-up frequency drift of 6EA8.

TYPICAL DATA

ELECTRICAL:

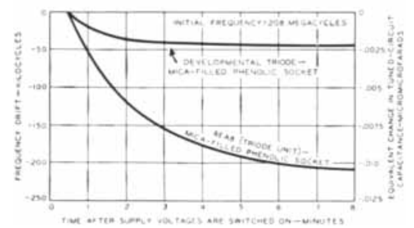
Heater, for Unipotential Cathode:		
Voltage (AC or DC)		6.3 volts
Current		0.14 amp

CHARACTERISTICS, CLASS A_1 AMPLIFIER:

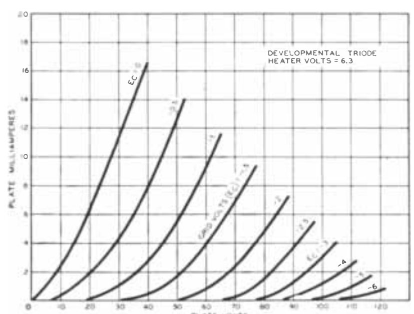
Plate Voltage	40	75 volts
Grid Resistor	1	-- megohm
Grid Voltage	--	−1.35 volts
Amplification Factor	31	31
Plate Resistance (approx.)	--	2600 ohms
Transconductance	12000	12500 μmhos
Plate Current	8.5	12.5 ma
Grid Voltage (approx.) for plate current of 10 μa	--	−6.5 volts

MAXIMUM RATINGS, DESIGN-MAXIMUM VALUES:

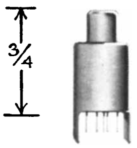
PLATE VOLTAGE	110 max. volts
GRID VOLTAGE	−55 max. volts
PEAK POSITIVE GRID VOLTAGE	2 max. volts
PLATE DISSIPATION	1.2 max. watts
PEAK HEATER-CATHODE VOLTAGE:	
Heater negative with respect to cathode	100 max. volts
Heater positive with respect to cathode	100 max. volts



▲OSCILLATOR FREQUENCY STABILITY CURVE

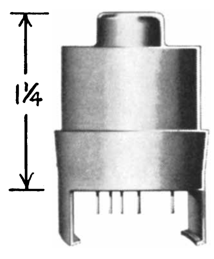


▲TYPICAL PLATE CHARACTERISTICS



NUVISTOR small-signal TETRODE

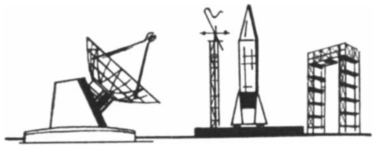
Developmental tube ready soon for limited sampling . . . an amplifier tube for experimental equipment designs in entertainment, industrial, and military applications.



NUVISTOR BEAM POWER TUBE

Now being developed . . . plate dissipation objective in the order of 30 watts; intended for beam-power applications in the entertainment, industrial and military fields.

RADIO CORPORATION OF AMERICA
Electron Tube Division **Harrison, N. J.**



what **NUVISTOR** *will mean to defense electronics.*

Nuvistor promises an extremely high level of performance and reliability never before anticipated from electron tubes produced in large quantities. Nuvistor tubes offer miniaturization capabilities that can significantly increase payload capacities of military vehicles. The electrical characteristics of Nuvistor tubes make them suitable for many different services . . . hold out the prospect of designing a large number of circuits "around" just a few tube types. These Nuvistor features can reduce requirements for replacement equipment and service personnel, can increase mobility of the equipped "arm".

what **NUVISTOR** *will mean to industrial electronics and entertainment products.*

The high-performance capability of Nuvistor and its inherent ability to function under difficult environmental conditions seem certain to stimulate new equipment designs for industry. Automation, electronic computers and business machines, closed-circuit television—in fact, the entire range of industrial electronics applications will be given a new platform from which to climb higher. In electronic equipment for home entertainment, more compact, more reliable, more attractive products are in store. New levels of performance can be expected in lightweight AM and FM radios, phonographs, hi-fi, and TV sets.

what **NUVISTOR** *will mean to you... the designer of electronic equipment.*

Remember way back when all tubes were big, fragile, and relatively inefficient? Miniaturization and rugged tubes were nonexistent. Design possibilities were limited. But, new developments in tube designs brought smaller envelopes, sturdier structures, the octal socket, the 7-pin and 9-pin miniatures . . . new techniques and new processes . . . electrical uniformity, reliability and efficiency! So, Nuvistor takes its place in the progressive advancement of the electronics industry with new criteria for electron-tube efficiency and reliability. And, you, the design engineer, will participate importantly as NUVISTOR electron tubes open a new world of unlimited possibilities in equipment design.

For more details on Nuvistors and for information on how you may obtain developmental samples of NUVISTOR small-signal TRIODE, call your RCA Field Representative at the Field Office nearest you.

ENTERTAINMENT SALES

- Newark 2, N. J., 744 Broad Street, HUmboldt 5-3900
- Detroit 2, Mich., 714 New Center Bldg., TRinity 5-5600
- Chicago 54, Ill., Suite 1154, Merchandise Mart Plaza WHitehall 4-2900
- Los Angeles 22, Calif., 6355 E. Washington Blvd. RAymond 3-8361

INDUSTRIAL SALES

- Newark 2, N. J., 744 Broad Street, HUmboldt 5-3900
- Detroit 2, Mich., 714 New Center Bldg., TRinity 5-5600
- Chicago 54, Ill., Suite 1154, Merchandise Mart Plaza WHitehall 4-2900
- Los Angeles 22, Calif., 6355 E. Washington Blvd. RAymond 3-8361

GOVERNMENT SALES

- Newark 2, N. J., 744 Broad Street, HUmboldt 5-3900
- Dayton 2, Ohio, 224 N. Wilkinson St., BAldwin 6-2366
- Washington 6, D.C., 1625 "K" St., N.W., DIstrict 7-1260

Albert Einstein...on the chief interest of science

"It is not enough that you should understand about applied science in order that your work may increase man's blessings. Concern for man himself and his fate must always form the chief interest of all technical endeavors, concern for the great unsolved problems of the organization of labor and the distribution of goods — in order that the creations of our mind shall be a blessing and not a curse to Mankind. Never forget this in the midst of your diagrams and equations."

—Address, California Institute of Technology, 1931

THE RAND CORPORATION, SANTA MONICA, CALIFORNIA

A nonprofit organization engaged in research on problems related to national security and the public interest

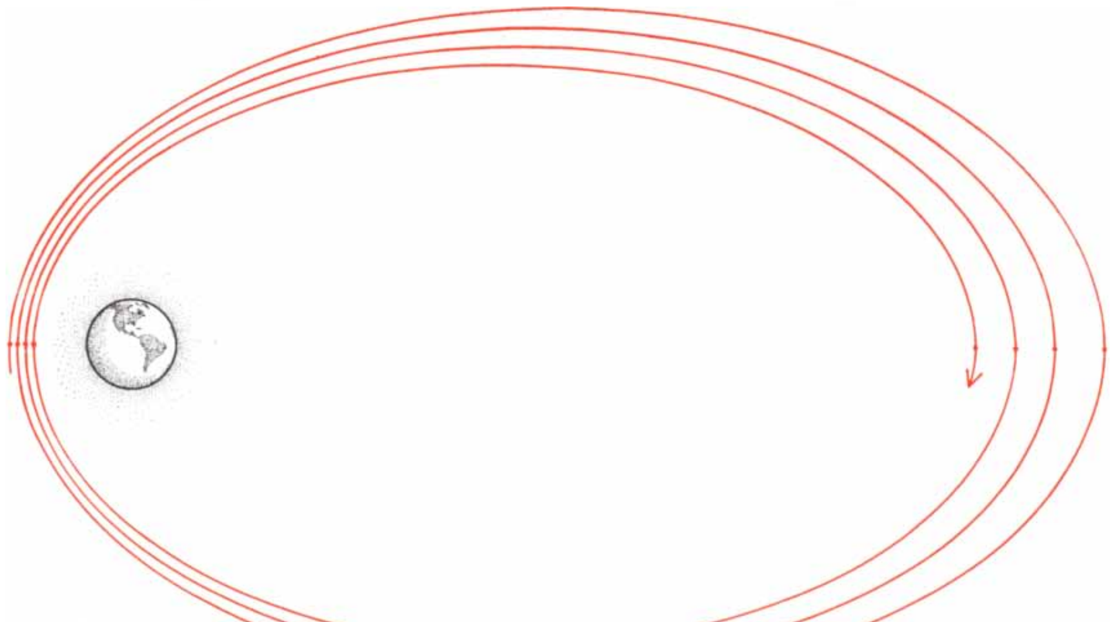
Established 1845 SCIENTIFIC AMERICAN August, 1959 Volume 201 Number 2

Artificial Satellites and the Earth's Atmosphere

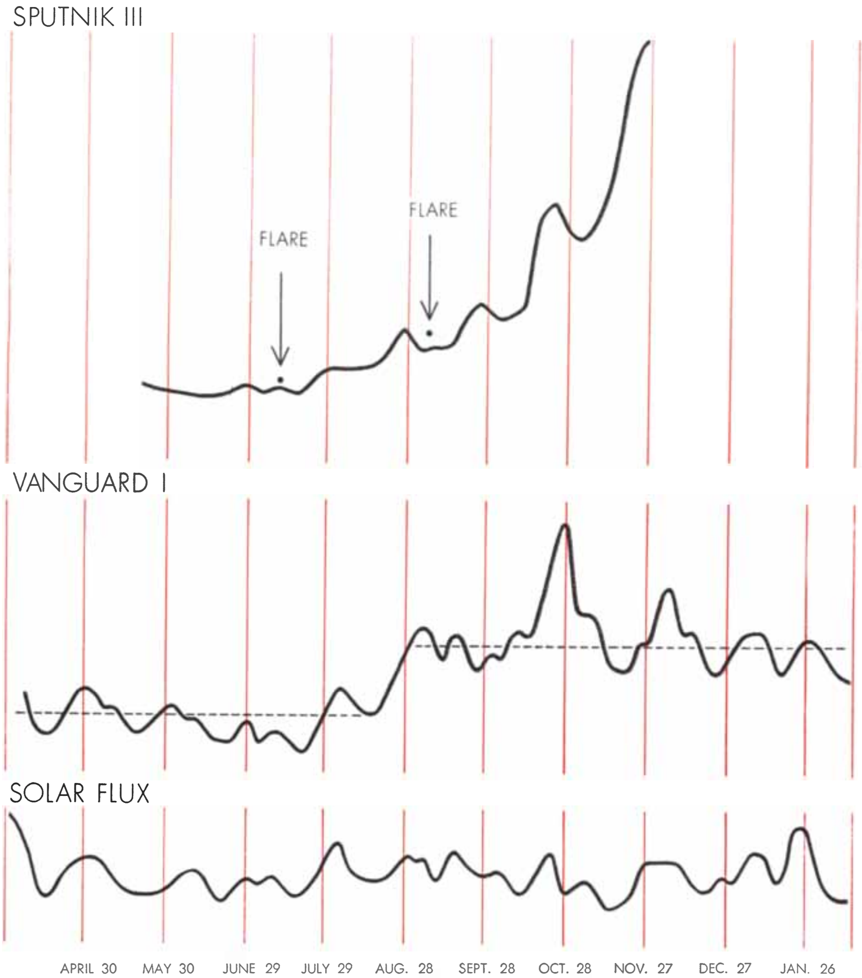
In the auroral zones the upper atmosphere is much warmer than it is over the Equator. Satellite data attribute this effect to solar particles trapped in the earth's great radiation belts

by Robert Jastrow

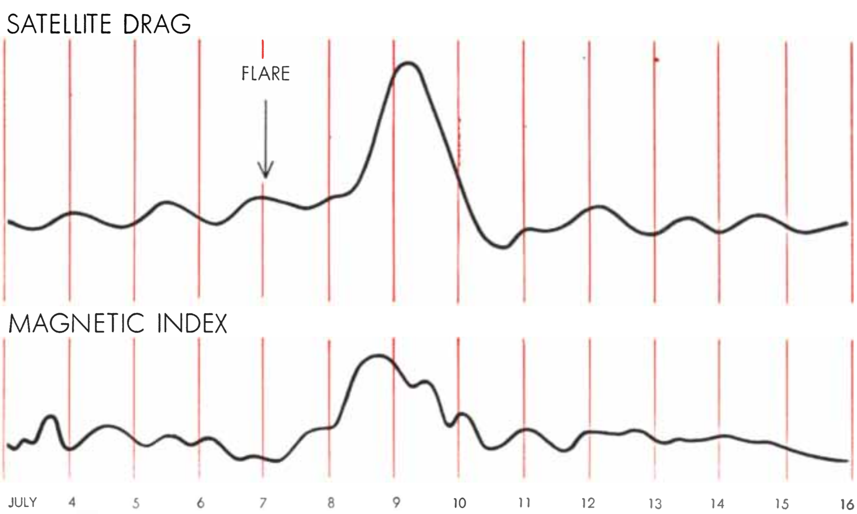
At the end of the International Geophysical Year, satellite and rocket measurements of the density of the upper atmosphere hardly seemed to be one of the great achievements of that world-wide scientific enterprise. There was certainly no lack of data on the subject. Since the density is derived from simple measurement of the time it takes a satellite to complete an orbit, the satellite data undoubtedly had as much to say about this as about any other single topic. But the measurements of atmospheric density paled in interest when compared with the discovery of the giant belts of charged particles trapped in the earth's outer magnetic field, or the finding that our planet is not simply a flattened sphere but is shaped slightly like a pear with its top at the North Pole. A few months ago, however, careful sifting of



ORBIT OF A SATELLITE shrinks steadily because of atmospheric drag. Friction with the relatively dense air at perigee sharply decreases the satellite's altitude at apogee, but the rarefied atmosphere at apogee produces only a small altitude loss at perigee.



SOLAR EFFECT ON SATELLITE DRAG was revealed by the fact that variations in drag (*top two curves*) were in phase with variations in the intensity of 10.7-centimeter solar radiation (*bottom curve*). The 27-day period of these variations is caused by the rotation of the sun. Apparently solar flares (*arrows*) produced short increases in the drag of *Sputnik III*, but affected *Vanguard I* more slowly, doubling its mean drag (*broken lines*) in four weeks.



INCREASE IN DRAG ON SPUTNIK III proved that particles, not radiation, from solar flare affected the satellite. Radiation from a solar flare reaches the earth almost immediately, but the particles emitted by the flare do not reach the earth until a day or two later. Sputnik showed its sudden increase in drag about a day after the flare, at the same time that a jump in the earth's magnetic index (*bottom curve*) indicated the arrival of solar particles.

the information on atmospheric density began to yield a series of unexpected discoveries.

Certain puzzling variations in the satellite orbits furnished the lead. These variations were found to match well-established fluctuations in the outpouring of radiation and high-energy particles from the sun. All at once the seemingly routine data disclosed a new and unexpected coupling between events on the face of the sun and the behavior of the earth's outer atmosphere. Additional probing of this data proved that satellite orbit variations depended on the arrival of particles from the sun.

This discovery in turn explained another finding. Evidence from rocket flights had shown that at high altitudes the atmosphere over the auroral zones was actually warmer than the upper atmosphere at Temperate and Equatorial latitudes. Apparently the outer of the earth's two belts of charged particles reaches down into the upper atmosphere over the Arctic and Antarctic and radically modifies the properties of the atmosphere over these regions. Finally, correlation of the features of the outer radiation belt with those of auroral displays has thrown a new light on the long-sought origin of the aurora.

The spadework in what first seemed to be an unpromising garden was performed by Luigi Jacchia of the Smithsonian Astrophysical Observatory. Jacchia studied the orbit data on *Sputnik III* and *Vanguard I,* seeking more accurate information about the temperature and density of the atmosphere above 200 kilometers. Prior to the Vanguard flight, rockets had established these properties with relative precision up to altitudes of only 100 kilometers and with less precision between 100 and 200 kilometers. Above 200 kilometers our knowledge rested upon uncertain extrapolations. At 500 kilometers, for example, the density of the atmosphere could have been anything between a million and 100 million particles per cubic centimeter.

Measurement of the properties of the upper atmosphere was one of the first assignments projected for the artificial satellites. The rate of change of the orbital period of a satellite, that is, the rate of change in the time it takes to fly its orbit, is directly proportional to the density of the atmosphere through which it passes. At perigee, the lowest point on its orbit, the satellite dips into the denser air close to the earth and there loses energy by friction with the atmosphere. This energy loss reduces the altitude to which the satellite can swing on its next pass through apogee, the highest point on its orbit. Any drag encountered in the much rarer atmosphere at apogee is reflected in turn on the next return to perigee.

As apogee and perigee decrease, the satellite takes less and less time to travel its shrinking orbit. Since the atmospheric density at apogee is so low as to be discounted, the shrinking orbit of a satellite provides measurements primarily of the density at perigee.

Vanguard I, the smallest of the earth satellites, has yielded by far the most accurate orbital data. Thanks to the solar batteries included in its 10-pound payload, it is still reporting to "minitrack" stations on the ground and may continue to do so for a long time to come. The minitrack records determine its orbital period within a few ten thousandths of a minute, or a few parts per million. Because its perigee is at 650 kilometers, *Vanguard I* has lifted the ceiling on accurate density measurements to this altitude and reduced the uncertainty in the measurements there from a factor of 100 to a factor of two. Drag data from other satellites have filled in the curve at intermediate altitudes.

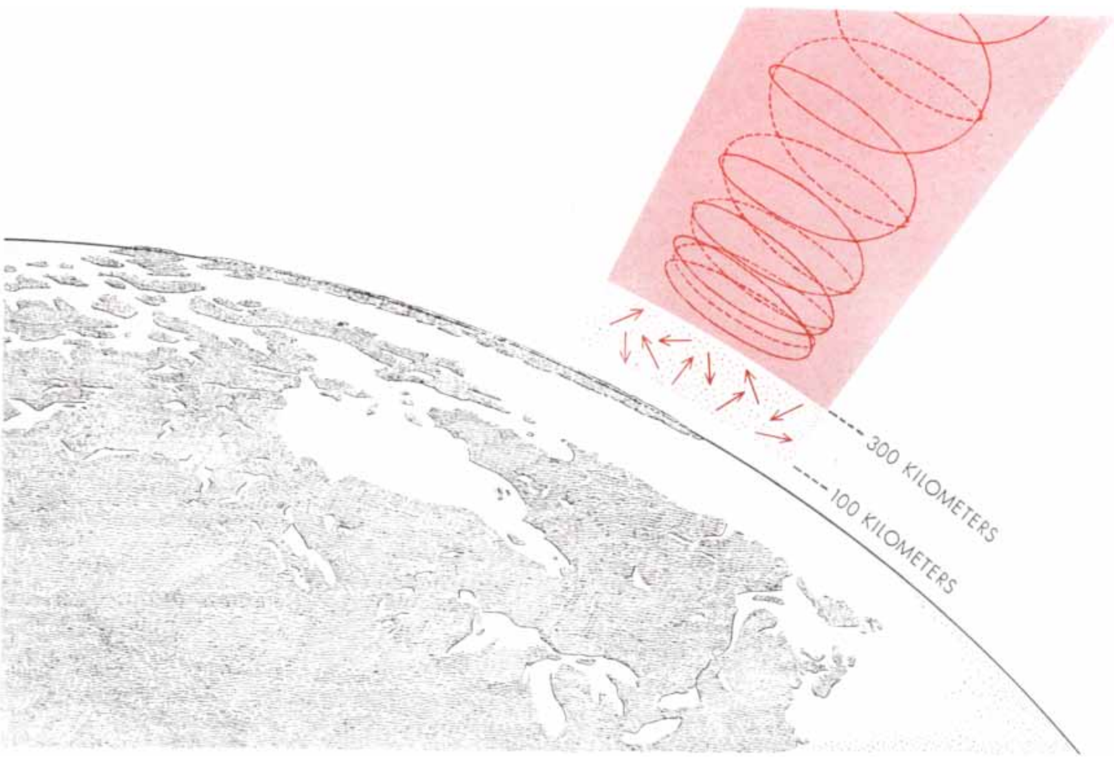
The analysis of satellite-orbit information by various groups in this country and abroad proceeded more or less routinely until Jacchia noticed an irregular variation in the rate at which the orbit of *Sputnik II* was shrinking. It seemed to recur approximately every 30 days. Several months later, when the more accurate tracking data on *Vanguard I* became available, he found the same persistent irregular variations in drag, this time with a recognizable period of 27 days. The number 27 struck Jacchia as quite interesting, since the period of rotation of the sun is also 27 days.

The coincidence became compelling when Jacchia checked the records for the *Sputnik III* rocket that was aloft at the same time as Vanguard. The ragged drag curves of both the U. S. and Soviet satellites showed almost identical irregularities [*see top illustration on opposite page*]. Jacchia then postulated that there must be some correlation between satellite motion and solar activity, and he published this idea and a curve of the drag variations in a Smithsonian report.

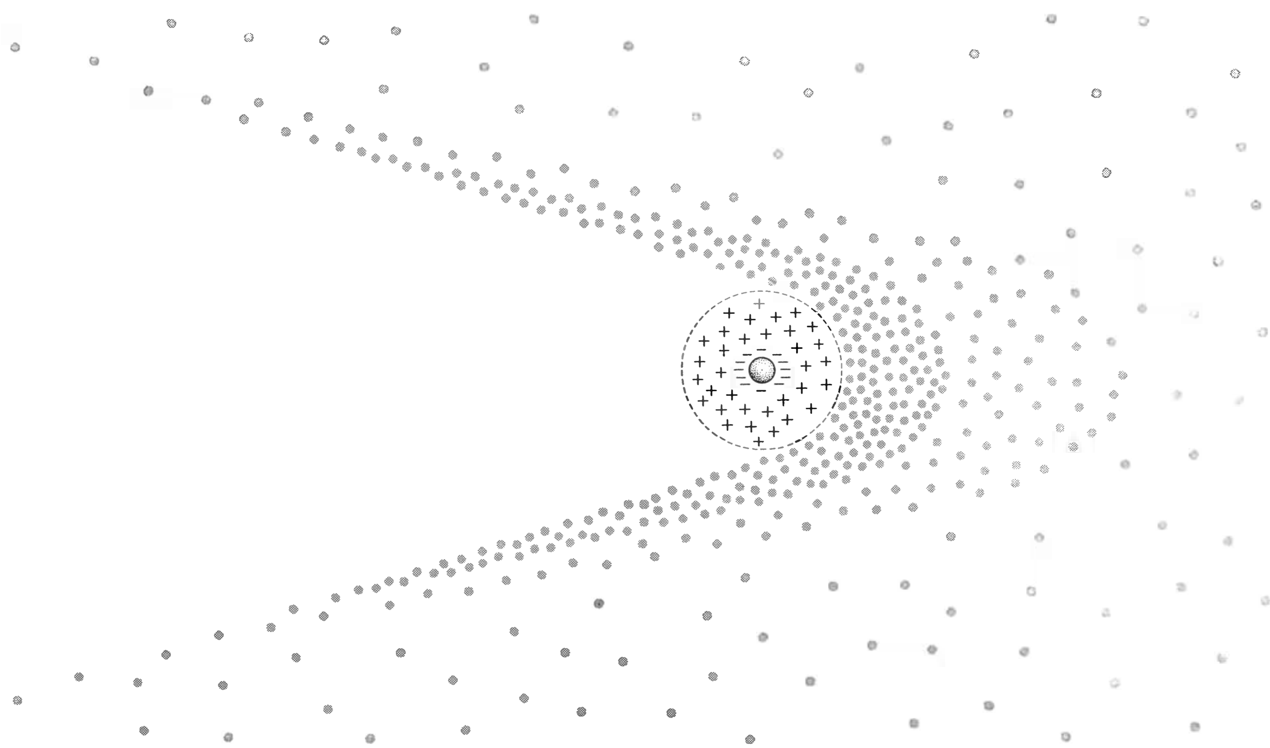
Jacchia's report caught the attention of the German radio astronomer W. Priester. He saw an immediate resemblance between the variation in the drag on the satellites and the variations in the 20-centimeter radio waves emitted by the sun. This radiation is an excellent measure of the intensity of sunspot activity and other disturbances localized on the vigorously boiling surface of the sun. The more active sites on this boiling surface spurt great gusts of charged particles and radiant energy into the solar system. As the sun rotates on its axis these areas of intense activity appear and disappear every 27 days so long as the activity persists.

Priester checked his measurements of the intensity of 20-centimeter solar radiation for the period covered by Jacchia's report and found that their ups and downs agreed rather well with the satellite curves. In a brief note Priester described his findings to G. F. Schilling of the Smithsonian Astrophysical Observatory.

Jacchia was delighted when Schilling told him of Priester's work, because the



TRAPPED SOLAR PARTICLES are funneled into the Arctic and Antarctic auroral zones, where the "horns" of the outer radiation-belt (*shaded area*) extend to within 300 kilometers of the earth. The particles follow corkscrew orbits from north to south in the earth's magnetic field; when they eventually leak out of the belt, they follow random paths (*indicated by arrows*). By the time they reach an altitude of 100 kilometers, most of the particles have lost all their excess energy in repeated collisions with the atoms and molecules of the upper atmosphere. These collisions heat and expand the atmosphere, and are also believed to be the cause of the aurora borealis and the aurora australis. In the center of the shaded area, where the density of energetic particles is highest, the temperature is about 2,500 degrees Kelvin; outside this area, the particle density falls off and the temperature drops to 1,000 degrees.



ELECTRICAL DRAG is produced by the motion of a charged satellite (*small sphere*) through clouds of charged particles like those in the earth's two radiation belts. As it enters one of the belts the satellite collides with high-energy electrons that give its metal skin a negative charge. The charge repels other electrons, creating a shell of net positive charge around the satellite. The diameter of this shell (*broken circle*) becomes the effective diameter of the satellite. This increased diameter causes increased atmospheric resistance to the motion of the satellite, mainly because the satellite has a greater number of collisions with thermal protons (*dots*).

radio data provided an accurate index of solar activity with which to correlate his drag data. He lost no time in comparing his curves with records of 10.7-centimeter solar radiation available at the Harvard College Observatory. The top illustration on page 38 shows what happened: The close fit of the curves established unmistakably that the activity of the sun somehow alters the drag on a satellite orbiting in the earth's atmosphere.

However, the fluctuations in the 10-centimeter radiation do not of themselves reveal just how the effect is transmitted. It has not yet been determined whether the 27-day variation is caused by solar particles (electrons and protons) or solar radiation. Further study of the variation in satellite drag may show that both phenomena play a part.

Upon close inspection of his drag curve for the *Sputnik III* rocket, Jacchia made another interesting discovery. He found two strong and abrupt fluctuations in the pattern. Comparison with solar records disclosed that these fluctuations, occurring in July and September, coincided roughly with two major solar eruptions of the kind known as flares.

Now the electromagnetic radiation given off by a solar flare reaches the earth in about eight minutes, because it travels at the speed of light, but the particles, traveling at lower speeds, do not show up until 24 hours later. Jacchia proceeded to refine his initial calculations and found that the drag on the *Sputnik III* rocket showed no change at the time of the flare, but increased sharply one day after the solar flare of July 7, at approximately the same time that the onset of a storm in the earth's magnetic field signaled the arrival of the gust of particles from the flare [*see bottom illustration on page 38*]. Thus in the case of these transitory fluctuations in the orbit of the rocket, Jacchia was able to conclude that the drag was produced by the particles rather than by the radiation from the flare.

Jacchia's deduction tied in nicely with the peculiar character of the rocket's orbit. Like its fellow Soviet satellites, *Sputnik III* was launched on an orbit inclined at the steep angle of 65 degrees to the Equator. This orbit swung it through the high Arctic and Antarctic latitudes, where it penetrated the "horns" of the outer radiation belt [*see illustration on preceding page*].

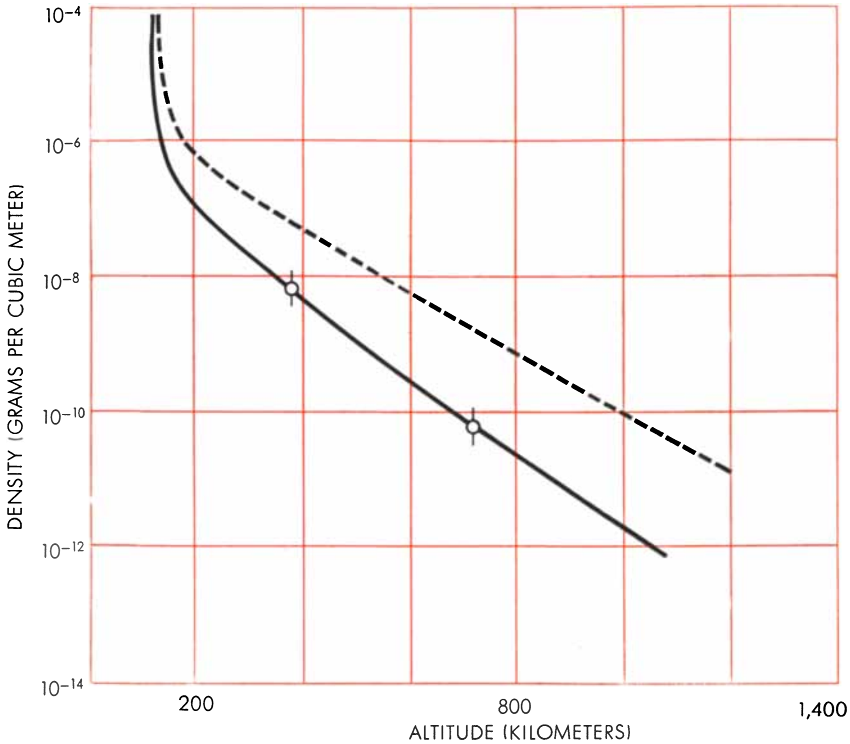
Observations made by *Pioneer III* and *Pioneer IV*, the lunar probes launched from the U. S. in December, 1958, and in March of this year, had established that the outer belt is fed directly by streams of particles from the sun; *Pioneer I*, which pierced the belt immediately after five days of intense solar activity, reported particle densities in the outer belt many times greater than those measured by *Pioneer III*.

Thus the solar flares that occurred during the *Sputnik III* observations must have built up the particle density of the outer belt; the resulting increase in the frequency of collisions between the particles and the atoms and molecules of the air must in turn have heated and expanded the atmosphere. Presumably the Sputnik rocket encountered the increased atmospheric density caused by the expansion. The orbit of *Vanguard I* showed no such fluctuation as that of *Sputnik III* in response to the solar flares. This might be explained by the fact that the Vanguard orbit is inclined at the shallow angle of 33 degrees to the Equator. At apogee the satellite penetrates not the outer, but the smaller, inner zone of charged particles. As Project Argus showed in 1958, using atomic explosions to inject charged particles into the upper atmosphere, the transfer of particles from the outer to the inner belt is very slow. The particles from the solar flares would not be expected, therefore, to have had an immediate effect on the Vanguard orbit.

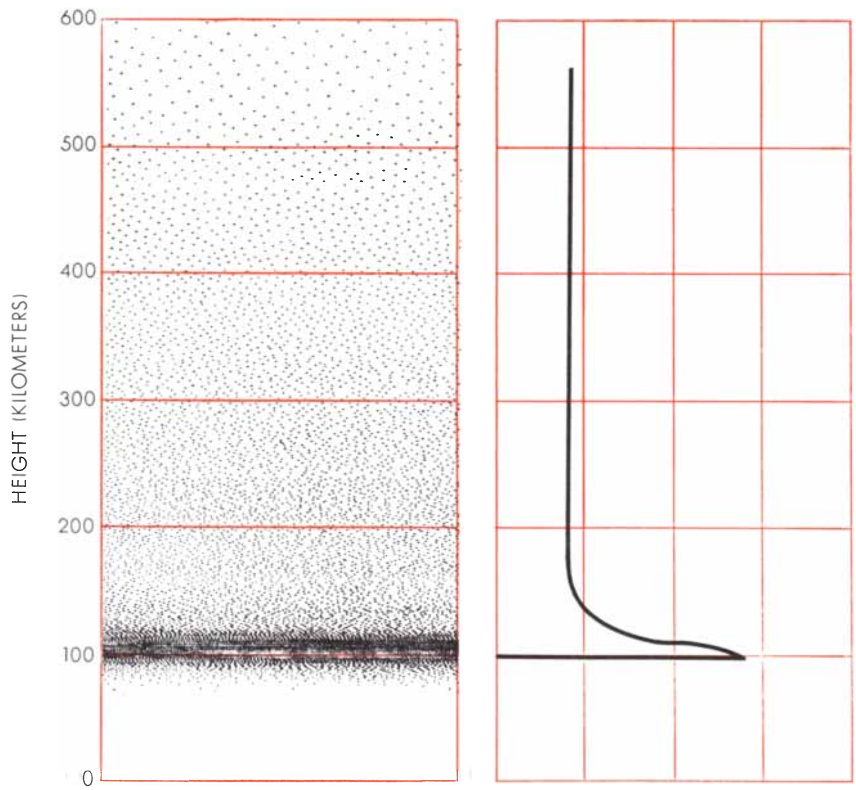
We cannot assume, however, that a density increase is the only mechanism for changing satellite drag. Drag increases may also be caused by a quite different phenomenon which C. A. Pearse and I studied at the Naval Research Laboratory a year before the first Sputnik was launched. We showed that the drag on a satellite might be increased by the acquisition of electric charges as the result of collisions with electrons in the outer atmosphere. The charged skin of the satellite would repel other electrons, creating a shell of net positive charge around it. In collisions with positively charged particles, the diameter of the positively charged shell would become the effective diameter of the satellite. This increase in diameter would correspondingly increase the satellite's drag.

When we first studied electrical drag, we postulated modest effects—drag increases of about 10 to 50 per cent—based upon potentials of about 10 volts. An extension of our calculations showed, however, that the energy flux of the electrons in the inner belt of particles is high enough to raise the potential on a satellite to some thousands of volts during each pass through the belt. A potential of roughly 1,000 volts would increase the effective radius of the Vanguard satellite by a factor of 10, increasing its cross-sectional area by a factor of 100. The resulting increase in drag at apogee, when *Vanguard I* traverses the inner zone of particles, would be sufficient to double the mean drag on the satellite. Electrical drag may also be responsible for the drag increases produced by the flares in the orbit of the *Sputnik III* rocket. Further experiments on the particles in the outer belt will yield the data necessary to make a good calculation of satellite voltages, and to separate the effects due to density changes from those caused by electrical drag.

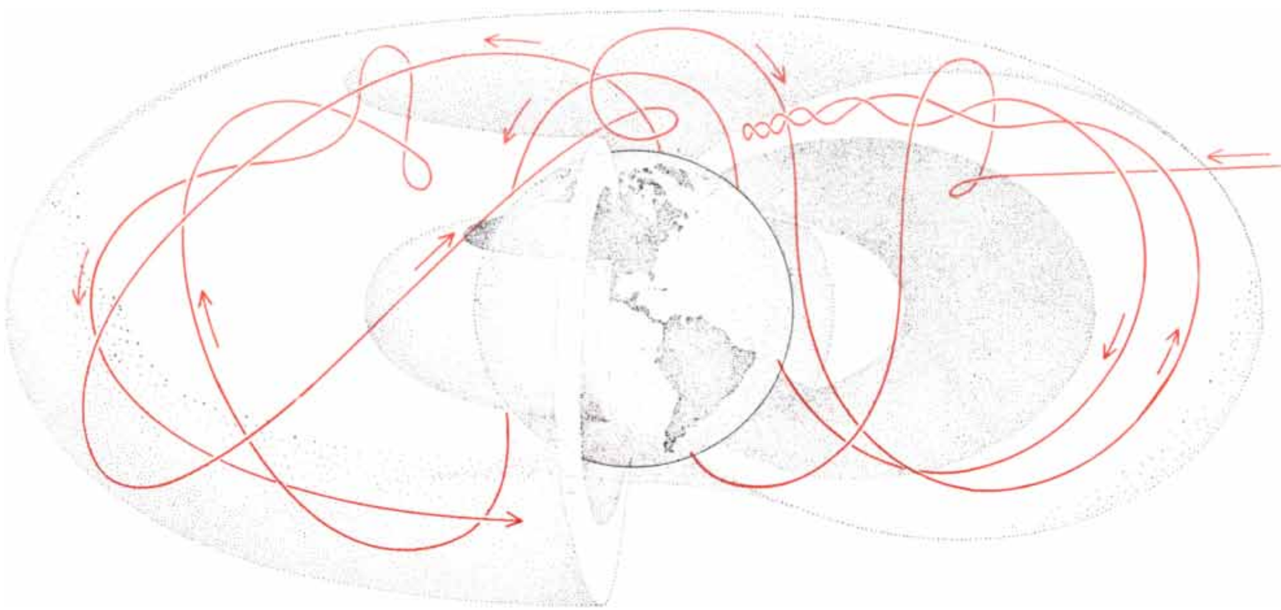
The irregularities of the orbits of *Sputnik III* and *Vanguard I* have thus yielded some surprising insights into the forces and conditions prevailing at the high altitudes of their apogees. But orbital studies were primarily motivated by interest in the density of the atmosphere at the lower altitudes explored by the satellites' perigees. The first data from satellite and rocket studies of the atmosphere during the I.G.Y. had developed a curious paradox and a conflict of evidence. Rockets fired to altitudes of from 150 to 200 kilometers over the White Sands missile range in New



TWO MODELS OF THE UPPER ATMOSPHERE are represented by these two curves. The broken curve shows the density of the atmosphere in the auroral zones, where the heating effect of energetic electrons expands the air, increasing the density of the atmosphere. The solid curve shows the atmosphere over the rest of the earth. Auroral curve is an extrapolation of rocket data; other curve is based on both satellite data (*circles*) and rocket data.



HEIGHT OF AURORAS can be explained in terms of the heat generated by collisions between energetic Van Allen electrons and the molecules of the atmosphere. The graph at left shows the height of more than 12,000 auroras, as plotted by the Norwegian astrophysicist Carl Størmer. At right is a calculation of heat generated by energetic electrons in the air. Both graphs reach a sharp maximum at 100 kilometers and drop to zero below 90 kilometers.



ELECTRON IS NEARLY TRAPPED by the earth's magnetic field and forced to follow a precarious orbit very similar to those of the completely trapped electrons in the Van Allen belts (*shaded areas*). Many electrons from the sun are pulled into such orbits when the earth's geomagnetic axis is perpendicular to a line drawn to the sun, a situation that occurs at the spring and fall equinoxes. Because they spend a relatively long time in the earth's field, these nearly trapped electrons are quite likely to be captured eventually.

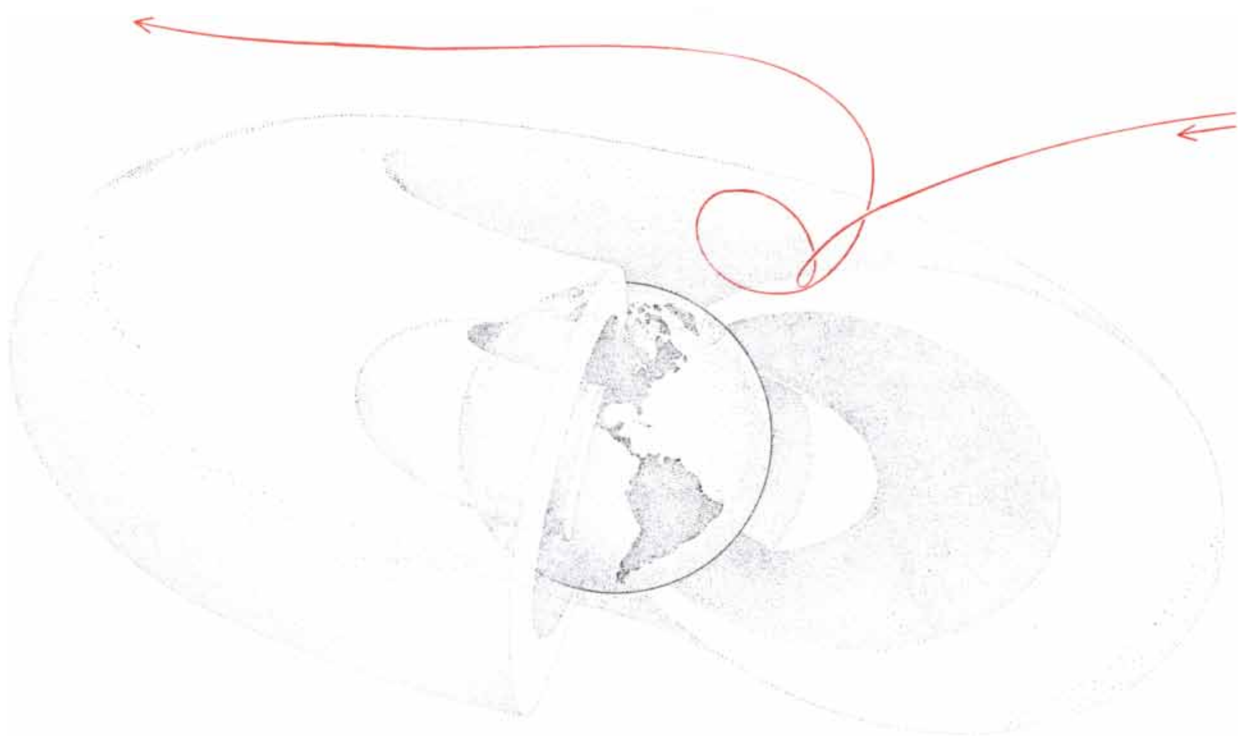
Mexico and over the Fort Churchill range in the Canadian auroral zone showed that on a summer day the upper air over the Arctic is both denser and hotter than the air over the southwestern desert: 2,000 degrees Kelvin (degrees centigrade above absolute zero) as compared to 1,100 degrees K. over White Sands. At first it was thought that heating of the atmosphere during the long Arctic summer day might account for this paradox. But over the course of a year the *Vanguard I* data showed no significant density changes that could be correlated with a rising temperature gradient from south to north. Since the perigee of the Vanguard satellite shifts from 33 degrees north latitude to 33 degrees south every 41 days, its orbit should have revealed a variation between these limits if there was any relationship between latitude and temperature. The conflict between this satellite result and the sharp latitude sensitivity of the rocket data provided one of the outstanding puzzles in the interpretation of data from the I.G.Y.

The discovery of the charged-particle belts provided a solution to the puzzle. In the March issue of SCIENTIFIC AMERICAN James A. Van Allen of the University of Iowa has told how the rockets, satellites and space probes have mapped the distribution of particles trapped in the magnetic field of the earth. In order to reconcile the rocket and satellite data we had only to assume that in the auroral zone the atmosphere is heated by the outer of the two belts, whereas outside of the auroral zone upper atmosphere conditions are relatively independent of latitude. Since the orbit of *Vanguard I* does not penetrate the outer belt, it was clear that this satellite could not have produced a measurement of the density and temperature there. The reconstruction of our picture of the earth's atmosphere that follows naturally from these observations also provides an insight into the processes that generate the marvelous displays of the aurora at the top and bottom of the earth.

For the theory that underlies the heating of the upper atmosphere over the Arctic region we are indebted to the work of Carl Størmer. Nearly half a century ago this Norwegian astrophysicist computed the trajectories on which charged particles would spiral back and forth on the lines of force between the north and south magnetic poles of the earth. Further calculations have shown that, when suitably trapped, the particles will remain in the earth's magnetic field for long periods of time. Thus even at slow rates of injection from outside, the number of particles can build up to large values.

Our theoretical group at the National Aeronautics and Space Administration has undertaken to show how the high temperatures over the Arctic zone may be explained by the activity of the particles in the outer belt. To carry out the necessary calculations Isidore Harris and I constructed an idealized model of the atmosphere [*see top illustration on preceding page*] in which we confined the heating effect of the particles to a narrow funnel in the auroral zone, the "horn" of the outer zone of particles. The boundaries of this funnel were assumed to be at a "temperate" level of 1,000 degrees K., in accordance with observed upper atmosphere temperatures in the Equatorial and Temperate zones. The rate of heat transfer within the funnel—by collision between the charged particles and the atoms of the upper atmosphere—could then be calculated from the combined rocket and satellite observations of the energies of the particles.

By solving the differential equation of heat conduction within these boundary conditions, we have shown that the temperature must rise to approximately 2,500 degrees at the center of the auroral zone. The agreement with observed temperatures is thus encouragingly close. We are now performing calcula-



ELECTRON ESCAPES EASILY **from the magnetic field of the earth during the summer and winter solstices, when the earth's geomagnetic axis is tilted toward or away from the sun. Many of the particles emitted by the sun during summer and winter are only temporarily snared by the earth's magnetic field; they approach the earth at high speed, make a few quick spirals along magnetic lines of force and then escape to infinity. This seasonal factor may explain why there are fewer auroras in the summer and winter.**

tions with a more realistic model in which the temperature changes gradually at the edge of the auroral zone.

As the evidence accumulates it is becoming clear that the earth's upper atmosphere can no longer be considered a homogeneous system, but must rather be regarded as two systems, one of which is heated to much higher temperatures than the other by interaction with the outer belt of charged particles. The contrasting curves of density at various altitudes for the "Temperate-Equatorial" and the "auroral" atmospheres are shown in the top illustration on page 41.

Meanwhile we have been encouraged to seek in the same data an explanation of the auroras. If the heating produced in the outer zone excites the atmosphere sufficiently to raise its temperature by several thousand degrees, then that same excitation may also cause auroral displays. In that case, we must also expect that auroras will occur most often at altitudes where the heating effect is greatest. Alongside Størmer's chart of the observed altitudes of more than 12,000 auroras we laid the curve of the heating effect of the particles as derived by our calculations from rocket and satellite measurements [*see bottom illustration on page 41*]. The basic correspondence between the two diagrams is striking: Both the intensity of energy transfer to the atmosphere and the frequency of auroral events reach a sharp maximum at 100 kilometers and disappear completely below 90 kilometers.

We believe that these results provide support for our explanation of the origin of the aurora: Apparently the frequency of auroral displays is governed by the population of the outer particle-belt, which in turn is controlled by the injection of streams of particles from the sun. Thus we have a tentative answer to an old and fascinating problem. Of course we still do not know what causes particular auroras to assume the shapes they do, changing into draperies, rays, arcs or flaming curtains that dance across the sky.

Our theoretical work has also suggested an explanation for the seasonal frequency of the auroras which may at least stimulate fruitful investigations. As is well known, the auroras occur with highest frequency at the spring and autumn equinoxes, when the earth's geomagnetic axis is nearly perpendicular to a line drawn from the sun [*see illustration on opposite page*]. We suggest that this orientation of the magnetic field to the streams of particles emitted by the sun is the most favorable for trapping the particles and building up the intensity of the outer radiation-belt. At such times the lines of magnetic force will pull the largest numbers of particles into what we call "nearly trapped" trajectories.

Thomas Kelsall and I came across this class of particle trajectories in the course of a detailed study of the motion of charged particles in the dipole magnetic field of the earth. They were doubtless known to Størmer and other workers in this thoroughly exploited field, but their potential significance in auroral phenomena had not been noticed.

Racing in on parallel courses from the sun, the particles that get caught in these trajectories make several close passes about the earth in the outer radiation-belt, much as trapped particles do, and then escape to infinity. A percentage of them are trapped after collisions and join the permanent residents on spiral trajectories around the lines of force. Thus we have concluded that the average particle population of the outer belt becomes higher at the equinoxes. With increased density in the belt the excitation of the atmosphere rises, increasing the frequency of auroras. The discussion has here entered the realm of speculation, but I am confident that "nearly trapped" trajectories offer another important clue to help us to unravel this long-standing mystery of nature.

OUR GALAXY AS A SPIRAL NEBULA has been mapped during the past few years by Dutch and Australian radio astronomers, who have observed the 21-centimeter radiation from clouds of neutral hydrogen stretched along the spiral arms of the galaxy. Our earth and sun (*encircled dot*) are located about 27,000 light-years from the center of the galaxy (*cross*). The galaxy rotates around this center, our region completing its revolution in about 200 million years. We can detect this rotation by measuring the Doppler shift in the radio signals from the drifts of hydrogen: If the gas moves toward us, its radiation shifts to slightly higher frequencies; if it moves away, its radiation appears at lower frequencies. We cannot detect the movement of the hydrogen clouds in the black, fan-shaped area extending from the sun to the opposite edge of the galaxy because it moves perpendicular to our line of sight, neither toward us nor away from us, and there is no detectable Doppler shift in its radiation. Hence this hydrogen does not appear on the map.

THE RADIO GALAXY

From somewhere near the center of our galaxy vast billows of hydrogen surge outward, emitting radio waves that elucidate the galaxy's spiral structure

by Gart Westerhout

During the past decade radio astronomers have been charting the sky on a new kind of map. At first glance this map looks like a contour map of a mountain range. The celestial contours, however, trace out the lines on which the sky shines with equal brightness in the wavelengths of the invisible radio spectrum. The outstanding feature of the topography of the radio sky, drawn in long sweeping contour lines, is the band of the Milky Way, which appears brighter to the radio telescope than it does to our eyes. Elsewhere on the map individual radio sources stand out as peaks of brightness, marked by more closely bunched concentric contours.

From study of such maps, made on several different radio wavelengths, astronomers are now deducing important features of the structure of our galaxy, hitherto invisible or obscured from view. The sky itself is a kind of map: a spherical projection at trigonometric "infinity" of the unbounded reaches of space that lie beyond. By various ingenious methods astronomers using light-gathering telescopes have translated this map into a three-dimensional picture of our galaxy. They have shown the galaxy to be a thin disk of stars with spiral arms. The center of the galaxy is located in the bright region of the Milky Way in the constellation Sagittarius. Over large regions of the sky, however, curtains of dust and gas hanging in space have dimmed or entirely blocked our view. These clouds are so thick and extensive that we can see only about a 20th of the galaxy with light-gathering telescopes. But interstellar clouds do not hamper radio telescopes any more than clouds in the terrestrial atmosphere interfere with radio transmission. These modern instruments open up the whole galaxy to view and permit us to look into its very center.

Of course we cannot "see" the heavens with a radio telescope. All we can see in a literal sense is the wagging needle of a voltmeter or the wiggling trace of a recording pen. But in the map of the radio sky constructed from these observations we are beginning to discern the fine structure of the galaxy. Measurements of the intensity and the Doppler shift of the spectral line emitted at the 21-centimeter wavelength by hydrogen in interstellar space have resolved the curtains of dust and gas into the spiral arms of the galaxy [*see illustration on opposite page*]. Measurement of the Doppler shift in this radiation has also revealed the rotational motions in a large part of the galaxy. It was already known that the sun and the stars in its neighborhood rotate around the galactic center once in about 200 million years. Similar studies of the 21-centimeter radiation from other galaxies, such as the Great Nebula in Andromeda and Messier 33, have established the density of hydrogen and the rotational motions in these systems. Radio emissions from the center of our galaxy are now completing the picture of the spiral structure and promise to give us new insight into the evolutionary process that accounts for it. They indicate the presence of a large mass of ionized hydrogen gas at the center and show that great waves of hydrogen are rippling outward from the central region in the plane of the galaxy. At the outer edge of these waves, where their outward rush has lost its impetus, new stars seem to be forming. Their newborn energy ionizes the gas in a brilliant ring of radio emission encircling the center. Based as it is upon the first penetration of the galactic nucleus, this picture is still speculative, but it suggests the major outlines of the evolution of our changing galaxy.

Much of the early work of charting the radio sky was done in the Netherlands. In fact, the first short-wave map of that part of the Milky Way which is visible in the Northern Hemisphere was made with the Leiden Observatory's 82-foot radio telescope located at Dwingeloo. When it first came into operation in 1956, this instrument was the largest of its kind. Now several radio telescopes in Europe and the U. S. equal it in size, and the reflector of the giant telescope at Jodrell Bank in England is more than three times larger.

The mounting of our telescope at Dwingeloo represents a departure from astronomical tradition. It is of "altazimuth" design, that is, the entire mounting rotates on a circular track around a vertical axis and the reflector pivots around a horizontal axis. The parabolic reflector is surfaced with a fine wire mesh and focuses the incoming radio waves on a small antenna mounted atop a 40-foot mast. From the antenna the signal travels to a 700-tube receiver and amplifier circuit designed to monitor the 21-centimeter line of un-ionized hydrogen, but tunable to the nearby wavelengths on which radiation from ionized hydrogen can be received.

The length of radio waves, millions of times longer than those of light, accounts for the large dimensions of a radio telescope. In general, the longer the wave, the larger the reflector needed to resolve its source. Our 82-foot reflector has a resolving power of .57 degree at a wavelength of 21 centimeters. This means that two sources of radiation closer together than .5 degree of arc are seen as a single source, and that an infinitely small source appears as a blur one degree across—twice the diameter of the moon as seen from the earth. As in the case of optical telescopes, however, a large reflecting surface confers large "light" gathering power to make the most of the tiny amounts of energy that reach us from any given point in the sky or from a discrete source in distant space. The telescope is sensitive to extremely faint radio sources and can locate them very accurately, although its accuracy compared to an optical telescope is heavily compromised by low resolving power.

In surveying the sky the telescope usually scans along the path of a star but eight times faster, starting behind the star, then catching up with it and passing it, sweeping a line 30 to 40 degrees across the sky. After each such scan, the reflector swings a fraction of a degree to one side and repeats its sweep. The telescope thus sweeps across a section of the sky in much the same way as an electron beam sweeps across a television screen, but months of slow scanning with the radio telescope are required to produce a single sky map. The sky signal is amplified in the telescope receiver and fed to a recorder, where it drives a pen tracing a continuous line on a moving strip of paper.

The effect of limited resolving power must be borne in mind in reading the record made by a typical scan with the telescope. The line drawn on the recorder corresponds to a strip of sky more than one degree wide, and it reflects only roughly the variations in signal strength that occur within a degree along its length. Thus it does not show stars or

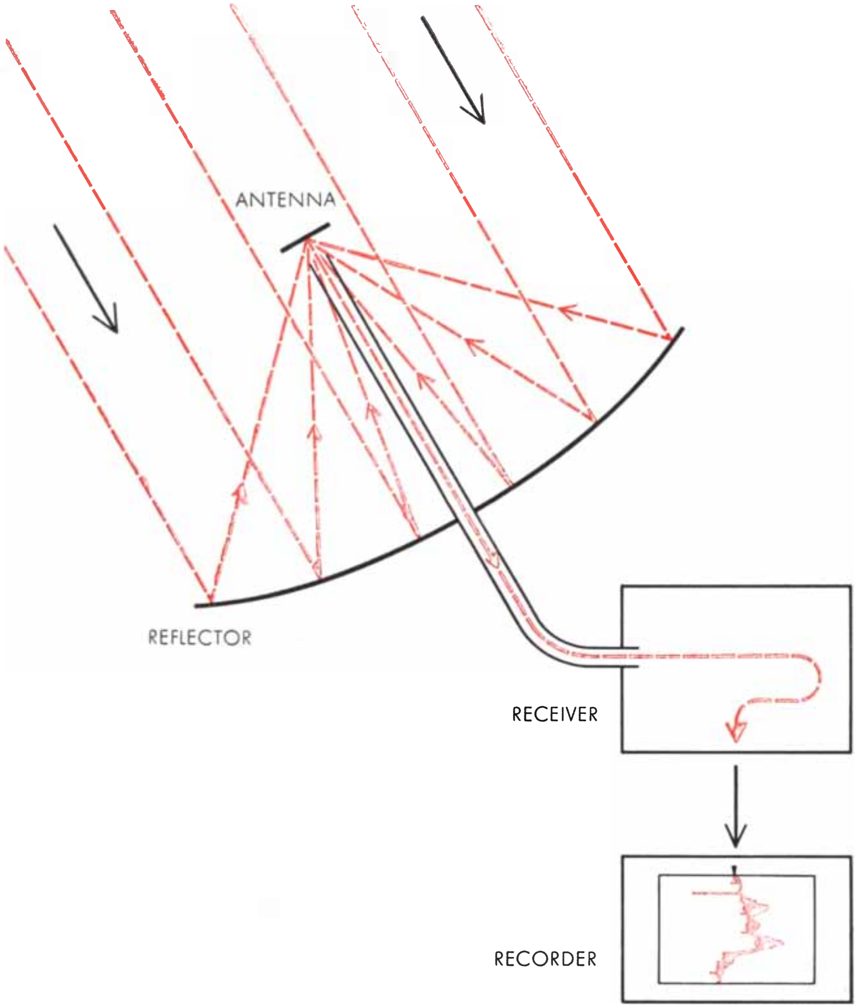
RADIO TELESCOPE that helped to determine the structure of our galaxy is located at Dwingeloo in the Netherlands. Its antenna and the first stages of its radio receiver are mounted atop the mast that juts from the face of the 82-foot reflector. The telescope framework revolves on a horizontal track, while the reflector tilts up and down. The main part of the radio receiver is housed in the laboratory built into the supporting framework of the reflector; the laboratory building rotates slowly as the telescope reflector scans the heavens.

nebulae as point sources. The strong radio source Cygnus A, for example, shows up on a radio map as a blur with a diameter of more than a degree; it has been identified as a pair of colliding galaxies with photographic dimensions smaller than .01 degree. This should warn us that the many other radio sources which have an apparent diameter the same as that of Cygnus A are also of much smaller size. In order to smooth out errors a map such as the one on the next two pages is built up from hundreds of scans —two for every one-third degree.

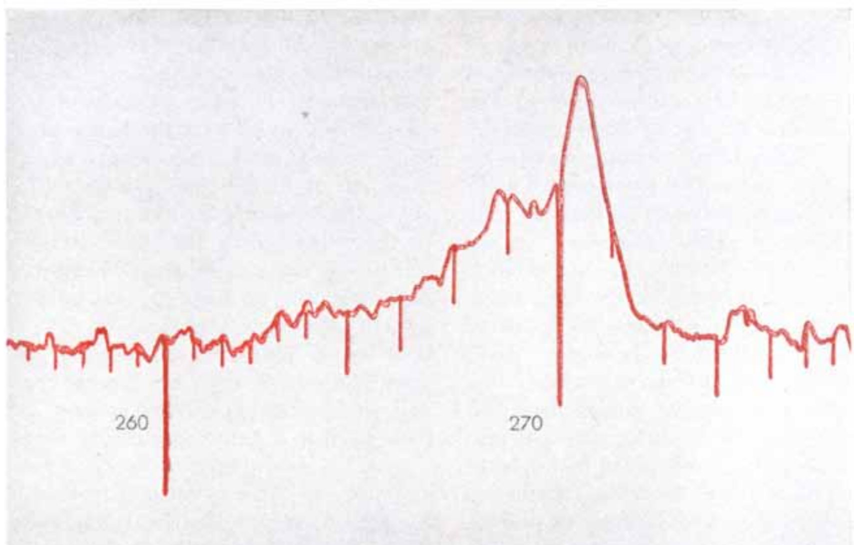
Radio maps made at different wavelengths differ significantly in what they show. On both long- and short-wave maps the Milky Way is the most striking region. A long-wave map (at, say, three meters and above) shows the Milky Way as a broad band across the sky, brightest in the region of Sagittarius. Bright radio peaks, the so-called discrete sources, cover the entire sky; so far some 2,000 of them have been located. While Cygnus A has been identified as an extragalactic source, the two other strong sources—the Crab Nebula and Cassiopeia A—have been identified as the remnants of stars that exploded within the galaxy. Are the other long-wave sources also exploding stars or colliding galaxies? No one seems to know. So far only a few of them have been identified with visible objects, although a considerable amount of detailed work remains to be done along this line.

On a short-wave map (25 centimeters and below) the Milky Way appears as a narrow ribbon, with the same ascendant brightness toward Sagittarius, but fading almost to invisibility near Orion. The discrete sources on this map are concentrated on and along the brightness ridge of the Milky Way; most of them do not coincide with the sources that appear on the long-wave map.

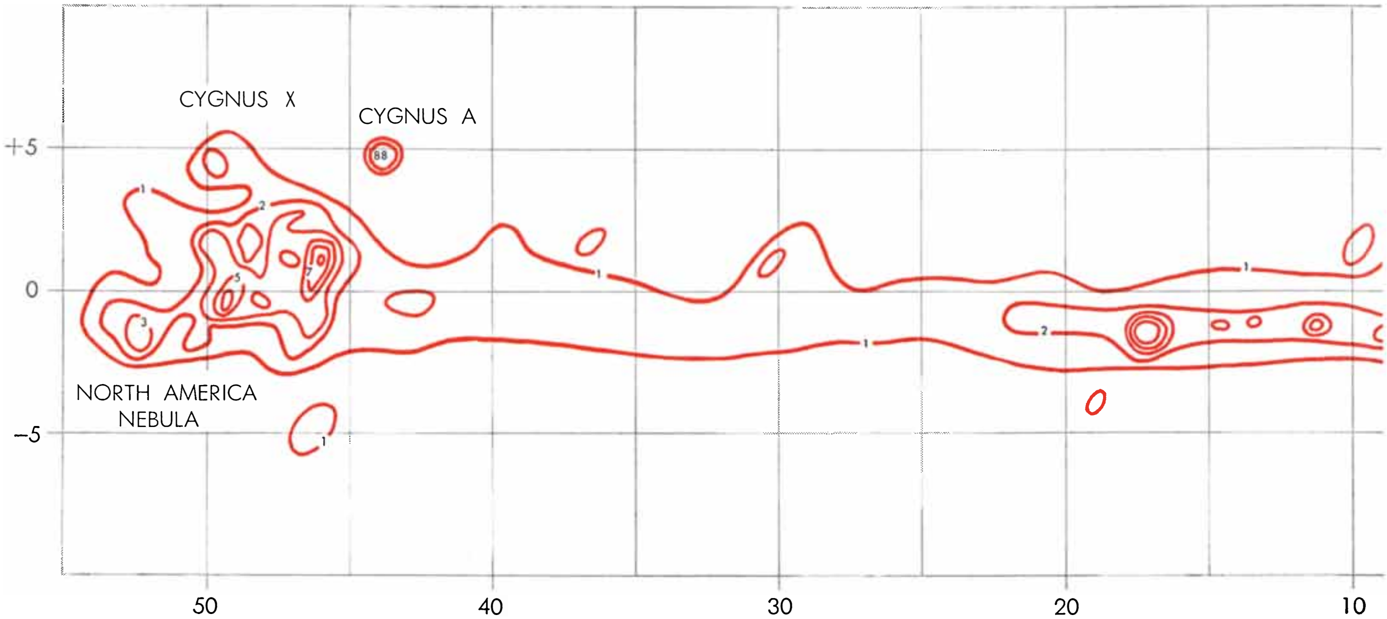
It is clear, therefore, that a complete radio atlas of the sky will require the making of many maps at many wavelengths. Radio astronomers all over the world are collaborating on a concerted effort to this end. At long wavelengths (3.5 to 15 meters) Australian observers have obtained remarkable results; British groups are working at wavelengths between 1 and 10 meters; an Ohio State University team has published an excellent 1.2-meter map [see "The Radio Sky," by John D. Kraus; Scientific American, July, 1956]. Our work at Dwingeloo continues in the wavelengths to which our instrument is adapted (21 to 75 centimeters), and the very short wavelengths (10 centimeters and be-



BLOCK DIAGRAM OF TELESCOPE shows how signal is picked up by the parabolic reflector and focused on the antenna. The signal is then amplified in a radio receiver and fed to a recorder, where a pen traces fluctuations in signal strength on a moving strip of paper.



TELESCOPE TRACINGS reflect variations in signal intensity along the telescope's path across the sky. This tracing is a cross section through the Milky Way; big hump is the nebula Messier 8, a bright radio source. Numbered dashes show degrees of right ascension.



RADIO MAP OF THE MILKY WAY was made by assembling a series of telescope tracings such as the one shown on the chart at the bottom of the preceding page. The contour lines on this map represent lines of equal radio brightness; very strong radio sources appear as a series of closely spaced concentric contours. The Milky Way appears as a narrow band across the sky, dotted with bright

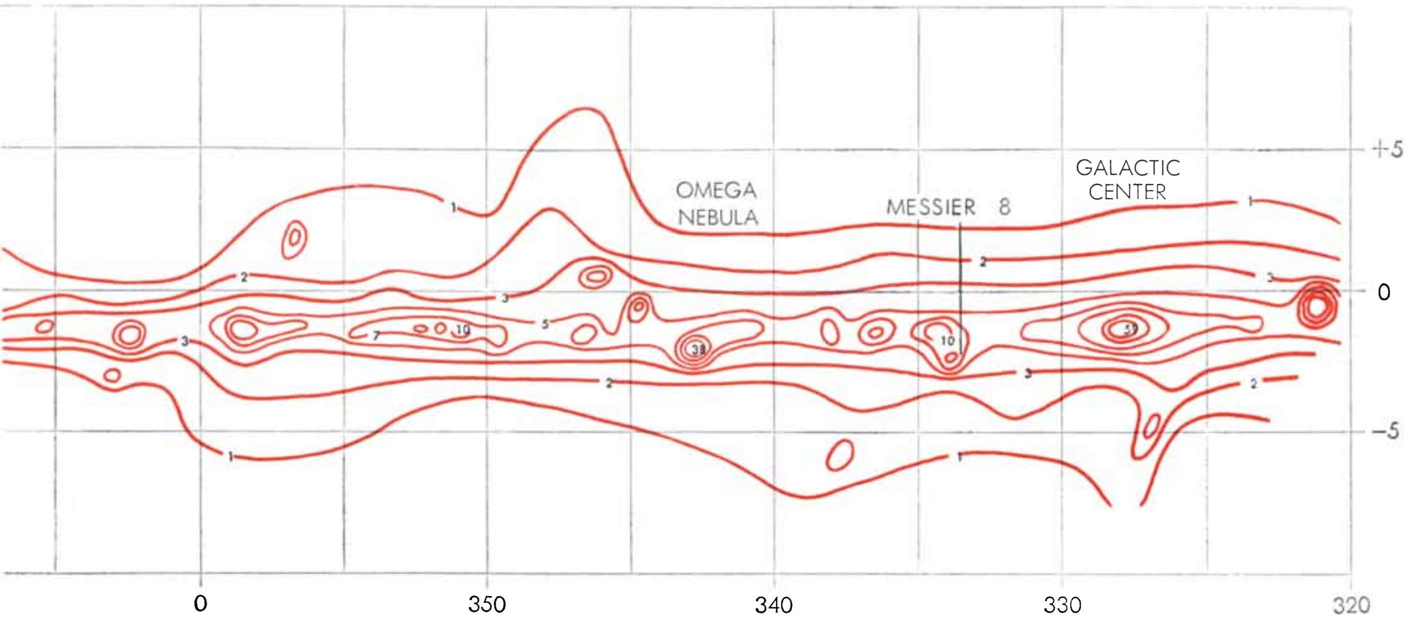
low) have been pioneered by workers at the Naval Research Laboratory in Washington, D.C.

Why the difference between radio maps of the sky? The answer is that radio signals that produce them are of different kinds, arising from quite different physical processes. The 21-centimeter radiation (more precisely 21.12 centimeters) of neutral hydrogen, for example, is generated by the quantum jump of the atom's single electron from one to the other of its two lowest-energy orbits. Most of the radiation from the Milky Way and from the discrete sources arrives, however, on a wide range of wavelengths. The typical short-wave map, at say 22 centimeters, charts the distribution of "thermal" radiation in the sky: radiation that is strong and roughly constant across the spectrum of short wavelengths and less intense at long wavelengths. The "nonthermal" radiation that is plotted in a typical long-wave map is bright at the long wavelengths and fades below the limits of detection at shorter wavelengths. As the term suggests, thermal radiation has its origin in the familiar process of excitation by heating. Stars, for example, may heat surrounding clouds of hydrogen to the temperature of ionization, separating the atoms into their constituent protons and electrons. These charged particles, accelerated by temperatures as high as 10,000 degrees absolute (degrees centigrade above absolute zero), move freely through the cloud. When an electron and a proton approach each other at high speed, they interact, causing each other to move in hyperbolic orbits and to lose energy [*see top illustration on page 51*]. They give up this energy as radiation, the wavelength depending upon their velocities and the distance at which they interact.

The origin of nonthermal radiation is not so well established, though we know that its intensity is too great to be explained by thermal processes. At present most of this radiation is attributed to the so-called synchrotron mechanism. In a synchrotron, electrons accelerated almost to the speed of light radiate on these wave-lengths (and others) when they are deflected into spiral paths around the lines of force in the machine's strong magnetic field. We know that our galaxy is permeated by magnetic fields, with their lines of force parallel to the galactic plane, and that the galaxy contains an as yet unknown quantity of ultrafast electrons. Presumably when the path of an electron is bent by one of these fields it, too, emits radiation.

Such theoretical understanding of the origin of the radiation at various wavelengths helped us derive the structure of the galaxy from radio maps. Another important set of clues is provided by matching the radio maps with photographic plates from such sources as the atlas compiled with the 48-inch Schmidt telescope on Palomar Mountain. We find that many of the radio sources at short wavelengths coincide with photographic images and, with almost equal significance, that almost none of the longwave sources do so. One whole set of coincidences shows us that most of the discrete sources in a short-wave map are emission nebulae, that is, diffuse clouds of hydrogen that surround bright stars and are highly excited by them. Both the light and radio emissions of such nebulae are given off by ionized hydrogen. The total radiation that they emit depends upon the size and the density of the gas clouds, both of which we can determine by radio-telescope measurements. Provided we have an optical determination of the distance, we can calculate the size of a nebula from its apparent diameter on a radio-telescope chart; and once its size is known, we can determine its density. Of course we can make the same estimates using light-brightness measurements, but they are more subject to error because the light from many nebulae is obscured by gas and dust clouds in intervening space.

Some emission nebulae are so completely hidden that only radio telescopes can find them; the radio source near the galactic longtitude of 358 degrees is a good example. This source is definitely a bright emission nebula, but no photo-



radio peaks. Most of these peaks, such as Messier 8, are emission nebulae: clouds of hot gas heated by stars embedded in them. Intense source on the right side of the map is the galactic center; the bright source at the left is Cygnus A, which lies far outside our galaxy. Many radio sources in the Cygnus region are hidden by interstellar dust clouds which dim or completely cut off their light.

graphic counterpart of it has been found. We can thus assume that this nebula is completely concealed by interstellar clouds. But how can we be sure? Here knowledge of thermal radiation supplies the answer. Emission nebulae are thermal emitters, which means that their radiation is strong at short wavelengths. Once we know the intensity of their radiation at one wavelength, we know what radiation to expect at other wavelengths. Let us suppose, for example, that we pick up a new source at long wavelengths. We then tune the telescope to a wavelength in the short-wave end of the spectrum. If the object is an emission nebula, it will show up at this wavelength. If it is a nonthermal emitter, such as a cloud of ions trapped in an interstellar magnetic field, we will not pick up its radiation, since the radiation from most nonthermal emitters is too weak to detect at short wavelengths except with the help of the extremely sensitive receivers now being developed.

By comparing radiation maps of the galaxy made at the short wavelength of 22 centimeters with those made at longer wavelengths I have been able to estimate the amount of ionized hydrogen in the galaxy and plot its distribution. Since ionized hydrogen emits only thermal radiation, the first step was to subtract the nonthermal background. The 3.5-meter survey made by B. Y. Mills and his associates in Australia provided a measurement of the nonthermal component of the total brightness of the Milky Way; it showed that almost half of the radio background at 22 centimeters in this region of the sky is nonthermal. From the separation of the thermal and nonthermal radiation it was possible to estimate the variation in thermal intensity along the ridge of the Milky Way and to measure the width of the thermal part of the ridge. The net result of this study was a reliable plot of the distribution of ionized hydrogen in the galaxy, most of it gathered into the numerous emission nebulae, some bright enough to be observed as discrete sources but many more too faint to be resolved.

One fact emerged immediately. The ionized gas, along with the neutral gas and the stars, is concentrated in a very thin disk, not more than 600 light-years thick but over 60,000 light-years in diameter. The total mass of this disk is only a thousandth the total mass of the stars, dust and gas in the galaxy. By comparing radiation from ionized hydrogen at 22 centimeters to the 21-centimeter radiation from neutral hydrogen, we found that only 5 per cent of the hydrogen in the galaxy is ionized, a figure that agrees with earlier data gathered with optical spectrographs.

When we swing a radio telescope toward the center of the galaxy, we are able to see some crucial features of its structure hitherto entirely concealed from observers. Between our sun and the center of the galaxy the density of ionized hydrogen slowly increases, reaching a maximum at about 14,000 light-years from the sun and 12,000 light-years from the center. Here, apparently, a ring of hot new stars ionizes the hydrogen around it. Beyond this ring, toward the center of the galaxy, the telescope shows that the density of ionized hydrogen drops off abruptly.

Well inside the ring of ionized hydrogen and new stars, at the very center of the galaxy, radio telescopes detect a hugely extended source of radiation, a region of nonthermal emission about two degrees wide in the plane of the galaxy and one degree deep at right angles to the plane. It encloses a few dense clouds of ionized hydrogen, with diameters of about .1 degree each. Here, apparently, is the nucleus of our galaxy. Similar blobs of light and radio brightness show up at the centers of nearby galaxies. No one can as yet explain the presence of these clouds at the center nor describe the mechanism by which they are ionized. From the rotational motion of the gas close to the center and from the intensity of the nonthermal emission it may be deduced theoretically that the nucleus contains stars and gas with a total mass equal to five million solar masses within a diameter of 100 to 200 light-years.

The Dwingeloo telescope tuned to 21

ONE OF THE BRIGHTEST RADIO SOURCES in the sky is Cygnus A, consisting of two colliding galaxies. Despite the intensity of their radio emission the galaxies are 270 million light-years away, and they appear only as two fuzzy spots in the middle of this photograph made with the 200-inch telescope on Palomar Mountain. Although Cygnus A is the strongest source in the 22-centimeter map on the preceding two pages, both Cassiopeia A (the remnants of an exploded star) and the sun are brighter at this radio wavelength.

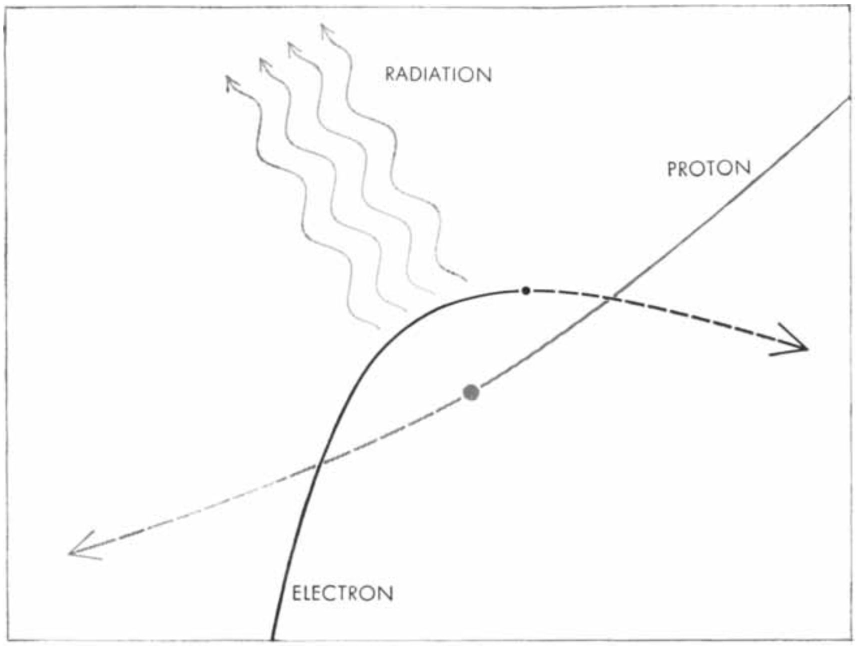
ANOTHER BRIGHT SOURCE, the emission nebula Messier 8, contains clouds of hot hydrogen that emit both radio waves and visible light. Some of the light is absorbed by the dark band of interstellar clouds that seems to divide the nebula. Messier 8 appears in the radio map on the preceding two pages as a small peak near a galactic longitude of 334 degrees; its radio signals pass unhampered through the dark clouds. Unlike the very distant source Cygnus A, the nebula Messier 8 lies within our own galaxy.

centimeters has revealed that neutral hydrogen surrounding the nucleus is moving radially outward from the center in the plane of the galactic disk at velocities varying from 50 to 200 kilometers per second. Apart from its radial motion the gas apparently also takes part in the general rotation of the galaxy under the influence of the galactic gravitational field. With the radial component of its velocity braked to 50 kilometers per second at about 10,000 light-years from the center, the density of the gas rises. It is just beyond this braking region, at 10,000 to 12,000 light-years from the galactic center, that the neutral hydrogen becomes ionized by the energy of hot new stars. Evidently the stars condense out of the gas; the higher density of the gas and the 10 million years it takes to flow through this zone provide favorable conditions for the formation of a large enough number of new stars to account for the ionization. Further study, with many more detailed observations, may lead to understanding of the evolutionary process by which a galaxy gives rise to new spiral arms.

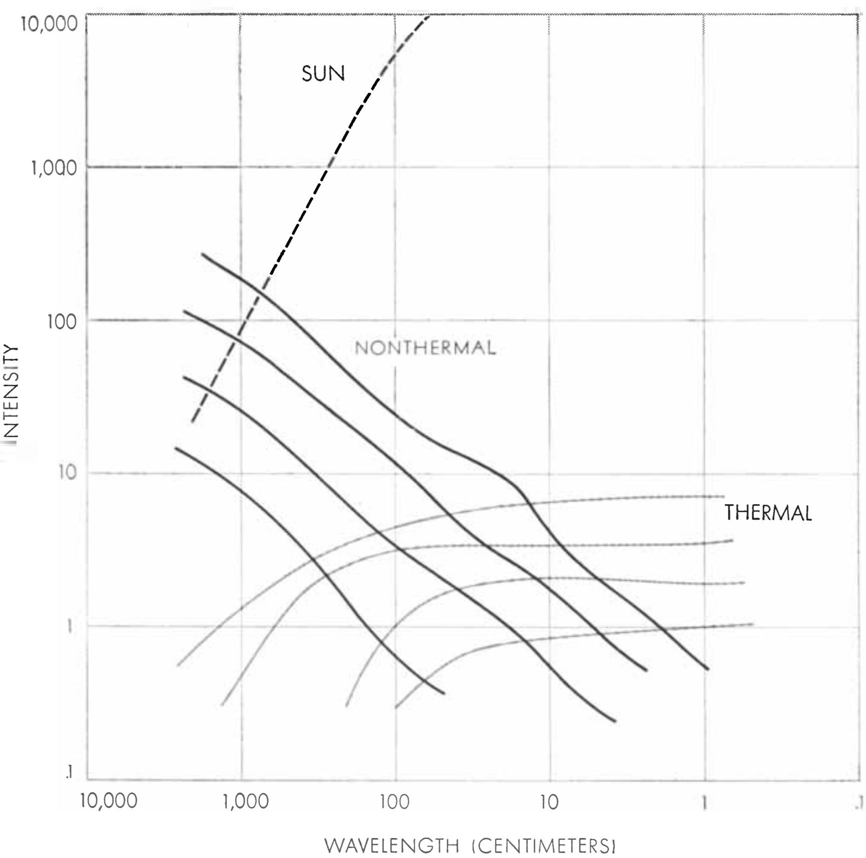
We do not, however, know where the neutral hydrogen that provides the substance of the new stars comes from. At the rate at which the hydrogen is emptying from the center of the galaxy, the entire supply must be exhausted in 30 million years, a day or two in the six-billion year history of the galaxy. Such a rapid loss of hydrogen would mean that the galaxy is exploding, a conclusion most astronomers are unwilling to accept.

It seems more likely that the supply of hydrogen at the center is continually replenished from some source outside. Perhaps this source is the galactic halo, a vast, thin sphere of ionized particles surrounding the galaxy which may be supplied in turn from hydrogen clouds ejected out of the galactic plane as the result of collisions or perhaps even from intergalactic space. We know almost nothing about the galactic halo, nor do we know by what mechanism, if any, its material is pulled unobserved into the center of the galaxy, although it is likely that magnetic forces would play some part in such a mechanism.

Even with very much better equipment it will be difficult to study the halo, because its density is extremely low. However, the telescopes and sensitive receivers needed to measure the distribution of ionized hydrogen in the galactic plane at wavelengths shorter than 22 centimeters will soon be available at various radio observatories in the U. S.



THERMAL RADIATION is produced when electrons and protons in ionized clouds of hydrogen pass each other at high velocities. The heavy proton is barely deflected from its path, but the lighter electron completely changes direction, thereby losing some of its energy. It gives up this energy by emitting light and radio waves. This radiation is called "thermal" because the original energy of the electrons depends on the temperature of the gas.



TWO MAIN CLASSES OF RADIO SOURCES, the thermal and the nonthermal emitters, can be distinguished from each other because thermal sources are weak at long wavelengths, but are strong and of approximately constant intensity at short wavelengths. Conversely, nonthermal sources are strong at long wavelengths and steadily diminish in intensity toward the short-wave end of the radio spectrum. The intensity of the sun is shown for comparison.

INCUBATOR BIRDS

These extraordinary fowl hatch their eggs not by sitting on them but by putting them in a hot place. Some species even rake together dead leaves, the decay of which heats the eggs

by H. J. Frith

On the mainland of Australia and the islands to the north lives a family of rather dull-looking black or brown birds about the size of domestic fowl. Called Megapodiidae, after their big feet, they rarely fly, have raucous calls and are seldom seen by man. These birds are of interest because they do not brood their eggs with the heat of their bodies as other birds do but hatch out their young in incubators. Depending upon their habitat, the various megapode species have developed different ways of finding and generating heat short of sitting on the eggs themselves. They bury their eggs in sun-warmed sand, in volcanoes or in compost heaps where fermentation supplies the heat. One Australian species, the mallee fowl, constructs huge mounds of soil and vegetable matter, enlisting both the heat of the sun and of fermentation, and manages to keep the temperature within a degree or so of 92 degrees Fahrenheit throughout the incubation period despite the vagaries of an often hostile climate. The chicks never see their parents. They hatch deep beneath the soil, dig their way upward to the surface and run away into the bush, fully feathered and able to fend for themselves from the start.

The first Europeans to hear of the incubator birds were survivors of Magellan's ill-fated 1519-1522 expedition around the world. One of them, Gemelli Careri, described in his memoirs a bird about the size of a small fowl that laid eggs bigger than itself and buried them in the ground to hatch from the heat of the sun and sand. The people of Europe at that time accepted mermaids and devils as normal inhabitants of the earth, but found the idea of birds building their own incubators too fantastic to believe. Careri's tale was rejected as just another sailor's yarn.

When early settlers in Australia discovered large mounds in the inland scrub, they marveled that aboriginal mothers should build such big sand

MALE MALLEE FOWL WATCHES FEMALE as she prepares to lay half-pound egg in hole he has dug in incubator mound. Egg will roll down to where female here has her head. Of this male the author says: "His co-operation has immensely assisted our studies."

castles to amuse their children. Later settlers in the north of the continent found really enormous mounds. They deduced that these monuments were the tombs of dead warriors. The natives, however, denied building mounds for either children or the dead. They stoutly claimed the mounds were birds' nests. But who could believe such a fantastic story from uncultured savages? The settlers continued to doubt the bushmen until 1840, when the pioneer naturalist John Gilbert took the obvious step of digging into the mounds. Sure enough, he found birds' eggs. The aborigines chuckled.

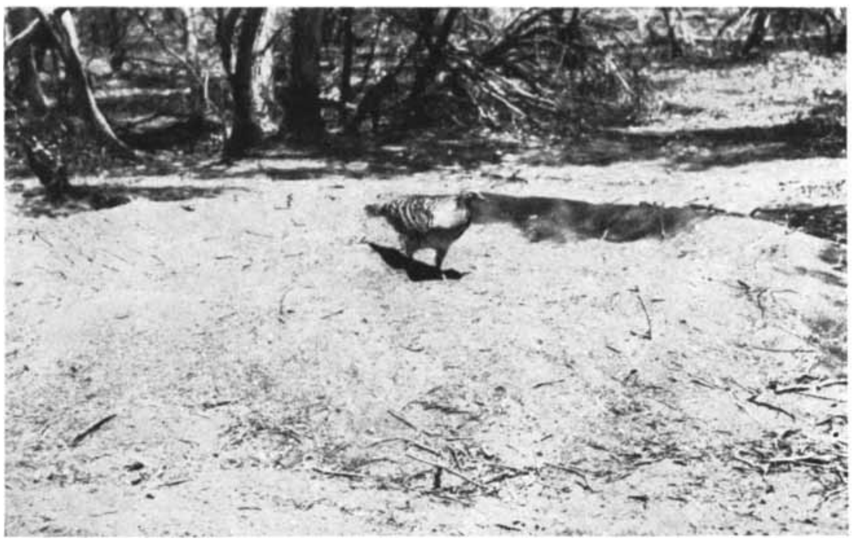
When I first heard of these mound builders, I wondered why other birds had not adopted this habit. Why should they not deposit their eggs in an incubator and lead a life of leisure instead of exposing themselves to the cares and dangers of the common method of incubation? Now, after a decade of studying the mallee fowl, I no longer wonder. The construction and maintenance of its incubator mound call for great skill and stamina and ceaseless heavy work for most of the year. Normal incubation must be easier in every way.

The megapodes that live on small islands in Celebes and the Moluccas have adopted somewhat less arduous methods. There the climate is warm and the temperature varies little during the day or over the course of a year. The shaded soil of the jungle, where these birds live, remains somewhat too cool. But the sand on the beaches becomes uniformly warm to a relatively great depth. The birds simply go to an exposed beach, dig a small pit deep enough to find the right temperature, and lay their eggs in it. In some places old lava-flows across the beaches have weathered to black sand. Here the birds unerringly choose the black sand for egg pits; presumably the better heat-absorbing properties of black sand make it slightly warmer. The jungle fowl, however, must face one difficulty. The beach is often as much as 20 miles away. Since they lay an egg every few days for several weeks, returning to the forest in between, their life during breeding season must be a constant promenade. A few of the birds do find warm spots in the forest soil at the edges of warm springs, and lay their eggs there.

The most widely distributed of all megapodes is the jungle fowl Megapodius. It is found from the Nicobars in the west to Fiji in the east, and from the Philippines to the central Australian coast, living on small coral atolls, larger

DIGGING MALE MALLEE FOWL works at dawn in spring. He opens his egg-incubator mound to let out heat of fermenting matter and keep the eggs at 92 degrees Fahrenheit.

IN MIDSUMMER the bird adds more soil to his already high mound to increase its insulation from hot sun. Fermenting leaves under the buried eggs now give off much less heat.



BY AUTUMN the male must work at midday to scoop out the mound and allow the sun's heat to penetrate to the eggs. He rebuilds the mound with sand warmed by the noon sun.

islands and on the continent itself. As might be expected, it is the most adaptable of the megapodes and varies its incubation method to suit each location.

On small islands this species lives in the jungle near the beach and lays its eggs in pits dug in the beach, side by side with the turtles that heave themselves from the sea for the same purpose. On islands where there is volcanic activity, Megapodius digs egg pits in places where steam issues from the ground and, on some islands, even in the volcanic ash of active craters. On larger islands and in Australia, the fowl lives in fairly dense forests and jungles at long distances from the exposed beaches and with no volcanic heat at hand. Here Megapodius adapts the heat of rotting vegetable matter to do the work of incubation.

The hard-working birds build mounds of soil and leaf material that may reach 50 feet in diameter and 15 to 20 feet in height. In open scrub near the seashore, where the sun shines brightly, they incorporate less organic material in their incubators. Such mounds represent perhaps no more than a first improvement on the simple egg-pit, elevating the pits for drainage and for safety from the tide. In dense jungle, however, where little sun reaches the ground, the mound will be almost entirely vegetable, and much heat is generated by fermentation. Between these two extremes are many mounds of intermediate composition. I find it remarkable that a bird is able to estimate the amount of organic matter it must add to a heap of soil so that the heat generated by fermentation is just enough to bridge the gap between the soil temperature and the temperature necessary for incubation. It almost suggests that these birds understand some chemistry.

Another group of megapodes, the brush turkeys, live in the dense, steamy rain forests of Australia and New Guinea, where the sun seldom penetrates. These birds find no difficulty in generating heat by fermentation, and depend on it entirely. The brush turkeys' mounds are heaps of rotting leaves 12 to 15 feet in diameter, scratched up from the forest floor with practically no soil. The mound is built in spring and, when it is wet with the summer rains, ferments so vigorously that, as we shall see, the birds are obliged to take active steps to control the heat.

The jungle fowl on their sunny beaches near the Equator, and the brush turkeys with masses of organic matter at hand, have no great difficulty finding sufficient heat for purposes of incubation. With the mallee fowl it is quite different.

This bird inhabits inland Australia, a region of semideserts and arid scrub with an annual rainfall of as little as eight inches. The hard, dry leaves do not rot where they fall. Instead, they are eaten by termites or they wither and blow away, and there is practically no leaf litter on the ground. Even if leaves are heaped up, they do not ferment but remain dry and are eventually burned by a brush fire or swept away by the wind. Clearly a bird wanting to generate heat by fermentation here has formidable obstacles to overcome.

Nor is solar heat dependable in this landscape. The air temperature ranges from 112 degrees F. to as low as 17 degrees. The days are blazing hot and the nights may be freezing cold. The temperature of the soil near the surface fluctuates madly, and the temperature deeper in the soil is only 60 degrees.

The ingenious mallee fowl is equal to the problem. It is the male bird that takes charge, building the incubator mound, tending it constantly and seldom going more than 200 yards away. He induces the leaf litter to ferment by burying it in the ground during the winter, when it is moist. The work begins in May (the Australian "November"), when he digs a hole 15 feet in diameter and three to four feet deep. Through the winter he rakes in the leaf litter from 30 to 40 yards around, piling it in the hole. Then, in August, he covers the heap with soil up to two feet thick. The organic matter is usually moist from the few winter showers and, sealed off from the dry air and sun, soon begins to ferment, raising the temperature in the mound. If it has been a dry winter and the leaves do not ferment, the birds abandon the mound and do not breed in that year.

The female is an egg-producing machine. She lays the first egg in mid-September and the last egg in late February or early March. She weighs only 3.5 pounds, but she justifies Careri's report of her by laying a half-pound egg and valiantly laying one every four to eight days for a total of as many as 35 in a season. Since an egg needs seven weeks to hatch, many of the chicks have already hatched and taken off long before the last eggs are laid—true assembly-line production.

During the whole time that eggs are in the mound the male carefully regulates the temperature. Many birds aim at exactly 92 degrees F., though others permit fluctuation between 90 and 95 degrees. When the last egg hatches, the mound is dug out and prepared for a new charge of organic matter.

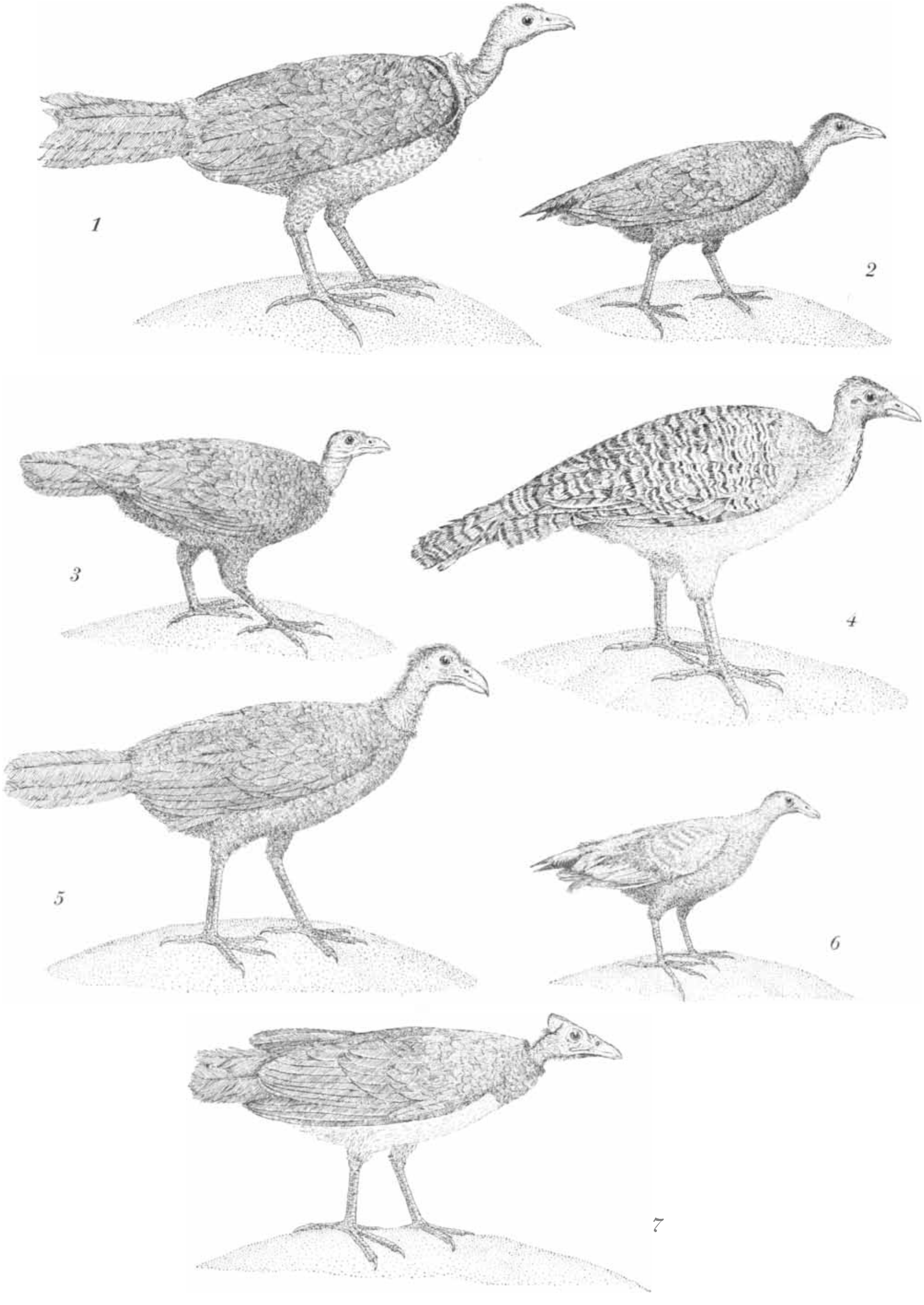
To use natural heat and to regulate it so closely, the birds must have a highly developed sense of temperature. In 1952 I set out to learn how the mallee fowl goes about it.

I found that the mound temperature will rise to 115 degrees F. in the spring if the male is kept away from it. The heat then quickly leaves as the fermentation burns itself out. I built mounds without organic matter and found that the temperature rises very slowly when heat comes only from the sun, and never reaches 92 degrees. When the internal temperature in a normal undisturbed mound rises to 92 degrees, the male goes to work and keeps it from going higher. Later in the season he must reverse his strategy and work to maintain the temperature in the mound above the declining temperature of the soil. He does so by balancing the heat from his two sources: fermentation and sun. The temperature of the eggs seldom fluctuates more than one degree during the whole season.

The male actually varies his activity from day to day according to the weather, but in general he follows three successive routines as conditions change during the breeding season. In the spring he must reduce the amount of fermentation heat reaching the eggs. He visits the mound before dawn each day and digs rapidly until he nears the egg chamber. After allowing just enough heat to escape he refills the hole with cool sand.

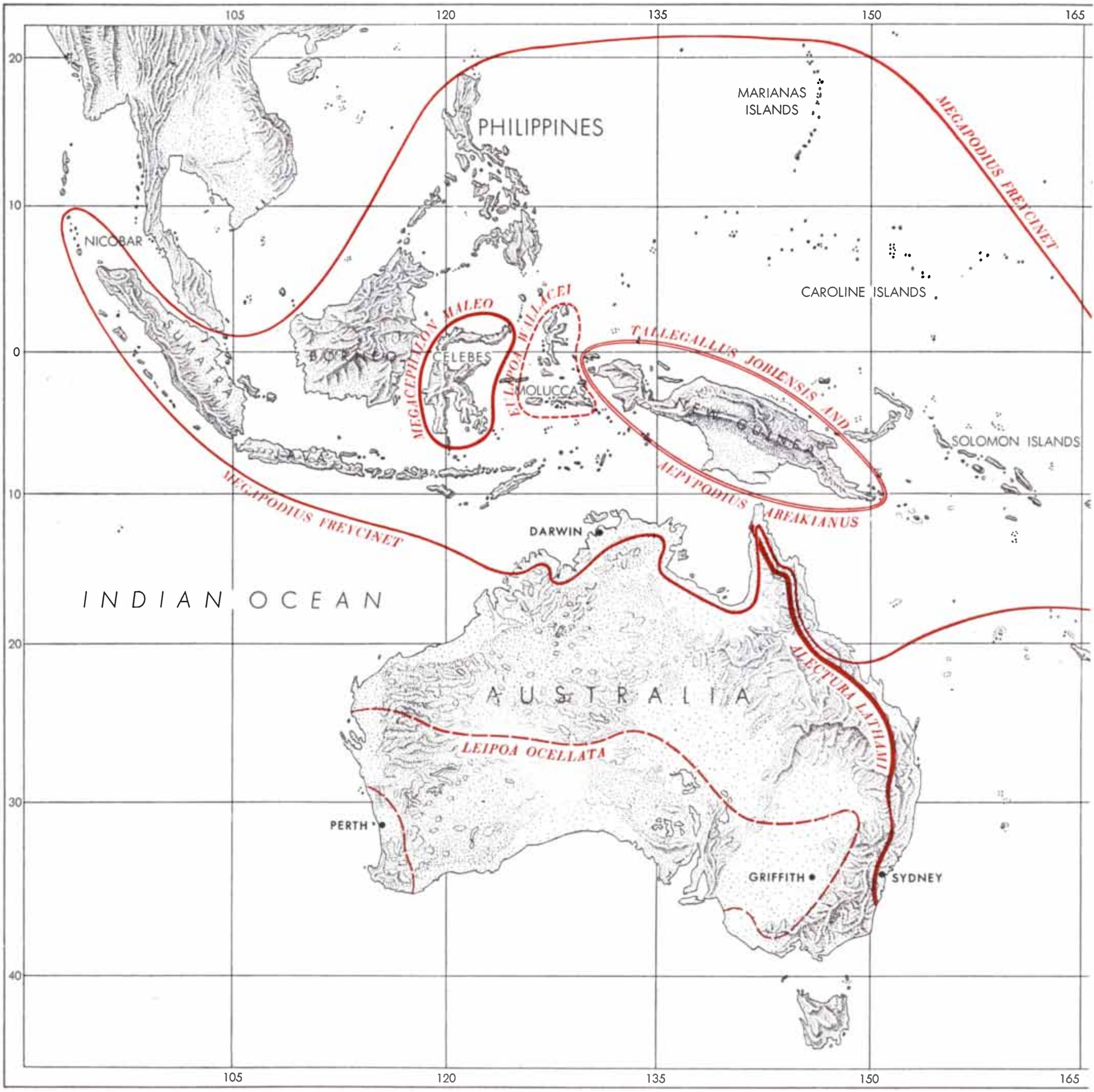
Later in the summer the sun gets very hot, and much heat moves by conduction from the surface of the mound to the egg chamber. Some heat still moves

SEVEN MEGAPODE SPECIES are depicted on the opposite page. They are: (1) *Alectura lathami* of eastern Australia; (2) *Megapodius freycinet*, spread throughout the South Pacific area; (3) *Aepypodius arfakianus*, which lives in New Guinea areas above 3,000 feet; (4) *Leipoa ocellata*, the mallee fowl of southern Australia; (5) *Talegallus jobiensis* of New Guinea; (6) *Eulipoa wallacei* of the Moluccas, and (7) *Megacephalon maleo* of the Celebes Islands.

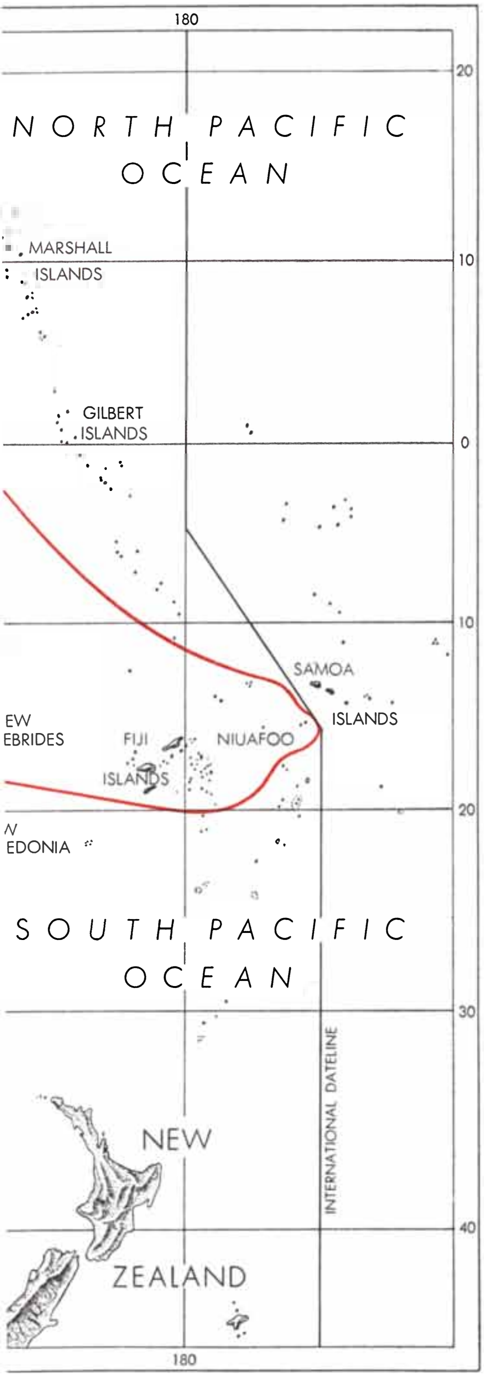

1
2
3
4
5
6
7

up also from the organic matter, though fermentation is slowing by this time. The eggs thus tend to overheat, and the bird must do something to reduce the temperature. There is little he can do to slow the fermentation rate, but he does lower the rate of solar conduction. Daily he adds more soil to the mound. As the mound grows higher and higher, the eggs for a while are more thoroughly insulated from the sun. After a time, apparently, the bird can build the mound no higher, and a wave of heat begins to go down toward the eggs again. Now the male bird visits the mound each week or so in the early morning, removes all the soil and scatters it in the cool morning air. When it is cool, he collects it and restores it to the mound. This is strenuous work, but effective in destroying the heat wave in the incubator. The temperature in the egg chamber remains steady at 92 degrees.

When autumn comes, the bird is faced with the opposite problem: falling temperature in the mound. The mound no longer generates fermentation heat, and the daily input of solar heat is declining. The bird now changes his activities to meet the challenge. Whereas he had scratched and scattered the sand to cool it in the early morning, often before



MEGAPODE HABITATS cover much of the South Pacific area, as shown on this map. *Megapodius freycinet*, the most widespread of all, varies its incubator-building habits with location. *Leipoa ocellata*, the mallee fowl of southern Australia, is the hardest work-dawn, he now comes to the mound each day at about 10 a.m., when the sun is shining on it. He digs almost all the soil away and spreads it out so that the mound resembles a large saucer, with the eggs only a few inches below the surface. This thin layer of soil, exposed to the midday sun, absorbs some heat, but not enough to maintain the temperature throughout the night. The saucer must be refilled with heated sand.



ing, because it lives in arid country where it is very difficult to get leaves to ferment.

Throughout the hottest part of the day the bird scratches over the sand he has removed from the mound, exposing all of it to the sun. As each layer gets hot, he returns it to the mound. He times the work so that the incubator is restored with layers of heated sand by 4 p.m., when the sun is getting low.

We thought it possible that all this temperature-control work could be merely part of a fixed behavior pattern evolved by natural selection to suit the seasons. But the birds, while changing their work with the season, make day-to-day adjustments. On an exceptionally hot spring day they do not open a mound; instead they pile more sand on top, presumably to insulate the eggs from the sun. Similarly, during a series of dull days in autumn, the birds build a mound up higher to conserve the interior heat, rather than scooping it out to spread the sand at midday. Our observations suggested that the birds know what is happening inside the mound and vary their activity deliberately. We decided to see whether the birds could detect unusual temperatures in the mound and cope with them.

In one case we sabotaged an actively fermenting mound by removing all the organic material. The internal temperature quickly fell from 92 to 60 degrees. The male bird had been visiting the mound daily to release heat. On his next visit he detected the fall in temperature. Although it was October, he immediately began his autumn type of digging and opened the mound in the heat of the day to warm it. He did this every day, but the spring sun was not strong enough. He only managed to get the mound to 80 degrees by midsummer. In December this male was slaving away warming his mound, while all the others were busy cooling theirs. Obviously he was aware that something was afoot.

In another series of experiments we installed heating elements in a mound so that we could control its temperature. By switching the heat on or off we were able to keep the male on the jump, making him change from working to warm the mound to striving to cool it. He always detected our trickery and was so efficient that our thermostats and our 240-volt generator could barely cope with his efforts. He almost won the struggle to keep the eggs at 92 degrees.

We have no doubt that the broad pattern of activity—the time of day a bird comes to the mound, whether he opens it on a given day, and so on—is determined by the weather. But our observations and experiments show that the work actually done on the mound in the course of a particular day is determined by its internal temperature. This implies that the birds can actually measure temperature. How else could they detect the variations we had caused inside the mound with our heating elements?

When a bird is working, he frequently pauses and buries his bill in the mound, withdrawing it filled with sand, which then trickles out. The work that follows is clearly influenced by the results of this probing. We have little doubt that this is the temperature-measuring action and that the bird's "thermometer" is inside the bill; it may be either the tongue or soft palate.

The temperature-taking is particularly significant during egg-laying. The male mallee fowl opens the mound, a job that takes an hour or more. The female then comes out of the scrub and probes the place in the egg chamber that he has exposed. If she is not satisfied, she goes off and sits under a bush, and the male must refill the hole and dig another one. This may happen three or four times before she is satisfied that her egg will be placed in a suitably warm spot.

The brush turkeys measure the temperature in the same manner, but their temperature-control work is neither so prolonged nor so precise. The male brush turkey is also in charge of the mound, and he savagely drives off the female except when she wishes to lay eggs. After the mound is built, in August, the male daily turns over the fermenting material while clouds of steam rise from it. He thus keeps it well aerated until the first burst of fierce heat from the rapid fermentation has passed. Then he allows the female to lay, and for the rest of the season watches over the mound. When fermentation lags he scratches small amounts of fresh material onto the mound, and when it gets too hot he digs out the center to cool it.

The jungle fowl's task is even simpler. Those that lay in warm sand simply choose a spot with exactly the right temperature. Those that build fermentation mounds do not attempt to control them, as the mallee fowl does, apart from judging the initial composition. They do, however, select the spot for the eggs. As the season advances they scrape additional material onto the mounds, starting new cycles of fermentation in successive layers. It seems probable that for each egg the jungle fowl choose the layer that is in the appropriate state of fermentation. They probe their mounds with their bills, just as the other megapodes do, no doubt to help decide where to place each egg.

All of this egg-laying, egg-burying, mound-building and temperature-control work is directed, of course, to only one end: the production of offspring. But the birds' preoccupation with eggs keeps them so busy that they have no time for their chicks. As a result young megapodes are probably more precocious than the nestlings of any other bird.

The mallee chick hatches three feet beneath the soil; we have watched them do so behind glass. The egg bursts and the chick immediately begins his struggle, moving slowly and spasmodically upward. The journey can take 15 to 20 hours. At last its head comes through; it breathes fresh air and takes stock of the situation. The outlook must be grim. Alone and defenseless, the infant is exposed to any predator that happens along; there is little food and no water.

The chick at last works free of the mound, tumbles down the side, and struggles to the nearest bush for shelter. Here it rests for a couple of hours and then moves purposefully off into the world. It is already able to run swiftly and soon can fly up to a limb to roost in safety. Throughout its early life it remains solitary and flees from anything that moves, including other mallee fowl.

The egg that yields a mallee fowl that grows up in turn to tend its own mound in the bush is one of a small minority. The incubator system is not particularly efficient, discounting the unremitting toil it involves for the bird. Many eggs fail to hatch because of mishaps to the mound, the commonest one being thunderstorms that catch the mound open and drench its interior. Foxes and other predators dig out and eat large numbers of the oversized eggs. The chicks that do hatch often suffocate before they escape. All in all, the megapodes are no more successful in breeding than other ground-nesting birds.

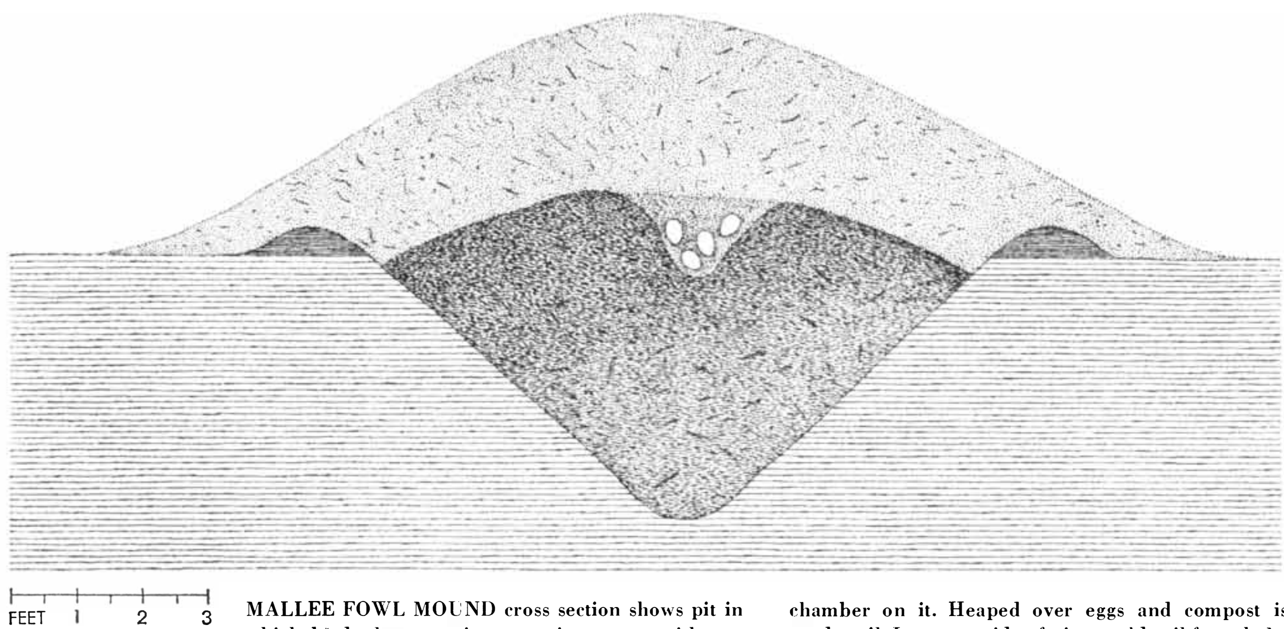
How, then, did they come to possess the mound-building habit? Some observers believe it is a survival from birds' reptilian ancestors. As the prehistoric reptiles began to develop wings and feathers, so the story goes, one group retained the habit of burying its eggs, as do turtles, crocodiles and many reptiles of today. Having watched the labors of the male mallee fowl and the less spectacular but equally precise work of the brush turkeys, however, I refuse to believe that it is a primitive characteristic. Every observation suggests that the incubation process is very highly developed and specialized.

It is more likely that the ancestors of the present-day megapodes were ground-nesting birds that developed the habit of covering their eggs with sand or leaves when leaving the nest, as a protection against predators. Several present-day birds, in fact, do this. Natural selection favored these individuals, perhaps because the covering tended to prevent severe fluctuations in the egg temperature and even, by accidental fermentation, provided some extra heat. The use of fermentation heat could have increased as the birds extended their range from the sunny beaches into the dense, shady forests.

To explain the temperature-control work of the mallee fowl we need only consider Australia's climatic history. Originally the interior of the continent was well watered and supported rain forests. It is probable that the ancestors of the mallee fowl ranged the forests building large leafy mounds like those of the present-day brush turkeys. In the Pleistocene epoch an arid cycle began, and deserts and scrub gradually replaced the forests. The birds then adopted the habit of covering the mound with sand to conserve its moisture and absorb the heat of the sun.

While the course of evolution that selected the mound-building habit may have helped the megapodes to survive, it certainly did not give them an easy way of life. It is strange to see a mallee fowl panting heavily, out in a clearing under the blazing desert sun, grimly digging in a huge pile of sand. When everything else in the bush is still and resting, the mallee fowl works. One early observer wrote: "Its actions are suggestive of melancholy, for it has none of the liveliness that characterizes almost all other birds, but stalks along in a solemn manner as if the dreary nature of its surroundings and its solitary life weighed heavily on its spirits."

Although I have a deep personal interest in these birds, I must admit that is a fair comment. They do seem to have little to live for.



MALLEE FOWL MOUND cross section shows pit in which bird places rotting organic matter, with egg chamber on it. Heaped over eggs and compost is sandy soil. Lumps at side of pit are old soil from hole.

Kodak reports on:

clear, competitive vision in the 2-8μ region of the infrared . . . an occasional dunk for the new oscillography . . . why it pays to be patient with the scientific mind . . . what $34.30 will fetch the gas chromatographer

"Irtran"—ask for it by name

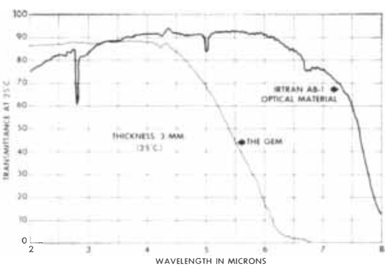
By dint of perseverance, knowledge, inspiration, judgment, experience, ambition, ingenuity, and the concentrated power of many clear heads and skillful hands, we have learned how to mold, grind, and polish a certain substance to make rugged, optically precise windows and domes that transmit efficiently the 2-8μ region of the infrared.

Around this whole package of technology we put a convenient string and tag it with a new trademark, "Irtran." Immediately—so robust is the American economy—we find ourselves in competition with some excellent fellows who also possess the above-named qualities and who make a most excellent infrared-transmitting optical material—a gem, synthetic but true, with a gem's name. To spell that name out would be as unmannerly as it is unnecessary for those caught up with infrared-actuated swords and plowshares.

Rather, we want such cognoscenti to spell out *Kodak Irtran Optics, Type AB-1.*

They cost a lot less than the gem makers have a right to ask.

They see clearly through the 3-5.5μ windows of the atmosphere.



They stay clear to at least 800°C instead of permitting Herr Kirchoff's law to blind them by their own emissivity.

They have a refractive index of only 1.301 at 6.7μ, paying scant tribute to M. Fresnel's celebrated equation about reflection losses.

They survive all the high temperature, thermal shock, weathering, humidity, and abrasion that the current tests for swords require.

Type AB-1 is only the beginning of the *Irtran* business, we suspect. Quartz was fine when lead sulfide was the practical detector; PbS quits at 4μ. Now the longer wavelength sensitivity of cooled lead selenide, lead telluride, and indium antimonide has outrun the transparency of good old quartz. Soon the boys will be banging on the 8 to 13μ window of the atmosphere. For lenses with optical power they'll want infrared-transmitting material of higher refractive index. *Type AB-1* may be only the beginning.

With what excitement the specifications for us to quote on will be drawn up and shot off to Eastman Kodak Company, Special Products Division, Rochester 4, N. Y.!

To permanize the unusual

Three good instrument manufacturers have been pushing for all they are worth a type of oscillograph that puts out a visible record instantly without chemical processing. Maybe you have one or a bank of them. They're terrific. They use *Kodak Linagraph Direct Print Paper.*

Occasionally—maybe often—you get a record that you wish had the long life that chemical processing gives. Now you can have your cake and eat it.

To offset such an old saw (an infelicitous one, moreover, to employ in discussing a prepared powder which so readily dissolves in a gallon of hot water), we have gone to the trouble of manufacturing a new word, "Permanize," as in *Kodak Linagraph Permanizing Developer.* Dunk as directed, fix, wash, and dry. No darkroom needed.

If your usual source of Kodak Linagraph Papers *cannot supply it, drop a sharp note of reproof to Eastman Kodak Company, Photo Recording Methods Division, Rochester 4, N. Y.*

Color film, fast but good

Has anything big come out of the Kodak Research Laboratories lately? Sure—*Kodak High Speed Ektachrome Film,*

now on sale at thousands of film counters in 20-exposure 135 magazines,

an outcome worth all the soothing of temperaments, all the technical conferences, all the writing and reading of reports,

a film with an Exposure Index of 160 in Daylight Type and 125 in the Type B (for 3200°K),

admitting no impairment of definition in return for speed,

asking little more light than fast black-and-white film in return for full color,

in slides that look right even if the photographer has not fussed much about the frigidity of his film storage cabinet or the color balance of his illumination,

and awfully near right at twice the official Exposure Index with three minutes more in the first developer.

Your dealer can arrange to have this film processed by Kodak or any other laboratory offering this service. You can also do it yourself with the Kodak Ektachrome Processing Kit, Process E-2, Improved Type.

Sorting out the vapors

Though these lines were written on a chilly evening in April, they are very likely being read when it's too hot for tedious ruminations on gas chromatography. All we want to do is hop on the bandwagon. Many a laboratory which had no gas chromatograph in April had one by July.

Should we be dismayed that 30¢-a-quart motor oil on ground firebrick can exhibit a differential in delay time for the components of a vapor mixture? That corn flakes or one of the popular four-letter household detergents can work? Can any serious gas chromatographer, mindful of the need for breadth of choice in stationary-phase liquids to fit instantly the largest variety of chromatographic occasions, doubt the wisdom of at once ordering

929 Benzyl Ether
3035 2-(Benzyloxy)ethanol
4738 Bis(2-ethoxyethyl) Ether
P4739 Bis[2-(2-methoxyethoxy)-ethyl] Ether
P6447 Di-n-decyl Phthalate
1968 N,N-Diethylformamide
5870 N,N-Dimethylformamide
2627 n-Propyl Sulfone
7311 Squalane
5404 Tetra-iso-butylene
P4770 Tri-iso-butylene
T4420 Tritolyl Phosphate . . . ?

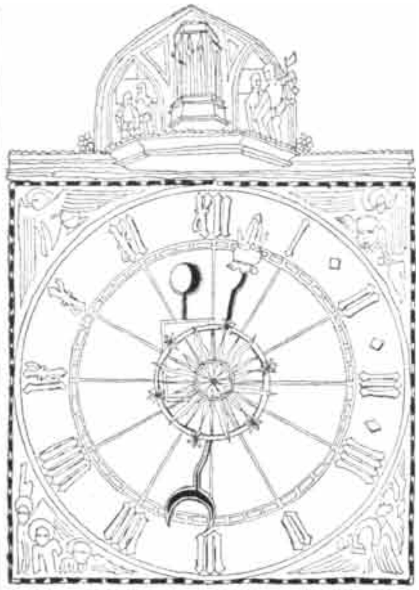
He can, but he shouldn't. A purchase order for $34.30 would fetch him the whole group, including enough of even the more expensive ones to treat a column of packing.

Have it made out to Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company). Whoever wants to fuss around looking up individual items among more than 3700 Eastman Organic Chemicals should write to the same address for List No. 41.

Price is subject to change without notice.

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

Kodak
TRADE MARK



SCIENCE AND

Biggest Dish

A radio telescope far larger than any now in existence is under construction in the mountains of West Virginia. Its saucer-shaped "dish" reflector will be 600 feet in diameter: roughly the size of Yankee Stadium in New York. Its theoretical range of 38 billion light-years—19 times that of the 200-inch telescope on Palomar Mountain—may exceed the size of the observable universe. The data it will provide on the distribution and velocities of distant galaxies should answer some of the most basic questions of cosmology, concerning the size, age and history of the universe.

The huge instrument, which is being built by the Naval Research Laboratory, was authorized in 1954 after five years of preliminary studies. The project was kept secret until recently because the telescope will have military as well as scientific applications. Work on its foundations began early this year; the instrument is expected to go into operation in 1962. It will be more than four times the size of the National Science Foundation radio telescope which is now under construction only 30 miles away, and more than twice as large as the 250-foot Jodrell Bank telescope in England, at present the world's largest. The U.S.S.R. is said to be planning a 350-foot telescope.

The giant instrument may finally settle the debate between proponents of the "evolutionary" and "steady-state" universes. The evolutionary theory holds that the universe originated in the explosion of a cloud of superdense matter some five billion years ago. On this assumption, distant galaxies should be more densely distributed than nearby ones; because of the finite velocity of light we see the distant galaxies at an earlier phase of their expansion. According to the steady-state theory, the distribution of galaxies should not change with distance, despite the expansion of the universe, because new galaxies are constantly being created.

The telescope may make possible another test of the two theories by measuring the velocities of distant galaxies. Galaxies outside our own recede at a velocity proportional to their distance. The evolutionary theory implies that very distant galaxies are moving even more rapidly than their distance requires. This effect is measurable, however, only at the extreme range of the 200-inch telescope. The new radio telescope will carry observation beyond this range to the distance at which galaxies may be unobservable. Most astronomers believe that galaxies at a distance of about 10 billion light-years are receding from our own at the speed of light. To an observer on earth, light (or radio waves) from these galaxies would be undetectable because its energy would be zero.

The new instrument should also provide an independent test of the validity of both theories. The evolutionary and the steady-state cosmologies both postulate that the universe contains much more matter than can be accounted for by the observed concentration of galaxies. The remaining matter presumably consists of hydrogen in intergalactic space. The new telescope, which is especially sensitive to the radio emissions of hydrogen, should establish whether the density of the element in intergalactic space reaches the postulated figure. If it does not, both theories will require fundamental revision.

The telescope will also be able to pick up complex signals from rockets exploring the solar system. Its designers estimate that it will make possible television reception from rockets near Saturn.

The design of the 600-foot reflector poses some knotty engineering problems. To ensure accurate reception the elements of the dish and the 100-foot antenna at its center must maintain their alignment within a fraction of an inch. However, the dish will be subject to powerful distorting forces from wind pressure and from the heat of the sun. The design therefore embodies an intricate series of servomotors that will compensate for the distortions by shifting sections of the reflector. The telescope will be aimed automatically at any point in the heavens by means of an inertial guidance system resembling that used in ballistic missiles.

The Test Conference

As it began the second year of talks on stopping nuclear tests, the Geneva Conference had before it new technical data on the sorest point under discussion: the detection of underground explosions. The report of the U. S. Panel on Seismic Improvement was transmitted last month to the delegates of the three participating nations: Great Britain, the U. S. and the U.S.S.R.

Appointed by President Eisenhower and under the chairmanship of geophysicist Lloyd V. Berkner, the Panel had addressed itself to three main problems: (1) whether presently available techniques can increase the efficiency of the 180-station detection network proposed by a group of experts at Geneva last summer; (2) whether research in seismology could lead to further improvements; (3) whether it is possible to muffle underground explosions, increasing the difficulty of distinguishing them from earthquakes.

In their original proposal the experts at Geneva relied chiefly on "first motion" to separate explosions from earthquakes. The first deep traveling-wave emitted by a quake is a compression in some directions and a rarefaction in others; an explosion produces compression in all directions. Thus if both rarefactions and compressions were picked up by a net of seismic stations, the source could be identified as an earthquake. The experts estimated that there would be only 20 to 100 quakes per year with an energy equivalent to that of 5,000 or more tons of TNT that could not be positively identified. However, according to U. S. authorities last fall's tests in Nevada indicated that these figures are far too low. The probable number was said to be several thousand.

The Panel's report suggests two improvements on the original Geneva system. The first would increase the number of seismometers at each station from 10 to 100; this would make it easier to distinguish first motion from the background noise of random vibrations. The second improvement would involve using surface waves to help separate the two types of events. The peak frequency of horizontal surface-waves is said to be twice as high for explosions as for earthquakes. With these changes, the report estimates, the network of 180 stations would have about the same capability for earthquakes with an energy equivalent of 10,000 tons and over as was originally estimated for 5,000-ton events. Furthermore, a supplementary system of unmanned seismic stations spaced at intervals of 100 miles in earthquake areas would make it possible to identify 98 per cent of earthquakes down to 1,000-ton events.

Seismological research, the Panel believes, would turn up several ways to increase efficiency of detection. In particular it mentions placing seismometers in holes several thousand feet deep to reduce background noise. In addition, computers might be helpful in reconstructing original wave-forms out of the disturbed patterns reaching distant seismic stations. The Panel recommends setting up a prototype detection-station where existing techniques could be tested and new ones tried out. Pointing out that all underground explosions thus far have been set off at one location, the group called for tests at other sites, using both ordinary and nuclear explosives.

According to the report, calculations show that the energy sent out by previous explosions can be cut 10-fold or more. Factors that influence the output are the location of the explosion, the type of rock in which it is set off and the design of the underground chamber. Further tests are needed to determine how effective the muffling can be.

Soviet delegates at Geneva continue to insist on the original experts' report as the basis for an initial agreement. They have steadily resisted any suggestion for increasing the number of inspections that would be necessary to establish the source of unidentified events.

In the opinion of the Federation of American Scientists, any agreement to ban nuclear tests will become more difficult if present U. S. plans for sharing nuclear weapons with NATO countries go into effect. Knowledge of the construction of nuclear devices will make it easier for other countries to undertake their own programs, the Federation says. Furthermore, if their armed forces are reorganized for nuclear warfare, these countries will have added incentive to develop their own weapons.

Hot Planes

Jet aircraft flying through the lower reaches of the stratosphere have been picking up patches of radioactive dust on oily parts of their surfaces. Some of these "hot spots" have a radiation intensity several hundred times that of the normal background radiation of the earth's surface. However, they do not appear to endanger the health of crews or passengers, according to the U. S. Public Health Service.

The radioactive patches first showed up a few years ago on military jets. Since the beginning of commercial jet flights last year, they have appeared on civilian planes, though these appear to be somewhat less affected because they generally fly at lower altitudes. Spectroscopic analysis has confirmed that the dust originated in nuclear explosions. Its main constituent is strontium 90.

The radiation level of the patches ranges as high as two milliroentgens per hour, somewhat higher than that of the average radium-painted wrist-watch dial (background radiation in the U. S. averages around .01 milliroentgen). While this level is well within the permissible limits specified by the Atomic Energy Commission, the swallowing or inhaling of the dust by maintenance crewmen might cause cumulative radiation poisoning. Several aircraft companies that operate jets have therefore begun to decontaminate them after each flight as a routine measure.

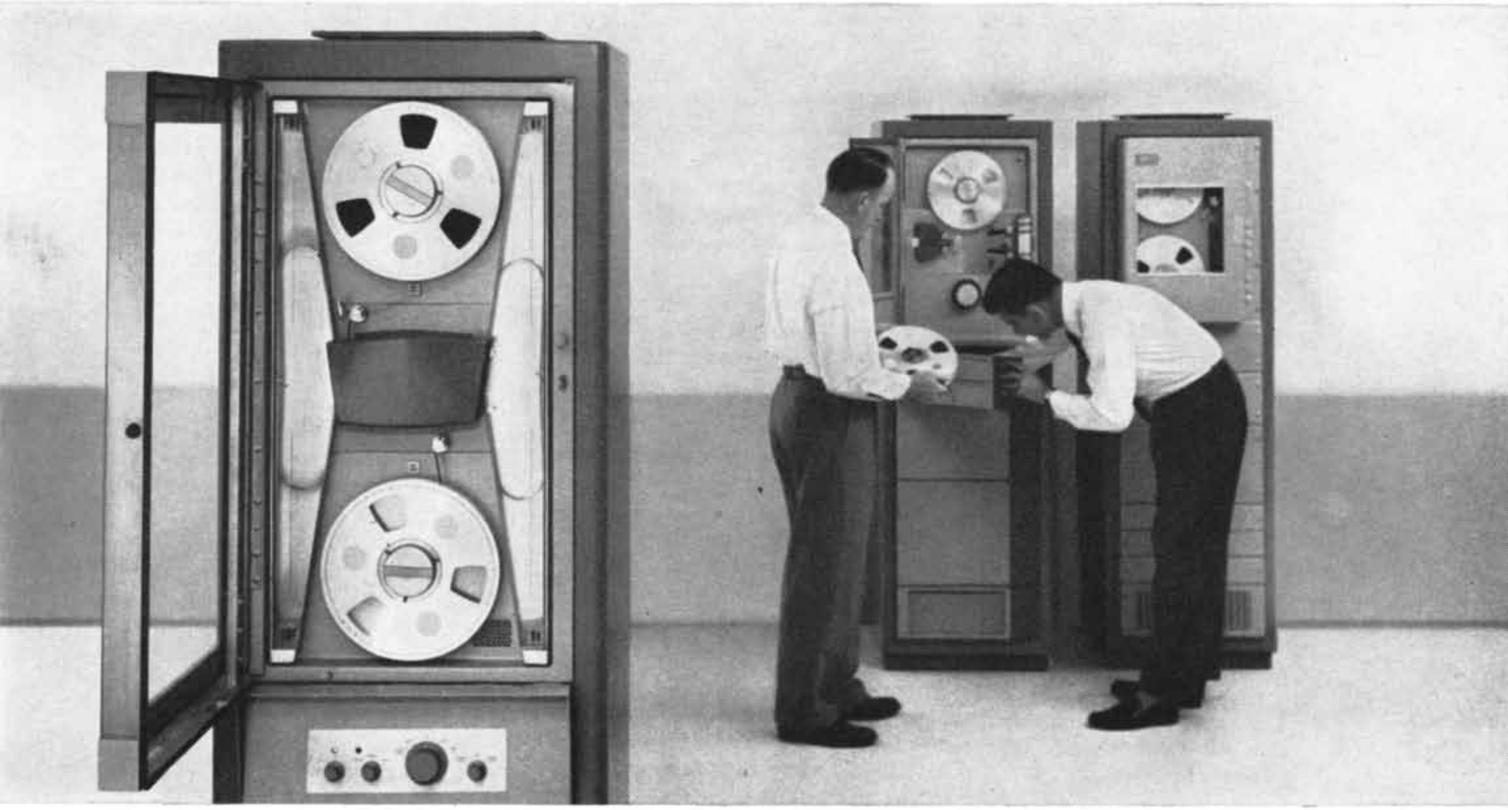
The Public Health Service is currently investigating radiation levels in the interiors of commercial jets. According to airline officials, measurements thus far have in no case exceeded normal background levels.

Radioiodine in the Thyroid

The biological importance of local concentrations of radioactive-fallout isotopes in the body has again been stressed in a recent study of iodine 131. This radioactive isotope is a minor and short-lived constituent of fallout. However, E. B. Lewis of the California Institute of Technology points out that its tendency to concentrate in the thyroid gland may greatly aggravate its capacity for biological damage. Most official estimates of the effects of fallout have assumed a uniform distribution of radioactive substances in the body.

Writing in *The Proceedings of the National Academy of Sciences*, Lewis

A five-foot bookshelf is a 10-minute task



for this AMPEX FR-300 digital tape handler

Yes, the Ampex FR-300 could easily "read" or "write" the digitalized equivalent of a five-foot bookshelf in less than ten minutes. Why is this important? Because today's big computers accept and present large quantities of data in a hurry. Their time may be worth as much as $1000 per hour. Keeping one waiting for data is expensive.

As the fastest available magnetic tape handler for "on-line" duty with these machines, the FR-300 maximizes utilization of high-speed digital computers. By placing two 6-bit alpha-numeric characters side by side on one-inch tape at 150 ips and 300 bits per inch, it achieves 90,000 character-per-second transfer rates.

Short, predictable start/stop times reduce buffer requirements and Ampex dependability further increases computer efficiency.

Ampex offers digital systems complete from head to tape (the sensational new Ampex Computer Tape, by the way) because a system designed as an integrated whole will out-perform those built from tape transports, magnetic heads, amplifiers and tape secured from a variety of different suppliers.

For lesser computers and "off-line" duty on such auxiliary digital equipment as converters, data plotters, printers, etc., the FR-400 and FR-200A tape handlers (not shown) provide a wide wide range of lower transfer rates. And in the background above are two fine analog recorders, the FR-100A and FR-1100, to remind you that only Ampex offers such a broad line of fixed and mobile recorders for instrumentation and control.

A folder on the FR-300 is available if you would like one.

First in magnetic tape instrumentation

AMPEX CORPORATION

AMPEX INSTRUMENTATION DIVISIO
934 Charter Street, Redwood City, Californi
Offices in USA and Canada. Engineering representatives cover the world.

notes that iodine tends to concentrate in cow's milk, a major item in the diet of infants and children. Most of the iodine ingested into the human body is taken up by the thyroid gland. A given amount of radioiodine ingested appears to deliver considerably more radiation to infant thyroids than to those of adults.

Last year a group of investigators measured the iodine-131 content of milk in five metropolitan milk sheds in the U. S. Basing his study on these findings, Lewis calculates that during the past few years the thyroid glands of U. S. infants and children have received an average radiation dose from radioactive iodine at least equal to that from natural background radiation. A recent statement by the Atomic Energy Commission estimates that the lifetime dose of fall-out radiation averaged over the entire body will approximate a 20th of the background radiation. Lewis also notes that there is some evidence that the thyroids of children are particularly sensitive to the cancer-producing effects of radiation.

The rapid breakdown of iodine 131 (its half-life is about eight days) makes it a short-term rather than a long-term danger. Thus Lewis indicates that infants fed on evaporated milk, which is consumed weeks or months after it comes from the cow, received little or no radioiodine. He also believes that the radioiodine level, even in fresh milk, has been insignificant since January because of the cessation of bomb testing last November.

Live-Virus Polio Vaccine

A week-long conference at Georgetown University in Washington, sponsored by the Pan American and World health organizations, heard last month that live-virus polio vaccines have been administered to five million persons, young and old, in Asia, Europe, Africa and the Americas. The vaccines appeared to be safe, and were effective in inducing polio-antibody formation in 80 to 95 per cent or better of the individuals to whom they were given.

Three different preparations were described, all worked out by well-known investigators of live-virus vaccines. One was developed by Albert B. Sabin of the University of Cincinnati; the second, by Hilary Koprowski of the Wistar Institute; the third and newest, by Herald R. Cox of Lederle Laboratories.

All three vaccines employ attenuated strains of virus obtained by many generations of serial passage through culture media. Each can contain all three antigenic types of polio virus. In the case of the Sabin and Koprowski preparations, however, three vaccines—one for each type—are often given separately, because interstrain interference has been reported in single doses. According to Cox, interstrain interference has not occurred with his vaccine, and it can be given in a single, combined dose.

The largest trials have been carried out in the U.S.S.R., and involved the Sabin vaccine. A. A. Smorodintsev of Leningrad said the Sabin preparation had been given without "any trouble" to 1.8 million children in Latvia, Byelorussia and Moldavia. M. P. Chumakov of Moscow reported its use in 1.5 million persons in other parts of the U.S.S.R. "with very good results, indicating complete safety, reactivity and high immunologic efficiency." Smaller trials of the Cox vaccine were reported from Pearl River, N. Y., and from a married-student community at the University of Minnesota; of the Koprowski vaccine, from the Belgian Congo.

The immediate attraction of live-virus polio vaccines is low cost and ease of administration. In contrast to Salk vaccine, a killed-virus preparation, live-virus polio vaccines can be given by mouth. Moreover, the required dose is smaller, since virus multiplication takes place in the patient and only part of the virus material required to induce immunity need be produced in a factory. A. M. M. Payne of the World Health Organization told the conference that live-virus vaccines would permit polio immunization in underdeveloped countries at a 10th of the cost of Salk vaccine.

One school of immunologists is also convinced that even single doses of live vaccines can induce stronger, longer-lasting immunity to polio than the Salk vaccine does. But immediately after the conference Surgeon General Leroy E. Burney indicated that the U. S. Public Health Service would follow a policy of caution on live-virus polio vaccines, particularly in view of the existence of the Salk vaccine. Further tests would be required, he said, especially to make sure that there is no danger of the attenuated viruses reverting to virulent type, before a live polio vaccine would be licensed.

Polio-Virus Architecture

The poliomyelitis virus, a sphere three millionths of a centimeter in diameter, is one of the smallest of all viruses. Its over-all dimensions were measured directly only recently. Now British biophysicists have begun to discover the detailed structure of the tiny particle.

J. T. Finch and A. Klug of the University of London study the crystals of polio virus by means of X-rays. In the pattern of diffracted rays they can discern not only the cubic stacking of virus particles in the crystal, but also something of the make-up of the individual spheres. Like all viruses, the polio agent consists of nucleic acid enclosed in a protein coat. It is the coat whose structure determines the X-ray pattern. Finch and Klug, reporting their findings in *Nature,* have deduced that the coat is made up of exactly 60 small protein molecules, identical (or nearly so) and about six 10-millionths of a centimeter across, packed together to form a spherical shell around the nucleic-acid core.

Earlier studies of two small plant-viruses showed that they too contain 60 protein molecules arranged in the same fashion. According to the London crystallographers the requirements of spatial symmetry may force this structure on all small spherical viruses.

Toward the Mohole

If funds become available in time, a first attempt to drill a hole in the deep-ocean floor will be made this fall as a preliminary to the Mohole, the miles-deep shaft U. S. geophysicists hope to bore through the earth's crust to the underlying mantle [see "The Mohole," by Willard Bascom; SCIENTIFIC AMERICAN, April]. The effort is to be made with *Cuss I,* the experimental barge of the Continental-Union-Shell-Superior offshore drilling group, and will be attempted in 3,000 feet of water in the channel between Catalina Island and the mainland of southern California. If the drilling is successful, *Cuss I* will move to the other side of Catalina Island and try another shaft in 6,000 feet of water. If this is accomplished, the barge will then go to Guadalupe Island, 200 miles south of San Diego, for an attempt to sink a 1,000-foot hole in sediments below 12,000 feet of water. The target date for completion of all three test holes is July 1, 1960.

Plans for the test holes were included in an outline of the Mohole project prepared by Gordon Lill, chairman, and Willard Bascom, technical director, of the National Academy of Sciences' AMSOC-Mohole Committee. The outline was presented late in June to the oceanography subcommittee of the House Committee on Merchant Marine and Fisheries.

The Mohole project, the Lill-Bascom statement estimated, will cost a total of $15 million: $3 million for the test holes; $9.5 million for design and construction of the special floating rig that will be required for the Mohole, and for the drilling of the Mohole itself; and $2.5 million for data evaluation. Meanwhile the National Academy has authorized the AMSOC-Mohole Committee to accept from the government or other sources up to $2.5 million for work on the unprecedented drilling project.

A detailed survey of one of the areas under consideration as a possible drilling site—the Outer Ridge area of the Atlantic 150 miles north of Puerto Rico—was completed in mid-June by a four-ship flotilla headed by the Columbia University research vessel *Vema.* At the end of June three Scripps Oceanographic Institution vessels left San Diego to survey a possible Pacific drilling site to the east of Guadalupe.

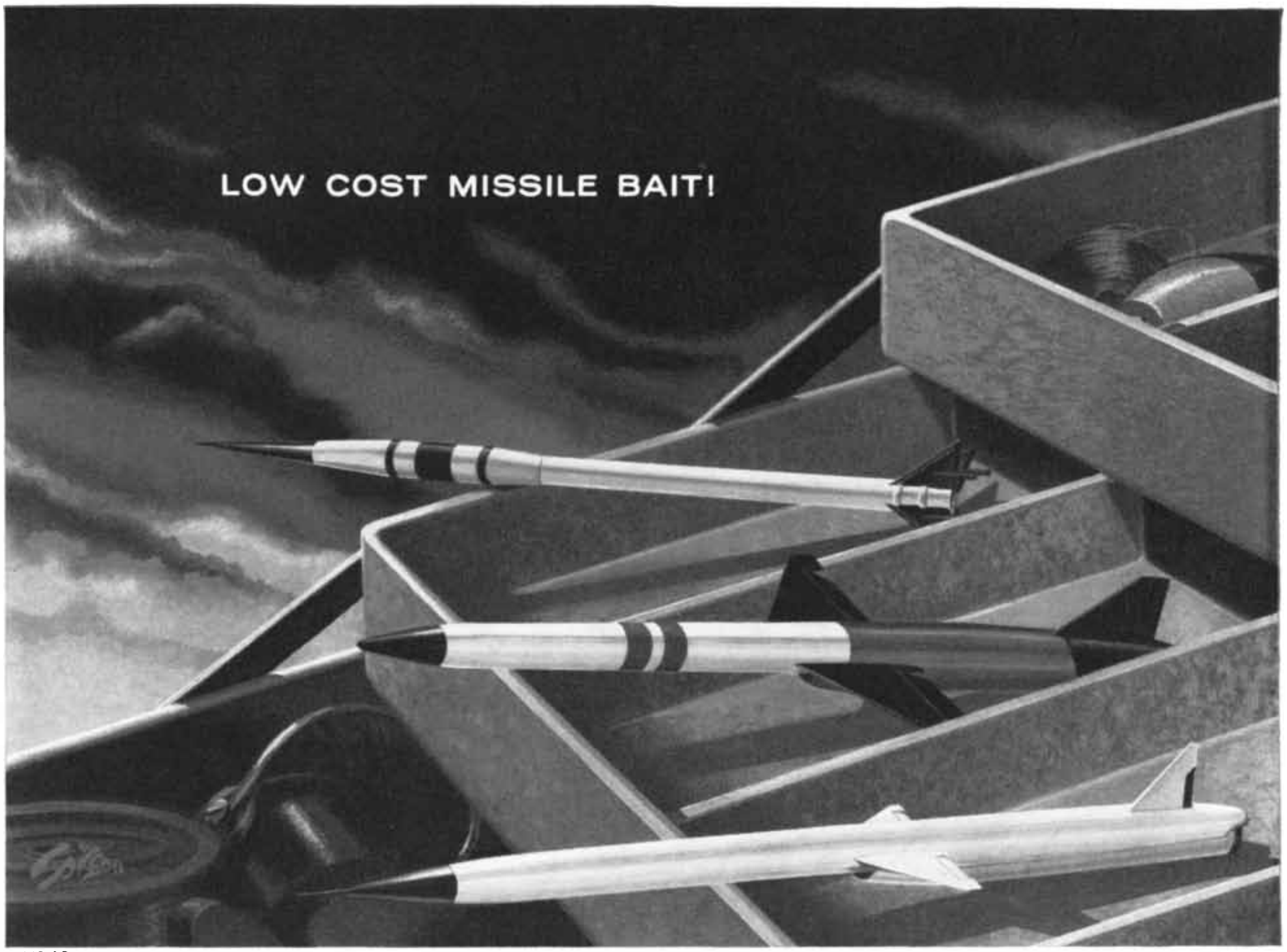
Whatever the outcome of the Mohole project, the Outer Ridge region of the Atlantic is now the world's best explored oceanic area. During 18 days of day-and-night seismic shooting, the four ships in the Outer Ridge survey fired a record $100,000 worth of explosives to obtain three 250-mile-long north-south profiles of the ocean bottom, and many shorter east-west profiles. Numerous bottom cores were also taken, and magnetic, bottom-depth, bottom-temperature and other studies were carried out.

The object of the drilling-site surveys is not only to choose a place where the earth's crust is thin and drilling conditions generally favorable, but also to pick a typical geological area for the first hole to the mantle. A final decision on the actual Mohole site will be made early in 1960, after a study of the data from the Outer Ridge and Pacific surveys.

Aid for Oceanography

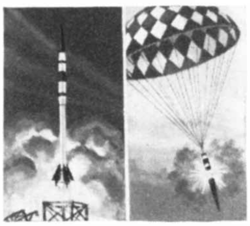
U. S. oceanographers have long had to carry out the often arduous tasks of sea research on ships that are generally small, frequently old and ill adapted to oceanographic work, and almost always miserably uncomfortable. A new deal for oceanographers should commence late in the summer of 1960, when the first of a fleet of 18 Navy-built research vessels is ready for sea.

The ships are to be constructed under TENOC, a 10-year program for the support of oceanography drawn up by the Office of Naval Research. Along with operating funds, the ships will be furnished to the dozen U. S. institutions engaged in deep-sea research. Additional grants are also to be made under TENOC to double, over the 10-year period, over-all U. S. oceanographic research facilities.

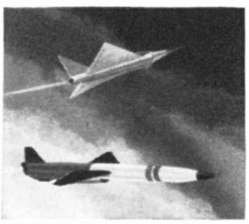


8442-AC

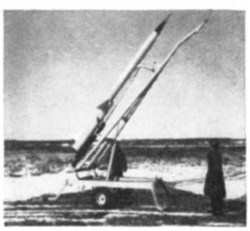
AERONCA TARGET MISSILES PERFORM A VARIETY OF MISSION PROFILES... WITH SUBSTANTIAL ECONOMY



POGO-HI
(II E3c)



P-107
AIR LAUNCHED



P-106
GROUND LAUNCHED

The adage "practice makes perfect" keynotes today's concept of missile warfare. Against supersonic targets, there isn't time for "the second barrel". Therefore, extensive operational testing of air defence systems . . . and training programs for personnel who operate them . . . must be conducted to assure national preparedness.

To accomplish this requirement at minimum cost, Aeronca has developed two expendable, lightweight, high-performance target systems under the Design-Tool-Produce envelope concept. These proprietary missile programs, the P-106 and P-107, are designed for supersonic performance and accurate scoring at all required altitudes, speeds and ranges. *And their production cost is projected to be substantially less than any current target missile system!*

Another Aeronca-produced missile project is *Pogo-Hi II E3c*. Ground launched to high altitudes, this target utilizes a radar reflective parachute and an infrared emitter package. It is used as "bait" for such current projects as *Nike, Talos, Sidewinder* and *Falcon*.

With integrated Design, Tooling and Production capabilities, Aeronca can produce weapon systems envelopes at either prime or subcontractor levels.

AERONCA manufacturing corporation
1722 GERMANTOWN ROAD • MIDDLETOWN, OHIO

Operational expansion has created openings for additional senior engineers. Write to W. W. Gordinier, Personnel Manager.

Construction of the first of the new research vessels is called for in the Navy building program for the fiscal year 1960. It will be 204 feet long and displace about 1,500 tons, a size considered by most oceanographers as a satisfactory compromise between the need for operating economy and for a vessel with adequate laboratory space and capable of carrying heavy gear.

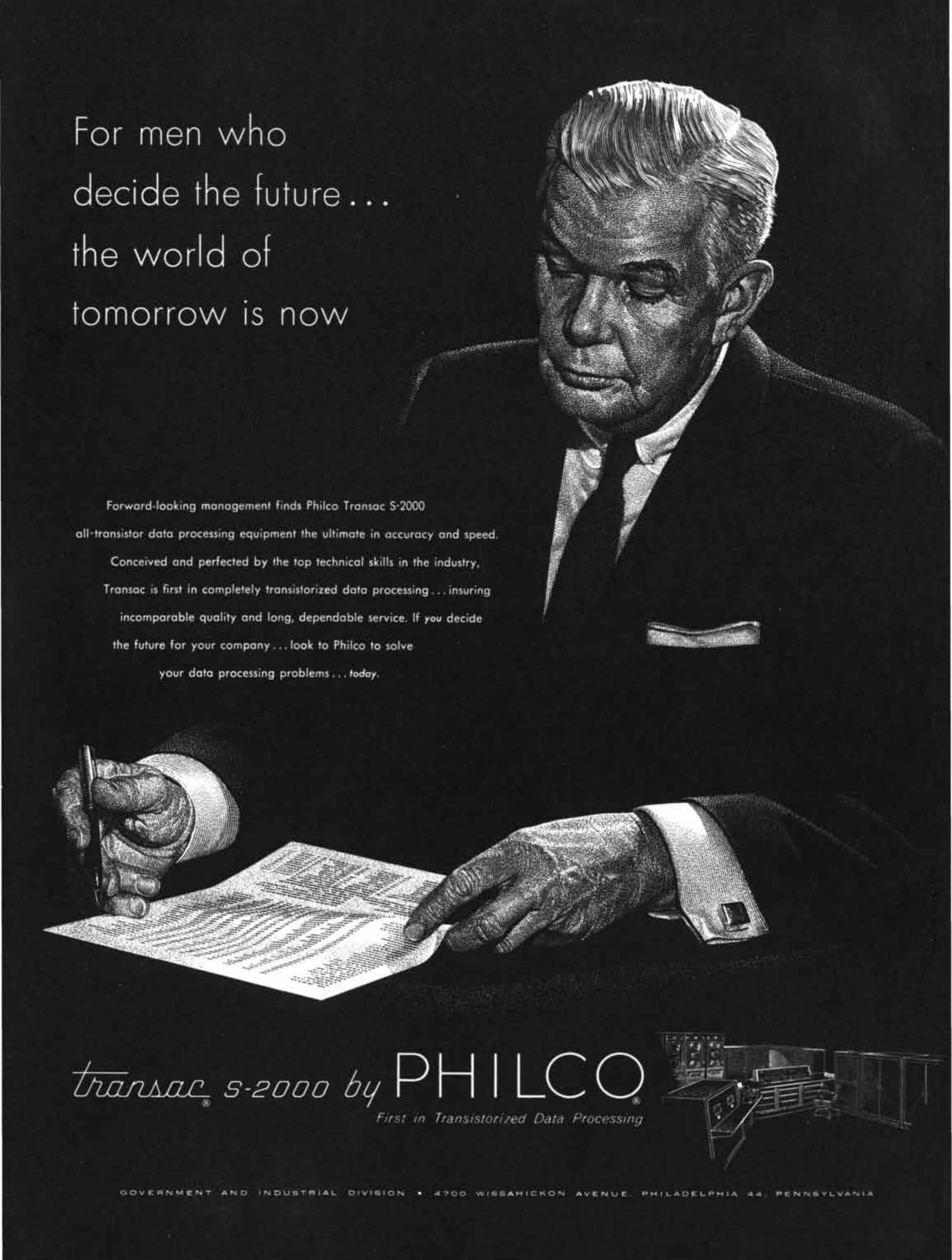
The most welcome improvement over existing research vessels, ONR officials said, will be in the living quarters for the scientific party. Special features will include a cruising range of 14,000 miles and a gas turbine in a vibration-proof mounting at the top of the funnel to supply power during "silent ship" (when engines and other noise-making equipment must be turned off to prevent interference with listening hydrophones). The ship, which will cost $4 million, will be delivered to the institution—not yet chosen—that is to operate it, complete with all standard gear, including a heavy winch for an ocean-bottom corer. Scientific equipment will be installed by the operating institution.

Designs of the remaining 17 vessels are not yet fixed, but the majority are expected to be comparable in size to the first. All of the vessels are to be completed by 1965.

Caged Radiokrypton

Some of the dangers inherent in the industrial use of radioactive isotopes may be sharply reduced by a new method of utilizing krypton 85, a radioactive isotope produced by the fission of uranium in nuclear reactors. D. J. Chleck and C. A. Ziegler of Tracerlab, Inc., have evolved a technique for trapping krypton atoms in the crystal lattice of the coal-tar derivative hydroquinone, much as other atoms can be trapped in zeolite "molecular sieves" [see "Molecular Sieves," by D. W. Breck and J. V. Smith; SCIENTIFIC AMERICAN, January].

Krypton 85 is an ideal source of ionizing radiation for many industrial purposes. Its relatively "soft" beta rays minimize the need for shielding, and because krypton is chemically inert it cannot enter into the metabolic processes of the human body. Heretofore, however, the usefulness of the isotope has been limited by the fact that krypton is a gas at ordinary temperatures. In order to use krypton 85 as a reasonably compact source of beta rays, the gas must be compressed in thick-walled containers that absorb much of its radiation. What Chleck and Ziegler have done is to make a krypton-hydro-quinone

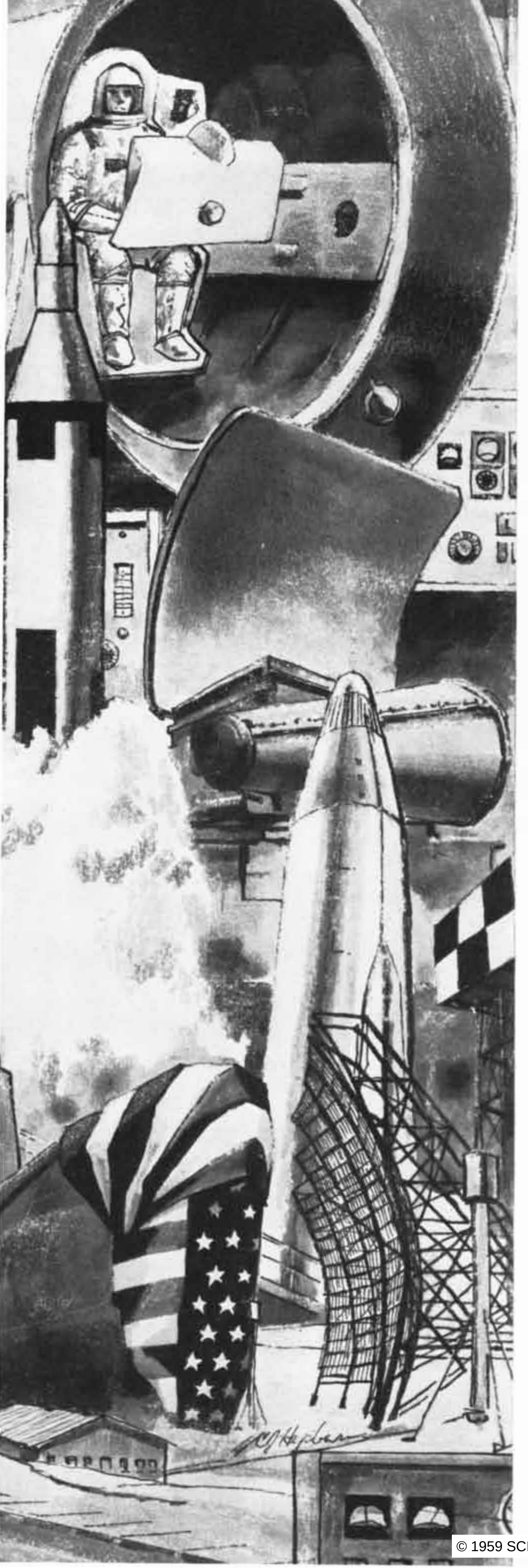

For men who
decide the future...
the world of
tomorrow is now
Forward-looking management finds Philco Transac S-2000 all-transistor data processing equipment the ultimate in accuracy and speed. Conceived and perfected by the top technical skills in the industry, Transac is first in completely transistorized data processing... insuring incomparable quality and long, dependable service. If *you* decide the future for your company... look to Philco to solve your data processing problems... *today*.
transac® S-2000 by PHILCO®
First in Transistorized Data Processing
GOVERNMENT AND INDUSTRIAL DIVISION • 4700 WISSAHICKON AVENUE, PHILADELPHIA 44, PENNSYLVANIA

"clathrate" (from the Greek word meaning "lattice") by heating the two substances together in a pressure bomb and cooling them slowly. The resulting crystals form a stable and almost leakproof container for the krypton trapped within them. They produce radiation more than 25 times as intense as that from an equal volume of krypton gas at atmospheric pressure.

Chleck and Ziegler suggest that their radioactive clathrates will lend themselves well to measuring the thickness of light materials such as paper. For gauging heavier materials requiring more penetrating radiation, they suggest mixing the crystals with substances that emit X-rays when irradiated by krypton 85. The crystals can also serve to detect the presence of minute amounts of certain substances. If these substances dissolve or oxidize the clathrate, they will release krypton; the radiation of the released gas provides a sensitive measure of the contaminating substance. An experimental air-pollution monitor based on this principle can detect concentrations of sulfur dioxide or ozone as low as a few parts per billion.

A Jug of Wine

A tide of fermented grape juice may have helped carry Bronze Age civilization from the Near East and the Aegean to southern Europe and thence northward. So suggests the British archaeologist Stuart Piggott in the journal *Antiquity*. Among the artifacts that typify the period are beaten-bronze vessels—bowls, buckets, cups, dippers and strainers—which were almost certainly designed for holding, serving and drinking wine. (The strainers in particular are a tip-off, Piggott says; the ancients' habit of adulterating wine with sea water, salt, pitch, pounded marble or potter's earth made for a sludgy potion.) The containers were manufactured in the grape-growing areas of Europe from about 1200 B. C. They are found over much of the rest of the continent as far north as Scandinavia. Apparently wine merchants, who presumably carried them north, are partly responsible for the spread of Bronze Age technology. "It is tempting to think," observes Piggott, "that the new bronze vessels manufactured and traded in continental Europe from the 12th century B.C. may not only have had a technical link with the Aegean or Levantine world in their mode of manufacture, but have owed their popularity, at least in part, to the civilizing qualities of their content."



General Electric moves to provide a more effective

DEFENSE

Top systems management, technical talent are concentrated in Defense Systems Department with a charter geared to modern defense needs for:

- **Systems-oriented management**
- **Pinpointed authority, responsibility**
- **Full back-up resources**

DIFFRACTION OF OCEAN WAVES is clearly visible in this aerial photograph of Morro Bay, Calif. The waves are diffracted as they pass the end of the lower jetty. Variations in the way the waves break are caused by contours of the shore and the bottom.

OCEAN WAVES

Men have always been fascinated, and sometimes awed, by the rhythmic motions of the sea's surface. A century of observation and experiment has revealed much about how these waves are generated and propagated

by Willard Bascom

Man is by nature a wave-watcher. On a ship he finds himself staring vacantly at the constant swell that flexes its muscles just under the sea's surface; on an island he will spend hours leaning against a palm tree absently watching the rhythmic breakers on the beach. He would like to learn the ways of the waves merely by watching them, but he cannot, because they set him dreaming. Try to count a hundred waves sometime and see.

Waves are not always so hypnotic. Sometimes they fill us with terror, for they can be among the most destructive forces in nature, rising up and overwhelming a ship at sea or destroying a town on the shore. Usually we think of waves as being caused by the wind, because these waves are by far the most common. But the most destructive waves are generated by earthquakes and undersea landslides. Other ocean waves, such as those caused by the gravitational attraction of the sun and the moon and by changes in barometric pressure, are much more subtle, often being imperceptible to the eye. Even such passive elements as the contour of the sea bottom, the slope of the beach and the curve of the shoreline play their parts in wave action. A wave becomes a breaker, for example, because as it advances into increasingly shallow water it rises higher and higher until the wave front grows too steep and topples forward into foam and turbulence. Although the causes of this beautiful spectacle are fairly well understood, we cannot say the same of many other aspects of wave activity. The questions asked by the wave-watcher are nonetheless being answered by intensive studies of the sea and by the examination of waves in large experimental tanks. The new knowledge has made it possible to measure the power and to forecast the actions of waves for the welfare of those who live and work on the sea and along its shores.

Toss a pebble into a pond and watch the even train of waves go out. Waves at sea do not look at all like this. They are confused and irregular, with rough diamond-shaped hillocks and crooked valleys. They are so hopelessly complex that 2,000 years of observation by seafarers produced no explanation beyond the obvious one that waves are somehow raised by the wind. The description of the sea surface remained in the province of the poet who found it "troubled, unsettled, restless. Purring with ripples under the caress of a breeze, flying into scattered billows before the torment of a storm and flung as raging surf against the land; heaving with tides breathed by a sleeping giant."

The motions of the oceans were too complex for intuitive understanding. The components had to be sorted out and dealt with one at a time. So the first theoreticians cautiously permitted a perfect train of waves, each exactly alike, to travel endlessly across an infinite ocean. This was an abstraction, but it could at least be dealt with mathematically.

Early observers noticed that passing waves move floating objects back and forth and up and down, but do not transport them horizontally for any great distance. From the motion of seaweeds the motion of the water particles could be deduced. But it was not until 1802 that Franz Gerstner of Germany constructed the first wave theory. He showed that water particles in a wave move in circular orbits. That is, water at the crest moves horizontally in the direction the wave is going, while in the trough it moves in the opposite direction. Thus each water particle at the surface traces a circular orbit, the diameter of which is equal to the height of the wave [*see illustration on next page*]. As each wave passes, the water returns almost to its original position. Gerstner observed that the surface trace of a wave is approximately a trochoid: the curve described by a point on a circle as it rolls along the underside of a line. His work was amplified by Sir George Airy later in the 19th century, by Horace Lamb of England in the present century, and by others.

The first wave experimentalists were Ernst and Wilhelm Weber of Germany, who in 1825 published a book on studies employing a wave tank they had invented. Their tank was five feet long, a foot deep and an inch wide, and it had glass sides. To make waves in the tank they sucked up some of the fluid through a tube at one end of it and allowed the fluid to drop back. Since the Weber brothers experimented not only with water and mercury but also with brandy, their persistence in the face of temptation has been an inspiration to all subsequent investigators. They discovered that waves are reflected without loss of energy, and they determined the shape of the wave surface by quickly plunging in and withdrawing a chalk-dusted slate. By watching particles suspended in the water they confirmed the theory that water particles move in a circular orbit, the size of which diminishes with depth. At the bottom, they observed, these orbits tend to be flattened.

As increasingly bolder workers contributed ideas in the 20th century, many of the complexities of natural waves found their way into equations. However, these gave only a crude, empirical answer to the question of how wind energy is transferred to waves. The necessity for the prediction of waves and surf for amphibious operations in World War II attracted the attention of Harald U.

Sverdrup and Walter Munk of the Scripps Institution of Oceanography. As a result of their wartime studies of the interaction of winds and waves they were the first investigators to give a reasonably complete quantitative description of how wind gets energy into the waves. With this description wave studies seemed to come of age, and a new era of research was launched.

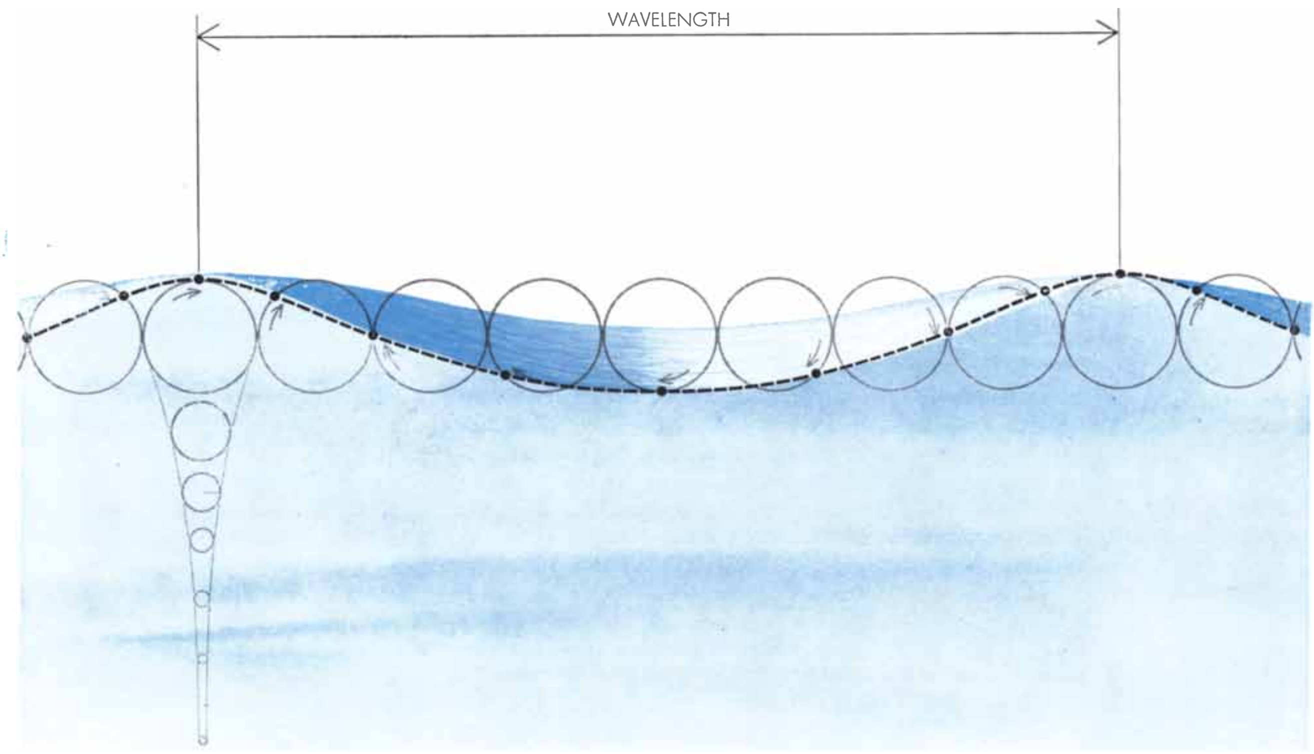
Let us follow waves as they are generated at sea by the wind, travel for perhaps thousands of miles across the ocean and finally break against the shore. The effectiveness of the wind in making waves is due to three factors: its average velocity, the length of time it blows and the extent of the open water across which it blows (called the fetch).

Waves and the Wind

Waves start up when the frictional drag of a breeze on a calm sea creates ripples. As the wind continues to blow, the steep side of each ripple presents a surface against which the moving air can press directly. Because winds are by nature turbulent and gusty, wavelets of all sizes are at first created. The small, steep ones break, forming whitecaps, releasing some of their energy in turbulence and possibly contributing part of it to larger waves that overtake them. Thus as energy is added by the wind the smaller waves continually give way to larger ones which can store the energy better. But more small waves are continually formed, and in the zone where the wind moves faster than the waves there is a wide spectrum of wavelengths. This is the generating area, and in a large storm it may cover thousands of square miles. If storm winds apply more force than a wave can accept, the crest is merely steepened and blown off, forming a breaking wave at sea. This happens when the wave crest becomes a wedge of less than 120 degrees and the height of the wave is about a seventh of its length. Thus a long wave can accept more energy from the wind and rise much higher than a short wave passing under the same wind. When the wind produces waves of many lengths, the shortest ones reach maximum height quickly and then are destroyed, while the longer ones continue to grow.

A simple, regular wave-train can be described by its period (the time it takes two successive crests to pass a point), by its wavelength (the distance between crests) and by its height (the vertical distance between a trough and a succeeding crest). Usually, however, there are several trains of waves with different wavelengths and directions present at the same time, and their intersection creates a random or a short-crested diamond pattern. Under these conditions no meaningful dimensions can be assigned to wave period and length. Height, however, is important, at least to ships; several crests may coincide and add their heights to produce a very large wave. Fortunately crests are much more likely to coincide with troughs and be canceled out. There is no reason to believe that the seventh wave, or some other arbitrarily numbered wave, will be higher than the rest; that is a myth of the sea.

Since waves in a sea are so infinitely variable, statistical methods must be employed to analyze and describe them. A simple way to describe height, for example, is to speak of significant height—the average height of the highest third of the waves. Another method, devised in 1952 by Willard J. Pierson, Jr., of New York University, employs equations like those that describe random noise in information theory to predict the behavior of ocean waves. Pierson superposes the regular wave-trains of classical theory in such a way as to obtain a mathematically irregular pattern. The result is most conveniently described in terms of energy spectra. This scheme assigns a value for the square of the wave height to each



CROSS SECTION OF OCEAN WAVE traveling from left to right shows wavelength as distance between successive crests. The time it takes two crests to pass a point is the wave period. Circles are orbits of water particles in the wave. At the surface their diameter equals the wave height. At a depth of half the wavelength (*left*), orbital diameter is only 4 per cent of that at surface.

frequency and direction. Then, by determining the portion of the spectrum in which most of the energy is concentrated, the average periods and lengths can be obtained for use in wave forecasting.

Over a long fetch, and under a strong, steady wind, the longer waves predominate. It is in such areas of sea that the largest wind waves have been recorded. The height of the waves in a train does not, however, bear any simple relationship to their other two dimensions: the period and the wavelength. The mariner's rule of thumb relates wave height to wind velocity and says that the height ordinarily will not be greater than half the wind speed. This means that an 80-mile-per-hour hurricane would produce waves about 40 feet high.

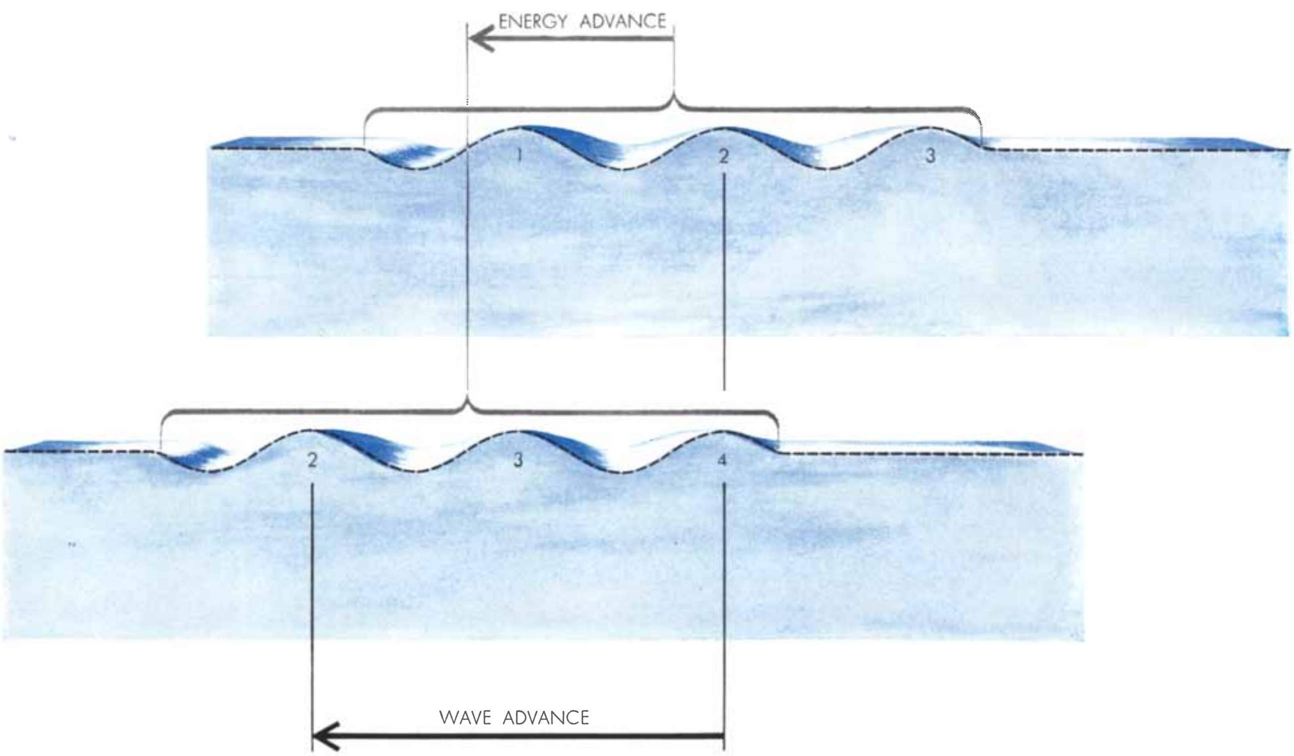
The question of just how large individual waves at sea can actually be is still unsettled, because observations are difficult to make and substantiate from shipboard in the midst of a violent storm. Vaughan Cornish of England spent half a century collecting data on waves, and concluded that storm waves over 45 feet high are rather common. Much higher waves have been fairly well authenticated on at least two occasions.

In October, 1921, Captain Wilson of the 12,000-ton S.S. *Ascanius* reported an extended storm in which the recording barometer went off the low end of the scale. When the ship was in a trough on an even keel, his observation post on the ship was 60 feet above the water level, and he was certain that some of the waves that obscured the horizon were at least 10 feet higher than he was, accounting for a total height of 70 feet or more. Commodore Hayes of the S.S. *Majestic* reported in February, 1923, that his ship had experienced winds of hurricane force and waves of 80 feet in height. Cornish examined the ship, closely interrogated the officers and concluded that waves 60 to 90 feet high, with an average height of 75 feet, had indeed been witnessed.

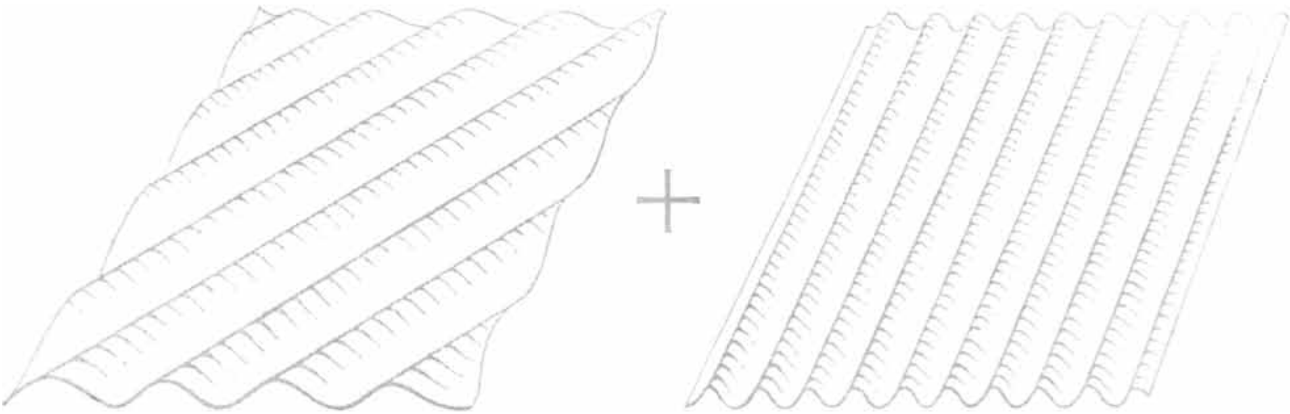
A wave reported by Lieutenant Commander R. P. Whitemarsh in the *Proceedings of the U. S. Naval Institute* tops all others. On February 7, 1933, the *U.S.S. Ramapo,* a Navy tanker 478 feet long, was en route from Manila to San Diego when it encountered "a disturbance that was not localized like a typhoon . . . but permitted an unobstructed fetch of thousands of miles." The barometer fell to 29.29 inches and the wind gradually rose from 30 to 60 knots over several days. "We were running directly downwind and with the sea. It would have been disastrous to have steamed on any other course." From among a number of separately determined observations, that of the watch officer on the bridge was selected as the most accurate. He declared that he "saw seas astern at a level above the mainmast crow's-nest and at the moment of observation the horizon was hidden from view by the waves approaching the stern." On working out the geometry of the situation from the ship's plan, Whitemarsh found that this wave must have been at least 112 feet high [*see illustration at the bottom of the next two pages*]. The period of these waves was clocked at 14.8 seconds and their velocity at 55 knots.

As waves move out from under the winds that raise them, their character changes. The crests become lower and more rounded, the form more symmetrical, and they move in trains of similar period and height. They are now called swell, or sometimes ground swell, and in this form they can travel for thousands of miles to distant shores. Happily for mathematicians, swell coincides much more closely with classical theory than do the waves in a rough sea, and this renews their faith in the basic equations.

Curiously enough, although each wave moves forward with a velocity



MOVING TRAIN OF WAVES advances at only half the speed of its individual waves. At top is a wave train in its first position. At bottom the train, and its energy, have moved only half as far as wave 2 has. Meanwhile wave 1 has died, but wave 4 has formed at the rear of the train to replace it. Waves arriving at shore are thus remote descendants of waves originally generated.



DIFFERENT TRAINS OF WAVES, caused by winds of different directions and strengths, make up the surface of a "sea." The various trains, three of which are represented diagrammatically here, have a wide spectrum of wavelengths, heights and directions. When

that corresponds to its length, the energy of the group moves with a velocity only half that of the individual waves. This is because the waves at the front of a group lose energy to those behind, and gradually disappear while new waves form at the rear of the group. Thus the composition of the group continually changes, and the swells at a distance are but remote descendants of the waves created in the storm [*see illustration on preceding page*]. One can measure the period at the shore and obtain from this a correct value for the wave velocity; however, the energy of the wave train traveled from the storm at only half that speed.

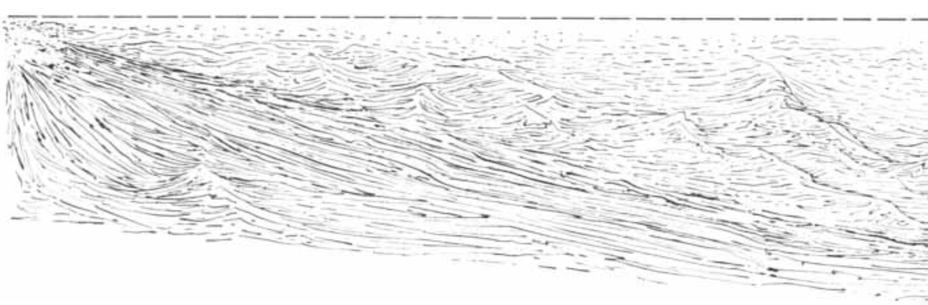
Waves in a swell in the open ocean are called surface waves, which are defined as those moving in water deeper than half the wavelength. Here the bottom has little or no effect on the waves because the water-particle orbits diminish so rapidly with depth that at a depth of half the wavelength the orbits are only 4 per cent as large as those at the surface. Surface waves move at a speed in miles per hour roughly equal to 3.5 times the period in seconds. Thus a wave with a period of 10 seconds will travel about 35 miles per hour. This is the average period of the swell reaching U. S. shores, the period being somewhat longer in the Pacific than the Atlantic. The simple relationship between period and wavelength (length $=5.12T^2$) makes it easy to calculate that a 10-second wave will have a deep-water wavelength of about 512 feet. The longest period of swell ever reported is 22.5 seconds, which corresponds to a wavelength of around 2,600 feet and a speed of 78 miles per hour.

Waves and the Shore

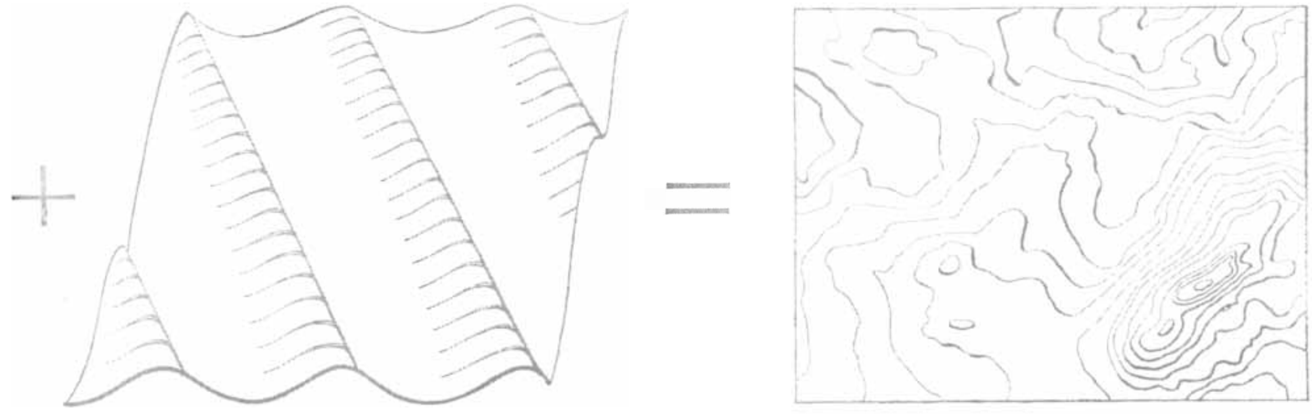
As the waves approach shore they reach water shallower than half their wavelength. Here their velocity is controlled by the depth of the water, and they are now called shallow-water waves. Wavelength decreases, height increases and speed is reduced; only the period is unchanged. The shallow bottom greatly modifies the waves. First, it refracts them, that is, it bends the wave fronts to approximate the shape of the underwater contours. Second, when the water becomes critically shallow, the waves break [*see illustration on page 84*].

Even the most casual observer soon notices the process of refraction. He sees that the larger waves always come in nearly parallel to the shoreline, even though a little way out at sea they seem to be approaching at an angle. This is the result of wave refraction, and it has considerable geological importance because its effect is to distribute wave energy in such a way as to straighten coastlines. Near a headland the part of the wave front that reaches shallow water first is slowed down, and the parts of it in relatively deep water continue to move rapidly. The wave thus bends to converge on the headland from all sides. As it does, the energy is concentrated in less length of crest; consequently the height of the crest is increased. This accounts for the old sailors' saying: "The points draw the waves."

Another segment of the same swell will enter an embayment and the wave front will become elongated so that the height of the waves at any point along the shore is correspondingly low. This is why bays make quiet anchorages and exposed promontories are subject to wave battering and erosion—all by the same waves. One can deal quantitatively with this characteristic of waves and can plot the advance of any wave across waters of known depths. Engineers planning shoreline structures such as jetties or piers customarily draw refraction diagrams to determine in advance the effect of waves of various periods and direction. These diagrams show successive



WAVE 112 FEET HIGH, possibly the largest ever measured in the open sea, was encountered in the Pacific in 1933 by the *U.S.S. Ramapo,* a Navy tanker. This diagram shows



they meet, the result is apparent confusion, represented at far right by a topographic diagram drawn from actual photographs of the sea surface. The pattern becomes so complex that statistical methods must be used to analyze the waves and predict their height.

positions of the wave front, partitioned by orthogonals into zones representing equal wave energy [*see illustration on next page*]. The ratio of the distances between such zones out at sea and at the shore is the refraction coefficient, a convenient means of comparing energy relationships.

Refraction studies must take into account surprisingly small underwater irregularities. For example, after the Long Beach, Calif., breakwater had withstood wave attack for years, a short segment of it was suddenly wrecked by waves from a moderate storm in 1930. The breakwater was repaired, but in 1939 waves breached it again. A refraction study by Paul Horrer of the Scripps Institution of Oceanography revealed that long-period swell from exactly 165 degrees (south-southeast), which was present on only these two occasions, had been focused at the breach by a small hump on the bottom, 250 feet deep and more than seven miles out at sea. The hump had acted as a lens to increase the wave heights to 3.5 times average at the point of damage.

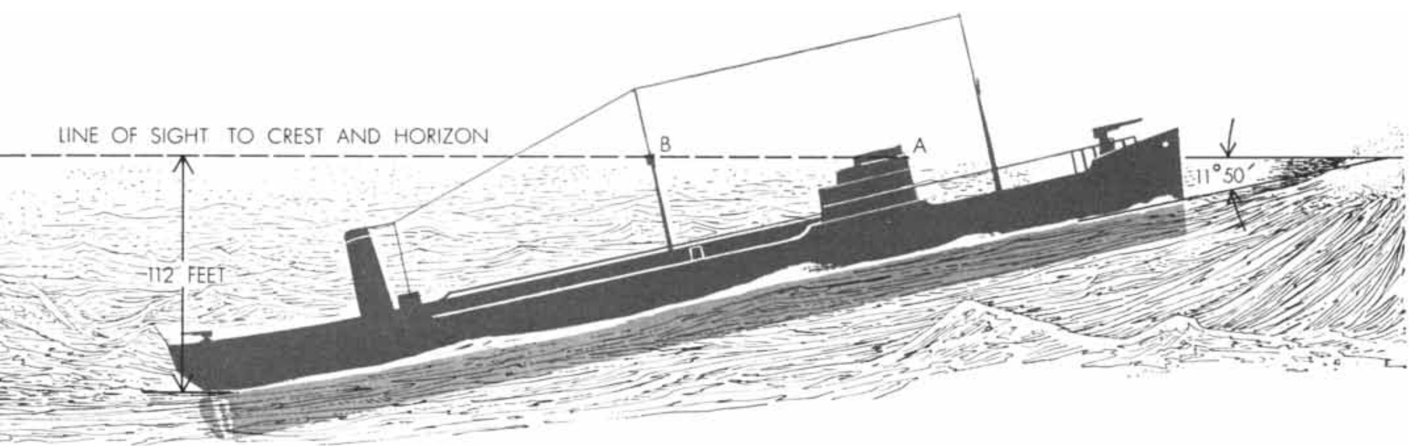
During World War II it was necessary to determine the depth of water off enemy-held beaches against which amphibious landings were planned. Our scientists reversed the normal procedure for refraction studies; by analyzing a carefully timed series of aerial photographs for the changes in length (or velocity) and direction of waves approaching a beach, they were able to map the underwater topography.

The final transformation of normal swell by shoal or shallow water into a breaker is an exciting step. The waves have been shortened and steepened in the final approach because the bottom has squeezed the circular orbital motion of the particles into a tilted ellipse; the particle velocity in the crest increases and the waves peak up as they rush landward. Finally the front of the crest is unsupported and it collapses into the trough. The wave has broken and the orbits exist no more. The result is surf.

If the water continues to get shallower, the broken wave becomes a foam line, a turbulent mass of aerated water. However, if the broken wave passes into deeper water, as it does after breaking on a bar, it can form again with a lesser height that represents the loss of energy in breaking. Then it too will break as it moves into a depth critical to its new height.

The depth of water beneath a breaker, measured down from the still-water level, is at the moment of breaking about 1.3 times the height of the breaker. To estimate the height of a breaker even though it is well offshore, one walks from the top of the beach down until the crest of the breaking wave is seen aligned with the horizon. The vertical distance between the eye and the lowest point to which the water retreats on the face of the beach is then equal to the height of the wave.

The steepness of the bottom influences

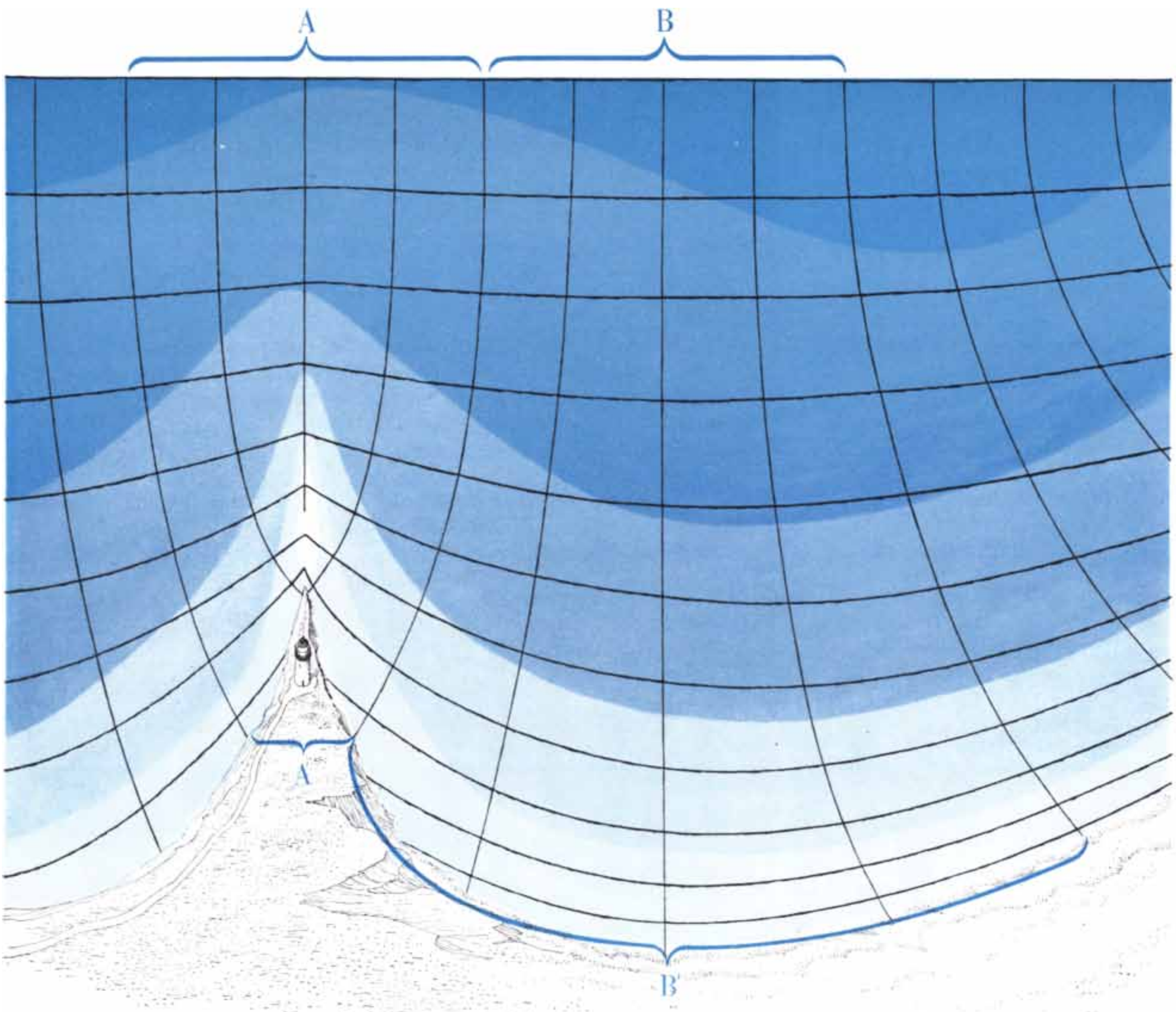


how the great wave was measured. An observer at A on the bridge was looking toward the stern and saw the crow's-nest at B in his line of sight to crest of wave, which had just come in line with horizon. From geometry of situation, wave height was calculated.

the character of the breakers. When a large swell is forced by an abrupt underwater slope to give up its energy rapidly, it forms plunging breakers—violent waves that curl far over, flinging the crest into the trough ahead. Sometimes, the air trapped by the collapsing wave is compressed and explodes with a great roar in a geyser of water [*see illustration on opposite page*]. However, if the bottom slope is long and gentle, as at Waikiki in Hawaii, the crest forms a spilling breaker, a line of foam that tumbles down the front of the partly broken wave as it continues to move shoreward.

Since waves are a very effective mechanism for transporting energy against a coast, they are also effective in doing great damage. Captain D. D. Gaillard of the U. S. Army Corps of Engineers devoted his career to studying the forces of waves on engineering structures and in 1904 reported some remarkable examples of their destructive power. At Cherbourg, France, a breakwater was composed of large rocks and capped with a wall 20 feet high. Storm waves hurled 7,000-pound stones over the wall and moved 65-ton concrete blocks 60 feet. At Tillamook Rock Light off the Oregon coast, where severe storms are commonplace, a heavy steel grating now protects the lighthouse beacon, which is 139 feet above low water. This is necessary because rocks hurled up by the waves have broken the beacon several times. On one occasion a rock weighing 135 pounds was thrown well above the lighthouse-keeper's house, the floor of which is 91 feet above the water, and fell back through the roof to wreck the interior.

At Wick, Scotland, the end of the breakwater was capped by an 800-ton block of concrete that was secured to the foundation by iron rods 3.5 inches in diameter. In a great storm in 1872 the designer of the breakwater watched in amazement from a nearby cliff as both cap and foundation, weighing a total of 1,350 tons, were removed as a unit and deposited in the water that the wall was supposed to protect. He rebuilt the structure and added a larger cap weighing 2,600 tons, which was treated similarly by a storm a few years later. There is no record of whether he kept his job



WAVE-REFRACTION DIAGRAM shows how energy of wave front at A is all concentrated by refraction at A′ around small headland area. Same energy at B enters a bay but is spread at beach over wide area B′. Horizontal lines are wave fronts; vertical lines divide energy into equal units for purposes of investigation. Such studies are vital preliminaries to design of shoreline structures.

and tried again. Gaillard's computations show that the wave forces must have been 6,340 pounds per square foot.

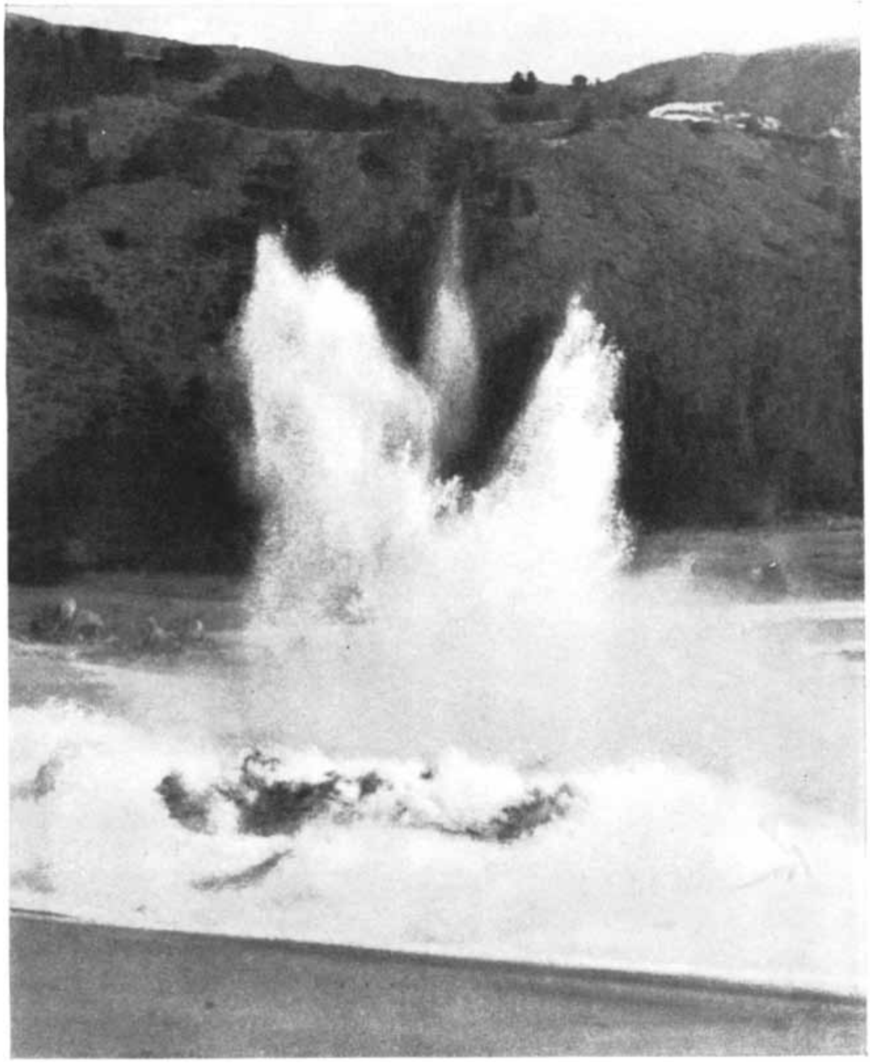
Tsunamis

Even more destructive than wind-generated waves are those generated by a sudden impulse such as an underwater earthquake, landslide or volcano. A man-made variation of the sudden impulse is the explosion of nuclear bombs at the surface of the sea, which in recent years have become large enough to be reckoned with as possible causes of destructive waves.

The public knows such waves as tidal waves, although they are in no way related to the tides and the implication has long irritated oceanographers. It was proposed that the difficulty could be resolved by adopting the Japanese word *tsunami.* Some time later it was discovered that Japanese oceanographers are equally irritated by this word; in literal translation tsunami means tidal wave! However, tsunami has become the favored usage for seismic sea waves.

Like the plunger in a wave channel, the rapid motion or subsidence of a part of the sea bottom can set a train of waves in motion. Once started, these waves travel great distances at high velocity with little loss of energy. Although their height in deep water is only a few feet, on entering shallow water they are able to rise to great heights to smash and inundate shore areas. Their height depends almost entirely on the configuration of the coastline and the nearby underwater contours. Tsunamis have periods of more than 15 minutes and wavelengths of several hundred miles. Since the depth of water is very much less than half the wavelength, they are regarded as long- or shallow-water waves, even in the 13,000-foot average depth of the open ocean, and their velocity is limited by the depth to something like 450 miles per hour.

These fast waves of great destructive potential give no warning except that the disturbance that causes them can be detected by a seismograph. The U. S. Coast Guard operates a tsunami warning network in the Pacific that tracks all earthquakes, and when triangulation indicates that a quake has occurred at sea, it issues alerts. The network also has devices to detect changes in wave period which may indicate that seismic waves are passing [see "Tsunamis," by Joseph Bernstein; SCIENTIFIC AMERICAN, August, 1954]. Curiously the influence of the system may not be entirely beneficial. Once when an alert was broadcast at Honolulu, thousands of people there dashed down to the beach to see what luckily turned out to be a very small wave.



WAVE-CREATED "GEYSER" results when large breakers smash into a very steep beach. They curl over and collapse, trapping and compressing air. This compressed air then explodes as shown here, with spray from a 12-foot breaker leaping 50 feet into the air.

Certain coasts near zones of unrest in the earth's crust are particularly prone to such destructive waves, especially the shores of the Mediterranean, the Caribbean and the west coast of Asia. On the world-wide scale, they occur more frequently than is generally supposed: nearly once a year.

A well-known seismic sea wave, thoroughly documented by the Royal Society of London, originated with the eruption of the volcano Krakatoa in the East Indies on August 27, 1883. It is not certain whether the waves were caused by the submarine explosion, the violent movements of the sea bottom, the rush of water into the great cavity, or the dropping back into the water of nearly a cubic mile of rock, but the waves were monumental. Their period close to the disturbance was two hours, and at great distances about one hour. Waves at least 100 feet high swept away the town of Merak, 33 miles from the volcano; on the opposite shore the waves carried the man-of-war *Berow* 1.8 miles inland and left it 30 feet above the level of the sea. Some 36,380 people died by the waves in a few hours. Tide gauges in South Africa (4,690 miles from Krakatoa), Cape Horn (7,820 miles) and Panama (11,470 miles) clearly traced the progress of a train of about a dozen waves, and showed that their speed across the Indian Ocean had been between 350 and 450 miles per hour.

A tsunami on April 1, 1946, originating with a landslide in the Aleutian submarine trench, produced similar effects,

HUNDRED-FOOT "TIDAL WAVE," or tsunami, wrought impressive destruction at Scotch Cap, Alaska, in 1946. Reinforced concrete lighthouse that appears in top photograph was demolished, as shown in lower photograph, which was made from a higher angle. Atop the plateau a radio mast, its foundation 103 feet above sea, was also knocked down. Lighthouse debris was on plateau. Same tsunami, started by an Aleutian Island earthquake, hit Hawaiian Islands, South America and islands 4,000 miles away in Oceania.

fortunately on less-populated shores. It struck hard at the Hawaiian Islands, killing several hundred people and damaging property worth millions of dollars. At Hilo, Hawaii, the tsunami demonstrated that such waves are virtually invisible at sea. The captain of a ship standing off the port was astonished upon looking shoreward to see the harbor and much of the city being demolished by waves he had not noticed passing under his ship. The same waves caused considerable damage throughout the islands of Oceania, 4,000 miles from epicenter, and on the South American coast, but they were most spectacular at Scotch Cap in Alaska. There a two-story reinforced-concrete lighthouse marked a channel through the Aleutian Islands. The building, the base of which was 32 feet above sea level, and a radio mast 100 feet above the sea were reduced to bare foundations by a wave estimated to be more than 100 feet high [*see illustration on opposite page*].

Uncontrollable geologic disturbances will cause many more seismic sea waves in the future, and since the world's coastal population is continuously increasing, the greatest wave disaster is yet to come. Within the next century we can expect that somewhere a wave will at least equal the one that swept the shores of the Bay of Bengal in 1876, leaving 200,000 dead.

Tides and Other Waves

The rhythmic rise and fall of the sea level on a coast indicate the passage of a true wave we call a tide. This wave is driven, as almost everyone knows, by the gravitational influence of the sun and the moon. As these bodies change their relative positions the ocean waters are attracted into a bulge that tends to remain facing the moon as the earth turns under it; a similar bulge travels around the earth on the opposite side. The wave period therefore usually corresponds to half the lunar day.

When the sun and the moon are aligned with the earth, the tides are large (spring tides); when the two bodies are at right angles with respect to the earth, the tides are small (neap tides). By using astronomical data it is possible to predict the tides with considerable accuracy. However, the height and time of the tide at any place not on the open coast are primarily a function of the shape and size of the connection to the ocean.

Still another form of wave is a seiche, a special case of wave reflection. All enclosed bodies of water rock with characteristics related to the size of the basin. The motion is comparable to the sloshing of water in the bathtub when one gets out quickly. In an attempt to return to stability the water sways back and forth with the natural period of the tub (mine has a period of two seconds). Similarly a tsunami or a barometric pressure-change will often set the water in a bay rocking as it passes. In fact, the tsunami itself may reflect back and forth across the ocean as a sort of super-seiche.

In addition to seiches, tides, tsunamis and wind waves there are other waves in the sea. Some travel hundreds of feet beneath the surface along the thermocline, the interface between the cold deep water and the relatively warm surface layer. Of course these waves cannot be seen, but thermometers show that they are there, moving slowly along the boundary between the warm layer and the denser cold water. Their study awaits proper instrumentation. Certain very low waves, with periods of several minutes, issue from storms at sea. These long-period "forerunners" may be caused by the barometric pulsation of the entire storm against the ocean surface. Since they travel at hundreds of miles an hour, they could presumably be used as storm warnings or storm-center locators. Other waves, much longer than tides, with periods of days or weeks and heights of less than an inch, have been discovered by statistical methods and are now an object of study.

The great advances both in wave theory and in the actual measurement of waves at sea have not reduced the need for extensive laboratory studies. The solution of the many complex engineering problems that involve ships, harbors, beaches and shoreline structures requires that waves be simulated under ideal test conditions. Such model studies in advance of expensive construction permit much greater confidence in the designs.

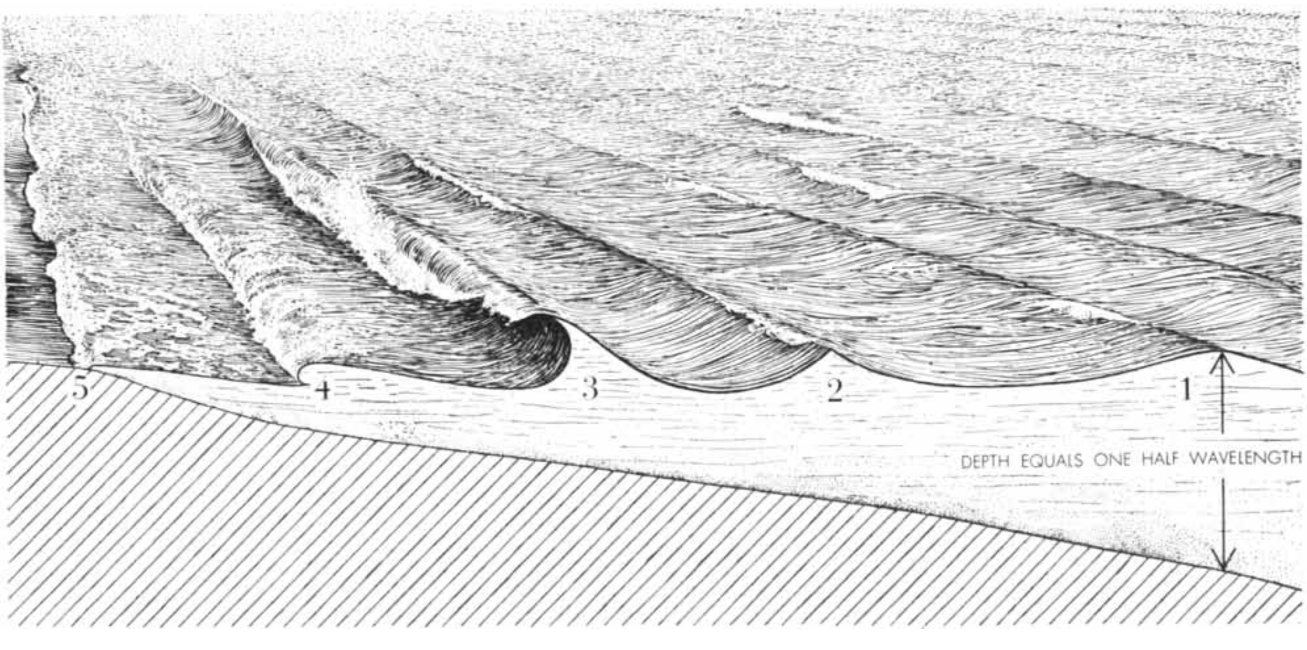
Experimental Tanks

The traditional wave channel in which an endless train of identical small waves is created by an oscillating plunger is still in use, but some of the new wave tanks are much more sophisticated. In some the channel is covered, so that a high velocity draft of air may simulate the wind in making waves. In others, like the large tank at the Stevens Institute of Technology, Hoboken, N.J. [*see cover*], artificial irregular waves approach the variability of those in the deep ocean. In such tanks proposed ship designs, like those of the America's Cup yacht *Columbia*, are tested at model size to see how they will behave at sea.

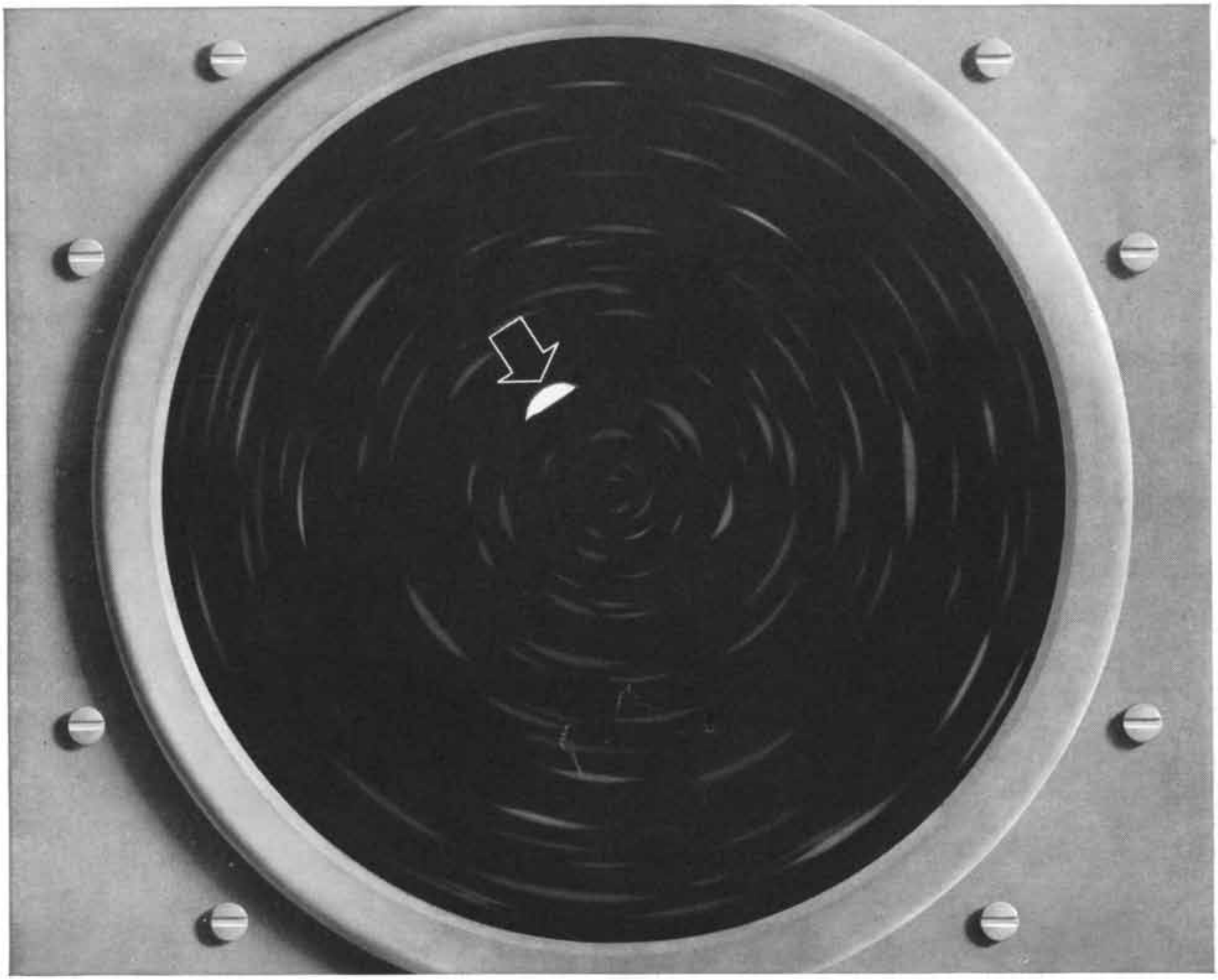
The ripple tank, now standard apparatus for teaching physics, has its place in shoreline engineering studies for conveniently modeling diffraction and refraction. Even the fast tsunamis and the very slow waves of the ocean can be modeled in the laboratory. The trick is to use layers of two liquids that do not mix, and create waves on the interface between them. The speeds of the waves can be controlled by adjusting the densities of the liquids.

To reduce the uncertainties in extrapolation from the model to prototype, some of the new wave tanks are very large. The tank of the Beach Erosion Board in Washington, D.C. (630 feet long and 20 feet deep, with a 500-horsepower generator), can subject quarter-scale models of ocean breakwaters to six-foot breakers. The new maneuvering tank now under construction at the David Taylor Model Basin in Carderock, Md., measures 360 by 240 feet, is 35 feet deep along one side and will have wave generators on two sides that can independently produce trains of variable waves. Thus man can almost bring the ocean indoors for study.

The future of wave research seems to lie in refinement of the tools for measuring, statistically examining and reproducing in laboratories the familiar wind waves and swell as well as the more recently discovered varieties. It lies in completing the solution of the problem of wave generation. It lies in the search for forms of ocean waves not yet discovered—some of which may exist only on rare occasions. Nothing less than the complete understanding of all forms of ocean waves must remain the objective of these studies.

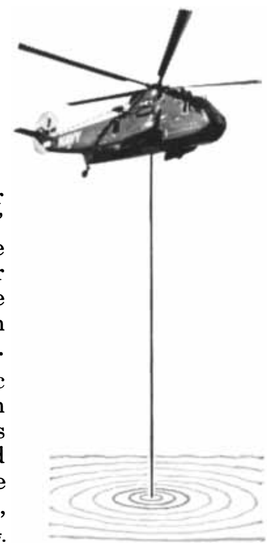


WAVE BREAKS UP at the beach when swell moves into water shallower than half the wavelength (1). The shallow bottom raises wave height and decreases length (2). At a water depth 1.3 times the wave height, water supply is reduced and the particles of water in the crest have no room to complete their cycles; the wave form breaks (3). A foam line forms and water particles, instead of just the wave form, move forward (4). The low remaining wave runs up the face of the beach as a gentle wash called the uprush (5).



Artist's drawing shows enemy submarine position (white pip indicated by arrow) as it appears on Bendix Sonar viewing scope in helicopter. It is the first airborne system to provide a visual presentation which pinpoints a target below the surface.

NOW NAVY HELICOPTERS, WITH BENDIX SONAR, "SEE" ENEMY SUBS UNDERWATER



Prowling enemy submarines will meet a deadly countermeasure in Bendix* Sonar equipped seagoing helicopters which have their own ways of hunting down *their* prey.

This is one phase of the U. S. Navy's potent and far reaching Anti-Submarine Warfare program. A pioneer in underwater detection and communications, our Bendix-Pacific Division in North Hollywood, California, developed this first airborne scanning sonar system for use in Sikorsky HSS-2 helicopters. It is the first airborne system to provide a visual presentation which pinpoints a target below the surface. In operation, a sending-receiving transducer is lowered into the water as the helicopter hovers. Known as "dunked" sonar, signals are transmitted through the water which echo back, somewhat like radar beams, from objects like submarines. The fact that the system is a long-range search and detection device adds greatly to its value.

Bendix produces a number of other sonic devices. These include the famous depth sounder or "fish finder"; sonic cleaners for the greatest efficiency in industrial and medical cleaning and the Cavitron* for the ultrasonic machining of germanium, glass, quartz, silicon or ferrite.

*REG. U.S. PAT. OFF.

A thousand products — Bendix AVIATION CORPORATION Fisher Bldg., Detroit 2, Mich. — *a million ideas*

Advanced land mass simulation concept demonstrates Pomona Division capability in realistic simulators for lower-cost training of America's air and spacemen.

IN DEVELOPMENT:

A Marquardt-conceived land mass simulation system that shrinks the map scale factor to 1:3,000,000, while enabling the operator to distinguish landmarks smaller than a football field from any altitude! Application today: ground-training airmen for inter-continental missions at great savings in cost — using a single 8-foot map to realistically simulate the radar reflectivity and shadow effects of a 4,000-mile mission. Application tomorrow: training the free world's first space explorer for his safe return to earth.

IN PRODUCTION TODAY:

Pomona Division's AN/GPS-T4 Radar Signal Simulator, a relatively low-cost training system that is simple, compact, flexible and realistic; producing synthetic target and IFF video information for radar display. Current mission: training USAF aircraft controllers to direct interceptor missions. Ready adaptability will permit the T4 to simulate missiles, radar surface targets and sonar targets.

IN THE U.S. DEFENSE INVENTORY:

The USAF's AN/APQ-T1, AN/APG-T1A, AN/APQ-T2 and T2A, and AN/APQ-T3 simulator-training systems, plus the USN's 15WV-2 AEW/CIC trainer system — all developed and manufactured by the Pomona Division and its predecessor companies. Numerous sub-systems, up-dating modification kits, adapters, spares, and a worldwide field service section add to the organization's total experience.

POMONA DIVISION of The Marquardt Corporation is an able and experienced organization with demonstrated capability in advanced research, design, development and production. The result is reliable hardware which provides solutions to the problems of training military operational personnel.

Drawing on the Corporation's overall management-engineering skills, additional facilities and financial support, Pomona Division now offers industry and the Armed Forces a unique and proven ability to get the job done—delivering vital simulator-training system both on-time and at minimum cost.

OPERATIONS AT:
Van Nuys and
Pomona, California
Ogden, Utah
SUBSIDIARY:
Cooper Development
Corporation,
Monrovia, California

THE Marquardt CORPORATION
POMONA DIVISION
2709 No. Garey Avenue, Pomona, Calif.

Engineers and scientists capable of contributing to advances in state-of-the-art are invited to write to: Dr. Wendell B. Sell, Vice-President. G-5.

WHAT'S NEW IN RARE EARTHS

Prompt shipments in tonnage quantities . . . attractive low prices . . . available as oxides, hydrates, chlorides, oxalates, metals and other forms

a report by LINDSAY

New . . . new . . . new. It's the old but still magic word that keynotes industrial planning for the products that may be big profit winners in the 1960's.

R&D work, in laboratories from coast to coast, is happily blessed with huge budgets for the ever-continuing search for what is new. New in processes, in methods, in materials. Whatever is new that will contribute to the development of new products to captivate the public fancy and meet the critical needs of industry.

New plastics. New exotic metals. New chemicals . . . and among them, the rare earths.

NOT NEW . . . BUT

You may say the rare earths are not new. True. We've been working with the rare earths for more than 50 years. Many industries have known and used them for years. *But they may be new to you.*

What *is* new in rare earths will command your attention and intrigue the interest of your people concerned with research and development work.

There's new availability in the rare earths! Commercial grades can be shipped promptly by the ton or carload. High purity grades up to 99.99% can be shipped in surprisingly large quantities. It may be news to you that Lindsay is currently producing more than 100 rare earth, yttrium and thorium salts for R&D work as well as for normal production operations.

There's new low pricing of rare earths. Costs have tumbled sharply during recent years. Partly because of rapidly increasing demand. Partly because of vastly expanded production facilities and improved techniques in refining our materials. (Which came first—the hen or the egg?) The important fact is that the rare earths are priced so low as to make their use extremely interesting. We are talking, in many cases, about ¢, not $.

Rare earths now available in metal form. Interested? You can obtain rare earth and yttrium in metal form, primarily as ingots and lumps. They are presently available in experimental quantities and offer interesting promise to many industries.

There are many new uses for the rare earths. This obviously is the result of research and development work carried on during recent years. In glass and ceramics. In electronics. In commercial nuclear energy. In plastics. In glass polishing. And in many other fields.

We would be modest indeed if we failed to hint that much of the rapid expansion—first in research and then in actual industrial use of the rare earths—has been at our gentle urging.

The facts speak for themselves. Rare earths have come of age. They are important production materials in a broad cross-section of American industry.

So if you are thinking *new* . . . new ideas, new processes, new materials, new products . . . look at the rare earths.

When you do, please remember these two facts. They are readily available in the grades, varieties, forms and quantities you will need. And they are priced at surprisingly attractive levels.

Our technical people will be happy to be helpful to you. We can supply pertinent data and will promptly supply detailed information if you will indicate your specific area of interest.

PLEASE ADDRESS INQUIRIES TO

® TRONA

LINDSAY CHEMICAL DIVISION

American Potash & Chemical Corporation

264 ANN STREET • WEST CHICAGO, ILLINOIS

OFFICES: CHICAGO • LOS ANGELES • SAN FRANCISCO • NEW YORK • PORTLAND (ORE.) • ATLANTA • COLUMBUS (O.) • SHREVEPORT

Conditioning and Brain Waves

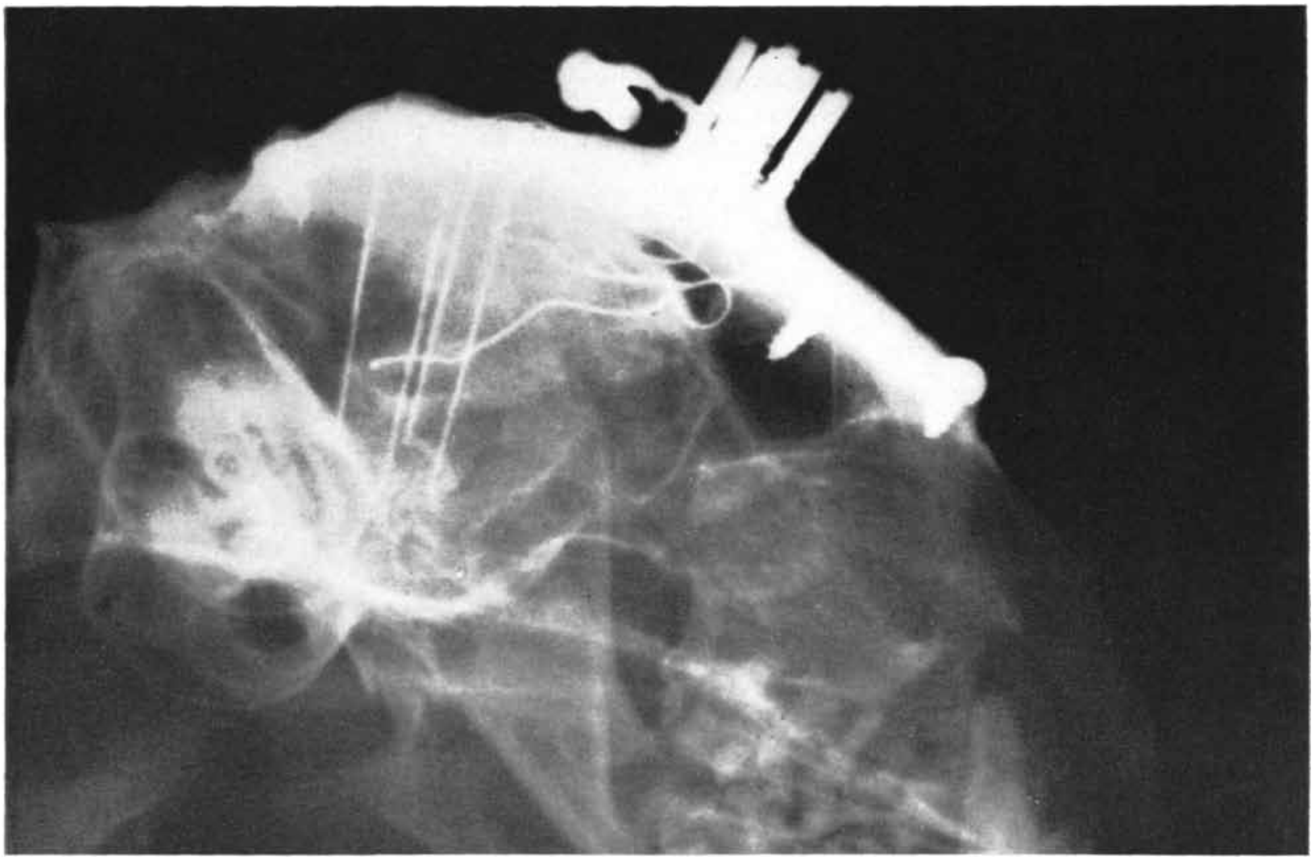
Recent investigations show that learning can change the pattern of electrical activity in the brain. These studies are beginning to elucidate the physiological substructure of mental phenomena

by Vernon Rowland

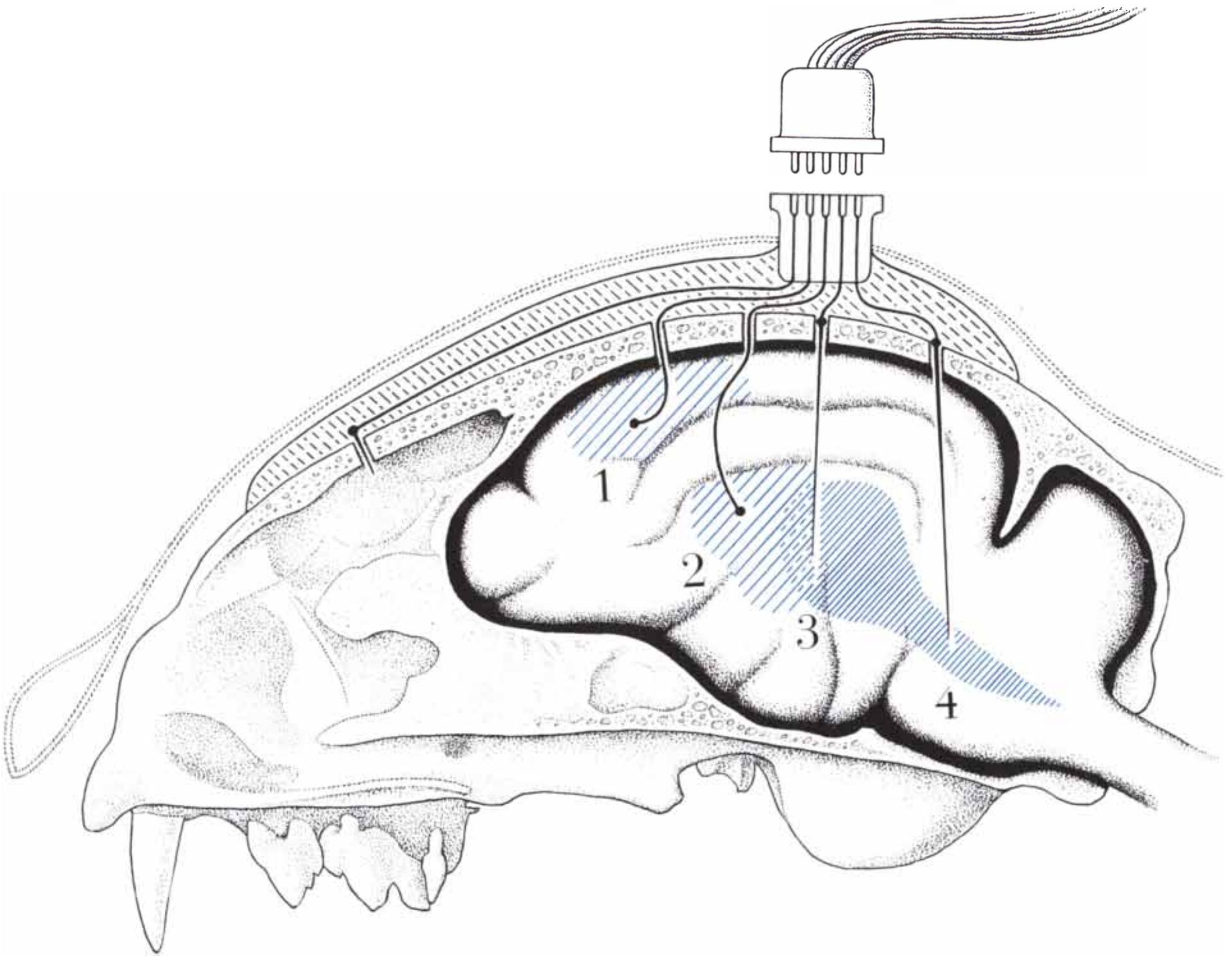
The complexity of the human mind is matched and perhaps surpassed by the intricacy of the human brain. Most of us take it for granted that one has something to do with the other. Until recently, however, physiology and psychology have had little to say from the experimental standpoint about transactions between mind and brain.

More than 200 years ago the English physician and philosopher David Hartley defined the mind-brain problem in a manner that can be little improved upon today. Hartley ascribed mental activities to the vibrations of infinitesimal particles in the nerves and brain. He reasoned that if these vibrations "can be shown . . . to attend upon all sensations, ideas and motions and to be proportional to them, then we are at liberty either to make vibrations the exponent of sensations, ideas and motions or these the exponents of vibrations." It might be impossible, he cautiously declared, "to discover in what way vibrations cause or are connected with sensations," one being material and the other mental. Yet observed parallels between vibrations and mental events might be true "in a very useful and practical sense" if not "in an ultimate and precise one."

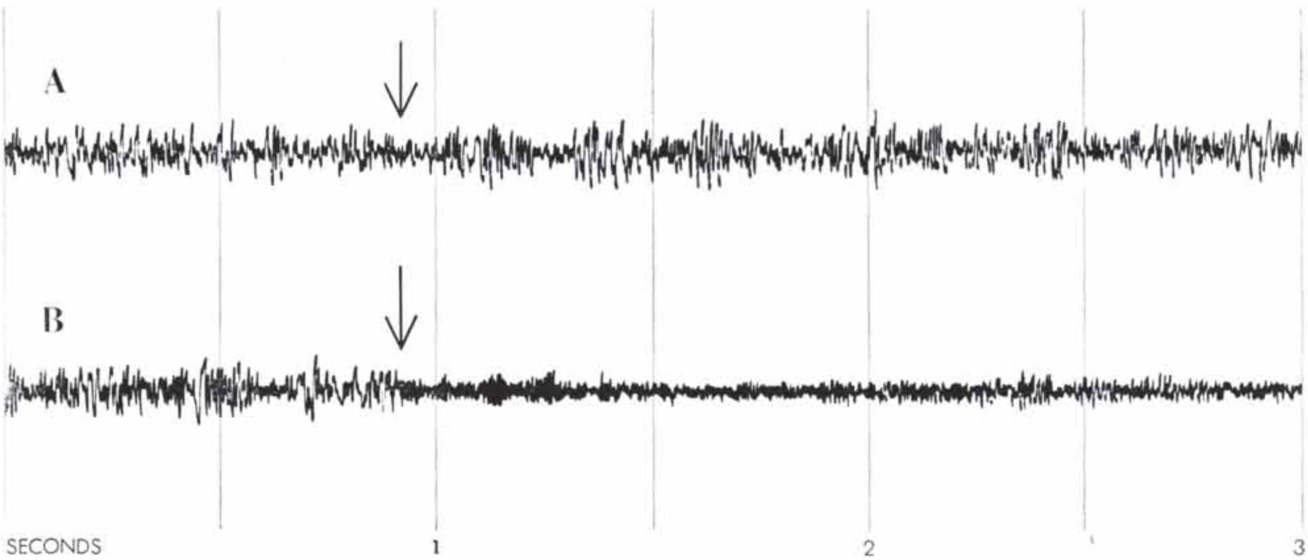
In 1876 the English physiologist Richard Caton discovered something very akin to Hartley's "vibrations" when he demonstrated the existence of electrical oscillations in the brain. By the 1930's



ELECTRODES PERMANENTLY IMPLANTED in the brains of cats have made possible studies of learned changes in brain waves. This X-ray photograph shows needle-like deep electrodes (*left*) and wires attached to brain surface. The animal feels no discomfort.



SCHEMATIC DRAWING of cat's brain shows surface electrodes attached to the association cortex (1) and the auditory cortex (2). Deep electrodes measure the output of the "reticular formation" (*close hatching*) within the thalamus (3) and the brain stem (4).



"SLEEP" AND "ALERT" PATTERNS in brain waves show differences in conditioned responses to two stimuli. In A the sounding (*arrow*) of a musical tone that has come to signify safety intensifies the slow, high-voltage waves typical of sleep. In B a burst of clicks that has become associated with a shock shifts the pattern from sleep to the rapid, low-voltage waves characteristic of the alert state.

these "brain waves"—variations in voltage measured and recorded by the electroencephalograph—had become a valuable aid in diagnosing such conditions as epilepsy and brain tumor.

As Hartley anticipated, the waves do indeed "attend upon all sensations, ideas and motions." However, investigators found them disappointingly constant. The intermittent changes in the oscillations apparently reflected little more than the shift from relaxed reverie to concentrated attention, or from sleep to wakefulness [see "The Electrical Activity of the Brain," by W. Grey Walter; SCIENTIFIC AMERICAN, June, 1954]. The most characteristic of these changes is from the "sleep pattern" of slow, high-voltage waves to the "alert pattern" of rapid, low-voltage waves [*see bottom illustration on opposite page*].

Donald B. Lindsley and Robert W. Lansing of the University of California at Los Angeles have suggested an explanation for this difference in rhythm. Their reasoning leads off from recent experiments which indicate that brain waves reflect activity on the input side of a nerve cell in the brain, as opposed to the output, or firing, side. The brain wave may thus be regarded as an excitability cycle. Lindsley and Lansing believe that brain cells respond to stimuli only when the cells are passing through the middle values of the brain-wave cycle; the cells are insensitive to impulses arriving at the high or low points of the cycle. The alerted cells of the awakened brain traverse the voltage range in which they are sensitive as often as 40 to 50 times a second; those of the sleeping brain, only three to five times a second. The higher voltages of sleep, at first glance the opposite of what one would expect, appear to reflect the synchronized fluctuations of large groups of cells. The lower-voltage alert pattern, corresponding to the activity of smaller groups, would thus bespeak a more elaborate division of labor within the awakened brain that would enhance the organ's capacity to direct complex activities.

Such gross changes as these seemed until recently to exhaust the brain's repertory of electrical activity. The encephalograph revealed no kaleidoscopic display of brain-wave patterns to match the phantasmagoria of the mind. During the past few years, however, investigators in several countries have made substantial inroads on the mind-brain problem by studying the brain waves of trained or conditioned animals. They have established a definite association between brain-wave patterns and conditioned behavior patterns in these animals. More subtle electrical changes seem to reflect different stages in the process of conditioning. Some of these studies have cast doubt on the hitherto accepted notion that the cerebral cortex—the convoluted roof of the brain—is the chief seat of learning. The subcortical regions of the brain appear to play a role of equal or even greater importance in the learning process.

Some of these investigations have employed the classical conditioning procedures of Ivan Pavlov. The elegant experimental techniques of the great Russian physiologist make it possible to conduct a controlled input-output analysis of the mechanism of behavior. When the salivating dog learns to associate the sound of a bell with the taste of food, some connection between the two sensations must have formed somewhere in the animal's brain. Pavlov himself evolved a detailed theory of how these connections are established. But he did little experimental work on the brain itself, and most non-Russian psychologists have viewed his theories as tenuous speculations. The recent marriage of encephalography and conditioning, however, has produced some "brain children" that appear to vindicate some of Pavlov's hypotheses.

The key step in this union was the development of techniques for permanently implanting electrodes in the brains of experimental animals. These procedures permit electrical measurements in the deeper portions of the brain, as well as on its surface areas, free of the obfuscating effects of the anesthesia, drugs and surgery used in traditional nervous system physiology. Animals with considerable hardware thus immobilized within their crania can live normally and comfortably for years. One merely has to plug them into the encephalograph amplifiers to have direct access to their innermost "vibrations."

Our work on conditioning and brain waves at Western Reserve University began in 1954 with a chance laboratory observation. We were recording the waves of a sleeping cat during some intermittent wall-pounding occasioned by extensive renovations in the adjoining room. The animal had long since grown accustomed to this racket and slept through it undisturbed with no change in the encephalograph records. During a quiet interval one day another cat in the laboratory emitted a soft mew. The brain waves of our experimental animal immediately changed from the sleep pattern to the alert pattern. Some 10 seconds later the animal raised its head and looked toward the other cat. It had evidently learned to discriminate, even while asleep, between loud pounding and a soft mew, as parents learn to sleep through a thunderstorm yet awaken to the cry of a child.

To study the nature of such "learned" brain wave responses we conditioned several cats to associate a brief series of rapid clicks with a mild electric shock. A musical tone not associated with anything served as a control stimulus, because we had to be certain that any changes in the brain resulted from the association between sound and shock, and not from the sound itself. As we expected, the brain waves soon displayed the typical alert response following the pain-associated clicks, and showed a continued sleep pattern following the tone. Animals that had been exposed only to the clicks during conditioning gave the alert response to both sounds during testing until, after a number of repetitions, they learned to discriminate between the two. More subtle discriminations between two "melodies" (for example, between the simple melodies CGC and GCG) produced equally clear electrical changes.

When we first tested the animals, they showed visible behavioral signs of waking soon after the beginning of the alert pattern. In later trials only the brain "awoke," the animals remaining to all appearances fast asleep. Evidently a characteristic pattern of activity in the brain can persist even after the behavior associated with it has disappeared. Other investigators have found that the electrical changes sometimes precede behavioral responses. These brain waves divorced from behavior might be said to reflect "thinking" processes.

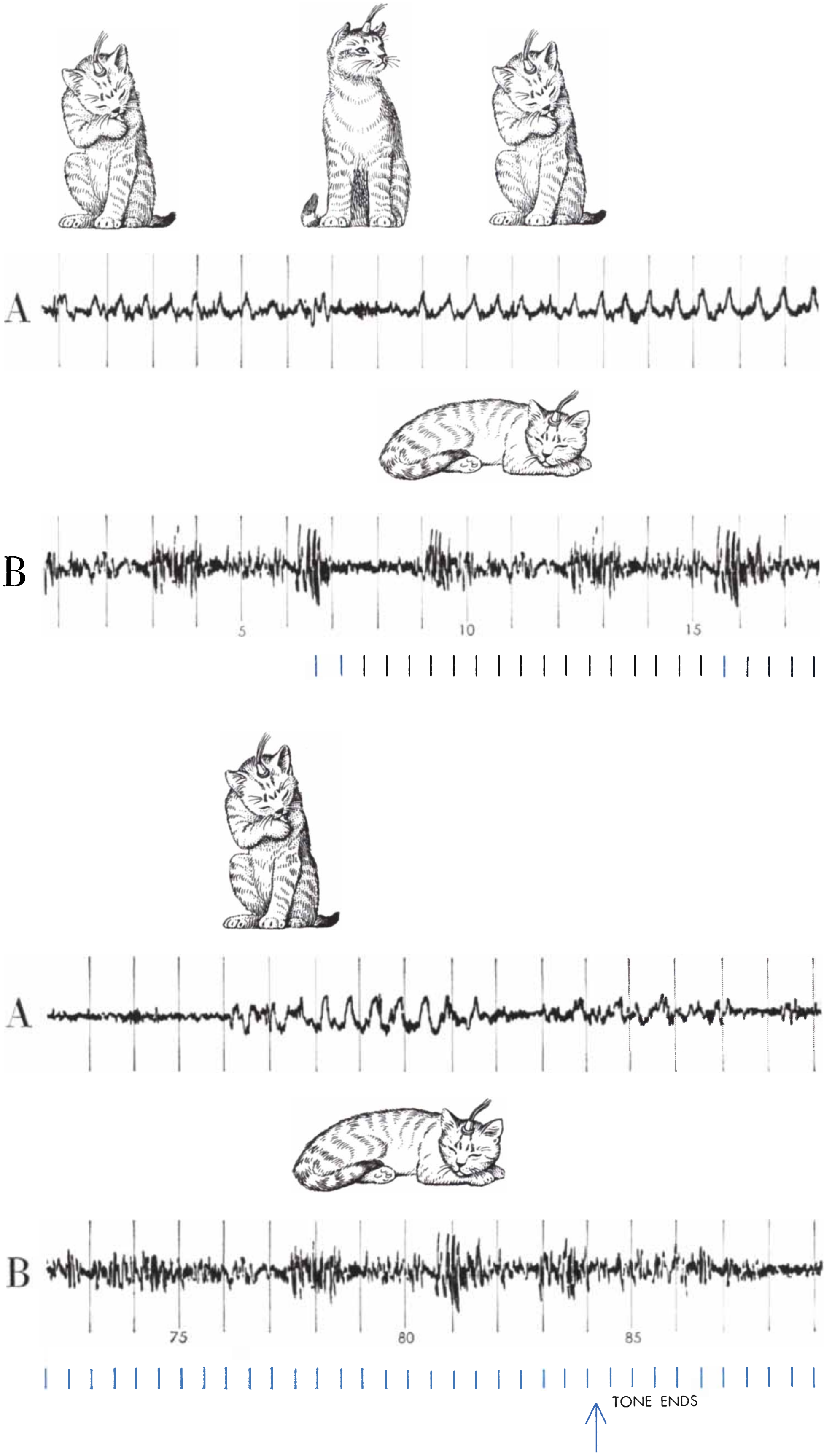
In further experiments we found that the control tone introduced an unforseen electrical change; it actually intensified the sleep pattern. Indeed, if an animal was slow in going to sleep we could sometimes put it to sleep by sounding the tone. Evidently this neutral stimulus had acquired a meaning of its own: safety.

Henry Gluck of our laboratory then set out to discover what would happen if a safety signal were opposed to a "danger" signal. For the latter he used a series of clicks lasting two full minutes before the shock was delivered. To this signal he added a 20-second tone which meant that the shock would not be given; when the safety signal was not sounded, the animal got the shock on schedule. Within 10 trials the tone clearly evoked the sleep pattern despite the competition of the continuous danger signal. The animal had evidently learned to interpret the tone as an "all clear." However, the encephalogram did not simply change from the sleep pattern to the alert pattern. The two-minute warning signal ultimately induced a more complicated response. When the signal began, the record immediately showed the alert pattern; within a few seconds, however, it reverted partially or completely to the sleep pattern. At about the end of the first minute it returned to the alerted state, which endured through the second minute until the delivery of the shock.

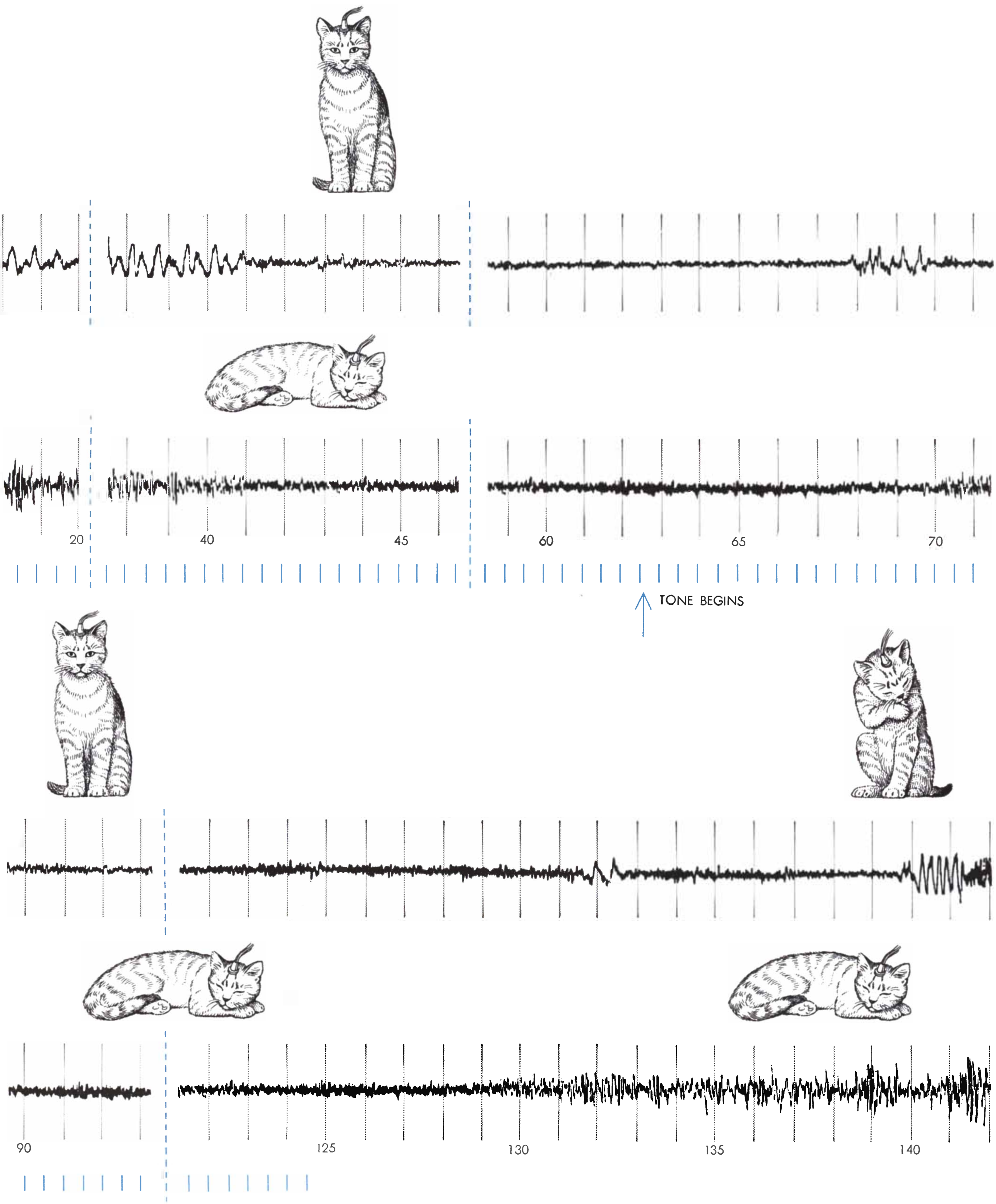
Since most of these sleeping animals showed no behavioral changes, we could not establish direct parallels between electrical and behavioral patterns. Occasionally, however, we tested animals during the periods of grooming (often annoyingly protracted!) which usually intervene between eating and sleeping. The start of the two-minute warning signal caused the animal to stop grooming for a few seconds. It then resumed its grooming during the remainder of the first minute but stopped again during the second minute. Thus the animal's behavioral pattern while it was awake completely paralleled its electrical pattern while asleep. If we sounded the safe signal during the second minute, the animal began grooming again, but stopped when the safe signal ended, not to resume until after the end of the warning signal. Here too the brain waves of active and sleeping animals showed a similar pattern of change [*see illustration on these two pages*].

The two phases of response following the first brief arousal—continued sleep during the first minute, renewed arousal during the second—recall some experiments of Pavlov in which he conditioned dogs to salivate a minute or so after the onset of a prolonged stimulus instead of immediately. These animals also showed a two-phase response—a first phase in which salivation was actively inhibited and a second in which it was facilitated. In some of these experiments Pavlov observed a brief initial spurt of salivation similar to our initial arousal.

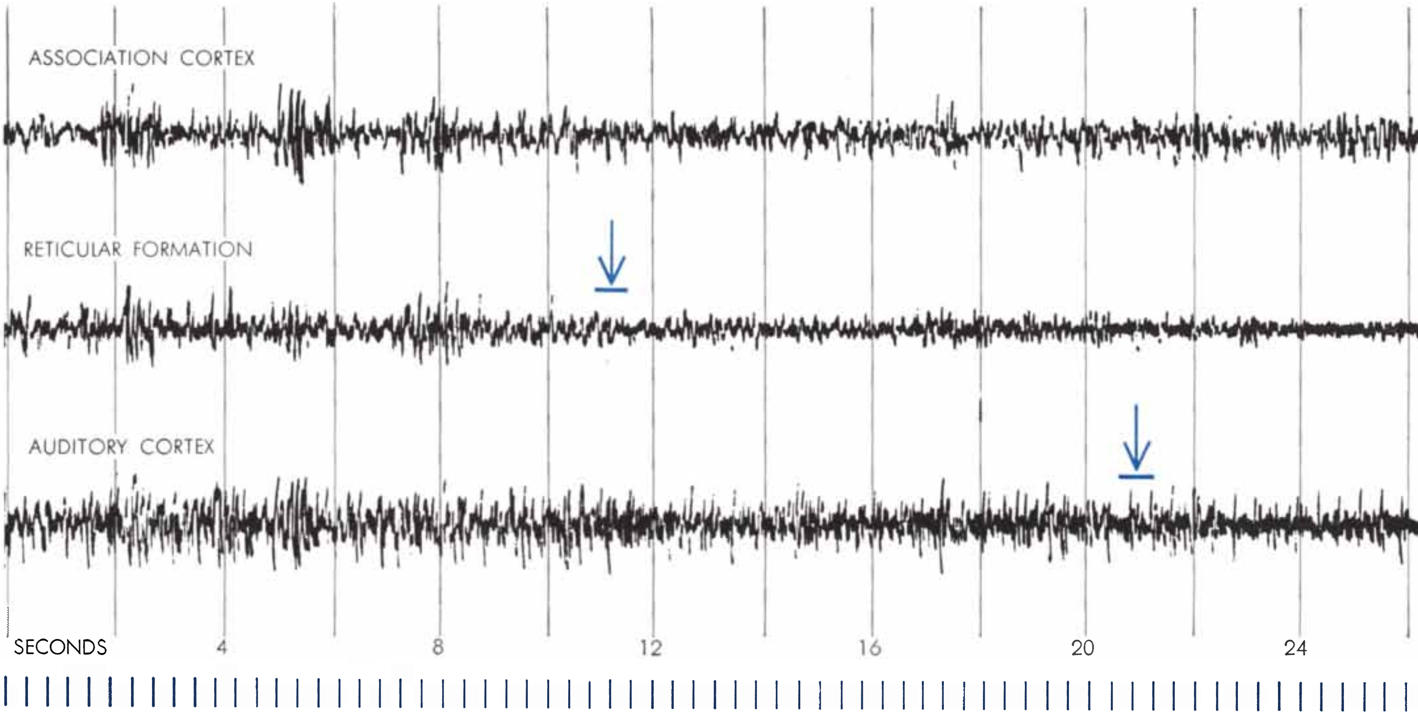
The parallel with Pavlov's observations suggested to us that going to sleep and waking may result from a similar interaction of inhibitory and excitatory processes. Our observations of the grooming animals strengthened this hypothesis, since the cessation of grooming appeared to result from active inhibition



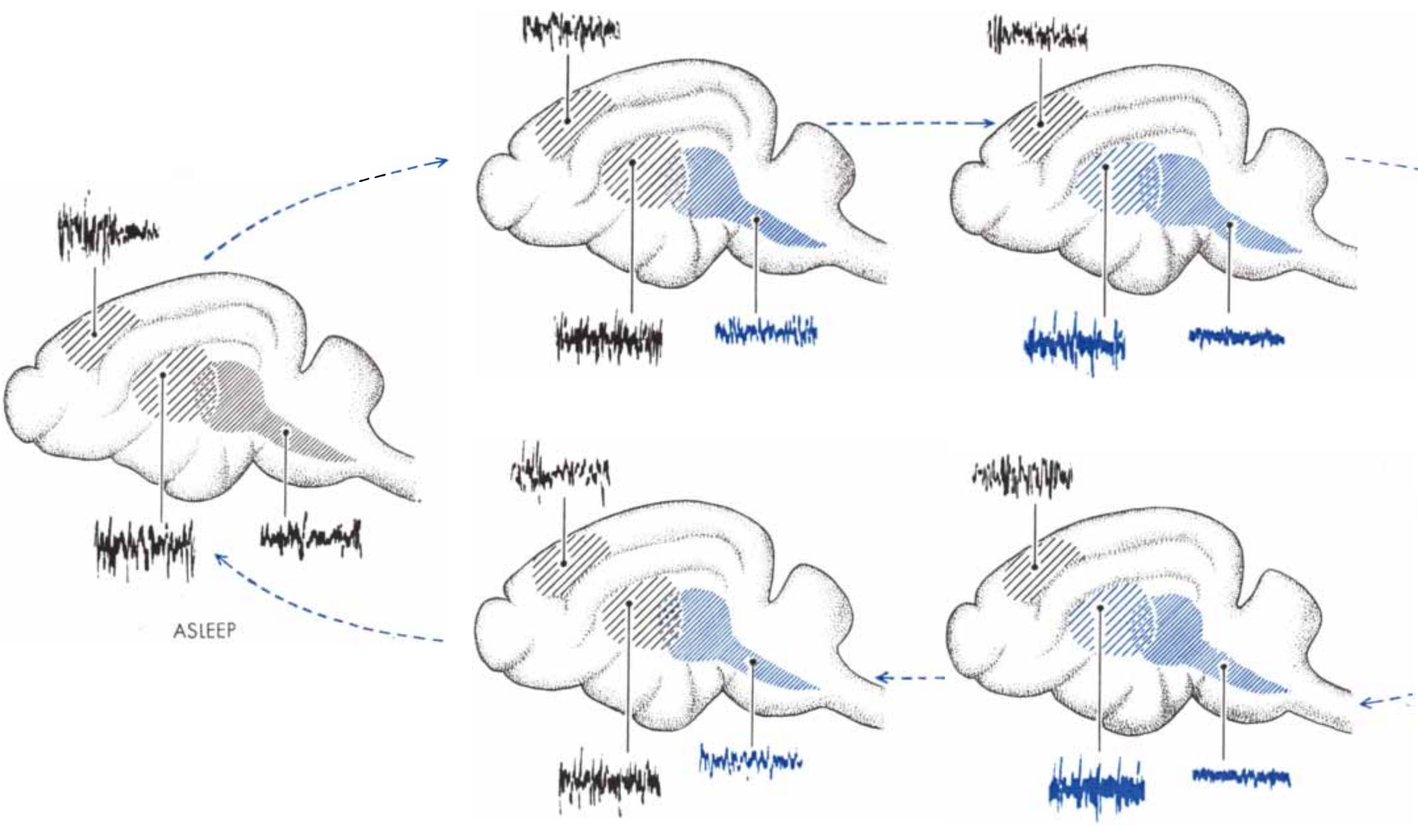
PARALLEL CHANGES in behavior and in brain waves show the similar conditioned responses of a sleeping and a waking cat. Grooming by the awake animal produces rhythmic patterns in its electrical output (A) due to swaying wires; cessation of grooming terminates these patterns. The "warning" signal of rhythmic clicks (*short colored lines*), which fore-



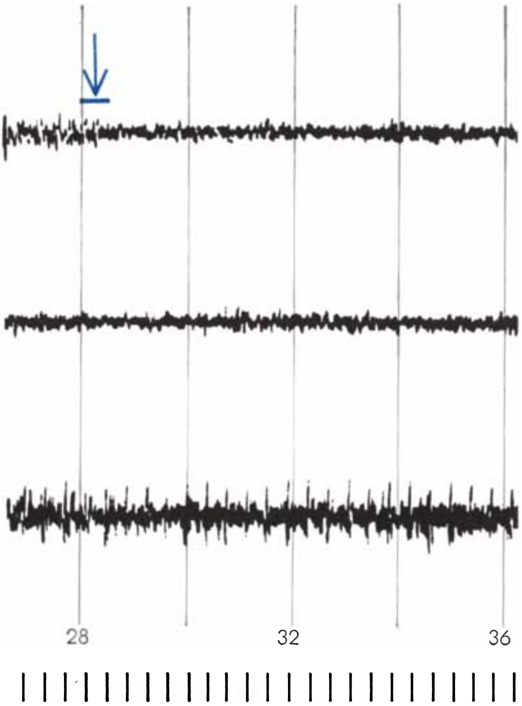
tells a mild shock, causes the cat to cease grooming, but only for a few seconds. After about a minute of the warning signal, the animal stops grooming again. It resumes grooming when the "safety" signal (a musical tone) begins, but stops when it ends, not to resume until the end of the warning signal. The sleeping cat shows no behavioral changes, but the same succession of stimuli produces shifts in its brain waves from the sleep to the alert pattern and back again which exactly parallel the changes in activity of the awake animal.



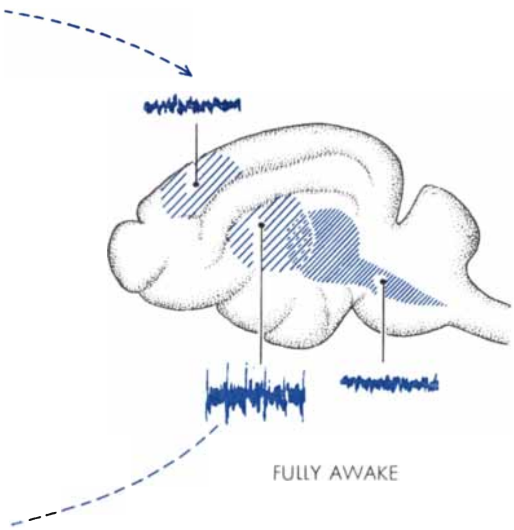
BRAIN AWAKENS PIECEMEAL, as shown by colored arrows, in response to a conditioned stimulus. Clicks (*colored lines*) associated with a shock first arouse the reticular formation. Arousal then spreads to the auditory cortex, which begins to display sharply peaked "evoked responses" synchronized with the clicks. The association cortex is the last brain area to awaken. This pattern is typical



SLEEPING AND WAKING appear to result from the interaction of opposed processes in the brain. The alert pattern (*color*) begins in the reticular formation, whence it spreads to other brain areas as shown at the top of these pages. The sleep pattern (*black*) ap-



of gradual awakening. Sometimes the animal arouses immediately; in this case all areas of brain awaken almost simultaneously.



pears early in the association cortex and gradually encompasses the rest of the brain.

rather than passive fatigue. Had they stopped grooming for the latter reason they would not have resumed when the safe tone went on. Moreover, we found that strengthening the shock curtailed the first phase of return to sleep, while weakening it prolonged the sleep pattern to within a few seconds of the shock. The stronger shock evidently strengthened the arousal processes, which normally dominate the electrical record as they do behavior. A weaker shock, or a safety signal, weakened the arousal forces and allowed the sleep-inducing processes to take over. From the physiological standpoint, apparently, we not only passively "fall" asleep but also actively "go" to sleep.

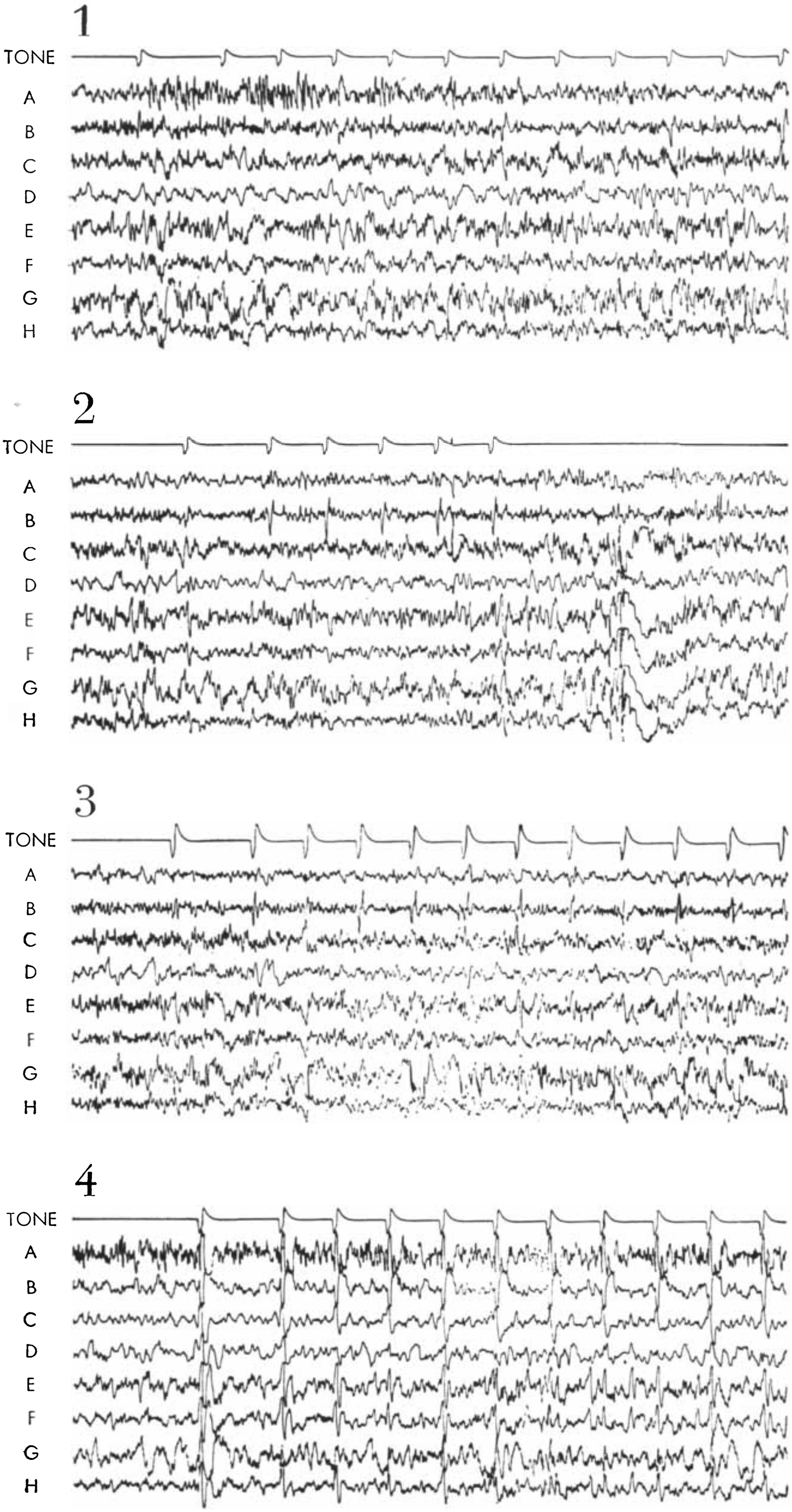
Further comparison of the sleeping and waking animals revealed more intricate brain-behavior parallels. The behavior of the grooming animals strongly suggested that we were dealing with two different kinds of alerting response. During the first brief alert the animals merely stopped grooming and perhaps looked toward the source of the sound; this seemed to be a sort of orienting or "What is it?" response. During the later, protracted alert they not only ceased grooming but also cowered slightly, bracing themselves against the expected shock as one braces for the drilling of a tooth. The brain waves of the sleeping animals spelled out the neurological nature of the difference. The first, "orienting" arousal produced simultaneous alert patterns over all the points of the brain at which our electrodes were planted, and thus appeared to waken the entire brain immediately. The "defensive" arousal was more gradual; the shift to the alert pattern at first involved only the "reticular formation" at the base of the brain, which is known to play an important role in alerting the brain [see "The Reticular Formation," by J. D. French; SCIENTIFIC AMERICAN, May, 1957]. The pattern then spread to the areas of the brain involved in hearing. Other areas, notably the "association cortex," appeared to resist the change, because they lagged 10 seconds or more after the leading sections. Thus the animals appeared to awaken piecemeal as the result of a struggle between the alerting and sleep-conserving forces—a struggle familiar to anyone who relies on an alarm clock. The reticular formation acted as a pacemaker for the rest of the brain. In reverting to sleep after the start of the safety signal the animals displayed a similar contending pattern. Here, however, the sleep pattern began in the association cortex and gradually involved the auditory centers, with the reticular formation the last to go under [*see illustrations on these two pages*].

These observations fall in neatly with Pavlov's views. He ascribed sleep to "irradiation" (*i.e.*, expansion) of inhibition and "concentration" (*i.e.*, contraction) of excitation in the brain. To be sure, he believed that these processes involved mainly the cortex. Our observations indicate that the irradiation of inhibition begins in the cortex but ultimately involves the lower brain centers as the excitatory pattern recedes.

All these studies chiefly concern learned changes in the sequence of the basic sleep and alert patterns. More subtle "vibrations" may enable us to trace the learning process itself in the brain. Thus if an animal is exposed to a series of clicks, its auditory cortex produces "evoked responses" in the form of synchronous spiky discharges. Robert Galambos of the Walter Reed Army Institute of Research and others have found that when an animal learns to associate the clicks with food or a shock, the evoked responses become larger and more complex. Some preliminary studies by Frederic G. Worden and James Marsh of U.C.L.A. indicate that in later stages of learning the evoked responses diminish in intensity. If the experimenter ceases to "reinforce" the stimulus with food, the responses enlarge once more. These changes seemingly parallel the changes from learning (increasing amplitude), to habitual or ingrained response (decreasing amplitude), to unlearning (increasing amplitude). They also point up the fact that, physiologically speaking, unlearning an old response amounts to learning a new one.

The evoked responses not only change their character during learning but their locus of action as well. Michel Jouvet of the University of Lyons and Raul Hernandez Peon of the University of Mexico report that as conditioning proceeds, the responses spread from the auditory cortex to other brain areas, notably those concerned with receiving the shock and responding to it.

Clearly some connection has formed between the auditory and "shock-receiving" regions, but we do not yet know how or where this junction takes shape. Henri Gastaut and his colleagues at the University of Aix-Marseilles have performed an elaborate series of experiments that point to the reticular formation rather than the cortex as the site of the junction. Their findings are consistent with the extensive observations by Horace W. Magoun at U.C.L.A. and Herbert Jasper at McGill University that



"EVOKED RESPONSES" change as a cat learns to press a lever when it hears a series of tones. These records, from experiments by Frederic G. Worden and James Marsh of U.C.L.A., show that near start of training (*1*) animal shows no behavioral or electrical response. Later the same day (*2*) it begins to react to the tones, and a "relay center" in the brain stem (*B*) shows evoked rhythmic peaks. On the following day (*3*) the peaks begin to show up in a higher relay center (*C*). Two days later (*4*), animal is almost perfectly trained; evoked responses have increased in amplitude and spread to all brain areas being recorded.

emphasize the importance of the reticular formation in integrating the brain's activities.

Some of our own experiments also implicate the reticular formation in learning. When we destroyed the auditory cortex in some of our conditioned animals, their brain waves showed that they could still discriminate between the click and the tone stimuli. However, when we tested them on the more difficult "melody" discrimination, they were aroused by both melodies instead of just the significant one. The reticular formation and other lower brain centers can apparently perform only simple discriminations; more complex decisions must be referred to the "higher echelons" of the cortex.

Jasper and his colleagues have found still other changes in brain waves during learning. In the early stages of conditioning the alert response involves most of the brain and is relatively long-lasting. As learning proceeds, the response becomes briefer and more localized. Presumably the first type of arousal is triggered by the lower portions of the reticular formation, which are known to produce generalized arousal when stimulated electrically; the later, more localized arousal would similarly stem from higher levels of the formation. Such a shift is plausible, since it would limit arousal to the portions of the brain needed for a given response, reflecting the lessened conscious effort that characterizes the attainment of a new skill.

The Montreal investigators have even been able to demonstrate changes in the function of single nerve cells after conditioning. Using minute electrodes, they have found that some cells are more likely to fire after conditioning than before. Other cells show a reduced firing rate following conditioned inhibition. Erwin R. John and Keith Killam at U.C.L.A. have found certain changes in the brain's electrical characteristics which appear to represent the hypothetical "memory trace" that psychologists have postulated in the effort to explain memory and learning.

All these findings, along with others based on experimental interruptions of pathways in the brain, electrical stimulation of various brain regions and brain changes induced by drugs, are opening up new horizons in the physiology of behavior. We seem to be on the road to discovering "in what way vibrations cause or are connected with sensations," not only "in a very useful and practical sense" but also "in an ultimate and precise one."

With a

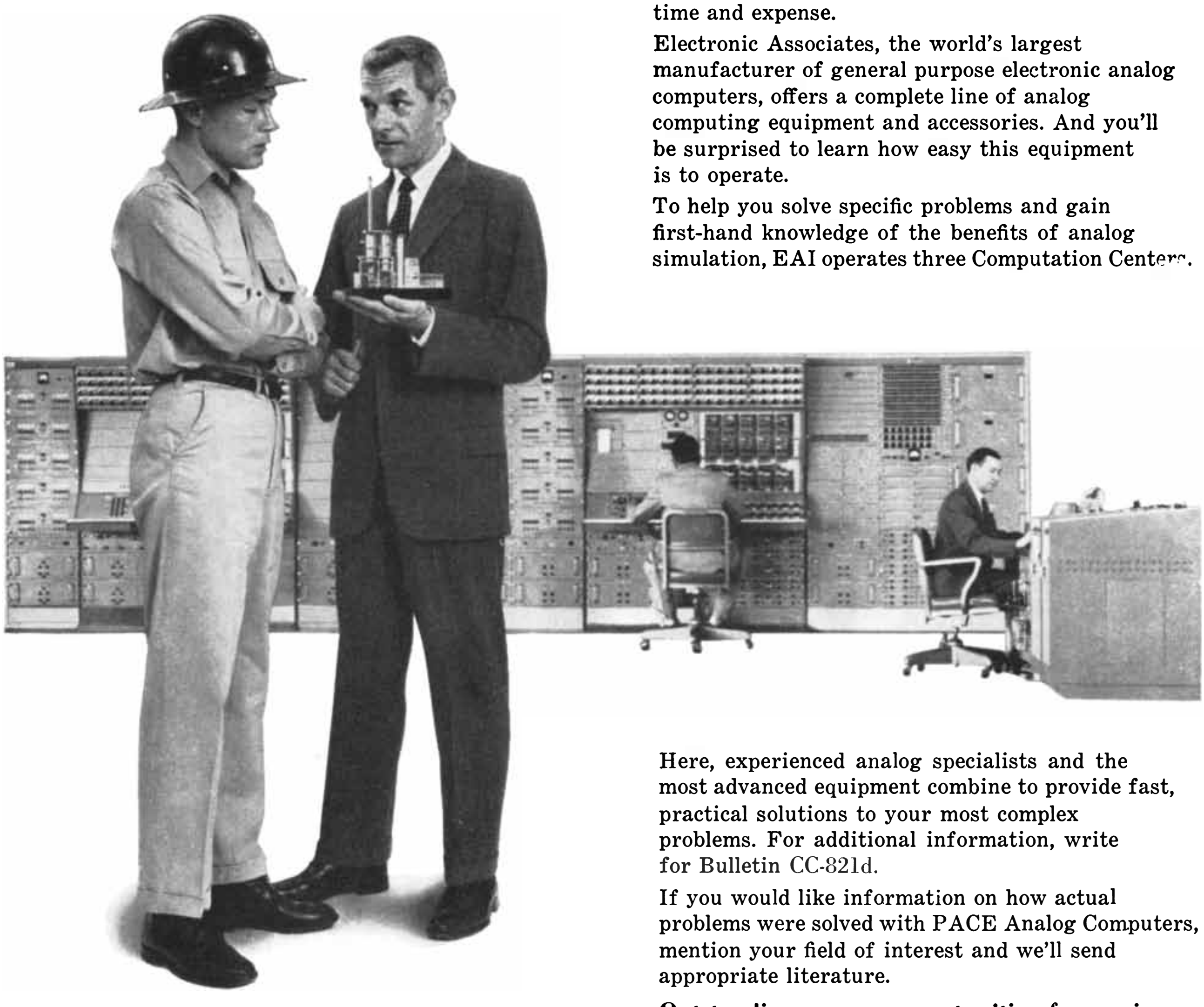
PACE *Computer you can* TORTURE A CAT CRACKER . . . *simulate* *any dynamic problem!*

These men are simulating the performance of a catalytic cracking tower on a PACE Electronic Analog Computer. They are developing the ideal combination of pressure, temperature and flow for better process control and improved refinery efficiency.

This ability to study dynamic characteristics on electronic analog computers and to test equipment to destruction before it is built—is aiding a variety of industries in upgrading processes and developing new designs. Analog computers simulate machine or process performance and chart accurate graphic pictures of what happens under extremes of speed, pressure, temperature, etc. When destruction or breakdown occurs, the reason is clearly indicated. This helps engineers to "design-out" problems before pilots or prototypes are built. It means new and safer methods of operation can be found—with less engineering time and expense.

Electronic Associates, the world's largest manufacturer of general purpose electronic analog computers, offers a complete line of analog computing equipment and accessories. And you'll be surprised to learn how easy this equipment is to operate.

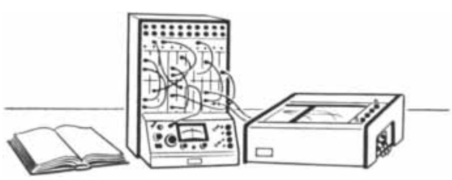
To help you solve specific problems and gain first-hand knowledge of the benefits of analog simulation, EAI operates three Computation Centers.



Here, experienced analog specialists and the most advanced equipment combine to provide fast, practical solutions to your most complex problems. For additional information, write for Bulletin CC-821d.

If you would like information on how actual problems were solved with PACE Analog Computers, mention your field of interest and we'll send appropriate literature.

Outstanding career opportunities for engineers with proven ability—résumés invited.



New solid-state computer and desktop X-Y plotter.

EAI

ELECTRONIC ASSOCIATES, INCORPORATED
Long Branch, New Jersey

Charles Lyell

He founded modern historical geology and set the stage for the achievement of Charles Darwin. Until late in his career, however, he was reluctant to accept the idea of evolution

by Loren C. Eiseley

"I feel as if my books," Charles Darwin once confessed, "came half out of Sir Charles Lyell's brain." The great biologist was admitting to no more than the simple truth. Sir Charles Lyell, who remained until late in his career a reluctant evolutionist, was paradoxically the ground-breaker for the triumph of the *Origin of Species*.

Lyell is remembered chiefly as a founder of modern historical geology. But he was also a biologist whose studies form the backbone of the achievement of Darwin and Alfred Russel Wallace. In his day he addressed tabernacles in both England and America full of people eager to hear the world-shaking views of the new geology. Today the man in the street has forgotten him. By a curious twist of history, Darwin replaced Lyell as a popular idol. Yet this gaunt-faced man who ended his days in near-blindness was one of the greatest scientists in a century of distinguished men.

A generation before Darwin he took a world of cataclysms, supernatural violence and mystery, and made of it something plain, expected and natural. If today we look upon our planet as familiar even when its bowels shake and its volcanoes grumble, it is because Lyell taught us long ago the simple powers in the earth.

It was as though we had been unable to see the earth until we observed it through the eyes of Lyell. Ralph Waldo Emerson wrote at mid-century: "Geology, a science of forty or fifty summers, has had the effect to throw an air of novelty and mushroom speed over entire history. The oldest empires—what we called venerable antiquity—now that we have true measures of duration, show like creations of yesterday. . . . The old six thousand years of chronology becomes a kitchen clock."

To Darwin and Wallace, Lyell gave the gift of time. Without that gift there would have been no *Origin of Species*. Geologic time is now so commonplace that the public forgets it once had to be fought for with something of the vigor that was later to be transferred to the evolutionary debates of the 1860's.

Lyell was, in modern terms, both zoologist and geologist. Indeed, he defined geology as that science "which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature." Today the splitting-up of science into numerous special disciplines has left Lyell one of the founders of historical geology. The world has tended to forget that he also wrote extensively upon zoological subjects, and that he exerted, as an older friend and influential scholar, a profound effect upon the career of Charles Darwin. "Lyell," remarked the great U. S. evolutionist Asa Gray in the year of Darwin's death "is as much the father of the new mode of thought which now prevails as is Darwin."

Yet in the first years of evolutionary controversy, beginning with Jean Baptiste de Lamarck and extending into the time of Robert Chambers and Charles Darwin, Lyell found himself popularly arrayed with the resistance to evolution. He was not to alter his public position until the autumn of his life. To us it may seem an almost willful rejection of the new age of science. Oddly enough we are wrong. Reading history backward is almost worse than not reading history at all. One must live both in a given time and beyond it to appreciate at once its complexities and its half-veiled insights.

Lyell's rejection of evolution was one of the first rational products of the new geology. A hint as to the nature of the situation is to be found in a passage in Lyell's *The Antiquity of Man*, published in 1863. The issue, to our modern eyes, is obscured by the terms in which it was argued. Lyell wrote: "It may be thought almost paradoxical that writers who are most in favor of transmutation (Mr. C. Darwin and Dr. J. Hooker, for example) are nevertheless among those who are most cautious, and one would say timid, in their mode of espousing the doctrine of progression; while on the other hand, the most zealous advocates of progress are, oftener than not, very vehement opponents of transmutation. We might have expected a contrary leaning on the part of both."

It is in the words "transmutation" and "progression," now unfamiliar, that the key to this mystery lies. When we come to know their significance, we will have learned that the road to the acceptance of evolution had unexpected turnings which, as we look backward, seem to have vanished, but which were real enough to the men of the 19th century. Before we can understand Lyell's position, this queer order of events has to be explored and comprehended.

Charles Lyell was born, the first of 10 children, to well-to-do parents in Scotland in 1797. His father possessed a strong interest in natural history and may have helped unconsciously to guide his son's interests in that direction. As Charles Darwin and Alfred Russel Wallace were later to do, the young Lyell collected insects in his boyhood. Absent-minded but versatile, tree-climber and chess player, he matriculated at Exeter College, Oxford, in 1816. Having early stumbled upon a copy of Robert Bakewell's *Introduction to Geology* in his father's library, he sought out Dean Buckland's geological lectures at Oxford, and from then on was a haunter of chalk pits, rock quarries, caves and river terraces.

In 1818 he made the usual continental tour with his parents and sisters. The slow carriage travel of that day promoted leisurely observation, and Charles made the most of it. He saw the red snow and glaciers of the high Alps as well as the treasures that lie open to the observant in the flints of the common road. Lyell had not as yet settled upon a career in geology. He was destined for the law, and shortly after his graduation from Oxford he came to London to prepare himself for the bar.

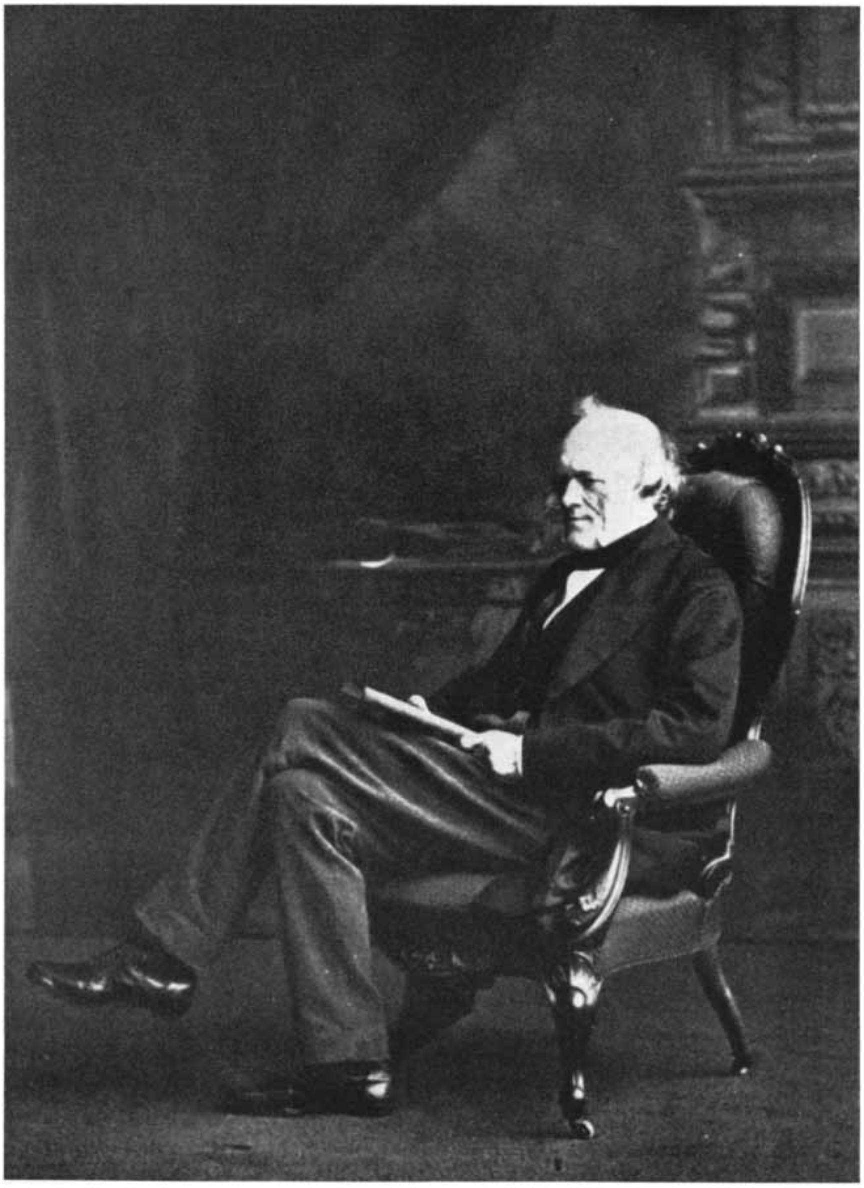
Even in London, however, Lyell was soon elected a Fellow of the Geological Society and joined the Linnean Society. Two handicaps tended to retard his legal career. His eyes were weak and troublesome, and he suffered from a slight speech difficulty, with which he was to contend bravely in his years as a lecturer on the natural sciences. When he was called to the bar in 1825 he was already contributing articles on scientific subjects to the *Quarterly Review*.

It has sometimes been intimated that Charles Lyell was "only an armchair geologist," that he was scientifically timid, a rich man's son who happened to dabble his way to success in a new science. But in those days there was little in the way of public support for science. Even the great schools were still largely concentrated upon the classical education of gentlemen. Only the man of independent means, like Lyell or Darwin, could afford to indulge his interest in science. With occasional struggling exceptions such as Wallace, it was the amateur who laid the foundations of the science of today. The whole philosophy of modern biology was established by such a "dabbler" as Charles Darwin, who never at any time held a professional position in the field. Charles Lyell and his great precursor, the Scotsman James Hutton, similarly laid the foundations of modern geology without claiming much in the way of formal institutional connections. Important though institutional and government support has come to be, it has led to a certain latent snobbery in professional circles. The amateur has had his day. But his was the sunrise of science, and it was a sunrise it ill becomes us to forget.

The charge that Lyell was an armchair worker will not stand against the facts. But even if the accusation held, the whole question would turn on what came out of the armchair. In actuality Lyell in his younger years made numerous trips to the continent to examine the evidence of geology at firsthand. Later, in the 1840's, he visited America, where he made similar ventures into the field, even though he was by then lecturing to thousands. As his biographer T. G. Bonney remarks: "Whenever there was hope of securing any geological information or of seeing some remarkable aspect of nature, Lyell was almost insensible either to heat or to fatigue." It is hard to see how a man suffering from bad eyes could have done more.

In support of the charge of scientific timidity, it is observed that Lyell opposed himself for many years to evolutionary views; it is said that his public and his private statements upon this score were vacillating. "How could Sir Charles Lyell," wrote one of Darwin's contemporaries, "for thirty years read, write and think on the subject of species and their succession, and yet constantly look down the wrong road?" From the vantage point of a hundred years this question can be answered. A whole new theory of life and time is not built by one man, however able. It is the product of multitudinous minds, and as a consequence it is also compounded of the compromises and hesitations of those same minds. Later, when the new world view comes to be ascribed, as it generally is, to a single individual such as Darwin the precursors of the discoverer begin to seem incredibly slow-witted.

Whatever men may think on this score, however, the record shows that



LYELL was born in Scotland in 1797 and died in 1875. He prepared for a legal career, but turned to geology. This photograph is in *Portraits of Men of Eminence*, published in 1863.

Lyell was a man of intellectual courage. He entered the geological domain when it was a weird, half-lit landscape of gigantic convulsions, floods and supernatural creations and extinctions of life. Distinguished men had lent the power of their names to these theological fantasies. Of the young Lyell, the "timid" Lyell who later strained Darwin's patience, a contemporary geologist wrote: "He stood up as a reformer, a radical reformer, denouncing all the old notions about paroxysms and solving every geological question by reference to the action of constant and existing physical causes. Never had a revolutionist harder work to get a sober hearing, or less prospect of overturning the works and conclusions of other men."

Geology at the beginning of the 19th century was known to many in England as a dangerous science. As such it both attracted and repelled the public. A body of fact and interpretation had arisen that could only be kept in accord with the Scriptural interpretation of earth's history by the exercise of considerable ingenuity. Theological authority was strong, and there was the greatest pressure upon geologists to avoid direct conflict with the church. Moreover, some of the early geologists were primarily theologians themselves, and were understandably anxious to reconcile geology with their religious beliefs. By degrees there had thus arisen a widely accepted view of geological history known as catastrophism.

This orthodox geological creed was an uneasy amalgam of the new scientific facts seen in the flickering, unreal light of mythological and romantic fantasy. Unlike the slow evolutionary successions that we recognize today, the record of geology was held to contain sudden catastrophic breaks. Mountain ranges were thought to be heaved up overnight; gigantic tidal waves, floods, paroxysms of the earth's crust were thought to mark the end of periods of calm. At such hours life vanished only to be restored through renewed divine creation, taking in the new period a more advanced form, and pointing steadily on toward the eventual emergence of man. It may thus be observed that the students of catastrophism had become aware of organic change in the rocks, but they saw the planet as having been molded by forces seemingly more powerful than those at work in the present day, and thus by implication supernatural.

Awareness of a succession of life-forms in the strata of the earth had been slowly increasing since the close of the 18th century. Furthermore, it was seen that these extinct forms of life showed an increasing complexity as one approached the present. Since the record of the land vertebrates is particularly incomplete and broken, there arose the idea that, instead of a genuine continuity of life from age to age, the breaks in the geological record were real breaks. There had been a genuine interruption between the life of one age and that of another; each geological period had its own flora and fauna largely distinct from that which preceded and followed it. The slow, grand progression of life was seen as through a jerky, discontinuous, ill-run motion picture.

Men still did not understand the real age of the earth, nor the fact that the

PRINCIPLES

OF

GEOLOGY,

BEING

AN ATTEMPT TO EXPLAIN THE FORMER CHANGES
OF THE EARTH'S SURFACE,

BY REFERENCE TO CAUSES NOW IN OPERATION.

BY

CHARLES LYELL, Esq., F.R.S.

FOR. SEC. TO THE GEOL. SOC., &c.

IN TWO VOLUMES.

Vol. I.

LONDON:

JOHN MURRAY, ALBEMARLE-STREET.

MDCCCXXX.

THE GEOLOGICAL EVIDENCES

OF

THE ANTIQUITY OF MAN

WITH REMARKS ON THEORIES OF

THE ORIGIN OF SPECIES BY VARIATION

By SIR CHARLES LYELL, F.R.S.

AUTHOR OF 'PRINCIPLES OF GEOLOGY,' 'ELEMENTS OF GEOLOGY,' ETC. ETC.

SECOND EDITION, REVISED

ILLUSTRATED BY WOODCUTS

LONDON

JOHN MURRAY, ALBEMARLE STREET

1863

The right of translation is reserved

LYELL'S PRINCIPAL WORK was *Principles of Geology*, published in 1830. Although the title page reproduced at left states that the book has two volumes, Lyell later wrote a third. At right is the title page of *The Antiquity of Man*, which was published in 1863.

breaks they found in the records of the rocks were not world-wide, but rather only local discontinuities. The imperfections of the geological record, or the passages between the discontinuities, could only be learned through the piling-up of empirical evidence, a task that had only begun.

The catastrophic school had a powerful religious appeal. It retained both the creative excess and fury of an Old Testament Jehovah. "At succeeding periods," wrote Adam Sedgwick, one of Darwin's geological teachers at Cambridge, "new tribes of beings were called into existence, not merely as the progeny of those that had appeared before them, but as new and living proofs of creative interference; and though formed on the same plan, and bearing the same marks of wise contrivance, oftentimes unlike those creatures which preceded them, as if they had been matured in a different portion of the universe and cast upon the earth by the collision of another planet."

People thought in terms of a geotheological drama, a prologue to the emergence of man on the planet, after which no further organic developments were contemplated. The theory predicted a finished world which, in some eyes at least, could be compressed into the figurative week of the Book of Genesis. "Never," commented Lyell, "was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption of the discordance between the former and the existing causes of change."

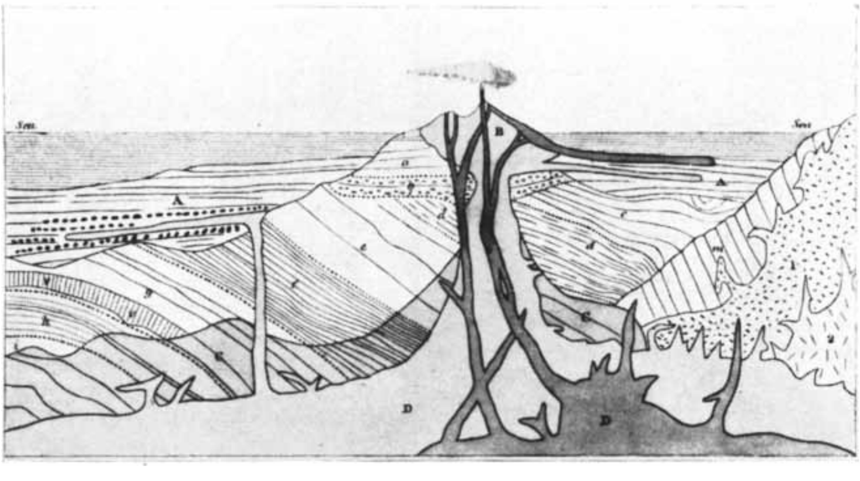
In this half-supernatural atmosphere Sir Charles Lyell in 1830 published the first volume of his *Principles of Geology*. Like most great ideas it was not totally original with its author. But to Sir Charles belongs the unquestioned credit of documenting a then unpalatable truth so effectively and formidably that it could no longer be ignored. In this respect again his career supplies a surprising parallel to that of Darwin. For Darwin too, at a later time, was the resurrector and documenter of forgotten and ill-used truths.

Lyell's principal precursor, James Hutton, died in intellectual eclipse in 1797, the very year that saw the birth of the man who was to revive his views—so tenuous and yet so persistent is the slow growth of scientific ideas. In the 1780's Hutton made the first organized and comprehensive attempt to demonstrate that the forces that had shaped the planet—its mountains, boulders and continents—are the same forces that can be observed in action around us today. Hutton had an ear for the work of raindrops, an eye for frost crystals splitting stones, a feel for the leaf fall of innumerable autumns. Wind and frost and running water, given time enough, can erode continents, ran his argument. Peering into the depths of the past, he could see "no vestige of a beginning, no prospect of an end."

Hutton, though not the first to suspect the earth's antiquity, nor the work that perfectly natural forces can perform, was the first to write learnedly and extensively upon the subject. His work fell, however, into undeserved neglect. He was criticized as irreligious. In England, particularly in the conservative reaction following the French Revolution, the catastrophism theory, with its grander scenery and stage effects, had a more popular appeal. The world of Hutton by contrast was an unfinished world still unrolling into an indeterminate future. Its time depths were immeasurable, and the public had recoiled from its first glimpses into that abyss.

Yet this was the domain, and this the philosophy, upon which Sir Charles Lyell was to force his colleagues to take a long second look. He was a more eloquent and able writer than Hutton. But beyond this he had the advantage of almost 50 years of additional data, including his own personal study of the continental deposits. "Lyell," remarks one of his contemporaries, "was deficient of power in oral discourse, and was opposed by men who were his equals in knowledge, his superiors in the free delivery of their opinions. But in resolute combats, yielding not an inch to his adversaries, he slowly advanced upon the ground they abandoned, and became a conqueror without ever being acknowledged as a leader."

By degrees the idea of gradual change (uniformitarianism, as it came to be called) succeeded the picture of worldwide catastrophes. Supposition and quasi-theological imaginings gave place to a recognition of the work of natural forces still active and available for study in the world about us. The disjoined periods of the catastrophists began to be seen as one continuous world extending into a past of awe-inspiring dimensions. The uniformitarian school began to dominate the geological horizon. With the success of the *Principles* Lyell became one of two or three leading figures in English natural science until the peak of Darwin's fame was achieved with the publication of the *Origin of Species* in 1859. It is no wonder that the young Darwin, just returned from the voyage



EARTH'S CRUST is depicted in Lyell's *Elements of Geology*. It is captioned: "Ideal section of . . . the Earth's crust explaining the theory of the . . . origin of the four great clafses of rocks." The classes were: aqueous (A), volcanic (B), metamorphic (C) and plutonic (D).

of the *Beagle* in 1836, gravitated so quickly to Lyell. It was Lyell's revision of geology that was to make Darwin's triumph possible.

Sir Charles Lyell had been raised in a more orthodox home than Charles Darwin. In fact, he was to confess in afteryears that it cost him a severe struggle to renounce his old beliefs. Nevertheless, in reviving the conception of limitless time, and in abandoning the notion of world-wide breaks in the geological record as urged by the catastrophists, Lyell was inevitably forced to confront the problem of life itself in all its varied appearances. His great predecessor, Hutton, had been largely able to avoid the issue because of the lack of paleontological information. In Lyell's time, however, the questions pressed for answer.

The catastrophist doctrine had given birth to a kind of romantic evolutionism to explain the increasing complexity of life. This was the doctrine of "progression" which Lyell opposed in many of his writings from the time of the *Principles* onward. Progressionism was the product of the new paleontology which had discovered differences among the life-forms of successive geological eras. The theory can be said to have borrowed from Lamarck the conception of a necessary advance in the complexity of life as we ascend through the geological strata to the present. Instead of establishing biological continuity (the actual physical relationship between one set of forms and their descendants) the progressionists sought to show only a continuity or an organic plan in the mind of God between one age and another. There was, in other words, no phylogenetic relationship on the material plane between the animals of one era and those of a succeeding one.

Progressionism thus implied a kind of miraculous spiritual evolution which ceases only when the human level has been attained. The idea is confusing to the modern thinker because he tends to read back into this literature true evolutionary connotations that frequently were not intended by these early writers. The doctrine is interesting as a sign of the compromises being sought between an advancing science and a still-powerful religious orthodoxy.

"I shall adopt a different course," the young Lyell had written when he was contending for the uniformitarian view in geology. "We are not authorized in the infancy of our science to recur to extraordinary agents." The same point of view led him, in company with T. H. Huxley, Joseph Hooker and, later, Darwin, to reject the claims of progressionism. All of these men, Lyell foremost among them, were uniformitarians in geology. They believed in the play of purely natural forces upon the earth. They refused or were reluctant to accept the notion of divine interposition of creative power at various stages of the geological record. They felt in their bones that there must be a natural explanation for organic as well as geological change, but the method was not easily to be had. Since Lyell was the immediate parent of the new geology, and since he was committed to natural processes, he was continually embarrassed by those who said: "You cannot show how nor why life has altered. Why then should we not believe that geological changes are equally the product of mysterious and unknown forces?"

We are now at the crux of the reason why Lyell was dubious about notions of "transmutation"—the term then reserved for ideas implying true physical connection among the successions of species or, as we would say, "evolution" from one form to another. Lyell's attitude toward evolution was influenced by the antipathy that he felt toward progression, toward the unexplainable. In bracketing the two together he in effect was indicating the need of a scientific explanation of organic change, if change indeed was demonstrable.

Beginning with the *Principles of Geology*, in which the second volume and part of the third are devoted to biological matters, Lyell had sought to examine the biological realm with an eye to answering the challenge of the catastrophist progressionists. As a consequence he came close to, but missed the significance of, the natural-selection hypothesis which was to establish the fame of Charles Darwin. It was here that he took the wrong turning that led him away from evolution. Yet ironically enough, though Lyell failed to comprehend the creative importance of natural selection, he did not miss its existence. In fact, through a strange series of circumstances just discovered in the literature, it is likely that he was fundamentally instrumental in presenting Darwin with the key to the new biology. He was so concerned, however, to array the evidence against the doctrine of progression that he missed the support that the same evidence gave for a rational explanation of the origin of species.

Against the progressionists' idea of mass extinction at each break in the geological record he cited the imperfections in that record. "There must," he contended, "be a perpetual dying out of animals and plants, not suddenly and by whole groups at once, but one after another." Although not solving the problem of the emergence of new forms of life, Lyell by arguing for geological continuity was bringing the question of extinction and of the origin of new species within the domain of scientific investigation.

He countered the progressionist hypothesis with a short-lived "nonprogressionism" in which he argued that the discovery of higher forms of life in older strata would demonstrate that the progressionist doctrine was based solely upon the fallible geological record. This retreat from straight evolution on the part of Lyell was somewhat wavering, but it continued into the 1850's. There is no doubt that it was an attempt philosophically to evade a problem which threatened to interpose into his system something miraculous and unexplainable that savored of the catastrophist doctrines he had struggled for so long to defeat. Only with the triumph of Darwin would a uniformitarian, a "naturalistic," explanation for the mutability of life be available to the uniformitarian followers of Lyell. It was only then that Huxley, Hooker and finally Lyell himself became converts to evolution, at a time when it was still being resisted by such men as Sir Richard Owen and Louis Agassiz—old-style catastrophists and progressionists who at first glance one might think would have eagerly embraced the new doctrine of genuine physical evolution.

Although the question has been obscured by hazy difficulties of terminology, Sir Charles Lyell had already described before Darwin the struggle for existence and, up to a certain point, natural selection. He had not, however, visualized its creative aspect. Lyell made the first systematic attempt to treat the factors affecting the extinction of species and the effects of climatic change upon animal life throughout the long course of ages. "Every species," Lyell contended, "which has spread itself from a small point over a wide area must have marked its progress by the diminution or the entire extirpation of some other, and must maintain its ground by a successful struggle against the encroachments of other plants and animals." He goes on to speak of "the tendency of population to increase in a limited district beyond the means of subsistence." Nor was Lyell unaware of plant and animal variation, although he believed such variation to be limited. "The best-authenticated examples of the extent to which species can be made to vary may be looked for in the history of domesticated animals and cultivated plants," he wrote, long before Darwin's investigations.

But Lyell did more than this. In the *Principles of Geology* he marshaled a powerful attack on the possibility that new evolutionary forms might be able thus to maintain or perfect themselves. Lyell advanced what he called his principle of "preoccupancy." In essence this principle simply assumes that creatures or plants already well fitted for occupying a given ecological zone will keep any other forms from establishing themselves in the new habitat, even assuming that the competitors are capable of evolving. "It is idle," said Lyell, "to dispute about the abstract possibility of the conversion of one species into another, when there are known causes so much more active in their nature which must always intervene and prevent the actual accomplishment of such conversions." Using a number of present-day examples Lyell sought to show that local alterations, say that from marsh to dry land, or fresh to brackish water, would never permit of slow organic change, because long before the organisms of the older environment could alter they would die out in competition with already adapted forms intruding to take advantage of the new conditions.

Lyell, in other words, could see how time and changing conditions might alter the percentages of living forms in given localities or change the whole nature of a flora. He understood that "the successive destruction of species must now be part of the regular and constant order of nature." What he still failed to grasp was that he was observing the cutting edge of the natural-selection process in terms of its normal, short-time effects. The struggle in nature that had so impressed him he had seen, if anything, too vividly. There was left no refuge, no nursing ground, by which the new could come into existence. The already created, the already fit, dominated every niche and corner of the living world. Lyell understood ecology before Darwin. He saw the web of life, but he saw it so tightly drawn that nothing new could emerge from it. As geographical or climatic conditions altered in the course of geological time, already existing forms moved from one area to another; he could see no evidence for a mechanism to explain the emergence of new forms.

His vision of the history of life was not wrong; it was simply incomplete. Lyell himself realized the complexities of the problem that beset him: There was a going-out without an equivalent coming-in, an attrition without a compensating creation.

"The reader will immediately perceive," Lyell wrote, "that amidst the vicissitudes of the earth's surface, species cannot be immortal, but must perish one after the other, like the individuals which compose them. There is no possibility of escaping this conclusion without resorting to some hypothesis as violent as that of Lamarck." Drawing back from this gulf, Lyell returns again and again to nonprogressionism. Nevertheless, like many naturalists of his day, he was willing to recognize "a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly, according to the species." Lyell recognized minor varietal differences of a seemingly genetic character in some animals. Beyond this he did not venture.

The term natural selection, introduced by Darwin and now everywhere regarded as the leading mechanism in evolutionary change, has a peculiar history. Under other names it was known earlier within the century, but this is little realized. Darwin introduced the principle to his readers under a new term and with new implications so that it has been widely assumed that it originated in his mind. One might say, without minimizing Darwin's achievement, that this widespread impression is not quite accurate. Charles Darwin in reality took a previously recognized biological device and gave it a new and quite different interpretation. In doing so he opened the doorway to unlimited organic change and provided that empirical evolutionary mechanism which had driven Lyell and other objective scientists away from the progressionists, even though the latter had been correct, in a general sense, about the ascending complexity of life. Darwin's achievement was an apt illustration of what can sometimes be done with old principles when someone looks at them in a new way and sees some unexpected possibility within them. Darwin altered our whole conception of the nature of the world in which we live. He did so by making use of a principle already known to Charles Lyell and one other man, a young zoologist by the name of Edward Blyth. Essentially it was the principle that Lyell advanced against the evolutionary arguments of Lamarck in the 1830's.

"Of all forms of mental activity," the historian Herbert Butterfield once wrote, "the most difficult to induce is the act of handling the same bundle of data as before, but placing them in a new system of relations with one another by giving them a different framework, all of which virtually means putting on a different kind of thinking cap for the moment." This is precisely what Charles Darwin did when he took the older conception of natural selection and by altering it a hairbreadth created that region of perpetual change, of toothed birds, footless serpents and upright walking apes in which we find ourselves. Yet difficult as Darwin's feat proved to be, he received a hint, a nudge as it were, which began with Lyell, was elaborated by young Edward Blyth and from him was apparently transferred to Darwin. No clearer sequence in the evolution of ideas can be perceived anywhere in the domain of science.

Edward Blyth was a man of 25 when he read Lyell and, impressed by his ideas, carried them a little further. In the British *Magazine of Natural History* in 1835 and again in 1837, the very year that Darwin opened his first notebook upon the species question, Blyth discussed what today we would call both natural and sexual selection.

"Among animals which procure their food by means of their agility, strength or delicacy of sense, the one best organized must always obtain the greatest quantity; and must, therefore, become physically the strongest and be thus enabled, by routing its opponents, to transmit its superior qualities to a greater number of offspring. The same law, therefore, which was intended by Providence to keep up the typical qualities of a species can be easily converted by man, into a means of raising different varieties."

This idea young Blyth referred to as his "localizing principle." Like Lyell he saw the conservative aspect of selection,

Synoptical Table of Recent and Tertiary Formations.

PERIODS.		Character of Formations.	Localities of the different Formations.
I. Recent.		Marine.	Coral formations of Pacific. Delta of Po, Ganges, &c.
		Freshwater.	Modern deposits in Lake Superior—Lake of Geneva—Marl lakes of Scotland—Italian travertin, &c.
		Volcanic.	Jorullo — Monte Nuovo — Modern lavas of Iceland, Etna, Vesuvius, &c.
II. Tertiary.	1. Newer Pliocene.	Marine.	Strata of the Val di Noto in Sicily. Ischia, Morea? Uddevalla.
		Freshwater.	Valley of the Elsa around Colle in Tuscany.
		Volcanic.	Older parts of Vesuvius, Etna, and Ischia—Volcanic rocks of the Val di Noto in Sicily.
	2. Older Pliocene.	Marine.	Northern Subapennine formations, as at Parma, Asti, Sienna, Perpignan, Nice—English Crag.
		Freshwater.	Alternating with marine beds near the town of Sienna.
		Volcanic.	Volcanos of Tuscany and Campagna di Roma.
	3. Miocene.	Marine.	Strata of Touraine, Bordeaux, Valley of the Bormida, and the Superga near Turin—Basin of Vienna.
		Freshwater.	Alternating with marine at Saucats, twelve miles south of Bordeaux.
		Volcanic.	Hungarian and Transylvanian volcanic rocks. Part of the volcanos of Auvergne, Cantal, and Velay?
	4. Eocene.	Marine.	Paris and London Basins.
		Freshwater.	Alternating with marine in Paris basin—Isle of Wight—purely lacustrine in Auvergne, Cantal, and Velay.
		Volcanic.	Oldest part of volcanic rocks of Auvergne.

ROCK FORMATIONS of Recent and Tertiary periods were tabulated in first volume of *Principles of Geology*. Such tabulations showed the continuity of formations over a large area. Before the rise of historical geology local breaks in the continuity of rock formations had been taken as evidence that the history of the earth was a series of catastrophic events.

but he saw it more clearly. He actually discussed its genetic aspects. As the above quotation indicates, however, he interpreted natural selection as a providential device eliminating the variant and unfit and holding each organism to its divinely appointed place in nature. Nevertheless in the course of his speculations he draws up short before a startling thought. "A variety of important considerations here crowd upon the mind," he confesses, "foremost of which is the enquiry, that, as man, by removing species from their appropriate haunts, superinduces changes on their physical constitution and adaptations, to what extent may not the same take place in wild nature, so that, in a few generations distinctive characters may be acquired, such as are recognized as indicative of specific diversity. . . ? May not then a large proportion of what are considered species have descended from a common parentage?"

The great question had been asked again, but this time more definitively, more perspicaciously, than it had ever been asked before. Sadly, timidly young Blyth in the end rejects his own question. Like Lyell, from whom he had drawn much, he found the new world he had glimpsed too dim, too distant, too awe-inspiringly new to be quite real. One rubbed one's eyes and it was gone. The safe, constricted world of the English hedgerows remained—the world in which everything held its place.

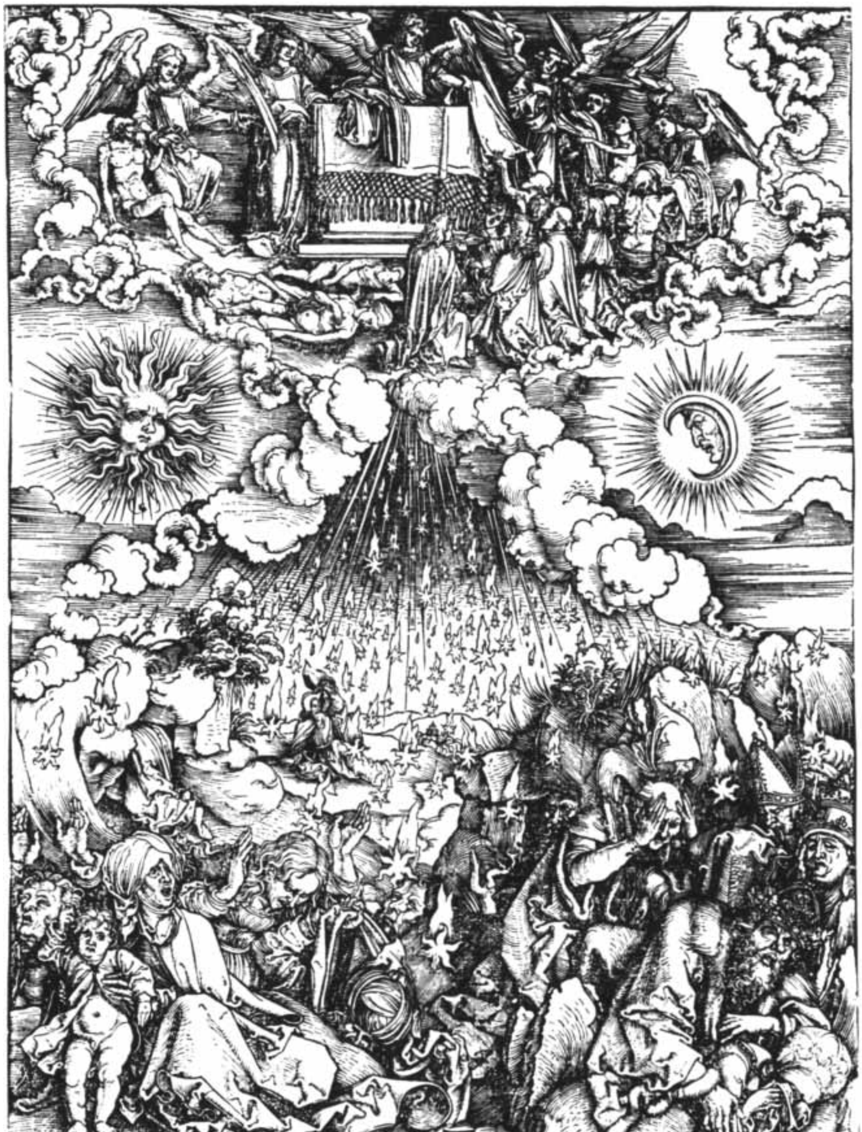
But the year was 1837. Charles Darwin was home from the Galápagos, home from the five-year voyage of the *Beagle*, home with turtles and coral, bird beaks and pampas thistles in his head. He read the *Magazine of Natural History* consistently in this time. We know it from recently discovered evidence. In fact, Darwin, in a somewhat cryptic early letter, tells us so: "In such foreign periodicals as I have seen, there are no such papers as White or Waterton, or some few other naturalists in Loudon's and Charlesworth's Journal would have written; and a great loss it has always appeared to me." Loudon's and Charlesworth's Journal is the *Magazine of Natural History*. There, to lie undiscovered for a century, reposed the hint that seemingly started Darwin along the road to the *Origin*. There at last is the reason for the sudden burgeoning of his ideas after the return from the voyage. Interior evidence in Darwin's early essays strongly suggests the relationship.

Later on in the century the two men became friends. As to whether Edward Blyth ever saw or grasped the connection between his youthful thoughts and the intellectual revolution that came in 1859, we do not know. After many years in India, where he devoted himself largely to ornithology, he was invalided home and died in 1873.

Passing from Lyell to Blyth to Darwin, the world faintly glimpsed by a few thinkers before them—that marred, imperfect and yet forever changing world which brings equally into being butterflies and men—dawns fully in our minds. If there is revealed to us the dark shadow of tooth and club by which we have arisen, we are taught also the utter novelty of life, its unguessed potentialities. The lost Eden which, as Francis Bacon had dreamed, might be repossessed by knowledge lies ahead of us, but it waits upon moral powers that may be as necessary to man as learning.

"Man is an ape and a beast," writes the pessimist. The true evolutionist will only say: "Man is a changeling. He is making himself blindly now, and dragging the dead past forward like a snake's cast-off skin whose fragments still bind him. He is a very young creature, a tick on Emerson's kitchen clock. Do not define him. Let the clock tick once more. Then we will know."

Already in Sir Charles Lyell's mind man's next hour was striking. As one surveys the long record of his life, as one sees his influence upon Edward Blyth, upon Darwin and upon Alfred Russel Wallace, as well as upon many other aspiring workers, one comes to recognize that to a major degree he set the scientific tone of the Victorian age. He brought to bear upon scientific thought and speculation a mind trained to the value of legal evidence. He was, on the whole, dispassionate, clear-headed and objective. By precept and example he transmitted that heritage to Darwin. He emphasized synthesis and logical generalization from facts. Both men eschewed small works and both amassed great bodies of material to carry their points. Lyell warned Darwin away from petty scientific bickering as a waste of time and nerves. At almost every step of Darwin's youthful career Lyell was an indefatigable guide and counselor. Then at that critical hour when Darwin was appalled by the reception of the news of Wallace's independent discovery of natural selection, it was Lyell and Hooker who counseled the simultaneous publication of the papers of both men.



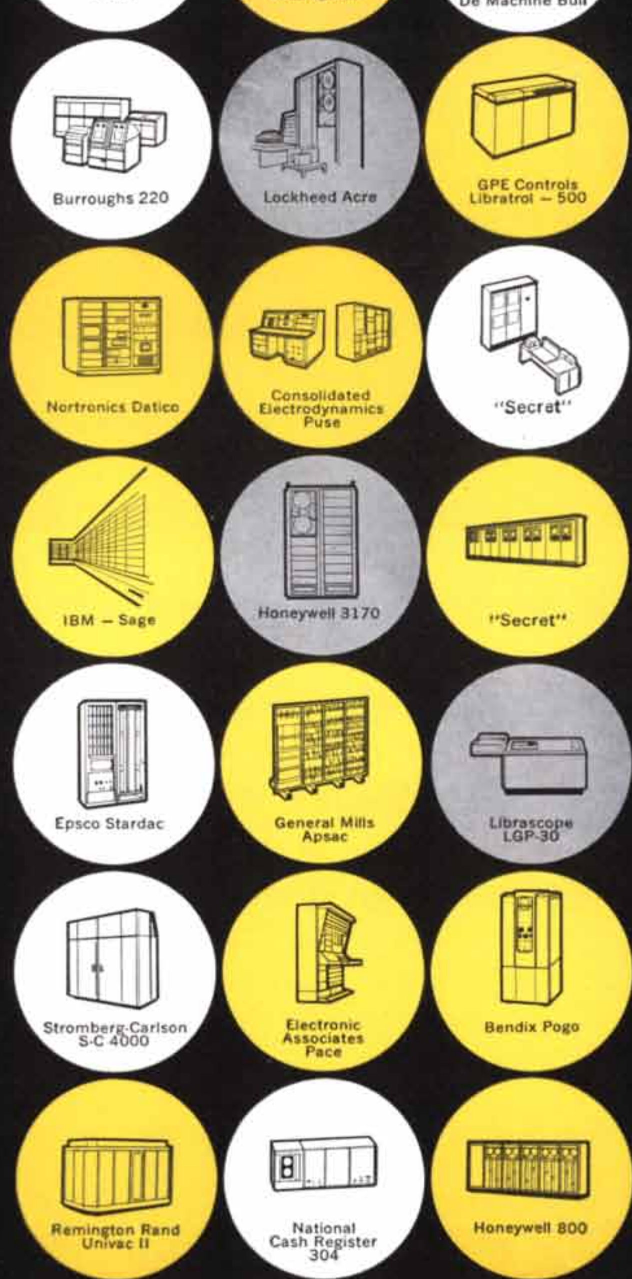
CATASTROPHIC VIEW of the earth's history is reflected in this engraving by Albrecht Dürer. The engraving illustrates the passage in the Bible (*The Revelations of Saint John the Divine*, Chapter 6, Verse 13) beginning: "And the stars of heaven fell unto the earth. . . ."

Darwin and Wallace were Lyell's intellectual children. Both would have failed to be what they were without the *Principles of Geology* to guide them. In science there is no such thing as total independence from one's forerunners. It is an illusion we sometimes like to foster, but it does not bear close examination. Even our boasted discoveries are often in reality a construct of many minds. We are fortunate if we sometimes succeed in fitting the last brick into such an edifice. Lyell himself knew this and tasted its irony.

He died in 1875 at the end of a long, outwardly uneventful life spent largely in the company of a beautiful, gracious and intelligent woman. After his wife's death in 1873 the light began to pass away from Lyell; he did not long survive her. A few years before, he had written to Ernst Haeckel: "Most of the zoologists forget that anything was written between the time of Lamarck and the publication of our friend's *Origin of Species*."

Much indeed had been forgotten. In this little sigh of regret Lyell was even then resigning his hold upon the public which had once idolized him. To the true historian of science, however, he remains the kingmaker whose giant progeny, whether acknowledging their master by direct word or through the lines of their books, continue today to influence those who have never heard his name.

Of Charles Lyell, Darwin himself said what is so often remarked in our day of Darwin: "The great merit of the *Principles* was that it altered the whole tone of one's mind and, therefore, that when seeing a thing never seen by Lyell, one yet saw it partially through his eyes."



wherever there's electronics...

there's Transitron

The heart of each of these computers consists of Transitron semiconductors. They provide the speed and reliability so essential to accurate performance. These machines are the calculating geniuses which guide more and more of the world's business and defense. At Transitron more than 3500 employees work exclusively to develop and produce high quality silicon and germanium semiconductors. In computers — as in missiles, radar, atomic subs, communications, jets, and thousands of other military and commercial applications — wherever there's electronics, there's Transitron, leading the field in advanced semiconductor reliability.

TRANSISTORS • DIODES • RECTIFIERS • REGULATORS • VOLTAGE REFERENCES

Transitron

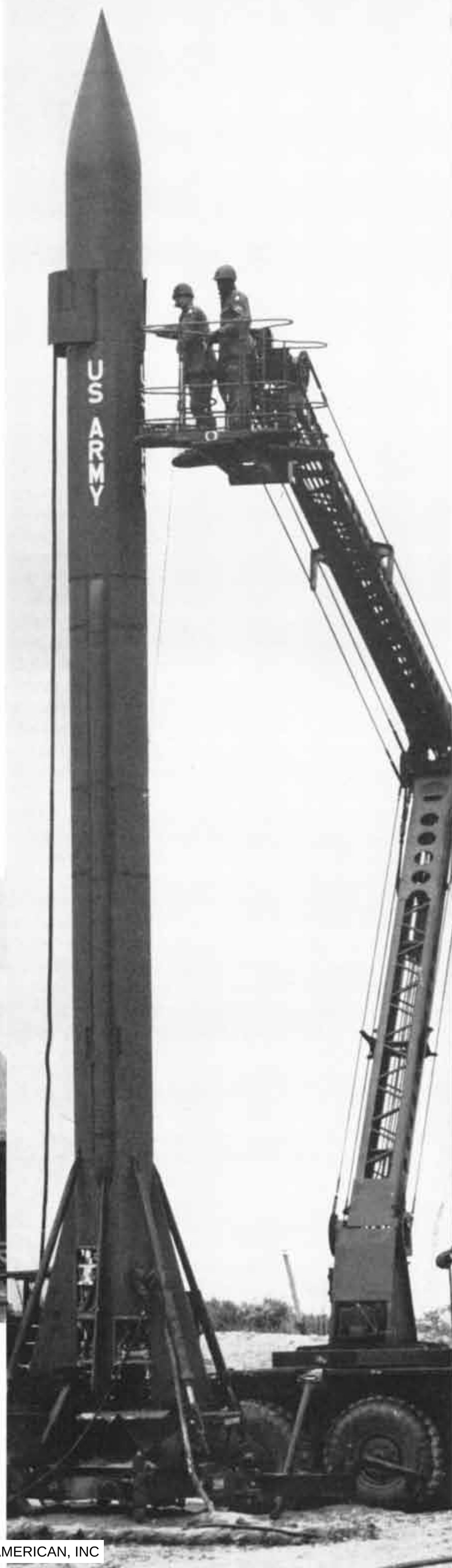
electronic corporation • wakefield, massachusetts

SALES OFFICES IN PRINCIPAL CITIES THROUGHOUT THE U. S. A. • CABLE ADDRESS: TRELCO

About the earthly side of the Corporal missile. The Army's Corporal missile is a surface-to-surface mobile artillery weapon. It's operational and it's in production. Tremendous quantities of materials fabricated into numerous pieces of ground support equipment operated by Army personnel are required to launch the Corporal with split-second timing and accuracy. And virtually all of the steel material required can be purchased from one source—United States Steel. Whether we're talking about carbon steel, high-strength low-alloy steel, alloy steel or Stainless Steel, steel fence, electrical cable,

How thin and light can you make the shipping container for a rocket, and still have a strong, impact-resistant shell? The transportation industry specialists in strong, lightweight construction have overcome this same problem with the help of United States Steel.

This Corporal transporter is made of steel. Why? Because this has to be a rugged piece of equipment to withstand the abuse of moving the missile over all types of rough terrain.


US ARMY

GLAUCOMA

This disease, a major cause of blindness, mainly afflicts people over 40. It occurs when fluid is secreted into the eye faster than it can drain out, thus increasing the pressure inside the eyeball

by Sidney Lerman

Glaucoma is probably the major cause of blindness in this country. The eye is a precision instrument; its function requires stability of structure. The light-bending organs in the front of the eye must be fixed precisely and steadily to bring the light into focus on the light-sensing organs at the back of the eye. But the tissues of the eye are inherently flexible and elastic. To give it stability the eyeball is inflated with fluid under pressure. Normally a balanced inflow and outflow of fluid maintains the pressure constant. In certain eyes, however, anatomical or functional defect blocks the outflow of fluid. With inflow undiminished, the pressure rises, sometimes steeply to three or four times normal. In such cases the onset of glaucoma is acute; there is intense pain, vision is fogged and lights are ringed with haloes. But often the disease is insidious; pressure in the eye rises slowly over long periods of time, and the symptoms are transitory and mild. In either circumstance prolonged elevation of pressure destroys the retina and the optic nerve, and blindness follows.

Glaucoma principally affects the aged, a cruel outcome of normal physiological decline. Anatomy, however, also plays a part; the markedly farsighted eye may be more prone to the disease than the normal or the nearsighted. Glaucoma can also be incidental to other conditions (for example, a tumor) that raise pressure in the eyeball. Occasionally it appears in infants, associated with congenital abnormality in the structure of the eye.

Progress in the diagnosis and treatment of glaucoma achieved during the last two decades permits the prediction that the next two decades will see a marked reduction in the numbers of the blind. Fulfillment of this hope requires a wider public understanding of the disease. Laymen and physicians must be alert to its symptoms and ready to take countermeasures before it has done irreversible harm.

It is in the forward part of the eyeball, containing the optical mechanism of the eye, that the trouble occurs. The eye has a double lens: the cornea (which possesses the major light-bending power) and the ocular lens proper (which is endowed with capacity to change its refractive power by the flexion of its front surface). Drawn snugly around the outer margin of the front surface of the lens is the colored iris, which by dilating or constricting controls the volume of light passing through the pupil to the retina [*see illustration on page 112*]. These are the working parts of the eye concerned with the physics of vision. Behind the lens the light enters the large rear chamber of the eye, which is sealed off from the optical mechanism in front. This chamber is filled with the vitreous humor: a perfectly transparent, gel-like tissue whose major functions are to maintain the shape of the eye and to transmit light without any further refraction. At the back of the eye the points of light focused on the retina are translated into nerve impulses and relayed by the optic nerve to the brain.

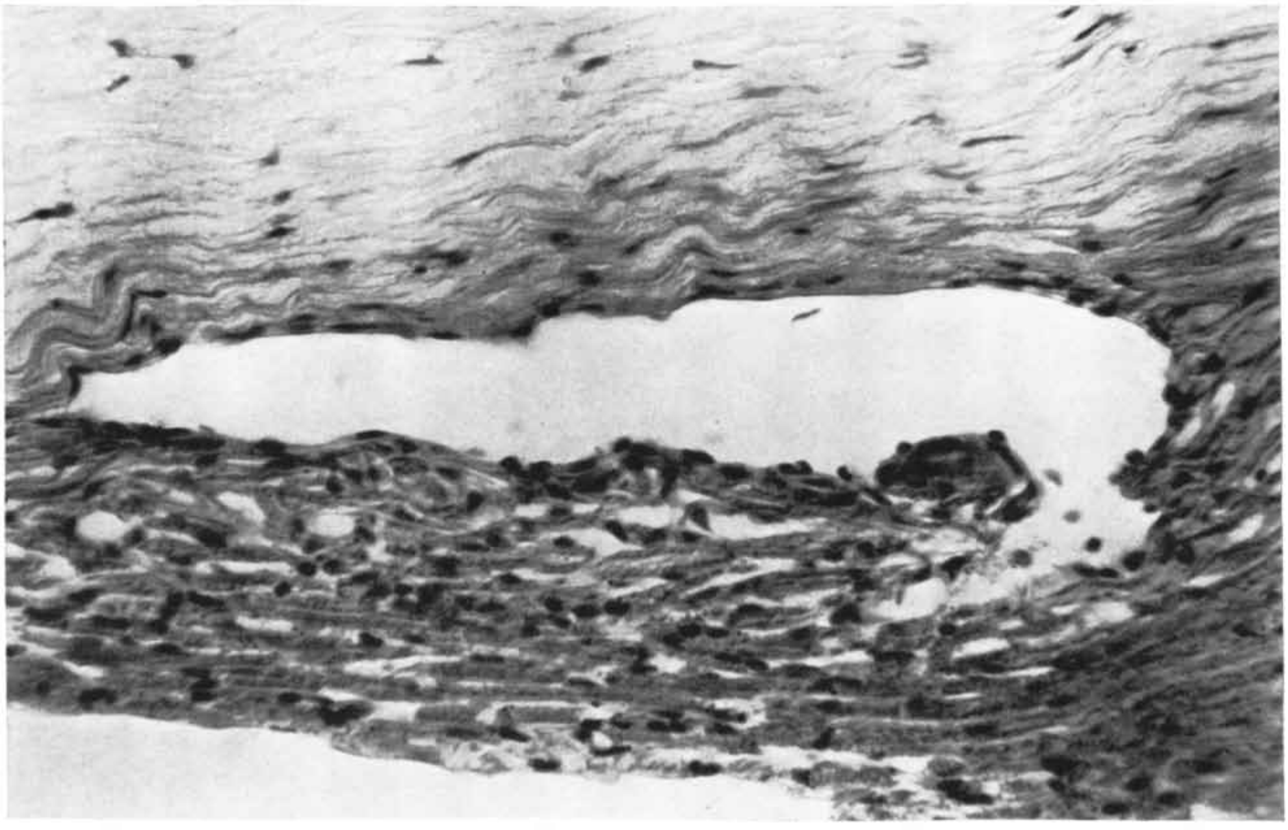
The hydrostatic pressure needed to stabilize the whole system is supplied by the aqueous humor, a thin, watery fluid that fills the forward part of the eye. It is secreted behind the iris by the ciliary body at the rate of approximately three cubic millimeters per minute. The fluid first fills the posterior chamber, an annular space between the iris and the lens. From here, the inflow pressure forces the fluid out through the pupillary aperture of the iris into the anterior chamber between the iris and the cornea. Since the two chambers together have a capacity of only 125 to 150 cubic millimeters, it is clear that the fluid must turn over every 40 to 50 minutes. The functioning of the outflow system is therefore of critical importance.

A simple but effective structure provides for drainage of the aqueous humor from the anterior chamber. It surrounds the periphery of the chamber just in the angle between the cornea and the iris. A spongy meshwork of fibers, lined by a single layer of cells, the so-called trabecular meshwork, affords a series of tiny canals, with small openings about one half the diameter of a red blood cell, to receive the fluid from the chamber. These canals in turn drain into a larger collecting vessel called Schlemm's canal, which finally returns the fluid to the veins in the "white" or scleral tissue of the eye. Strips of fine muscle-tissue, intertwined with the fibers of the trabecular meshwork and surrounding Schlemm's canal, promote the percolation of the fluid through this system by rhythmic contractions that exert a "milking" action.

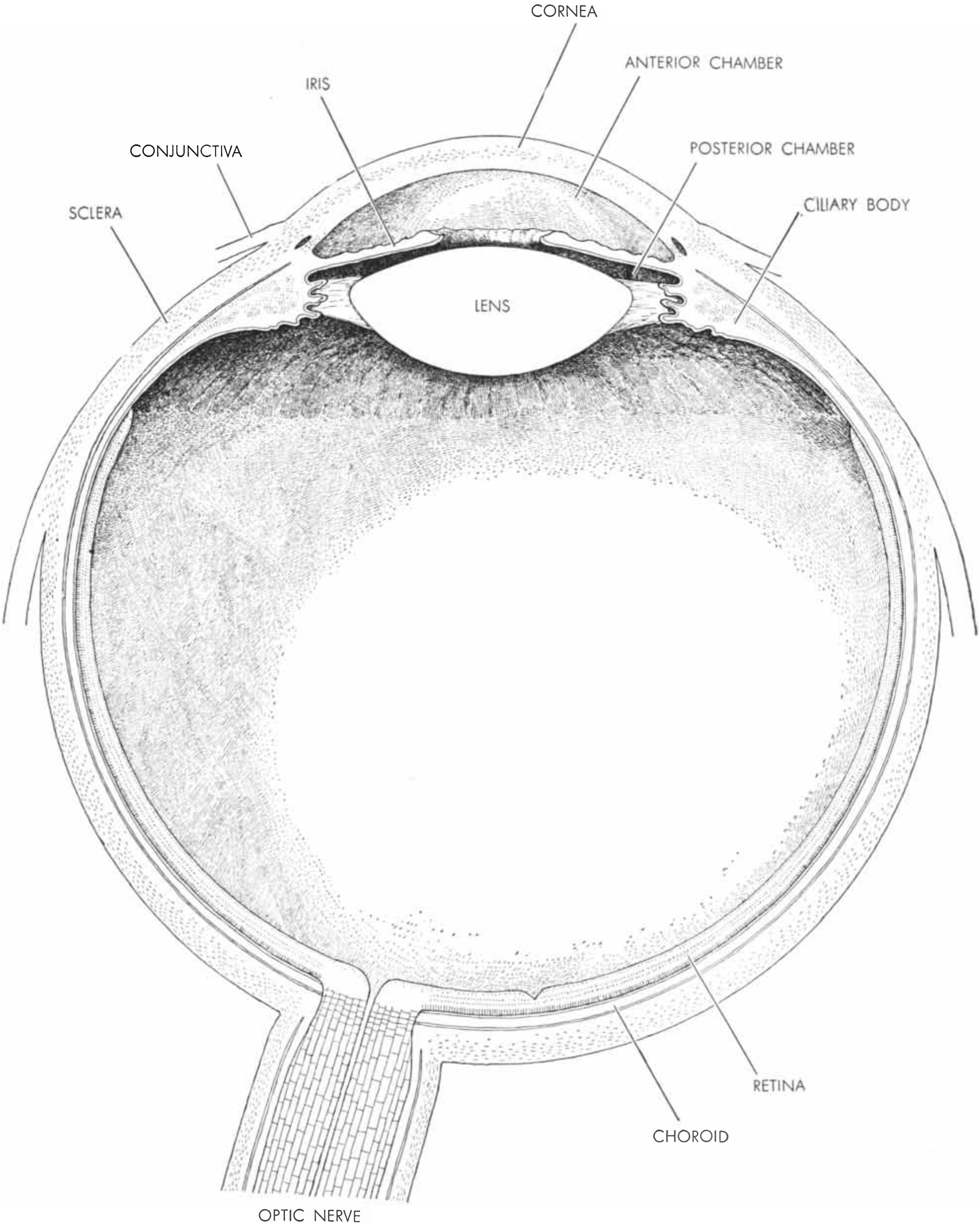
The operation of the outflow system is so delicately adjusted to the inflow of fluid that the pressure in the normal eyeball varies little throughout a lifetime. In the population as a whole the pressure may range between 14 and 25 millimeters of mercury in the eyes of healthy individuals. But in any one individual it does not vary more than one or two millimeters. Just how the balance of inflow and outflow is maintained no one knows. According to one theory the pressure regulates itself via a neural and chemical feedback linkage.

A small but statistically significant percentage of our adult population un-

SECTION OF THE EYE where the cornea (*top*) joins the iris (*below open area at left*) is enlarged some 120 diameters. Knobby protrusions are part of the ciliary body, which secretes aqueous humor into the eyeball. This fluid drains out of the eye through structures at the edge of the cornea (*see photograph below*). Both photographs were made by R. L. Carpenter of Tufts University.



DRAINAGE MECHANISM, here enlarged about 460 diameters, consists of Schlemm's canal (*elongated hole*) and the trabecular meshwork (*below hole*). Aqueous humor enters the meshwork through tiny pores and then filters through tiny canals composed of fibers lined with a single layer of cells. These canals empty into Schlemm's canal, which in turn is drained by a system of veins.



MAIN STRUCTURES OF THE EYE are labeled in this diagram of a section of the eyeball. The cornea and lens bend light rays so that they focus on the retina, which sends impulses to the brain via the optic nerve. The iris regulates the amount of light entering the eye. The sclera and conjunctiva are protective tissues. The choroid is composed mainly of blood vessels. The ciliary body secretes aqueous humor, which fills both the anterior and posterior chambers. The space behind the lens is filled with the vitreous humor, a gel.

knowingly harbors a tendency toward developing an acute type of glaucoma: the "angle-closure" glaucoma. These people have eyes with shallow anterior chambers—that is, the distance between the cornea and iris is significantly smaller than in the average individual—and the angle where the two come together is abnormally acute. Their eyes are sometimes actually smaller in diameter from front to back than the average. In such an individual the space between the iris and cornea becomes smaller with advancing age, decreasing the volume of the anterior chamber still further and making the angle between the cornea and iris even more acute. Since the trabecular meshwork is located in this angle, its tiny intake pores begin to be dangerously confined. Now when the pupil of the eye opens to its fullest, the iris bunches up on itself. If the angle between the iris and cornea is very narrow, the thickened iris may push against the trabecular meshwork, plug its pores and stop the outflow of fluid. The pressure in the eye rises rapidly, and the victim experiences a sudden attack of glaucoma. Since the pupil opens to its fullest in prolonged darkness, it is not surprising that many persons suffer their first attacks of this type of glaucoma at the theater. Emotional disturbances or pain may also initiate an attack by causing the pupils to dilate or by producing swelling (edema) in the iris and other eye tissues.

Within an hour of the blockage the pressure in the eye may reach three or four times the normal value. Fortunately the elevated pressure eventually inhibits the secretion of aqueous humor, otherwise the eye would rupture. As it is, the eye feels "hard as a marble" to the touch and appears grossly red and inflamed. If the pressure remains elevated for a while, fluid is taken up by the cornea, causing it to become waterlogged; it loses its transparency and appears steamy both to the observer and to the patient, who may complain of seeing rainbows and haloes around lights, due to a prism effect caused by droplets of water accumulating between the corneal fibers. The pain in and about the eye and the severe headache that attend these attacks may cause further and more prolonged dilation of the pupil, thereby aggravating the condition; frequently the patient may also suffer from nausea and vomiting.

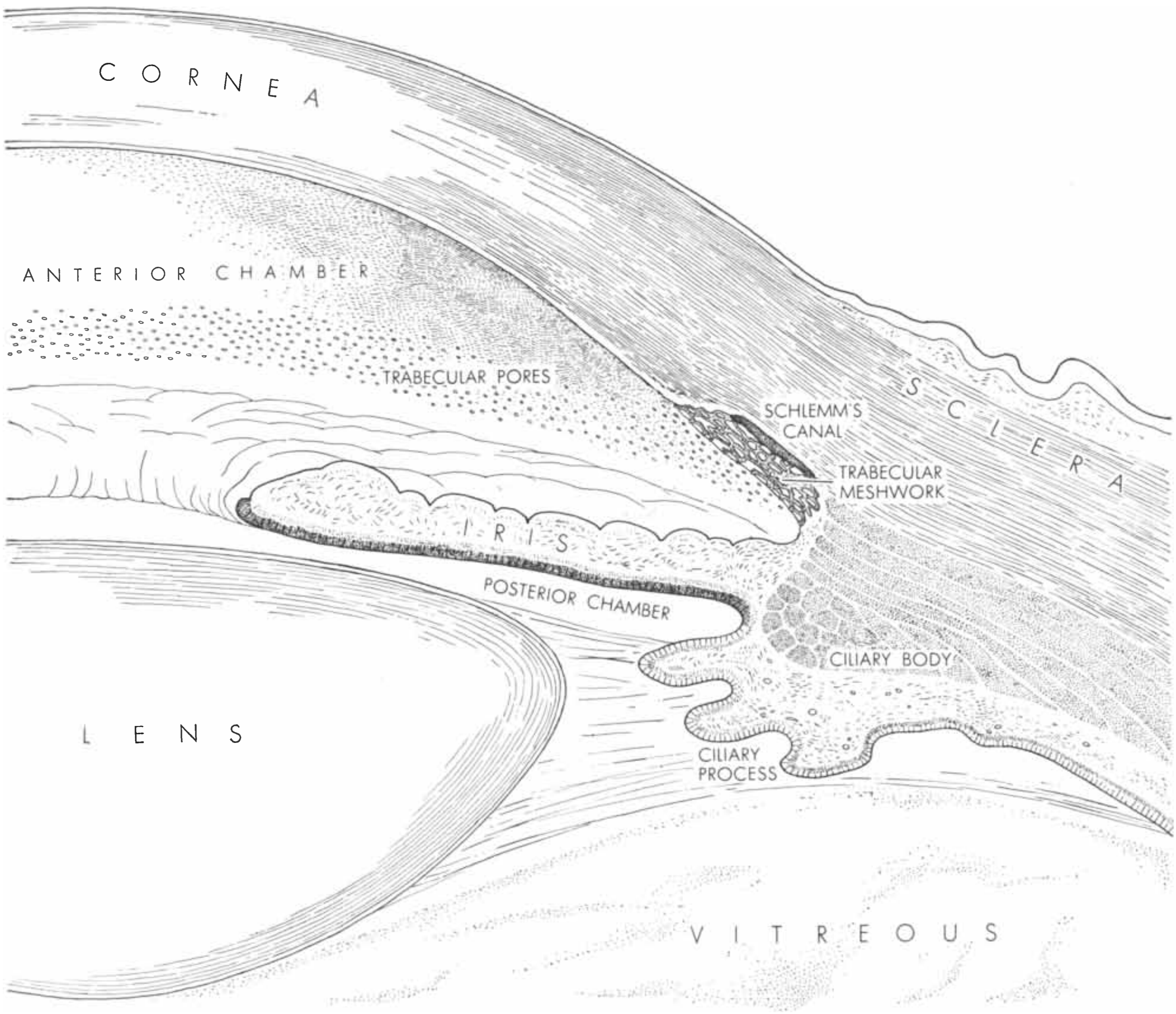
Although the immediate consequences of this sudden rise in intraocular pressure are dramatic and distressing, permanent damage can be averted by prompt diagnosis and treatment. Should the high pressure persist for more than 36 to 48 hours, however, the eye may be severely damaged and even blinded. An attack of this kind should therefore be handled as a true medical emergency. If there is any doubt, the diagnosis can be substantiated by simply pressing gently on the eye and comparing its consistency with that of the unaffected eye. For a more precise estimate of the intraocular pressure the ophthalmologist uses an instrument called the tonometer, which measures the degree to which the cornea can be indented by the pressure of a known weight on its surface.

Treatment to bring down the pressure should begin at once. Since iris tissue has been pushed into the outflow pores by dilation of the pupil, the obvious thing to do is to make the pupil constrict. Fortunately there are several drugs (such as eserine and pilocarpine) that rapidly induce this effect when they are instilled into the eye in the form of drops or ointment. These drugs act directly on the sphincter muscle within the iris, and pull the iris tissue away from the trabecular area. The fluid once again drains out of the eye, and the intraocular pressure falls.

As is apparent, it should also be possible to relieve the pressure by reducing the secretion of fluid. A new drug called Diamox has this effect, cutting down the inflow of aqueous humor from about three cubic millimeters per minute to one cubic millimeter. This drug can be administered orally, but it is more effective when it is given intravenously. When the reduction of inflow is combined with the freeing of the outflow channel, the pressure drops within minutes, and the eye resumes its normal state, appearance and function. But the degree of recovery depends to a great extent on the length of time the eye has had to endure high pressure.

If the iris tissue remains too long in contact with the trabecular meshwork, fibrous tissue eventually forms between them. These "adhesions," composed of a dense material, close off the trabecular pores permanently and render the drainage mechanism functionless. Continued high pressure leads to the atrophy and degeneration of the nerve fibers within the retina and in the optic-nerve head. Since nerve tissue emanating directly from the brain does not regenerate, the eye loses its sight.

Though serious consequences may be averted in the initial attack, the patient stands in grave peril of a recurrence. With each succeeding attack the



SEGMENT OF THE EYEBALL between the lens and the cornea is drawn in three dimensions. The iris partly separates the two chambers. Schlemm's canal, a cross section of which appears at the cut surface, extends all the way around the edge of the anterior chamber. The canal is covered by the trabecular meshwork, the pores of which are visible in the intact wall of the chamber.

risk of damage and visual impairment increases. Furthermore, the other eye may be afflicted; it too harbors the same anatomical defect, that is, a narrow angle between cornea and iris. The customary preventive is to instill a pupil-constricting drug into the eyes at specified times each day; in most cases the patient must keep up the treatment for the remainder of his life.

Within the last decade or two it has actually become possible in many cases to cure this form of glaucoma and free the patient from a life of continuous treatment. The treatment consists of a relatively simple operation, in which a small piece of tissue is removed from the outer edge of the iris disk. The success of this procedure depends on the fact that under normal conditions the pressure in the posterior chamber, where the aqueous humor is produced, is slightly higher than that in the anterior chamber, into which the fluid flows through the pupil. The difference in pressure tends to bulge the iris in the direction of the cornea. Cutting a hole in the iris permits the aqueous humor to flow directly into the anterior chamber. With the pressure equilibrated in the two chambers, the iris is no longer bowed toward the cornea; the anterior chamber deepens, and the widening of the angle between the iris and the cornea frees the outflow pores. If the operation is done before adhesions have closed the pores, it often produces excellent results. The tiny hole is hardly discernible among the natural striations of the eye. Because the operation is relatively simple, results in practically no disfigurement of the eye and is so frequently successful, many ophthalmologists advocate treatment of both the affected eye and its fellow.

If adhesions have already formed, the chances of success depend on the degree to which they obstruct the drainage system. Until recently it was difficult to estimate the damage. In some cases the ophthalmologist could determine the extent of the adhesions by visual inspection with an instrument known as the gonioscope. It is now possible, however, to measure the performance of the damaged system directly, by means of a continuously recording tonometer, or tonograph, held on the cornea for several minutes. Because the cornea is indented during this procedure, the volume of the eye is decreased and a corresponding amount of aqueous humor is squeezed out of the eye. In the case of a healthy eye the readings will show a decline in intraocular pressure since aqueous humor is flowing out at an increased rate. In the glaucomatous eye, however, the pressure decreases much more slowly. From the readings of this test a series of computations yields a measure of the functional ability of the drainage mechanism. The ophthalmologist can then decide on the course of therapy.

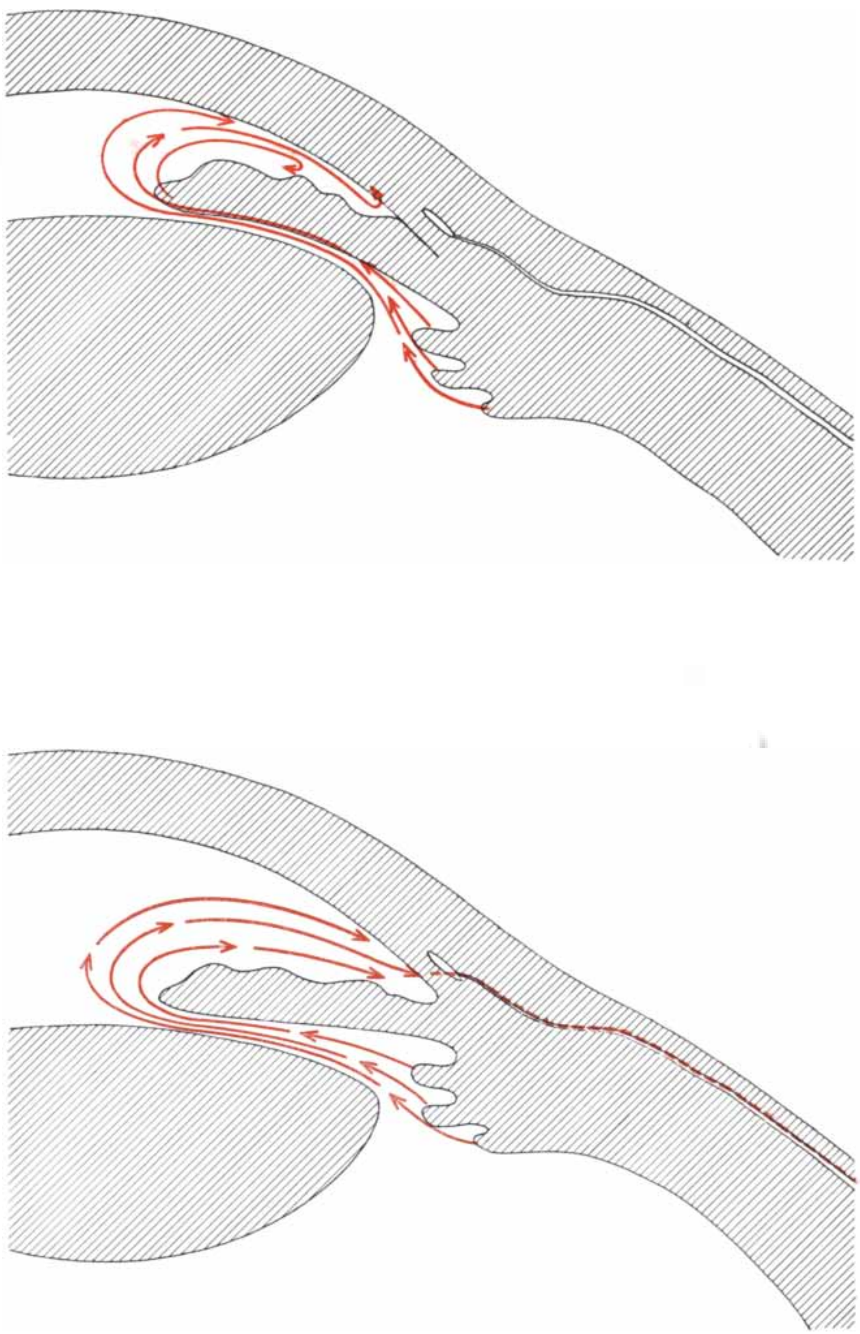
If the test indicates that the drainage mechanism is no longer capable of functioning, surgery of the iris obviously offers no relief. In such a case surgery must be aimed at building a new drainage mechanism for the eye. By a variety of procedures the surgeon undertakes to open a new channel between the anterior chamber and the tissues containing the collecting veins. Unfortunately the results of these operations are uncertain, and much research is now directed toward their improvement.

A less dramatic but far more widespread disease is the chronic form of glaucoma. It is known as open-angle glaucoma, and, as the name implies, the drainage angle between the iris and the cornea offers no obstruction to the flow of fluid. The trouble lies within the drainage system itself. Just how open-angle glaucoma starts is not clear. It probably results from a disturbance in the mechanism that controls intraocular pressure. The disturbance brings a diminution in the size of the trabecular pores and thus slows the outflow of aqueous humor. Another cause of open-angle glaucoma may be the gradual thickening and sclerosis of the trabecular fibers with increasing age. These are normal processes which usually proceed so slowly that they do not interfere perceptibly with aqueous drainage during the average lifetime. In some persons, however, they develop early enough in life to bring trouble.

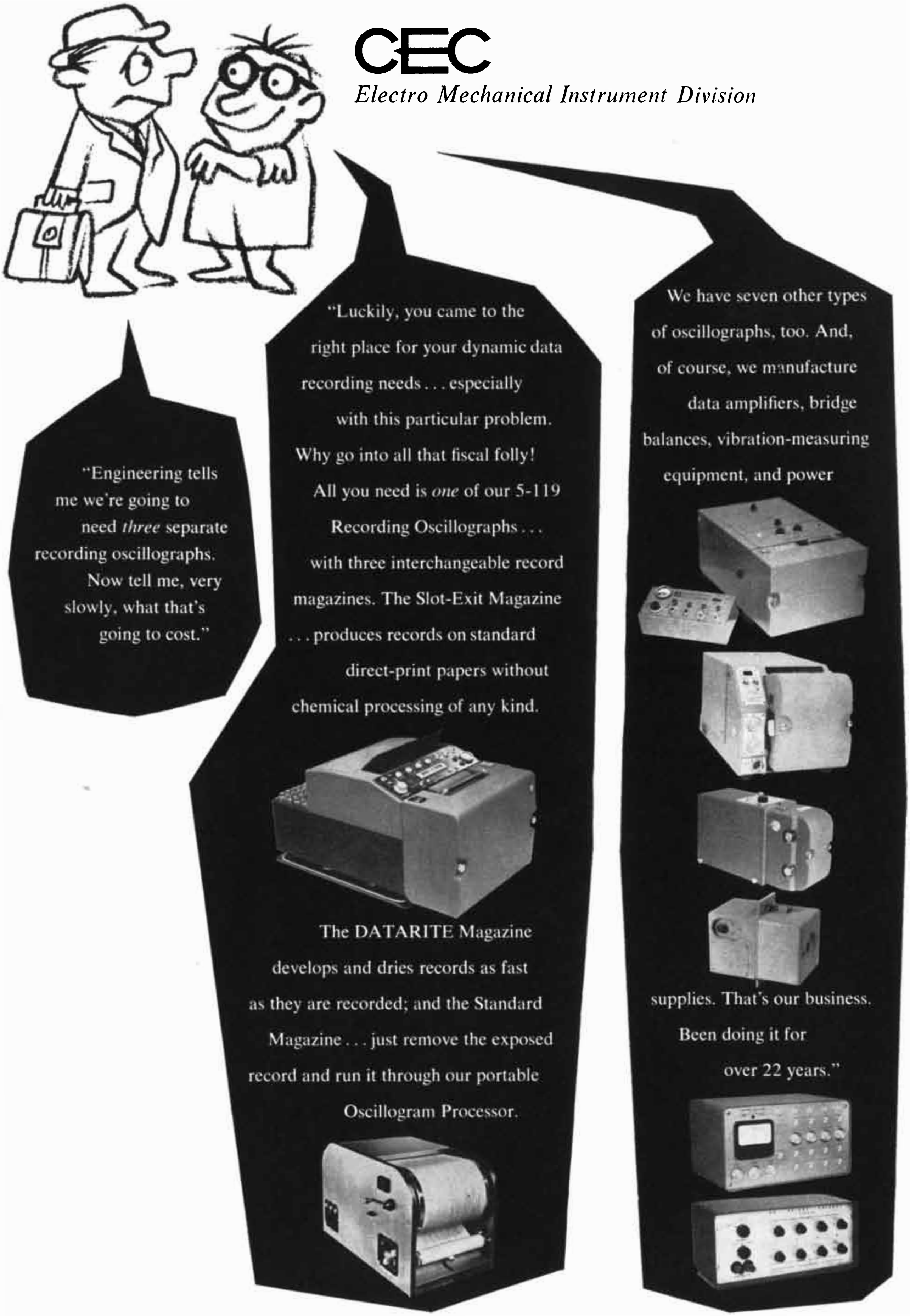
Whatever the cause, the clogging of the drainage mechanism proceeds at a gradual pace. Since intraocular pressure builds up over a long period of time, the eye has time to adapt itself, remaining white, giving no pain and otherwise showing no warning symptom. Many victims therefore remain unaware that the disease is in progress until it actually impairs their vision by destruction of the optic-nerve fibers. The occasional headache and the sensation of rainbows and haloes around lights, arising from intermittent corneal edema, do not cause sufficient distress to suggest the need for medical attention.

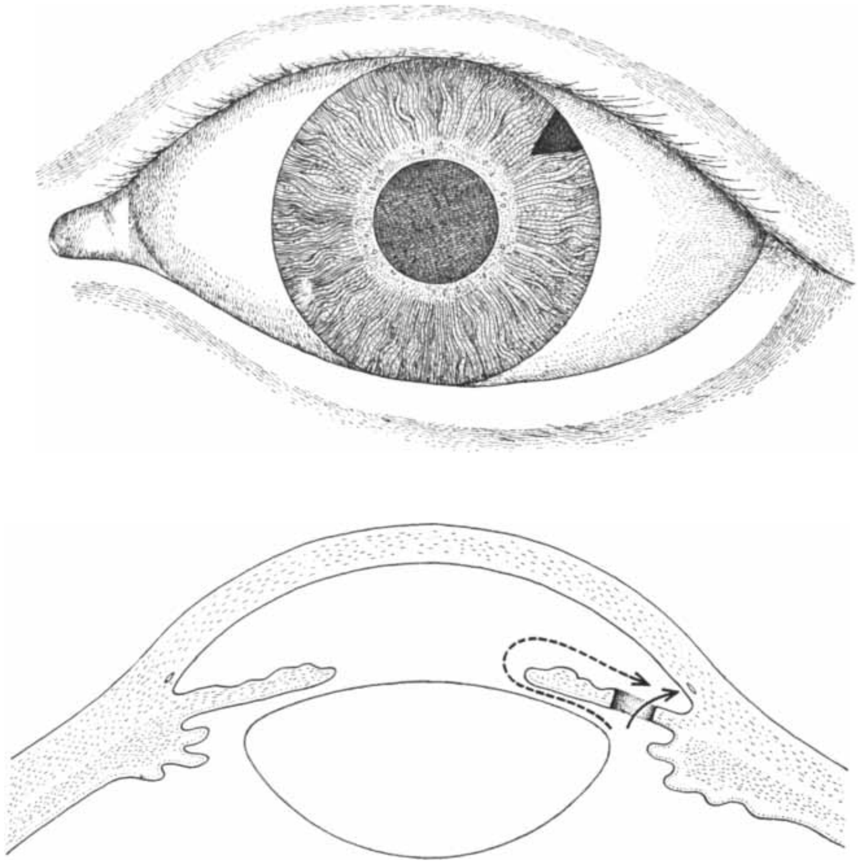
Once the condition is discovered, the intraocular pressure can often be adequately controlled by medication alone. Drugs like Diamox which decrease the input of fluid obviously are of help. The pupil-constricting drugs such as eserine may also be beneficial in this condition because they stimulate the muscles of the ciliary body to open up the narrowed pores and in general improve the drainage. Ophthalmologists usually do not advise surgery so long as the intraocular pressure responds to the drugs and there is no further visual loss. When necessary, surgery may be attempted to develop an artificial drainage route.

In the rare appearance of glaucoma in infants the symptoms may be somewhat different from those in adults. The young growing eye, unlike the adult eye, is capable of being stretched and enlarged by an abnormally high internal



GLAUCOMA RESULTS from the failure of aqueous fluid to drain properly. In angle-closure glaucoma (*top*) iris tissue closes off the angle of the eye and clogs the trabecular pores; the flow of aqueous humor (*arrows*) is therefore blocked. In open-angle glaucoma (*bottom*) the pores and canals inside the trabecular meshwork are narrowed or clogged, cutting down the rate of flow (*broken line*) into Schlemm's canal and the collecting veins.


CEC
Electro Mechanical Instrument Division
"Engineering tells me we're going to need *three* separate recording oscillographs. Now tell me, very slowly, what that's going to cost."
"Luckily, you came to the right place for your dynamic data recording needs . . . especially with this particular problem. Why go into all that fiscal folly! All you need is *one* of our 5-119 Recording Oscillographs . . . with three interchangeable record magazines. The Slot-Exit Magazine . . . produces records on standard direct-print papers without chemical processing of any kind.
The DATARITE Magazine develops and dries records as fast as they are recorded; and the Standard Magazine . . . just remove the exposed record and run it through our portable Oscillogram Processor.
We have seven other types of oscillographs, too. And, of course, we manufacture data amplifiers, bridge balances, vibration-measuring equipment, and power supplies. That's our business. Been doing it for over 22 years."



PERIPHERAL IRIDECTOMY, the cutting out of a tiny piece from the edge of the iris (*top*), corrects the condition which leads to angle-closure glaucoma. Before the operation aqueous humor flows in a roundabout way (*broken line in lower diagram*); this causes the pressure in the posterior chamber to be slightly higher than that in the anterior chamber and pushes the iris forward. After the operation aqueous humor flows more directly (*solid line*) and the pressure in the two chambers is equalized. Since the iris is no longer pushed forward by unequal pressure, the space between the iris and the cornea increases in depth.

pressure. The consequent bulging of the eye gives the condition the name buphthalmos, meaning ox-eye. Unfortunately, since the infant is unable to complain of any specific symptoms, diagnosis is usually delayed until the eye becomes quite obviously enlarged and the cornea appears steamy as a consequence of being waterlogged. Though glaucoma may appear in infants as a secondary disorder, caused for example by an intraocular tumor, it may also be due to congenital defect in the development of the front part of the eyeball. In the embryo the anterior chamber is filled with mesodermal tissue which, as development proceeds, regresses and splits away to form the drainage mechanism and the anterior structure of the iris. If this process does not go to completion, the drainage mechanism may be malformed or plugged by iris tissue that has failed to regress. The plug can sometimes be cut away. Another type of congenital glaucoma is caused by abnormal arrangement and performance of the muscle strands that actuate the trabecular fibers and Schlemm's canal; the muscles close off the canals when they constrict instead of promoting the flow. This condition can be treated with specific drugs that act to prevent the ciliary muscle from contracting.

From the standpoint of public health the larger problem is the chronic form of glaucoma in the aging adult. Too often by the time a patient experiences enough discomfort or loss of sight to seek diagnosis of the condition, the amount of irreversible damage is considerable. Yet ophthalmologists can now detect this disease in its earliest stages by means of the simple tonographic test. The obvious solution is to encourage individuals over the age of 40 to seek a proper eye examination by a qualified ophthalmologist at yearly intervals. This will bring to light many hitherto undetected and early cases which, with proper treatment, can be arrested before there is great visual loss.

From resins and rubbers to foodstuffs and soaps, very small percentages of organotins and inorganic tin compounds have proved their ability to protect products against degradation through exposure to air, heat and light—or from the harmful catalytic effects of impurities or contaminants. The results have been entirely new life-expectancies or new application possibilities for a wide range of products.

Our "summary of reported stabilization applications" will be helpful to those concerned with the problems of product degradation. Request a copy as a "starter" and you can count on further help from M&T based on the detailed information contained in our extensive application files.

M&T Chemicals

METAL & THERMIT Corporation, Rahway, N. J.

Sn Sb P Si Ti Zr inorganics and organometallics

The Enzyme-Substrate Complex

The fleeting union of the enzyme and the substance on which it acts holds a key to our understanding of life processes. Many ingenious techniques are in use today to isolate it for study

by Earl Frieden

We seek him here, we seek him there,
Those Frenchies seek him everywhere.
Is he in heaven?—Is he in hell?
That demmed, elusive Pimpernel?

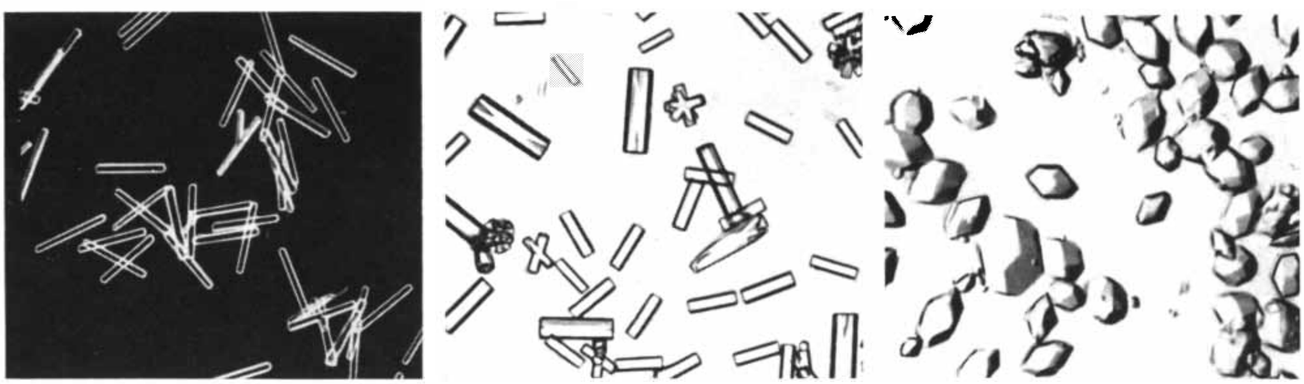
Biochemists have an elusive Pimpernel in the enzyme-substrate complex: the transitory combination of the enzyme and the substance upon which it acts. Like the protean hero of Baroness Orczy's romantic novel, it turns up here, there and everywhere in the chemical reactions of life, acts its decisive part and then disappears. For 30 years the complex was more than elusive; it was a figment of the biochemist's imagination. Nevertheless many biochemists believed an enzyme could work only by joining briefly with its substrate. Two decades ago they demonstrated that the complex exists, but they could not isolate it; its existence is too fleeting. Today they are closing in on the quarry; capture appears imminent.

Without enzymes biochemical processes would be far too slow to carry on what we know as life. Enzymes are catalysts: substances that accelerate reactions without themselves being chemically changed. All the enzymes isolated thus far are proteins: huge molecules made up of chains of amino acid units. Most enzymes are highly specific, acting either on a single substrate, on a group of closely related substrates, or on a characteristic region in various substrate molecules. But just how does the enzyme act upon the substrate? The momentary union of enzyme and substrate conceals the answer. If one could trap the complex long enough to elucidate its structure, one might hope to understand how an enzyme promotes the transformation of the substrate into its end product.

The systematic study of enzymes began in 1835, when the Swedish chemist Jöns Jakob Berzelius included biological reactions among the chemical changes he termed "catalytic." The fact that a mixture of enzymes from potatoes breaks down starch faster than sulfuric acid does made a great impression on Berzelius. With remarkable insight he predicted that it would eventually be found that all substances in living organisms are made under the influence of catalysts. A century later chemists were still making discoveries that confirmed his prediction, and were finding enzymes where one might think them unnecessary.

For example, few chemical reactions are as rapid as the decomposition of carbonic acid into carbon dioxide and water. This reaction is what we see whenever we open a bottle of carbonated beverage. Indeed, it occurs in our lungs every time we exhale. In 1928 O. M. Henriques of Denmark observed that the unaided reaction is not fast enough to account for the evolution of carbon dioxide in the lungs. He deduced that some enzyme in the blood must catalyze this reaction. In 1932 two British biochemists, N. U. Meldrum and F. J. W. Roughton, found the enzyme (named carbonic anhydrase) in red blood cells, again verifying Berzelius's prediction.

Despite the contention of Berzelius, many chemists doubted that enzymes were catalysts. Some doubted their very existence, even after James B. Sumner of Cornell University succeeded in crystallizing the enzyme urease in 1926. For one thing, enzymes seemed to disobey the chemical law of mass action, which states that the velocity of a chem-



ENZYME, INHIBITOR AND COMPOUND of the two are seen in these photomicrographs. At left are crystals of the enzyme trypsin. In center are those of a substance that inhibits or stops the action of trypsin by combining with it. At right are crystals of the compound. Moses Kunitz and John H. Northrop at the Rockefeller Institute isolated enzyme and inhibitor from beef pancreas extract.

ical change is proportional to the active masses, or molecular concentrations, of the reacting substances. The speed of an enzyme reaction is proportional to the amount of substrate only at very low substrate concentrations; higher concentrations do not affect its rate. Furthermore, it was observed that a tiny amount of enzyme transforms an unbelievably large quantity of substrate.

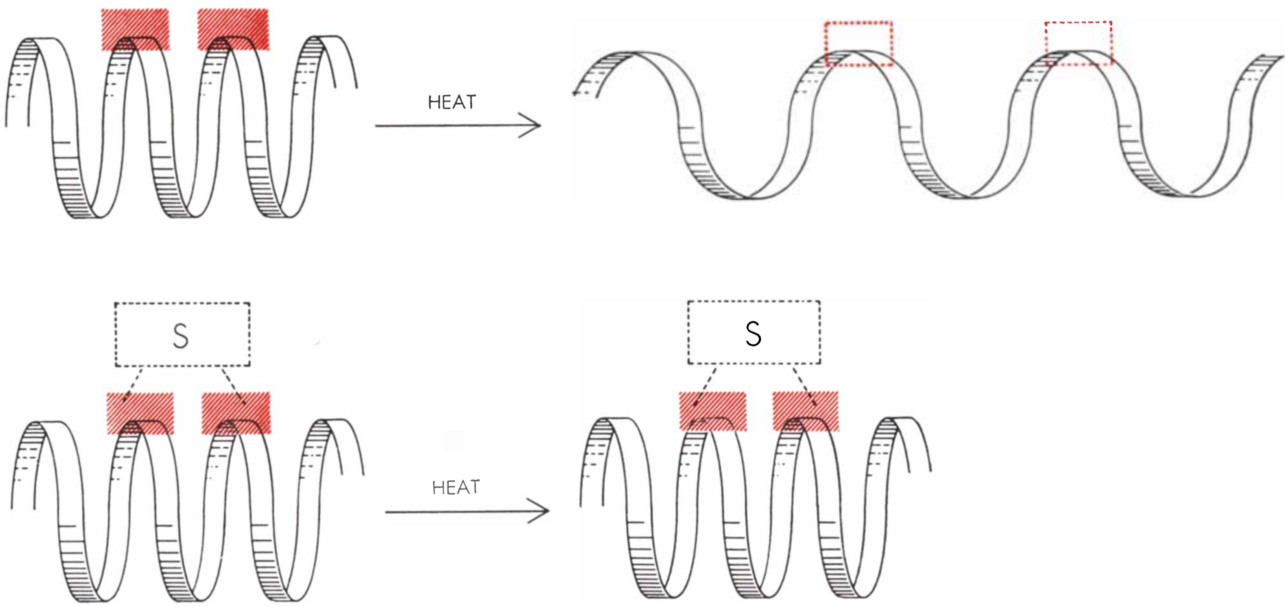
On the other hand, the enzyme concept found support in the mainstream of chemical theory and in a growing body of experimental evidence. Before the end of the 19th century chemists understood that a molecule must obtain extra energy from another molecule before it can react. This may happen when one molecule collides with another (a frequent occurrence in gases and liquids, made more frequent by heat). The molecules with extra energy are said to be "activated." Thus in a reaction that converts substrate molecules (S) to product (P) the molecules must be in the activated state (designated S^*) in order to yield P. The more S^* molecules there are, the faster the reaction will go. In 1888 the Swedish chemist Svante Arrhenius published a simple equation for calculating the activation energy for a given reaction.

How do catalysts fit into this scheme? Arrhenius himself suggested that the most sensible way to explain the action of any catalyst is to suppose that it forms an intermediate compound with its substrate. From this intermediate the reaction proceeds at a lower energy of activation. The catalyst contributes no energy, but alters the reaction path so that S goes to P by a different route. With an enzyme (E) the reaction is $E + S \rightleftharpoons ES^* \rightarrow E + P$. As this equation shows, the catalyst is regenerated unchanged and can participate in the reaction again and again. Thus a small amount of enzyme can cause reaction in a prodigious volume of substrate.

Of course not all catalysts are enzymes. But enzymes generally reduce activation energies far more effectively than inorganic catalysts do, and they permit reactions to take place at lower temperatures. For example, to decompose hydrogen peroxide into water and oxygen requires an activation energy of 18,000 calories per gram molecule of hydrogen peroxide. Catalytic iron brings this figure down to 13,000 calories; platinum, to 12,000. But the liver enzyme catalase reduces the activation energy to less than 5,000 calories.

As early as two years after Arrhenius had proposed the existence of a catalyst-substrate complex, Cornelius O'Sullivan and F. W. Tompson of England found evidence for it in a reaction involving an enzyme. They employed a stratagem still used today to protect an enzyme when separating it from other protein. To a solution containing the yeast enzyme invertase they added its substrate, sugar. When the solution was heated, the unwanted proteins coagulated and precipitated, leaving the invertase to be recovered intact. The addition of the substrate had apparently protected the enzyme from the effects of heat. O'Sullivan and Tompson believed this was evidence for the existence of an enzyme-substrate complex. We have since learned that enzymes can be stabilized against heat by other combining substances, such as coenzymes and inhibitors. The degree of stabilization correlates well with the protective agent's affinity for the enzyme.

By the early 1900's Victor Henri of France and Adrian J. Brown of England, presenting the results of independent studies of invertase action, proposed the formation of an enzyme-substrate complex as the best explanation of that enzyme's action. Historically, however, the concept of the enzyme-substrate complex is usually credited to Leonor Michaelis and Maude Menton of Berlin. They published a remarkably clear and complete paper on the subject in 1913, and we often refer to the complex as the Michaelis complex. Since then the idea has played a central role in the interpretation of numerous studies of the kinetics, or rate, of enzyme reactions. However usefully the enzyme-substrate complex has served the purpose of these investigations, the investigations themselves have yielded no direct evidence to establish the existence of the complex. The evanescent compound must somehow be captured so that we can examine it, even if only briefly.

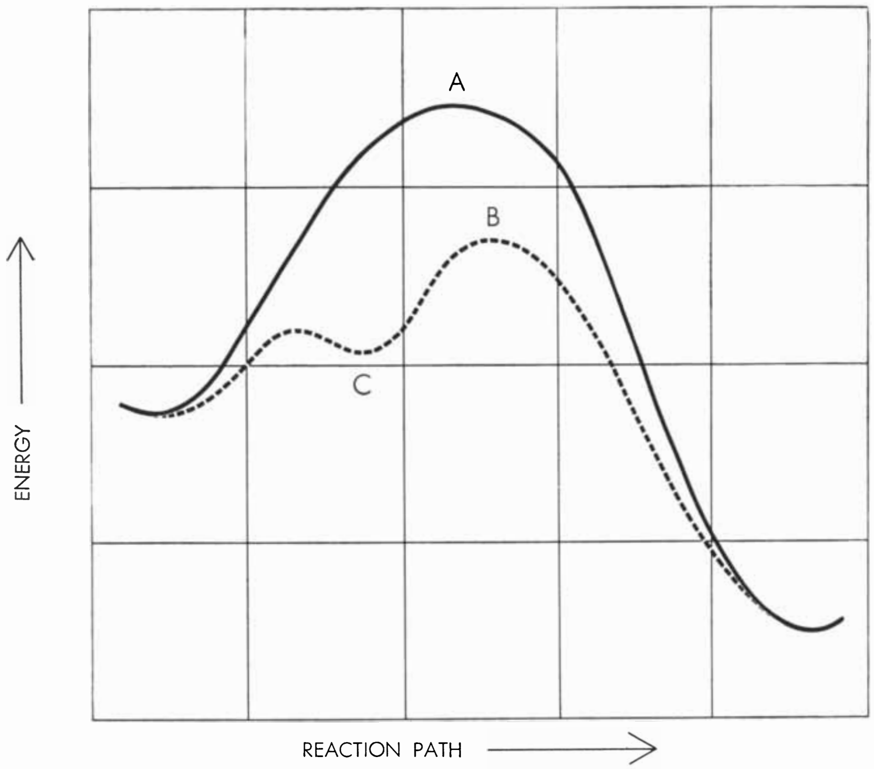


PROTECTION OF AN ENZYME against heat is effected by a substrate. At top left a bit of the helical enzyme molecule is shown, its active site hatched in color. Heat damages the helix and inactivates the site, as at top right. When substrate (S) is present, presumably attached in a complex at the active site, the same amount of heat leaves the enzyme and active site intact, as shown at bottom.

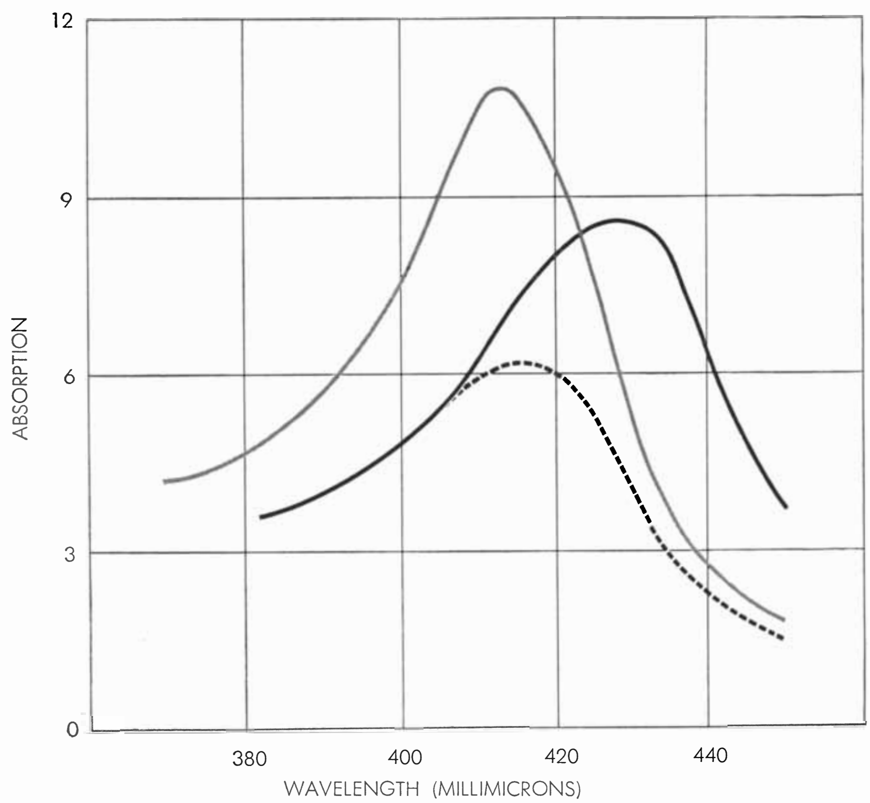
The first concrete evidence for the complex came in 1936, when Kurt Stern, then at Yale University, and David Keilin and Thaddeus Mann of the University of Cambridge simultaneously reported that the mixing of certain enzymes with their substrates in solution brought a change of color in the solution. Stern's enzyme was catalase, and Keilin and Mann used peroxidase isolated from horse-radish. Peroxidase catalyzes the reaction between hydrogen peroxide (or simple peroxide derivatives) and many reducing agents to form water and an oxidized substance. In doing this it first joins hydrogen peroxide in a complex; this enzyme-substrate complex is then capable of oxidizing a reducing agent such as ascorbic acid or malachite green. A solution of peroxidase is brown, but when hydrogen peroxide or another substrate is added to the solution, it turns green. Then, a few seconds later, it turns red. The addition of ascorbic acid regenerates the original brown color of the free enzyme. Keilin and Mann attributed the color changes to the formation of a complex. Their work and Stern's constituted the first qualitative capture of the enzyme-substrate complex.

In a series of brilliant papers beginning in 1940 Britton Chance of the Johnson Foundation at the University of Pennsylvania gave the complex further respectability by measuring it quantitatively. He took advantage of the fact that in the peroxidase and catalase reactions the enzyme and substrate each have light-absorbing properties that differ from those of the complex. Using very rapid mixing and flow techniques and a highly sensitive spectrophotometer, he followed the growth and decay of the enzyme-substrate complex by reading the changes in the color of the solution. He found that the complex forms rapidly, reaches a maximum and a steady state for a brief period and then declines slowly to zero [*see illustration at right*]. Chance's measurements of the kinetics agree so closely with theoretical predictions that we presently accept his work as the most convincing proof of the existence of the union of enzyme and substrate.

In addition to studying the complex directly, we can investigate analogous combinations. For example, certain enzymes are formed by the more or less temporary combination of an apoenzyme (a protein molecule) and a coenzyme (a small nonprotein molecule); the activity characteristic of the enzyme appears only when the two are combined. Some of these combinations are structurally



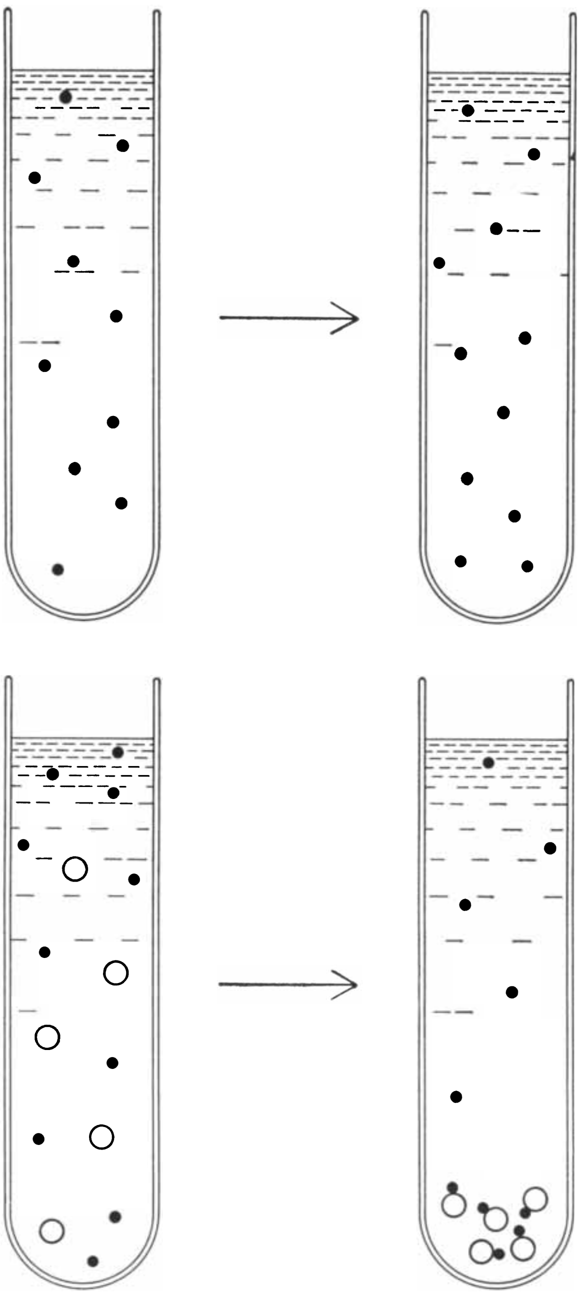
SUBSTRATE REACTION PATH is changed by an enzyme. Solid line represents reaction path without the enzyme, where high energy of activation (A) is required. The path with an enzyme present (*broken line*) shows lower activation energy (B) due to complex at C.



LIGHT-ABSORPTION CURVES provided first demonstration of a complex. Absorption by the enzyme peroxidase gives rise to brown color (*gray line*), but complex of the enzyme and the substrate hydrogen peroxide is green (*broken line*). Change to red color (*black line*) quickly follows. The complete visible spectrum of these compounds is not shown.

similar to the enzyme-substrate complex. In 1951 Hugo Theorell and Roger K. Bonnichsen of Sweden investigated the complex formed by the protein and the coenzyme that together comprise alcohol dehydrogenase, a liver enzyme that catalyzes the oxidation of alcohol. They found that a significant change in the absorption of light—a shift of the point of maximum absorption 30 millimicrons toward the ultraviolet—attends the combination of the coenzyme and the protein. As in the case of the colored enzymes, the close correspondence of the kinetic and spectral data confirms the presence of the elusive protein-coenzyme complex. Helmut Beinert of the Institute for Enzyme Research in Madison, Wis., has observed very rapid color changes in several enzymes containing the bright yellow vitamin riboflavin, a coenzyme. The transient intermediate that appears during enzymic activity probably represents a highly reactive or free-radical form of the coenzyme.

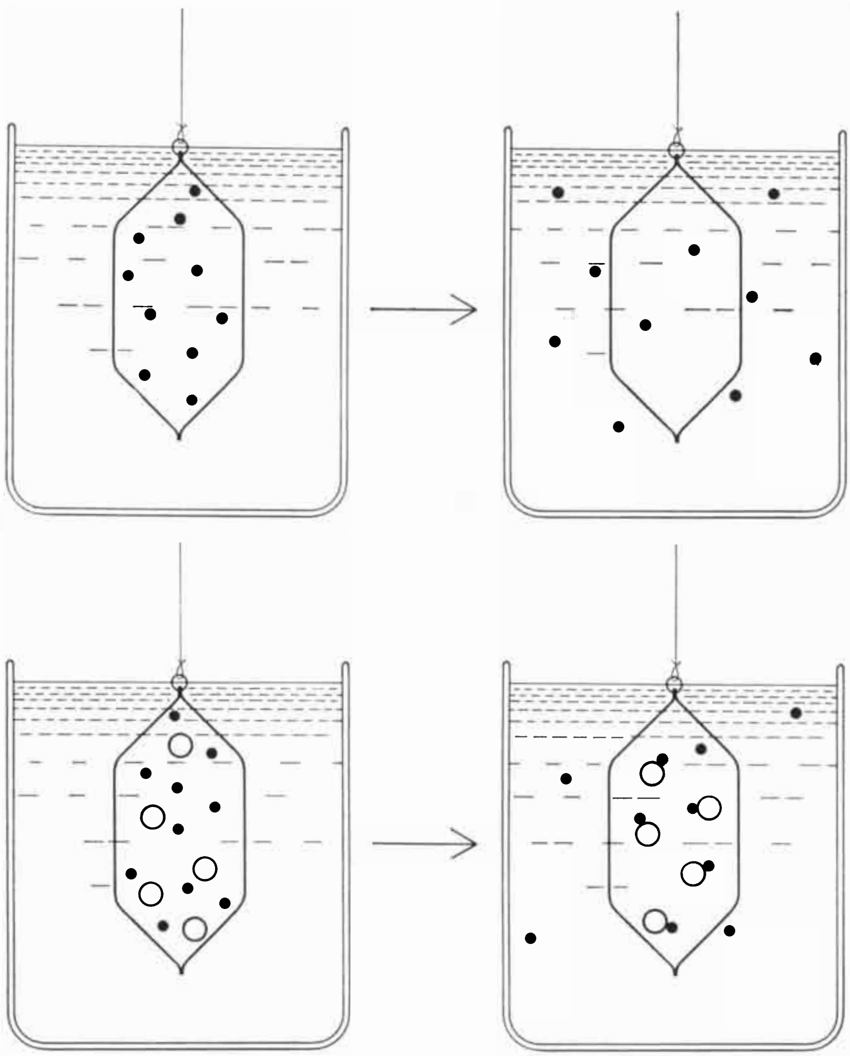
To trap the intermediate of a substrate or a coenzyme Sidney F. Velick of the Washington University Medical School devised the unique method of mixing the protein of alcohol dehydrogenase with its coenzyme or a substrate, and spinning them at 60,000 revolutions per minute in an ultracentrifuge. The heavy protein concentrates at the bottom of the centrifuge cell, along with any complex, while the lighter coenzyme or substrate molecules not combined with the protein remain above in the solution [*see illustration at left*]. Upon measuring the amounts of coenzyme or substrate carried to the bottom of the cell in transitory combination with the protein, Velick found them to be in full accord with the Michaelis-Menton equations.



ULTRACENTRIFUGE SEDIMENTATION traps the complex. This drawing shows tubes from ultracentrifuge, at left before application of forces 100,000 times gravity, at right after spinning in the machine. At top substrate molecules (*dots*) do not sediment. At bottom, with enzyme (*circles*), some substrate is held in complex in sediment after spinning. Comparison of substrate in solutions (*top and bottom right*) gives quantity of complex.

Another substitute for the substrate that may be employed to form stable complexes with enzymes are enzyme inhibitors. These are substances that block the normal activity of the enzyme without destroying its chemical integrity; the enzyme can be regenerated intact from the combination with its inhibitor. We believe that the inhibitor becomes attached to the enzyme at its "active" site, that is, at the very section of the molecular chain which forms the transitory bond with the substrate. The enzyme-inhibitor complex thus provides an excellent analogy with the enzyme-substrate complex.

David G. Doherty and Fred Vaslow have conducted a fruitful investigation on this line at the Oak Ridge National Laboratory. They have employed dialysis, one of the older techniques of biochemistry, to detect the enzyme-inhibitor complex. When a solution containing small and large molecules is placed in a bag permeable only to the small molecules, the small molecules tend to migrate into the fluid outside the bag until an osmotic equilibrium is reached [*see illustration on opposite page*]. Ideally, in the detection of the enzyme-substrate complex, the concentration of small substrate molecules showing up outside the bag would provide an indication of the concentration of free substrate remaining inside. Unfortunately a true substrate is always changing to product, and the system does not reach equilibrium. Accordingly Doherty and Vaslow used an inhibitor instead of a substrate. They labeled the inhibitor with radioactive atoms, calculated the amount of enzyme that formed a complex with one molecule of inhibitor, and showed that there

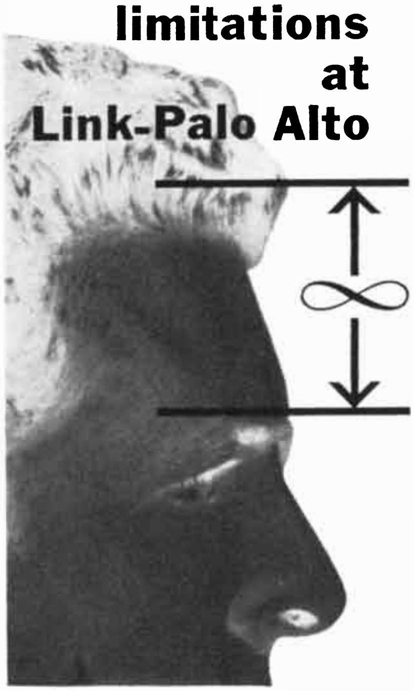


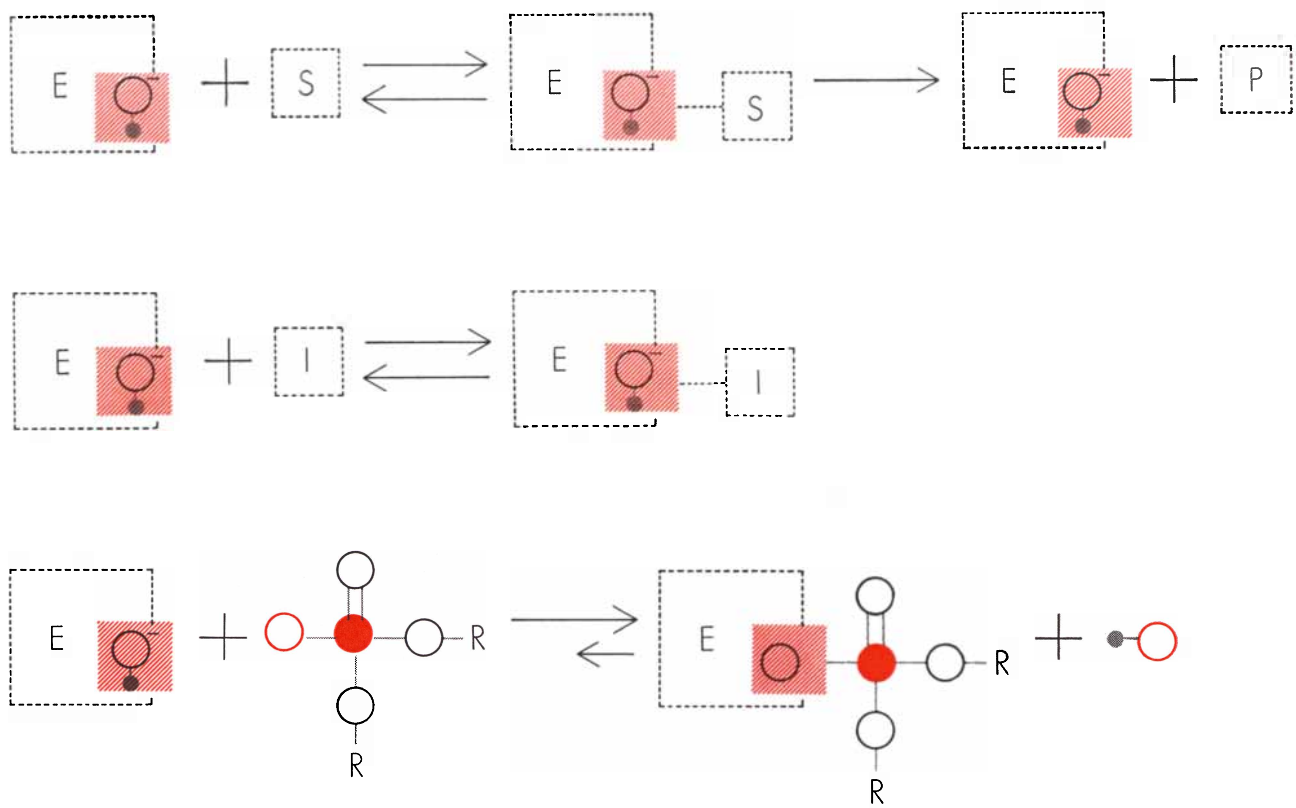
EQUILIBRIUM DIALYSIS with inhibitor molecules alone in permeable dialysis bag (*upper left*) ends with inhibitor distributed uniformly in the solution inside and outside the bag (*upper right*). Enzyme molecules (*circles in bag at lower right*) attach to inhibitor, retaining a larger number of its molecules inside the dialysis bag at the end (*lower left*).

is only one active site on each enzyme molecule. By repeating the dialysis at different temperatures and calculating the heat given off during the formation of complex they deduced some important predictions about the behavior of this enzyme. They were even able to conceive of a brand-new substrate and to show that the enzyme would act upon it.

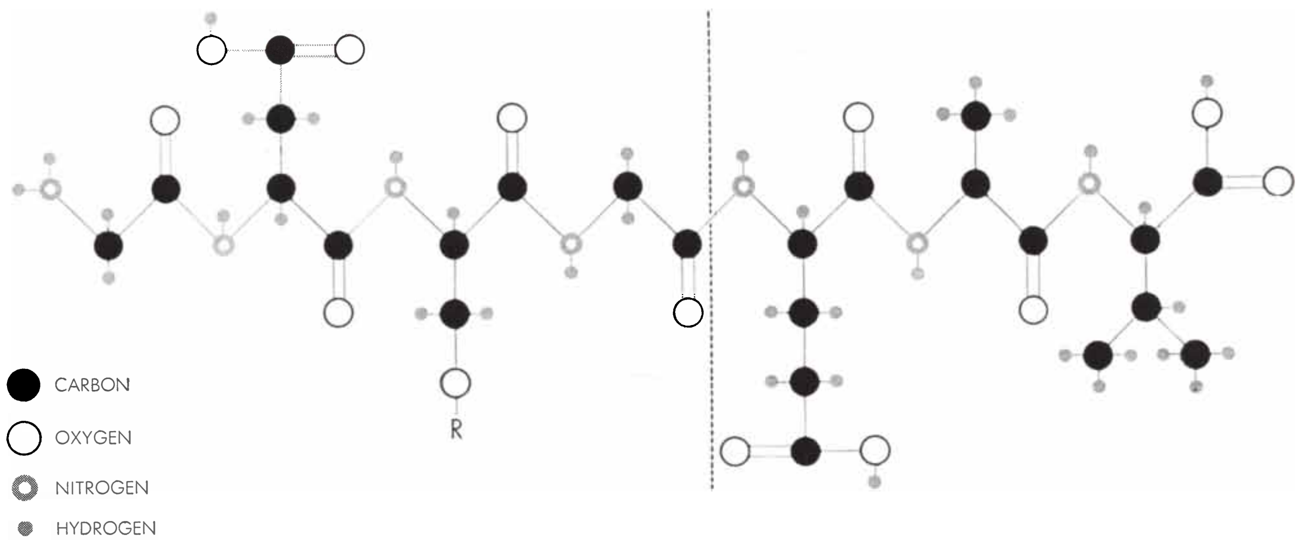
The use of inhibitors to identify the active site in the structure of various enzymes now constitutes a major line of attack in the field of enzyme chemistry. Biochemists frequently employ the so-called nerve gases for this purpose because they form some of the most interesting complexes. The nerve gas diisopropylfluorophosphate (DFP) combines with nerve enzyme cholinesterase to yield a "DFP-enzyme" and release hydrogen fluoride. The gas is lethal because, by this reaction, it inhibits cholinesterase and thus prevents the transmission of nerve impulses. Antidotes to the nerve gas free the enzyme because they form compounds more readily with the DFP molecule.

DFP is a good research tool because it joins the enzyme at its active site. The chemist must purify the DFP-enzyme compound and obtain it, if possible, in crystalline form. He then gently breaks down the compound with other enzymes and uses paper chromatography to separate the resulting pieces of the molecule. From the fragments he determines the order in which the amino acids are linked up in the intact molecule and establishes the site at which the DFP molecule is attached. The DFP is labeled with radioactive phosphorus for easy detection. This technique has been employed by J. A. Cohen of the Netherlands





THREE TYPES OF ENZYME reaction are depicted in these diagrams. In the top diagram an enzyme (E) and a substrate (S) form a complex at a hydroxyl (*oxygen and hydrogen atoms*) active site of the enzyme, then yield the enzyme and the product (P). In the middle diagram a competitive inhibitor (I) forms a complex with an enzyme. If a substrate were present, the inhibitor would slow but not stop the enzyme-substrate reaction. In the bottom diagram the nerve gas diisopropylfluorophosphate (DFP) forms a complex with an enzyme, liberating hydrogen fluoride (*hydrogen and fluorine atoms*) and ending the catalytic activity of the enzyme. The letter R denotes radicals, or groups of atoms, on the DFP molecule.



SEQUENCE OF AMINO ACID UNITS in the vicinity of the active site is identical in four enzymes. An inhibitor, the nerve gas DFP (*labeled* R), was used to discover this. Here it is attached to active site. To left of the broken line the enzymes have the same sequence: glycine-aspartic acid-serine-glycine. The active site of the DFP reaction is at the serine. The enzymes chymotrypsin and phosphoglucomutase both have the glutamic acid-alanine-valine sequence shown to the right of the line; trypsin and cholinesterase differ on the right.

with the enzyme chymotrypsin, by Hans Neurath of the University of Washington with trypsin, by Daniel E. Koshland, Jr., of Brookhaven National Laboratory with phosphoglucomutase, and by Robert Schaffer of the Army Chemical Center with cholinesterase.

All of these workers find that DFP reacts with the amino acid serine in the structure of all four enzymes. They have made an even more remarkable discovery. All four enzymes seem to have the same amino acids in exactly the same order at the DFP-reactive site: glycine-aspartic acid-serine-glycine. The sequence beyond the serine-glycine group is glutamic acid-valine-alanine for chymotrypsin and phosphoglucomutase, but it is proline-valine for trypsin. The finding that enzymes with such different catalytic activities have such closely related active sites suggests that the specificity of their action must depend upon the molecular structure adjacent to the active site, rather than only upon the small active area. We are only at the threshold of this realm of study.

Many enzymes have built-in markers at their active site, and it is not necessary to use DFP or some other inhibitor to detect it. At Florida State University we are trying to isolate the active site in a group of copper-protein enzymes. We know that copper is involved in the catalytic activity because the enzyme becomes inactive when we remove it. We can restore the activity by adding more copper ion. The identification of the copper-containing amino acid groups separated from these enzymes should lead to the pin-pointing of the active sites.

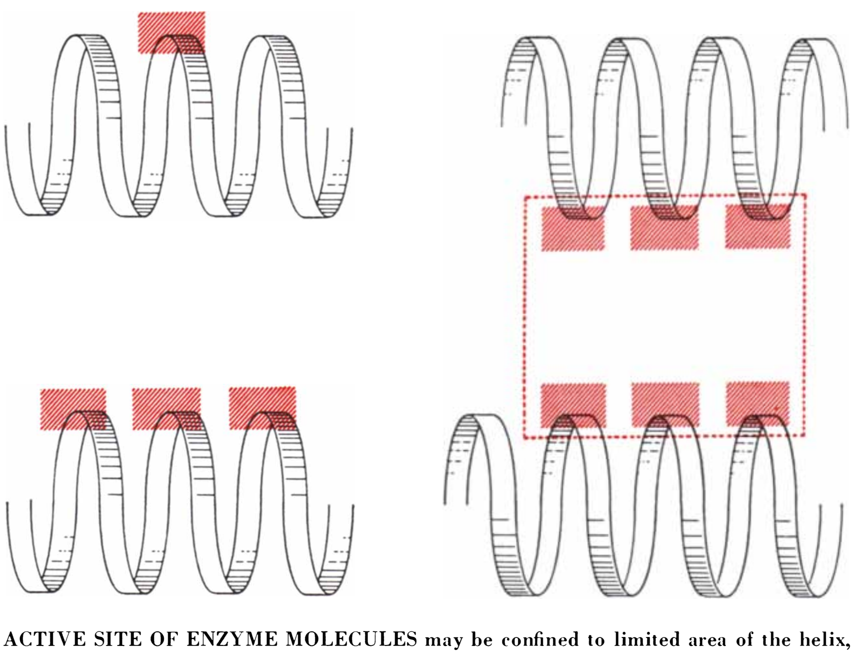
Though the theory that enzymes function by means of an active site is now backed by considerable experimental evidence, biochemists still do not know whether the full catalytic activity of an enzyme resides in the structure as a whole or in a small part associated with the active site. The molecules of certain enzymes have been trimmed down to somewhat smaller size without appreciable loss in catalytic activity. For example, the red respiratory enzyme cytochrome C has been considerably degraded, and the resulting smaller molecule has retained some of the catalytic properties of the original enzyme. The enzyme ribonuclease loses little of its activity when its molecule is partially degraded. The molecule has also been broken into a large part and a small part that are inactive separately but become active when they are put into solution together.

Yet the effort to locate the catalytic activity of enzymes at a small spot on a large protein molecule may be doomed to failure. The extraordinary success of proteins as selective catalysts may depend on much more than the simple order of the amino acid units of which they are made. The chains of these units are arranged in helixes folded in various and intricate ways. The geometrical relationship of one helix to others may be crucial to catalytic activity. Heat or other relatively mild treatment easily inactivates many enzymes, though the effect of heat must be limited to changing the three-dimensional orientation of the chains and could not affect the basic order of amino acid units. Some chemists have suggested that, when the enzyme and substrate form their complex, the enzyme structure changes extensively before it exerts any catalytic activity. It is difficult to imagine such gross spatial changes in simple chains of a limited number of amino acid units.

We may find, nonetheless, that the catalytic activity of some enzymes does depend upon a relatively simple section of the long chain of the molecule. We are now discovering numerous examples of short-chain molecules that resemble a section of an enzyme molecule and have specific biological activity. Vincent du Vigneaud of the Cornell University Medical College has determined the structure of two peptide hormones of the pituitary gland: oxytocin and vasopressin. Each hormone has nine amino acid units in a chain, and differs from the other in only two of its component units. Other active short-chain molecules are the antibiotics gramicidin and tyrocidin and the growth factor streptogenin. As our knowledge of these smaller active molecules increases, we may learn a great deal from them about the formation of complexes.

What will the capture of the enzyme-substrate complex mean? Consider the part that enzymic catalysis plays in the processes of life. The many thousands of biological reactions are mediated by virtually an equal number of highly specific enzymes. The reactions vary from relatively simple ones, such as the decomposition of hydrogen peroxide or carbonic acid, to the complicated, step-by-step synthesis of huge molecules like the nucleic acids that control heredity. Yet all this variety of activity resides in essentially one type of molecule, assisted in some cases by other substances of low molecular weight. The versatility of enzymes is a source of wonder to the chemist.

As the biochemist Ernest Borek has written: "We live because we have enzymes. Everything we do—walking, thinking, reading these lines—is done with some enzymic process." Life is essentially a system of cooperating enzyme reactions. A unifying theme in all this diversity may be discovered with the help of a close look at the enzyme-substrate complex, now that it is no longer so elusive.



ACTIVE SITE OF ENZYME MOLECULES may be confined to limited area of the helix, as in color hatching at upper left. It may overlap several coils of the helix, as at lower left. Or perhaps two or more helixes of the enzyme, as at right, would have to be intact in order to preserve the active site of the molecule in its proper three-dimensional relationship.

HOW VITON® BEATS THE HEAT

FIRST STEP in fabrication of "Hustler" fire seal is creating the pattern. White paint is sprayed through pattern onto asbestos fabric—white areas are then cut out.

AFTER STITCHING with asbestos wire thread, assembled parts are coated with VITON cement and the fire seal is ready for installation in wing.

FIRE SEAL IS FASTENED to wing tunnel by 3/16″ bolts. Since it must be bent and pulled into position, the fire seal becomes dirty and must be cleaned with solvent.

AT MACH 2

Asbestos coated with new fluoroelastomer takes 500° F. temperatures in fire zone seals for B-58 "Hustler"

This new Convair B-58 "Hustler" flies *twice* as fast as sound, cruises faster than the *top speed* of previous American bombers. It is the world's first supersonic bomber and represents a completely new concept in aircraft design.

"Hustler" fights fire with rubber

High operating temperatures encountered at Mach II speeds presented a number of design challenges in the B-58. For instance, the delta wing is crammed full of tanks, lines and equipment. Consequently, access tunnels for ground maintenance work are required. These are compartmentalized with fire seals to stop accidental fire from spreading through the wing. The fire seals must resist heat, ozone, jet fuels, fumes and corona . . . and they must be flexible.

Convair pioneered the use of rubber coated asbestos fire seals in the B-36 bomber. But the synthetic rubber coating on those fire seals was good for a top operating temperature of only 250° F.—not nearly high enough for the supersonic B-58.

New Du Pont VITON synthetic rubber solved the problem.

EQUIPMENT LINES (air conditioning, hydraulic, fuel and electrical) are pushed through openings and securely clamped. Installed VITON-coated seal will withstand flight temperatures of 500° F.

New fabric equals stainless steel

High-temperature VITON meets government specification MIL R25897 for a high-temperature, fluid-resistant synthetic rubber for aeronautical application. It steps up the top operating temperature of B-58 fire seals to 500° F. . . . resists pressure and vibration . . . prevents wicking of fuel and oil through the asbestos . . . keeps asbestos from losing its tensile strength. The VITON-coated fabric actually performs *better* than aluminum would. According to Civil Aeronautics Administration specifications, it is equivalent to stainless steel in fireproofing qualities.

Versatile VITON

Du Pont VITON synthetic rubber has withstood temperatures as high as 600° F. in certain applications. In addition, it resists an extremely wide range of oils, fuels, solvents and corrosive chemicals. It has good resistance to compression set, even at elevated temperatures. Current applications for VITON include seals, O-rings, gaskets, hose and tubing, diaphragms, and a host of molded parts for engines, instruments, transmissions. If you can use VITON's unique combination of properties, write for complete information to: E. I. du Pont de Nemours & Co. (Inc.), Elastomer Chemicals Department SA-8, Wilmington 98, Delaware.

DU PONT
REG. U. S. PAT. OFF.

Better Things for Better Living . . . *through Chemistry*

SYNTHETIC RUBBER

NEOPRENE
HYPALON®
VITON®
ADIPRENE®

MATHEMATICAL GAMES

About phi, an irrational number that has some remarkable geometrical expressions

by Martin Gardner

Pi, the ratio of the circumference of a circle to its diameter, is the best known of all irrational numbers; that is, numbers with decimal expansions that are unending and nonrepeating. The irrational number phi (φ) is not so well known, but it expresses a fundamental ratio that is almost as ubiquitous as pi, and it has the same amusing habit of popping up where least expected.

A glance at the line at the bottom of this page will make the geometrical meaning of phi clear. The line has been divided into what is commonly called the "golden ratio." The length of the line is to segment A as the length of segment A is to segment B. In each case the ratio is phi. If the length of B is unity, we can compute the value of phi easily from the following equation:

$$\frac{A+1}{A} = \frac{A}{1}$$

This can be written as the simple quadratic $A^2 - A - 1 = 0$, for which A has the positive value:

$$\frac{1+\sqrt{5}}{2}$$

This is the length of A and the value of phi. Its decimal expansion is 1.61803398 . . . If the length of A is taken as unity, then B will be the reciprocal of phi ($1/\varphi$). Curiously, this value turns out to be .61803398 . . . Phi is the only number that becomes its own reciprocal by subtracting 1.

Like pi, phi can be expressed in many ways as the sum of an infinite series. The extreme simplicity of the following two examples underscores phi's fundamental character:

$$\varphi = 1 + \cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\dots}}}}$$

$$\varphi = \sqrt{1+\sqrt{1+\sqrt{1+\sqrt{1+\dots}}}}$$

The ancient Greeks were familiar with the golden ratio; there is little doubt that it was consciously used by some Greek architects and sculptors, particularly in the structure of the Parthenon. The U. S. mathematician Mark Barr had this in mind 50 years ago when he gave the ratio the name of phi. It is the first Greek letter in the name of Phidias, the famous Greek sculptor who used the golden proportion frequently in his work. Perhaps one reason why the Pythagorean brotherhood chose the pentagram or five-pointed star as the symbol of their order is the fact that every segment in this figure is in golden ratio to the next smallest segment.

Many medieval and Renaissance mathematicians, especially confirmed occultists such as Kepler, became intrigued by phi almost to the point of obsession. They called it the "divine proportion" (the term "golden section" did not come into use until the 19th century). A 1509 treatise by Luca Pacioli, entitled *De Divina Proportione* and illustrated by Leonardo da Vinci (a handsome edition was published in Milan in 1956), is a fascinating compendium of phi's appearances in various plane and solid figures. It is, for example, the ratio of the radius of a circle to the side of an inscribed regular decagon. And if we place three golden rectangles (rectangles with sides in golden ratio) so that they intersect each other symmetrically, each perpendicular to the other two, the corners of the rectangles will mark the 12 corners of a regular icosahedron as well as the centers of the 12 sides of a regular dodecahedron.

The golden rectangle has many unusual properties. If we cut a square from one end, the remaining figure will be a smaller golden rectangle. We can keep snipping off squares, leaving smaller and smaller golden rectangles, as shown in the top illustration on page 130. Successive points marking the division of sides into golden ratio lie on a logarithmic spiral that coils inward to infinity, its pole being the intersection of the two dotted diagonals. Of course these "whirling squares," as they have been called, can also be whirled outward to infinity by drawing larger and larger squares.

The logarithmic spiral is traceable in many other constructions involving phi. An elegant one makes use of an isosceles triangle that has sides in golden ratio to its base [*see bottom illustration on page 130*]. Each base angle is 72 degrees, which is twice the top angle of 36 degrees. This is the golden triangle involved in the construction of the pentagram. If we bisect a base angle, the bisector cuts the opposite side in golden ratio to produce two smaller golden triangles, one of which is similar to the original. This triangle can in turn be divided by a base-angle bisector, and the process can be continued endlessly to generate a series of whirling triangles which, like whirling squares, also stake out a logarithmic spiral. The pole of this spiral lies at the intersection of the two medians shown as broken lines.

The logarithmic spiral is the only type of spiral that does not alter in shape as it grows, a fact that explains why it is so often found in nature. For example, as the mollusk inside a chambered nautilus grows in size, the shell enlarges along a logarithmic spiral so that it always remains an identical home. The center of a logarithmic spiral, viewed through a microscope, would look exactly like the spiral you would see if you continued the curve until it was as large as a galaxy and then viewed it from a vast distance.

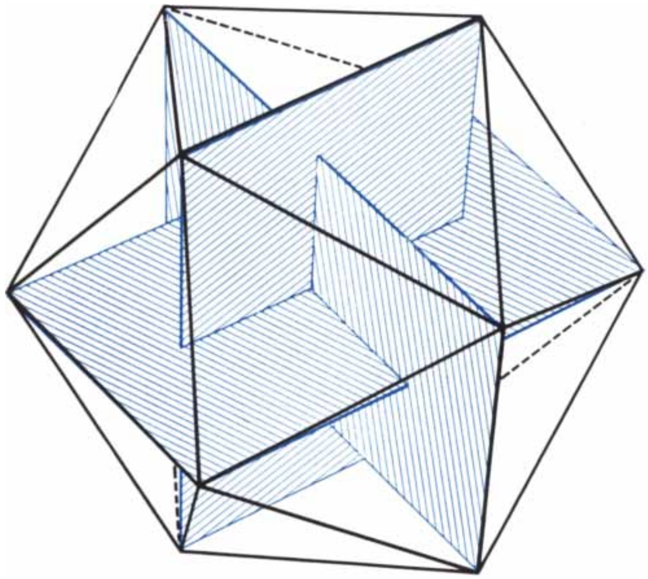
The logarithmic spiral is intimately related to the Fibonacci series (1, 1, 2,

The golden ratio: A is to B as A + B is to A

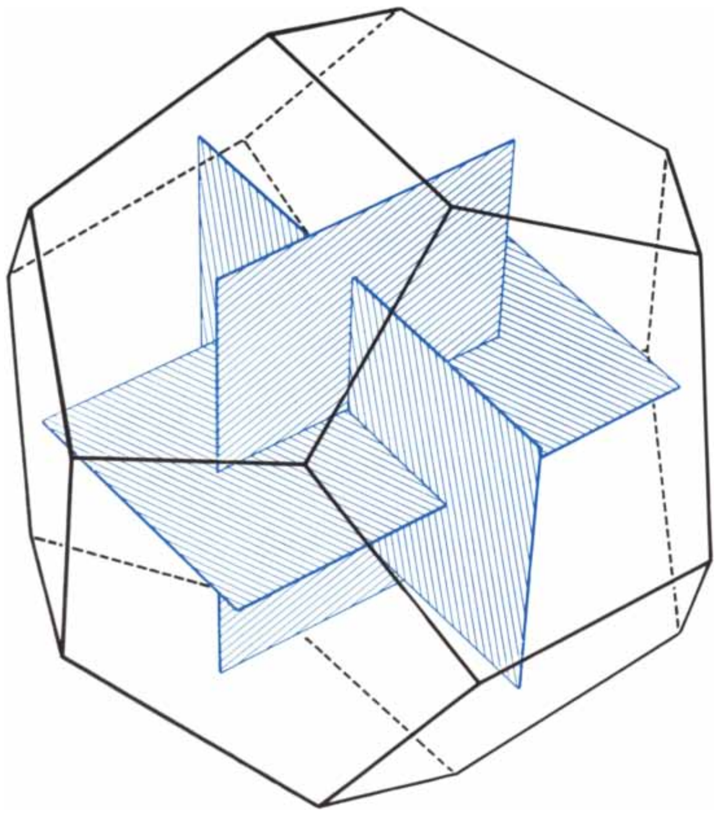
3, 5, 8, 13, 21, 34 . . .), in which every term is the sum of the two preceding terms. Biological growth often exhibits Fibonacci patterns. Commonly cited examples concern the spacing of leaves along a stalk, and the arrangements of certain flower petals and seeds. Phi is involved here also, for the ratio between any two consecutive terms of the Fibonacci series comes closer and closer to phi as the series increases. Thus 5/3 is fairly close to phi (a three-by-five file card is hard to distinguish from a golden rectangle), but 8/5 is closer, and 21/13 is 1.619, which is closer still. In fact, if we start with any two numbers whatever and form an additive series (*e.g.*, 7, 2, 9, 11, 20 . . .), the same convergence takes place. The higher the series goes, the closer the ratio between consecutive terms approaches phi.

This can be illustrated neatly by whirling squares. We begin with two small squares of any size, say the squares marked A and B in the top illustration on page 132. The side of square C is the sum of the sides of A and B. D is the sum of B and C, E is the sum of C and D, and so on. Regardless of the sizes of the two initial squares, the whirling squares get closer and closer to forming a golden rectangle.

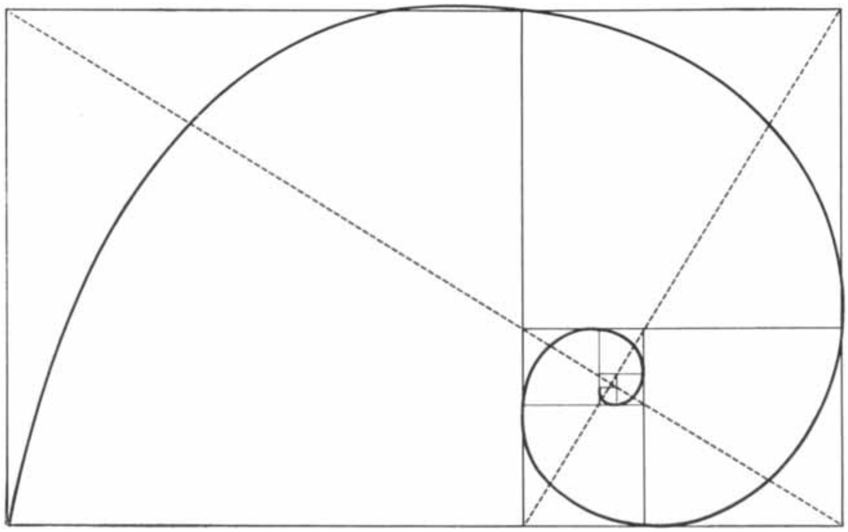
There is a classic geometrical paradox that brings out strikingly how phi is linked to the Fibonacci series. If we dissect a square of 64 unit squares [*see bottom illustration on page 132*], the four pieces can be put together again to make a rectangle of 65 square units. The paradox is explained by the fact that the pieces do not fit exactly along the long diagonal where there is a narrow space equal to one square unit. Note that the lengths of line segments in these figures are terms in a Fibonacci series. In fact, we can dissect the square so that these segments are consecutive terms in any additive series and we will always get a form of the paradox, though in some cases the long rectangle will gain in area and in other cases it will lose area because of overlapping along the diagonal. This reflects the fact that consecutive terms in any additive series have a ratio that is alternately greater or less than phi. The only way to cut the square so that there is no loss or gain of area in the rectangle is to cut it with segment lengths taken from the additive series $1, \varphi, \varphi + 1, 2\varphi + 1, 3\varphi + 2$ . . . Another way to write this series is $1, \varphi, \varphi^2, \varphi^3, \varphi^4$ . . . It is the only additive series in which the ratio between any two consecutive terms is constant. (The ratio is of course phi.) It is the golden series



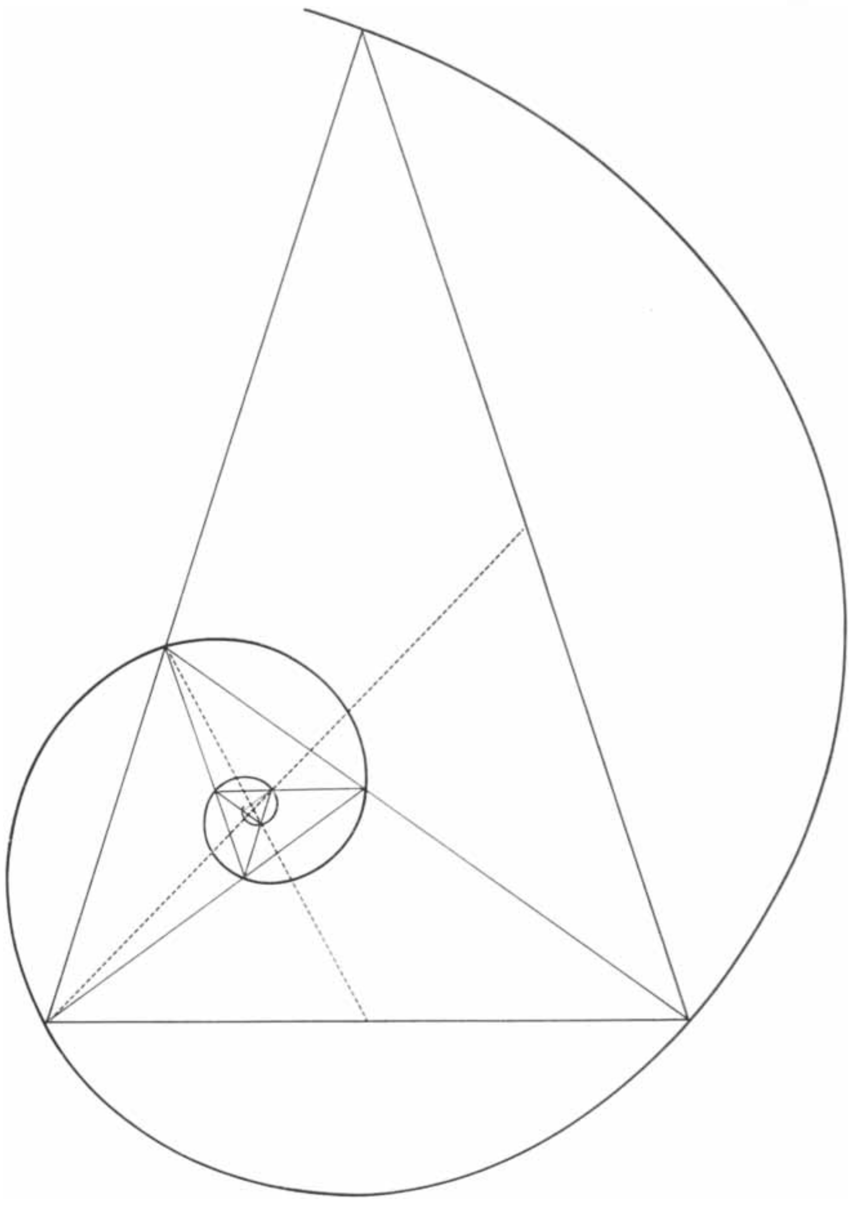
The corners of three golden rectangles coincide with the corners of an icosahedron



The corners of the same rectangles coincide with the centers of the sides of a dodecahedron



A logarithmic spiral indicated by "whirling squares"



A logarithmic spiral indicated by "whirling triangles"

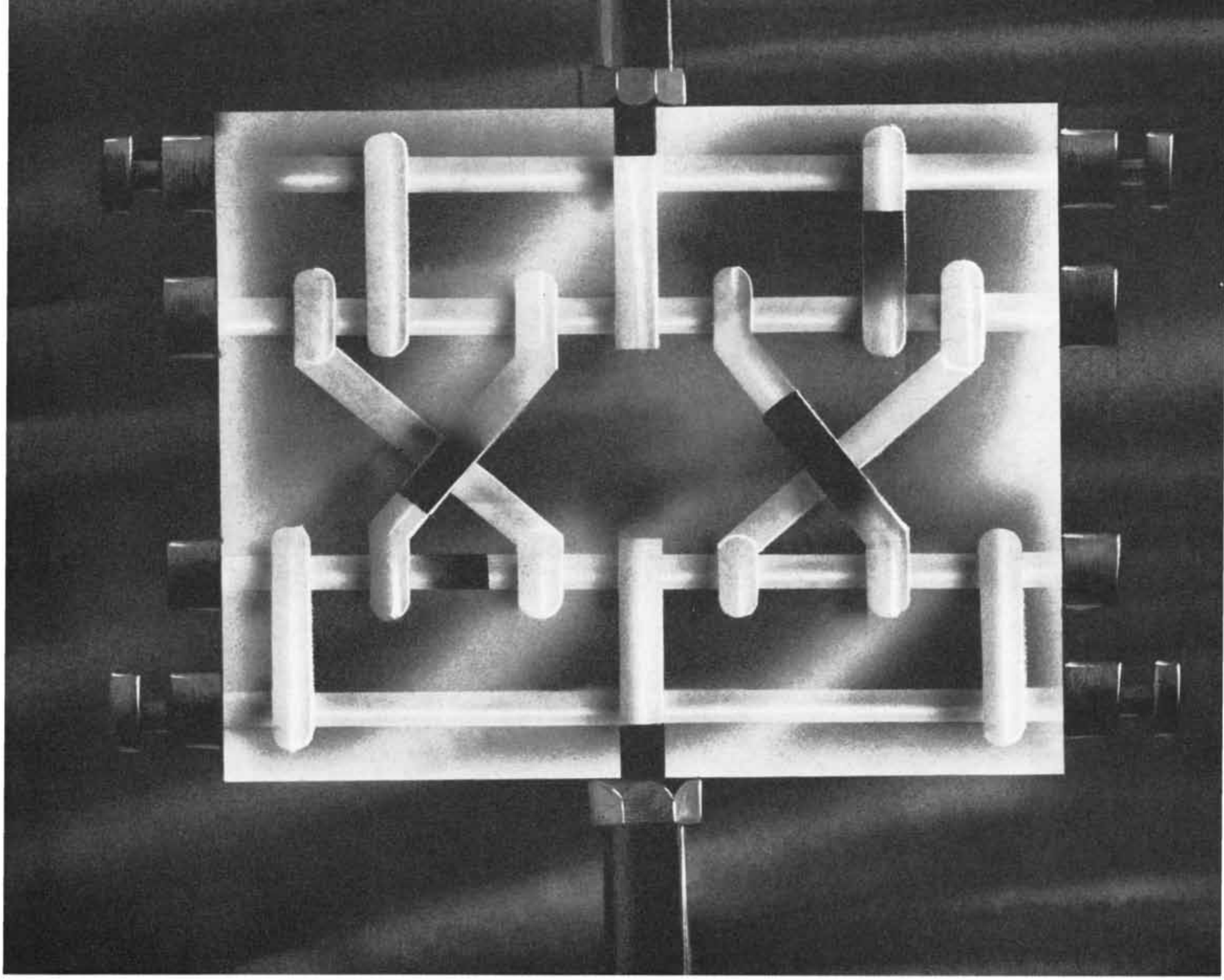
that all additive series strive vainly to become.

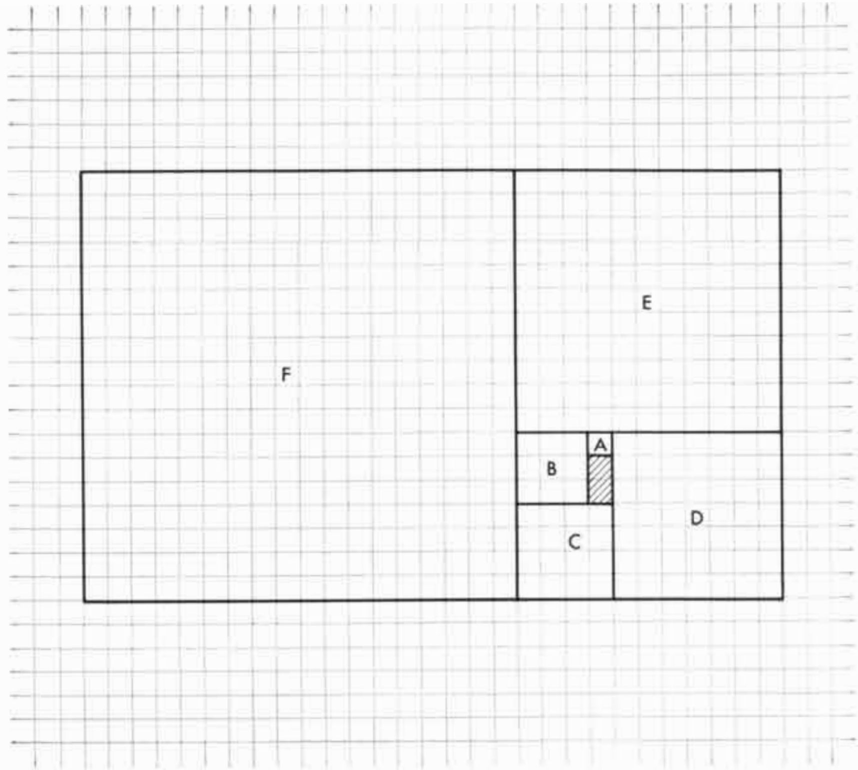
In recent times an enormous literature has developed around phi and related topics that is almost as eccentric as the circle-squaring literature revolving about pi. The classic is a 457-page German work, *Der goldene Schnitt*, written by Adolf Zeising and published in 1884. Zeising argues that the golden ratio is the most artistically pleasing of all proportions and the key to the understanding of all morphology (including human anatomy), art, architecture and even music. Less crankish but comparable are Samuel Colman's *Nature's Harmonic Unity* (1913) and Sir Theodore Cook's *The Curves of Life* (1914).

Experimental esthetics may be said to have started with Gustav Fechner's attempts to give empirical support to Zeising's views. The great German psychologist measured thousands of windows, picture frames, playing cards, books and other rectangles, and checked the points at which graveyard crosses were divided. He found the average ratio close to phi. He also devised many ingenious tests in which subjects picked the most pleasing rectangle from a group, drew the most pleasing rectangle, placed the bar of a cross at the spot they liked best, and so on. Again, he found that preferences averaged close to phi. But his pioneer experiments were crude, and more recent work along similar lines has yielded only the cloudy conclusion that most people prefer a rectangle somewhere between a square and a rectangle that is twice as long as it is wide.

The American Jay Hambidge, who died in 1924, wrote many books defending what he called "dynamic symmetry," an application of geometry (with phi in a leading role) to art, architecture, furniture design and even type fonts. Few today take his work seriously, though occasionally a prominent painter or architect will make deliberate use of the golden ratio in some way.

More recently Frank A. Lonc of New York has given considerable thought to phi. His booklets are obtainable from Tiffany Thayer's Fortean Society, which also sells a German slide rule on which phi appears. Lonc has confirmed one of Zeising's pet theories by measuring the heights of 65 women and comparing these figures to the heights of their navels, finding the ratio to average 1.618+. He calls this the Lonc Relativity Constant. "Subjects whose measurements did not fall within this ratio," he writes, "testified to hip-injuries or other deforming accidents in childhood." Lonc denies that the decimal expansion

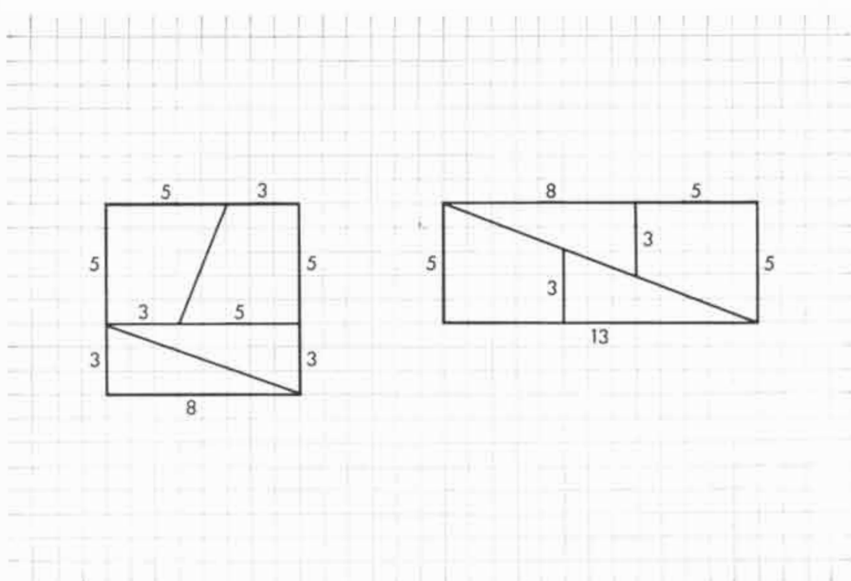




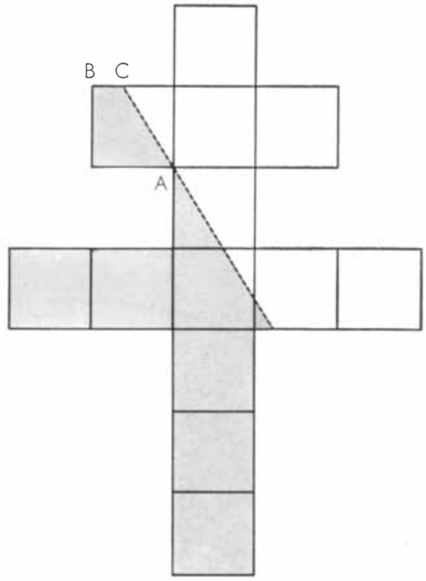
Squares show the convergence toward phi between consecutive terms in any additive series

of pi is 3.14159 . . . , as is widely believed. He has computed it more accurately by squaring phi, multiplying the result by 6, then dividing by 5 to get 3.14164078644620550.

I close with an interesting problem involving phi and the emblem made familiar by Charles de Gaulle, the two-beamed cross depicted in the illustration on page 134. The cross is here formed of 13 unit squares. The problem is to draw a straight line through point A so that the total area on the shaded side of the line equals the area on the other side. Exactly how long is BC if the line is accurately placed? (In the illustration the diagonal is incorrectly drawn so as to give no clue to its correct position.) The



A paradox based on the properties of any additive series



How long is the line BC?

answer, as well as a simple method of constructing the line with compass and straightedge, will appear in this department next month.

Last month's paper-folding problem is best handled as a maxima-minima problem in calculus. If x be the distance from corner A (the corner that is folded over) to where the crease strikes the bottom edge, then $8 - x$ will be the distance remaining on the bottom edge. The distance from the lower left corner to the point where corner A touches the left edge will be $4\sqrt{x - 4}$, the distance from the corner A to the spot where the crease strikes the right edge will be $2x/\sqrt{x - 4}$, and the crease itself will be $\sqrt{x^3}/\sqrt{x - 4}$. If the derivative of this last function is equated to zero, x will have a value of 6. The corner therefore touches the side edge at a point $4\sqrt{2}$ above the bottom, and the crease will be $6\sqrt{3}$ or a little more than 10.392 inches.

The interesting feature of this problem is that, regardless of the paper's width, the minimum crease intersecting the bottom edge is obtained by folding so that x is exactly three fourths of the paper's width. This three-quarter length multiplied by the square root of three gives the length of the crease. If the value to be minimized is the area of the part folded over, then x is always two thirds of the paper's width.

The crease in the simpler problem (in which the paper's width is 7.68 and the corner is folded to a point 5.76 above the base) is exactly 10 inches long.

THE AMATEUR SCIENTIST

A sundial that shows how any spot on earth is lit by the sun at any time

Conducted by C. L. Stong

Why is it that a man who owns a perfectly good watch and several clocks will buy or build a sundial? It is not enough to say that a sundial makes a pleasant ornament in the garden. A deeper answer is that there is considerable intellectual charm in a device which, though it is motionless, converts the constantly changing motion of the sun into accurate time.

Of course a sundial that tells the time with any real accuracy is exceedingly rare. The problem is that the earth moves faster along its orbit in January than it does in July, and that the height of the sun's path across the sky changes every day. These difficulties account for the exceptional interest of a sundial constructed recently by Richard M. Sutton, professor of physics at the California Institute of Technology.

"If you leave a tennis ball undisturbed in the closet for a week," writes Sutton, "it turns completely around in space seven times! This simple fact, which ordinarily escapes notice, can be put to good use. Most people would say that the ball has not moved at all, yet they would admit the intellectual fact that the earth turns on its axis. The ball is turned by the earth around an axis parallel to that of the earth, and at just the rate at which the earth turns: 15 degrees per hour.

"If we combine the fact that the ball turns completely around once a day with an equally simple fact, we can convert any globe of the earth into a remarkable universal sundial that tells more about sunlight, the earth's motions in space and the conditions of sunlight in distant lands than might be supposed. The second fact is that the light falling on the earth from the sun comes in a flood of substantially parallel rays. Because of the great distance of the sun (some 93 million miles), even the extremes of a diameter of the earth are struck by rays that diverge by only .005 degree. This means that the angle subtended by a line 8,000 miles long seen at a distance of 93 million miles is about 1/200 of a degree. The significance of this fact will be apparent below.

"The rules for setting up the globe are simple and easily followed. It is rigidly oriented as an exact copy of the earth in space, with its polar axis parallel to the earth's axis, and with your own home town (or state) right 'on the top of the world' (where most of us like to think we belong anyway!). First turn the globe until its axis lies in your local meridian, in the true north and south plane that may be found by observing the shadow of a vertical object at local noon, by observing the pole star on a clear night, or by consulting a magnetic compass (if you know the local variation of the compass). Next turn the globe on its axis until the circle of longitude through your home locality lies in the meridian just found. Finally tilt the axis around an east-west horizontal line until your home town stands at the very top of the world. If you have followed these three steps, then your meridian circle (connecting the poles of your globe) will lie vertically in the north-south plane, and a line drawn from the center of the globe to your own local zenith will pass directly through your home spot on the map. Now lock the globe in this position and let the rotation of the earth do the rest. This takes patience, for in your eagerness to see all that the globe can tell you, you may be tempted to turn it at a rate greater than that of the turning of the earth. But it will take a year for the sun to tell you all it can before it begins to repeat its story.

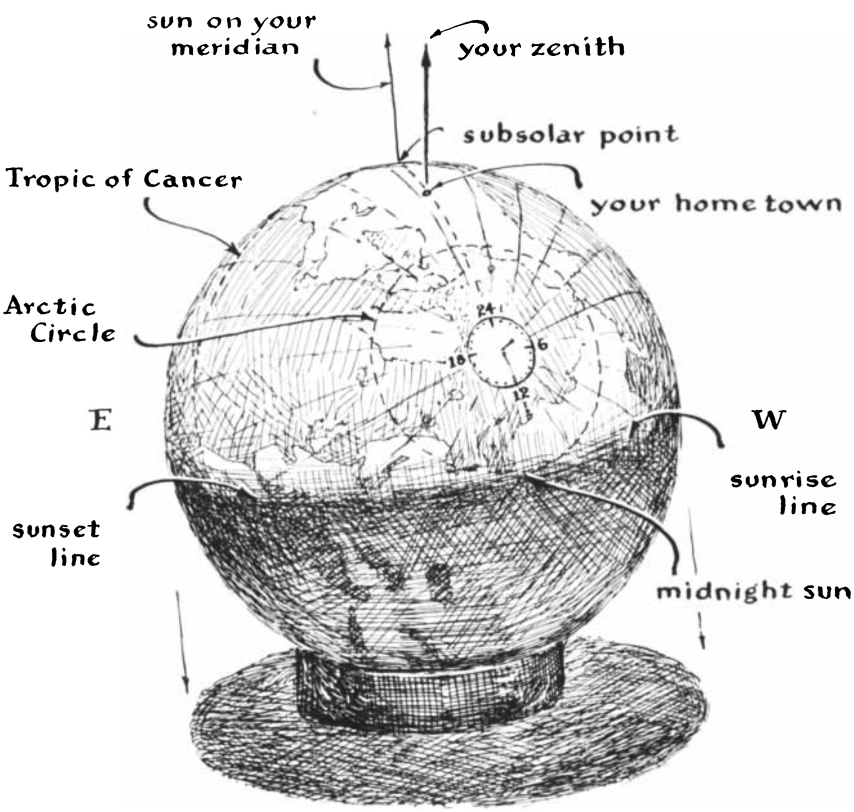
"When you look at the globe sitting in this proper orientation—'rectified' and immobile—you will of course see half of it lighted by the sun and half of it in shadow. These are the very halves of the earth in light or darkness at that moment. An hour later the circle separating light from shadow has turned westward, its intersections with the Equator having moved 15 degrees to the west. On the side of the circle west of you, the sun is rising; on the side east of you, the sun is setting. You can 'count up the hours' along the Equator between your home meridian and the sunset line and estimate closely how many hours of sunlight still remain for you that day; or you can look to the west of you and see how soon the sun will rise, say, in Japan. As you watch the globe day after day, you will become aware of the slow turning of the circle northward or southward, depending upon the time of year.

"Let us take an imaginative look at the globe as it sits in the sun. Suppose it is during those days in June when the sun stands near the zenith in our new state of Hawaii. The globe dial shows that it is still sunlight at 9:30 p.m. in Iceland, that the midnight sun is shining on the North Cape of Norway. It is between late and early afternoon on the U. S. mainland, being about 6 p.m. in New York and 3 p.m. in San Francisco. The eastern half of South America is already in the darkness of its longer winter nights. The sun has recently risen *next day* in New Zealand and the eastern half of Australia, and most of China and Siberia are in early-morning light, whereas in Japan the sun is already four hours high in the sky. Alaska is enjoying the middle of a long summer day with the sun as high in the sky as it ever gets. Seattle is in early afternoon about two sun-hours ahead of Honolulu in the midst of a 16-hour day, while Sydney, Australia, is just starting a day with only 10 hours of sunlight.

"Now you don't have to be in Honolulu to see all this happening. Your own globe tells it to you. The same is true for persons who set up their globes in Fairbanks, Honolulu, Tokyo, Caracas, Havana or anywhere else. They will all see exactly the same story at the same time if in each place they have taken the small trouble to set up their globes for their own home towns as directed. If we choose, we can follow the progress of the circle of light and dark through the year. Three months later, for example, when the sun has returned close to the celestial equator, and when it passes day by day close to the zenith along our own Equator, we will see the circle between light and dark apparently hinged on the polar axis of our globe. This is the time of the equinoxes, when every spot on earth has 12 hours of light and 12 hours of darkness. On December 21 the sun will have gone to its position farthest south, now failing to light any spot within the Arctic Circle but lighting the region within the Antarctic Circle completely (as you may see by stooping and looking at the lower part of your globe).

"From its position farthest south, the sun starts its way north again at a rate that may seem painfully slow for those in northern latitudes who wait for spring. By March 21 it has again reached the Equator, and we find it at the vernal equinox, the astronomers' principal landmark. Through the centuries this was the time for the beginning of the year. Only as recently as 1752 did December cease to be the 10th month of the year, as its name implies. January 1, 1752, was the first time that the calendar year began in January in England and the American colonies! At the vernal equinox in March there is a sunrise lasting 24 hours at the North Pole, and a sunset lasting 24 hours at the South Pole. Now, as the months advance, we will find that on June 21 this circle of light has advanced to its position farthest north. Sunlight does not enter the Antarctic Circle on the bottom side of your globe at all, but it extends clear over the North Polar region to the Arctic Circle beyond. At noon in your garden on this day you will see how people living on the meridian 180 degrees from your home are enjoying the midnight sun, provided they live within the Arctic Circle. Thus in imagination we have made a complete trip around the earth's orbit and have watched the progress of sunlight during the 365 or 366 intervening days—all right in the garden.

"It is not easy to appreciate the fact that the sun's rays are parallel as they fall on the earth. Let me suggest a simple experiment. On a bright morning take a piece of pipe or a cardboard tube and point it at the sun so that it casts a small, ring-shaped shadow. Now if at the very same moment someone 120 degrees east of you—one third the way around the world—were to perform the same experiment, he would point his tube westward at the afternoon sun. Yet his tube and yours would necessarily be parallel to within a very small fraction of a degree. If you point the tube at the sun in the afternoon, and someone far to the west simultaneously does the same in his morning, his tube will again be automatically parallel to yours. This experiment will help explain how it is that, when our globes are properly set up, people all over the world who are in sunlight will see them illuminated in just the same way.

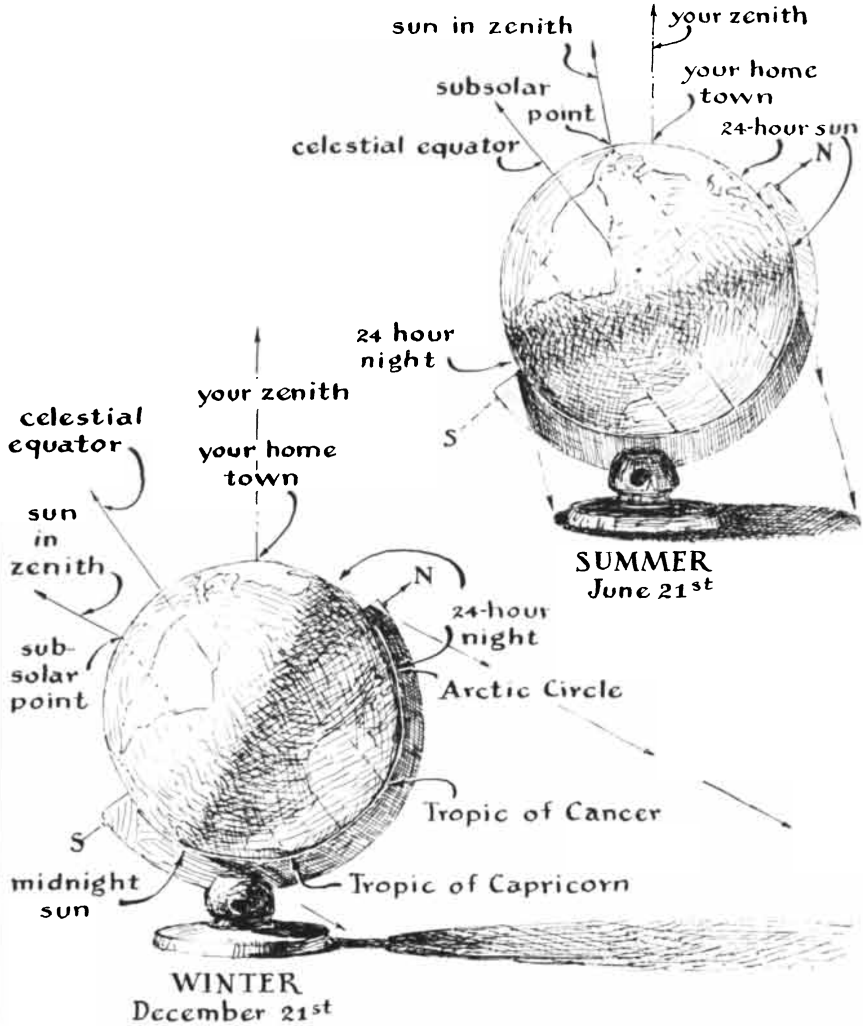


The global sundial, showing the North Pole on June 21

"How easy it is, with this global dial, to imagine oneself in a distant land, seeing the sun in that sky at that time of day. A pin held at any point on the globe immediately shows the direction of the shadow of a man standing at that spot. Your globe has become a 'terrella,' a little earth that shows what the big earth is doing in space.

"It was from long experimenting with a precision sundial drawn on the floor of my office at Haverford College that I slowly came to the idea of this dial. I had developed that dial to the point where I could tell the time within five seconds. But the global dial is more exciting. When it came to me, I was enthralled by its simplicity and profundity: to be able to see at a glance everything about sunlight all over the world without budging from my own garden or office. However, I had a strong feeling that an idea so simple and universal could not have escaped intelligent people at other times and other places. I have now learned that it was recognized some 300 years ago, when globes were playthings of the wealthy. People were then regarding their world with new understanding, made much richer by the great sailing explorations and the increasing recognition of the earth's sphericity. To be sure, the early Greeks had seen that the earth must be a sphere. For example, Archimedes based his great works on floating bodies on a proposition that reads: 'The free surface of any body of liquid at rest is part of a sphere whose center is the center of the earth.' Imagine that for 200 B.C.! There is much evidence in the writings of the Greek mathematicians that they appreciated this fact. Their estimates of the earth's size were correct in principle and not bad in actual result, but men seem to have ignored their observations and the reasoning behind them until the great age of exploration which we date from Columbus and the discovery of the New World.

"In a book on sundials by Joseph Moxon, first published in 1668, there is a description of 'the English globe, being a stabil and immobil one, performing what ordinary globes do, and much more.' Moxon, who was hydrographer to Charles II (and whose book was dedicated to Samuel Pepys, Principal Officer of the Navy), ascribes this globe



The illumination of the global sundial in winter and summer

to the Earl of Castlemaine. It seems certain that the globe existed in London by 1665. In 1756 another global sundial was described by Charles Leadbetter. Consider the delightful title of Leadbetter's book: 'MECHANICK DIALLING, or the New Art of Shadows, freed from the Obscurities, Superfluities, and Errors of former writers upon the Subject—the whole laid down after so plain a method that any person (tho' a Stranger to the Art) with a Pair of Compasses and Common Ruller only, may make a Dial upon any Plane for any place in the World, as well as those who have attained to the greatest Knowledge and Perfection in the Mathematics. A work not only usefull for Artificers but very entertaining for Gentlemen, and those Student at the Universities that would understand Dialling without the Fatigue of going through a Course of Mathematics.' They knew how to make full use of a title page in those days!

"Leadbetter tells how to erect an immobile stone sphere and inscribe a map on it. He says: 'According to their true latitudes and longitudes (for various spots on earth) you may discover any moment when the Sun shines upon the same, by the illuminated parts thereof, what Places on Earth are enlightened, and what Places are in darkness. . . . The Extremity of the Shadow shows likewise what Places the Sun is Rising or Setting at; and what Places have long Days; these with many more curious Problems are seen at one View, too many to be enumerated in this place. The dial is the most natural of all others because it resembles the Earth itself, and the exact manner of the Sun's shining thereon.' Leadbetter suggests that a pin be placed at each pole in order to use the global sundial to tell time. Around each pin are 24 marks—one every 15 degrees—corresponding to the hours; the time is read by noting the position of the pin's shadow with respect to the marks. I, too, have used this system. Leadbetter adds:

COOPER-BESSEMER SALES & SERVICES ABROAD

The Cooper-Bessemer Corporation:
International and Export Headquarters, 25 West 43rd Street, New York City.

Sales Representatives:
Gerson & Sons, Ltd., Bangkok, Thailand · C. Itoh & Co., Ltd., Osaka, Japan · Sociedade Comercial Orey, Antunes & Cia. Lda, Lisbon, Portugal · E. P. Karakassis, Athens, Greece.

Cooper-Bessemer of Canada, Ltd.:
Toronto · Edmonton · Calgary · Halifax

Sales Representative:
Maxwell, Simson & Associates, Vancouver, B. C.

Cooper-Bessemer, S.A.
Chur, Switzerland
The Hague, Netherlands

Cooper-Bessemer International Corporation:
New York City · Caracas, Venezuela · Mexico City

Sales Representatives:
Picardo y Antelo S.R.L., Buenos Aires, Argentina · Maquinarias Mendoza, Caracas, Venezuela · Industrial y Comercial, S.A., Montevideo, Uruguay · Ingenieria Electrica S.A.C., Santiago, Chile · Maquinas y Motores, Asuncion, Paraguay · Basil Fearn, St. Johns, Newfoundland · Ferromar, S.A., Havana, Cuba.

Cooper-Bessemer Overseas Corporation:
New York, New York

Licensees:
Harland & Wolff, Ltd., Belfast, Ireland · Termomeccanica Italiana, La Spezia, Italy · Societe des Forges et Ateliers du Creusot, Paris, France.

Charles G. Cooper, *Vice President,*
The Cooper-Bessemer Corporation, explains...

How Cooper-Bessemer can serve you anywhere in the world

If you need heavy-duty engines or compressors, Cooper-Bessemer can serve you promptly with the world's most advanced designs . . . whether you are located in Europe, Asia, South America or any other area of the globe. We have developed an outstanding organization of representatives, subsidiaries and licensees to provide experienced, full-scope service throughout the world. These companies can supply your needs in Cooper-Bessemer products backed by experienced, highly efficient engineering and technical service.

BRANCH OFFICES: Grove City • New York • Washington • Gloucester • Chicago • Minneapolis • St. Louis • Kansas City • Tulsa • New Orleans • Shreveport • Houston • Greggton • Dallas • Odessa • Pampa • Casper • Seattle • San Francisco • Los Angeles • *SUBSIDIARY:* C-B Southern, Inc., Houston

Cooper-Bessemer

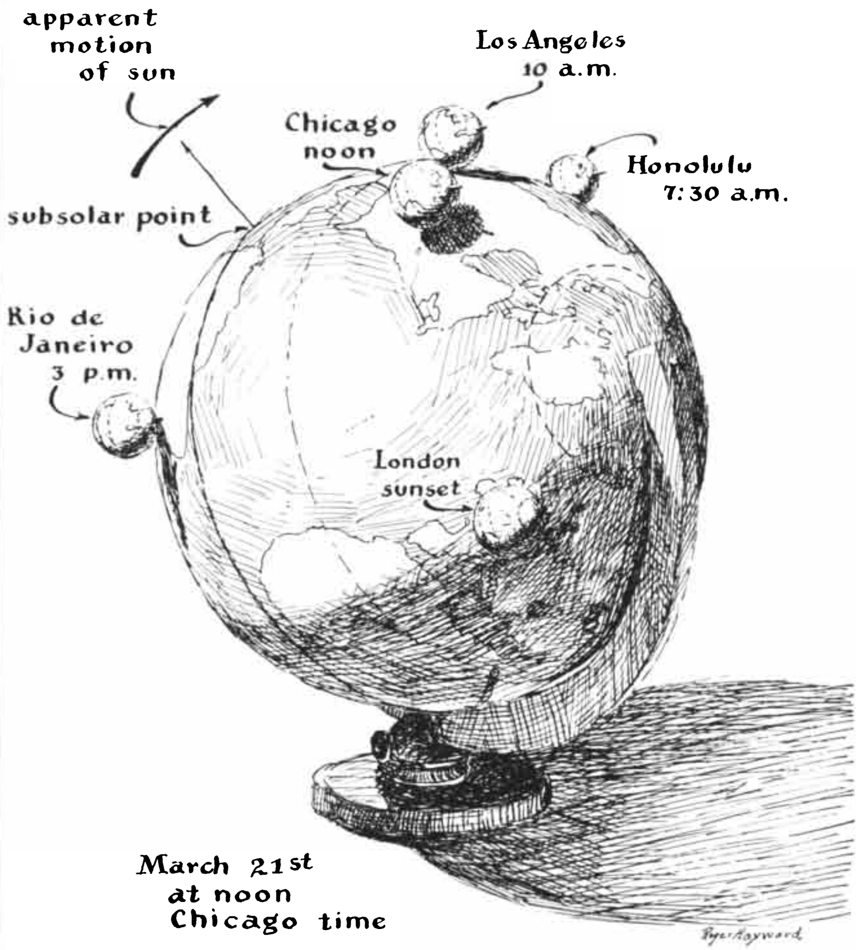
GENERAL OFFICES: MOUNT VERNON, OHIO
ENGINES: GAS · DIESEL · GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL, ENGINE OR MOTOR DRIVEN

'As you see, that [pin] at the North Pole will give the hour in summer, that at the South Pole the hour in Winter.'

"There is *no* spot on earth with which we do not at some time during the year share the light from the sun. One might object that surely the nadir, that spot directly beneath our feet on the other side of the earth, has no sunlight while we ourselves have it; but atmospheric refraction keeps the sun in the sky longer than geometry alone predicts, making every sunrise about two minutes early and every sunset about two minutes late.

"It is easy to tell from the global sundial just how many hours of sunlight any latitude (including your own) will enjoy on any particular day. All you need to do is to count the number of 15-degree longitudinal divisions that lie within the lighted circle at the desired latitude. Thus at 40 degrees north latitude in summer the circle may cover 225 degrees of longitude along the 40th parallel, representing 15 divisions or 15 hours of sunlight. But in winter the circle may cover only 135 degrees, representing nine divisions or nine hours. As soon as the lighted circle passes beyond either pole, that pole has 24 hours of sunlight a day, and the opposite pole is in darkness.

"One or two other concepts may make the dial even more useful. First, we can answer the question: Where is the sun in the zenith right now? Can we find the spot on earth where men find their shadows right at their feet? Easily. Hold the end of a pencil at the surface of the globe and move it until its shadow is reduced to its own cross section. When the pencil points from the center of the sun to the center of the globe, the spot on the map where its end rests corresponds to the point immediately beneath the sun. Better still, if you use a small tube instead of a pencil, you can let the sunlight pass down the tube to cast a ring-shaped shadow at the point beneath the sun. This point is important, because it gives the latitude and longitude of the sun at that moment and locates the center of the great circle of daylight. Ninety degrees around the globe in any direction from that point is a point where the sun appears on the horizon, either rising or setting. At the north and south extremes of the circle



Rectified globes anywhere on earth show the same lighted part at any time

DYNA-SOAR

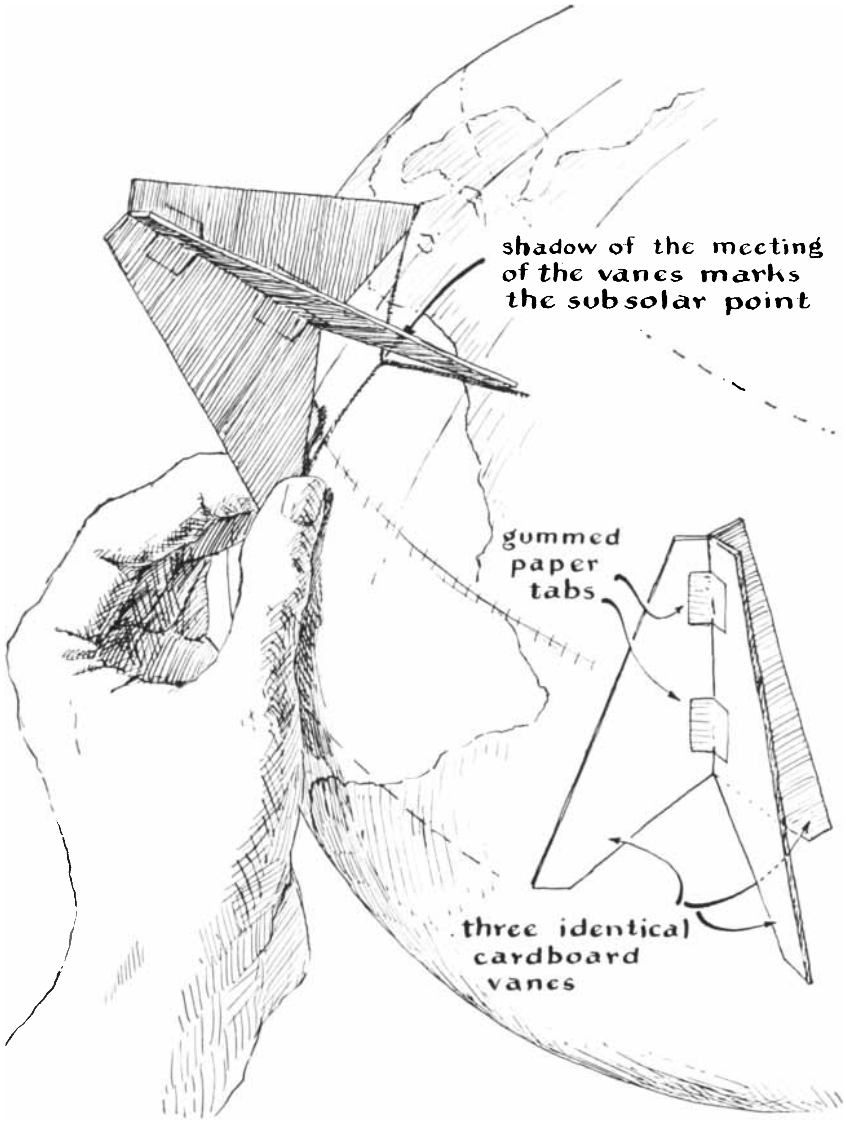
Dyna-Soar (for dynamic soaring) is a joint project between the Air Force and the NASA, and is an attempt to solve the technical problems of manned flight in the sub-orbital regions. Advance knowledge on the project indicates how a boost-glide vehicle can operate from the outer fringes of the atmosphere where it can maneuver and be recovered undamaged. Studies show that by varying the original rocket boost, and thus the velocity, and with the control available to the pilot, the Dyna-Soar aircraft can circumnavigate the earth, followed by a normal and controlled landing. Boeing Airplane Company, one of the competing companies for the development contract for the complete boost-glide system, has delegated to RCA the responsibility for the development of important electronic components of Dyna-Soar.

RADIO CORPORATION of AMERICA

DEFENSE ELECTRONIC PRODUCTS

CAMDEN, N. J.

Tmk(s) ®



Triangular fixture for locating the subsolar point

between light and darkness are 'the points where sunrise and sunset meet.' In June, for example, the southern point shows where the sun barely rises and then promptly sets in Antarctica, and the northern point (beyond the North Pole) shows where the midnight sun dips to the horizon and immediately rises again.

"To find the point directly beneath the sun still more accurately, you can construct a simple cardboard tripod. Just cut three identical pieces of cardboard and fasten them together with gummed paper as shown in the accompanying illustration [*above*]. When the tripod stands on a level table, the line joining the three vanes is vertical. When the tripod rests on the surface of your globe, the line extends outward along a radius of the globe. If you move the tripod about until the shadow of its three vanes disappears into three lines, you find the subsolar point at the junction of these lines. Once you have found the subsolar point, and hence the exact location of the sun in our system of coordinates, it is a simple matter to count off the hours since or until your local noon, to tell your local sun-time, to forecast the time until sunset and to tell how long it is since sunrise. You can also determine these things for locations other than your own.

"Perhaps this little sundial, so simply set up, will clarify the apparent motions of the sun, caused of course by the earth's daily rotation on its axis and its annual revolution around the sun. Surely it is fun to bring so much of the system of the world into your garden. The global dial can give one a fuller appreciation of the sunlight on which all men depend. If it thereby strengthens your feeling of kinship for people far away, the instrument will have served you well."

NEW DESIGNS IN MARLEX

PLAX selects MARLEX*

for new, featherweight 1-gallon plastic bottle

- Saves weight . . . 2½ lbs. lighter than glass jugs of equal volume!
- Saves shipping space . . . 37% less bulk!
- Safe for most liquids—from shampoos to corrosive chemicals!

The most exciting new container in the field of bulk liquids shipment is this unique, square 1-gallon bottle, blow-molded from MARLEX by PLAX Corp., Hartford, Connecticut.

By using MARLEX *rigid* polyethylene, PLAX obtains an ultra-lightweight bottle, with extra-strong, thin walls. This new bottle is unbreakable and resistant to corrosion and permeation by most chemicals. It can be frozen or sterilized. It is so inexpensive that it is used as a throwaway container!

The new PLAX gallon bottle uses 37% less warehouse, truck and carload space . . . weighs only 3 oz.—1/15th the weight of comparable glass bottles! Thinner corrugated with less tare weight can be used with these MARLEX "gallons", because they are lighter and do not risk breaking.

This new PLAX "gallon" is suitable for a wide variety of liquids, including: **shampoo, vanilla extract, pool chlorifiers, defoliant, paint primer solvent, arsenic acid, hydrofluoric acid, sulfuric acid, muriatic acid, hydrochloric acid, disinfectants, cleaning agents, and windshield washer fluid.** The U. S. Public Health Service has adopted it for shipment of pharmaceuticals.

If you are packaging with molded containers, transparent film or blown bottles, you should know more about MARLEX. Write for new technical brochure today!

*MARLEX is a trademark for Phillips family of olefin polymers.

PHILLIPS CHEMICAL COMPANY, Bartlesville, Oklahoma

A subsidiary of Phillips Petroleum Company

PLASTICS DIVISION OFFICES

NEW ENGLAND	NEW YORK	AKRON	CHICAGO	WESTERN	SOUTHERN	EXPORT
322 Waterman Avenue	80 Broadway, Suite 4300	318 Water Street	111 S. York Street	317 N. Lake Ave.	6010 Sherry Lane	80 Broadway, Suite 4300,
East Providence 14, R. I.	New York 5, N. Y.	Akron 8, Ohio	Elmhurst, Ill.	Pasadena, Calif.	Dallas, Texas	New York 5, N. Y.
GEneva 4-7600	DIgby 4-3480	FRanklin 6-4126	TErrace 4-6600	RYan 1-6997	EMerson 8-1358	DIgby 4-3480

MARLEX®
Phillips 66
A PHILLIPS 66 PLASTIC

Checking Einstein with

Purity Plus—*Hughes Products Division engineer checks semiconductor materials to insure purity.*

Exit cones *capable of withstanding temperatures of 6000° F. represent one example of advanced engineering being performed by the Hughes Plastics Laboratory.*

an atomic clock in orbit

To test Einstein's general theory of relativity, scientists at the Hughes research laboratories are developing a thirty pound atomic maser clock *(see photo at left)* under contract to the National Aeronautics and Space Administration. Orbiting in a satellite, a maser clock would be compared with another on the ground to check Einstein's proposition that time flows faster as gravitational pull decreases.

Working from the new research center in Malibu, California, Hughes engineers will develop a MASER (Microwave Amplification through Simulated Emission of Radiation) clock so accurate that it will neither gain nor lose a single second in 1000 years. This clock, one of three types contracted for by NASA, will measure time directly from the vibrations of the atoms in ammonia molecules.

Before launching, an atomic clock will be synchronized with another on the ground. Each clock would generate a highly stable current with a frequency of billions of cycles per second. Electronic circuitry would reduce the rapid oscillations to a slower rate in order to make precise laboratory measurements. The time "ticks" from the orbiting clock would then be transmitted by radio to compare with the time of the clock on earth. By measuring the difference, scientists will be able to check Einstein's theories.

In other engineering activities at Hughes, research and development work is being performed on such projects as advanced airborne systems, advanced data handling and display systems, global and spatial communications systems, nuclear electronics, advanced radar systems, infrared devices, ballistic missile systems...just to name a few.

The variety and advanced nature of the projects at Hughes provides an ideal environment for the engineer or scientist who wishes to increase his professional stature.

Newly instituted programs at Hughes have created immediate openings for engineers experienced in the following areas:

Communications	Environmental Engineering
Thin Films	Logical Design
Electron Tubes	Radar Circuit Design
Field Engineering	Material & Component Eng.
Semiconductors	Systems Analysis
Test Equipment Eng.	Nuclear Electronics

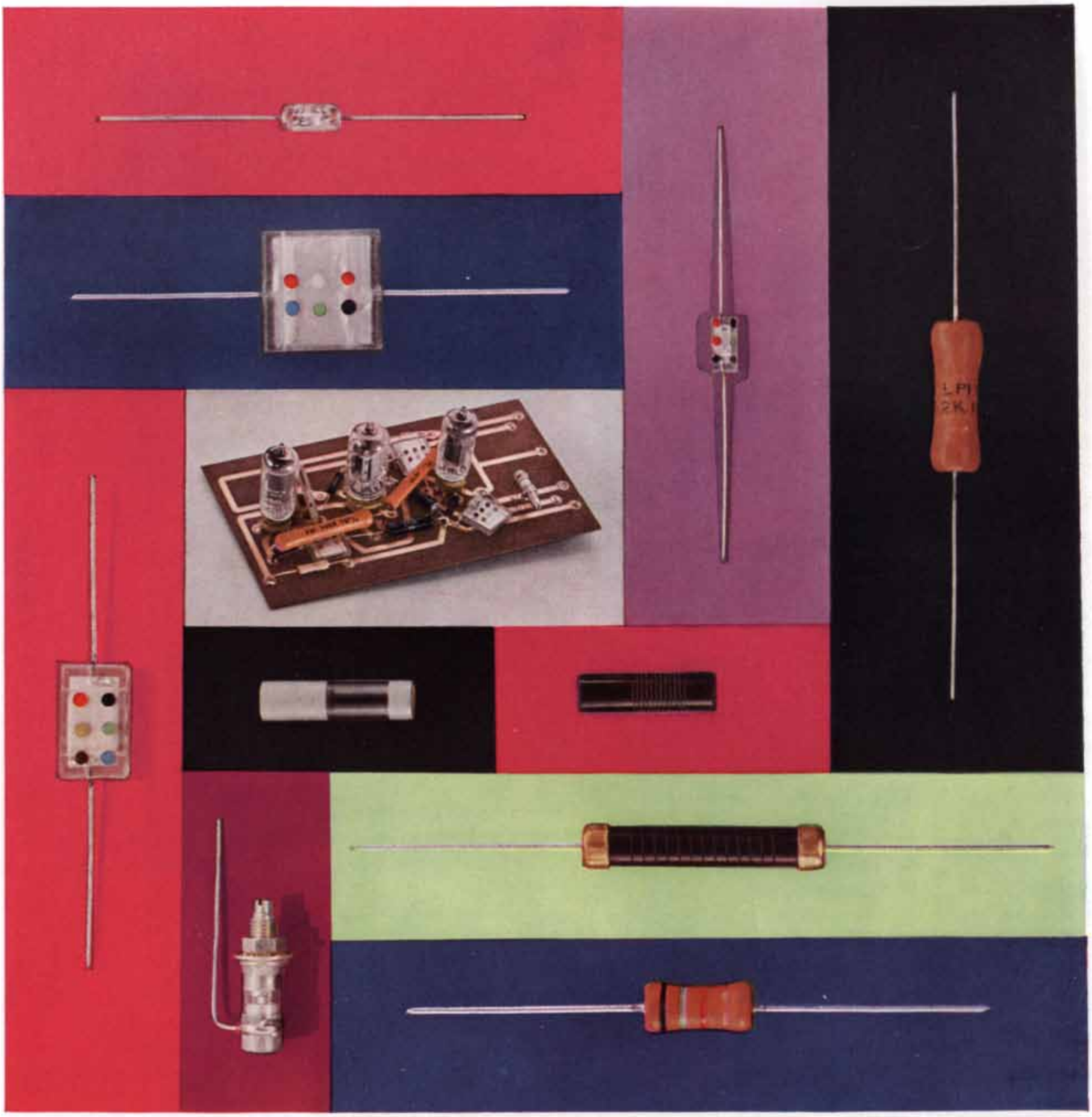
Write in confidence to Mr. Don Eikner, Hughes General Offices, Bldg. 6-H8, Culver City, Calif.

The West's leader in advanced ELECTRONICS

HUGHES

HUGHES AIRCRAFT COMPANY

Culver City, El Segundo, Fullerton, Newport Beach, Malibu and Los Angeles, California; Tucson, Arizona



Glass offers unique *sets* of properties to constructions like these electronic resistors, capacitors, and printed circuit boards. Write Corning Electronic Components, 549 High Street, Bradford, Pa., for technical data.

Why glass is a dielectric *nonpareil*

You can cover glass with dirt. Freeze it. Boil it. Bounce it. Take it up ten thousand miles where the air is rare. Bury it deep in a salted sea. And still it remains itself . . . with a set of electrical properties you can count on to stay fixed.

When you know its secrets well, you can put a metallic coating on glass, cut spirals in it, and come up with a rugged resistor. You can seal layers of aluminum between strips of glass and achieve a compact, reliable capacitor. You can make printed circuit boards on glass, and other components to the tightest specs.

Many are the marvels of glass. There are pipes of glass that combine transparency with unsurpassed resistance to acids and harsh organics. There are optically ingenious street lights and signals that make roads and railroads safer.

"This Is Glass" will acquaint you better with this material, help you spot applications in your own field. For a free copy of this brochure, write Corning Glass Works, 49 Crystal Street, Corning, N. Y.

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS

CORNING CAN DO ALMOST ANYTHING WITH GLASS

BOOKS

The tortured life of an influential modern philosopher: the late Ludwig Wittgenstein

by James R. Newman

LUDWIG WITTGENSTEIN: A MEMOIR, by Norman Malcolm. Oxford University Press ($2). THE BLUE AND BROWN BOOKS, by Ludwig Wittgenstein. Harper & Brothers ($6).

Darkly wise and a riddle: a strange man and a stranger philosophy, each unmistakably touched with genius. Wittgenstein died in 1951, acknowledged as one of the most influential philosophers of the century. His famous work, the *Tractatus logico-philosophicus*, appeared soon after the First World War and founded a movement. Two volumes of his papers have been translated and published since his death (Gilbert Ryle reviewed one of them, *Philosophical Remarks on the Foundations of Mathematics*, in this magazine in 1957), and most recently his celebrated *Blue and Brown Books*, dictated in English to his students between 1933 and 1935 and long in circulation in mimeographed form, have been reissued. No full-scale biography has yet appeared, and perhaps none will for a long time, but the Malcolm memoir provides an intriguing entry into the life of this extraordinary thinker, and its interest and value are enhanced by an excellent prefatory biographical sketch written by Georg Henrik von Wright of the University of Helsingfors.

Ludwig Josef Johann Wittgenstein was born in Vienna in 1889. His family, which had migrated from Saxony to Austria, was of Jewish descent, but his grandfather had been converted to Protestantism; Ludwig was baptized a Catholic, the religion of his mother. It was a wealthy and cultured home. His father was an engineer prominent in the steel and iron industry, and both parents were artistically and intellectually inclined, with a deep interest in music. Johannes Brahms was a close friend of the family.

Ludwig was the youngest of five brothers and three sisters. Deep instability as well as talent marked the children: three of his brothers were later to commit suicide. He lived always "on the border of mental illness," fearful of being driven across it; but it would be wrong, says von Wright, to think of him as morbid. He was strikingly original, often difficult to follow and certainly given to eccentricity; his later work suffered from an almost wayward obscurity, but his earlier labors had, in von Wright's view, "the same naturalness, frankness and freedom from all artificiality that was characteristic of him."

Until he was 14 Wittgenstein was educated at home. Thereafter he attended school in Linz in upper Austria and a technical high school in Berlin. At first he intended to study physics under Ludwig Boltzmann in Vienna, but the latter's death put an end to this wish and Wittgenstein turned to engineering. (Machines continued to fascinate him throughout his life. Even in his last years he could spend a whole day with "his beloved steam engine" in the South Kensington Museum, and there are anecdotes about his serving as a mechanic when some contraption got out of order.) In 1908 he went to England and registered as a research student in engineering at the University of Manchester. For three years he focused his attention on aeronautics, studying jet engines, experimenting with kites, working on propeller design. The mathematical aspect of propeller design absorbed him, and by that route he came to pure mathematics and the foundations of the subject. He had been unhappy and restless in his engineering researches, but in the new world of abstractions he found deep and growing satisfaction. He read Bertrand Russell's *Principles of Mathematics*, which was a revelation, and Gottlob Frege's writings on symbolic logic; this was the "gateway" through which he entered philosophy. On the advice of Frege, whom he visited in Jena, he entered the University of Cambridge to study with Russell.

During 1912 and 1913 he was at Trinity College, working as an advanced student in philosophy and psychology. This was a great period in the intellectual life of the university; Wittgenstein thrived on the rich ferment of ideas. He became friendly with John Maynard Keynes, G. H. Hardy and the logician W. E. Johnson; he was very close to David Pinsent, a young mathematician who fell in the war (the *Tractatus* is dedicated to his memory); he saw much of G. E. Moore and Alfred North Whitehead. With Bertrand Russell he formed an intimate relationship, and each man was to have a profound influence upon the thought of the other. At first Russell had difficulty in appraising this queer fish. Was he a genius or merely an eccentric? At the end of Wittgenstein's first term at Cambridge he came to Russell (who tells the story) and said: "'Will you please tell me whether I am a complete idiot or not?' I replied, 'My dear fellow, I don't know. Why are you asking me?' He said, 'Because, if I am a complete idiot, I shall become an aeronaut; but if not, I shall become a philosopher.' I told him to write me something during the vacation and I would then tell him whether he was a complete idiot or not. At the beginning of the following term he brought me the fulfillment of this suggestion. After reading only one sentence, I said to him, 'No, you must not become an aeronaut.'" They took long walks together; Wittgenstein would frequently come to Russell's rooms at midnight and for hours "would walk backward and forward like a caged tiger." Wittgenstein would announce that when he left he would commit suicide. "On one such evening, after an hour or two of dead silence, I said to him [Russell writes]: 'Wittgenstein, are you thinking about logic or about your sins?' 'Both,' he said, and then reverted to silence." He must have been trying, but enormously stimulating too. "Getting to know Wittgenstein," Russell said in a memorial article, "was one of the most exciting intellectual adventures of my life."

Wittgenstein entered the Austrian

army as a volunteer at the outbreak of the First World War. At the beginning he fought on the eastern front, but in 1918 he was transferred to the southern; when the Austro-Hungarian army surrendered, he was taken prisoner by the Italians. Men of passionate intellect take their work with them everywhere, and Wittgenstein, like Descartes, did not find soldiering an insuperable obstacle to creative thinking. When he was captured he had in his rucksack the manuscript of the *Tractatus* which he had completed on a leave of absence in Vienna in August, 1918. He had thought about its logical questions before the war and had formed certain of his major conclusions, but the idea of language as a picture of reality occurred to him, as he told von Wright, one day in a trench on the eastern front while he was reading a magazine in which there was a picture of the possible sequence of events in an automobile accident. The picture, he said, served as a proposition whose parts corresponded to things in reality; and so he conceived the idea that a verbal proposition is in effect a picture, "by virtue of a similar correspondence between *its* parts and the world." In other words, the *structure* of the proposition "depicts a possible combination of elements in reality, a possible state of affairs." The *Tractatus*, as von Wright observes, may be called a synthesis of theory-of-truth functions and the idea that language is a picture of reality, giving rise to the doctrine "of that which cannot be *said*, only *shown*."

While still a prisoner at Monte Cassino, Wittgenstein was able, through the intervention of his friend Keynes, to send the manuscript of the *Tractatus* to Russell and a copy to Frege. Before the war Wittgenstein had given Russell a short typescript consisting of notes on various logical points; these, together with what Russell had gained from their many conversations, strongly affected his thinking. The manuscript of the *Tractatus* stirred him even more profoundly. Writing in a British magazine the early part of this year, Russell said: "I do not feel sure that either then [1914] or later, the views which I believed myself to have derived from him [Wittgenstein] were in fact his views," adding that Wittgenstein always "vehemently repudiated expositions of his doctrines by others, even when those others were ardent disciples." Yet whether or not the *Tractatus*, at times a distressingly aphoristic and Delphic piece of writing, successfully communicated its author's meaning, or whether its influence (as Russell now questions) was "wholly good," there can be no doubt of its dominating effect on the British philosophical world. It cut a new channel for 20th-century thought.

Though he was able, despite the mortal uncertainties and confusion of the time, to complete the *Tractatus*, it cannot be imagined that the war gave Wittgenstein ease of mind. He became acquainted during this period with the ethical and religious writings of Leo Tolstoy, which had a strong influence on his view of life and also led him to study the Gospels. After his release as a war prisoner, Wittgenstein entered a Viennese college for elementary-school teachers. He took a two-year course, then for six years served as a schoolmaster in various remote Austrian villages. He had no private means because, though his father had in 1912 left him a great fortune, immediately after the war he gave all his money away and practiced a Tolstoyan simplicity and frugality. His secluded life as a schoolteacher suited his mood but not his temperament. He was in "constant friction" with the people around him, and finally, after a serious crisis, resigned his post. For a time he worked as a gardener's assistant in a monastery near Vienna and even considered becoming a monk. In the autumn of 1926 he tried his hand at architecture. He built a mansion in Vienna for one of his sisters. Von Wright describes it as a work "highly characteristic of its creator down to the smallest detail . . . free from all decoration and marked by a severe exactitude in measure and proportion." The materials were concrete, glass and steel; the house had horizontal roofs and its beauty was "of the same simple and static kind that belongs to the sentences of the *Tractatus*." He also did sculpture, but along more classical lines than those he followed in architecture; one of his creations is "the head of a girl or an elf."

It was evident that he was restless, troubled, uncertain of his course. He had written his book, it said all he had to say, and he saw no reason to continue in philosophy. "I am of the opinion," he wrote in the preface to the *Tractatus*, "that the problems have in essentials been fully solved." He had turned philosopher, as John Passmore remarks, "in his engineer's way, in order to drain what seemed to him a swamp. The task was completed; there was no more to be said." However, the actual publication of the *Tractatus* in 1922 had not been a joy either to him or to Russell. The circumstances were typical. Russell went to Holland to discuss the manuscript with him. It was hard to find a publisher, but Russell succeeded, and then wrote an introduction that Wittgenstein strongly disapproved. Finally he turned his back on the whole undertaking. But of course he was not through with philosophy. While he was still a schoolteacher the brilliant young philosopher Frank Ramsey, who had assisted in the translation of the *Tractatus* and had written an admirable review of it for the journal *Mind*, sought out Wittgenstein in Austria and tried to persuade him to return to England. These conversations with Ramsey, Wittgenstein says, woke him from his dogmatic slumber. With the help of Keynes, who raised the money, Wittgenstein visited his English friends in 1925. Another of his philosophical contacts during this period was the Austrian Moritz Schlick (who was to become founder and leader of the famous Vienna Circle), who had seen the *Tractatus* and esteemed it a first-class work.

In 1928 Wittgenstein heard the Dutch mathematician L. E. J. Brouwer, founder of the intuitionist school of mathematical philosophy, lecture in Vienna on the foundations of mathematics. This was the spark, it is said, that revived Wittgenstein's interest in philosophy. He now felt that he could again do creative work. In 1929 he returned to Cambridge as a research student, and the following year he was elected a fellow of Trinity College. During the next three or four years he wrote a good deal on the philosophy of mathematics, but published only a single article (on logical form). Those who had access to his manuscripts were impressed with his ideas, but he was evidently in a transitional stage of development and "fighting his way out of the *Tractatus*." The break with the past occurred about 1933. "There came to him at this time," says von Wright, "those basic ideas whose development and clarification absorbed him for the rest of his life." Frege and Russell had contributed much to the shaping of the ideas in the *Tractatus*; their views were undoubtedly, as Passmore has observed, Wittgenstein's point of departure, but the philosophical ancestry of his later views, of which so many echoes can be heard in the writings of the Vienna Circle, is less clear. It has been said that the influence of G. E. Moore is plainly visible, but von Wright dismisses this suggestion, arguing instead that the "impression of resemblance" between the views of both men is due to the influence both had on the trend known as analytic or linguistic philosophy. Norman Campbell's *Physics* and William James's *Principles of Psychology*—for a time James's work was the only one visible on Wittgenstein's bookshelf—have been mentioned as playing a part in the growth of his "new"

philosophy. In any case he now came to repudiate some of the fundamental thoughts of the *Tractatus*, thoughts that had been strongly criticized by Ramsey, and by another of Wittgenstein's friends, the Italian economist Piero Sraffa. (He said that his discussions with Sraffa, when he taught at Cambridge, "made him feel like a tree from which all branches had been cut.")

For the rest of his life, with some interruptions, Wittgenstein lived in England, teaching for many years at Cambridge. When the Germans swallowed Austria, he became a British subject, but for all the years he lived in England, for all the freedom and security and intellectual nourishment it gave him, it never became his country. He could not get used to English ways of life and he disliked the academic atmosphere at Cambridge. In 1935, when his Trinity fellowship expired, he planned to settle in the U.S.S.R., and a visit there with a friend pleased him. Events of the middle 1930's, however, contributed to the abandonment of this plan. For a year (1936) he lived in solitude in a hut he owned in Norway, where he began to write the *Philosophical Investigations*. In 1937 he returned to Cambridge and two years later succeeded to Moore's chair in philosophy.

Malcolm, an American student holding a Harvard fellowship at Cambridge, met Wittgenstein in 1938. The *Memoir* gives a vivid impression of him at that time. Though he was 49 years old, he looked about 35. He was some five feet six inches in height, slender, with curly brown hair. His face was lean and brown, his profile aquiline and "strikingly beautiful," and he had deep eyes that were often "fierce" in expression. The effect was of a commanding, even "imperial," personality that instantly drew attention at any gathering. Sometimes he was hesitant and would stammer, but usually he was emphatic and expressive, though obviously deeply immersed in his thoughts and desperately anxious, as one would expect from the bone and blood of his philosophical creed, to convey his exact meaning. He spoke excellent English, "although occasional Germanisms would appear in his constructions."

In contrast to his manner, his dress was extremely simple. "He always wore light grey flannel trousers, a flannel shirt open at the throat, a woolen lumber jacket or a leather jacket. Out of doors, in wet weather, he wore a tweed cap and a tan raincoat. He nearly always walked with a light cane. One could not imagine Wittgenstein in a suit, necktie or hat. His clothes, except the raincoat, were always extremely clean and his shoes polished."

Twice a week he met his class for two hours from five to seven. Students brought their own folding chairs, and if someone came a little late this involved a disruption, because chairs already placed in the crowded room had to be moved. Tardiness made Wittgenstein very angry; the late-comer had to face his formidable glare. His rooms were austerely furnished. There was no easy chair or reading lamp. The walls were bare. He slept on a canvas cot, and in the living room were two canvas chairs and a plain wooden chair, with an old-fashioned iron stove to provide heat. The only adornment was flowers in a window box and in a couple of pots. He did his writing on a card table and kept his manuscripts in a metal safe.

During class Wittgenstein sat on his wooden chair in the center of the room. "Here he carried on a visible struggle with his thoughts." This often led him to feel that he was confused; he would say, "I am a fool," or, "You have a dreadful teacher." He thought about certain problems as he went along; his classes were more conversation than lectures. When he was wrestling with an idea, he would "with a peremptory motion of the hand" prohibit further discussion, so that there were frequent and prolonged periods of silence "with only an occasional mutter from Wittgenstein, and the stillest attention from the others."

It is easy to imagine that he frightened his students. He was impatient, irritable, insulting. He drove himself, scourged himself to achieve understanding, and was no less sparing of his class. They respected his passionate honesty, and if not petrified were spurred to hard mental exertion; but two hours of such severe and tense probing exhausted both teacher and pupils. When it was over, Wittgenstein, full of self-reproach, would eagerly seek relief from his ordeal. Often he would "rush off to a cinema immediately after the class ended," taking a friend with him. He would buy a bun or an execrable English cold pork-pie and munch it while he watched the film. He insisted on sitting in the front row so that the screen "would occupy his entire field of vision, and his mind would be turned away from the thoughts of the lecture and his feelings of revulsion." No matter how wretched the picture he became totally absorbed in it. He liked U. S. films and detested British ones—part of his distaste for English culture; Carmen Miranda and Betty

DON'T MISS THE MOST REMARKABLE OFFER WE HAVE EVER MADE!

Limited quantities of 31 current new scientific works at less than ½ price! Build your library at small fractions of the prices you might expect to pay! Save as much as $12.50 per work. We have purchased a small surplus of 31 important backlist books on chemistry, engineering & technology issued by Reinhold. All are latest editions; no revisions planned; perfect, complete, identical with full-price copies. These are not remainders, not closeouts—simply once-in-a-lifetime price reductions offered to reduce a small surplus. Our supplies are very limited. Send in your order immediately.

RA. RESIDUAL STRESSES IN METALS & METAL CONSTRUCTION, ed. W. Osgood. 22 papers: fractures, fatigue, microstresses, flow, measurement, etc. "Very valuable," Journal, Franklin Inst. 200 illus. 371pp. 6 x 9. Cloth. (Only 304 copies) Pub. at $10.00. Here only **$4.49**

RB. BASIC LUBRICATION PRACTICE, A. F. Brewer. Select, use effective lubricants; unusual coverage of bearings, chains, gears, cable, turbine, motors, etc. "Inestimable value," Scien. Lubrication. Bibliog. of 1000 items. 125 illus. 292pp. 6 x 9. Cloth. (Only 326 copies) Pub. at $7.50. Here only **$2.49**

RC. PATENT LAW IN THE RESEARCH LABORATORY, J. Wise. Protect your interests; basic knowledge may save litigation, time, expense. "Excellent," Chem. Lit. 145pp. 4½ x 6¾. Cloth. (Only 309 copies) Pub. at $2.95. Here only **$1.00**

RD. MANUFACTURE & APPLICATION OF LUBRICATING GREASES, C. Boner. Theory, structure; additives; processes; all major types of greases. "Most comprehensive attempt I have seen," Journal, Franklin Inst. Bibliog. of 1250 items. 250 illus. 1001pp. 6 x 9. Cloth. (Only 402 copies) Pub. at $18.50. Here only **$5.95**

RE. BIOCHEMISTRY OF B VITAMINS, R. Williams, etc. Am. Chem. Soc. Monograph. Basic; cognizance of varying viewpts. Characteristics, distribution, extraction, catalytic functions, etc. Bibliog. of 2500 items. 752pp. 6 x 9. Cloth. (Only 211 copies) Pub. at $17.50. Here only **$5.95**

RF. CHEMICAL PROCESS ECONOMICS IN PRACTICE, J. Hur. Figure costs; easy, direct, practical. Accounting, investment, costs, market, etc. "Good job, fills a real need," Chem. & Eng. News. 115pp. 5 x 7¼. (Only 386 copies) Pub. at $3.95. Here only **$1.25**

RG. INDUSTRIAL DETERGENCY, W. Niven, ed. Authoritative, thorough, practical; materials, methods, equipment; scientific, engineering; both basic & accessory operations. "Meets a demand," Textile Research Journal. Over 300 illus. 345pp. 6 x 9. Cloth. (Only 225 copies) Publ. at $8.75. Here only **$3.49**

RH. HANDBOOK OF FOOD & AGRICULTURE, ed. F. C. Blanck. Encyclopedic coverage. Soils, microbiology, insects, growth, storage, preservation, spoilage, cereals, dairy, meat, fish, etc. "A remarkable book," NATURE. Bibliog. of 2,000 items. 250 illus. 1045 pp. 6 x 9. Cloth. (Only 486 copies) Pub. at $15.00. Here only **$5.95**

RI. 5th SYMPOSIUM ON COMBUSTION: ENGINES & COMBUSTION KINETICS. 101 papers; combustion, kinetics, fuels, combustion of solids, diffusion flame, etc. Rocketry, automobile, metals, physics, oxidation chemistry, etc. "Indispensable," Journal, Franklin Inst. 500 illus. 818pp. 6¾ x 10. Cloth. (Only 298 copies). Pub. at $20.00. Here only **$8.49**

RJ. ENGINEERING USES OF RUBBER, ed. A. MacPherson, A. Klemin. Complete coverage of engineering uses, special problems, new applications. Properties, behavior, application, tailoring; synthetic & natural. "Very complete, very valuable," J. Inst. of Engineers. 100 illus. 497pp. 6 x 9. Cloth. (Only 337 copies) Pub. at $12.50. Here only **$4.95**

RK. FABRICATED MATERIALS & PARTS, T. Dumond. Selecting methods to be used, costs, castings, forgings, extrusions, spinning, etc. "Extremely useful," Sheet Metal Indus. 102 illus. 337pp. 5½ x 8½. Cloth. (Only 421 copies) Pub. at $6.50. Here only **$2.25**

RL. ALUMINUM PAINT & POWDER, J. Edwards, R. Wray. 3rd enlgd ed. Powder, paste; properties, composition, vehicles, special uses, etc. "Clear, authoritative, complete," Science. 76 illus. 228pp. 6 x 9. Cloth. (Only 198 copies) Pub. at $5.50. Here only **$1.98**

CHROMIUM, ed. M. J. Udy, 2 vol. set, Am. Chem. Soc. Mono. 132. 36 experts. Vol. One: chemistry of chromium, compounds, chemicals, use, production, etc. Vol. Two, metallurgy of chromium & alloys, production, properties, uses, etc. "Cannot be too highly recommended," Jour. Royal Inst. of Chem.
RM. Vol. One. 200 illus. 441pp. 6 x 9. Cloth. Pub. at $11.00. Here only **$4.49**
RN. Vol. Two. 200 illus. 410pp. 6 x 9. Cloth. Pub. at $11.00. Here only **$4.49**
RO. Two vol. set, complete, contents as above. (Only 225 sets available) Pub. at $19.50. Here only **$7.98**

RP. ECONOMIC GEOGRAPHY OF INDUSTRIAL MATERIALS, Ed. A. Carlson. All impt. raw materials: population, power, transpt, metals, wood, etc. Production, American & world, consumption, etc. "Valuable reference Source," Journal, Franklin Inst. 200 illus. 505pp. 7 x 10. Cloth. (Only 187 copies) Pub. at $15.00. Here only **$5.95**

RQ. WOOL, ITS CHEMISTRY & PHYSICS, P. Alexander, R. Hudson. Exhaustive: morphology, surface properties, sorption, rate processes, chem. composition, stereochemistry, etc. Useful for all in protein studies; unusual treatmt. of diffusion processes. 100 illus. 412pp. 5½ x 8½. Cloth. (Only 209 copies) Pub. at $10.00. Here only **$4.95**

RR. VEGETABLE FATS & OILS, E. Eckey. Virtually all veg. fats & oils, by botanical classification. Most thoro coverage ever printed. "A veritable encyclopedia, valuable reference work," Science. 1200 item bibliog. 200 illus. 845pp. 6 x 9. Cloth. (Only 248 copies) Pub. at $17.50. Here only **$5.95**

RS. TITANIUM & TITANIUM ALLOYS, J. Everhart. Selective basic summary, commercial uses, etc. "Painless orientation for graduate engineers," Lib. Journal. 189pp. 4 x 6½. Cloth. (Only 414 copies) Pub. at $2.95. Now only **98¢**

RY. CHEMISTRY OF PORTLAND CEMENT, R. Bogue. 2nd ed., with new electron microscopic, crystallographic studies. All aspects of cement. "Truly comprehensive," Science. Over 400 illus. 813pp. 6 x 9. (Only 212 copies) Pub. at $16.50. Here only **$5.95**

RU. QUALITY CONTROL FOR PLASTICS ENGINEERS, ed. L. Deming. Easy intro; despite title, not restricted to plastics, but for all manufactures. 147pp. 6 x 9. Cloth. (Only 138 copies) Pub. at $4.95. Now only **$1.49**

RV. SHELL MOLDING & SHELL MOLD CASTINGS, T. Dumond. All aspects, stressing cost, efficiency, practicality. Reveals much not in print because of patent litigation. 25 illus. 135pp. 4 x 6½. Cloth. (Only 425 copies) Pub. at $2.00. Here only **98¢**

RW. QUALITY CONTROL & STATISTICAL METHODS, E. Schrock. 2nd enlgd ed. Lucid intro. to modern techniques; equal stress on math & on organizational methods. 100 problems. 260pp. 6 x 9. (Only 340 copies) Pub. at $6.75. Here only **$2.49**

RX. THE CHEMISTRY OF PETROLEUM HYDROCARBONS, ed. by B. Brooks, etc. 3 vol. set, most valuable single reference & research source; every aspect of chemistry, fundamental theory, physical methods; industrial & non-industrial. "Practically no aspect . . . not discussed; modern treatment, of great value," Jour. Royal Inst. of Chem. "All chemists in petroleum & related fields will benefit," Chem. & Eng. News. 3000 item bibliog. Over 1,500 illus, charts. 1820pp. 6 x 9. 3 vol. set. (Only 248 sets left) Pub. at $49.50. Here only **$18.50 per set**

RT. SODIUM, ITS MANUFACTURE, PROPERTIES, USES, M. Sittig. Am. Chem. Soc. Monograph. No other book with so much useful information; latest developments. Metallic sodium, solubility, alloys, uses, reactions, etc. "So thorough we consider it indispensable," Chem. & Eng. News. 2000 item bibliog. 150 illus. 538pp. 6 x 9. Cloth. (Only 289 copies) Pub. at $12.50. Here only **$3.95**

ELEMENTS OF FOOD ENGINEERING, M. E. Parker, etc. Complete coverage of unit operations in 2 vols. (vols. 2 & 3 of set, complete in themselves). Vol. Two: assembly, preparation, conversion of raw materials. Vol. Three: conversion, contd, treatment of final products. "Highly recommended," Food Technology. (Only 273 sets.)
RAA. Vol. 2 180 illus. 366pp. 6 x 9. Pub. at $8.50. Here only **$3.98**
RBB. Vol. 3 140 illus. 248pp. 6 x 9. Pub. at $6.75. Here only **$2.49**

RCC. DETERIORATION OF MATERIALS, ed. G. Greathouse, C. Wessel. Most thorough reference by 24 specialists; techniques for retarding deterioration. "A great service to us all," Chem. & Industry. 400 illus. 850pp. 6 x 9. (Only 435 copies) Pub. at $14.00. Here only **$4.95**

RDD. PRINCIPLES OF EMULSION TECHNOLOGY, P. Becher. Theoretical & applied; physico-chemical theory. Material from food, cosmetics, paint, etc. 45 illus. 156pp. 4⅝ x 6¾. (Only 401 copies) Pub. at $4.50. Here only **$2.20**

REE. PLASTICS TOOLING, M. Riley. Background of jigs, fixtures, dies, moulds, etc. Advantages, disadvantages, costs, materials. "Worth acquiring," Engineer. 34 illus. 135pp. 4½ x 6¾. (Only 300 copies) Pub. at $2.50. Here only **98¢**

●

AL503. ILLUSIONS & DELUSIONS OF THE SUPERNATURAL & THE OCCULT, D. Rawcliffe. Most penetrating analysis of seemingly supernatural phenomena: auras, telepathy, poltergeists, stigmata, levitation, suspended animation, firewalking, visions, paranormal drugs, etc. Will explain factors that permit primitive claptrap to survive in our day; extensive study of psychology of occult belief & hallucination. 25-page bibliog. 551pp. Paperbd. **$2.00**

AL523. HOW TO TELL THE BIRDS FROM THE FLOWERS, Robert Williams Wood. Quaint humor classic by outstanding American physicist. Largest, most complete edition ever printed. 106 illustrations, full verses. 64pp. Paperbd. **75¢**

AL367. 101 PUZZLES IN THOUGHT & LOGIC, C. Wylie. No math needed. Solutions. 128pp. Paperbd. **$1.00**

AL510. THE ADVENTURE OF CHESS, Edward Lasker. Engaging personal account of chess history; personal experiences with Alekhine, Dr. Lasker, Capablanca; chess frauds; chess automata; chess lore. New chapter on electronic chess machines. 2nd edition. 64 illus. 320pp. Paperbd. **$1.45**

AL394. FADS AND FALLACIES IN THE NAME OF SCIENCE, Martin Gardner. Puzzle editor of Scientific American in standard coverage of cults, delusions, like Atlantis, flying saucers, dianetics, orgone energy, etc. 395pp. Paperbd. **$1.50**

AL465. HOAXES, C. MacDougall. Prof. of Journalism at Northwestern analyzes more than 350 hoaxes in art, science, history, current events. 347pp. Paperbd. **$1.75**

AD492. SYMBOLIC LOGIC and GAME OF LOGIC, Lewis Carroll. Not modern symbolic logic, but amusements, puzzles based on classical logic. Altogether over 400 recreations in these two books. Counters for game of logic. Solutions. Total of 280pp. Paperbd. **$1.50**

AD493. PILLOW PROBLEMS, and A TANGLED TALE, Lewis Carroll. With above, all Carroll's mathematical recreations. Pillow Problems, until now a rare book costing up to $35, contains 75 problems; A Tangled Tale, puzzles in story form. Solutions. 280pp. Paperbd. **$1.50**

AL505. YOGA, A SCIENTIFIC EVALUATION, K. Behanan. Philosophy, physiology, breathing exercises, therapeutic effects, controlling unconscious muscles, etc. Rational, based on work done at Yale; experimental, physiological. 17 photos. 290pp. Paperbd. **$1.65**

●

LISTEN & LEARN RUSSIAN now available! Three 33⅓ records, manual, only $5.95 per set

Specially designed to help you in colloquial language, Listen & Learn is most useful for travel, excellent as a refresher, for self-study, or as a supplement to any course or text. Also first-rate as an introduction via the modern, phrase method. Check these unusual features: (1) modern language, no deadwood; no technicalities; no trivia; (2) high fidelity recording; (3) English & foreign language recorded, with pause for you to repeat; (4) 128 page, or 196 page for Russian, booklet with full record text, plus phonetic aids. Only fully indexed set on market. (5) Guaranteed. Return it within 10 days if you do not like it. Not a markdown; simply a wonderful value. "High quality, practical, inexpensive," N. Y. Herald Trib. Each set has 3 33⅓ records (1½ hrs.), manual, album.

AL875. **LISTEN & LEARN FRENCH,** set, **$4.95**
AL876. **LISTEN & LEARN SPANISH,** set, **$4.95**
AL877. **LISTEN & LEARN GERMAN,** set, **$4.95**
AL878. **LISTEN & LEARN ITALIAN,** set, **$4.95**
AL879. **LISTEN & LEARN RUSSIAN,** set, **$5.95**

new revised edition of
THE STRANGE STORY OF THE QUANTUM
by Banesh Hoffmann

Completely non-mathematical, yet wholly faithful to the basic concepts of quantum mechanics, this book tells the fascinating story of the quantum revolution. It acquaints the layman, by means of analogies, examples, and imaginative insights, with the development and meaning of such theories as Bohr's energy levels of the atom, Pauli's exclusion principle, de Broglie's wave theory, Schroedinger's wave equation, Heisenberg's uncertainty, Dirac's laws, Sommerfeld's fine structure theory, Feynman's world lines, electron spin, invariance, quantum number, and the other concepts that drastically changed our notion of the universe. A long postscript, written for this edition, brings the reader up to 1958. "Of the books attempting an account of history & contents of modern atomic physics . . . this is the best," H. Margenau, Prof. of Physics, Yale. "Superb piece of expository writing," Mathematics Magazine.
New second edition. 1958 postscript. 32 illustrations. 275pp. 5⅜ x 8. **AL518** Paperbound **$1.45**

Dept. 245, Dover Publications, Inc.
180 Varick St., N. Y. 14, N. Y.

Please send me the following books (give key number or letters before book, price).

I am enclosing $............................ in full payment. Payment in full must accompany all orders except those from libraries or public institutions, who may be billed. (Please add 10¢ per book to your remittance on orders less than $5 for postage & handling charges.) Please print

Name ....

Address..

City..............................**Zone**........**State**..............

GUARANTEE. Your satisfaction unconditionally guaranteed. All books returnable within 10 days for full cash refund.

Hutton were two of his favorite actresses.

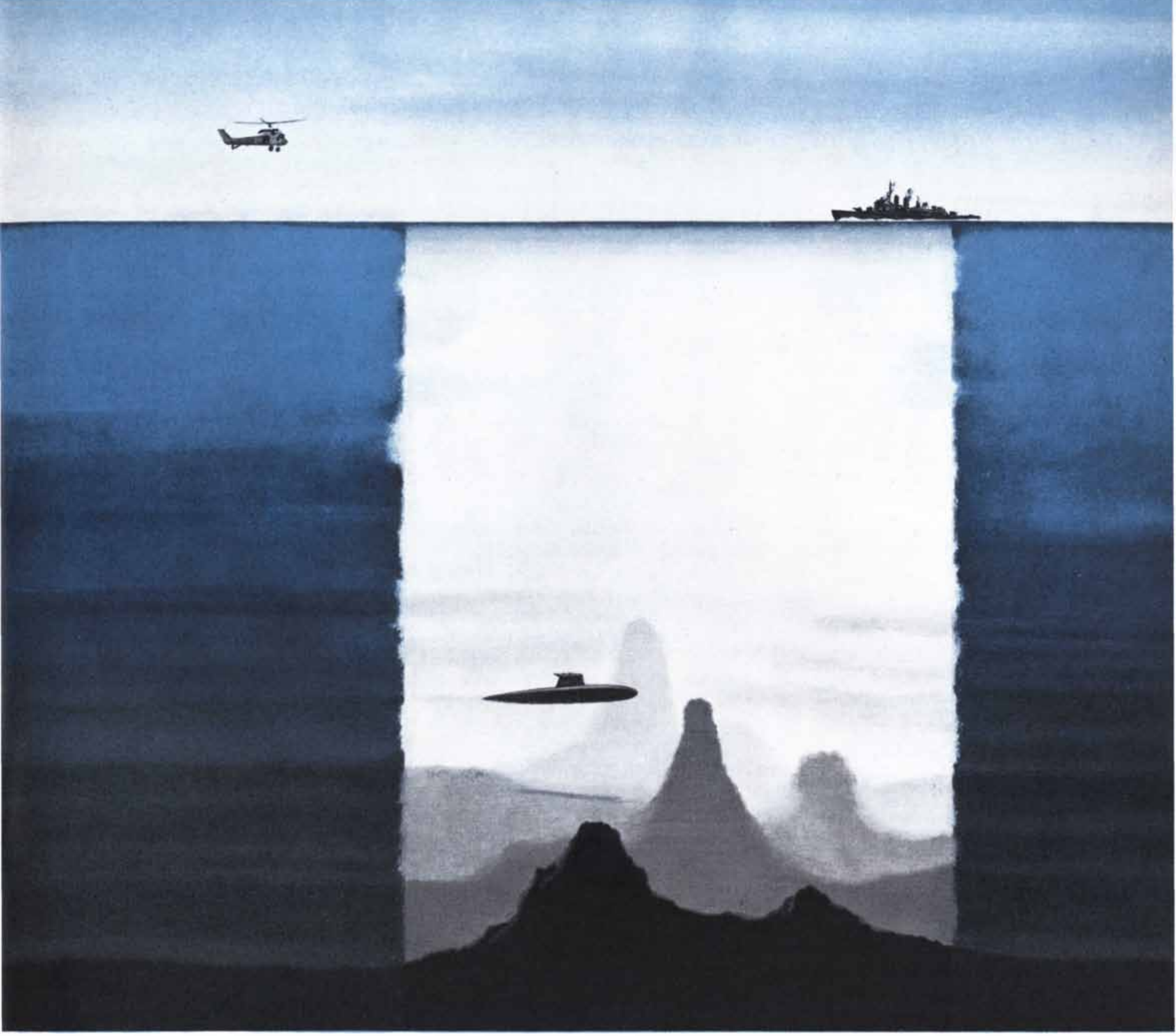
It was important to Wittgenstein to make friends with members of his classes. Philosophy went better, he felt, with friends, and he was stimulated by the sight of "friendly faces." He liked to make jokes to illustrate a point, and to laugh at his own cleverness, but if a member of the class laughed Wittgenstein would reprove him. Facetiousness had no place in philosophical discussions, at least the facetiousness of others.

He would invite students individually for tea, but no small talk was permitted. As in class the conversation was interspersed with long silences. Though a teacher of philosophy, he would try to persuade students to give up the subject. This was not so much because he felt they had no useful contribution to make as that he hated academic life in general and professional philosophers in particular. A normal human being, he believed, could not be a university teacher and also an honest and a serious person. He could not stand the society of academic colleagues; he would not dine in the Hall of his college, "being revolted by the artificiality of the conversation."

Wittgenstein argued with Malcolm to abandon philosophy and take a manual job. When it became clear that Malcolm intended to follow the less honest but more mental career, Wittgenstein gave him money so that he could continue his studies at Cambridge. They became good friends and saw much of each other. They would take long walks, which were apt to be exhausting. The tempo was in fits and starts. Wittgenstein would walk rapidly in spurts, would stop suddenly to look into Malcolm's eyes with a "piercing gaze" and then would trot off again, all the while expounding the most serious and even gloomy thoughts, erratically punctuated with "jests" which he alone was permitted to laugh at. He was exquisitely touchy. Once on a walk in 1939 Wittgenstein and Malcolm saw a news vendor's sign which announced that the German Government accused the British Government of instigating an attempt to assassinate Hitler. Wittgenstein suggested the German claim might be true; Malcolm repudiated the idea on the grounds the British were "too decent" to attempt anything so underhanded, and that it was against their "national character." Wittgenstein became extremely angry, told Malcolm that he was stupid and that he had evidently learned nothing from the philosophical training Wittgenstein was trying to give him. When Malcolm refused to back down, Wittgenstein would not talk to him any more; soon afterward they parted. Wittgenstein came no more for his walks and, although the friendship was resumed later, the episode was never forgotten. Wittgenstein managed to be enraged even by G. E. Moore. Having read one of Moore's papers with which he disagreed, he went to Moore's home and for two hours furiously harangued him, giving him no chance to reply. Later, when Moore told him he had been rude, he made a "stiff and reluctant apology."

In February, 1940, Malcolm returned to the U. S. He had been ill just before his departure, and Wittgenstein came to see him as a gesture of reconciliation. He fussed over the patient and said he was sorry about the assassination argument. He also gave the sound advice: "Whatever else you do, I hope that you won't marry a lady philosopher!" The two men kept up a correspondence. Wittgenstein was an avid reader of detective magazines, and as a connoisseur preferred those of Street & Smith; these being unobtainable in England during the war, Malcolm would send him bundles of them from time to time. Wittgenstein said he could not understand why anyone would read *Mind*, "with all its impotence and bankruptcy, when they could read Street & Smith magazines." In at least one case a story so entranced him that he wanted to write the author and thank him. "If," he wrote Malcolm, "this is nuts, don't be surprised, for so am I." When Malcolm got his Ph.D., Wittgenstein congratulated him and wrote: "I wish you good, not necessarily clever, thoughts, and decency that won't come out in the wash." On another occasion Wittgenstein wrote to Malcolm: "I wish you could live quietly, in a sense, and be in a position to be kind and *understanding* to all sorts of human beings who *need it*! Because we all need this sort of thing very badly."

For part of the war Wittgenstein worked as an orderly in Guy's Hospital in London; later he worked in an infirmary and in a clinical research laboratory. He could not do philosophy and he was "tired and sad." In 1944 he was back at Trinity, writing *Philosophical Investigations.* He thought it was "pretty lousy" but felt he couldn't improve on it if he tried "for another 100 years." He was reading Samuel Johnson's *Life of Pope*, also his *Prayers and Meditations*, which he liked very much. He commented that Freud was both "charming" and "full of fishy thinking," but that this did not detract from his "extraordinary scientific achievement." In 1946 his lectures went pretty well, but at the



No hiding place for underseas prowlers

Raytheon sonar is as far-reaching as the sea itself. From the air, the surface and the depths, underwater vision is eliminating the hiding places of underseas prowlers. Development of sonars for the highly diversified vehicles and environments necessary to achieve complete surveillance requires a highly adaptable engineering staff.

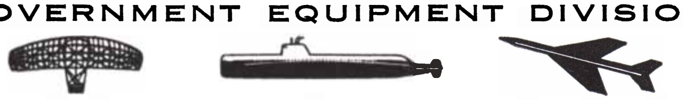
PROFESSIONAL ASSOCIATION WITH A FUTURE is open to qualified engineers and scientists with BS or advanced degrees. Positions are available in systems, development, design or manufacturing engineering of a wide range of complex equipments. Please write Donald H. Sweet, Government Equipment Division, Raytheon Company, 624 Worcester Road, Framingham, Massachusetts.

Engineering Laboratories: *Wayland, Maynard, Sudbury, Mass.; Santa Barbara, Calif.*
Manufacturing Facilities: *North Dighton, Waltham, Mass.*

RAYTHEON

Excellence in Electronics

GOVERNMENT EQUIPMENT DIVISION



AEROSPACE

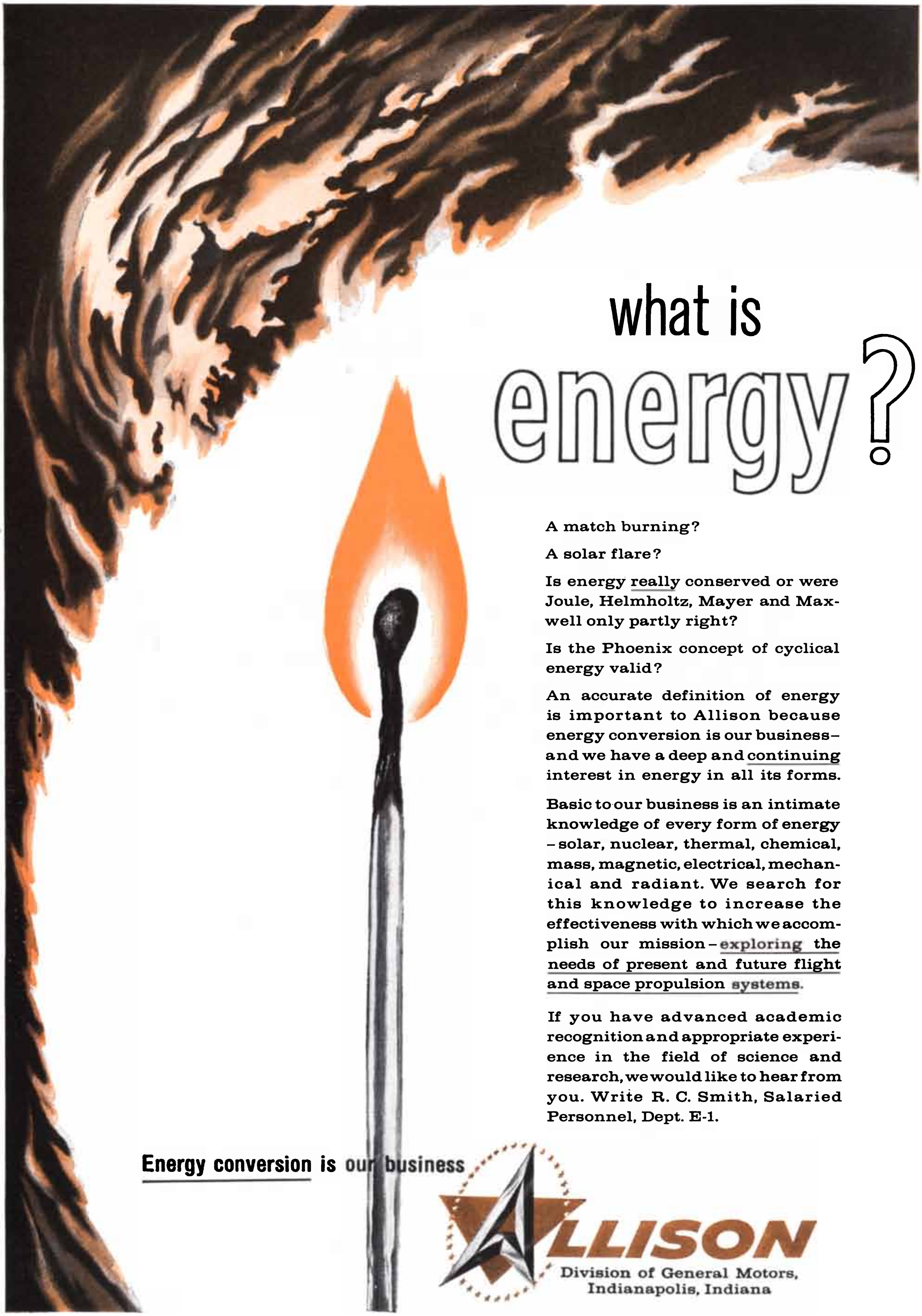
end of the term he said he felt his brain was "burnt out, as though only the four walls were left standing, and some charred remains." The same year Malcolm returned to Cambridge, which gave Wittgenstein the opportunity to meet his wife. At first he was suspicious of her, as he was of all "don's wives," but he got over this and became a frequent visitor. After supper he often insisted on washing the dishes, a feat performed in characteristic style with great thoroughness in the bathtub.

There are many more anecdotes in Malcolm's memoir. They reinforce the impression of Wittgenstein's complex and difficult personality. He was terribly hard on his friends, and just as hard on himself. His suspicions and fears, amounting almost to mania, kept disrupting his relationships. But people put up with him not alone because of his extraordinary gifts, but also because of his ruthless honesty and sincerity. When he was charming, or gracious or kind—as he could be—his purity shone through.

In the fall of 1947, after a trip to Austria, he resigned his Cambridge professorship. He was not finished with philosophy, but he had reached the end of his tether in the academic world. He spent some time in Ireland. He was depressed, ill in body and mind. In a lonely cottage on the west coast right on the sea, seeing nobody except the man who brought his milk, he dreamt, brooded, walked, watched the sea birds, worked a little. He didn't miss conversations, he said, but "only someone to smile at occasionally." Malcolm's shipment of detective magazines put him in better spirits. The concern of the Malcolms for this sad, proud, fading man was touching. They invited him for a long visit to Cornell University. He envisaged all sorts of difficulties, but he was eager to come and the matter was arranged. Malcolm met him when the *Queen Mary* docked. He came "striding down the ramp with a pack on his back, a heavy suitcase in one hand, cane in the other." He seemed vigorous and in excellent spirits. At Ithaca he was nearly his old self, taking long walks, worrying linguistic problems, indulging in small tyrannies and eccentricities. Even his diversions were intellectual. For example, on one walk he decided to measure the heights of the trees. The procedure was that he would place himself at a distance from the tree, sight along his arm and cane at the top of the tree, his arm at about a 45-degree angle from the horizontal; then Malcolm would pace off the distance to the foot of the tree and Pythagoras would provide the approximate height. Wittgenstein directed this activity with "real zest." Malcolm's wife once gave Wittgenstein some Swiss cheese and rye bread for lunch, which he greatly liked. Thereafter he asked for this combination at all meals, largely ignoring the various dishes that Mrs. Malcolm had prepared. He explained this by saying "it did not much matter to him *what* he ate, so long as it was *always the same*."

Wittgenstein met with Malcolm's colleagues and graduate students to discuss philosophy. At these sessions there were signs of his old fire, but illness gradually encroached upon him and he had to forego attendance. He was not too ill to be insulting. When he suggested that the *Philosophical Investigations* might be mimeographed, and Malcolm disparaged the idea, Wittgenstein was angered and accused him of being reluctant to see the work made public "because people would then know where my own [Malcolm's] philosophical ideas came from." Malcolm had merely meant that it was not fitting that a book of such importance should be distributed in mimeographed form: "It should be bound in leather and gold." One more anecdote catches the great logician at work. It was a hot summer, and Wittgenstein's room at the Malcolms' was often stuffy. He suggested removing the window screens to permit freer circulation of the air. Malcolm pointed out that the insects would be worse than the heat. Wittgenstein doubted this, and referred to the fact that screens were rare in England and on the Continent; Malcolm answered that we had more insects, which Wittgenstein didn't believe. He went out for a walk to see whether other houses had screens or whether this was simply one of Malcolm's peculiarities. On finding that all other windows had screens he inferred not that there must be a good reason for it, but ("with some irritation") that "Americans were the victims of widespread and unthinking prejudice as to the necessity of window screens."

In October he returned to England. The latter part of his stay had been wretched because of illness. He was sure he had cancer, and while he was quite prepared to die he was afraid he would be kept at the hospital for surgery. He didn't want to die in America. "I am a European—I want to die in Europe," he said to Malcolm in a frenzy. He had his wish. In December he wrote the Malcolms from Cambridge that he had cancer of the prostate. Medication alleviated the symptoms of the disease; he was able to go about, even to visit Vienna. He read various odds and ends and was


what is
energy?
A match burning?
A solar flare?
Is energy really conserved or were Joule, Helmholtz, Mayer and Maxwell only partly right?
Is the Phoenix concept of cyclical energy valid?
An accurate definition of energy is important to Allison because energy conversion is our business—and we have a deep and continuing interest in energy in all its forms.
Basic to our business is an intimate knowledge of every form of energy—solar, nuclear, thermal, chemical, mass, magnetic, electrical, mechanical and radiant. We search for this knowledge to increase the effectiveness with which we accomplish our mission—exploring the needs of present and future flight and space propulsion systems.
If you have advanced academic recognition and appropriate experience in the field of science and research, we would like to hear from you. Write R. C. Smith, Salaried Personnel, Dept. E-1.
Energy conversion is our business
ALLISON
Division of General Motors,
Indianapolis, Indiana

not depressed. For a few months he lived in Oxford, then he went to Norway for a month. In 1951 he returned to Cambridge to stay in the home of his physician. He even resumed work. He died very suddenly in April. Though much of his life had been spent in unhappiness, even torment, his last words to the wife of his host were: "Tell them I've had a wonderful life."

Short Reviews

Determinism and Freedom in the Age of Modern Science. A philosophical symposium edited by Sidney Hook. New York University Press ($5). This volume contains papers presented by 10 philosophers and physicists at the first annual New York University Institute of Philosophy held in 1957. Also included are 17 briefer comments by participants in the conference on issues raised by the main speakers. The general intellectual level of the proceedings is high, despite considerable variation in the quality of the contributions, some of which are rubbish. In their stimulating papers, P. W. Bridgman and Alfred Landé accept the currently orthodox view that quantum theory supports the claim that subatomic processes are radically indeterministic; but they also maintain that an element of objective indeterminism is present even in familiar macroscopic phenomena. However, as Milton Munitz points out in his excellent analysis, these claims are based on the dubious assumption that a physical theory is an adequate instrument for scientific research only if it provides information about the supposedly "ultimate" traits shared by all things. Moreover, the claims also overlook the fact that the indeterminism recognized in quantum mechanics is not something capable of direct observation. On the contrary, the data of observation are inherently neither deterministic nor indeterministic, and can be so characterized only on the basis of a theoretical interpretation of what is observed. Max Black illustrates the efficacy of the linguistic method in philosophy in his defense of the use of causal language in ordinary affairs of life. He shows beyond doubt that, though the introduction of such causal notions into theoretical physics generates serious difficulties, it is both insincere and foolish to deny that in contexts involving human action there are causally determined occurrences. Nevertheless the relevance of Black's discussion to any of the issues generated by modern science is at best highly tenuous. With one exception, the papers dealing with determinism and human responsibility are threadbare performances. The exception is H. L. A. Hart's illuminating analysis of the conditions under which the imputation of criminal responsibility is compatible with a belief in determinism, and is at the same time both rational and moral.

The Social History of Lighting, by William T. O'Dea. The Macmillan Company ($8.50). This is a most engaging book. The author, keeper of the Science Museum in London, tells the story of lighting from prehistoric times to the present. Fires and firebrands were the first sources of light; stone and shell lamps were in use about 15,000 years ago and lit the walls for the Lascaux cave painters. By the third millennium B.C. alabaster and gold lamps hung in the wealthier homes of Ur of the Chaldees, copper lamps were common in Egypt, tow wicks in bowls lit the streets of Babylon at festivals, pottery lamps were in wide use in the centers of the ancient world. Thereafter, for four or more millennia, there was little improvement in lighting. "The night cometh, when no man can work" was the Biblical description of the general attitude to the hours of darkness. Toward the end of the 18th century came the first revolutionary advance in lamp design since prehistoric times: Argand's lamp, with its cotton wick bent into a tubular form so that air could be drawn up through the center to assist the peripheral currents in effecting complete combustion. Soon glass chimneys were added, and there was a 10-fold increase in illumination capacity. O'Dea's survey describes the different lighting instruments for the traveler, from carriage lamps and traffic signals (a gaslit red and green light stanchion with semaphore arms was installed outside Parliament in London in 1868 to safeguard members of Parliament as they crossed the street) to arc-light towers to illuminate whole cities. Other chapters are devoted to mine lighting, lights for military operations and for surgical theaters, shop lighting, the lighting of art galleries, theater and motion-picture production lighting, light for gaiety, sports, and great occasions (such as the funeral of the Duke of Wellington, when blacked-out St. Paul's Cathedral was lit by thousands of gas jets), the immense machinery of lighthouses, the materials used for light, the various means of striking a light. A sampling of oddments: the illumination of billiard tables in the 18th century by means of candles set in large square frames hanging over the table; the lighting of 4,000 candles in less than

"THE PROGRAMMING FIELD is on the verge of tremendous changes. If we consider the developments in programming techniques and computer hardware that are currently in progress, these alone are enough to make one pause. Added to this are the new uses to which digital computers are being put, such as in management and process control systems. These new uses have created classes of problems for which we do not even have an adequate language to formulate the problems.

"We at SDC are aware of these imminent changes and are preparing for them by extensive activity in pure and applied research in computer programming. Realizing that a large computer based system consists of many integrated components, we are also undertaking interdisciplinary research among such diverse fields as computer programming, electrical engineering, psychology, and operations research.

"If you are a senior member of the programming profession and would like to participate in advanced research projects, you are invited to contact Mr. William Keefer at System Development Corporation, 2420 Colorado Ave., Santa Monica, Calif."

Robert Bosak

Robert Bosak, Head of the Data Processing Research Staff

Robert Bosak, *Head of the Data Processing Research Staff*

11-119

SDC

SYSTEM DEVELOPMENT CORPORATION

SANTA MONICA, CALIFORNIA · LODI, NEW JERSEY a minute at the crowning of George II of England (the candles were linked up by trains of flax impregnated with gunpowder); the custom of lighthouse-keepers at the Isles Sanguinaires in Corsica of reading Plutarch aloud to each other to keep awake during the monotonous vigil; the use of the stormy petrel as a lamp (by threading a fiber wick into the bird); the complaint of the kindly inhabitants of Lizard Point in Cornwall in 1619, when a lighthouse was erected there, that the structure took away "God's Grace from them," by which they meant that they would receive no more benefit from shipwreck, and that the profits they had reaped from the calamities of the ruin of shipping were so long established that they should be regarded as "hereditary." Excellent illustrations.

THE WAY THINGS ARE, by P. W. Bridgman. Harvard University Press. ($5.75). P. W. Bridgman, as everyone knows, is more than a first-class physicist; he is a lively, penetrating, honest, tough-minded individualist, interested in many things from social ethics to transfinite mathematics. This book is a summing-up of conclusions he has reached over the years on a wide variety of subjects, among them probability theory, gasoline taxes, quantum mechanics, democracy, scientific method, Marxism, the uses of language, psychology, war, extrasensory perception, grammar, time, Franklin D. Roosevelt. It is, in other words, a report on how things are for Bridgman. The work is of course discursive, yet a central theme confers a certain unity upon it: Bridgman the individualist stresses the precious and essential role of individuality. All creative activities, he says, are private activities. What the individual sees through his own eyes, interprets for himself, proves to his own satisfaction counts, but nothing else; for in the last analysis he can prove nothing to others nor accept their proof on anything as final. Only through such individuality is creative science possible. We may agree, to be sure, that this qualified solipsism is neither a profound nor a novel idea, but in following through its implications Bridgman feels that he has gained fresh insights that help to clarify critical problems of science and human relations and that require a fundamental revision of outlook. Gödel's proof, which in effect says that a system cannot deal with itself without running into trouble, is for Bridgman the paradigm of his generalizations. In common-sense terms, one cannot get away from oneself, yet in the refined intellectual processes of science one acts as if this were possible, as if complete objectivity could be attained through emancipation from self. Inevitably one gets entangled. It is because we refuse to admit certain inescapable limitations on understanding, or pretend to do so, but then smuggle in ambitions we have renounced, that some of the major paradoxes of modern science—of causality, determinism, consciousness, free will, logic and probability—have arisen. For example, because we are the size we are and have to rely upon sensory organs of given dimensions and range, ours is necessarily a world of macroscopic experience. This is the way things are for us; it is on that level that our meanings must be found. (Fleas or viruses might have a different kind of physics.) Now in dealing with the microscopic world we must make certain transformations and adjustments, a necessarily awkward process in the course of which we cannot dispense with macroscopic apparatus, manipulations and ways of thinking. This means trouble. Quantum theorists pay lip service to this limitation, as Bridgman points out, yet in stating flatly that ordinary concepts fail when they are pushed into the microscopic domain, the theorists claim to have arrived at new truths instead of admitting that like Alice, without her magic drink-me bottle, they simply cannot shrink enough to get through the keyhole to see what is on the other side of the door. A successful experiment requires the operation of isolation; the object or event to be described must be enclosed so as to make sure that nothing crosses the boundaries from the outside to muddle the measurements. But the operation fails, says Bridgman, when we attempt to execute it in the microscopic world, and this failure may well be the root of all the revolutionary aspects of the quantum theory. We have not yet found the right way to deal with the tiny things on this level, and until we do we are in no position to assert that the concepts of causality and determinism valid for ordinary-size things or on the common-sense level of daily life are inapplicable in the quantum sphere. Bridgman has sharp and leavening opinions about other branches of science; his discussion of the so-called statistical corroboration of E.S.P., for example, is a delight. But his salty, Yankee, no-nonsense-and-above-all-no-metaphysics approach is not always successful. Certain of his methodological critiques and his appraisals of fundamental mathematical ideas are quite superficial; often they appear to dispel confusion when in fact they merely replace a grandiose idea with a breezy epigram. Bridgman is a

...NEWS IS HAPPENING AT NORTHROP

Meeting the Challenges of Unmanned Flight and Space Age Recovery Systems – at Radioplane

by Dr. Vincent William Howard

Director of Advanced Systems Engineering, Radioplane Division, Northrop Corporation

At Radioplane, the world's leading producer of drones and space age recovery systems, the scientist and the engineer create an entire family of unmanned aircraft. Radioplane drones *serve* the U.S. Armed Forces and many of our allies in target training and evaluating advanced weapon systems, and can *save* men in the surveillance of enemy territory.

For training purposes, nothing matches a live target in the sky. The supersonic target drones from Radioplane are a direct result of more than 20 years' experience. Athough produced at low cost, they deliver predictable reliability, are simple to operate and maintain, and are recoverable by parachute for re-use.

To evaluate the seek-and-kill capacity of advanced weapon systems, we equip drones with scoring systems that record and transmit the performance of attacking missiles. Our targets are equipped with radar augmentation to simulate the appearance of the enemy threat. When necessary, these augmentation systems are coupled with electronic countermeasures. Evasive maneuvers and tactics, or formation flights to simulate both high- and low-level attack can be provided. We also provide sophisticated drones for multi-purpose weapon systems evaluation.

For combat surveillance, Radioplane produces drones equipped with a variety of advanced sensory and associated data link systems. These drones perform complex missions with high reliability required for operation by tactical field groups.

Besides leading in drone production, Radioplane is America's foremost company in creating space vehicle recovery systems. Today we are developing new materials and new designs for parachutes and deceleration devices that must withstand unusually severe problems associated with the re-entry into the earth's atmosphere.

Recently Radioplane was selected to design and produce the recovery system for the NASA-McDonnell Aircraft Corporation Project Mercury Space Capsule.

The continuing advances in all areas of Radioplane activity are the result of the proper utilization of creative talent. Scientists and engineers are urged to develop new ideas and techniques in the missile, drone and space recovery fields. Radioplane provides the facilities and the in-house programs that encourage creativity. Growth opportunities are limited only by the ingenuity and capacity of the individual.

Current papers by Northrop scientists and engineers include:

"High-Performance Digital Computers"— Richard Keppel

"Digital Conversion Techniques" — Stanley Grief

For copies of these papers and additional information about Northrop Corporation, write:

NORTHROP CORPORATION

Dept. K3-1300-32, P.O. Box 1525
Beverly Hills, California

facile and witty writer, a skill which sometimes leads him into misleading analogies and glib solutions. The chapter on social relations contains a good deal of distressing nonsense: for instance, his statement that the possible extinction of the human race, as an alternative to "intellectual stultification," is no longer a matter of "such supreme and absolute importance" nor so shocking as it might have been 20 years ago, now that astronomers are talking seriously of the possibility that life occurs in billions of other places in the sidereal universe. "I am willing to let the human race perish," he writes, "if its survival must be purchased at the price of not freely using its mind." This is the kind of unfeeling, oracular rubbish that has been heard recently from the Archbishop of Canterbury, but one does not expect it from Bridgman. It remains, of course, that he is an admirable man, blunt and unafraid, and that his book has more than enough good to outweigh its blunderbuss aberrations.

BIRDS OF CYPRUS, by David A. Bannerman and W. Mary Bannerman. Oliver and Boyd (63 shillings). Because of its geographical position, the island of Cyprus has long been of special interest to ornithologists. It lies at the extreme eastern corner of the Mediterranean almost due north of Suez and of the delta of the Nile, "that great artery to the heart of Africa by which countless migratory birds from Europe and Asia pass annually on their way to and from their winter quarters." Records of Cyprian bird life go back to the 14th century: In 1336 a Westphalian cleric reports that a nobleman at court keeps 11 falconers; in 1394 King Jacques I kept 300 hawks of all kinds; in 1533 "doves and very fat partridges delight the heart of a priest of Brie"; in 1533 an Englishman, John Locke, notices the trade in pickled beccaficos, '1200 jarres' being sent to Venice. A tribe of indefatigable recorders, among whom are high-court judges, kings' advocates, soldiers, surgeons, sportsmen and all varieties of British civil servants on duty in Cyprus has in six centuries observed some 333 species of birds, only a small proportion of which are permanent residents of the island. Typical examples of summer visitors are the black-headed bunting and the Cyprus chat; winter visitors include Finsch's chat, a great number of water birds (swans, ducks and geese), starlings and larks; but the passage migrants make by far the largest group. The 14 endemic races of Cyprus consist, among others, of the Cyprus hooded crow, Cyprus jackdaw, Cyprus jay, Cyprus great tit, Cyprus warbler, Guillemard's crossbill, Cyprus scops owl, Cyprus warbler, Cyprian chukor. The distinguished British ornithologist David Bannerman and his wife, who were invited in 1952 to make a survey of Cyprian birds, present in this most enjoyable volume the results of their study. They visited nearly every accessible part of the island—this despite the tense, emergency conditions that prevailed during their second visit—and personally identified two thirds of the total bird population. As one expects from the Bannermans, their book is scientifically accurate, comprehensive and a delight. The contents comprise a systematic list of species, a history of Cyprian ornithology, a compendium of the ornithologists who have built up knowledge of the island's birds, information on topography, vegetation, climate and temperature (the extreme heat and cold of Cyprus have a great bearing on the status and distribution of the bird population) and descriptions of each species, covering appearance, distribution, migration and breeding habits. The little life sketches are uncommonly good. Bannerman's inexhaustible enthusiasm, enormous range of knowledge and sure feeling for vivid details and small anecdotes, enliven all he writes, even the most matter-of-fact synopses. The book is illustrated by 16 color plates by D. M. Reid-Henry and Roland Green, 15 halftone plates, many excellent line drawings and a fine folding map of Cyprus. The entire production is a joy, and the price, of less than $9, is incredibly modest.

MACMILLAN EVERYMAN'S ENCYCLOPEDIA, edited by E. F. Bozman. The Macmillan Company ($59.95). What used to be called simply *Everyman's Encyclopedia*, and was well known as a compact, dependable British reference work, now appears in a fourth edition under the title given above, revised, updated and adapted for the use of U. S. readers. There are 50,000 articles in 9,292 pages (almost nine million words) and 2,500 illustrations; the 12 volumes are 5¾ by 8½ inches, durably made, printed in rather small but perfectly legible type, and are accompanied by a sturdy desk rack (no extra charge). It is as easy as knocking over ninepins for a reviewer to skim through a work of this kind and find omissions, distorted allocations of space and other more-or-less obvious shortcomings. But this is only to say that critical readers and editors are bound to disagree as to the proper scope and emphasis of any reference compendium, especially an abbreviated

one. Nevertheless certain brief comments about the new *Everyman's* are in order. The main point perhaps is that it remains, though Americanized, essentially British in its orientation. This is evident in the treatment of, among other things, history, politics, biography, social institutions, government, contemporary affairs. To give one example, the articles on atomic energy and nuclear power contain not a single reference to Oak Ridge, Los Alamos, Hanford or any other Atomic Energy Commission installation, do not describe U. S. military or peaceful programs, but devote several paragraphs to the accomplishments at Harwell and Calder Hall. A second point is that *Everyman's* is not at its best as a reference source in science. The bread-and-butter articles on physics and mathematics are accurate but rarely achieve the lucidity that the average user craves and needs. It is no good telling him what he cannot understand even if it is correct, and the fact that someone who knows the subject finds the discussion satisfactory is irrelevant. This is an old ailment of encyclopedias, and *Everyman's* editors have found no cure for it. Also, despite updating, *Everyman's* is substantially behind the times in scientific coverage and bibliography: among conspicuous omissions are information theory, half-life, parity, plasma, cybernetics, feedback, game theory, programming, David Hilbert, magnetohydrodynamics, einsteinium. *Everyman's* is, of course, not intended as a substitute for the *Britannica* or *Americana;* nor is it designed to meet the needs of youngsters, as is, say, the *World Book.* It is, however, a sound, modestly priced, quick-reference tool for the high-school student or general reader who is not primarily interested in science, does not have much shelf space and cannot afford one of the larger and more expensive encyclopedias.

WORLD RAILWAYS, 1958-1959, edited and compiled by Henry Sampson. Simmons-Boardman Books ($20). Railways may be growing steadily less profitable, but this form of transportation is still vigorously expanding. The number of steam locomotives continues to dwindle but electrics and Diesels are replacing them; new lines are being opened up, most of them electrified, in Africa, Asia, Australia, the U.S.S.R. and elsewhere; there are new subway systems in Leningrad and Nagoya; advances are being made in the mechanization of marshaling yards and centralized traffic control; there are such innovations as "piggyback" (highway trailers carried on flat cars) and door-to-door service by containers which can be loaded at the consigner's plant, taken to the nearest rail point, transferred to a train, carried to another depot, reloaded on a truck and delivered to the consignee.

THE SCIENCE OF CULTURE, by Leslie A. White. Grove Press, Inc. ($1.95). This paper-back reprint of a book published in 1949 consists of a number of stimulating essays by a University of Michigan anthropologist. Whether or not one agrees with the author's general diagnosis of the dynamics and diseases of culture, and recognizing that "culturology" (coined by the chemist Wilhelm Ostwald) is one of the most unattractive and unnecessary words ever coined, even by a German savant, there is no doubt that White is a perceptive, courageous, often exciting analyst.

AUSTRALIA'S ABORIGINES, by Frederick D. McCARTHY. W. S. Heinman ($20). A lavishly illustrated, authoritative account of the life of the aborigines, with chapters on their origin, physical characteristics, economic life, technology, social life, religion, magic and art, and the historical background of their culture. The author, who is curator of anthropology of the Australian Museum in Sydney, has written a skillful, attractive introduction to the study of these people whom many of his fellow countrymen have done their best to rob, mistreat and exterminate—a chapter on human inhumanity which has parallels but has not been outdone.

Notes

SCHIZOPHRENIA: A REVIEW OF THE SYNDROME, edited by Leopold Bellak. Logos Press ($14.75). A comprehensive survey consisting of papers on schizophrenia based on a review of more than 4,000 contemporary studies: vital statistics of the disease, etiology, pathogenesis and pathology, diagnosis and symptomatology, physiological and psychological studies, psychoanalytic aspects, general psychotherapy, insulin-shock treatment, electric shock, tranquilizers, psychosurgery, prognosis, childhood schizophrenia, sociocultural factors.

SPECIAL RELATIVITY FOR PHYSICISTS, by G. Stephenson and C. W. Kilmister. Longmans, Green and Co., Inc. ($3.75). An up-to-date account of the special theory of relativity, containing a large number of applications of interest to the research physicist and engineer, including particle accelerators, classical meson

theory, particle-decay schemes and magnetohydrodynamics.

The Blackfeet, by John C. Ewers. University of Oklahoma Press ($5.75). The 49th volume in the Civilization of the American Indian Series is a detailed history of the individual and tribal life of the famous raiders on the northwestern plains who had a reputation for savage and relentless warfare, horse-stealing and other depredations from their bases in Canada and Montana, but who gradually lost ground late in the 19th century as the buffaloes were exterminated, and are now moving toward complete assimilation in the white cultures that overwhelmed theirs.

Masters of Modern Architecture, by John Peter. George Braziller, Inc. ($15). More than 200 excellent photographs depict the structures of the leading modern architects, including Louis Sullivan, Frank Lloyd Wright, Le Corbusier, Mies Van Der Rohe, Walter Gropius, Richard Neutra, Eduardo Torroja; also a brief text and notes about each of the buildings. An enjoyable parade.

A Compendium of Mathematics and Physics, by Dorothy S. Meyler and O. G. Sutton. D. Van Nostrand Company, Inc. ($5). A well-designed compilation, in handy form, of frequently used formulae of mathematics and physics. The scope of the book makes it suitable for students and research workers who are familiar with the calculus and elementary statistics.

Comptes rendus du Congrès international de Physique nucléaire: Interactions nucléaires aux basses Energies et Structure des Noyaux, edited by P. Gugenberger. Dunod (9,500 francs). This thick volume presents the proceedings of an international congress on nuclear physics held in Paris in July, 1958. The results of theoretical and experimental research on low-energy nuclear reactions and the structure of the nucleus are reported in many papers by physicists from all parts of the world.

Law and Administration: Progress in Nuclear Energy, Series X, Vol. 1, edited by Herbert S. Marks. Pergamon Press ($26.50). There are collected in this volume articles on various aspects of atomic-energy laws and agencies in the U. S., United Kingdom and elsewhere, and a number of organic documents presenting laws, decrees and agreements of some 25 countries from Argentina and Australia to Uruguay and Yugoslavia. A useful compilation.

Aristotle, by W. D. Ross. Meridian Books, Inc. ($1.45). This paperback is a reprint of the fifth edition (1953) of a noted British scholar's exposition of Aristotle's works and thought: his theories of logic, physics, biology, psychology and metaphysics, his doctrines of ethics, politics, rhetoric and poetics.

History Begins at Sumer, by Samuel Noah Kramer. Anchor Books ($1.45). A paper-back reprint of this vivid story of one of the world's oldest societies: education, government, social reform, the law, medicine, agriculture, literature, war, everyday life. An attractive, well-illustrated book.

History of the Persian Empire, by A. T. Olmstead. University of Chicago Press ($2.95). An unabridged paper-back reprint of the late A. T. Olmstead's admirable presentation of the history of the Persian Empire from Cyprus's extension of Persian rule to Greece to the burning of Persepolis by Alexander the Great. Eighty plates and maps.

Hypersonic Flow Theory, by Wallace D. Hayes and Ronald F. Probstein. Academic Press, Inc. ($11.50). An advanced monograph on the fundamental concepts of a branch of the science of fluid mechanics. The book covers the original work of the authors as well as researches by others.

Biographical Memoirs, National Academy of Sciences: Vol. XXXIII. Columbia University Press ($5). Among the scientists whose biographies appear are the botanist Albert Francis Blakeslee, the geographer Isaiah Bowman, the entomologist Leland Howard, the mathematician Dunham Jackson, the geologist C. K. Leith, the physicist R. A. Millikan, the biologist T. H. Morgan, the bacteriologist F. G. Novy, the philosopher Josiah Royce (this éloge is 43 years delayed), the psychologist Lewis M. Terman, the pharmacologist Horatio C. Wood, Jr. (elected to the Academy the same year as Willard Gibbs).

Trees of Britain, by Robert Gurney. Faber and Faber (30 shillings). An attractive guide describing the common trees of Britain, wild and cultivated. The text contains interesting and informative sidelights, and the author's numerous line drawings and a number of beautiful photographs illustrate the book.

AEROJET-GENERAL CORPORATION, A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY 158
Agency: D'Arcy Advertising Company

AERONCA MANUFACTURING CORPORATION 67
Agency: Penn and Hamaker, Inc.

AERONUTRONIC, A DIVISION OF FORD MOTOR COMPANY 6, 7
Agency: Honig-Cooper, Harrington & Miner

AINSWORTH, WM., & SONS, INC. 10
Agency: Walter L. Schump, Advertising

AMERICAN MACHINE & FOUNDRY COMPANY, GOVERNMENT PRODUCTS GROUP 15
Agency: Cunningham & Walsh Inc.

AMERICAN SMELTING AND REFINING COMPANY 135
Agency: Needham, Louis and Brorby, Inc.

AMPEX CORPORATION, INSTRUMENTATION DIVISION 25, 63
Agency: McCann-Erickson, Inc.

ARRIFLEX CORPORATION OF AMERICA 70
Agency: Advertising Aides

AUTONETICS, A DIVISION OF NORTH AMERICAN AVIATION, INC. 2
Agency: Batten, Barton, Durstine & Osborn, Inc.

AVCO CORPORATION 71
Agency: Benton & Bowles, Inc.

B & H INSTRUMENT CO., INC. 171
Agency: The Kotula Company

BAUSCH & LOMB OPTICAL CO. 4
Agency: Wolff Associates, Inc.

BEAN, MORRIS, & COMPANY 20
Agency: Odiorne Industrial Advertising, Inc.

BELL AIRCRAFT CORPORATION 154
Agency: The Rumrill Company Inc.

BELL TELEPHONE LABORATORIES 21
Agency: N. W. Ayer & Son, Incorporated

BENDIX AVIATION CORPORATION 85
Agency: MacManus, John & Adams, Inc.

BENDIX AVIATION CORPORATION, SYSTEMS DIVISION 133
Agency: MacManus, John & Adams, Inc.

BENDIX COMPUTER DIVISION OF BENDIX AVIATION CORPORATION 33
Agency: Shaw Advertising, Inc.

BESELER, CHARLES, COMPANY 68
Agency: Dale and Finkels Incorporated

BLISS, E. W., COMPANY 18
Agency: Feeley Advertising Agency, Inc.

BOEING AIRPLANE COMPANY 152, 165
Agency: Fletcher Richards, Calkins & Holden, Inc.

BURGESS BATTERY COMPANY 68
Agency: Kane Advertising

BURROUGHS CORPORATION 5
Agency: Campbell-Ewald Company

CARBORUNDUM COMPANY, THE 28, 29
Agency: G. M. Basford Company

COLLINS RADIO COMPANY ..... Inside Back Cover
Agency: W. D. Lyon Company

CONSOLIDATED ELECTRODYNAMICS CORPORATION 116, 117
Agency: Hixson & Jorgensen, Inc., Advertising

CONTROLS COMPANY OF AMERICA 8
Agency: Klau-Van Pietersom-Dunlap, Inc.

CONVAIR, A DIVISION OF GENERAL DYNAMICS CORPORATION ..... Back Cover
Agency: Lennen & Newell Inc.

INDEX OF ADVERTISERS

AUGUST, 1959

CONVAIR ASTRONAUTICS, CONVAIR DIVISION OF GENERAL DYNAMICS CORPORATION ... 144
Agency: Barnes Chase Company

COOPER-BESSEMER CORPORATION, THE ... 141
Agency: The Griswold-Eshleman Co.

COPPER & BRASS RESEARCH ASSOCIATION, THE ... 26, 27
Agency: J. M. Mathes Incorporated

CORNING GLASS WORKS ... 148
Agency: The Rumrill Company Inc.

DATASYNC, A DIVISION OF BERNDT-BACH, INC. ... 70
Agency: Van der Boom, Hunt, McNaughton, Inc.

DOVER PUBLICATIONS, INC. ... 153
Agency: James R. Flanagan Advertising Agency

DU PONT DE NEMOURS, E. I., & CO., INC., ELASTOMER CHEMICALS DEPT. ... 126, 127
Agency: N. W. Ayer & Son, Incorporated

DU PONT DE NEMOURS, E. I., & CO., INC., FILM DEPT. ... 172
Agency: Batten, Barton, Durstine & Osborn, Inc.

DUREZ PLASTICS DIVISION, HOOKER CHEMICAL CORPORATION ... 1
Agency: The Rumrill Company Inc.

EASTMAN CHEMICAL PRODUCTS, INC., SUBSIDIARY OF EASTMAN KODAK COMPANY, CHEMICALS DIV. ... 62
Agency: Fred Wittner Company

EASTMAN KODAK COMPANY ... 59
Agency: The Rumrill Company Inc.

EDMUND SCIENTIFIC CO. ... 139
Agency: Walter S. Chittick Company

ELECTRONIC ASSOCIATES, INCORPORATED 97
Agency: Gaynor & Ducas, Inc.

ERIE RESISTOR CORPORATION, ELECTROMECHANICAL DIVISION ... 101
Agency: Meldrum & Fewsmith, Inc.

GARFIELD, OLIVER, CO., INC. ... 132
Agency: Daniel & Charles, Inc.

GENERAL ELECTRIC COMPANY, DEFENSE SYSTEMS DEPARTMENT ... 72, 73
Agency: G. M. Basford Company

GENERAL MOTORS CORPORATION, ALLISON DIVISION ... 157
Agency: Kudner Agency, Inc.

GILSON SLIDE RULE CO. ... 140

GOODYEAR AIRCRAFT CORPORATION, A SUBSIDIARY OF THE GOODYEAR TIRE & RUBBER CO. ... 156

GRAPHIC SYSTEMS ... 142
Agency: Diener & Dorskind Incorporated

HOOKER CHEMICAL CORPORATION, DUREZ PLASTICS DIVISION ... 1
Agency: The Rumrill Company Inc.

HUGHES AIRCRAFT COMPANY ... 146, 147
Agency: Foote, Cone & Belding

INTERNATIONAL BUSINESS MACHINES CORPORATION ... 32, 61, 131
Agency: Benton & Bowles, Inc.

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION ... 24
Agency: J. M. Mathes Incorporated

IRISH EXPORT PROMOTION BOARD ... 23
Agency: Weiner & Gossage, Inc.

JAEGERS, A. ... 142
Agency: Carol Advertising Agency

LIBRARY OF SCIENCE, THE ... 151
Agency: Wunderman, Ricotta & Kline, Inc.

LINDSAY CHEMICAL DIVISION, AMERICAN POTASH & CHEMICAL CORPORATION ... 88
Agency: C. Franklin Brown, Inc.

LINGUAPHONE INSTITUTE ... 162
Agency: The Kaplan Agency, Inc., Div. of Mogul Lewin Williams & Saylor, Inc.

LINK AVIATION, INC., A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION ... 123
Agency: Gaynor & Ducas, Inc.

LOS ALAMOS SCIENTIFIC LABORATORY OF THE UNIVERSITY OF CALIFORNIA ... 170
Agency: Ward Hicks Advertising

MAGNAVOX CO., THE, GOVERNMENT AND INDUSTRIAL DIVISION ... 136
Agency: Rothbardt & Haas Advertising, Inc.

MARQUARDT AIRCRAFT CO. ... 86, 87
Agency: Grant Advertising, Inc.

M. I. T. LINCOLN LABORATORY ... 12
Agency: Randolph Associates

METAL & THERMIT CORPORATION ... 118
Agency: Marsteller, Rickard, Gebhardt and Reed, Inc.

MINNESOTA MINING AND MANUFACTURING COMPANY, MAGNETIC PRODUCTS DIVISION ... 9
Agency: MacManus, John & Adams, Inc.

MITRE CORPORATION, THE ... 163
Agency: Deutsch & Shea, Inc.

MODERNOPHONE, INC. ... 156
Agency: The Kaplan Agency, Inc., Div. of Mogul Lewin Williams & Saylor, Inc.

NEWBURY INDUSTRIES, INC. ... 132
Agency: Rova Company

NORTHROP CORPORATION ... 161
Agency: Erwin Wasey, Ruthrauff & Ryan, Inc.

NORTON COMPANY, REFRACTORIES DIVISION ... 19
Agency: James Thomas Chirurg Company

NUCLEAR-CHICAGO CORPORATION ... 14
Agency: Don Colvin & Company, Inc.

OPERATIONS RESEARCH OFFICE, THE JOHNS HOPKINS UNIVERSITY ... 103
Agency: M. Belmont Ver Standig, Inc.

PERKIN-ELMER CORPORATION ... 70
Agency: G. M. Basford Company

PHILCO CORPORATION, GOVERNMENT AND INDUSTRIAL DIVISION ... 69
Agency: Maxwell Associates, Inc.

PHILLIPS CHEMICAL COMPANY, A SUBSIDIARY OF PHILLIPS PETROLEUM COMPANY 145
Agency: Lambert & Feasley, Inc.

PITTSBURGH LECTRODRYER DIVISION, McGRAW-EDISON COMPANY ... 66
Agency: The Griswold-Eshleman Co.

QUESTAR ... 134

RADIO CORPORATION OF AMERICA, DEFENSE ELECTRONIC PRODUCTS ... 143
Agency: Al Paul Lefton Company, Inc.

RADIO CORPORATION OF AMERICA, ELECTRON TUBE DIVISION ... 34, 35
Agency: Al Paul Lefton Company, New York Division Inc.

RAMO-WOOLDRIDGE, A DIVISION OF THOMPSON RAMO WOOLDRIDGE INC. 105
Agency: The McCarty Co.

RAND CORPORATION, THE ... 36
Agency: Fletcher Richards, Calkins & Holden, Inc.

RAYTHEON COMPANY ... 11
Agency: Donahue & Coe, Inc.

RAYTHEON COMPANY, GOVERNMENT EQUIPMENT DIVISION ... 155
Agency: Donahue & Coe, Inc.

RAYTHEON COMPANY, MISSILE SYSTEMS DIVISION ... 30
Agency: Donahue & Coe, Inc.

SERVO CORPORATION OF AMERICA ... 31
Agency: Smith, Winters Mabuchi, Inc.

SHELL CHEMICAL CORPORATION ... Inside Front Cover
Agency: J. Walter Thompson Company

SIGMA INSTRUMENTS, INC. ... 22
Agency: Culver Advertising, Inc.

SINGER MANUFACTURING COMPANY, THE, MILITARY PRODUCTS DIVISION ... 13
Agency: O. S. Tyson and Company, Inc.

SYLVANIA ELECTRIC PRODUCTS, INC., SYLVANIA ELECTRONIC SYSTEMS DIVISION 83
Agency: J. Walter Thompson Company

SYLVANIA ELECTRIC PRODUCTS INC., SEMICONDUCTOR DIVISION ... 169
Agency: J.Walter Thompson Company

SYSTEM DEVELOPMENT CORPORATION ... 159
Agency: Stromberger, LaVene, McKenzie: Advertising

TECHNICAL RESEARCH GROUP ... 160
Agency: Commerce Advertising Agency

TEXAS INSTRUMENTS INCORPORATED ... 160
Agency: Don L. Baxter, Inc.

THOMPSON RAMO WOOLDRIDGE INC., TAPCO GROUP ... 64, 65
Agency: Meldrum & Fewsmith, Inc.

TRANSITRON ELECTRONIC CORPORATION ... 107
Agency: The Bresnick Company, Inc.

UNITED STATES STEEL CORPORATION, MISSILES DIVISION ... 108, 109
Agency: Batten, Barton, Durstine & Osborn, Inc.

UNITRON INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO. ... 140
Agency: Larcom Randall Advertising, Inc.

UNIVERSITY OF CHICAGO, THE HOME-STUDY DEPT. ... 162
Agency: Garfield-Linn and Company

WEIGHING AND CONTROL COMPONENTS, INC. ... 101
Agency: Thomas R. Sundheim Incorporated

WESTINGHOUSE ELECTRIC CORPORATION, DEFENSE PRODUCTS GROUP ... 16, 17
Agency: Ketchum, MacLeod & Grove, Inc.

WHITE, S. S., DENTAL MFG. CO., INDUSTRIAL DIVISION ... 60
Agency: W. L. Towne Company, Inc.

BIBLIOGRAPHY

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

ARTIFICIAL SATELLITES AND THE EARTH'S ATMOSPHERE

IRREGULARITIES IN THE DENSITY OF THE UPPER ATMOSPHERE: RESULTS FROM SATELLITES. D. G. King-Hele and D. M. C. Walker in *Nature*, Vol. 183, No. 4,660, pages 527-529; February 21, 1959.

THE POLAR AURORA. Carl Størmer. Oxford University Press, 1955.

TWO ATMOSPHERIC EFFECTS IN THE ORBITAL ACCELERATION OF ARTIFICIAL SATELLITES. Luigi G. Jacchia in *Nature*, Vol. 183, No. 4,660, pages 526-527; February 21, 1959.

CORPUSCULAR RADIATION AND THE ACCELERATION OF ARTIFICIAL SATELLITES. Luigi G. Jacchia in *Nature*, Vol. 183, No. 4,676, pages 1,662-1,663; June 13, 1959.

THE UPPER ATMOSPHERE. H. S. W. Massey and R. L. F. Boyd. Hutchinson of London, 1958.

THE RADIO GALAXY

THE CHANGING UNIVERSE. John Pfeiffer. Random House, 1956.

THE EXPLORATION OF SPACE BY RADIO. R. Hanbury Brown. John Wiley & Sons, Inc., 1958.

INCUBATOR BIRDS

BREEDING HABITS IN THE FAMILY MEGAPODIIDAE. H. J. Frith in *The Ibis*, Vol. 98, No. 4, pages 620-638; October, 1956.

NESTING HABITS OF THE BRUSH-TURKEY. D. H. Fleay in *The Emu*, Vol. 36, Part 3, pages 153-163; January, 1937.

TEMPERATURE REGULATION IN THE NESTING MOUNDS OF THE MALLEE-FOWL, LEIPOA OCELLATA GOULD. H. J. Frith in *C.S.I.R.O. Wildlife Research*, Vol. 1, No. 2, pages 80-95; December, 1956.

OCEAN WAVES

BREAKERS AND SURF: PRINCIPLES IN FORECASTING. Hydrographic Office Publication No. 234, 1944.

THE OCEANS: THEIR PHYSICS, CHEMISTRY AND GENERAL BIOLOGY. H. U. Sverdrup, Martin W. Johnson and Richard H. Fleming. Prentice-Hall, Inc., 1942.

PRACTICAL METHODS FOR OBSERVING AND FORECASTING OCEAN WAVES BY MEANS OF WAVE SPECTRA AND STATISTICS. Willard J. Pierson, Jr., Gerhard Neumann and Richard W. James. Hydrographic Office Publication No. 603, 1958.

CONDITIONING AND BRAIN WAVES

THE CENTRAL NERVOUS SYSTEM AND BEHAVIOR. Edited by Mary A. B. Brazier. Josiah Macy, Jr. Foundation, 1959.

OBSERVATIONS ON MAN, HIS FRAME, HIS DUTY AND HIS EXPECTATIONS. David Hartley. Thomas Tegg and Son, 1834.

RETICULAR FORMATION OF THE BRAIN. Edited by Herbert H. Jasper, Lorne D. Proctor, Robert S. Knighton, William C. Noshay and Russell T. Costello. Little, Brown and Company, 1958.

CHARLES LYELL

CHARLES DARWIN, EDWARD BLYTH AND THE THEORY OF NATURAL SELECTION. Loren C. Eiseley in *Proceedings of the American Philosophical Society*, Vol. 103, No. 1, pages 94-158; February 28, 1959.

CHARLES LYELL AND MODERN GEOLOGY. T. G. Bonney. Macmillan & Co., 1895.

DARWIN'S CENTURY. Loren C. Eiseley. Doubleday & Co., Inc., 1958.

LIFE, LETTERS AND JOURNALS OF SIR CHARLES LYELL, BART. Edited by his sister-in-law, Mrs. Lyell. John Murray, 1881.

PRINCIPLES OF GEOLOGY. Charles Lyell. John Murray, 1830.

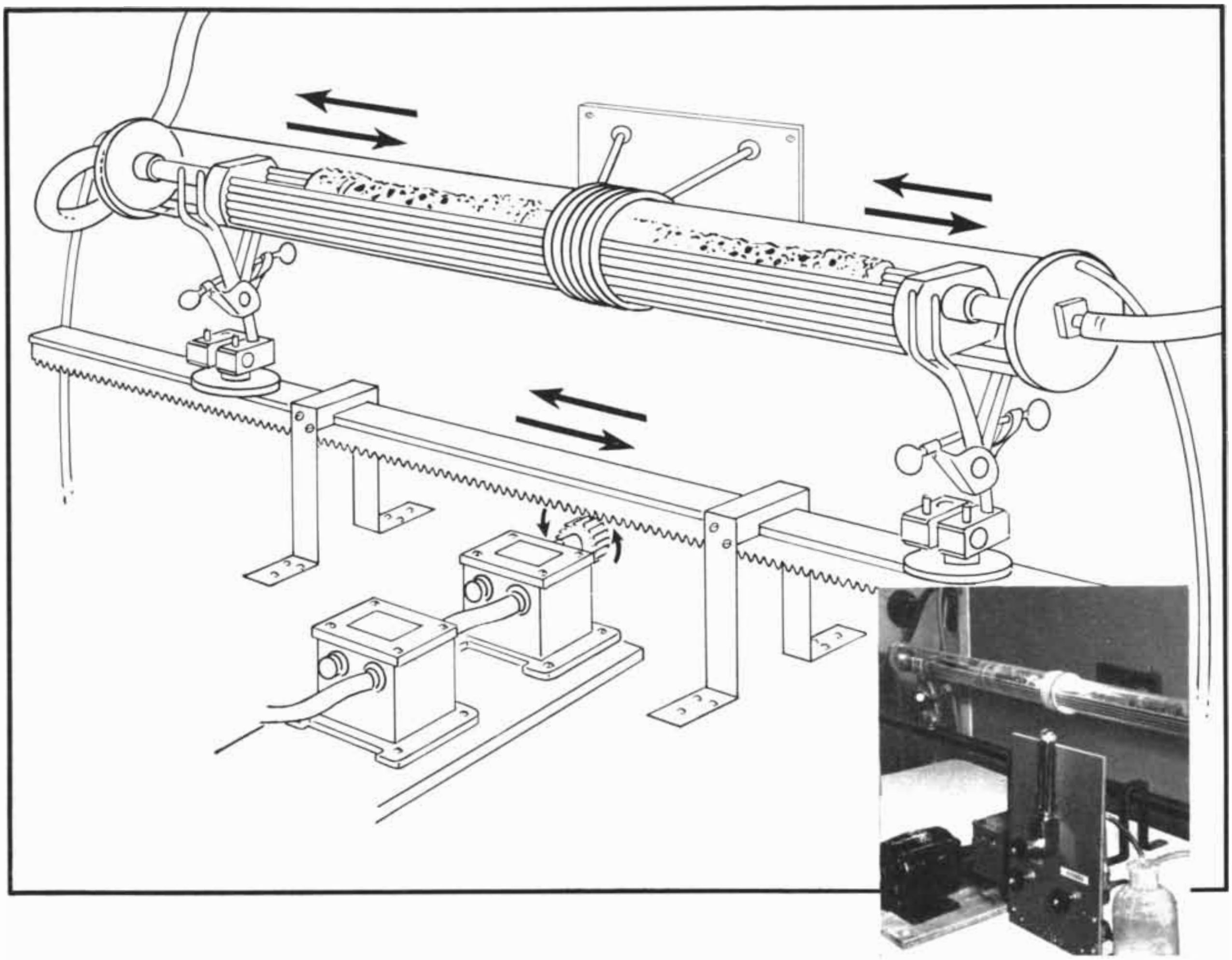
GLAUCOMA

CARBONIC ANHYDRASE INHIBITION AND AQUEOUS FLOW. Jonas S. Friedenwald in *American Journal of Ophthalmology*, Vol. 39, No. 4, Part II, pages 59-64; April, 1955.

CURRENT STUDIES ON ACETAZOLEAMIDE (DIAMOX) AND AQUEOUS HUMOR FLOW. Jonas S. Friedenwald in *American Journal of Ophthalmology*, Vol. 40, No. 5, Part II, pages 139-146; November, 1955.

MECHANISMS OF GLAUCOMA. Sidney Lerman in *Survey of Ophthalmology*, Vol. 4, No. 1, pages 47-74; February, 1959.

PHYSIOLOGY OF THE OCULAR AND CERE-



BROSPINAL FLUIDS. Hugo Davson. Little, Brown and Company, 1956.

THE ENZYME-SUBSTRATE COMPLEX

THE DEVELOPMENT OF ENZYME KINETICS. Harold L. Segal in *The Enzymes*, edited by Paul Boyer, Henry Lardy and Karl Myrbäck, pages 1-48. Academic Press, Inc., 1959.

ENZYME MECHANISMS IN LIVING CELLS. Britton Chance in *A Symposium on the Mechanism of Enzyme Action*, edited by William D. McElroy and Bentley Glass, pages 399-460. The Johns Hopkins Press, 1954.

ENZYME-SUBSTRATE COMPOUNDS. J. B. Neilands and Paul K. Stumpf in *Outlines of Enzyme Chemistry*, pages 174-184. John Wiley & Sons, Inc., 1958.

PROTEIN STRUCTURE AND ENZYME ACTIVITY. K. V. Linderstrøm-Lang and J. A. Schellman in *The Enzymes*, edited by Paul Boyer, Henry Lardy and Karl Myrbäck, pages 443-510. Academic Press, Inc., 1959.

THERMODYNAMIC STUDY OF AN ENZYME-SUBSTRATE COMPLEX OF CHYMOTRYPSIN: I. David G. Doherty and Fred Vaslow in *Journal of the American Chemical Society*, Vol. 74, No. 4, pages 931-936; February 20, 1952.

THERMODYNAMIC STUDY OF SOME ENZYME-INHIBITOR COMPLEXES OF CHYMOTRYPSIN: II. Fred Vaslow and David G. Doherty in *Journal of the American Chemical Society*, Vol. 75, No. 4, pages 928-932; February 20, 1953.

MATHEMATICAL GAMES

THE GOLDEN NUMBER. Miloutine Borissavliévitch. Philosophical Library, 1958.

THE GOLDEN SECTION, PHYLLOTAXIS AND WYTHOFF'S GAME. H. S. M. Coxeter in *Scripta Mathematica*, Vol. 19, No. 2-3, pages 135-143; June-September, 1953.

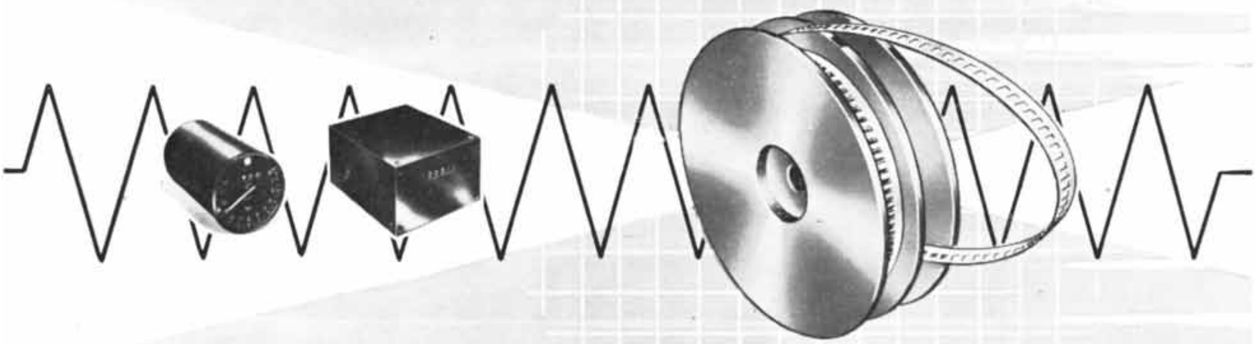
ON GROWTH AND FORM. D'Arcy Wentworth Thompson. Cambridge University Press, 1917.

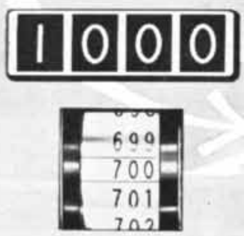
THE AMATEUR SCIENTIST

EVERYBODY'S WATCHES. Arthur Tremayne. N. A. G. Press, 1942.

HOW TIME IS MEASURED. Peter Hood. Oxford University Press, 1955.

SUNDIALS: HOW TO KNOW, USE AND MAKE THEM. R. Newton Mayall and Margaret L. Mayall. Charles T. Branford Company, 1958.




1000
699
700
701

Bomarc reception committee for the enemy intruder

COLLINS ELECTRONICS

SPLASH ONE . . . ENEMY AIRCRAFT DESTROYED . . . Safely out from our heartland, intruding aircraft will be knocked out of the skies by this Air Force long range, pilotless interceptor. Launched at command from an electronic control center, the Boeing Bomarc seeks out its target at supersonic speeds. It unleashes its destruction at a precise instant determined by a highly educated radar proximity fuze developed and manufactured by Collins Radio Company under the direction of the Army's Diamond Ordnance Fuze Laboratories.

COLLINS

COLLINS RADIO COMPANY • CEDAR RAPIDS, IOWA • DALLAS, TEXAS • BURBANK, CALIFORNIA


Convair
and the ages
we live in
JET AGE • MISSILE AGE
SPACE AGE • ATOMIC AGE
In this era that probes beyond all scientific horizons, the Convair division of General Dynamics Corporation has attained famous firsts in all four areas. JET AGE: B-58, first supersonic bomber. MISSILE AGE: Atlas, our first Intercontinental Ballistic Missile. SPACE AGE: The world's first ICBM to be placed in orbit. ATOMIC AGE: Convair was first to make tests on a nuclear reactor carried in flight.
Convair, as a member of the General Dynamics industrial family, is assisting to assure world peace and expanded scientific knowledge in the four ages we live in—an era unequalled in all of history!
ATLAS
USAF
CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION